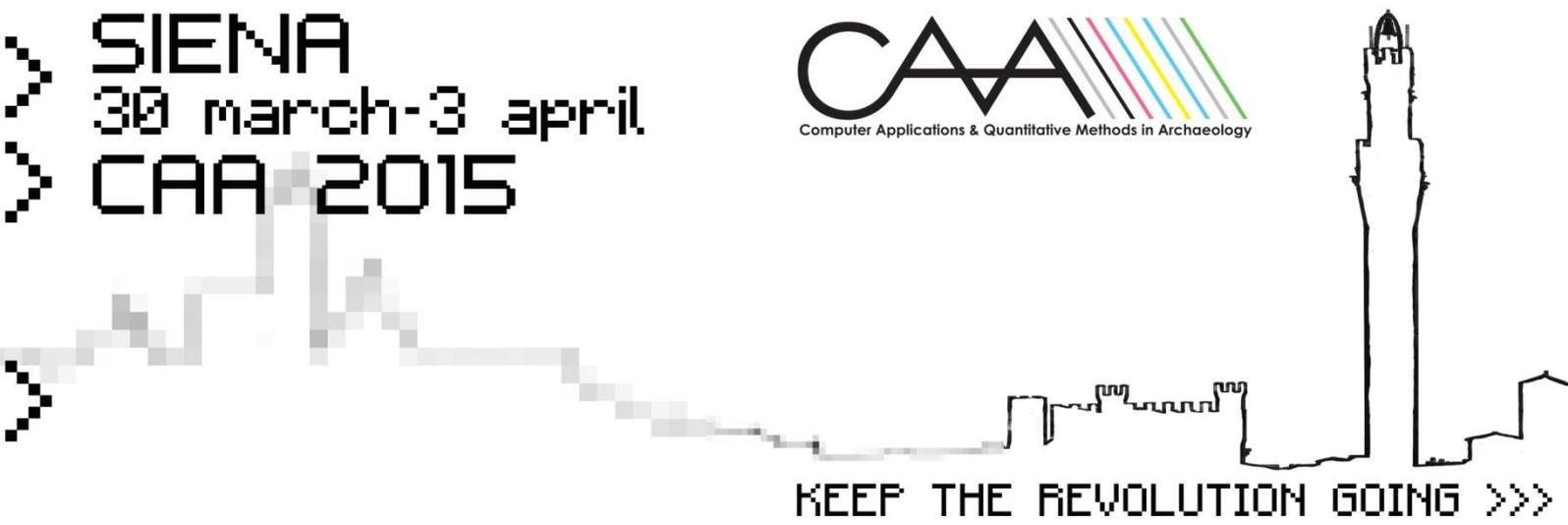


SIENA
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43rd Computer Applications and Quantitative Methods in Archaeology

Annual Conference

Book of Abstracts

University of Siena

Department of History and Cultural Heritage



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San Niccolò University Building

In the early 2000s, the University of Siena restored the building, a former monastery that in early 800s was a sort of village organized into pavilions to accommodate mentally ill people. Some University departments have been housed in the wide rooms of the former psychiatric hospital that is located in the town centre, very close to Porta Romana.

The Teaching Centre has many teaching rooms, including those of the Outer Room Pavilion which comprises six 100 seat multi-functional rooms (transformable into a 700 seat auditorium).

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SESSION 1A-
DIGITAL FRONTIERS
IN MARITIME ARCHAEOLOGY

DIGITAL FRONTIERS IN MARITIME ARCHAEOLOGY

Authors Øyvind Ødegård, Asgeir J. Sørensen, Martin Ludvigsen, Stein M. Nornes

Title *Underwater Robotics in Marine Archaeology*

Abstract Recent years have seen an increasing adoption of advanced technology into mainstream marine archaeological research and management. Improvements in user friendliness, availability and data quality have helped to put hi-tech gadgets and advanced computer software into the archaeological toolbox, and what happens at the digital frontiers in maritime archaeology will no doubt have great impacts on the discipline's future. The Applied Underwater Robotics Laboratory (AUR-Lab) at the Norwegian University of Science and Technology (NTNU) is a multidisciplinary collaboration between the faculties for engineering, natural sciences and the humanities. Through shared infrastructure and joint research cruises, developers and end users of technology work together on overcoming challenges and optimizing methods related to marine sciences, including marine archaeology. Using Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) as platforms several novel sensors have been applied to selected underwater cultural heritage sites. This paper will present some examples of data acquired by an Underwater Hyperspectral Imager (UHI), Synthetic Aperture Sonar (SAS) and stereo camera photogrammetry. It will discuss the platform's and sensor's suitability for different archaeological operations (detection, recording and monitoring). Further it will present current research on guidance, navigation and control in underwater robotics at AUR-Lab, and discuss its potential benefits for marine archaeological research and management applications.

Authors Crystal Safadi

Title *An evaluation of the maritime accessibility and protection afforded by bronze age and iron age Levantine harbours.*

Abstract This paper evaluates the natural affordances of Bronze Age and Iron Age harbours located in central and southern Phoenicia, on the coast of modern-day Lebanon. It looks at two factors that characterise a harbour location: its maritime accessibility and protection, in light of its physical topography. The evaluation is carried out through an enhanced framework of analysis that includes modelling of winds along the Levantine basin, and of wave heights for each harbour site. A review of the maritime developments and activities during the Bronze and Iron Age, and of the maritime environment of the eastern Mediterranean, suggests that localised and enhanced frameworks of studies are substantial in order to bypass general observations and trends. Through the modelling of winds, regional differences in mean wind speed and direction are distinguished. These shed insight on the potential of sailing along the Levantine basin, particularly on the Lebanese coast.

Moreover, in accordance with the topography of harbour sites, the wind models highlight their maritime accessibility: direction of sailing from and to each site, and their protection from predominant winds.

Congruently, the modelling of wave heights for each harbour site reveals the level of protection they afford for ships and boats.

This paper puts forth a detailed approach that testifies to the local character of the Mediterranean, and proves the necessity of integrating enhanced and localised analysis within a holistic study of ancient harbours. It also presents a new model by which to examine ancient harbours in general.

DIGITAL FRONTIERS IN MARITIME ARCHAEOLOGY

Authors Madeline McAllister

Title *Virtual diving: Analysis of the archaeological value in image-based digital recording and reconstruction of underwater shipwreck sites in Western Australia*

Abstract

The fundamental problem within archaeology is that knowledge is ultimately formed through the guided destruction of the cultural heritage resources that are being studied. Consequently, accurate and highly detailed recording of sites during all stages of archaeological work is essential. Additionally, when applying archaeology to an underwater environment speed and accuracy become key factors of any recording technique. Photographical recording fulfils ethical requirements of completing archaeological work to the highest possible standard and is widely acknowledged as one of the archaeologist's most significant and frequently used tools. As Baker and Green (1976) emphasised, the greatest value in recording with photographs is the infinite detail, surpassing even the best archaeological site plan. Until recently, acquiring photographs of an underwater site and processing them into a digital 3D reconstruction was time consuming and required specialist skills. Advances in algorithms for computer science and machine vision now allow raw images to be quickly processed and 3D reconstructions automatically derived. These advances are enabling archaeologists with minimal training to create geometrically accurate image-based 3D reconstructions of underwater archaeological sites, fulfilling essential archaeological requirements of recording a site quickly and accurately. This recent and significant increase in digital 3D reconstructions raises the need for basic guidelines for digital recording of archaeological material and sites to ensure that standards are upheld and that there is a thorough understanding of exactly what is presented in the final model. Moreover, we should perhaps pause and reassess what these image-based techniques provide in terms of accurate recording of archaeological data before they become mainstream and conventional archaeological techniques. Do they promote interpretation of archaeological data and sites, or do they only present narrow, highly subjective views? How objective are these techniques? How do they influence the current archaeological process?

In this paper I discuss my PhD research, which proposes to contribute to techniques and methods for recording underwater archaeological sites by testing, analysing and refining a methodology for accurate and affordable image-based recording and reconstruction of shipwrecks in Western Australia (WA). Ultimately, providing a detailed, accurate and informative digital representation of shipwreck site/s for archaeological interpretation. Overall, both legacy data (data previously collected) and new data (collected during this research) will form the basis for the project.

This dissertation is running in conjunction with the Australian Research Council Linkage project 'Shipwrecks of the Roaring Forties: a maritime archaeological reassessment of some of Australia's earliest shipwrecks' (LP130100137, Lead CI: Paterson). The Roaring Forties Linkage Project aims to make a significant contribution to our understanding of Europeans active in the Indian Ocean and the Western Australian region during the 17th and 18th centuries through reassessing maritime archaeological sites and examining how approaches to maritime archaeological sites have changed over time in terms of both new research questions and new technologies.

DIGITAL FRONTIERS IN MARITIME ARCHAEOLOGY

Authors **Pat Thomas Tanner**

Title *3D Scanning, Contact Digitising and Advanced 3D Digital Modelling for the reconstruction and Analysis of Boats and Ships*

Abstract Using examples from the Traditional Boats of Ireland project which has used 3D laser scanning to record more than 60 vessels over the past three years, case studies will demonstrate the capability of 3D laser scanning to rapidly capture three dimensional data in the field, and create a three dimensional digital model. In creating the digital model, each individual component is solid modelled in the computer software and assigned a material. This enables the software to calculate important factors such as centre of gravity, density and establish a floatation condition for the vessel, in order to examine construction details, hydrostatic analysis, and analyse external influences such as ballast, cargo and crew, wind load on rigging and hull, and sea conditions.

A second case study using the remains of the mid 15th century clinker built Newport Medieval Ship, which has been excavated, cleaned, documented, modelled and is now midway through PEG and freeze-drying conservation treatment. Digital documentation methods, including laser scanning and contact digitising were used extensively. Individual ship timbers were recorded using contact digitisers to record full size three dimensional wireframe models, and to record important features such as tool marks, fasteners and edges. Different features, such as nails and wood grain, were recorded on separate layers and in specific colours. The wireframe data was then surfaced to create a digital solid model which accurately represented the volume and geometry of each individual timber, and finally physically manufactured at 1:10 scale using an additive manufacturing process called selective laser sintering.

The manufacture and assembly of a 1:10 scale physical model of the vessel remains has provided both construction sequence information and a suitable foundation from which to reconstruct the missing or damaged areas. The physical scale model was 3D laser scanned to create a digital version and used as the basis for a digital reconstruction. The digital model is then repaired, and a set of lines extracted and faired using Rhino3D software. The lines were turned into a digital hull model and analysed in a related software program called ORCA, which has been used to determine hydrostatic and hydrodynamic characteristics. The use of the abovementioned advanced digital modelling software and approach quickly allows for multiple variables to be tested and modified in order to reach a definitive original hull form.

Authors **Carlo Beltrame**

Title *Underwater photogrammetry applied on two cargos of marble of Roman age*

Abstract In the last two years, the team of maritime archaeology of the Università Ca' Foscari di Venezia, directed by Carlo Beltrame, has experimented and compared on shipwrecks various techniques of underwater documentation. The better results come from the multi-image photogrammetry technique. This system reproduces the archaeological evidence in a precise and correct way, both from an iconic point of view, because it uses photographic texture, and from a metric point of view, because the final errors are minimal and derisory.

The photogrammetric documentation is supported by a metric documentation, with coordinates, to scale and arrange the 3D model in a topographic system.

We want to show two Roman shipwrecks with cargos of marble. Both cargos are represented

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by huge blocks with different depth, number and disposition on the seabed. Those characteristics determine the choice of the documentation which has to integrate the photogrammetry.

The Marzamemi I Roman shipwreck is composed by 14 marble elements consisting in blocks, big columns and squared stones, scattered on the seabed; some of the blocks lies far from the main cluster. It has been necessary a subdivision of the photogrammetry in four different clusters, which are then positioned with a trilateration method. The trilateration was realized with a DSM (direct survey method) technique which produces not absolute coordinates, which must be georeferenced with a GPS.

The Capo Granitola Roman shipwreck is composed by a 'coherent' cargo of 65 squared marble blocks, found in the stowage position; the upper part of these blocks lies at a depth from 2 to 3 meters. In this case we have decided to use a differential GPS to measure the markers on the blocks.

Each coordinate is inserted in the 3D model realized by photogrammetry which must be scaled, controlled and corrected. Because to realize a complete study of an archeological underwater site we need to obtain a 3D model with correct measures, the use of the 3D technical documentation method, as a support for the multi-image photogrammetry, has proved an important and essential part of the documentation.

- Authors** **Dominique Rissolo, Alberto Nava Blank, Vid Petrovic, Michael Bianco, Perry Naughton, Eric Lo, Falko Kuester, Roberto Chavez Arce, Antonella Vilby.**
- Title** *Refining techniques for underwater structure-from-motion (SfM) image acquisition and processing*
- Abstract** Structure-from-motion (SfM), as a means by which 3D reconstructions can be generated from 2D photographs, has been widely adopted as an accessible and empowering technique for rapid documentation and visualization of archaeological objects, features, and sites. However, its application in underwater environments presents certain physical and methodological challenges. Open source and commercial 3D reconstruction software applications are readily available, though limitations include domain specific capabilities, data preconditioning, computational complexity, and accuracy. The Center of Interdisciplinary Science for Art, Architecture, and Archaeology (CISA3) at the University of California, San Diego is developing innovative tools for cultural heritage diagnostics, analytics, and dissemination and is focused on new advanced protocols for underwater SfM documentation and visualization of underwater cultural heritage sites.
- Authors** **Dejan Veranič, Aixa Andreetta**
- Title** *The »PALAFITTES GUIDE«: personal guide to the pile dwellers and their settlements.*
- Abstract** On June 27th 2011 the Prehistoric pile dwellings around the Alps were added to the UNESCO World Heritage List. There are 111 enlisted sites out of around a thousand known. Six participating countries: Switzerland, Austria, France, Germany, Italy and Slovenia established common management for the serial site. As a brand new member of World Heritage list the image of pile dwellings being one serial site was and still is of great importance.

SESSION 1A

DIGITAL FRONTIERS IN MARITIME ARCHAEOLOGY

The need of presenting the site's outstanding universal value also contributed to the forming of the audio guide.

On behalf of the international coordination group, leading archaeologists in conjunction with science journalists from Texetera, compiled the "Palafittes Guide". It is a great example of transnational cooperation. At more than 80 locations in Switzerland, Germany, Austria and Slovenia users can learn about the way of life of the ancient pile dwellers, and the work of the archaeologists who study them. There is a German and English version of the application that also has Slovenian audio tracks.

The application works with iPhone and Android devices which has three modules. The first is a map of the Alpine region that shows the user's current position and the locations of the prehistoric pile-dwelling sites. Attached to every site is an audio file lasting about three minutes in which users can learn more about the particular location. The audio guide works best when used on site. That way orientation in space and time is much easier. Usually there is one key point described per site. Here one can also find information about museums where the objects from the sites are contextualized. The second module contains a comprehensive collection of interesting background material about the pile dwellers. The last one has information about current events, special exhibitions, lectures and publications that concern pile dwellings.

Pile dwelling sites are not seen on the surface and the application gives us a good opportunity to understand them without disturbing the landscape. The application is a tool for heightening awareness and understanding the early farming communities in central Europe and building local and regional identity.

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SESSION 1B-
THE CHALLENGE
OF THE PREVENTIVE ARCHAEOLOGY :
EFFICIENCY AND QUALITY

Authors Ann Degraeve

Title *Preventive archaeology: how can we bridge the digital gap?*

Abstract Being part of the urban building planning process within a legal framework and forced to produce a maximum of data within a minimum of time, preventive archaeology is thus thought to be the perfect setting for new digital techniques. These are supposed to offer archaeologists the possibility of gaining time within the harvesting, the production and the safeguarding of the data. We are however contrived to observe, after some years of preventive archaeology management, that this is unfortunately not the case.

Although several basic digital operations found their way into the daily modus operandi in the field, such as the use of a total station, other techniques and tools, like photogrammetry and 3D-scans, are clearly still not fully part of the basic knowledge in digital recording. For several reasons, many archaeological operations still lack the necessary digital input not only to save the archaeological data from their destruction inherent to urban development and this within an often very short time frame, but also, and in a worrying way, within the storing of the archaeological data, jeopardizing thus the necessary conservation of the archaeological heritage.

As managing organization of preventive archaeology faced with the multiplicity of the actors and this digital gap, we should subsequently take our responsibilities towards the various actors. This communication wants therefore to focus on the problems encountered in the (unfortunately not widespread) use of digital systems within preventive archaeology and how we cope with this on a daily basis in the urban archaeology within the Brussels Capital Region, Belgium.

The Brussels' workflow consists of three main fields of action starting with the preparation of the field work via cartographic assessment of the archaeological potential. A multitude of ancient maps have therefore been vectorised and georeferenced towards the actual cadaster forming the legal base for the organization of preventive archaeology, i.e. the Atlas of the Archaeological Potential in the Brussels Region. During field research, a combination of various registration techniques has been put in place according to the type of data gathering and production to be done. A general management database system has been put in place obliging every archaeologist working within the Brussels Capital Region to enter their excavation data. The database system includes not only the data from field research (registration of layers, features, objects, samples etc.) but also the data concerning the laboratory and restoration activities and the management of the storage and archiving facilities (eg. "geo"-localization of the archaeological objects and samples within the storage rooms). This standardized data management offers thus the possibility of easy exploitation and sharing of data between researchers. It is, since 2014, coupled with a systematic open access publication of the excavation reports and paleo-environmental analyses, allowing thus the grey literature to disappear and give access to the archaeological results both to researchers and the general public.

Authors Maxime Seguin, Yaramila Tcheremissinoff

Title *A Systematic photogrammetric survey in a context of preventive archaeology: the collective grave of "Cavalade-Mas Rouge"*

Abstract The collective grave of "Cavalade – Mas Rouge" was discovered before the construction of the A9 bypass of Montpellier city (Hérault, Languedoc-Roussillon, France). An excavation of this structure took place from August 2013 to January 2014. It is located on the outskirts of a previously excavated Neolithic village and was used around -3300 BC. The burial place occupies a large digging of 6 meters by 4 meters and 2 meters deep. The primary purpose of

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this cavity was a large domestic cellar. The funeral destination took place in a second time.

The context and characteristics of this structure has led us to choose a recording method that permits an exhaustive and rapid acquisition. A specific recording protocol was set before the excavation phase in consultation with the administering authority for archeology (Service Régional de l'Archéologie). The objectives were to record all human remains and artifacts in three dimensions in a reliable and systematic manner. The manual drawing was excluded given the time constraints, the classical image registration could not guarantee the requested accuracy, and the use of a laser-scanner was not appropriate. Consequently, photogrammetric survey has been chosen for its set up comfort and low cost.

The process allows, for each stage of digging, to produce an orthophotography and a digital elevation model (DEM). The resolution of these orthophotographies is 0.5 mm. The horizontal and vertical accuracy of the DEM is millimetric. Twenty photogrammetric surveys were conducted during five months : one 20-minute acquisition per week. The computations were performed with the MicMac software suite developed by the French National Institute of Cartography (IGN). It is dedicated to scientific purpose and is distributed under a free and open-source license. Tacheometric surveys were only used to measure ground control points. An overall photogrammetric survey of the cellar was also conducted at the end of the excavation. All produced data can be exploited through the QuatumGIS software.

To our knowledge, a photogrammetric survey of such a volume in a context of preventive archeology remains unique. It has led to a significant gain of efficiency, time and accuracy. The interest of this case study also lies in the use of a completely free and open-source professional software suite. In the short term, this method could be used on a regular basis on other similar projects.

Authors

Rupert Gietl, Luca Bezzi, Alessandro Bezzi

Title

Preventive Archaeology along the WW1 high alpine frontline. Challenges – Approaches – Limitations.

Abstract

In occasion of the 100th commemoration of the beginning of WW1 on the Italian front in May 2015, the Cultural Heritage Department of South-Tyrol together with Arc-Team has started a first pilot project aiming to find a reasonable way to handle the huge amount of remains on a 600km long frontline on altitudes up to 4000m. The project started in 2012 on a restricted area of approximately 6 km² on an altitude between 2000 and 2400 meters where we were able to record more than 1000 structures of a large second line Austro-Hungarian artillery cluster. Facing up to this facts, we tried to evolve a work-flow starting from archive-studies going on with large-scale geodata analyzes and finally arriving to low altitude aerial photography, ground survey and 3D-documentation.

The method was tested and improved during a European project along the Italian and Austrian border in 2014, which gave us the possibility to study an area with the presence of fist line defences of both warring parties: The complexity of the situation, mirroring the heterogeneity of the war-infrastructure itself, urged us to optimize another time.

The final target is to get a quick, exact, low cost and open source based method of data collection which we want to present in our contribution.

At the end of the project we were able to compare the results of ground survey with the yield of information got from different geodatasets, historical maps and low altitude aerial photos.

The impressive gap between the effective density of the structures and the idea we have got interpreting aerial photos and digital terrain data should be another point to take up.

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Finally we want to broach the subject of data presentation and communication to the public. We are testing different ways of sharing the results with the user, pointing at applications for mobile devices using geolocalization, camera tracking and augmented reality.

Authors **Enrico Petruzzi**

Title *Collecting, managing and sharing archeological data: Preventive archeology in a urban context. Porto Torres, Sardinia, Italy.*

Abstract

Cities with a long continuity of life represent one of the most stimulating and problematic field for the implementation of preventive archaeology. The frequency of the archaeological operations, the multiplicity of interests interacting and the complexity of urban structure make "multistratified cities" the context of the most strident opposition between modification and respect of existing evidences, planning of the future city and sharing of historical information within the society.

The urban area of Porto Torres presents interesting features, related to recurrent processes of expansion and contraction of the city over the centuries since the foundation of the *Colonia Iulia Turris Libisonis* in the first century. B.C.

The paper intends to retrace the development process of specific tools for managing geographic archaeological data, functional to the practices of preventive archeology, developed in recent years according to the implementation of the rules of protection provided by the Regional Landscape Plan of Sardinia. This path of conceptual evolution of the methodological approach to the study of the archaeological city, will be illustrated starting from the methods of acquisition of data often processed and stored in very heterogeneously forms from a basis of knowledge built over a century and a half of investigation.

The partnership between heritage protection and State agencies and universities has marked this process since an early stage. Currently the strong collaboration between the Department of Architecture, Design and Urbanism of the University of Sassari (DADU) and the Superintendence for Archaeological Heritage is the ideal setting for testing the parameters of SITAN (Geographic Information Archaeological National System), research project born within a network of universities and supported by MIBAC and ICCD.

The application of SITAN parameters is required by the Ministry of Cultural Heritage for the application of the methods of preventive archeology and for the sharing of archaeological data. Porto Torres is one of the first experimental contexts of this tool that allows to organize and share informations starting from punctual positioning of all types of archaeological data.

The work is currently going forward on a double track:

Acquisition of archaeological data by reviewing the documentation from most recent excavation conducted along the coast line, the most sensitive area to the urban transformation in the immediate future.

Creation of computer applications for predictive knowledge of the context focused primarily to the activity of heritage protection and urban planning but that can also be used for the dissemination of knowledge in the near future. Through the use of a postgresQL DB server, connected via web using PostGIS client to open source GIS (QGIS) is enabled the acquisition, processing and online publication of the data and its direct use by the responsible for the institution of protection through the use of a positioning system based on web mapping API for smartphones and tablets.

SESSION 2A-
INTERDISCIPLINARY METHODS
OF DATA RECORDING,
MANAGEMENT AND PRESERVATION

Authors **Liat Weinblum, Stefan Münger**

Title ***DANA (Digital Archaeology and National Archives) – A New Software Tool for Field Archaeologists***

Abstract The paper presents and showcases a new archaeological documentation system jointly developed since 2011 by the Israel Antiquities Authority (IAA) and the Department of Jewish Studies, University of Bern (Switzerland). It is based on software elements previously developed for the Kinneret Regional Project database framework, operating since 2003.

Governmental archaeological institutions, such as the IAA, are normally involved in rescue excavations and/or complex, long-term projects, often facing difficult work situations in urban/constructional contexts and usually bound to especially tight time frames. Therefore, the envisioned digital tool not only needs to streamline and facilitate the archaeological documentation process but is also required to simplify the administrative reporting workflow, including a seamless integration into the broader, already existing IT-framework of the national archives.

Likewise, the system is expected to guarantee highest academic standards during fieldwork and in the following publication phases.

The basis for DANA – the digital documentation tool under discussion – is the well-known Filemaker Pro database software (V. 12.0.3 and higher). This technically simple database environment allows easy programming, fast debugging and a handy fallback on already existing resources. However, the basic tools offered by Filemaker Pro would not allow a fluid and professional work environment. Thus, DANA is packed with additional technologies, improving both, communication with the different components of the software and the user experience.

In its experimental stage, DANA was successfully tested on five medium scale IAA salvage excavations, of which each one imposed different requirements on the system. Based on these test cases, DANA has been further improved towards a first productive version and was implemented in 2014 in all IAA excavations, counting more than 300 each year.

Authors **Francesca Anichini, Gabriele Gattiglia**

Title ***Preserving Italian archaeological open data: the MOD solution.***

Abstract The MAPPA Open Data (MOD) archaeological repository (www.mappaproject.org/mod) stores and consider openly accessible all kind of archaeological data from raw data to linked open data produced during the research process, including metadata, and it's connected with the Journal of Open Archaeological Data for good quality data. Our infrastructure is hosted on GNU/Linux of the Centro Interdipartimentale di Servizi Informatici per l'Area Umanistica (CISIAU) of University of Pisa, is designed on an Open Source LAMP technological platform using an Apache HTTP Server, PHP 5.x scripting language and MySQL Open Source relational database. The growing volume of openly accessible data has a great impacting factor in the management and preservation of data. Currently, as our main purpose was to persuade the archaeological community of the importance of open data, we use a basic policy for data management: we acquire raw data from archaeologists, and we validate the data from a legal point of view.

We published a detailed guide in which are explained the procedures that must be followed to prepare and provide the material to be published. In compliance with the laws, published documents are not expected to contain the personal data of natural persons who have not

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previously agreed to their publication, whether they are authors or third parties mentioned inside the records. Specific disclaimers have been prepared and can be downloaded to help authors correctly collect the authorisations needed to put their material online. Once validated the data, we embed metadata to each dataset describing all the information regarding the dataset itself, we stored the data in our repository, providing protection. We use a metadata schema for each dataset describing all the information regarding the dataset itself: the structure and format of the digital data, the history of the archaeological investigation, the sources used, the method and the relationship with the physical data. The schema is composed partly from Dublin Core and partly from ISO 19115 metadata core for the geographical section. We don't describe the quality of data, because we firmly believe that the quality of research data must be responsibility of researchers in a sort of open peer review method. Preservation should ensure the authenticity, reliability and logical integrity of data in perpetuity. The solutions we adopt are: normalization, i.e. migration to widely supported open standards; version migration, i.e. migration through successive versions of a format, in many cases it's the only option for preserving proprietary formats that don't migrate to open standards (this is practical where the software using proprietary formats is widely used within a research community); format migration, i.e. migration to other formats for dissemination; refreshment media, i.e. migration between media which leave data unchanged. Finally, strongly pushing towards reuse, because reuse itself aids preservation, for this reason all datasets are licensed with CC-BY or CC-BY-SA licenses and published with a DOI (Digital Object Identifier).

Authors

Giuliano De Felice, Andrea Fratta

Title

A dig in archive. The case of Herdonia.

Abstract

Since 2004 the Department of Humanities at University of Foggia holds the historical archive of Herdonia, containing the documentation of archaeological research carried out in the Roman town of Northern Apulia since 1963. Started as a Belgian project in 1962, in 1993 the Herdonia project became fully international, involving other European Universities and evolving into a wide field school for hundreds of archaeologists and students until year 2000 when field activities definitively stopped.

The story hidden into the archive is long and complex, written in the documentation produced during 40 years of excavation and survey that led to the discovery of one of the largest daunian, roman and medieval site of Southern Italy. The archive is a unique memory covering a long time span, containing documents that are parts of the history of archaeological research, linked with various methodologies (from long trenches and Wheeler method to big areas) and realized using different techniques and technologies (from paper drawings to CAD models, to 3D scans). Moreover the archive contains other kinds of data such as excavations diaries, drafts, inventories, photos and also video tapes.

The purpose of activities carried out at Digital Archaeology Lab is to share all the documents of Herdonia archive starting from spatial data, carrying out specific workflows for building a common environment in which digitized legacy data and digital born data can stay together.

The first phase of the project has been thus the recovering all the hand-drawn maps, their digitizing and georeferencing in an open source GIS. For the first time all of the sectors and trenches dug up on Herdonia Site stay together, georeferenced, under the same roof.

The main topic that will be discussed in the paper is the workflow used for referencing and blending sources belonging to different phases of the research, starting from graphic documentation and written sources. These kinds of documents represent the majority of our - and we can imagine most - archaeological archives and it is mandatory to extract from this kind

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of documentation as much information as it is possible.

As we believe that it is mandatory to make these data available for all kind of users, we are currently implementing a WebGIS platform that can be handy for several purposes, from research planning to visitor support. This platform is currently undergoing test phase on a smaller context of the roman Forum, where a very complex stratigraphy describes life phases from pre-roman times to early Middle Ages; the aim is to build an interactive 3D environment with a reconstruction of the whole chronological sequence and share it on a website.

Authors

Kang Li

Title

Computer-assisted archaeological line drawing by viewpoint-related feature extracting method

Abstract

Archaeological line drawing is one of the most important data recording technologies in an archaeological excavating process, and also an essential component of an archaeological report. Archaeologists use archaeological line drawings to illustrate the appearance and accurate geometric measurements of heritage objects. Traditional methods for archaeological line drawing is manually record line-drawing in 2D methods, the process hence quite laborious and time-consuming and the results varies between different recorders. In this paper, we propose a computer-assisted method to generating archaeological line drawings on 3D triangle meshes reconstructed from 3D laser scanning data of fragments of Terra-cotta Warriors and Horses of Qin by Creaform VIUScan. First, to reduce redundant lines detected on the rough and noisy surfaces with holes, we use the de-noising, holes filling, and mesh simplification method. Second, to extract the lines of 3D model, we introduce a viewpoint-related ridges and valleys extracting method. Third, because lines extracted from the second step are not connected, and some parts stiff, we proposed a stylized silhouette rendering method by a improved line expanding algorithm. Finally, we generate the line drawing from the apparent geometric features of 3D object. Experimental results show that line drawing generated by this method can describe the shapes and appearance of heritage objects precise and clear. Compared with the traditional manual method, our method is more accurate and efficiency. The results is used as the line frames for the archaeologists to generate line drawings of archaeological report of the third excavation of Terra-cotta Warriors and Horses of Qin Dynasty.

Authors

Enora Maguet

Title

Palaeoenvironmental records and PHP possibilities: results and perspectives on an online bioarcheological database

Abstract

Palaeoenvironmental records, which represent now a rich amount of information, set complex problems of data management. Thus, they need to be stored within an appropriate device, such as a local or online RDBMS.

Indeed, several European bioarcheological database projects already exist (Bioarch, BioarchoDat, Arbodat), but they concern more often anthracological and archaeozoological samples than palynological records. For these reasons, we decided to gather the palynological

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and anthracological results of the investigatory works carried out among the archaeological unit of Rennes (UMR 6566 CreAAH). Afterwards, we built an online relational database whose aims were to allow palaeoenvironmentalists to record, read and exploit this information.

The database, called ABCData (for Archeology, Biodiversity, Chronology Data), was created using the FuelPHP framework, which respects the *Hierarchical Model View Controller* architecture, and allowed us to generate the numerous files associated to the CRUD (Create, Read, Update, Delete) functions of the different tables. The tables are stored in a PostgreSQL database, hosted on the OSURIS server (Rennes 1), and were created through the administration PhpgAdmin interface. The user interface, (<http://archeosciences-abcdata.osuris.org/>), required the use of several programming languages, as well as two free libraries, PhpExcel and D3.js. The first one allows the user to import and export spreadsheets, and the second one to generate graphic representations of the palynological results.

A prior attention was brought to ensure possibilities of interdisciplinary and interoperability with other palaeoenvironmental remains and databases, and more specifically to foresee the problems associated to the dating and chrono-attribution of the samples, and to the taxonomic references.

The php database also permitted the construction of a palynological query interface, in association with a SVG (Scalable Vector Graphic) generator. These tools provide an interesting way of analyzing the sample data, crossing the different records and studying the impact of numerous parameters such as the topographic implantation or the sediment characteristics throughout the Holocene period. We conducted a series of analyses based on the palynological content of 43 sedimentary cores from the Paris Basin, in order to compare ABCData's performances to the synthetic history of the basin vegetation set on the empiric merging of the same data, since the late Epipaleolithic times. This study revealed a great accordance between the two methods, and highlighted some bias and the necessity of permanently watching over of the statistic distribution of the samples.

Therefore, it seems that the ABCData project could bring fertile bioarcheological hypothesis, especially by developing interdisciplinary queries. Likewise, the D3.js library used for the SVG generator could provide new forms of palaeoenvironmental representations, like dynamic 3D graphs.

Authors	Smaragdi Papagiannopoulou, Niki Naoumidou
Title	<i>When Archeology and Conservation meets in a cultural information system for movable archaeological finds so-called: Mnemosyne</i>
Abstract	<p>Introduction: Through the definition of the profession of conservator as given by the ICOM-CC and the Charter of Venice it becomes clear that the documentation and recording is important for each stage of its work. The volume of information either analog or digital resulting from conservation and other scientific disciplines for movable archaeological finds are great. Therefore, for the appropriate management, preservation, storage and evaluation, the use of information systems is necessary.</p> <p>Purpose of the poster:</p> <p>The purpose of this poster is the presentation of "Mnemosyne", a web-based management and documentation system for movable archaeological finds.</p>

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Presentation of the system:

Some of the topics that will be presented are: The purpose of the system, the requirements analysis, the users, the structure-design, the content, the software selection and the compliance with international standards.

"Mnemosyne" was created to meet the needs for documentation and management of archaeological information and information of conservation of excavation finds, by recording all scientific and administrative procedures incur from the discovery of the excavation finds in any change in their condition. Every action is documented, by the use of photographs, designs, with the use of physical and chemical parameters and with the use of bibliography, linking the responsible person that acted, the time frames of the action, the place of it as well as the motivation and the means used.

For its implementation, it was used a free and open source software. It was developed in PHP programming language, with the Drupal Content Management System in an Apache server. The database was designed in MySQL. For the data modelling, archaeological information and conservation information of the 1st Ephorate of Prehistoric and Classical Antiquities, have been studied. The system was designed and implemented as the bachelor thesis in the Department of Conservation of Antiquities and Works of Art, TEI of Athens, Greece

Conclusions – Results:

In conclusion, "Mnemosyne" is an interdisciplinary system that connects information from different scientific fields where users are classified into specific roles. It sufficiently supports the inductive procedure of recording information from fragments to the complete object and presents them under two central axes, the conservation report and the archaeological report. It is compatible with international standards such as the CIDOC - CRM, Object ID, directions of AIC etc. It is an online platform that creates in real-time a fully supervisory overview.

Authors	Arianna Traviglia, Stephen White, Andrew Wilson, Beatrice McLoughlin
Title	<i>Digital laboratory recording: workflows and data models for artefact processing</i>
Abstract	<p>The registration and cataloguing of artefacts has almost completely moved from paper to computers in a variety of forms, and with the introduction of powerful mobile devices comes the opportunity to digitally record this process in ways that are efficient, flexible enough to be adapted to different projects and different regulatory regimes, and capable of generating sophisticated highly linked datasets.</p> <p>This poster presents two examples of the application of this approach using Android tablets, Open Data Kit Collect xForms application and a server-based data modelling and management system.</p> <p>The first example is the process of automated artefact primary inventory, further cataloguing and study applied within "Beyond the city walls (BCW): the landscapes of Aquileia", a landscape archaeology project based in Aquileia, Italy. Routine collection of artefacts is undertaken during field walking survey and a large amount of manifold archaeological artefacts were collected over four years of the project (2010/2013). To handle the cataloguing and</p>

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storing of a considerable number of artefacts an efficient process was set up to minimise the time spent in primary inventory procedures and to automate them as much as possible, as well as provide a valuable analysis tool in the following artefact study phase.

The second example is the inventory of artefacts from the Zagora Archaeological Project (ZAP) a multi-disciplinary investigation of the Early Iron Age settlement of Zagora on Andros, Greece. Important aims in this project have been to use digital data capture and storage as much as possible, the integration of new data with the extensive records from the earlier investigations managed within an existing database, and the provision of preliminary feedback to fieldworkers and researchers, in the form of annotated photographs, as quickly as possible.

In both cases initial development included the creation of a data model. The inventory workflows were then identified and data collection forms created for each workflow. The forms – with the existing data model integration mapping – were downloaded into the ODK Collect Android application running on Lab-dedicated tablets. Data collected was then uploaded, tracked and ingested seamlessly into the data model of the server database. Our experience demonstrated that choosing a flexible delivery system, such as ODK, that allows applets to capture data in a customised way means the system can be easily adapted for a variety of data collection needs. A fundamental aspect of our approach is the decoupling of the data collection workflow from the ultimate data model. This made possible efficient data collection in the lab and automated processing to conform to the data model in the database.

Authors

Andrea Bardi, Luisa Dallai, Alessandro Donati, Vanessa Volpi

Title

Archaeological and physicochemical approaches to the territory: on-site analysis and multidisciplinary databases for the reconstruction of historical landscapes .

Abstract

Archaeological surveys combined with physicochemical analysis and the statistical treatment can be used as powerful tools to offer a comprehensive picture of historical territories impacted by ancient settlements mine exploitation. Despite the fact that information could be hidden depending on different historical circumstances and local conditions (i.e. overlapping stratification, concurrent influences etc.), in fact traces of different activities persists as fingerprints in the landscape.

Following archaeological and historical questions, a number of scientific techniques applied on environmental matrices (i.e. soil, stream sediments, water, plants) can be employed with both predictive and descriptive goals (Benvenuti *et alii*, 2014). In particular, high throughput techniques can be used in multi-scale investigations (intra-situ and medium-large territorial scale) in order to obtain detailed chemical and/or geochemical maps. The merging of these data with archaeological maps will give a more accurate interpretation of the historical context and can be very advantageous in the excavation planning of a site (Dallai *et alii*, 2013).

This model need a specific care in the classification, storage and recovering of the data. Consequently the production of a "smart database" is mandatory in order to have a correct inter-exchangeability of the data and flexibility in the data-mining.

In the present work the methodological approach of our research is reported together with key studies demonstrating its validity and robustness.

In particular we focused our attention on some ancient mining and smelting sites of "Colline Metallifere", a wide territory located in the south-west of Tuscany. This area is characterized for the presence of arsenic and heavy metals contamination associated with a relevant and long-standing tradition of ore mining and processing (Donati *et alii*, 2005). The great development of mining activity was due to the presence of a large mineral deposit, mainly constituted by

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mixed sulfide ores that were exploited since Eneolithic age for the production of copper, silver, lead and iron. Beside this, considerable alunite deposits underwent to a systematic extraction activity recorded from Late Middle Age to early XIXth century. Here, archeological research has been developed since '80 through excavations and surveys, covering a territory of more than 145 km², recording and describing over 2500 sites (about 50% of these were ancient mining and/or smelting sites) (Bianchi *et alii*, 2009).

Through this multidisciplinary approach several sites were investigated; the results have contribute to propose a possible historical interpretation of the landscape, with a special focus on their mining and metallurgical aspects, and have offered new possible perspectives to ongoing archaeological researches.

Authors**Jean-Yves BLAISE****Title*****Putting architectural changes into context: the historySkyline visual metaphor*****Abstract**

When trying to understand and recount how pieces of architecture get transformed as time passes by (may we observe one particular historic edifice or a whole urban structure), analysts pull together a variety of documentary hints helping them to spot and depict changes over time, and to order (if not date) those changes.

The word “changes” means here of course morphological or structural modifications such as extensions or demolitions, addition of new architectural components or removal of deprecated technical solutions, replacement of a material by another, etc. But it may also refer to successive functions devoted to a piece of architecture or to successive ownerships and role in the city for instance.

At the end of the day, analysts try to end up with a sort of “chain of events” where periods of stability and changes are assessed and ordered in time, and where the actual physical layout of pieces of architecture is likely to be represented in 2D or 3D through contemporary geometric modelling platforms (typically, VR applications).

But when looking at it from closer, what exactly are architectural changes? A random, accidental, phenomenon, a sort-of matter of chance?

What initiates them? Why do they occur? Why do they precisely occur in one specific place at one specific time?

In this contribution we base on the claim that it can be worth considering architectural changes over time as consequences – and accordingly to try and cross-examine the underlying possible causes.

More modestly and pragmatically, the research is aimed at relating architectural changes to potential causal factors by correlating information on architectural changes (in terms of morphology, structure and function) with information on a global context (legal issues, natural phenomena, demography, wars and rulers, etc.).

We introduce a visual metaphor called historySkyline aimed at aligning architectural events (any changes, including destruction or extension) and facts that may have impacted these events (in short, pieces of information about historical contexts). The visualization combines a recount over time of architectural transformations (by type) with indications on the amounts of historical evidence available and with a variety of contextual information such as wars, natural disasters, life of important people, demography, new laws, etc. The visualisation does not actually mention causality: it barely puts facts that occurred at the same period side by side. It is applied to architectural changes on Cracow's Main Square (over 40 edifices at one time, 3

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left today – 371 architectural changes recorded, 538 bibliographic sources, 478 pieces of information about various elements of contextualisation). It builds on an infovis-birtherd mantra: using vision to think, with here a specific bottleneck – highly heterogeneous data sets.

The contribution introduces the methodological and technological choices behind the historySkyline visual metaphor, and discusses its practical benefits and limitations in terms of information discovery on the abovementioned test field

Authors **Michal Gilewski**

Title *Slow-motion videography and recording experimental archaeology*

Abstract Since the very beginning digital imaging techniques have been of great importance for archaeology. The material remains of the past found during the process of excavation have static character. This is why the use of photographic stills dominates archaeological imaging. Modern archaeology deals not only with creating frozen images of the past, but also with understanding the variety of dynamic processes that happened. While some processes in past societies took generations to occur, others happened within the blink of an eye. The examples of the latter are frequently related to studies of how material culture was created, and often are recreated through experiments.

All such cases demand very scrupulous documentation of the process. Especially so, if some of the reenacted phenomena appeared very fast. Even less dynamic events may not necessarily be well understood when observed in real time. Such problems can be dealt with by introducing methods that have already been in frequent use in industrial experiments or sports coaching - slow motion videography. This used to require expensive equipment but now such imaging is possible with some consumer grade digital cameras or smartphones, therefore becoming easily accessible to archaeologists. It is perfect for documenting phenomena, for instance related to material endurance or improving the understanding of stone tool making gestures. Such video recordings provide certain characteristics that facilitate adequate, reflective perception of experiment, but also produce as a “by-product” videos with considerable aesthetic qualities which are suitable for dissemination among popular audiences.

Authors **Tiina Väre, Jaakko Niinimäki, Milton Núñez, Markku Niskanen, Sanna Lipkin, Sirpa Niinimäki, Matti Heino, Annemari Tranberg, Rosa Vilkkama, Saara Tuovinen, Timo Ylimaunu, Titta Kallio Seppä, Juho Antti Junno**

Title *Virtual excavation of burials utilizing Computed Tomography imaging*

Abstract We utilize computed tomography (CT) imaging to study naturally mummified remains of individuals buried beneath Northern Finnish churches during the early modern period. Otherwise human remains seldom survive in the acid soil of the region.

Our aim is to determine their physical measurements and pathological lesions to derive information about their living conditions by using diagnostic software of the CT scanners. Since the future preservation of the remains is uncertain, a further aim is to assess their preservation and save the physical attributes of the mummified remains in digital form.

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Moreover, these methods allow us to perform repeated 3-dimensional, layer-by-layer dissections not only of the human remains but also of the burials as entities. We are also able to gather information about burial materials – such as the coffin itself as well as the textiles, ornaments, plant elements and other accessories sealed inside it – without harming this unique heritage. In a sense, the examination functions as a virtual, repeatable and non-invasive archaeological excavation. Prior to this project we had already utilized pQCT (peripheral quantitative computed tomography) and CT scanning in osteological method development and other studies of bone material. Although CT imaging is widely used in the research of mummified human remains, this is the first such study on naturally mummified individuals from Finland. Additionally, the examination of the artefacts associated with the burials solely via CT imaging is somewhat of a novelty. It is for instance possible to study preservation, form and quality of textiles using exclusively CT images. The project was initiated in 2011 with a CT study (64-slice CT scanner, Discovery 690, General Electric Medical Systems, Milwaukee, WI, USA) of the mummified remains of a 17th century Northern Finnish vicar. This pilot study proved CT imaging to be a useful method in reconstructing past lives of people from the northern periphery of Europe. More recently the coffins of seven sub-adult individuals were imaged using updated hardware (2x128-slice dual-energy CT-scanner, Somatom Definition Flash, Siemens Healthcare, Erlangen, Germany). Studies focusing on their anthropometrics and burial textiles are on their way and even dendrochronological analyses of the wooden coffins may be possible.

Authors

Thom Corah, Douglas Cawthorne

Title

Driving Engagement in Heritage Sites Using Personal Mobile Technology

Abstract

In a recent UK Arts and Humanities Research Council (AHRC) funded project researchers from De Montfort University, the University of Nottingham and the University of Durham have collaborated with two community heritage groups to produce two innovative new mobile apps. The project and the apps are intended to address particular issues surrounding the use of mobile digital technologies for co-production of community heritage interpretation in community archaeology and to examine how the explanatory and interrogatory potential of mobile device software can be used to build community led interpretive paradigms for post excavation analysis, presentation and education in community archaeology projects.

The use of smartphone and tablet devices has been growing significantly over the past five years and is now becoming more common in heritage and museum settings.

The aim is often to further develop public engagement with tangible and intangible cultural heritage, explain and explore existing information about artefacts, sites and cultures and present new information in engaging, accessible and meaningful ways to a range of audiences. Community archaeology groups are becoming alert to this trend and wish to engage with it too, particularly for 3D exploration of built archaeology and the artefacts associated with it. This poses a number of challenges to these aims that differ from those for artefacts and documents in museum settings alone. It also poses contextual challenges in relation to specific and highly engaged user groups like community archaeologists.

This paper describes the completed apps which have been designed to address some of these unique challenges of interpreting and exploring 3D digitally reconstructed historic buildings on mobile platforms for community archaeology and heritage groups. Concepts underlying the design and implementation of the apps are addressed and examples of their use in two specific archaeological projects in England are described; a Roman bath house in Northumberland and an historic urban fabric in Southwell, Nottinghamshire. The paper focusses upon paradigms adopted for visualisation and exploration and also upon the web-based management methods

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developed to allow the community heritage groups themselves to upload, interpret and present their own data and media in relation to the 3D visualisations of the buildings in the apps and by doing so take substantive control of the interpretation of the archaeology they are involved with. This rich, community produced media content such as documents, images and videos forms a persuasive body of constantly evolving evidence and knowledge which distinguishes this innovative approach from many other 3D visualisations of historic buildings on mobile devices. The paper concludes with observations on the use of the apps by the groups and in particular upon the user experience, changes in the focus, strategy and thought prompted by use of the apps and on their effect upon wider public engagement.

Authors Cynthia Mascione, Luca Passalacqua, Rossella Pansini

Title *Integrated methodologies for the reconstruction of the ancient city of Lixus (Morocco)*

Abstract

In 2010-12 the University of Siena, in collaboration with the INSAP (Institut National des Sciences de l'Archéologie et du Patrimoine) and the University Mohamed V- Souissi of Rabat, carried out an archaeological project in Lixus (Larache), one of the most important centres of antique Morocco. The site lies on a hill over the Loukkos river estuary. It was inhabited, not continuously, between the VIIIth century BC and the XII-XIIIth century AD. The city area was first investigated in the XIXth century and under the Spanish Protectorate in Morocco (1912-56). In recent years, other archaeological expeditions were led by the University of Valencia and the INSAP. Previous research brought to light several public, private and productive structures. Among these, the *cetariae* quarter is nowadays the largest fish processing complex of the Roman Empire. The topography of Lixus was documented by some aerial images, produced by a photogrammetric survey realised in 1966, and by some building plans.

Our research strategy aimed at integrating different techniques and methods:

- acquisition and study of relevant documentation, both in published and archival records,
- geophysical prospections of unexcavated areas,
- topographical survey of emerging structures,
- DGPS survey,
- 2D and 3D land-based and aerial photogrammetry,
- survey and analysis of the archaeological stratification and building techniques of the city walls,
- analysis of the diachronical urban evolution of a quarter located on the eastern slope of the hill, close to the supposed *forum*.

All the data were managed in CAD environment and then transferred on a GIS platform.

This multidisciplinary approach produced a great amount of data, that led to the revision of Lixus urban plan and the definition of the historical and archaeological evolution of the city walls and of the eastern slope quarter.

Authors Anais Guillem, Dejan Veranič, Roko Zarnic

Title *UNESCO World heritage serial property Prehistoric Pile Dwellings around the Alps, Monitoring of pile dwelling near Ig, in Ljubljana Marsh Nature Park with photogrammetry and BIM approach.*

Abstract The serial of Prehistoric Pile Dwellings around the Alps comprises a selection of 111 out of about 1000 known archaeological pile-dwelling sites in six countries around the Alps (Switzerland, Austria, France, Germany, Italy and Slovenia). In Slovenia, Ljubljana marsh clusters forty pile dwellings, dating from 4600 BC to around 1600 BC. Only a part of the sites had been excavated until now. The results show us the early agrarian societies in interaction with their environment during the neolithic and bronze Ages. In the case of prehistoric pile dwellings, the monitoring of the sites is crucial to ensure the continuing integrity and authenticity of the sites and their contexts. In prehistory area of Ljubljana marsh was covered with lake. Now a mosaic of different habitats provides living space for many, including vulnerable and endangered, species. Ljubljana marsh is a natural protected area and the area of pile dwellings in Ig, a monument of national importance.

When we talk about the remains of pile dwellings *in situ* we think of the cultural layers created during the formation, use and decay of the settlements. Extremely well preserved organic material is a specificity of these archaeological sites. They were preserved due to the constant presence of water, absence of oxygen, and consequently low activity of microorganisms. The constant presence of water is therefore crucial for pile dwellings to remain intact. Pile dwellings in lakes are threatened by erosion and water transportation. The results of the monitoring of groundwater levels with piezometers in Ljubljana marsh and Špica in Ljubljana indicates that the cultural layer is not currently threatened. But river erosion is a potential danger: there are reports of several endangered sites and presently we lack basic monitoring for the identification of current erosion.

This paper proposes a protocol of pile dwelling monitoring. Its location in a marshland in the river bed makes it vulnerable to water erosion and limits the possibilities of monitoring with traditional techniques. Our protocol uses photogrammetry as technical survey for its accuracy and its relative ease of use in the work field. Non accessible on foot, the different photographic campaigns have to be carried out from the channel aboard a canoe. Data processing- meshing, segmentation, semantic enrichment-, should lead to the integration of data in a BIM system. The comparison of the different data sets will result in a quantitative and qualitative analysis of erosion of the pile-dwelling site in a year. This protocol is tested to be applied to the monitoring of all pile-dwelling sites to facilitate management both in terms of research and protection and to support the interpretation of sites.

SESSION 2B-
INTEGRATING 3D DATA
FROM FIELD ARCHAEOLOGY

Authors **Maria Doriana De Padova**

Title ***Re-shaping the excavation - The use of Computer Vision to bring back to life everyday tools and burial contexts***

Abstract Since a “reconstruction” is no more the right way to interpret archaeological excavations, small finds and bones, Computer Vision tools are considered the best way to bring them back to life after an -obviously- destructive excavation. Given different interpretations by different people working on-field, traditional techniques are no more that objective and need to be integrated with advanced technological in-field tools, creating opportunities to visualize and interpret ancient contexts and possibilities to evaluate small features both in everyday tools and in human bones. Features of the stone furnishings under analysis were acquired using Computer Vision methodologies and processed with MeshLab. The present project aimed at using Computer Vision potential to evaluate and analyse, in a non-invasive way, medieval artefacts, their function, as well as tiny marks in human bones, applying filters to meshes so as to inspect small features, the real artifact shape, and to take actual measurements. This in turn permits to compare them with similar objects found in the same context, providing a new way of “re-shaping” the excavation thanks to new interpretations and to a quick, cheap and effective way of comparison of more similar objects excavated throughout many years in different past campaigns. Acquiring several graves and their grave goods in “real-time”, georeferencing them, connecting them with furnishings found in houses and workshops helps reconstructing a perfect timeline and finding in the end a strict connection between dead bodies and everyday space belonging to alive people.

Authors **Roosje de Leeuwe**

Title ***Integration of 3D scans, photogrammetry and Total Station data in forensic archaeological case work***

Abstract In the Netherlands Forensic Archaeology is an archaeological discipline applied to crime scenes, specifically those with buried or scattered human remains or buried objects. As discipline it is positioned within the Netherlands Forensic Institute (NFI). Crime scene work is a cooperation between various disciplines, where a forensic archaeologist works together with the visualization team of the National Police Corps. The visualization team makes 3D scans and record parts of the crime scene with a Total Station. Afterwards, the 3D scans and Total Station data is integrated by the forensic archaeologist in GIS with other (by means of photogrammetry) recorded data, such as collected evidence. The results presented in the NFI report clarifies the situation at the crime scene. This helps for example tactical police officers to test a scenario or it helps a judge to understand and reconstruct the actions of a perpetrator at the crime scene. By means of several case examples the practical integration of 3D scans, photogrammetry and Total Station data in GIS will be explained.

Authors **Katie Simon, Eileen Ernenwein, Chistopher Angel, Christine Markussen**

Title ***Integrating remotely sensed surface and subsurface data in three dimensions for a new look at old spaces***

INTEGRATING 3D DATA FROM FIELD ARCHAEOLOGY

Abstract

Over the past century, traditional field surveys and excavations in Petra, Jordan have contributed greatly to a wider understanding of Nabataean materials, architecture, society, and spaces. Recent implementations of archeo-geophysical methods are proving to supplement this ever-growing body of research successfully. Our recent ground penetrating radar and terrestrial laser scanning surveys at the Monastery (ad-Deir) in Petra have had similar success in identifying new features that have previously gone undetected. Individually, each method yielded interesting datasets about the Monastery providing new insights about this enigmatic façade. On their own, single method approaches are often limited to either surface (e.g. terrestrial and airborne lidar) or sub-surface (volumetric GPR or 2.5 dimensional geophysical imagery) spatial data types at scales specific to the each individual dataset at site-specific scales. Relationships between datasets remain unexplored and limited attention is paid to their greater context and the complex socio-spatial landscapes of Petra. By amalgamating these approaches through data fusion in a single visualization, we explore the potential for alleviating these limitations by implementing an integrative methodology that considers the multi-dimensional (surface/sub-surface), mutli-sensor, and multi-scalar datasets of the Monastery within broader temporal/cultural/physical socio-spatial landscapes of Nabataean Petra .

Authors

Arian Goren, Kay Kohlmeyer, Thomas Bremer, Susanne Brandhorst, Arie Kai-Browne, Alexander Hennig, Felix Balda, David Strippen, Sebastian Plesch

Title

Past progressive: Interacting with simulated archaeological assets

Abstract

As cooperating interdisciplinarily gradually becomes the core of many archaeological projects, integrating data from multiple and diverse sources is seen as an indispensable component in the work pipeline. Digital and 3D data are common components in archaeological information databases, however expectations regarding their employment steadily rise beyond their service as aids in passive visual representations. The rapid progress in real-time rendering software and more accessible computational power enables to assemble 2D and 3D data-sets into comprehensive repositories faster and more efficiently. Furthermore, through manipulation of 3D simulation and game-design techniques those integrated data-sets (re)gain relevance in the process of interpreting archaeological contexts.

Retaining high level of details and geometric relations of a complex scene while reconciling inherent variations in the scale, format, and resolution of input data (ranging from 2D and 3D field recordings to satellite imagery) has been already successfully achieved in the simulation of the Temple of the Storm God of Aleppo, realised by the interdisciplinary working group *Virtual Archaeology project*. The current focus of the working group is aimed at evaluating the potential of virtual reality platforms in interpretative archaeological applications, to be tested through continuous adjustment of definition and functionality of interfaces in 3D simulated spaces. Real-time interaction with a modelled space and its assets, and mutual collaborative scientific work can take place within a single simulated space. Administered through advanced interfaces and supported by dynamic data input first-hand testing of research objectives, evaluating suggested reconstruction, or (re)interpreting archaeological records is made available.

These exiting new measures, presented in this talk through an exemplary work session, demonstrate the considerable potential of real-time virtual environments as effective tools in integrating diverse data sources into the archaeological toolbox, and as means to re-think and re-assemble interpretation of archaeological scenarios.

INTEGRATING 3D DATA FROM FIELD ARCHAEOLOGY

Authors Loes Opgenhaffen, Martina Revello Lami

Title *Pottery goes digital. 3D laser scanning technology and the study of archaeological ceramics.*

Abstract Over the last fifteen years, three-dimensional digitization has been successfully used for the study and preservation of a wide range of cultural heritage objects, from architecture to in situ monuments, from archaeological artefacts to precious manuscripts. Most frequently brought into play for documentation purposes, 3D scanning systems are highly precise measurement tools, which provide a high quality, high-resolution three-dimensional archive of an object's surface topography. However, the possibilities offered by 3D scanning technologies have not been fully explored in archaeological research so far, where these systems have been mainly used in order to speed up the traditional practice of visual recording and to build automated classifications and typologies. Pottery studies, in particular, have paid greater attention to the development of increasingly sophisticated methods for deducing from 3D scanner output most accurate and representative profiles of complete ceramic vessels as well as small fragments, largely overlooking other promising applications.

To bridge this gap, we will present the preliminary results of a pilot study carried out on consistent bodies of pottery, spanning from the Iron Age to the Mid Republican period, in which systematic ceramic analyses have been coupled with 3D scanning technologies. By means of this integrated approach, we aim at demonstrating that the full potential of 3D scanning technology applied to archaeological ceramics goes way beyond accurate documentation procedures. In receiving the complete account of surface geometry, texture and volume, 3D models enable to determine vessels capacity, calculate the density of ceramic material and virtually assemble dislocated fragments. More importantly, three-dimensional models provide additional information on the very process of making a pot, shedding light on manufacturing methods, technological choices and potters' motor habits. In fact, the detailed recording of surface topographies can lead to more accurate analysis of features such as grooves, spiral ridges and cracks, commonly examined to assess different shaping techniques (wheel throwing, moulding, coil-building). Likewise, 3D models may establish different degrees of variability in the morphological attributes of a ceramic assemblage, contributing therefore to trace scale and intensity of pottery production.

SESSION 2C-
SUPPORTING RESEARCHERS
IN THE USE AND RIUSE
OF ARCHAEOLOGICAL DATA:
FOLLOWING THE ARIADNE THREAD

SUPPORTING RESEARCHERS IN THE USE AND REUSE OF ARCHAEOLOGICAL DATA: FOLLOWING THE ARIADNE THREAD

Authors Sorin Hermon, Franco Niccolucci

Title *The problem with simpl(istic) fundamental concepts in archaeology and their formal representation in a digital environment – the case of “archaeological site”*

Abstract “Archaeological site” is one of the most recurrent and widely used terms in any scientific publication of the Archaeology domain and yet, there are surprisingly very little attempts at trying to properly define and describe it. There are even fewer discussions on the possible “negative” impact of the uses of computer-based databases, digital text descriptions, knowledge repositories, etc. on our understanding of the term “archaeological site”. A brief survey of the term returns an interesting conclusion: an archaeological site becomes into existence only after a formal archaeological activity (survey or excavation) in a given geographical space. Consequently, it is clear that an “archaeological site” has very blur geographic boundaries: do they match (and what is the accuracy of this matching) with the excavation area, are there “annexes” (possibly unexcavated but identified through remote sensing, land survey, etc.) or the human occupation in the area extends over un-identified borders. An attempt to provide a solution to this challenge was to estimate extension of sites according to density distribution of artefacts or observed features. Another dilemma regards the temporal borders of “archaeological sites” – can a “site” accommodate only a single human occupation phase (how long one may consider a “homogeneous” phase?), or multiple occupations of various types, intensities and socio/cultural natures? There are further, known problems, in visual representation of archaeological sites (e.g. GIS maps), in particular related to scale issues and boundaries, issues which are yet to be solved in a formal manner. The situation further aggravates when heterogeneous datasets and digital repositories are integrated within large research environments. Solutions proposed by the Semantic Web technologies, such as harmonization of terms and vocabularies does not offer a proper solution to the above. We are proposing instead a formal “de-construction” of the term and formal description of its components within the frame of CIDOC-CRM. Thus, the attributes describing the “archaeological site” will be formally described within the CRM ontology, through its properties and relations. These can be: method of discovery (coming into being), nature of its geographical extension and how it was determined, temporal boundaries, type of features and social activity, etc. Thus, the essence of an “archaeological site” is reflected through its attributes and, consequently, the integration of the term within large research environments, connecting countries, languages and conceptual differences, will be obtained through the harmonization proposed by the CIDOC-CRM, assuming of course that in due time all such datasets will have a CRM layer embedded within them.

SUPPORTING RESEARCHERS IN THE USE AND REUSE OF ARCHAEOLOGICAL DATA: FOLLOWING THE ARIADNE THREAD

Authors Nikolaos A Kazakis, Nestor C Tsirliganis

Title *Scientific Datasets in Archaeological Research*

Abstract The aim of archaeology is the understanding of humankind. A further objective is the reconstruction of the lifeways of the people through the material remains of past societies. In this endeavour the recent years, archaeology interacts increasingly with natural sciences and informatics to take advantage of the possibilities they offer and reduce the subjective element. The combined information from the various scientific disciplines allows the investigation of theories and interpretations that shed light on the human past and environment.

The re-creation of the material culture reveals the social, political, economic and cultural structure and evolution of ancient societies as well as their interactions within sites or regions. Ceramic artifacts, usually pottery, are a simple and convenient means for this purpose due to their abundance in excavation sites, their resistance to erosion, easy transportability and many functions. They represent also a sophisticated merging of separate domains of human knowledge and experience.

Provenance of ceramics, namely seeking an answer to the question of where the artifacts were produced, is a vital point in archaeological studies, since it illuminates various aspects of the civilization that produced them, such as their technological level, cultural contacts and economic interactions between communities in a broader area.

Provenance studies of ceramic objects constitute one of the best examples of the joint action of various sciences, such as chemistry, physics, petrography, geology, mathematics and informatics in the archaeological research. Using analytical methods several measurements are conducted to determine the chemical composition, physicochemical properties and structure of the materials along with the morphology and the physicochemical parameters of the excavation environment. The above, in conjunction with their statistical processing, result in the production of numerous important *scientific data* which represent a unique “*fingerprint*” for each artifact which shall shed light on their (common) provenance, since featural variations *between* sources should be greater than *within* sources.

All the information extracted from the materials using advanced scientific methods produce data, which do not merely serve as tools for answering individual archaeological questions, but also allow the complete scientific documentation of the artifacts and the creation of large scientific reference datasets. These datasets include data of various formats (e.g. numbers, spectra, charts) and types (e.g. raw data, calculation results), while their metadata (e.g. experimental method, instrumentation, date) are essential for their evaluation and constructive use, especially when comparisons are attempted.

Significance of such datasets is further enhanced when they conform to a formal standardized structure, like CIDOC CRM, that provides a common and extensible semantic framework that any cultural heritage information can be mapped to. Such a modeling of information will assure the credibility and durability of a scientific database, since it would encompass only the necessary data and metadata devoid of any excessive information, which along with their interdisciplinary character should contribute to the building of an integral archaeological research infrastructure.

The present work provides an overview of the recent trends in provenance studies and presents certain case studies that illustrate best practices in the field.

SUPPORTING RESEARCHERS IN THE USE AND REUSE OF ARCHAEOLOGICAL DATA: FOLLOWING THE ARIADNE THREAD

- Authors** **Gisli Palsson**
- Title** *From Site to SEAD: bridging the gaps between fieldwork, laboratory analysis and online archiving*
- Abstract**
- Archaeologists working in the North Atlantic, like in so many other regions face a daunting backlog of poorly integrated datasets. These data, fuelled by large multinational research projects and rescue excavations,
- There are particular issues associated with integrating these datasets. The majority of research projects in the North Atlantic are either primarily concerned with environmental data or heavily reliant on palaeoenvironmental analysis. The datasets for environmental proxies are rarely integrated, however, and neither are the post-excavation lab results consistently linked back to the fieldwork archives. The main dating method of Icelandic archaeology, tephrochronology also offers great potential in consistently phasing sites, but comparing sites based on tephrochronology currently needs a great deal of manual work.
- To address some of these Issues I have begun developing a software application as part of my PhD. that aims to simplify the archiving and integration of existing and future archaeological data. The application is based on the following principles:
- An easy-to-use normalised data entry where a stratigraphic unit table acts as a central fulcrum for the integration of all additional work associated with an excavation. A postgresQL structure with a PostGIS component where all elements are related back to the context definitions.
 - Harris Matrix relational logic allowing for an automatic generation of matrix diagrams.
 - Chronological phasing based on the Harris Matrix logic.
 - Links to existing online Cyberinfrastructure to ensure simple online archiving on open-access platforms. The application is tied to the Strategic Environmental Database (www.sead.se) and uses the data ontology developed by the SEAD project. The application will also be linked to Tephabase (www.tephrbase.org), providing a range of information about tephra found in excavations as well as adding to the knowledge of tephra coverage in Iceland.
- This presentation will cover some of the issues related to North Atlantic archaeological data and illustrate the potential uses of the software tools described above.
- Authors** **Keith May, Ceri Binding**
- Title** *Paths through the Labyrinth: Finding ways to express data from differing archaeological recording methodologies to enable cross-search and reuse*
- Abstract**
- The increasing opportunities for better data integration of datasets from multiple archaeological investigations and reusing legacy data to inform current research or future investigations, is a key driver for a number of initiatives undertaken by staff at English Heritage (soon to become known Historic England).
- Initial work was carried out to model the archaeological processes undertaken by English Heritage archaeological recording teams using the CIDOC CRM ontology to explicitly express the conceptual relationships between archaeological records regardless of the actual database system used to hold those records.

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This conceptual modelling was based on the widely adopted archaeological recording methodology - single context recording - used by English Heritage and most commonly by other archaeological organisations across the UK. Those archaeological extensions of CIDOC CRM have become known and implemented as the CRM-EH (Tudhope et al. 2011).

More recent work under the ARIADNE FP7 project (<http://www.ariadne-infrastructure.eu/>) has explored the requirement to model the integration of data from a range of different data sets across Europe that have been recorded using sometimes quite differing archaeological recording methodologies. This has led to a re-examination of the CRM-EH modelling to understand where the key elements for integrating Single Context Recording with other archaeological methodologies should be made. This work has led to a new set of CIDOC CRM extensions known as CRMarchaeo (2014) that has been modelled with the intention of being able to integrate a broader range of archaeological data recorded using different excavation processes along with single context recording data. In particular the aim under ARIADNE is to enable greater integration reuse and cross-search of 'legacy' data along with new excavation results from across Europe.

This paper will examine some of the work and thinking that has gone into the new CRMarchaeo modelling, based on lessons learned from implementing CRM-EH and will discuss some key elements of expressing the archaeological conceptual relationships between the data that can be made use of by semantic technologies.

Authors	Angela Trentacoste, Sarah Whitcher Kansa, Eric C. Kansa, Anthony Tuck
Title	<i>Linked Open Data in the Etruscan World: A Zooarchaeology Case Study</i>
Abstract	We present the results of collaborative data publications that represent the first step in making the archaeology of the Etruscan world open for comparative analysis and reuse. Our approach centers on integrating increasingly mature Web technologies, especially Linked Open Data, into scholarly communications and publishing practices. As a starting point, this project brought together zooarchaeological datasets from Poggio Civitate, Poggio Colla, and Forcello, spanning the 8th- 3rd centuries BCE. We published the faunal data in Open Context (opencontext.org), an open access data sharing platform that adds value to the datasets through editorial processes and Linked Data annotation referencing relevant Web datatypes and ontologies including the Encyclopedia of Life (biological taxa), UBERON (for anatomical entities), and more specialized vocabularies for osteometrics and age characterization. We give examples of how this approach to the comprehensive publication of datasets helps us explore research questions and observe patterns not possible with single-site assemblages. Our results demonstrate the power of data publication and annotation in improving the intelligibility and usefulness of datasets, and making them useful to a wider research community beyond archaeology. We propose this approach as a starting point and invite our colleagues working with Etruscan materials to build on this work to create a comprehensive body of open data for Etruscan studies.

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- Authors** **Stephen Stead, Dominic Oldman, Jonathan Whitson Cloud**
- Title** *Exploring inferences, time and space in the annotation of museum catalogues: The Sloane catalogues*
- Abstract**
- Modern digital museum catalogues differ from historic manual catalogues in that the record boundary is virtual, in the digital and physically on the page, for the manual. The history of the edits in digital systems can only be determined if the change history is explicitly recorded or if periodic snapshots of the data are preserved (although this only gives periodic aggregates of edits). In contrast the pre and post edit states of each edit and annotation are visible on the page in a physical catalogue volume. Card index systems vary in their completeness in this respect, as in some circumstances the card is replaced rather than updated. This has the effect of producing an aggregate of edits similar to a periodic digital snapshot.
- Within the catalogue entries there are many possible interpretations of the use of geographical place names. For instance they can refer to the place of manufacture, the region of use, the place of collection, the region of a particular culture or the origin of the manufacturer. Each such interpretation has a different semantic meaning and consequently a different mapping to the CIDOC Conceptual Reference Model (CIDOC-CRM).
- Similarly dates and other temporal appellations can have many meanings: date of manufacture, date of collection, date of accession into the museum, date of record compilation and/or editing or significant dates in the history or provenance of the object. Again these different meanings have different mappings to the CIDOC-CRM.
- In addition to these content elements, there are spatial and temporal relationships between the catalogue entries and annotations in historic manual catalogues and between annotations in card index systems. These too have particular mappings to the CIDOC-CRM.
- This paper continues the work on these different CIDOC-CRM mappings in the context of catalogues of the Sloane collection. In particular it will look at harnessing the mark-up of the entries and annotations to allow the documentation of inferences made from them.
- Authors** **Maria Theodoridou, Martin Doerr, Edeltraud Aspöck, Anja Masur**
- Title** *Mapping archaeological databases to CIDOC-CRM*
- Abstract**
- The exponential growth of the Web and the availability of large number of digital datasets revealed the need for integrated access to heterogeneous and autonomous data sources. In the Cultural Heritage domain, ARIADNE, an FP7-INFRASTRUCTURES-2012-1 EU project (Grant agreement no: 313193), brings together and integrates existing archaeological research data infrastructures so that researchers can use the various distributed datasets and new and powerful technologies as an integral component of the archaeological research methodology.
- The primary role of the CIDOC-CRM (ISO 21127:2006) is to enable information exchange and integration between heterogeneous sources of cultural heritage information. CIDOC-CRM was chosen as a good starting point for defining ARIADNE's Global Model, a coherent global ontology for deep integration of scientific and cultural-historical evidence and facts.
- There is an ongoing effort in ARIADNE to systematically provide sample mappings for the most relevant types of archaeological data sets and in this context several mapping activities

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were initiated trying to convert existing schemata of archaeological data to CIDOC-CRM and its extensions.

In this paper we will present the collaborative work between FORTH and OEAW defining mappings of two archaeological databases to CIDOC CRM. The mapping of dFMRÖ (*digitale Fundmünzen der Römischen Zeit in Österreich*), a relational database of Pre-Roman and Roman Imperial period coins found in Austria and Romania, presents an interesting use case of relational database mapping where there is need to address and separate both categorical and factual information. We introduce two specialized relations in order to support categorical production, similar to relations used in the FRBR model. The mapping of *Gräberfeld Franzhausen-Kokoron*, a database of 400 Late Bronze Age cremation graves from Franzhausen-Kokoron, Austria, with about 3800 records, serves as a test case for the recently developed CRMarchaeo. CRMarchaeo is an extension of CIDOC-CRM to support archaeological excavations and allows for a common representation of archaeological records and survey data, widely independent of local methodology. The two main concepts of the CRMarchaeo – *A1 Excavation Process Unit* and *A8 Stratigraphic Unit* – will be introduced and the importance of conceptually separating past activities from present archaeological activities and interpretations will be demonstrated.

For the mapping definition we used X3ML, an XML based language which describes schema mappings in such a way that they can be collaboratively created and discussed by experts. To further facilitate the mapping process we have implemented the Mapping Memory Manager, an editor for creating X3ML definitions which is also presented in this paper. Links:

<http://www.oeaw.ac.at/numismatik/projekte/dfmroe/dfmroe.html>

<http://epub.oeaw.ac.at/franzhausen-kokoron2/> <http://www.ics.forth.gr/isl/CRMext/CRMarchaeo.rdf>

<http://www.ics.forth.gr/isl/3M>

Authors

Ceri Binding, Douglas Tudhope

Title

Connecting ARIADNE vocabularies for data integration and cross search

Abstract

The ARIADNE project [1] involves multiple data providers having multiple data sets, indexed using multiple controlled vocabularies in multiple languages. The project does not aim to replace existing archaeological data repositories, but rather to consolidate their metadata in order to facilitate cross search. There is therefore a need for some form of common ground to enable effective data integration; however it would clearly be unreasonable to expect to achieve domain-wide agreement on adoption of any single database schema or controlled terminology.

In the course of previous Knowledge Organization projects undertaken by University of South Wales (STAR/STELLAR/SENESCHAL) [2] we have addressed issues around the conversion of archaeological datasets and their associated controlled vocabulary resources to semantic web formats, making them available online for searching and browsing. One key issue that emerged was the fragmented nature of the various controlled vocabularies in use. In an ideal world conceptual knowledge about the archaeology domain would not be split and duplicated across modern territorial / political / organizational boundaries, but in the real world this is inevitably often the case. Local vocabularies are created for the purposes of controlled indexing of local resources to aid subsequent retrieval, but perhaps having less regard to any issues of wider integration – so no formal semantic links exist between these vocabularies. Any project seeking to implement such wider integration must tackle this issue to achieve data interoperability.

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The creation of mappings between local vocabularies can provide a mediating platform to enable cross search; however the number of possible direct links between equivalent items originating from different vocabularies can quickly become unmanageable as the number of vocabularies increases. A more efficient and scalable approach would be the adoption of an intermediate structure onto which concepts from each local vocabulary may be mapped. A search on a concept originating from any one vocabulary can then utilise this mediating mechanism to route through to concepts originating from any of the other vocabularies, possibly expressed in multiple languages.

An exploratory exercise for the ARIADNE project was undertaken to demonstrate the utility of this approach. The poly-hierarchical structure of the Getty Art & Architecture Thesaurus (AAT) [3] was extracted for use as an example mediating structure to interconnect various multilingual vocabularies originating from ARIADNE data providers. Vocabulary resources were first converted to a common concept-based format (SKOS) [4] and the concepts were then manually mapped to nodes of the extracted AAT structure using some judgement on the meaning of terms and scope notes. The overall composite structure could then be queried.

The exercise demonstrated an effective method by which cross search could be achieved over multiple multilingual vocabularies using such a mediating structure, with a significant added benefit of introducing semantic expansion to potentially improve recall without affecting precision. The search results obtained can then be used to find related archaeological resource records from throughout the ARIADNE data. In the next stages larger scale mappings will be produced, to be published in the ARIADNE repository.

Authors

Matteo Dellepiane, Federico Ponchio, Marco Callieri, Roberto Scopigno

Title

Ariadne media service: easy publishing of advanced visual media for archeological databases

Abstract

One of the goals of the EC Infra “ARIADNE” project is to design, implement and deliver a number of digital services for the archaeological community, which will be integrated in the ARIADNE web portal.

Ariadne media service Browse Upload Help Contacts

Ariadne media service

Create your online showcase for 3d models, images and RTI.

[Upload >](#)

3D models

3D representations produced with 3D scanners or photogrammetry are extremely high-resolution and hard to visualize at interactive rate. This service produces a web page that supports interactive visualization of your data, after converting it into an efficient multiresolution encoding.

[View details >](#) [Demo](#)

RTI images

Relightable images (called Reflection Transformation Images, RTI, or Polynomial Texture Maps, PTM) are becoming an increasingly used media. This service closes a current gap, giving support for easy publication on the web and interactive visualization of RTI images.

[View details >](#) [Demo](#)

High-resolution images

High-resolution images are a commodity resource in archaeology. Unfortunately, they are most often disseminated and published on the web by using low-resolution versions (a single 40Mpixel images is 120MB in uncompressed format and around 10MB when lossy compressed).

[View details >](#) [Demo](#)

Visual Computing Lab - ISTI - CNR

SUPPORTING RESEARCHERS IN THE USE AND RIUSE OF ARCHAEOLOGICAL DATA: FOLLOWING THE ARIADNE THREAD

The ARIADNE Media Service is aimed at providing support for the easy publication and presentation on the web of complex media assets. The idea is to build an automatic service able of transforming any media file uploaded by ARIADNE archives managers into a format that will allow easy and efficient access and remote visualization on the web. The service is based on a simple web interface and supports three types of visual media: high-resolution images, RTI (Reflection Transformation Images), and high-resolution 3D models.

These types of media are not easy to show on the web, because their visualization may need to download the entire file, and possibly select/install dedicated software. Moreover, the owner of high quality data may prefer not to give the possibility to visitors to freely download them, in order to protect the ownership of the data.

After accessing the service, the user finds a simple web form that allows to upload its own data (3D model, hi-res image or RTI) and to provide some basic information about the media. The service processes the input data in an automatic way and creates an online page. At the end of the processing step, the user receives an email containing a link to the visualization page (hosted on the Ariadne web-service and open to any external user) and to an admin page, where the associated data can be modified. It is also possible to download the created page (html code + processed 3D Model or image) in order to integrate the content on the user local server or archive.

In the case of 3D models, the geometry is processed, converting a possible complex 3D model into a multiresolution format (Nexus, <http://vcg.isti.cnr.it/nexus>). This multiresolution structure is streaming-friendly, and is used to create a visualization webpage using a web presentation tool (3DHOP, <http://www.3dhop.net>) based on WebGL and developed by CNR-ISTI.

Analogously, also high resolution images are transformed into a multi-resolution format, supporting progressive streaming; the service transforms each image in a web-compliant format: similarly to Google maps, the high-resolution image will be regularly divided in chunks and a hierarchy of images at different resolution is produced from these chunks; then, a rendering webpage is created where it will be possible to navigate the model in a WebGL frame.

RTI are managed similarly to hi-res images, even if the encoding for the web streaming is a bit more complex, and WebGL rendering also takes care of the input and calculation of the variable-lighting.



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With this setup, even naive users can easily create an efficient webpage to display complex 2D or 3D content. Alternatively, for more experienced users, these basic webpage may be the starting point for the development of more complex visualization, or for the integration of these visualization inside existing websites, taking advantage of the features of the 3DHOP platform (www.3dhop.net).

Finally, the data structures for remote visualization (multi-resolution for 3D models, image pyramids for images and RTI web encoding) protects the original data, since a direct download of the multimedia file in a single plain format is not possible.

The Ariadne Media Service represents a first step towards a full integration of visual media in the context of archeological datasets

Authors Fabrizio Galeazzi, Marco Callieri, Matteo Dellepiane, Roberto Scopigno, Julian Richards

Title *ADS 3D viewer: a web-based dynamic working environment for archived 3D data*

Abstract The advancement of web technology has caused a shift of paradigm in the use of the web. It is no longer simply a way to search for data in repositories, download and open it on a local PC. Instead it is a work-enabled platform where data can be explored dynamically and used for data analysis and interpretation directly within the web browser.

In the framework of the ARIADNE European project and a Marie-Curie fellowship, we are working to implement a web-based working environment (ADS 3D Viewer), on top of an existing and well known repository of archaeological data, Archaeology Data Service (ADS), a UK-based cyber-infrastructure hosted at the University of York. Starting from the ADS project archives, we have extended the web-based project browsing functionality with dynamic visualization of the available data. Since the granularity of the data preserved in the repository is at object level, we firstly implemented an automatic 3D model viewer to explore the digital model in its own repository page. This exploits another service developed in the ARIADNE project, the Ariadne Media Service, which automates the creation of web-based 3D viewers using the 3DHOP tool (<http://vcg.isti.cnr.it/3dhop/>).

The ADS 3D Viewer project aims to allow the user to browse 3D geometry using a simple trackball directly in the webpage containing all the information related to the digital model. Researchers can measure the 3D model and, using a "share view" feature, save and share the current settings of the 3D viewer (viewpoint, zoom, and lighting) with other users. The "share view" feature will help scholars to share their personal visual exploration and analysis of the 3D model on the web. Simple as they may seem, these features are nevertheless a way to directly use the 3D models in the repository without having to download them and use specialized 3D software.

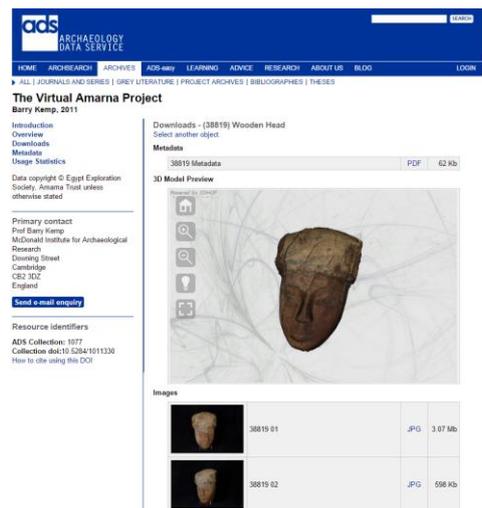
The second aim of the project is to create a viewer for a very specific kind of "aggregated" data, overcoming the object level granularity of the data in the repository. We chose to develop a 3D viewer for the exploration of archaeological stratigraphic data. Before the development of ADS 3D Viewer the repository stored the 3D models of each stratigraphic unit as single objects, without the possibility to explore their spatial and temporal relationship. The ADS 3D Viewer aggregates the different geometric layers in a single 3D environment, where the user may turn layers on and off according to different patterns (single layer, all layers under this

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SUPPORTING RESEARCHERS IN THE USE AND RIUSE OF ARCHAEOLOGICAL DATA: FOLLOWING THE ARIADNE THREAD

one, two layer comparison, etc.), control their transparency, and explore the layered geometry using a specialized trackball. The tool offers the same measuring and "share view" feature of the single object, but also the possibility to select hyperlinks that provide extra information on all the features contained in the layer (i.e. text, pictures, stratigraphic unit sheet, etc.).

While this second viewer is still under development, we believe the final version will represent a usable and useful instrument for the remote, collaborative study of complex archaeological datasets, and promote discussion between scholars.



The screenshot shows the ACS Archaeology Data Service website. The main content area is titled "The Virtual Amarna Project" and features a 3D model preview of a wooden head. The page includes a navigation menu, a sidebar with project information, and a table of images.

ACS ARCHAEOLOGY DATA SERVICE

HOME ARCHRESEARCH ARCHIVES ADS-APP LEARNING ADVICE RESEARCH ABOUT US BLOG LOGIN

ALL | JOURNALS AND SERIES | GREY LITERATURE | PROJECT ARCHIVES | BIBLIOGRAPHIES | THESES

The Virtual Amarna Project

Barry Kemp, 2011

Introduction
Overview
Downloads
Metadata
Usage Statistics

Data copyright © Egnet Exploration Society, Amarna Trust unless otherwise stated

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Resource identifiers
ADS Collection: 1077
Collection doi:10.5284/1011330
[How to cite using this DOI](#)

Downloads - (38819) Wooden Head
Select another object

Metadata
38819 Metadata PDF 62 Kb

3D Model Preview

Images

Image ID	File Name	Format	Size
38819 01	38819 01	JPG	3.87 Mb
38819 02	38819 02	JPG	596 Kb

SESSION 2D-
LINKED DATA:
FROM INTEROPERABLE
TO INTEROPERATING

Authors Philipp Gerth, Sebastian Cuy

Title *Connecting Cultural Heritage Data: The Syrian Heritage Project in the IT infrastructure of the German Archaeological Institute*

Abstract The ongoing armed conflict in Syria has led not only to a humanitarian disaster, but also threatened the rich cultural heritage of Syria. As an active involvement is not possible at the moment, the German Archaeological Institute (DAI) in cooperation with the Museum for Islamic Art Berlin and the German Foreign Office have started the Syrian Heritage Archive Project in November 2013. Its aim is to create an extensive systematic documentation system from the various available source that can be used to support preservation and reconstruction and also helps to prevent illegal trade. One major challenge posed in that project was integrating the various types of research data generated by archaeological, art historical and architectural history projects in order to create a comprehensive national registry of archaeological sites. In the past years the DAI was able to implement applications and web services for various domains and types of data relevant for archaeological studies. Not only did using these existing Systems in the Syrian Heritage Project ensure sustainability. The open application interfaces of the applications allowed us to aggregate the heterogeneous research data like excavation data, texts, archives, cadastral plans, historical maps, etc. and to present them in a unified user interface. Especially the DAI's resources for managing geo data were of particular value for this enterprise. On the one hand the geoserver "iDAI.geo" makes various sets of spatial information accessible, while on the other hand the "iDAI.gazetteer" is used as a hub to connect the different resources within the DAI infrastructure and also acts as a gate to the Linked Data cloud by establishing links to existing resources like Pleiades, Pelagios and geonames. Thus users can not only view all data collected in the project but also to use the resulting application as a starting point for further research into other systems.

Authors Karsten Tolle, David Wigg-Wolf

Title *How to move from Relational to Linked Open Data 5 Star – a numismatic example*

Abstract In our database solution *Antike Fundmünzen Europa* (AFE), where we record finds of ancient coins, we want to preserve as much information as possible. This also includes containments of possible coin types, or marking attributes of a coin as uncertain if the exact value can not be assured. As many others our backend-system is based on a traditional relational database (MySQL). In order to become a Linked Open Data 5 Star, we mapped our data to different ontologies from Nomisma.org, Dublin Core, SKOS and others. Besides providing these data to others, we also benefit from the new ability to view our relational data in a totally different way, by loading the data back to a graph database.

We will present how we mapped our data based on an existing mapping language called D2RQ Mapping Language, without the need for changing the underlying database. In our case this was less problematic due to the fact that internally we had already set AFE up based on Nomisma.org thesauri. However, the thesaurus mapping can also be part of the mapping. With this mapping established, one can for example provide a SPARQL endpoint to others in order to allow them to access the data in an ontological way. However, for full interoperability there are still barriers that need to be overcome.

Even if the same vocabulary is used, different modelling approaches might hinder full interoperability – this will be the focus of our talk, explaining what we mean by this. This problem does of course not occur when the modelling is identical. We are currently planning

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to combine different databases instances that are all build on top of AFE (such as Germany and Poland, as well as Romania which is under construction) based on the same mapping in order to demonstrate the potential.

We will further report about benefits we see from the ability to use graph visualizations of the data. We will report on our experiences with AllegroGraph as a graph database allowing reasoning for some standard properties, and Gruff as a visualization and query interface on top of it.

Authors

Florian Thiery, Thomas Engel

Title

The Labeling System: A bottom-up approach for enriched vocabularies in the humanities

Abstract

Shared thesauri of concepts are increasingly used in the process of data modelling and annotating resources in the Semantic Web. This growing family of linked data thesauri [1] follows a top-down principle. Vocabularies and broader concepts (SKOS-) are being created, maintained and provided under the supervision of central authorities to provide general and generic approaches used by scientists in the humanities. But the diversity of research questions in the humanities makes it virtually impossible to create shared controlled vocabularies that cover a wide range of potential applications, and therefore satisfy the needs of diverse stakeholders. Reliable interconnections among independent systems could solve this conceptual bottleneck of controlled vocabularies.

The Labeling System (LS), developed by i3mainz and IEG [2] in contrast follows a bottom-up approach, enabling scientists working in the digital humanities to manage, create and publish their own controlled vocabularies as a SKOS concept scheme and concepts provided via a REST API and URIs [3]. One term of the vocabulary can be linked to broader corresponding concepts of domain experts and will become labels. The labels embed those broader concepts persistently into existing structures using a clean and straightforward UI. Technically the LS is defined over a flat ontology and can be queried through its triple store [4].

The created concepts can then be interlinked with well known LOD resources from e.g. The Getty Research Institute or the British Museum, but also to authorities maintaining linked data resources from natural science domains. The LS is domain independent, while uniting perspectives of different scientific disciplines on the same label and therefore contributing to interdisciplinary collaboration for building up cross and inter-domain linked data communities. As the newly created expert resources are available persistently, the concept is quotable, which strengthens the scientific discourse of their semantic shape.

The paper addresses principles of the Labeling System in the light of heterogeneous archaeological data from Western Europe and the Middle East. Consequently, “usual” archaeological topics of conceptualizing and interlinking temporal and spatial concepts (meaning) will be discussed. To what extent is it possible to align existing concepts with “inserting” specific concepts of domain experts? How can the LS be used to solve the ambiguity of a place type and its role or function in a specific archaeological meaning?

Furthermore, we will show how the non-technical researcher can use the Labeling System to get introduced into the process of linked-data conceptualization. Finally, the paper details the benefits of enriching linked-data concepts through relating to linked-data communities of other domains, e.g. geology [5] or anatomy [6]

LINKED DATA: FROM INTEROPERABLE TO INTEROPERATING

- Authors** Paul J Cripps, Douglas Tudhope
- Title** *From interoperable to interoperating Geosemantic resources; practical examples of producing and using Linked Geospatial Data*
- Abstract** The concept of using geospatial information within Semantic Web and Linked Data environments is not new. For example, geospatial information was very much at the heart of the CRMEH archaeological extension to the CIDOC CRM a decade ago (Cripps et al. 2004) although this was not implemented; a review of the situation regarding geosemantics in 2005 commented “*the semantic web is not ready to provide the expressiveness in terms of rules and language for geospatial application*” (O’Dea et al. 2005 p.73). It is only recently that Linked Geospatial Data has begun to become a reality through works such as GeoSPARQL (Perry & Herring 2012; Battle & Kolas 2012), a W3C/OGC standard, and the emerging CRM_{geo} standard (Doerr & Hiebel 2013). This paper presents some real world, practical examples of creating and working with archaeological geosemantic resources using currently available standards and Open Source tools.
- The first example demonstrates a lightweight mapping between the CRMEH, CIDOC CRM and GeoSPARQL ontologies using data available from the Archaeology Data Service (ADS) digital archive and Linked Data repository. The second example demonstrates the use of Ordnance Survey (OS) Open Data within a Linked Data resource published via the ADS Linked Data repository. Both examples feature the use of Open Source tools including the STELLAR toolkit, Open Refine, Parliament, OS OpenSpace API and custom components developed and released under open license.
- The first example will also be placed in the context of the GSTAR project which is using the approaches described to produce Linked Geospatial Data for research purposes from commonly used platforms for managing archaeological resources within the UK heritage sector. These include the Historic Buildings and Sites and Monuments Record (HBSMR) software from exGesis, used by UK Historic Environment Records (HERs), and MODES, used by museums for managing museum collections. As such, the outputs from the GSTAR project have wider applicability in moving geosemantic information from interoperable to interoperating.
- Authors** Olivier Marlet, Stéphane Curet, Xavier Rodier, Béatrice Bouchou-Markhoff
- Title** *Using CIDOC CRM for dynamically querying ArSol, a relational database, from the semantic web.*
- Abstract** MASA Consortium (*Mémoire des archéologues et des sites archéologiques* <http://masa.hypotheses.org/27>), from the *Très Grande Infrastructure de Recherche* Huma-Num (<http://www.huma-num.fr/>) aims to provide to the french community of archaeologists several tools to improve their data interoperability. In this context, we propose to open the ArSol database to the semantic web, using the CIDOC-CRM ontology and a tool that implements Ontology-Based Data Access (OBDA) principles.
- The ArSol (*Archives du Sol*: Soil Archives) system has been used by the “Archéologie et Territoires” Laboratory (CNRS – Tours University) since 1990 for processing archaeological data. It can be used for all stratigraphic excavations and has the dual purpose of data

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management and research. It was constructed, with proprietary software, as an open system that is flexible and above all not conditioned by the integration of predefined thesauri. The ArSol client-server system is designed to integrate data from different sites. ArSol is designed both as a recording and data management research tool for use during excavation, and as an exploratory data analysis system for post-excavation work.

Firstly, we designed a set of mappings from a selection of ArSol fields to the CIDOC CRM ontology. This manual alignment has been reported in CAA 2014. It allows us to transpose the ArSol data in an RDF format fully compatible with the CIDOC-CRM.

We present in this article a new step, which is to implement the software architecture to query ArSol from a SPARQL endpoint. We chose to use Ontop, software developed at the University of Bozen-Bolzano that allows to query a relational database via an ontology, using SPARQL. In this way we do not need to move our data from our efficient database in order to benefit from the semantic web capabilities (semantic interoperability, RDF/OWL 2 QL inference, etc.). We avoid the extract-transform-load (ETL) process for exporting our data in an RDF store and for updating it when data change in ArSol. Via the SPARQL endpoint, users or applications can query ArSol using the CIDOC-CRM part that we selected to represent our ArSol data. We used the Ontop Protégé plugin to design the OBDA mappings that are necessary for the SPARQL-to-SQL rewritings.

Our final goal is to devise an application that will offer a single interface to query several distributed and independent archaeological databases, with heterogeneous structures, using CIDOC-CRM to relate them to each other. Querying ArSol in SPARQL via the CIDOC CRM is an important step towards this goal.

SESSION 3A:
A DIALOGUE BETWEEN
ARCHAEOLOGICAL SCIENCE
AND COMPUTER VISUALIZATION

Authors **Ömer Uzunel**

Title ***3D Structural Analyses of Euromos Zeus Lepsynos Temple***

Abstract Euromos is an ancient settlement where locate at three kilometers distance from south of Selimiye Town that depends on Milas district of Mugla province, in Turkey. Archeological relics were unearthed back to the archaic era as a result of the excavation works in Euromos. Initial excavation works were carried out in 1967 by Ümit Serdaroğlu. After forty-four years, excavation works have been resumed by Abuzer Kızıl since 2011.

There are many archeological relics in the ancient city. These principles relics are Theater, Agora, Zeus Lepsynos Temple and city walls. Unfortunately, these buildings used as a quarry by the surrounding villagers and materials of buildings had moved at the modern settlement.

The most important building is Zeus Lepsynos Temple in the ancient city. The temple square measures within 26.80 m by 14.40 m. Temple structure has a peripheral plan within 6 by 11 layouts of columns that built according as a Corinthian order in the 2nd century of A.D.

In 2012, documentation work was carried out with the *Leica C 10 Laser Scanner* in the temple. The aim of study was documentation and assessment studies before excavation in the temple area of the ancient city. An abnormality was determining in the 3D structure when the data obtained from scan process transferred to the data medium of 2D. According to abnormality; static structure of one column was disrupted where is the northwest corner of temple and this column has been made pulling force within another columns which are connect to itself. This abnormality has been presented grave danger for fall down of all temple construction. Scan progress has been studied at regular periods on the temple since after this detection and all data registered about to verify this abnormality is progress or stagnation.

The purpose of study reveals for this disorder of static structural and their reasons. Defect works of restoration to present in during the excavation and after excavation to the scientific world.

Authors **Douglas Cawthorne, Steffan Davies**

Title ***Authenticating Anastylis: Para Data in the Digital Reconstruction of Greyfriars Church Leicester and the Tomb of King Richard III***

Abstract Creating visualisations of historic buildings and interiors from partial evidence requires realistically implementable strategies for managing the evidence upon which they are based and for documenting the decisions taken concerning the selection and value judgements made about that evidence. This paradata is essential for scholarly audiences for whom the degree of authentication and probability of correctness are central issues in developing trusted research. Several methods of generating this paradata are already recorded in the literature but while often systematic they are also complex and largely text based and for this reason it is recognised that their use is still the exception rather than the norm. In early 2014 Archaeologists at the University of Leicester in the UK discovered the remains of King Richard III, who died in 1485.

This internationally important archaeological discovery prompted Leicester City Council to commission the Digital Building Heritage Group at De Montfort University to use the newly discovered archaeological evidence and pre-existing literary and circumstantial evidence to create a highly detailed digital reconstruction for public exhibition of the now lost church and medieval precinct in which the king was buried. The international scrutiny surrounding this case required particular quality control over the paradata and the required development time for the reconstruction also required that any process used should be efficient, and practical to implement in a compressed time-frame. Experience was therefore drawn from quality control

A DIALOGUE BETWEEN ARCHAEOLOGICAL SCIENCE AND COMPUTER VISUALIZATION

processes in the construction industry to authenticate decision-making using a particular form of drawing we call “body-maps”. These are graphic representations which specify options applicable to generic 2D and 3D representations of buildings and artefacts allow their development and change in design, allow the recording, over marking and notation of selections made, alternatives proposed, final decisions arrived at and official endorsement or “signing off” of the final visualisation. We have found this diagram based approach a time and cost efficient vehicle for generating a rich and accurate paradata record and one which can be easily stored digitally and retrieved for future examination. One of its advantages is that because they are largely graphical in format the “body-map” drawings can be read in chronological sequence and so provide a narrative with minimal use of explicitly narrative text. Factors which affect the method’s use are the need for personnel who can use simple computer based drawing packages like Sketchup and Photoshop to create and modify the base “body-maps” and a willingness amongst the participants to engage in basic hand-drawing diagramming and over-marking on paper print-outs. Interestingly we found that formal drawing ability has little if any effect upon the utility of the process with all participants from a range of backgrounds able to intuitively engage with it. Furthermore the process actively encourages thoughtful and reflective practice and the development of shared frames of reference between different disciplines.

This paper explains the detail of the process we have developed, with examples of body-maps and their use, the resulting reconstructions and the methods we propose to archive and curate the paradata arising from it.

Authors	Melda Küçükdemirci, Salvatore Piro, Niyazi Baydemir, Daniela Zamuner, Elif Özer
Title	<i>The application of mathematical and statistical integration Approach on archaeological prospection data, case studies from Aizanoi, Turkey.</i>
Abstract	<p>The success of geophysical prospection methods applied on archaeological sites, to detect and identify the buried structures under the ground, depends on the nature of the features such as physical and geometric properties and environmental effects such as soil conditions, sensibility of equipments and experience of reserachers. Consequently, to obtain reliable and complemantary results, it is recomended to apply multi-geophysical methods and integration approaches on archeogeophysical field data (Weymouth, 1986; Neubauer et al,1997; Piro,2000; Clay,2001). An application of geophyscal integration methods which often appealed are divided into two class as qualitative and quantitative approches. Qualitative approache includes depicting the location of cultural features and interpretation of combined maps obtained from different geophysical methods. Besides that, quantitative approach includes the mathematical and statistical solutions for integration (Kvamme et al.,2006).</p> <p>The purpose of this work is the application of mathematical and statistical integration approaches by using different geophysical data on archaeological site. For this purpose, the synthetic models were generated to correlate between integration approaches. The processes were applied on field data obtained by using ground penetrating radar and magnetic methods at the Aizanoi Archeological site, Kütahya, Turkey.</p> <p>Primarily, the geophysical data were examined individually by referencing archaeological maps and the anomalies which are related to possible walls, roads or foundations were identified. In order to obtain clear informations about these anomalies, integration techniques were applied on field data. For the integration process, mathematical approaches as Sums and Products of the obtained processed maps and statistical approach as Principal Component Analysis were applied to elaborate the GPR and gradiometric datasets. The results of all integration approaches provided more details about the anomalies related to the archaeological features. Particularly, the application of Principal Component Analysis is thought to be an alternative</p>

A DIALOGUE BETWEEN ARCHAEOLOGICAL SCIENCE AND COMPUTER VISUALIZATION

technique for mathematical approaches. By using all those applications, it is clear to obtain a complementary images about the archaeological relics under the ground.

Authors **Carlotta Capurro, Dries Nollet, Daniel Pletinckx**

Title *ENAME 1288: A walk through Saint Saviour abbey*

Abstract This work focuses on the research about and reconstruction of the Saint Saviour abbey in Ename (Oudenaarde, Belgium) in the 13th century both in its architectural decoration and in its furnishing. The Saint Saviour abbey was build by the count of Flanders in 1063, on the remains of a major medieval trade settlement. It existed until 1795 when it was abolished in the French Revolution.

The reconstruction is based on the historical sources and archaeological data provided during more than 25 years of extensive excavation and studies on the site[1][2]. A great number of iconographic sources from illuminated manuscripts was used to model furniture, tools and ornaments.

Aim of the reconstruction is the creation of an educational game for the visitors of the Provincial Heritage Centre, built just next to the archaeological site of the abbey, that will allow them to virtually walk in the abbey and discover the daily life of monks. The game will be deployed in a room on the top floor of the building, overlooking the archaeological site. In this way it emphasises the strong link between the archaeological site and its digital reconstruction.

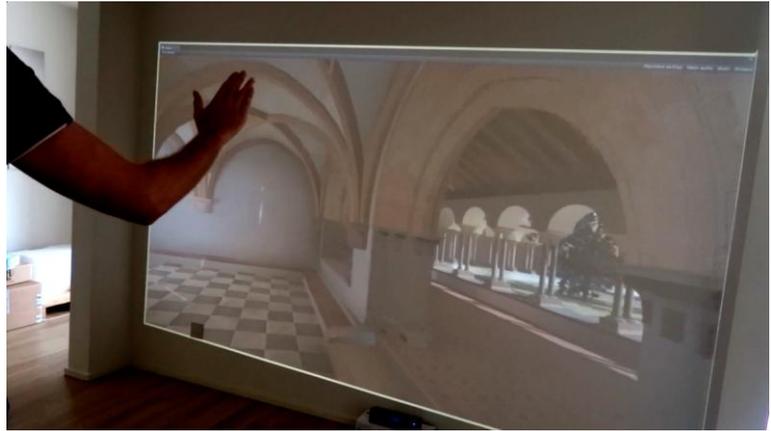
The educational game has multiple goals. First of all, the 3D visualisation on a large screen shows the splendour of the medieval phase of this abbey and allows a natural perception of spaces and dimensions.

A second important goal is the re-contextualisation of the objects that have been excavated at the abbey's site and are today on display in the Provincial Archaeological Museum (pam) of Ename. In the digital reconstruction of the abbey, artefacts are digitally restored and shown with their original function. This not only helps the visitor to better understand their nature, but explains also the concept of heritage, and the reason why we spend effort and budget to excavate and preserve objects from the past.

The third goal is a better interpretation of available archaeological and historical data. Reconstructing the inside of the abbey has improved significantly the understanding of the structure of the buildings, their function and interrelation[4].

The game is targeted to school children and is structured as a treasure hunt. The story is unraveled bit by bit by selecting objects in the scene. The virtual world is projected on a large screen and interaction with the scene happens through natural interaction based on a Kinect2 camera[3]. The goal is to develop a natural interaction without menus or modes, in which all activities of navigation, object selection and object manipulation happen through a defined set of gestures.

It will also be possible to explore this virtual environment of the abbey in a non-gaming mode. In this way, museum guides will be able to show around visitors in the virtual abbey to link with the archaeological remains and excavated objects on display in the museum.



Authors **Barbara Cerasetti, Lynne M. Rouse, Roberto Arciero, Jens Frissen**

Title ***Hydrology and Social Transition in the late 2nd millennium BC Murghab Alluvial Fan, Turkmenistan***

Abstract

In this paper we re-visit hypotheses about the changing social and environmental landscapes in southern Central Asia during the transitional period between the archaeologically-defined late Bronze – early Iron Age (late 2nd millennium BC) and the numerous documented changes in the archaeological and geo-physical record during this time. We focus on the northeastern Murghab alluvial fan (Turkmenistan) as one window into this complex period. Our analysis incorporates nearly 400 new archaeological sites documented in the northeastern Murghab since 2006, which have not previously been included in published models of settlement and/or hydrological dynamic. By combining this new data with the already existing data, collected since the beginning of the project in 1990, we come to a total of around 2000 sites. Although there have been previous studies on the paleochannels and sites visible on the surface, using the updated survey database and additional remote sensing analysis techniques we attempt to create a more complete picture by using these to discover the ‘missing’ sites and paleochannels against three obscuring factors: sand dunes in the north, alluvium in the south, and growing areas of modern cultivation. To cancel out these obscuring factors we will use the ASTER GDEM and SRTM as base maps in combination with Russian topographical maps from the 1950s and (historical) remote sensing data, such as Corona, Landsat, Ikonos and aerial photographs. Based on the work previously done in the project we hope to deepen our understanding of the landscape by applying newly analyzed remote sensing data. With this data we try to determine the relationship between the location of archaeological sites and mapped ancient watercourses (palaeochannels) through time. Our initial findings suggest that the periods of the Late Bronze Age and Early Iron Age (Yaz I) demonstrate two distinct access-to-water practices and probably different processes of socio-territorial control being implemented.

We hope to validate this observation by using different statistical analysis in our GIS environment based on remote sensing maps. While no single line of evidence can adequately disentangle the complex intertwined processes of environmental and social change, our results provide valuable information toward a reassessment of the “common knowledge” of the local processes of socio-environmental development in the Murghab, and fit within emerging discourse that recognizes the importance of micro-scale processes and adaptation in Eurasian prehistory.

A DIALOGUE BETWEEN ARCHAEOLOGICAL SCIENCE AND COMPUTER VISUALIZATION

Authors **Nicholas Andre Holmer, Kassandra Mcfarland, Buck Benson, Herbert D.G. Maschner**

Title *Using online digital content as a reference collection: A critique*

Abstract Any good zooarchaeological analysis will include two aspects: a solid literature review containing all pertinent information regarding the site in question along with a list of specimens that could be found in that particular geographic region. Second, and more importantly, a zooarchaeologist must secure access to a relevant osteological reference collection. There are no single reference collections that can be considered complete therefore extraneous material is always utilized. This poster describes the use of one such extraneous material in conjunction with an 'in-house' reference collection. The Virtual Zooarchaeology of the Arctic Project (VZAP) was designed to provide a digital reference collection that can be accessed anywhere in the world. VZAP houses 2D and 3D material of most Arctic mammals, birds and fish suggesting that it is ideally suited for this task. We discuss its pros and cons and illustrate how this tool can be effectively used to identify faunal remains using real archaeological material. Using a previous study testing the ability of VZAP to help identify bones, we highlight how these data can improve our efforts in the future for education, identification and curation.

Authors **Jacopo Crezzini, Francesco Boschin, Simona Arrighi, Marco Giamello, Annamaria Ronchitelli**

Title *Zooarchaeology, Prehistoric Art and digital imaging: quantitative analysis of bone modifications using 3D microscopy*

Abstract Digital imaging allows to collect and process morphometric quantitative data on archaeological finds. The Research Unit of Prehistory and Anthropology of the University of Siena is currently developing new protocols for the analysis of bone modifications using a Hirox Digital Microscope KH-7700. This instrument captures 3D images of the observed surfaces enabling the direct observation of butchering marks, artistic engravings and non-anthropogenic evidences (for instance tooth marks) from several points of view; it also allows a rapid procurement of several quantitative data (linear and angular measurements) that can be processed through univariate and multivariate statistics. After the analysis of more than four hundred specimens, we are presenting in this paper the results of several case-studies from Italian Palaeolithic and Metal Age sites: we demonstrated that processing quantitative data it is possible to separate between butchering marks inflicted using stone and metal tools; to identify the kind of stone tool used to produce prehistoric artistic engravings; to separate between butchering marks and artistic engravings.

All data coming from the analysis of archaeological specimens are compared with those obtained carrying out experimental proofs; it allows to corroborate our results.

The encouraging obtained outcome confirms the validity of our protocols and the important role that computer applications and quantitative methods play for understanding prehistory.

SESSION 3B-
OCCUPATION FLOORS
OF HUNTER-GATHERERS
IN THE DIGITAL ERA:
IMPACT AND EXPECTATIONS
BEYOND GEOMATICS
AND COMPUTATIONAL PERSPECTIVE

Authors Francesca Romagnoli, Amelia Bargalló, María Gema Chacón, Maria Joana Gabucio, Bruno Gómez de Soler, Pablo Sañudo, Manuel Vaquero

Title *A storey is a floor, but a floor could be many stories! The problem of time in the definition of occupation floor.*

Abstract The identification and interpretation of ancient behaviour within the archaeological record is the main goal of current archaeological research. The archaeological layers are formed by a complex interaction between cultural dynamics (social and behavioural procedures) and natural processes. The recognition of these processes (e.g. Binford 1981; Schiffer 1983) is essential to identify non-anthropogenic ground noise in archaeological layers before identify and interpret behavioural patterns. The analysis of site formation processes is particularly relevant to perceive the temporal resolution which is a critical issue for reconstruct human behaviour and for test hypotheses on long-term processes in ancient human populations.

Traditionally the archaeological record is defined according to two different concepts: the living floor and the palimpsest. Bailey (2007) has shown that all the archaeological layers are palimpsest. This concept is expressed with a variability of types of time and space relationships between depositional episodes overlapped within the archaeological layer. While the palimpsest is the reflection of diachronic activities, the concept of living floor implies that the activities attested on an archaeological soil were carried out simultaneously. A living floor is like a picture which seizes a moment within the life of a human group. As a living floor reflects a short-time scale, it has been used to interpret the archaeological record within ethnographic models. According to Villa (1976) the archaeological criteria to identify a living floor are (i) a small thickness, (ii) a medium density of artefact and (iii) a spatial distribution of artefacts attesting distinct activity areas. Refits between these areas are used as evidence of contemporaneity (e.g. Delagnes et al. 2006). Recent studies have shown that this “ethnographic” scenario is an illusion and the activity areas of a living floor could be related to many independent import, production and use events (e.g. Turq et al. 2013).

Here we will present some case studies from Abric Romaní site, a Middle Palaeolithic rockshelter located north-east of Iberian Peninsula (Capellades, Barcelona). Researches in the site are focused on the reconstruction of Neanderthal behaviour through a multidisciplinary high-resolution approach (e.g. Carbonell 2012). The extended surface excavated and the temporal analysis of the assemblages formation allow to reach a short-time scale in the spatial analysis of the living floors (e.g. Gabucio et al. 2014; Vaquero 2008; Vaquero et al. in press).

The data that we will present in this Conference clearly highlight that a single living floor is representative of a complex succession of diachronic activities, which are not visible analysing the archaeological record as a whole.

The results of our researches suggest that a temporal perspective is essential for perceiving the single events carried out in a site and approaching the synchronic social and cultural organisation of group of co-residents. Our results imply that a useful and significant spatial analysis needs a previous analysis of the archaeological record.

We should develop methodology and models for spatial pattern analysis at event-time-scale to be able to understand demographic and cultural long-term processes of past human groups

OCCUPATION FLOORS OF HUNTER-GATHERERS IN THE DIGITAL ERA: IMPACT AND EXPECTATIONS
BEYOND GEOMATICS AND COMPUTATIONAL PERSPECTIVE

Authors **Alejandro García-Moreno, Sabine Gaudzinski-Windheuser, Jarod Hutson, Lutz Kindler, Eduard Pop, Wil Roebroeks, Geoff Smith, Elaine Turner, Aritza Villaluenga**

Title *Evaluating the influence of hydrological processes on Pleistocene “occupation floors”: a comparative case study of archaeological material orientation from Schöningen 13II-4 and Neumark-Nord 2/2 (Germany).*

Abstract Open-air lakeland localities were attractive places for Palaeolithic settlement, since they provided a broad spectrum of resources. Sedimentary basins constitute unique archaeological archives due to their excellent conditions of preservation, allowing for extensive, high-resolution environmental and archaeological analyses. This is especially important in the case of Central Europe during interglacial periods, where numerous archaeological sites were located in lacustrine settings, providing evidence for hominin adaptations to warm, forested environments. However, these sites were often subjected to complex littoral site formation processes, including overland flow, channel flow or wave action. Understanding the possible influence of these hydrological processes in the formation and post-depositional histories of Pleistocene deposits is essential for the interpretation of Palaeolithic hunter-gatherers behaviour.

In this paper, we present a comparative study of two Pleistocene interglacial lakeshore sites, Schöningen 13II-4 ‘Spear Horizon’ (MIS 9) and Neumark-Nord 2/2B (MIS 5e). Both sites yielded large, well-preserved faunal assemblages, allowing for in-depth analyses of Middle Pleistocene hominin subsistence. The excavations at both sites were large (around 500 m² in Neumark and 1.500 m² in Schöningen), enabling detailed spatial analyses to be undertaken. The rich assemblages, excellent preservation and large scale of these sites provided a solid foundation to assess pre-Neanderthal and Neanderthal spatial behaviour within these unique environments.

In order to understand the spatial behaviour of these hominins, it is necessary to evaluate the possible impact of hydrologic processes in the distribution of artefacts and faunal remains at these sites by applying GIS to artefact orientation. Lithic and bone orientations were calculated from vectorised planes, and later analysed using circular statistics, in order to identify the presence or absence of significant preferred orientations. Patterns observed at both sites were compared with experimental observations, to identify which processes might have affected site formation. Finally, formation processes at both sites were compared, to evaluate differences and similarities between them. Evaluating the influence of non-anthropogenic processes in the distribution of archaeological material will improve our understanding of spatial organisation of the assemblages and, consequently, the spatial behaviour of Middle Pleistocene hominins.

Authors **Jens Axel Frick**

Title *Visualizing occupation layers in homogenous sediments: Examples from the Grottes de la Verpillière I & II, Burgundy, France*

Abstract This talk presents the methodological approaches used to reveal otherwise invisible layers in homogenous, fine-grained, aeolian/fluviial rock-shelter sediments containing archeological deposits from the Late Middle Paleolithic to the Early Upper Paleolithic. The excavations and analyses at the sites of Grotte de la Verpillière I and II have combined multiple technological solutions (archeological, geological and geographical) to build three-dimensional models of nearly invisible archaeological features in these sediments. The identification of occupation surfaces has been possible largely due to the piece-plotting of thousands of individual charcoal fragments, and these interpretations are supported by additional spatial data, lithic refits, and

OCCUPATION FLOORS OF HUNTER-GATHERERS IN THE DIGITAL ERA: IMPACT AND EXPECTATIONS BEYOND GEOMATICS AND COMPUTATIONAL PERSPECTIVE

technological analysis. In-field analysis of these data has informed approaches to the excavation of the sites. Detailed mapping and data analysis following fieldwork has focused on the reconstruction and interpretation of distinct occupation surfaces.

Meticulous collection of spatial data, geoarchaeological observations (discolored, sintered, or disturbed sediments, grain size differences, etc.), high-resolution digital imaging and digital color analysis are employed in combination with traditional archeological techniques like refitting of lithic and organic material, technological lithic analysis, and raw-material analyses. Most of these techniques are relatively standard practice today, but our unique combination of multiple, low-cost solutions to data collection and digital imaging is the key to reliable interpretations of the archeological sites, and can be easily put into practice by excavators working in a variety of contexts. The importance of mapping charcoal distribution and the insights that this approach offers are the emphasized.

Authors **Fabio Martini, Domenico Lo Vetro, Michele De Silva, Giovanna Pizziolo, Enrico Ortisi, Vincenzo De Troia, Paolo Machetti**

Title ***Ritual use of Romito Cave during the Late Upper Palaeolithic: an integrated approach for spatial reconstruction***

Abstract The Grotta del Romito (Northern Calabria, Italy), with its rare examples of rock art and several burials, is one of the most significant Upper Palaeolithic archaeological sites on the Italian peninsula. The cave was occupied during the Palaeolithic from ca. 24,000 to 10,000 BP. To date, nine intact, well preserved burials have been recovered from stratigraphic layers dating from ca. 18,000 to 11,000 BP, the majority of burials is referred to Late Upper Palaeolithic. This period corresponds to a greater intensity of occupation of the site, inferred from numerous fireplaces and extensive accumulations of bone and lithics. The site is at the foot of a rock cliff and is composed by a rock shelter and a cave. The western part of the cave, near the entrance, and the rock shelter would have connected during the Palaeolithic to form a large living space. The site has a long history of excavation: a first field season during the sixties of the last century and a second season started in the 2000 and still on going.

Therefore different type of documentation have been used in order to record data in this cave context spanning from traditional distribution maps to laser scanner data acquisition.

This contribution presents an overview of the technologies used to collect data during both excavations and lab processing phases and discusses the integration of several approaches (CAD, QTVR, 3D-modelling, Laser scanner). The project focuses on the spatial use of the cave as a ritual context aiming to integrate in a unique analytical environment the rock art and burial evidences distributed inside the cave and the shelter in order to perceive this space as a whole scenario

SESSION 3C-
COMPUTER
AND ROCK ART STUDIES:
DATA COLLECTION,
INTERPRETATION
AND COMMUNICATION

Authors **Margarita Diaz-Andreu, Tommaso Mattioli**

Title ***Archaeoacoustics of rock art: quantitative and qualitative approaches to the acoustics and soundscapes of rock art in the Western Mediterranean***

Abstract Archaeoacoustics has made a breakthrough in the field of rock art research, as it represents a completely new way of studying the landscapes in which rock art was made. It looks beyond the materiality of the past and tries to retrieve, quantify and qualify other less evident or intangible cultural signs, such as those related to soundscapes and the acoustic experiences sought by prehistoric communities. Several articles have shown the relevance of acoustics as a factor for the production, location and active use of rock art sites and landscapes in Europe. However, there is a variety of alternative methods of research, some related to specific issues (physical, physiological, cognitive, cultural, etc.) and others to specific acoustic effects. This paper will present a basic framework for the investigation and recording of acoustic phenomena by incorporating both quantitative and qualitative aspects and measurements and characterization of spaces, aiming to establish a useful link between theory and practice. Examples will be drawn not only from Spain, but also from Italy, where new research is currently being undertaken.

Authors **Johan Linderholm, Paul Geladi, Claudia Sciuto**

Title ***Field based Near Infrared analysis of Rock paintings in northern Scandinavia***

Abstract Rock art and rock paintings attract a lot of scientific interest in archaeology and various archaeometric approaches have been applied in order to shed light on pigment composition etc. This study comprises of field based NIR measurements on rock paintings from late Stone Age in northern Scandinavia. Different documentation approaches have been tested where simplicity and true field functions have been key words. Seven different sites have been investigated and generated large amounts of multivariate data requiring multivariate data analysis. Spectral information and classification results from these sites are presented and also some archaeological implications.

Authors **Enrique Cerrillo-Cuenca, Marcela Sepúlveda**

Title ***Photographic recording and the digital enhancement of pigments: recent applications in the rock art of Northern Chile***

Abstract The digital recording of rock art has benefited of an increasing number of software solutions, mostly photogrammetry and the enhancement of pigments from photographs. Regarding to this last field, we have assisted in the last decade to two different trends: the popularization of DStretch software and the application of advanced statistical methods through specialized software, which is not suitable for all the archaeologists.

During the last years (Cerrillo et al. 2014) we have utilized open source scientific libraries for enhance pigments in a currently under development software codenamed PyDRA. PyDRA is composed of a graphical user interface (GUI) and the implementation of several statistical processes for the enhancement of pigments. The aims of these statistical procedures are:

1) The enhancement of pigments in the image through Principal Components Analysis (PCA)

and Decorrelation Stretch algorithm (DS).

2) The creation of tracings for enhanced images by classification algorithms like K-means.

The results are tracings (binary images) that can be superimposed for creating complex compositions. The main advantage is the detailed scientific documentation of the procedures, which makes this solution robust from the point of view of its scientific application. In this paper we present the results of the application of PyDRA to a join of rock art sites from the precordillera of Arica, Northern Chile (Sepúlveda 2011), which cover a wide chronological span from the Archaic Period (8500 cal BP) to the beginnings of Spanish colonial period. The results have shown that the combination of classification and enhancement techniques can provide clear tracings, especially for washed and deteriorated paintings. This approach is leading to a systematic recording of archaeological sites, boosted by the “replication” of procedures in PyDRA.

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Authors	Paolo Emilio BAGNOLI, Andrea Samuelli
Title	<i>Computer graphics-aided recording of open-air extensive rock-art panels.</i>
Abstract	<p>The accuracy (minimization of measurement errors) and resolution (minimum size of details) of the graphical documentation of archaeological sites or objects, including rock-art, is an essential requirement for the correct interpretation and conservation.</p> <p>In the case of recording of widely extensive rock-art panels using conventional techniques, the preservation of the two above properties may imply a dramatic increase of the execution time, both in situ and in the post-processing phase. On the other hand in some cases the time and/or environmental conditions (urgent archaeological digs, underwater digs, rock art placed in dangerous or elevated positions) make the use of sophisticated scanning equipments unsuitable and should require faster, low-cost but still accurate recording methods, at least in the acquisition phase.</p> <p>The present communication deals with a method for graphical recording of planar engraved surfaces with wide extension able to maintain a high degree of accuracy and resolution. This method uses digital photography and a dedicated software and produce the map directly in a digital image format.</p> <p>Beside it was firstly designed and applied to record rock-art sites in the Apuane Alps (Tuscany, Italy), however it may be applied to several other archaeological contexts.</p> <p>The main characteristics of the method are the followings:</p> <p>a) it hallow the minimization of the needed distance measurements and therefore greatly decreases the time to spend in situ;</p>

COMPUTER AND ROCK ART STUDIES: DATA COLLECTION, INTERPRETATION AND COMMUNICATION

- b) it can be applied mainly on planar surfaces, also with wide extensions and/or where the spatial relationships among different groups of details are crucial;
- c) high degree of accuracy and graphical resolution may be achieved;
- d) it does not require regular grids but only irregular ones;

The application of the whole method consists of three different operative phases on the field and three phases of data post-processing with the help of a dedicated software program.

The three field actions are: 1) the built-up of an irregular grids of points (primary and secondary measurement stations) where each point is progressively numbered; 2) digital photographs of the details where each photo contain three points (stations); 3) measurements of the distances among the primary stations and between each primary station and all the secondary ones.

The post-processing phases are: 4) built-up on the computer of the grid map of the stations using the software programs; 5) two color contour tracing of the details (including the position of the stations) on each photo also eliminating the use-less substrate; 6) pasting in semi-transparency the photos on the grid map by connecting the stations on the photo with the corresponding ones on the map.

Finally some application examples performed by the archaeological groups of Pisa and Massarosa will be shown.

At the time of the conference the used software, implemented in MATLAB environment, will be given on the web as open source program.

Authors	Alexander Pakhunov
Title	<i>Simple and low-cost method for the tracking of biological activity on cave art sites</i>
Abstract	<p>Microorganisms populating caves produce organic acids that damage and dissolve a calcite substratum. This might have been the primary cause of degradation of numerous Paleolithic paintings in many caves. Attempts to track the spatial distribution of microorganisms' colonies using naked eye and conventional macro photography often yield low-contrast images that cannot be used for solid image analysis and thus, are highly unreliable. Ultraviolet light source can be used to improve the contrast for it is widely known that many microorganisms emit intense luminescence under the ultraviolet radiation. The colour of luminescence is more specific when using a 254 nm deep ultraviolet (UVC) source (Bearman et al., 2013), but this kind of light source is not as widespread as near ultraviolet 365 nm (UVA) source. It is also at least two times more expensive.</p> <p>By using a portable LED UVA light source and a high-resolution photo camera, we took the ultraviolet fluorescence images of a series of Paleolithic paintings in Kapova Cave, Russia.</p> <p>The raw files were processed according to the recommendations of American Institute of Conservation (Warda, 2008), followed by the "similar colour" treatment in VIPS software (Martinez & Cupitt, 2005). The destination colour values of colonies in Lab colour space were measured with a digital colour picker. Resulting images contain only black and white pixels - the black ones are blank pixels while the white ones are the corresponding matching pixels. The precise number of white pixels was found by plotting the histograms of the whole picture or its parts. Comparing images in the visible and ultraviolet light clearly demonstrates a specific spatial distribution of colonies – with minimum colony density on smooth surfaces of the</p>

defectless substratum (note that surface roughness was estimated based on reflection transformation imaging (RTI) (Diaz-Guardamino & Wheatley, 2014) whereas the maximum colony density corresponds to the coralloid structures that have a high surface area and are covered by soot.

Some paintings in Kapova were uncovered under thick calcite layers by the restorers in early 1960s. It was found that the serifs on the surface of calcite precisely match the points of colonization by various microorganisms. To preserve paintings, we recommend using both RTI for the control of surface defects and UVF imaging for the accurate count of colonies. Based on these data, it is possible to make reasonable decisions as to what the course of local conservation intervention should be.

Authors Frank Boochs, Stefanie Wefers, Burkhard Tietz, Tobias Reich

Title *Support of Petroglyph analysis through processing and viewing of 3D scans*

Abstract

Traditionally stone inscriptions or drawings are documented through pictures or rubbings. The latter ones represent an analogue copy of the stone's surface and its features which are reproduced on paper. The disadvantage of this technique is the physical impact to the stone and the contained elements. Images reproduce the surface without contact. However, they might be affected by geometrical distortions and need appropriate lighting conditions to show the signs properly.

These problems will be avoided by means of non-contact 3D measuring techniques, like fringe projection. Such high resolution 3D techniques provide an exact geometrical copy of the original petroglyph, offering better results in legibility compared to traditional techniques. Moreover, it gives a more objective base for analysis and has less impact on the sometimes sensitive and eroded surfaces. Furthermore 3D data allows more extensive and further possibilities in processing and gives better preconditions for the interpretation.

However, depending on factors like resolution, scanned surface and degree of overlap between individual scans original 3D datasets may represent large up to really massive volumes of data. An effective use of such datasets can only be realised if they are condensed and prepared in a suitable way. This means reduction of the data volume, minimising any disturbing influence emerging from the spatial shape of the surface and emphasizing relevant information. The corresponding preparation of the data will then be a good base for a interpretation performed by the human science specialist through an adapted visualization. In addition the data should be prepared for high performance presentation to a wider community via the internet.

Processed digital copies of the Petroglyphs are visualised in order to enable the user to inspect the processed scans of the objects. By inspecting the scans the application provides a mass of functionality for achieving different views into the Petroglyphs and their appearance. This comprises on the one hand a simple 2D viewer for the processed data, and on the other hand a 3D viewer with interactive changeable light positions and water levels as well as a viewer for applying various lookup tables (colour), predefined image filters (convolution) and template matching (matching) regarding individual characters.

Provided functionality of the 3D viewer is based on features of 3D computer graphics. Surface normal vectors from the grey values of the processed scans and a light direction vector from an interactively changeable light source are computed. In addition shading is complemented by water filling, whereby the gray values are limited by the water level selected. Individual modifications are possible to improve the subjective impression by the user, trying to support him in his process of interpretation. Interactive changes of the light source directly affect the

shading of the surface and provide a better idea of the 3D surface of the inscription board. Dynamic virtual water filling enables the user to obtain an even better impression of the depth of the individual characters and emphasise weathered characters.

The paper will explain the developed techniques and document its potential at selected data sets.

Authors**Andrea Arcà****Title*****Digital practices for the study of the Great Rock of the Naquane National Park, Valcamonica - Italy: from graphic rendering to figure cataloguing*****Abstract**

Concerning rock art, or better rupestrian archaeology, studying engraved rocks is like an archaeological digging: a carved rock panel corresponds to a site, its figures to archaeological finds; at the same time the sequence of the engraving phases is intended as an archaeological stratigraphy. For these reasons each engraved rock must be recorded with the greatest possible accuracy. In doing this, computer software is an indispensable working tool. From the graphic side, the need to obtain a detailed reproduction of figures and superimpositions may greatly benefit, like in cartography, of vector drawing software. The same goes for editing and publication: the final output of tracings, plates and tables should be managed in a graphically professional manner. From the analytic side, the necessity to deduce for each petroglyphic complex the taxonomy of its iconographic items, to define and count them and their relations, may lead to the compilation of a specific software, in order to produce detailed stats and listings, as well as a catalogue of figures. This is the case of the study – performed by the author and which will be illustrated in this communication – of the Great Rock of the Naquane National Park in Valcamonica (Italy); it's one of the most important prehistoric figurative palimpsest of the entire alpine rock art, where more than two thousands prehistoric figures are stored. Nearly one hundred square meters of tracings of the engraved surface has been produced, digitally acquired and drawn as vectors. A dedicated software was compiled, in order to store and to count all the qualitative and quantitative data of the engraved figures, such as dimensions, morphology, relations, chronology and so on. Figures records are compiled on the base of the final rendering of the tracings; once completed the job, listings, stats and catalogue are produced in a few seconds in html format, including textual data, drawings and pictures, ready to be published online or re-worked for a printed book. Like archaeology in general, rock art studies need to publish and share data: as demonstrated by this study, a large set of electronic instruments – for graphics and for the data analysis – are to be intended now as a fundamental tool box for the careful and up-to-date rock art archaeologist.

SESSION 4A- MANAGING ARCHAEOLOGICAL 3D MODELS

Authors **Andrea D'Andrea**

Title ***Providing 3D content to Europeana***

Abstract From 2012 to 2015 the European Project 3DICONs focused on the providing of 3D content to the Europeana. The project aimed to exploit existing tools and methods and to integrate them in a complete supply chain of 3D digitisation to contribute a significant mass of 3D content to Europeana. The project has been carried out by an interdisciplinary consortium including partners from different European countries and with different competences. The models range from large and complex architecture and archaeological monuments to small findings giving a wide impression about the potentiality of the 3D data capture, processing and visualization. Through 3D models the general public can visit sites which may be in remote locations, fragile and in some cases difficult to understand. 3DICONs contributed to the expansion of 3D Models into Europeana by offering enhanced experiences for its users by bringing exciting and engaging content for archaeological monuments and historic buildings. The project provided many reports on the 3D data-acquisition, 3D data-processing and 3D data visualization. A large number of case studies have been presented in the guidelines. All these contributes are downloadable for free from the web-site of the project. They represents an updated technical pipeline of the 3D Model creation with the addition of rich metadata describing the real object and its digital replica. Mainly in terms of metadata the project provided an innovative schema including information about provenance and paradata to keep tracks of the complete digitisation process. As one of the main 3D-ICONs goals was to develop a metadata schema able of capturing all the semantic present in the digitation processes (provenance) and in understanding and interpreting data objects (paradata), the project updated the CARARE schema by adding classes or entities and properties to make the original schema compliant to the 3DICONs requirements. The paper reports about the solutions adopted by the 3DICONs project as far as the metadata are concerned and other quality recommendations have been implemented. Some case studies will be presented and the complete pipeline from the object to the final model currently visualized in Europeana will be shown.

Authors **Achille Felicetti**

Title ***MaDAM: A new generation Digital Asset Management for Cultural Heritage***

Abstract This paper describes the development and implementation of a digital asset management system flexible but at the same time fast and easy-to-use tool for creating and managing a complete digital archive of archaeological objects including 3D models, images, and any other media object .

The system has been developed around the CARARE model, a metadata schema developed for harvesting and delivering information concerning digital models of objects, monuments and other similar cultural heritage entities. But the metadata indexing model of the system is general enough and can easily be adapted to any other XML enabled schema.

Upload facilities are easy to use and very efficient. The user is only required to upload data while maintaining simple naming conventions in order to associate the digital objects with their metadata, and to ingested the created packages into the system with a simple FTP client.

The system comes with a real-time search and analytics engine able to index the uploaded in a fast and efficient way and to create a network of relationships between the different entities described in order to build a rational and well organised knowledge graph to ensure a faster and accurate retrieval at query time.

MANAGING ARCHAEOLOGICAL 3D MODELS

The system is also able to dynamically create landing pages for the digital objects, based on customizable templates, where all the related descriptions and metadata regarding the digital objects are reported. Thumbnails and previews of the objects are also provided. The indexing mechanism includes functions for the automatic generation of all the necessary URIs/URLs for the standard identification and web localisation of the digital resources. URIs to other relevant external information (e.g. terms from widely used thesauri, concepts coming from different ontologies and so on) are also generated on the fly.

A set of query tools and interfaces provide advanced and real time retrieval features, included the ability to filter relevant results by means of faceted facilities, temporal and special entities.

The indexing mechanism and the dynamic creation of landing pages allow, through a set of efficient mapping operations, the immediate availability of the data in the Europeana metadata format (thanks to the existing mapping between the CARARE and the EDM schemas) and the ability to upload the existing information directly in the Europeana digital library, without further action by user.

The system was created as part of the 3D ICONS project but with the purpose to provide a flexible and highly configurable tool that can be used in many different contexts and in various usage scenarios. Subsequent developments of the tool will allow the possibility to enrich the metadata by means of entities and semantic relationships in order to provide support for more advanced queries and punctual retrieval of relevant information. The ability to publish data in RDF format will constitute the basis for the creation and serialisation in Linked Open Data form of the information contained in the database.

Authors Athanasios Tsaouselis, Konstantinos Stavroglou, Anestis Koutsoudis, Fotios Arnaoutoglou, Anastasia Michailidou, Despoina Tsiafakis, Christodoulos Chamzas

Title *The 3D Icons Portal: A Web tool for the dissemination of European 3D Cultural Heritage Objects*

Abstract Web portals are entry points for information presentation and exchange over the Internet used by a community of interest. A part of the European cultural heritage thesaurus has already being offered as digital collections using various formats and thus there is a requirement for management, preservation and archiving of such digital assets as well as better communication of the cultural heritage assets to the users. There are a number of metadata schemas that are used to describe the content of these digital collections. In order to handle the additional metadata needed by the 3D Cultural Heritage Objects produced within the 3D Icons project, an extension of the original CARARE schema was developed, the CARARE2. The CARARE2, a harvesting schema, supports now provenance, transformation and paradata required for quality assurance of 3D models. It is used for the delivery of digital content to Europeana with the use of a mapping between the CARARE2 schema and Europeana's EDM. The need to demonstrate the full richness of the CARARE2 metadata elements, resulted to the development of the 3D Icons portal (3dicons.ceti.gr).

The main aspect of the 3D Icons portal is to provide a geographical mapping of the digital assets provided by the 3D ICONS partners using the CARARE metadata schema. One of the main reasons behind the implementation of the specific Web application was to provide a supplementary to Europeana single access point that is able to allow the user to explore the digital assets of the 3D Icons project while querying with a set of alternative mechanisms that can be accessed over a geographical mapping visualisation graphical user interface.

The development process of the Web application consisted of two main phases. In the first phase a metadata parser was developed in order to extract/harvest metadata from a digital

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repository via an API. In the second phase we developed a tool that allowed the visualisation of the digital assets in relation to their spatial/geographical distribution. The user interface of the Web application provides two basic functionalities for the exploration of the digital cultural assets. The first is based on the selection of geographical regions of interest on an interactive map that depicts the digital assets on their actual geolocation. The second is a more conventional approach that allows the user to compose queries based on filters such as organisation names, type of the digital asset, size, date as well as keywords. An additional administration panel sets the Web application as a tool that can be used for other applications while handling metadata schemas.

Authors

Britt Lonneville, Berdien De Roo, Cornelis Stal, Bart De Wit, Alain De Wulf, Philippe De Maeyer

Title

Google Earth and KML as GIS tools for archaeological 3D models

Abstract

Since its introduction in 2005, Google Earth has been downloaded over 1 billion times. It is by far the most popular virtual globe and has gained academic interest as well, mainly due to the incorporation of KML (Keyhole Markup Language). KML is an XML-based open source language that has been adopted as an OGC standard since 2008 and allows users to represent their own data on the virtual globe. KML is of particular interest for archaeologists, as it combines three key components of archaeological research: objects, space and time. Since the introduction of KML 2.0, georeferenced and textured 3D models (objects) can be added to any KML file and visualised in the virtual context provided by Google Earth (space). Furthermore, the fourth dimension – i.e. time – can be added by using time stamps or time spans. In order to reduce computation time and enhance the user's experience, it is possible to define various levels of detail. A certain 3D model is represented with a specific pre-defined level of detail based on its zoom level. Semantic enrichment is achieved by linking text, tables, images and web pages to the respective models. This way, metadata and further information are easily accessible for the end users. KML, in combination with Google Earth as a visualisation platform, can be of great value once archaeological research has ended, as it allows researchers to disseminate their results to the general public. As Google Earth is a well-known, low cost and straightforward tool, it does not scare off potential users with limited IT knowledge and/or budgets.

This research paper implements the aforementioned process for a specific archaeological site (Edzna, Mexico). The entire site, containing 16 buildings, is modelled using both terrestrial and aerial imagery supplemented with total station and GNSS measurements. Afterwards, these models are incorporated into a KML file using three levels of detail and adding semantic data and specific time spans for every modelled building. To improve the quality of the visualisation, an ortorectified image is used as a backdrop for the models. The case study shows the value and usability of this method and can function as an incentive for other archaeologists to disclose their research in a similar way.

SESSION 4B-
NEW TRENDS IN 3D ARCHAEOLOGY:
INNOVATIVE TECHNIQUES
AND METHODOLOGIES
FOR THE ACQUISITION, RETRIEVAL
AND ANALYSIS
OF CULTURAL HERITAGE

Authors

Dirk Rieke-Zapp

Title

3D digitization - state-of-the-art and future challenges

Abstract

Structured light scanning serves as one of the key digitization and measurement technologies for 3D data capture with high-resolution and high-precision. New challenges include a) the combination of 3D data capture with high-resolution color textures; b) further automation of data acquisition and processing; c) standardized meta-data collection coupled to the scanning process; d) presentation of data in 3D viewer environments . In this paper a short overview of state-of-the-art scanning technology will be provided comparing several digitization methods - i.e. Ct-scanning, structured light scanning, photogrammetry, laser scanning - with regard to resolution, precision and degree of automation. Concepts of automation will be compared from mobile solutions over turn-/tilt applications to robotic solutions for cultural heritage applications. Besides hardware automation, an overview will be provided comparing software improvements of recent projects for faster workflows and automatic as well as robust processing of 3D data including color textures. Concepts for metadata acquisition will be shown and the need for a general/standardized solution will be thermalized. A brief discussion on standard 3D data models with advantages and drawbacks that established themselves as quasi-standard over the last decades will lead towards a discussion on 3D data viewers, concepts and future needs.

Authors

Herbert D.G. Maschner

Title

A Revolution in Archaeology: 3D Technologies and the Democratization of Prehistory

Abstract

The key to making archaeological collections relevant in the twenty-first century is the creation of virtual repositories with built –in analytical tools. While many museums are now making efforts in 3D visualization, virtual collections, and integrated database management presentations, we must take this further by putting entire collections online in a virtual repository. The goal of the Democratization of Science Project is to use 3D technologies to put entire archaeological collections, or entire museums, online so that any student, any child, any scientist, or any politician, anywhere, can do their own analyses. We suspect that important scientific and educational advancements are often not made simply because people do not have access to the collections. We hope to change this by democratizing access through virtualization, and we have developed the model for how this should be done and implemented the first examples.

This required new developments in three areas. The first is in 3D virtualization and we are getting accuracy approaching +/- .005 mm, but we also developed new rendering techniques that bridge science and art without loss of accuracy or resolution. The second is in hyper-plastic database structures. This means that the database is so flexible that any type of data can be added without restructuring. In conjunction, we developed new techniques of database image storage. We serve over 70,000 high resolution images with real time resolution enhancement (resolution changes with zoom) while still maintaining integration with the database structure, and nearly 15,000 3D models. Third, these two structures are integrated with on screen measurement tools that allow the creation of multivariate datasets from any computer monitor. These measurement tools have been tested and shown to be accurate to .005 mm.

The democratization of science is about using online media to make local, often inaccessible collections part of the world's scientific agenda, and allowing distant, often isolated individuals, classrooms, or collaborators the opportunity to conduct their own investigations on museum collections from anywhere on the planet. This should be the museum model for the next century, and it will drive collections use, collection's publication, and firmly establish and

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maintain the relevance of archaeological collections as key sources of science and enlightenment. As a first step, we announce a new \$10 million project to scan some of the most important collections available to archaeological research.

- Authors** **Edgar Roman-Rangel, Diego Jimenez-Badillo**
- Title** ***Recognizing the shape of archaeological objects by extracting local orientations of points on the surface of 3D models***
- Abstract** Following a presentation in Paris during the CAA-2014 conference -in which we demonstrated the importance of computerized shape analysis, this paper reports new advances in the automatic recognition of archaeological artefacts by means of computer vision algorithms.
- We assess a novel technique for local description of 3D surfaces called Histogram of Spherical Orientations (HoSO). The HoSO local descriptor consists of the quantization of the local orientations of a point with respect to its nearest neighbours. Such local orientations are computed both in the azimuth and the zenith axes. The frequencies of the local orientations are stored in a histogram, which can then be used for comparison and matching purposes.
- The approach consists in computing HoSOs for a large sample of points on the surface of a 3D mesh (i.e. an archaeological object) and then comparing the histograms of a query model with the histograms of other 3D models stored in a repository. The comparison and matching steps are done using the so-called bag-of-words model.
- The approach is applied to archaeological objects from the prehispanic collection of the Templo Mayor museum (Mexico City), which contains an interesting set of stone masks, as well as other types of ritual artefacts. This approach presented here, however, can be applied to many different classes of objects.

- Authors** **Giuliano De Felice**
- Title** ***The new trend of 3D archaeology is ... going 2D!***
- Abstract** Nowadays one cannot imagine any archaeological activity such as fieldwork, lab work or historical analysis and synthesis without the support of technologies. 3D is a relevant part of this scenario, considering that archaeology is a reality composed of 3D entities that have to be measured, analysed, understood and reconstructed.
- No surprise then if 3D reconstruction of monuments and sites is one of the most important applications of IT to archaeology, considering the ability to measure and recreate, in a perfect and realistic form, something that does not exist anymore. Relying on this strength, 3D visualization is today the main medium also for archaeological communication.
- Its strong visual impact gives archaeologists the chance to visually realize their reconstructive thoughts and gives the wide audience a chance to interact with scientific process of research and interpretation.
- But what if we move our focus from visualization techniques to content? Starting from the

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consideration that before determining the use of a peculiar technology it is always better to evaluate the communication aspects, we have to consider the fact that 3D sometimes could not be the right solution, considering that any archaeological site or object is more complex than its material aspect and that even the most accurate 3D survey or the most precise virtual reconstruction are nothing but parts of a research process, tools to help interpretation. If our goal is to make the real meaning of archaeology fully understandable to a wide audience a 3D model is not enough: we need a story.

As a matter of fact, 3D visualization is a branch of computer graphic, nothing but a tool coming from the world of film technique. And we must have a director, a plot, a screenplay, a script and maybe actors and so on, before choosing the tools. In other words, first comes the story: the good news is that archaeology is a story itself, and we only have to choose how to narrate it. So, the first questions to pose, starting a communication projects about archaeology should be “which story I am going to tell?” “Whom I am going to tell my story to?”. Then, in a second moment we can ask ourselves “Which is the best tool to realize it?”.

In this paper I will show the results of Living Heritage project, that led us to develop storytelling methodologies and techniques and to bind them with archaeological knowledge. The main result of the project has been the production of a prototype of a storytelling engine (swipe story) that can be easily used by authors to realize narrations about cultural communication, focusing on content and visual styles more than on technologies and tools. The engine can easily manage any kind of content, from texts to music to 2D and 3D computer graphic, but it needs a story to start!

Authors **András Patay-Horváth**

Title *Master-hand Attributions of Classical Greek Sculptors by 3D- Analysis at Olympia - Some Preliminary Remarks*

Abstract The sculptural decoration of the temple of Zeus at Olympia (built ca. 475-455 BC) is generally considered to be one of the most important and most magnificent works of ancient Greek art. The preserved fragments have been thoroughly studied since their discovery in the 1880's, but they still pose some important questions. Perhaps the most difficult and the most distressing problem regards the identity of the master(s) of these works. Despite the high artistic quality and their excellent workmanship, nobody really knows, who the sculptor (or the sculptors) of these pieces actually was (were) and where he (they) came from. A conventional art historical method (master-hand attribution developed by G. Morelli) is therefore combined with the possibilities provided by the most recent 3D technologies in order to investigate the problem. The paper gives an outline of the project and its principles and discusses basic methodological problems connected with it.

Authors **Valeria Vitale**

Title *The Iseum in Pompeii: a case study on the use of an RDF ontology to document 3D visualisation of archaeological heritage.*

NEW TRENDS IN 3D ARCHAEOLOGY: INNOVATIVE TECHNIQUES AND METHODOLOGIES FOR THE ACQUISITION, RETRIEVAL AND ANALYSIS OF CULTURAL HERITAGE

Abstract

Although the crucial importance of transparency in 3D visualisation for archaeology is widely recognised by the researchers in the field (Denard 2012, Johanson 2009, Frisher et al. 2002), the lack of a standardised process of peer review, referencing and documenting still prevents 3D virtual environments from being seen and used as proper tools of research and not just illustrations targeting the general audience (Favro 2006). A tailored RDF ontology has been proposed as a time- and cost-effective way to document scholarly 3D virtual environments and the research process that they express (Vitale 2014).

This paper presents the first results of the experimental application of the SCOTCH (Semantic Collaborative Ontology for 3D-visualisation of Cultural Heritage) ontology, and the related methodology, to document the 3D visualisation of the Iseum in Pompeii.

As the name states, SCOTCH is meant to be designed and implemented collaboratively by the large and diverse community of virtual archaeologists. However, a first subset of the ontology has been developed as a proof of concept, to show the potentiality of the method and to be used as starting point for a wider discussion.

In part due to the huge popularity in the archaeology of Pompeii, the case study has selected buildings from that location. Two hundred and fifty years of unbroken interest from scholars and visitors, have generated a substantial number of (verbal and visual) records, a large bibliography and many entries in museum catalogues. Moreover, many of these resources are free from copyright and can be found in online digital archives and repositories, making Pompeii the ideal scenario for experimenting with linked data.

This paper will discuss the challenges encountered, the results achieved and possible improvements, suggesting a workflow that, through linked data, integrates the research process, the modelling, the documentation and the online publication.

More specifically, the paper will:

propose a simple naming convention to label the elements in an historical 3D virtual environment.

present a way to describe the provenance of the information associated with each element, the relationship with its material referents and with the historical sources, the original research introduced by the author. The ontology does not aim at establishing a hierarchy of preferable sources, but simply states their origin and the rationale of the author's choices.

discuss possible ways to address the issue of fragmentary, inhomogeneous and conflicting sources.

suggest a method to record some of the most frequent operation of normalisation, regularisation and simplification that are usually embedded in 3D visualisations.

show how the ontology can capture, at least partially, the complexity of a cultural heritage object, representing different voices and interpretations across time and cultures.

present the potential interaction of the virtual environment with external (online and offline) information.

Authors

Valeria Poscetti, Juan Torrejón Valdelomar, Wolfgang Neubauer, Florian Martin Müller

Title

The Roman Villa of Oberlienz: A multidisciplinary 3D reconstruction.

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Abstract

High resolution archaeological geophysical prospections allow for the non-invasive investigation of subsurface features. In particular, the high resolution Ground Penetrating Radar (GPR) measurements permit the accurate investigation of the subsoil offering the possibility for the detailed 3D mapping of archaeological structures and virtual reconstructions of archaeological complexes.

In this paper, we present a 3D reconstruction of a Roman Villa located in Oberlienz-Lesendorf (Austria), part of the former Roman province *Noricum*, which has been investigated by GPR.

The 3D GIS-based mapping of the features detected by GPR is conducted within ArcGIS 10.2 allowing for the improved 3D editing of vector features and detailed description through attributable information. Extruded 2D (2.5D) and 3D interpretation models of the buried Roman structures are created based on the dynamic and interactive analysis of the prospection data in the GIS environment, in which the GPR data are visualized in form of animated sequence of raster images.

Based on the GIS interpretation models the virtual reconstruction is performed within 3D modelling software environment allowing for the interactive modelling and texturing of the mapped 3D objects. In this step, analogies together with written sources play a crucial role since they provide additional data and documentation which can be used to enrich the lack of information. A systematic comparison between the detected remains and excavated archaeological sites in the provinces *Noricum* and *Raetia*, where similar buildings and complexes have been investigated, was conducted with the goal to achieve a comprehensive and reliable reconstruction of the Roman villa. In order to achieve the interactive investigation of the virtual 3D model in a georeferenced environment, the textured 3D objects are re-imported into the 3D ArcGIS environment (ArcScene and ArcGlobe) and integrated into the GIS-based 3D maps, in which the objects and related attributable information can be queried, interactively, by means of HTML popups.

Structures belonging to different phases are clearly detectable in the GPR data. Finds dating to different periods were also collected at the site at the beginning of the 20th Century. Based on this fact, we argued that the Roman villa was probably used for a period of at least 300 years. Based on the analysis of the GPR data and analogies with similar buildings and complexes, the presumed diachronical evolution of the Roman villa with main houses and ancillary buildings is presented dynamically through the use of animations. The work which was conducted within the multidisciplinary team of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology in collaboration with the Vienna Institute for Archaeological Science (VIAS) of the University of Vienna, also has the aim to demonstrate the high potential of the integrated and systematic use of non-invasive Archaeological Prospection Methods and Virtual Archaeology for the investigation, digital documentation and scientific dissemination of the "invisible" archaeological heritage.

Authors

Riccardo Olivito, Emanuele Taccola, Niccolò Albertini

Title

Hand-free interaction in the virtual simulation of the agora of Segesta.

Abstract

The aim of the paper is to illustrate the work of an interdisciplinary team composed of young archaeologists and researchers of the Scuola Normale Superiore and the University of Pisa. The synergy between these Centres has recently allowed for a more articulated three-dimensional simulation of the agora of Segesta. Here, the archaeologists discovered the remains of a huge stoa, whose first monumental phase dates back to the Late-Hellenistic Period. Computer graphics and image-based approaches (i.e. terrestrial and aerial SfM) have been used in order to

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monitor, document and record the different phases of the excavation activity (layers, findings, wall structures), and to create a 3D model of the whole site.

In order to increase as much as possible the level of interaction within the immersive virtual environment visualizable into the CAVE (Cave for Automatic Virtual Environment of the DreamsLab), a new dedicated application has been created. By using hands tracking sensor in a non-standard way, the application allows a completely hand-free interaction with the simulation of the agora of Segesta and the different phases of the fieldwork activities. More specifically, the operator can use a natural interface with hand gestures to slide and visualize the perfectly overlapped models of the archaeological layers, pop up the models of single meaningful objects discovered during the excavation, and obtain all the relative metadata (stored in a dedicated server) which are visualizable on external devices (e.g. tablets or monitors) without further wearable devices. All these functions are contextualized within the whole simulation of the agora, so that it is possible to verify old interpretations and enhance new ones in real-time, simulating within the CAVE the whole archaeological investigation, going over the different phases of the excavation in a more rapid way, getting information (measurements, position of the finds) which could have been ignored during the fieldwork, and verifying, even ex-post, issues not correctly documented during the fieldwork. The opportunity to physically interact with the 3D model of the agora, makes it possible to drastically increase the level of affordance between operator and 3D simulation, and to verify with a completely new approach issues which can be hardly investigated by using 2D models (e.g. physical relations between objects and monumental context, internal and external visibility, relation between open and closed spaces, lighting inside the building).

The application has been recently implemented on the Oculus Rift DK2. The last release of this device has a higher resolution and, as a result, makes it possible to visualize all the metadata directly within the virtual environment, without using any other device. In addition to this, the portable nature of the Oculus will allow us to use the application on site, during the next excavations.

Authors**Catriona Cooper****Title*****Auralization: analysing the sound properties of cultural heritage*****Abstract**

The process of auralization has been a focus of acousticians for many years. As with early research within visualisation cultural heritage sites have often been used as case studies for exploring how acoustics can be modelled. The work has mostly been either recording sites as they stand today (Martellotta, 2009), or beginning to model them using software packages such as CATT and Odeon (Farnetani, Prodi, & Pompoli, 2008). In recent years archaeologists have begun to engage with sound in more detail, some of these approaches have been theoretical (Hamilakis, 2011; Weiss, 2008) or exploratory (Reznikoff, 2008; Waller, 1999), while others more technologically based (Mlekuz, 2004).

Unlike digital visualisation modelling, acoustics has not been heavily critiqued and there has not been the drive for archaeologists to learn to undertake the work independently. Instead archaeologists aim to team up with acousticians (Till, Scarre, & Miguel Fazenda, 2013; Till, 2011; Watson & Keating, 1999; McBride, 2013). However, this does not foster a true understanding of the results; acousticians do not theoretically engage with space, while archaeologists do not understand the nuances of the technique.

In this paper I present a methodology for discussing the acoustical properties of a closed space. Focussing on a case study of Ightham Mote in Kent this paper discusses geometrical acoustic methods of auralizing the Great Hall. I will bring together the results of the survey to discuss

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the experience of sound in the place and how this can be used alongside our understanding of the experience of sound in a medieval household

Authors **Christine Wittich, Tara Hutchinson**

Title ***Dynamic Characterization and 3D Reconstructions of Massive Human-Form Archaeological Statues for Earthquake Loading***

Abstract Archaeological and cultural heritage artifacts are often housed in a variety of locations such as laboratories or on display in museums and can potentially be subject to natural hazards such as earthquakes. While smaller, lightweight artifacts tend to respond favorably to seismic loads, massive statues are extremely susceptible to damage and destruction in the event of an earthquake. A recent project focused on characterizing the dynamic properties of three massive sandstone statues using a combination of non-destructive modal analysis and light-detection and ranging (LiDAR). The three artifacts originate from Saudi Arabia and date back approximately 2000 years. The statues are constructed of sandstone, are approximately 2.5 m tall, and weigh in excess of 1 ton. The statues are part of an exhibition travelling to multiple locations around the world; however, the dynamic characterization took place in collaboration with the Smithsonian Institute and the Asian Art Museum (AAM) in San Francisco, California, USA. Testing took place on site at the AAM in October 2014. Characterization of the artifacts began with recording the in-situ geometric configuration and boundary conditions (i.e. restraint mechanisms) using light-detection and ranging techniques (LiDAR). The resultant high-resolution, geometrically accurate point clouds are triangulated to form watertight surface meshes in order to calculate mass properties. The second step in the characterization is the non-destructive modal analysis or system identification in which the resonant frequencies of the in-situ statue-restraint system are determined. The physical test consisted of outfitting the statue with small, lightweight, high-sensitivity accelerometers, imparting a small force, and measuring the output vibration at multiple locations along the statue. The ratio of the frequency response of the output to the input yields the natural frequencies (modes) of the system as well as damping and mode shapes. These characteristics of the statue system can be used to understand the seismic vulnerability of the statue and predict the response to earthquake loadings.

Authors **Igor Barros-Barbosa, Kidane Fanta, Panagiotis Perakis, Christian Schellewald, Lise Kvittingen, Theoharis Theoharis**

Title ***Establishing Parameter Values for the Stone Erosion Process***

Abstract A computer simulation model of the naturally occurring stone erosion process is attractive because of the many potential applications to studies of cultural heritage and the built environment. Such a model could enable us to predict the future state of important cultural heritage monuments based on different environmental scenarios, allowing us to take timely appropriate action. However, a simulation model of this type is extremely challenging, due to the large number of parameters involved and also the difficulty of establishing their values given the large timespan over which they evolve. This complexity also makes simple observation of these parameters on stones in the natural environment unproductive.

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One way to establish parameter values in a manageable timeframe is through the use of chambers that can subject stone samples to accelerated erosion. Simulating all the natural effects that contribute to erosion is difficult; however one can identify the most important effects and try to simulate these in isolation.

This paper describes the design and construction of two low-budget automatic erosion chambers to simulate the Freeze-Thaw and the Salt effect respectively, based on a control system using off-the-shelf components. It also details the parameters monitored after each erosion cycle, obtained with the use of 3D scanning, electron microscopy, micro computed tomography, 3D microscopy, XRD and petrography. This long list of parameters poses challenges of integration in a single 3D model and our achievements in this area will be discussed. The recording of these parameters is intended to eventually lead to a publicly available database for erosion benchmarking. In the current instance we are only considering Pentelikon marble and two types of sandstone. This work forms part of the PRESIOUS EU project (www.presious.eu).

Authors**Willem Vletter****Title*****An 4-D analysis of historical road and path networks*****Abstract**

In Archaeology and in other academic fields, the application of LiDAR data for creating a 3D model of an area is already well known. Moreover, it is the only remote sensing technique that can visualize on a large scale the micro topography in (densely) forested areas. In general areas historical road and paths are better preserved, in forested than on agricultural land. Therefore, the objective of my PhD thesis research was to develop a methodology based on LiDAR data to investigate historical road and path networks in forested areas.

The developed methodology exists out of four steps. In the first step the (semi-) automatic visualisation and extraction of linear features from ALS data is tackled. In the second step a method is presented to determine the relative chronology of historical roads and paths. The third step deals with the predictive modelling of unknown networks. The last step combines a 3-D environment with a time element, resulting in a temporal-spatial visualisation of the road and path networks found.

In this presentation the focus lays on the fourth step. More precisely on the use of gaming software (Unity) to visualize elaborated LiDAR data. On a 3D model (semi-) automatic extracted and (relatively) dated roads and path networks are draped. Thanks to the dating, networks from different periods can be shown. This provides a temporal dimension to the model, making it 4D. Being a gaming software the model can be made more realistic by coloring and adding (different) vegetation to the scenes of the various periods. In addition agents can be introduced in the application, resulting in that one can experience the landscape. In this way one can not only 'travel in landscape' but also 'in time', expanding the analytical possibilities.

SESSION 4C-
FORMAL APPROACHES
TO VISIBILITY ANALYSIS
IN ANCIENT ARCHITECTURAL SPACES
AND CULTURAL LANDSCAPES

Authors Giacomo Landeschi, Nicolò Dell'Unto, Daniele Ferdani

Title *A vector-based pipeline for assessing visibility: a 3D GIS perspective*

Abstract 3D GIS systems have been recently used as a powerful means to store, query and analyze archaeological datasets. The latest technological developments in 3D and GIS technology led to the introduction of innovative work pipelines that allowed archaeologists to import even geometrically-complex texturized 3D models in GIS. Such an achievement, opened up to very promising research lines where the level of accuracy of the 3D reconstruction can effectively integrate the analytical power of GIS platforms. In this sense, the Pompeian house constitutes a very valuable case study to make an assessment of the visual significance connected to specific classes of objects: many of them were originally put in display with the specific purpose of being seen by someone else. Detecting and quantifying those visual patterns is a necessary step for better catching symbolic and ideological meanings that regulated the displacements of the artifact inside the built space of the Roman house.

In the frame of the Swedish Pompeii Project a recently-developed research line allowed us to test an entirely 3D GIS-based approach to evaluate the visual impact of different categories of artifacts, like wall inscriptions and paintings and to describe a work pipeline that could be effectively used and repeated in many other study contexts. To reach this goal, a vector-based line-of-sight analysis has been carried out and the encouraging results obtained constitute a valid starting point for discussion and to extend this kind of methodological approach on a wider sample of data.

Authors Michael Auer, Heather Richards-Rissetto, Jennifer von Schwerin, Nicolas Billen, Lukas Loos, Alexander Zipf

Title *MayaArch3D: Web based 3D Visibility Analyses in Ancient Cityscapes – the role of visible structures at the Maya Site of Copán, Honduras*

Abstract The MayaArch3D project is developing a web-based archaeological research platform using as a case study 24 square kilometers surrounding the UNESCO World Heritage Site of the ancient Maya kingdom of Copan (Honduras). This research platform combines information from a traditional, non-spatial archaeological database of the German Archaeological Institute (DAI) with 2D and 3D GIS data stored in a geospatial-database. This combined system supports the visualisation and analysis of large archaeological landscapes down to 3D models of small stone objects.

One part of the project's research agenda deals with questions about the socio-political structure of the ancient city, whose buildings have been classified into five socio-economic classes from simple huts to ceremonial temples. In contrast to the architectural types that represent buildings constructed by a broad spectrum of society, smaller stone monuments at Copan – the so-called stelae and altars, were commissioned exclusively by Copan's nobility (or rulers and elite). These contain textual and iconographic messages that scholars have been working for over a century to decipher and understand. New methods of analysis made possible by 3D web GIS can now aid in testing these hypotheses. Specifically, the visibility or inter-visibility of monuments and buildings of different social classes (and also to or from common pathways that inhabitants of different social quarters may have taken while moving through the city), may reveal new insights into the socio-political structure of the city, the functionality of certain monument types (e.g. stelae), and how and to whom certain messages were addressed.

In particular, to test the functionality of the stelae that are dispersed across Copan's landscape, a network of visibility relations can be established and used to test existing hypotheses about the stelae function; for example, that the stela locations might have been used to transfer smoke

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signals from the outskirts of the valley to the center of power. Other theories on stela functionality assign them the role of boundary markers or delimiters of power, markers using the sun position coinciding with the start of the planting season, stations of a procession route or as landmarks to guide incoming visitors to the center.

Our objective is to perform visibility analyses in a web-based context. Because large amounts of data are involved in visibility computation using, for example, terrain models stemming from LiDAR surveys, a web-based analysis system has to either support processing services to displace the computation load to a remote computer, or it must intelligently split the analysis and its necessary data into parts, aiming to minimize the amount of data to be downloaded and processed.

Authors **Nicolo' Dell'Unto**

Title *Using different eyes: the case of the medieval Cathedral of Dalby*

Abstract This paper discusses a methodology based on the use of 3D technology to acquire, post process and simulate the use of the space in ancient buildings. This approach implies the use of 3D acquisition technologies, such as laser scanning or image based reconstruction, to build libraries of 3D objects to use for visualizing different versions of the same historical environment. The construction of such virtual interpretations and their implementation inside three-dimensional visualization platforms allows retrieving new information concerning how the space was organized and used in the past. This methodology has been tested in the medieval church of Dalby, Sweden, to retrieve information concerning the medieval crypt and its use. The church of Dalby was funded at the beginning of the XI century and it is considered the oldest still standing stone church in Scandinavia. Since its construction the original structure changed several times and the current configuration of the space doesn't allow an evaluation of how the crypt was used in the past. This experiment proved how this methodology permitted to retrieve new information for the interpretation of the crypt. The preliminary results of this project will be presented and discussed.

Authors **Rodrigo Mora**

Title *The development of 3D VGA tools: an application in a case of weak heritage in Valparaiso, Chile*

Abstract In the last ten years, isovist analysis has emerged as a fundamental method to reflect a person's visual experience in cities and buildings. However, until now most studies used a two-dimensional, planar perspective, thus neglecting the three-dimensional nature of vision. This paper presents a method to construct 3D isovists. The idea is to give a more realistic account of a person's visual experience in hilly urban scenarios where a person can see places that are not directly accessible. The paper aims to contribute to the construction of objective methods to represent the environment in a more ecological way.

The method is tested in the city of Valparaiso, a heritage city that spreads across thirty hills forming a natural amphitheatre, and whose charm rests, to a great extent, from the visual

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experience that arises from observing distant parts of the city that are not directly accessible. The results show that three-dimensional isovists are capable of capturing the underlying visual properties of ravines and urban viewpoints (miradores) of Valparaiso.

SESSION 4D-
3D RECONSTRUCTION,
ANALYSIS AND IMMERSIVE
TELEPRESENCE AT ROCK-ART SITES

Authors **Thomas Höll, Gert Holler, Axel Pinz**

Title ***A scanner-prototype for geometric and radiometric reconstruction of rock-art sites***

Abstract

The accurate geometric and radiometric reconstruction of rock-art sites is a challenging task due to their remote location and the non-laboratory data acquisition situation. We present a portable stereo-vision based rock-art scanner prototype that enables a fast and accurate scanning of the geometric and radiometric characteristics of such sites.

We are interested in the reconstruction of whole rock-art sites and the spatial relationship between them. To do so, our scanner produces a geo-referenced 3D reconstruction of the sites. We achieve an accurate 3D reconstruction by augmenting a Structure from Motion approach with additional knowledge of the scanner's stereo-setup and tachymeter measurements. The stereo-setup is used to determine the scale of the reconstruction and the tachymeter measurements are used at first hand to geo-reference the reconstruction, and second to compensate the drift induced by the Structure from Motion method. By doing so, we obtain a geo-referenced 3D reconstruction with a precision of 0.1mm. A major advantage of this approach is, that the geo-referenced reconstruction is obtained without the usage of ground control points. On the other hand, if a geo-referenced reconstruction is not necessary the scanner can also be used without a tachymeter.

One of the challenges in scanning radiometric surface properties is the illumination condition at the rock-art sites. Different from the laboratory one is confronted with non-controllable illumination conditions and cast shadows caused for example by nearby trees. Despite of these conditions the proposed scanner prototype is able to deliver radiometric surface properties beyond photo-texture. In order to achieve this we design a custom LED-illumination and for each scanner position we acquire two images, the first with the LED-illumination and the second without LED-illumination. We subtract the second from the first image to obtain an image that is free from ambient light effects. To estimate the radiometric surface properties we solve an inverse rendering problem using the knowledge of the 3D reconstruction and the scanner calibration.

To verify the performance of the scanner prototype we present various experiments. The geometric accuracy of the scanner reconstruction is shown by a comparison of our reconstruction and ground truth data of already scanned rock-arts. Colour targets with known radiometric surface properties are used to verify the radiometric reconstruction.

Authors **Ken Saito, Chris Musson**

Title ***3D Recording of Rock Art in Harsh Environmental Conditions at Ughtasar, Armenia***

Abstract

Armenia has a rich heritage of prehistoric rock art, one of the most spectacular sites being at Ughtasar, in the mountainous southern part of the country. At a height of 3300m above sea level, and under snow for most of the year, the study area discussed here occupies the crater of an extinct volcano within which many hundreds of rock-art figures have been pecked or carved into the surfaces of the glaciated rocks. Animals, humans, wheeled vehicles and abstract figures are all present, sometimes in apparent scenes involving hunting and other social activities. The harsh natural conditions of the site place a premium on speed and effectiveness of recording in the short period each summer during which a largely self-funded Armenian/UK team of archaeologists and other specialists has been systematically recording the rock art for the past 6 years. The presentation will concentrate on practical experience with multi-image photogrammetry during the 9 days of site work undertaken each year during 2013 and 2014. Following preliminary trials in 2012 and 2013 one of the specific objectives of the work in

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2014 was the 3D recording of 120 of the most important, distinctive or fragile carved panels within the 900 or so recorded up to the end of the previous year. The recording is seen as a form of ‘preservation by record’, particularly important because the site is coming under increasing pressure from visitors who do not always understand the damage that can be caused by walking on or touching the rock art panels. This aspect of the work thus represents a case-study in non-destructive recording aimed at the documentation and conservation of endangered archaeological features on a site which presents many practical difficulties because of its remoteness, inaccessibility and harsh environmental conditions.

The 3D data at Ughtasar has been collected with three main aims – selective preservation-by-record, visualization, and research. The link between the three is that the most important of the rock art panels and surroundings should be capable of 3D reconstruction in a digital environment so as to serve any one of these three objectives. Thus 3D representations showing both the local setting and a high degree of detail in the individual rock-art panels are required for purposes of preservation, interpretation and research. In addition, digital models are seen as important for visualization, increasing the potential effectiveness of communication both with fellow specialists and with the general public at local, national and international levels. It is worth observing, however, that at Ughtasar – as elsewhere – the practicalities of web-based communication for this kind of dissemination have yet to be fully explored or resolved.

The Project has been carried out under the joint direction of Tina Walkling and Anna Khechoyan. Descriptions of the site, the project objectives and the results achieved so far can be found at <http://www.ughtasarrockartproject.org>.

Authors Vera Moitinho de Almeida, Luis Teira, Roberto Ontañón Peredo

Title *Analysing Rock Art: a quantitative approach using 3D models*

Abstract In this paper we present a framework based on quantitative methods and 3D digital models for the analysis and interpretation of prehistoric art (or prehistoric graphic expression). The object of study is located at the source of the River Ebro (Cantabria), in the North of the Iberian Peninsula. It consists of a set of 23 antropomorphic figures, from the Early Bronze Age, aligned side by side and carved on the vertical surface of a bedrock. We chose the central and larger figure, the only armed anthropomorphic figure from this set, as an optimal test case for 3D scanning (structured light scanner, 280 µm resolution) and for further geometric analysis. Our aim is to provide meaningful information towards a better comprehension of the manufacturing procedures, by: describing quantitatively different types of microtopographies (ISO 25178) and other geometrical features; Differentiating morphologies within figures; Associating the observed macro traces with possible gestures, sequences, carving techniques and used tools. This research falls into a wider reflection on the contribution of controlled and replicable imaging process towards comparative studies of prehistoric graphic expressions.

Authors Matthias Zeppelzauer

Title *Intelligent Rock Art Processing: from Automated 3D Segmentation to Shape Classification*

Abstract The UNESCO world heritage site Valcamonica contains numerous rock panels with petroglyphs that have been pecked, scratched or carved. We present recent research in the area of automated processing of rock art that has been performed in the 3D Pitoti project (3d-pitoti.eu). A major goal of the project is to model the rock surfaces by 3D scanning to generate high-resolution reconstructions of petroglyphs. Once a rock surface is scanned and mapped in 3D we extract the petroglyphs from the surface by automatic 3D segmentation. In a subsequent processing step we analyze the shape of the petroglyphs. For this purpose, we refine the raw segmentations (shape preprocessing) and fit a skeleton into the petroglyph (skeletonization). The skeleton is an abstract and highly invariant representation of the shape and serves as a basis for the automated indexing. The indexing enables the search and retrieval of petroglyph shapes, i.e. to find similarly shaped petroglyphs to a given one. Finally, we propose techniques for the classification of petroglyphs into different classes provided by a comprehensive typology. The talk gives an overview on the entire processing chain from 3D segmentation to shape classification of petroglyphs and presents challenging research results in this domain.

Authors Carlo Inglese, Marco Carpicci, Fabio Colonnese

Title *Mediated representations after laser scanning. The Monastery of Aynali and the architectural role of red pictograms*

Abstract The monastic settlement of Aynali is located in Cappadocia, a short distance from the Open Air Museum in Goreme. It is just outside the large semi-circular rock *cavea* constituting the heart of that singular confederation of monastic communities. Possibly the whole area was ruled by a common social structure, in which each core was constantly in touch with the other ones, sharing the need for subsistence and contemplation.

The rooms of the monastery of Aynali are on two main levels and were excavated around a rectangular court. The Northeast front can be assumed as the main facade: two openings allow people to enter the great room, which is covered by a barrel vault and divided in three parts by two light suspended arches, while a third opening leads to the church through a small vestibule. The church is roughly square, with a large central apse; four large columns divide its space into three naves covered by barrel vaults.

The church and other parts of the monastery follow approximated geometrical rules and are rarely comparable to simple geometric shapes. This would suggest they are the result of an extemporaneous and uncoordinated program of excavation. Conversely, rooms facing the rectangular court seem to share the geometries of traditional architecture. The “traditional form” of such environments, however, is only apparent: in fact even the main hall, although to a lesser degree than the church, is suffering from a sensitive deformation that significantly alters the alleged rectangle of the plant.

The decorations in the church and the main rooms follow the red monochrome type, quite common in this area. This monochrome pictograms show a predominant geometric character and are generally used to describe and highlight the rock-cut surfaces according to those elements which play the figurative role of “architectural constituents” such as columns, pilasters, capitals, architraves and cornices. This kind of depicted decorations have been

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connected to some sort of apotropaic process of sanctification which was imposed by the need of using those spaces as soon as possible, delaying later the moment of the realisation of the final decorations. But even these pictograms appear the result of a hasty and rough work, their symbolic value and meaning should not be overlooked. In fact, the monochrome painting must be seen as the last stage of the architectural achievement. While in “traditional architecture” the elements of the orders play also the role of describing visual hierarchies and structural behaviours of the parts as well as decorating the key elements of surfaces, in Cappadocian rock-cut architecture this function is played by red pictograms, with the secondary consequence of transforming the architecture itself in a huge representation, a sort of full-scale model to design its final configuration with. But most important is that those paintings have being studied together with the rock surface supporting them thanks to integrated applications of laser scanning and digital photography, as this paper is to describe, in order to contribute to archaeological and historical researches on Cappadocian rupestrian architecture.

Authors Neil Smit, Matt Howland, Thomas Levy

Title *Digital field recording in the 4th dimension: ArchField C++*

Abstract With the rapid adoption of laser scanning and photogrammetry among the archaeological community the full digital documentation of archaeological sites is now becoming common place. In field excavations, however, the continual exposure of archaeological layers requires a digital toolset in which to record, categorize and spatially locate artifacts, installations, and loci within a site’s daily 3D or aerial scan. We present ArchField C++, the latest version of our digital field recording software that enables real-time digital GIS Top Plan production within a rendering engine designed for visualizing massive point cloud datasets. Archfield directly connects to Total Stations and our RTK GPS units to record sub-centimeter measurements for artifacts, scanning markers, loci boundaries, and camera positions. The processing pipeline enables the generation of publishable orthographic and perspective maps from the first day of excavation to the last. As a backend it uses a PostGIS database and the ability to export and import various vector, raster, dem and 3D datasets. We present its application to our 2014 field excavations of the early Iron Age site of Khirbat al-Jariya located in Southern Jordan.

Authors Tommaso Empler, Barbara Forte, Emanuele Fortunati

Title *Cultural Heritage 3D modeling view in Real time: the Forum of Nerva in Rome in the time of Imperial Rome and Medieval Ages*

Abstract One of the Cultural Heritage application is the possibility to reconstruct past places and environments that appears today as archaeological sites.

3D modeling and the possibility of navigation/view reconstructions in "real time", allows both scholars and to those who do not have an in-depth scientific knowledge, to be able to understand what was the real shape of an archaeological site in the past. The opportunity is offered by the use of software designed for other areas of interest, such as video games, using tools developed specifically for the video game industry. Procedures coming from the world of video games are transposed in the field of historical reconstruction and 3D modeling. In order to ensure a smooth navigation is necessary to realize 3D models where is good the balance

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between solid modeling and surfaces modeling with the use of specific texture of historical reconstruction. It is also important to be able to use appropriate algorithms, which allow the simplification of the calculation of the shadows.

As a case study is proposed the reconstruction and 3D visualization in "real time" of the Forum of Nerva (in the imperial archaeological center of Rome), so far subject of little interest and study from this point of view, obtained by the game engine of an application open source like Blender.

Thanks to the assistance of archaeologists and historians from the point of view of content, and the ability to govern the modeling tools in 3D, by the representative, it is for the first time assumed a reconstruction and exploration of the Forum of Nerva in Imperial Rome and Medieval periods.

The most interesting and innovative goal is the ability to switch from the reconstruction of the period of Imperial Rome to the Medieval age, through the use of the "space bar" on the computer keyboard, allowing the "navigator" to make a time leap into the past with a "subjective" view. The displacements in the 3D model can be carried out both with the mode that uses the four letters "W - A - S - D" on the keyboard of the computer, respectively, to go forward, left, back and right, both with the use of a joypad or a pad bluetooth. The application is complete and running .exe file for both Windows and iOS devices, that does not require a previous installation of Blender.

**Authors**

Emanuel Demetrescu, Ivana Cerato

Title

From survey data to 3D extensive landscape reconstruction. A taxonomic - metadata approach to Montegrotto Terme area.

Abstract

The Montegrotto Terme area is characterized from the prehistory to nowadays by thermal and extensive agricultural activities. Such a presence of natural elements can supply some important guidelines to understand the anthropization process. Starting from the archaeological data (field survey, cartography, digs) and the environment record (botany and geology) we

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reconstructed a part of Montegrotto Terme from prehistoric to modern times.

The virtual model is a valid cognitive tool and is a fundamental medium through which a user (a scholar, a student or simply somebody who shows an interest for the subject) can interact with 3D models and agents in a virtual environment. This technology can be applied to the world of cultural heritage as a vessel for preservation, reconstruction, documentation, research and promotion (Fabio Bruno, Stefano Bruno, Giovanna De Sensi, Maria-Laura Luchi, Stefania Mancusoc, and Maurizio Muzzupappa, 2010).

In the last years there are many examples of 3d archaeological landscape visualization and interpretation but there is a lack in terms of data transparency regarding to the cognitive process involved (Kreuter, Couper, and Lyberg 2010; Bentkowska-Kafel, Denard, and Baker 2012). Dealing with a large and complex set of data collected we organized all the elements (3d models, sources, visualization strategies) in a common metadata framework able to enrich semantically the landscape reconstruction.

From a data transparency point of view we will propose some possible solutions to store the metadata directly in the 3d models and achieve some communications strategies to retrieve them during the virtual visit. As a major goal we will make clear the cognitive process followed to obtain the landscape reconstruction including the para-data information. Transparency is essential to understand and build research hypothesis and conclusions, particularly in areas where data is questionable, incomplete or conflicting. Data transparency and reliability of reconstruction are necessary for a scientific review of the 3D outcome; while data transparency allows an evaluation of the raw data used for the digital reconstruction, reliability refers to a method of quantification of the research results, by the researchers themselves (Sorin Hermon, Joanna Nikodem 2008). As a result the metadata and paradata remain in the mind of the researchers not enabling a 3d models validation process from the scientific community. In the same way the lack of open datasets could be a major issue in the development of the field of study. As a result the model will be enriched not only with the description but will explain the scientific-archaeological process. We will make available the raw data we collected during our research to make possible to other researchers to provide other interpretations and all the pipeline is based on open source software and open formats.

Authors	Stephan Beck, André Kunert, Alexander Kulik, Bernd Froehlich
Title	<i>Collaborative Visual Analysis of 3D Scanning Data: The 3D-Pitoti Scientists Lab</i>
Abstract	<p>We present an interactive 3D visualization system for the collaborative exploration and analysis of large and highly detailed 3D scanning data. The system is based on novel multi-user 3D display technology that provides groups of users with a shared virtual environment. All users perceive the displayed 3D scans from their individual perspectives which supports the individual exploration of geometric features and their collaborative discussion using direct pointing and tracing gestures. The system further exploits novel rendering techniques for the interactive visualization of large 3D point clouds.</p> <p>In the context of the European research project 3D-Pitoti we show detail scans of prehistoric rock art with sub-millimetre accuracy embedded in their natural environment and thus provide an almost one-to-one correspondence to the physical situation of the archaeological artefacts. Moreover, we present novel visualization- and interaction techniques that are being developed for fluent and efficient collaborative data analysis in immersive virtual environments.</p>

SESSION 4E-
FROM 3D SCANNING
OF OBJECTS AND MONUMENTS
TO AUGMENTED REALITY THEORETICAL
AND METHODOLOGICAL ISSUES
OF ADVANCED
3D IMAGING TECHNOLOGIES

Authors

Katalin Tolnai

Title

The Study of the Past in In-depth? – A 3D approach in the integrated interpretation of archaeological data

Abstract

The paper presents the use of integrated interpretation methods on different kind of archaeological data sets in the three dimensional space. It further seeks answer for the question of the methodological issues, how can the different types of data sets help in answering archaeological research questions in order to reach a 3D framework.

Archaeological investigations are carried out in three different scales. Most frequently larger groups of objects are investigated which lead to the understanding of the artifactual chronology of a given period. As a next step, sites as composition of archaeological features from a given geographical location are analysed. This later can be then extended to the largest, landscape scale without, most probably, any limits. This complex understanding of materials on different scale can then lead to the bird-eye view of historic periods.

In most archaeological research these layers of information are dealt separately from one another, and mostly only a brief overview is given to the understanding of the big picture.

As a result of the latest developments of digital data recording large data sets are now available to help understanding our past. The acquired data can also be understood as the representation of archaeological remains. Furthermore, scaling can also be managed, using digital techniques and solutions, such as GIS environment. The present research aimed to present the links and connections between these scales and their methodological questions. The analysis is performed in a GIS environment in which all types of data are connected to each other based on their geographic location. The methodology, as a part of my PhD research at the University of Vienna, Initiative College for Archaeological Propection, is tested on case study areas from the medieval sites of the Pilis region from Hungary and the Viking age remains of the region of lake Mälaren, Sweden. In the two case study areas the data acquisition was performed on different ways, which resulted in various datasets providing substantial new information of each scale. On the landscape scale aerial images, Lidar measurement and geophysical measurements of different types provide 3D datasets. On site scale 3D terrestrial laserscanning of excavated layers, or land surveying of today's surface of remains and features add new, digital information. Objects can also be archived with the help of 3D scanners.

Acquiring more and more digital datasets however raise new problems too which leads now to the question of big data management. With the help of digital datasets not only the data acquisition but also the data interpretation can be done of various scales not only parallel, but connected to each other.

Authors

Andreas Hadjiprocopis

Title

Cloud-based 3D Reconstruction of Archaeological sites using photographs from Aerial Surveying, hand-held devices and Open Access Image Repositories

Abstract

A large number of photographs of Cultural Heritage items and historical monuments is available for free in Open Access Image Repositories (OAIR). Metadata inserted by camera, user or OAIR may help determine photograph content, geo-location and date of capture, and localise these photos in space and time with relative success. Additionally, the affordability, reliability and ease-of-use of low-altitude Unmanned Aerial Vehicles (UAV) makes the use of Aerial Surveying in the domain of Archaeology and Architecture a popular choice, yielding - for the first time - an unprecedented volume of high-resolution, geo-tagged image-sets of historical sites from above. Most importantly, recent developments in Photogrammetry, such

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as Structure from Motion, provide a simple and cost-effective method of generating relatively accurate 3D models from 2D images. Finally, cloud processing and storage technology has reached a high level of maturity which makes the use of such services easy and affordable. The convergence of the aforementioned technologies combined with GPS-enabled mobile devices with high resolution cameras and large-bandwidth Internet connectivity may provide a new tool at the disposal of those who need to reconstruct, visualise, share and annotate 3D models in the field. In this paper we present a Cloud-based service intended to be used by Archaeologists, Historians, Architects and also the general public, to reconstruct in 3D, views of archaeological sites. Our main goal is not only to build a software tool for fast and accurate 3D reconstruction from a variety of photo sources but also to provide a platform on which these models can be annotated and enriched collectively. Thus, photographs from UAV and hand-held cameras and mobile devices can be uploaded to the Cloud and the corresponding 3D model can be produced in up to millimetre accuracy within hours. Additionally, our service provides a high-level image search through many OAIR (Flickr, Picasa, Europeana) based on geographical and description tags and image and camera characteristics. Our open-source 3D reconstruction pipeline consists of public domain software (Bundler, SURE) and our modified image matching algorithm in order to reduce processing time by up to half by using lower-resolution versions of the input images. Beside the benefit of reduced processing time and decentralized storage, we envision that the presented cloud-based service will have significant impact on the documentation of Cultural Heritage by enabling professionals, scientists and the general public to share material and build 3D models and enrich them **collectively**. Additionally, the hardware requirements concerning the end user device are significantly decreased, which enables the usage of mobile/smart devices. This is not only useful in the field, but also reacts to the limited financial resources within projects in the domain of archaeology and Cultural Heritage documentation in general.

As proof-of-concept three case studies are presented:

- a) tens of images from a hand-held device of a Vatican museum statue,
- b) hundreds of images of the Asinou Church (Cyprus) by UAV-attached camera, and
- c) thousands of images of the Coliseum (Rome) downloaded from Flickr OAIR.

Results are compared to those obtained by commercial software Agisoft Photoscan.

Authors Anestis Koutsoudis, Fotios Arnaoutoglou, Vasilios Liakopoulos, Athanasios Tsaouselis, George Ioannakis, Christodoulos Chamzas

Title *Creating 3D replicas of medium-to-large scale monuments for Web-based dissemination within the framework of the 3D-ICONS project*

Abstract Web dissemination of cultural heritage 3D content has been vividly increased over the last decade. EU-funded research and development projects establish affordable pipelines for such 3D documentation and dissemination. The 3D-ICONS project aimed at the 3D digitisation of outstanding cultural importance monuments and their dissemination through a Web-based single access point such as Europeana. In this work, we discuss the methodologies applied by our team for the 3D digitisation of six (three of them are included in Unesco's world heritage list) medium-to-large scale monuments located in the area of Northern Macedonia and Thrace, Greece.

The digitisation was completed by following a two-stage pipeline. The first stage was focused on the data collection procedures (DC) while the second on the data processing (DP), content generation and Web-based visualisation. More specifically, DC included terrestrial (height range 1.5m – 6m using tripods, monopods) and aerial photoshooting (height range 7m – 40m), terrestrial TOF laser scanning, total station and empirical measurements between temporarily

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positioned targets or strong features on monument's surfaces. A custom UAV was used to allow close-range (in some cases <3m distance from surface) aerial. Challenges such as weather conditions, wing gusts, monument's and environment's morphology as well as accessing times are discussed. Each monument was reconstructed by image sequences varying between 1.000 and 9.500 images.

On the other hand, DP exploited the Structure-from-Motion/Multiple View Stereovision (SFM/MVS) for the generation of the primary 3D models. A commercial SFM/MVS software tool was used. In some cases more than 190 hours were required for the spatial image alignment (9.200 image sequence) on a high-end computer system. A 3D model scaling and data quality evaluation was performed based on the data provided by the laser scanner, the total station and the empirical measurements. A dynamic landing-Webpage was implemented based on a customised version of the X3DOM WebGL-based framework in order to deliver the different resolution 3D models into a vast range of both desktop and mobile devices. A special Google cardboard stereoscopic/3D visualisation mode is also supported. 3D models' digital derivatives such as non-realistic renderings and orthographic photos were produced. We have created photorealistic fly-around video sequences with post-processing effects in order to visualised high resolution data in low-end devices. A number of DC challenges such as extremely demanding (CPU/GPU/RAM) algorithms with long processing times, big data handling and visualisation have confronted.

Authors**Gábor Bődő****Title*****Understanding Heritage through Augmented Reality Development*****Abstract**

3D imaging and scanning devices are truly symbolic technologies of the 21st century. The rapid development of 3D imaging is sweeping through every corner of it. Capturing, processing, modeling, and the output products, like virtual or augmented reality, 3D printing etc. are key elements of these technological development processes. Perfecting targets and many other aspects of the 3D technology are connected to the refinement of capturing hardware, while software development is aimed at the faster, high-fidelity processing of the data. New database concepts enabling multipurpose utilization of the huge datasets as well as the further development of multimedia output formats and displaying devices offer for the viewer multimedia experience ever closer to the reality.

The main concept of the presentation is to explore both the technological side and the implementation dimensions of this state of art technology. The primary objective of the presented project is to digitally document historical sites and archaeological finds in 3D with high fidelity and precision, organized in a database accommodating cross disciplinary scientific research as well capable to provide multimedia (narrated augmented reality) experience for research purposes. With the help of these detailed virtual digital 3D models of the historical sites and artifacts were generated.

Special emphasis was given to 3D scanning, which is a powerful tool to survey objects with exceptional preciseness, from tiny ones to entire buildings. The scanned images can be converted into complex digital models of the objects that can be manipulated, rescaled, transformed, etc. This model was used as virtual reconstruction of the present state or was developed to a more complex model form to reconstruct the whole structure. Elements of this model are measurable, can depict the various parts of it even in different stages of construction or decay in the course of time. Combined with other imaging technologies, notably photogrammetry, the original visual surface of the object can be recreated in impressing details by applying textures.

The models were also organized into searchable databases where a wide spectrum of physical

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and non-physical property descriptors (metadata) can be associated with them.

Although scanning provides information about the shape, appearance and conservation condition of the heritage/object, its digital representation offers much more versatile application possibilities than just document its present condition. Therefore another objective of the presentation is to summarize the concept of the BIM (Building Information Management) in the domain of heritage preservation, archaeological research and reconstructions.

In order to cope with the problem of transformations and changes in different historical periods, we propose to use one of the most advanced interactive storytelling technology, Augmented Reality (AR). AR is capable to extend our normal way of perceiving things in the real-world. Thus, our objective is to share and introduce these scanned datasets and models (reconstructions) for a non-specialist audience, by creating interactive presentation forms.

Authors

Gary Devlin, Anthony Corns, Robert Shaw, Patrick Griffin

Title

Modelling Irelands iconic sites: Generating online digital models from massive pointcloud datasets

Abstract

As a partner in the EU funded 3D-ICONS project The Discovery Programme has been surveying a wide range of cultural heritage sites in Ireland. This pan-European project with sixteen partners from nine countries had the aim of establishing a complete pipeline for the production of 3D digital models and to publish the content to Europeana for public access. Seventeen of Irelands most iconic sites have been surveyed as part of this project, ranging in scale from landscape to small artefacts, and using the range of laser scanning techniques from Lidar to object scanning. Sites recorded include Skellig Michael and Brú na Bóinne, both on the UNESCO World Heritage List.

The challenge:

Reduce the massive data sets associated with laser scanning

To deliver an aesthetically pleasing digital model

The online model would not require proprietary software

The model would not take too long to load up

All the complexities and irregular shape of the surveyed object would remain in the model

This paper will outline the finished pipeline developed by the Discovery Programme to achieve this objective. The method discussed reduces the volume of data to less than 1 percent of its initial surveyed size, whilst maintaining all the intricacies of these iconic sites. This reduction in model size is achieved by using a number of sampling and decimation approaches, some originally developed for the gaming industry.

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Authors **Carolyn von Groote-Bidlingmaier, Klaus Hilbert, Sabine Timpf**

Title *Deriving settlement patterns using environmental information*

Abstract The goal of this research is to derive settlement patterns and functions of the pre-Columbian Konduri culture in the Amazon Basin (around 800 B.P. – 400 B.P.). The main hypothesis is that settlements of the Konduri culture occurred at the same time in different environmental locations and that the properties of the locations allow different functions for each settlement. We assume that the settlements networked with each other and that the community profited from the diverse capabilities that existed at the different locations. The aim of this paper is to separate these categories of capabilities and detect the different function(s) each settlement played within the larger community.

Our approach is to look closely at the environmental conditions under which a settlement becomes feasible and sustainable over a period of time. For living, several environmental conditions must be fulfilled, such as the availability of varied food sources, stone, and wood, the opportunity for shelter, defense, and transportation, as well as a maximum density of people. The forest and the rivers were main sources for food. Agriculture was practiced and known settlements (from excavation sites) had several “forest gardens”. Permanent settlements and agricultural sites were located on the so-called “Terra Firme”, the areas never inundated because they rise high above the rivers. The availability of food varies according to the river and lake type and also according to the season (e.g. varzea of white water rivers with possibility to grow food in the dry season). One of the few things known is the importance of the waterfalls upstream. Stones were not available further downstream, however, archaeologists found stones at each excavation site, which supports the view of a networking community.

In our analysis we initially focus on the widely spread river network, which is known to be used as food supplier as well as transportation and trade route. The forest occurs wherever terra firme can be found, thus it is considered to be ubiquitous. The climate does not vary across the research area, therefore we exclude it from the analysis. In a first step several tests for complete spatial randomness (CSR) show that the excavation sites are usually closer to a river or a lake compared to randomly dispersed points. In a second step a Cluster Analysis is performed to derive the different functionalities based on the availability of resources and the ability to trade them. A hierarchical cluster method is used and results in eight clusters which can be separated into different settlement functions such as e.g. defense function, food supply function or tool supply function. The results already show a promising spatial pattern of functional settlements. In future research we would like to include additional considerations such as strategic locations with long-distance viewing capabilities or accumulation of functions in one single settlement.

Authors **Kayeleigh Sharp, Melissa Litschi**

Title *Integrated Technological and Spatial Analysis: Fuzzy Data Mining on the North Coast, Peru*

Abstract How can meaningful dimensions of social differentiation and complex social interrelationships be elucidated through archaeological data? Focusing on long-standing debates concerning the nature of Gallinazo (aka Virú) and Mochica (aka Moche) interrelationships during the first millennium, our long-term work has two key objectives: (1) to implement in-depth quantitative investigations of technological choices and activity patterns, and (2) to carry out high-level multivariate spatial data analysis to identify patterns and expose social asymmetries that may arise in situations of cultural coexistence. We present preliminary findings from our integrated approach that combines quantitative and qualitative studies with spatial statistical analysis. Mixed-type data from various sources (GPS, pXRF, low-resolution microscopic, etc.) were integrated into our geodatabase and then used to identify technological constellations using a

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fuzzy taxonomic classification system. This system is based on technological rather than stylistic characteristics, and is useful in a broader range of applications. The resultant data was then subjected to various data mining techniques to identify meaningful patterns and establish association rules that can be used to distinguish among a broader range of coexisting artifact assemblages. As our preliminary work shows, we have moved one step closer toward resolving critical debates concerning the Gallinazo-Mochica relationship by integrating high-powered tools borrowed from the geographic information and computer sciences. As a means for eliciting characteristics of social differentiation, the techniques applied herein have the capacity to generate nuanced feature classes within our geodatabase, which can then be used for higher-level spatial-statistical analyses. The ultimate utility and efficacy of this integrated approach will be assessed based on the ability to detect patterned differences or similarities in the multivariate datasets generated through systematic excavations that are planned for the near future. In the meanwhile, the integrated approach we present has broader applicability for anthropologists working inside and outside of the Andes as a means by which to refine our vision of the past using state-of-the art archaeometric, spatial analysis and computer science techniques.

- Authors** **Miłosz Giersz, Patrycja Prządka-Giersz, Wiesław Więckowski, Julia Maria Chyla, Roberto Pimentel Nita, Jacek Kościuk, Anna Kubicka, Krzysztof Misiewicz, Miron Bogacki, Wiesław Małkowski**
- Title** *Geomatic approaches in evaluation and inventorying of pre-Columbian heritage in danger at the coastal deserts of the Ancash Region of Peru*
- Abstract** Since 2002 the Culebras and Huarmey valleys of the desert coast of the Ancash Region of Peru has been the focus of an extensive archaeological surface survey and numerous excavations in selected sites carried out by Polish and Peruvian scholars. Over one hundred previously unknown archaeological sites have been recorded so far, and tentative interpretations of their chronology, functions and settlement patterns have been suggested. One of the main objectives of the after mentioned research program was evaluation and inventorying of the pre-Columbian heritage in danger, using traditional and remote sensing techniques. The creation and commissioning of photogrammetric and geophysical datasets of globally unique archaeological sites –like the only known intact royal burial chamber under Wari imperial mausoleum found by the authors at the El Castillo de Huarmey site– brought about better understanding of human activity in the past, and gave sensitive results in decision-making process for future restoration and restitution projects. The successful attempts to implement new non-invasive techniques of archaeological prospection on stratified pre-Columbian sites with remains of monumental architecture resulted in the development of highly accurate, rapid and relatively inexpensive methods of evaluation and inventorying of the pre-Columbian heritage at risk for nowadays Peru. The survey included GPS RTK mapping, aerial photogrammetry, caesium magnetometry, 3D scanning, GIS spatial analysis with multispectral and NIR satellite images, which allowed to assess exact size and extension of archaeological remains, and to evaluate existing threats and therefore to prepare and propose future plans of protection, conservation and restoration.

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- Authors** **Cristina Castagnetti, Eleonora Bertacchini, Elisa Benozzi, Carolina Orsini, Rossi Paolo, Alessandro Capra, Veronica Williams**
- Title** ***GPS and GIS for documentation and spatial representation in two valleys of the middle calchaquí basin (Salta Argentina)***
- Abstract** The main purpose of the research is the study and the documentation of the archaeological landscape of two valleys in the central or middle sector of Calchaquí river (Salta, Argentina): Brealito and Luracatao. Despite their historic significance documented in the ethnographic or historical sources, these areas have never been subjected to deep archaeological studies. The geomatic approaches were helpfully adopted to support the contextualization of agricultural sites, residential, and numerous shelters that were registered during 4 years of prospecting. The challenge of the project is to document the complexity of large settlements associated with agricultural structures (sometimes exceeding 100 hectares), in a context where there are no large-scale maps.
- The large spatial variability and the environment complexity suggested the use of remote sensing techniques, such as satellite images, to deepen the knowledge of the local geomorphology. Unfortunately no stereo-pairs were available in the area so that the three-dimensional reconstruction had to be diversely achieved. A large GPS (Global Positioning System) survey, performed in continuous and stop&go kinematic modes, was carried out and allowed to delineate the boundaries of each archeological site and to describe the morphology within the site. In particular, in Brealito valley the GPS was successful in describing the location and distribution of archeological remains and in obtaining 2D archaeological maps whereas in Luracatao valley it proved to be an excellent support to the 3D reconstruction of the investigated area. The DTM (Digital Terrain Model) was used to extract the outflow channels and make some hypothesis about the hydraulic model used in the ancient irrigation system for agricultural terraces. The paper will describe the synergy and the combination between these technologies and the traditional methods of ground archaeological prospection and validation. The main final output of the research will be a GIS (Geographic Information System) joining data about the spatial description of the ancient cultural landscape together with data about the ancient settlement, the caravan routes and the artificial modification of the pre-Hispanic landscape (agricultural terraces and irrigation systems).
- The integrated documentation of all these elements will be crucial to understand the population dynamics and to design effective strategies to protect this delicate widespread heritage. The international cooperation between Italian and Argentine research groups aims to share knowledge and provide best practices for the most profitable documentation in similar contexts.
- Authors** **Jennifer von Schwerin, Michael Auer, Nicolas Billen, Lukas Loos, Heather Richards-Rissetto, Markus Reindel, Alexander Zipf, Fabio Remondino, Belen Jimenez Fernandez Palacios**
- Title** ***A 4DWebGIS for the Documentation and Analysis of Complex Archaeological Sites***
- Abstract** Archaeological projects are acquiring different types of 3D data sets, ranging from individual finds to whole landscapes. However, it is still a challenge to make these data accessible for researchers and cultural heritage managers, link these models to geo-referenced datasets, and

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use them for visualization and analysis. Yet another challenge is that the spatial data are different in kind and resolution, including 2.5D raster surface models, geographic coordinates of archaeological sites, 3D models of objects, and textual meta-data.. Ideally, all of these kinds of data should be accessible and query-able in one, web-based platform granting secured access to sensible datasets.

To address these requirements, the MayaArch3D project (MayaArch3D.org) is developing a state-of-the-art, open source, 4D WebGIS online system for the 3D documentation and visualization and 4D analyses of archaeological sites. This system should be able to store, manage, and visualize 3D data of different formats and resolutions, and combine these with the analytical functions of Geographical Information Systems (GIS) into a single platform. Users will be able to query databases to analyze archaeological data inside of virtual environments in order to carry out 3D and 4D spatio-temporal analyses of architecture and landscapes. The test data is from the ancient Maya kingdom of Copan, Honduras and has been gathered in collaboration with the Honduran Institute of Anthropology and History (IHAH). However, because the project is following international data sharing and security standards, this prototype tool also can be adapted for other archaeological sites worldwide.

The system architecture includes an archaeological database and 2D / 3D geodatabases, linked by standard and custom (geo-)webservices to 2D and 3D-Geobrowsers that enable a range of spatial-temporal queries as well as a set of 3D visibility analyses. The system includes data on the extent of archaeological sites across Honduras down to individual structures, inscriptions and iconography at Copan. A 3D Single Object Viewer supports analyses of high-resolution, segmented models and a QueryBuilder allows the user to query the database directly. A user management system offers public and password log-in.

The project has acquired, structured, and integrated a large, heterogenous data set ranging from 6000 GPS points for archaeological sites across the Maya region, to terrain models based on airborne LiDAR for Copan, to 3D models of sculpture pieces and their meta-data. This broad set of datatypes allows us to demonstrate possible types of analyses and recommend standards for preparing data for 4D WebGIS systems. Initial beta tests indicate that this system will be a useful tool to support international, collaborative management, visualization, and analysis of complex archaeological data online.

Authors	Guadalupe Zetina-Gutierrez, Patricia Castillo-Peña
Title	<i>Geomatics at conservation and study of domestic context of core and periphery of El Tajín, Veracruz; México: Research based in GIS, LIDAR and Photogrammetry.</i>
Abstract	<p>During last decades have have a fast grow of technologies to management of georeferenced information. Geomatic revolution have taken by our archaeological discipline doing possible reach unimaginable goals decades ago by traditional methods and techniques. Now is possible obtain more integral answers to our inquiries about the past with quantitative tools based in the most advanced technologies (Flores 1996, Cabero, 1998).</p> <p>Combination of use of remote sensing (LiDAR and photogrammetry) together with GIS and CAD allow us identify, record, preserve and understand and nature of domestic contexts in core and periphery of Archaeological site of El Tajín. El Tajín was the most important ritual city of cultural región of the “Gulf Coast” precisely in Gulf Coast of México. Its architecture with niches, spiral motifs, reliefs, sculptures and the large number of temples and ball courts becoming in unique in Mesoamerica (castillo Peña, 2011; 2011a). However, few have been told about nature of habitational areas of El Tajín. Domestic context have been eclipsed by beauty</p>

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and monumentality of temples and civil buildings.

During 2011, LiDAR and photogrammetry was acquired and during 2012 a GIS was created to carry on an inventory of new archaeological remains and research nature of this Pre-Hispanic city (Zetina Gutiérrez, 2013, on press a, in review. How much we can know about domestic context in the core and in the periphery of this ancient city with geomatic tools? Through these technologies, we could understand in more clear way relationship of these contexts and its natural environment and also relationships of core and periphery. The main advantage of use of remote sensing is understanding of the landscape as a continuum of information without holes allowing us analyze patterns of distribution and use of spaces in a complete way. This means the comprehension of the city and its immediate región as a whole.

SESSION 5A-
MODELLING APPROACHES
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Authors**Tilman Baum, Claas Nendel****Title*****Combining two modelling approaches to examine prehistoric husbandry methods and land use of the pre-alpine wetland settlements*****Abstract**

The earliest unambiguous record of prehistoric crop production in Central Europe is connected with the Linear Pottery Culture and dates around 5500 BC. Especially in the context of the circumalpine pile-dwellings, dating roughly from 5000-500 BC, extraordinary taphonomic conditions preserved traces of husbandry and land-use systems in unmatched detail. Dendrochronological analyses of the construction timber of the houses allow for absolute dating of these sites and reveal a highly dynamic settlement system, especially in the beginning of the 4th Millennium BC. Since the beginnings of pile-dwelling research more than 150 years ago, proof on husbandry and land-use methods is furnished especially by two methods: macrobotanical analyses of on-site findings and palynological analyses of mainly off-site sediment cores. The findings and interpretations, however, do not necessarily match, and contradictory models have been deduced. In this project, the most influential models are used as a background for the presentation of a new method to better understand prehistoric husbandry and land use. The main questions are: 1) Which environmental implications and systemic feedbacks go alongside with the published hypotheses on land-use systems? 2) What was the spatial and temporal availability of non-finite resources? 3) Could excessive resource use have caused the observed dynamic settlement pattern? To answer these questions, we processed and refined published data using two different modelling tools. MONICA is a mechanistic agroecosystem model, which we use to simulate the influence of soil properties, degrading soil fertility and changing weather conditions on crop yields. WELASSIMO is an agent-based model written in NETLOGO and is driven by the calorie requirements and the demand in non-finite resources (timber, cultivable soils, livestock pasture, and hunting and gathering grounds) of standardized households (n=1-20) consisting of six persons. These are grouped in a hypothetical settlement located in a dynamic model environment comprising of grid cells of 25×25 m. We simulated the implications of the two major hypotheses on crop husbandry in the north-western pre-alpine forelands at the beginning of the 4th Millennium: Shifting Cultivation and Intensive Garden Cultivation. Alongside with these, a new hypothesis on a third scenario that we call “Integrated Forest Horticulture” is presented and discussed. Results include an assessment of the relevance of individual model parameters on the security of the settlements’ calorie supply and of the area required for meeting the caloric and resource demand of the households. We can show that the availability of suitable timber may have been a common reason to justify a settlement shift, while local scarcity in the other non-finite resources was less likely. We conclude that “Integrated Forest Horticulture” explains the data better than the previous models. Thus we contribute to the understanding of the superordinate settlement system of the wetland settlements in the 4th Millennium BC in the northern pre-alpine forelands.

Authors**Alžběta Danielisová, Kamila Olševičová, Jan Procházka****Title*****Socio-economic map of an iron age region: subsistence and interactions (using gis, agent based modelling and network analysis)*****Abstract**

Our aim is to apply social simulation and network analysis to provide the picture of society and environment during the period of late Iron Age in central Europe and to explore hypotheses about the demographic evolution, carrying capacity, agricultural practices and social and economic interactions among settlements influenced by the foundation of a regional center. The model builds on empirical data (archaeological evidence), GIS data (primary and secondary map layers) and relevant theoretical background: The archaeological evidence serves as a source of fragmented, uncertain data on the original network of settlements.

GIS data describe overall characteristics of the landscape in qualitative and quantitative sense

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(topography, accessibility – friction/cost surface, soil quality, land cover). Scalar stress and requirement of new organizational structures are regarded as theoretical explanatory mechanisms of gradual development of settlement spatial networks and formation of hierarchies and interactions with centres, i.e. emerging patterns that are object of our interest.

We propose the agent-based model of spatial dispersion of the network of settlements within the agricultural landscape (modelled using GIS). The hierarchy of settlements is represented by the network of agents of different types (household agents, settlement agents). The main model design concept is *ecological, economic and population potential* which captures the relationship between *renewable resources* and *energetic requirements* of settlement of certain size in certain location, according to general knowledge of economic practices in the Iron Age.

On one side, the maximum sustainable yield increases with the growing working capacity of the settlement, on the other hand the reserves of renewable resources can become exhausted and large areas of distant areas cannot be exploited at that stage of technological progress (the law of diminishing returns).

Our model is designed to enable experimenting with:

different initial sets of settlements, from random choice of locations in the map of the region (baseline) to precisely selected subsets of archaeological sites (alternative hypotheses),

population dynamics, i.e. overall annual population growth of the region and appropriate growth of settlements, including relevant depopulation scenarios,

combinations of triggers (incentives) which might cause either dispersion or aggregation of settlements.

interactions (economic and social) upon various levels of site's function and position within the regional settlement hierarchy. In our contribution, we present the model including experimental results.

Authors**Jamie Joyce, Philip Verhagen****Title*****Keeping the home fires burning: spatial dynamic modelling of the wood-fuel economy of the Roman limes zone in the Netherlands.*****Abstract**

Wood in the Roman world was the most important and, in many areas, the sole source of fuel for rural, urban and military settlements (Veal & Thompson, 2008). It has been estimated that fuel in the form of wood or charcoal comprised half of the per capita energy consumption (Malanima, 2011). It is surprising therefore that, in spite of fuel's importance within ancient economies, few studies have attempted to engage with it as a primary resource. Commendable exceptions exist (namely van Dinter et al. 2013; Veal, forthcoming 2015), yet many deal with the palaeoeconomy in general terms or model supply to, and consumption in, specific localities. Modelling the fuel supply within the macro-regional scale is lacking.

The NWO-funded "Finding the limits of the limes" project aims to apply spatial dynamical modelling to reconstruct and understand the development of the cultural landscape in the Dutch part of the limes zone between ca. 15 BC – 270 AD. It focuses on modelling economic and spatial relations between the Roman army and the local population, in particular the interaction between agriculture, animal husbandry and wood management. Modelling of wood management in the region presents a significant challenge as remains of carbonised wood in the Netherlands are scant. Macrobotanical evidence, therefore, of the daily tasks of keeping warm and cooking food, as well as of less regular tasks such as pottery manufacturing and metallurgy, is missing. Furthermore, the study area comprises a combination of a fluvial dynamic landscape with pre-Roman deforestation and the development of a military

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infrastructure with a related shift from subsistence to surplus agricultural production. Changes and continuity in strategies of resource exploitation and woodland management in the Dutch limes zone are thus ripe for investigation within a modelling environment.

In light of the above, I will propose a spatial dynamic model of the fuel economy of the Dutch limes zone. The model is constructed in NetLogo and tested via the BehaviourSpace utility. By also utilizing the GIS extension, existing palaeogeographic reconstructions and settlement patterns can be added. As a result, this tool can be used both heuristically, to investigate hypothetical scenarios, as well as simulating scenarios grounded in archaeological data. With the aid of cases studies, resource competition between settlements, the limitations posed from both the natural environment and household decisions, and strategies of exploitation and mitigation can be tested and analysed using this tool.

Authors **Angelos Chliaoutakis**

Title ***An application of a self-organizing Agent-based model in Minoan Crete***

Abstract

Some of the most interesting questions one can ask about early societies, are about people and their relations, and the nature and scale of their organization. In this work, we attempt to answer such questions with approaches introduced by multiagent systems (MAS) and GIS. Agent-based modelling (ABM) and simulation within a GIS environmental framework is increasingly used in Archaeology during the past decade, as a tool for assessing the plausibility of alternative hypotheses regarding ancient civilizations, their organization, and social and environmental processes at work in past ages [1,2]. Its emerging popularity is due to its ability to represent individuals and societies, and to encompass uncertainty inherent in archaeological theories or findings. Indeed, the unpredictability of interaction patterns within a simulated agent society, along with the possibility of emergent behaviour, can help researchers gain new insights into existing archaeological theories; or even come up with completely novel paradigms regarding the ancient societies being studied.

In this paper, we develop a generic agent-based model for simulating ancient societies. Agents in our model are completely autonomous, in contrast to most existing ABMs used in archaeology. We employ this model to evaluate the impact of different social organization paradigms and agricultural strategies (intensive and extensive farming) on population dynamics and evolving spatial distribution of agriculture potential areas and settlement locations of ancient societies. Equipped with such paradigms, our model allows us to explore the transition from a simple to a more complex society by focusing on the historical social dynamics—i.e., the flexibility and evolution of power relationships depending on social context and time.

As a case study, we employ our model on an artificial ancient society during the Bronze Age (Minoan civilization) located in the wider area of Malia in East Crete. Model parameter choices are based on archaeological studies [3,4], but are not biased towards any specific assumption. Results over a number of different simulation scenarios demonstrate an impressive sustainability for settlements adopting a socio-economic organization model based on self-organization, which was inspired by a recent framework for modern self-organizing agent organizations [5]. This is the first time a self-organization approach is incorporated in an archaeology GIS and agent-based model.

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Authors **Andrea Kay, Jed Kaplan**

Title *A classification of subsistence lifestyles and land use in prehistoric Africa*

Abstract The Iron Age in sub-Saharan Africa is characterized by not only the appearance of metallurgy, but in many areas also the first widespread establishment of agricultural societies. The shift from foraging to farming and metallurgy in Africa fundamentally altered the relationship between humans and their environment, and may have had widespread consequences for regional climate and hydrology, which in turn could have had feedback effects on human populations. During the period from approximately 1000 BCE to 1500 CE, the Iron Age spread episodically from West Africa east and south, with periods of rapid spread interspersed with stagnation and even abandonment of agricultural lifestyles. Theories for this sporadic transition range from exogenous environmental factors and mass migrations, to animal disease distributions and endogenous niche construction in response to growing populations. The Quantifying the economic and environmental transformation of Africa during the Iron Age (ACACIA) project seeks to explore this problem through the use of integrated human-environment models.

As a first step towards developing these models, this paper presents a societal-subsistence based classification of land use in sub-Saharan Africa during the Iron Age. Each category in the classification considers environmental, geographic, temporal, and technological attributes, but also allows for some variation within each category. The classification is based on a broad synthesis of published archaeological, archaeobotanical, and ethnographic observations, and illustrates the various degrees of land use intensity employed by different groups at different times, e.g. wild-forage, herding, vegetable or cereal crops, and the firing of pottery or iron metallurgy. Our classification scheme will inform the development of models that will be used to quantify the impact of Iron Age Africans on their local and regional environments, and test hypotheses about the importance of human agency for the development of African environments over the late Holocene.

Authors **Christina Collins, Eleni Asouti, Matt Grove, Douglas Baird, Richard Chiverrell, Lee Bradley**

Title *Results of the 'Unfamiliar Landscape' project: Palaeoenvironmental modelling and the origins of agriculture in Central Anatolia.*

Abstract The Konya Plain, Central Anatolia, is a key landscape for understanding the origins of cultivation and herding. Famed for the large site of Çatalhöyük, various settlements in this landscape trace the shift from foraging and low-level food production to eventual full cultivation and herding. In particular the sites of Pınarbaşı and Boncuklu provide data on resource choice and landscape use prior to the adoption of agriculture. Here we present some results of The *Unfamiliar Landscapes* project. The project sought to reconstruct the environment of the Konya Plain during the Early Neolithic in order to understand why the hunter-gatherers of this landscape switched from foraging to cultivation.

As part of the project we reconstructed the vegetation and fauna of the plain during the Early Holocene. This was based on modern locality data for relevant species, their modelled tolerance curves, and palaeoclimatic projections, producing a probability surface for each species. We then combined these individual surfaces into a single 'benefit surface',

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representing the utility of each patch to humans in the landscape, as well as their distance from known sites. Through comparing the modelled density of individual plant and animal species with their observed presence in the archaeological record, we are able to uncover some aspects of human resource choice and economic decision-making. The benefit surface and modified site catchment analysis also allows us to understand landscape use at this key time in human history.

Authors

Sebastian Vogel, Florian Seiler, Michael Märker

Title

The SALVE research project: Sarno River plain – Ancient Life in the Vesuvian Environment

Abstract

The ancient city of Pompeii, buried by the explosive AD 79 eruption of Mount Vesuvius, is excavated and intensively studied for more than 265 years. However, in an archaeological perspective, its hinterland, in which the urban centre was politically and culturally embedded and from which it was economically dependent, is still relatively unknown. As yet no comprehensive and integrated study exist that focus on both the socio-economic as well as paleoenvironmental conditions of the Sarno River plain in Roman and pre-Roman times.

To close this gap of knowledge, in 2006, the German Archaeological Institute and the Heidelberger Academy of Sciences and Humanities initiated a research project bringing together scholars from the archaeologies and geosciences from Italy and Germany to reconstruct the pre-AD 79 cultural landscape of the Sarno River plain. As this paleolandscape and almost all ancient sites lie buried underneath 1 to 15 m of volcanic deposits conventional archaeological methodologies had to be combined with interdisciplinary and up-to-date techniques such as stratigraphic investigations, GIS-based spatial analysis, geostatistics and predictive modelling.

At first, a comprehensive GIS database of archaeological evidence of the pre-Roman and Roman period was build up, which yielded a dataset of more than 600 entities. Furthermore, about 1,900 drilling stratigraphies were collected to generate a high resolution landscape model of the Sarno River plain using a machine learning modelling approach. In a following integrative project phase, the geodata were combined with the archaeological data to answer more detailed questions of the socio-economic system of the plain, concerning the rural settlement structure, land division (centuriation) or infrastructural organisation such as the ancient road network.

Finally this wide-range cross-section approach provided insights into the development and dynamics of the hinterland of Pompeii and its complex interdependencies between the physiographic conditions and the anthropogenic influence on the paleo-landscape before AD 79. Furthermore, the Sarno River plain was characterized by a highly specialized and export-oriented rural economy that focussed on wine production and thus was of great economic importance for the Italian peninsula as well as for the entire circum-Mediterranean region.

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Authors **Monica De Cet**

Title *Menorca and its Past Socio-Economic Sphere: a Methodological Approach to Model Production and Demography on a Mediterranean Island.*

Abstract This paper focuses on the methodology and research results of a section of my PhD project. In this part, I developed a methodological approach for the investigation of the socio-economic context of past communities by GIS-based modelling. In particular, the methodology was designed for the Spanish case-study of Menorca, which represents an island scale of approximately 700 km², located in the Mediterranean. Moreover, the spatiotemporal framework was characterised by a long-term chronology, lasting from Later Prehistory until the 19th century CE.

Through this paper, I aim to illustrate the main methodological steps that I implied in order to model over long-term two specific aspects of the past socio-economic sphere: production and demography. Considering as theoretical background the Social Space Theory and Basic Economic Scheme, included in the Aguas Project (Castro et al. 1998: 8-11), I took as starting point a collection of archaeological features and environmental layers. I applied a combination of GIS-based modelling techniques that allowed me to reconstruct the development of the demographic and productive processes over long-term. Furthermore, I modelled their geographical distribution across the territory. Significant results regarding settlement pattern, demographic densities, territories of cultivation, agro-economic focus, and possible socio-economic political entities have been obtained from settlement sites.

The final aim is to contribute to the discussion on the resolution of socio-economic results obtained using techniques of GIS-based modelling. I will demonstrate how analytical data from ethnography as for instance cereal harvest or population numbers, can be useful to validate the modelling results. Moreover, I will show the practical utility of additional analyses e.g. Stable Isotopes analyses as support for the interpretation of the modelling outputs. Finally, the potentialities of my methodological approach in terms of environmental policy making for the Mediterranean regions will be discussed.

Authors **Joan Negre Pérez, Juan Antonio Barceló Álvarez**

Title *Agricultural yields and demographic size. An experimental approach to regional-scale population estimate in a medieval Islamic hinterland (Tortosa, Northeast Iberian Peninsula).*

Abstract This communication develops an interdisciplinary approach to the study of agricultural yields in order to determine a population estimate for the territory of the city of Tortosa (Tarragona, Spain) in the Late Islamic Period (11th-12th centuries). The main goal of this proposal, therefore, have been to model the potential use of agrarian soils regarding their physico-biological features and use this information to infer the number of people that could be provided by this hinterland. As happens in such a variety of historical case studies, both written and archaeological sources have been managed to present the best-fitted scenario. From Latin administrative sources have been taken all mentions with relation to crop and plot distribution, hydraulic infrastructures and the location of the main settlement network. These detailed texts were written in the middle-12th century in order to register the spoils after the conquest of this territory by the feudal armies. Two archaeological survey campaigns were also carried out in

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this area to identify small farms that were not included in the written record and to sequence all the archaeological sites. In addition, this fieldwork led to study several anthropic markers in order to define functional areas, such as silos fields and other storage facilities linked to the city government (Negre, 2013).

Making cross-reference to previous works in different scenarios, this proposal tried to deal mainly with traditional subjective population estimate for the Middle Ages. This is a recurring issue in medieval historiography for which we propose a solution from an interdisciplinary GIS-based standpoint. In this direction, it was considered that a Land Capability Classification approach offered the possibility of modelling the potential use of the soils for cultivation purposes. As regarded by Arnoldus-Huyzendveld in the case study of the plain of Grosseto (Tuscany, Italy), from this perspective it could be suggested a first hypothetical assessment about demographic size at medium-scale (Arnoldus-Huyzendveld, 2011). Moreover, combining this method with our accurate written historical data and detailed archaeological fieldwork it was also possible to improve the precision of the soils classification model and the demographic estimate.

We dealt, nevertheless, with some common issues during the development of this model, such as the assessment of the variables involved, their weights and the presence of confounders. Despite the range of variability of the calculations, this model presents, in the worst-case scenario, a remarkable improvement regarding previous subjective calculations. Thus, it is now possible to propose a contrastable hypothesis about the productivity of this territory and the range of population that could be nourished by it (Amir et alii, 1994; Araus et alii, 2005). It would be also interesting to contrast this proposal with other approaches in demographic estimation so as to compare pros and cons of each one of them.

SESSION 5B-
CONTINUING THE REVOLUTION
WITH SPATIAL METHODS &
ARCHAEOLOGICAL INTERPRETATION:
THE HOW AND WHYS
OF SPATIAL ANALYSIS

Authors Moritz Mennenga, Gary Robert Nobles, Georg Schafferer

Title *Continuing the Revolution with Spatial Methods & Archaeological Interpretation: the how and whys of spatial analysis*

Abstract Presentation of spatial data is a powerful tool, allowing the archaeologist to highlight the areas, and thus inferences, they deem to be of interest to the reader. But such pretty maps can be corrupted either intentionally or unintentionally. Although we try our best to present geospatial data in a way everyone can get the same message, this message can be reinterpreted in a way which was not intended. In order to get beyond our own cultural biases when presented with visually interpretable geospatial data various spatial statistical tools have been developed. Some have been designed specifically for archaeology and some have been transferred from other disciplines, notably mathematics and geography. Such methods were never designed for use by archaeologists and not tailored to the various archaeological questions we want to put to our data.

In the realm of this spatial archaeology we try to reconstruct the past based upon the materials which remain. Such reconstructions range in their scale: from the everyday habitual activities to the wider landscape setting. Our aim: to take these materials and bring aspects of various activities back to life. As such we combine the use of geospatial techniques with archaeological interpretation, but to what degree are these tools compatible with our discipline? How can they be used to shed light on the behaviour of people in the past?

Therefore, we warmly invite papers which apply analytical spatial methods and demonstrate the validity of these methods for archaeological interpretation to give meaningful interpretations to our datasets.

For example, various topics could include, but not limited to:

1. The use of Tobler's First Law of Geography for archaeological spatial distributions (e.g. spatial autocorrelation).
2. Detecting structures from archaeological feature distributions (e.g. Nearest Neighbour Analysis, pattern recognition).
3. Detecting spatial social structures from archaeological artefact distributions and inferences which can be derived for the social use of space (e.g. statistical manipulation of distribution data).
4. Reconstructing dispersal patterns taking into account site formation processes (e.g. spatial refitting of materials).
5. Detecting spatial patterns of sites in landscapes (e.g. group membership of monuments in temporal landscapes)

Authors Rebecca Elizabeth Kibble

Title *Using open-source GIS to enable the multi-scalar, spatio-temporal analysis and visualisation of complex zooarchaeological datasets.*

Abstract The paper presented reports on a new GIS-based tool for the processing, analysis and visualisation of complex zooarchaeological datasets. The tool utilises the potential of open-source GIS to integrate, interrogate and envisage the spatio-temporal, multivariate and multi-scalar dynamics of such datasets.

Zooarchaeological data is inherently multi-scalar and multivariate. For example to understand husbandry regimes; zooarchaeologists deal with multiple components within an assemblage. They will statistically organise the assemblage into MNI, use percentages of bone elements

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THE HOW AND WHYS OF SPATIAL ANALYSIS

from certain taxon alongside attributes such as butchery marks, age, sex and fragmentation to determine husbandry practices. Zooarchaeologists also consider the significance of taphonomic processes (weathering, preservation and spatial deposition). Research may focus on differences in husbandry practices across a site or landscape; changes through time; relationships between sites; the significance of certain husbandry practices in relation to specific archaeological features.

Yet traditional approaches to the study of zooarchaeological datasets are based upon simplification and dilution. For instance, at excavation stage, recording practices fix spatial scale at the point of data capture; generalising temporal affiliation to set phase/period (with little consideration of fuzziness and uncertainty). Traditional methods of analysing zooarchaeological data are profoundly aspatial and atemporal; confined to a de-facto standard suite of multivariate tests (using stand-alone statistical packages). Visualisations of subsequent results are static, fixed in scale and abstracted; limited to charts and spreadsheets.

Although there has been an important disciplinary shift towards the standardisation of attribute recording with the advent of TDAR categorisation system, the above problems remain. The paper seeks to address precisely these problems, building pragmatically upon recent innovations in archaeological GIS. Specifically, the work of Green (2008) developing methodological processes for incorporating data with spatio-temporal complexity and ambiguity and Knight's (2002) research on spatialising results of multivariate datasets (intra-site butchery patterns). Presently, this work has not progressed beyond proof-of-method and has been conducted within an isolated scalar boundary and/or investigated through limited, pre-determined statistical patterns. Lacking has been any attempt to bring these isolated developments together, in order to facilitate comprehensive multivariate, multi-scalar, spatio-temporal analysis simultaneously within a singular platform.

Using faunal datasets from Iron-Age hillfort sites in Central and Southern Britain; a dedicated extension to QGIS has been established, allowing researchers to analyse large, complex datasets which encompass a range of spatial scales, variables and temporal uncertainties. The software translates differently recorded datasets into a consistent set of spatially referenced variables (based upon TDAR categories). The user is then free to vary the scales at which they want to explore the data. The extension provides a direct link to Pysal libraries, allowing a full suite of multivariate statistical analyses to be carried out. Subsequent results are visualised using EDA techniques (e.g. Chernoff faces) and spatialised using QGIS mapping functionalities.

Authors	Christophe Landry, Bertrand Moulin
Title	<i>When GIS Goes to the Countryside : Detecting and Interpreting Roman Orchards from the “Grand Palais” (Drôme, France)</i>
Abstract	In the last two decades, preventive archaeology had a huge impact on our understanding of Roman agriculture. The large amount of widely studied fields helped to recognize, for instance, spatial farming organization and the way vine growing spread on the territory of Gauls. This led to a large panel of detailed studies about wine, as a highly symbolic product of Mediterranean Antiquity. Thanks to these, the remains of Roman vineyards are nowadays well known, particularly in southern France. This situation applies as well to another embodiment of Mediterranean cultures, olive oil, a topic that also led to numerous studies about production equipment.

However, little has been done so far on the remains of olive groves, due to a certain lack of interest in other tree species than vine in Roman Gauls. Thus, extensive information on the

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spatial patterning of planting pits are scarce; but when they are identified, these remains clearly show a strong spatial organization, which is already claimed in many antique Roman agronomic manuals. The recent preventive excavations of the Grand Palais, in Châteauneuf-du-Rhône (Drôme), provide very opportune informations to fill this gap. Indeed, this huge villa showed a massive and specialized fruit production during the whole Roman High Empire, among which olives, before ending as an extremely rich rural palace in the Late Antiquity.

The lack of artefacts and ecofacts in the planting pits does not allow the use of common environmental methods (carpology, anthracology, malacology or palynology) to characterize the structures distribution and, subsequently, the type of plantation. In addition, the large number of planting pits – more than 1,000 pits found on less than 1 ha, makes it impossible to recognize coherent patterns at first sight.

The search for the meanings in the distribution first started with a bibliographic study, in order to identify the antique metrics that were used and for which plantation type (olive groves, orchards, vineyard, etc.). With the help of these informations, interpretation models were constructed and tested on the planting pits distribution of the Grand Palais, leading to the recognition of several spatial patterns. The GIS also helped in the interpretation and reconstitution of plans, through the systematization of geometrical parameters measurement. Furthermore, the geometrical pattern of the plantations was defined through a statistical analysis of the dataset. A correspondence analysis, followed by a hierarchical cluster analysis, led to the identification of different types of plantations in the Grand Palais. The results were finally compared to the data issued from other excavations and summarized into a wider typology of orchard remains, as well as providing a spatial characterization guideline for plantation analysis and a welcomed meaning to a spatial dataset in which patterns first seemed totally invisible.

Authors

Joan Negre Pérez, Juan Antonio Barceló Álvarez

Title

Reading between the dots. The use of non-Euclidean metrics for the study of settlement patterns in heterogeneous regions.

Abstract

In the statistical analysis of point patterns is assumed the correlation between the elements of the spatial distribution as a function of their Euclidean distance (Møller and Toftaker, 2012). This premise has been used in Spatial Analysis to describe settlement processes, taking into account homogeneous and undifferentiated surfaces. From this framework, geographers have developed most of their explanations for the past centuries, from Von Thunen's model of land use to Hägerstrand's spread of innovation formulation (Tobler, 1993). Nevertheless, this assumption fail when we consider the historical and economical dynamics that took place in space, as well as its movement constraints.

Thus, our approach is based on the idea that relationships and transformations performed by social environment on the spatial sphere should be considered in terms of an articulated social construct. It is the ability to influence and to be influenced by the social environment what generates the heterogenic and anisotropic characterisation of the space. In other words, social interactions generate directional dependence in the spatial variability of places where social action was performed. We consider, therefore, that distances between synchronous settlements are socially and spatially dependent and cannot be analysed using Euclidean metrics. This is an issue largely discussed in other topics, such as Least Cost Paths or Cost Surfaces, but also neglected in point pattern analysis. Consequently, the main goal of this communication is to propose a possible solution to implement non-Euclidean measures in the study of settlement patterns (Negre, 2015).

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We have developed a Ripley's K-function adaptation, based on the multi-distance scaled transformation of a cost-weighted distance matrix as a possible appropriated solution to this issue. This technique is thought to provide a more exact insight of the spatial structure, taking into account topographical relief and attractor points. The higher the irregularity of the studied area the lower the strength of the spatial autocorrelation, so the more needed are these new ways of calculating the degree of overdispersion within the configuration of points (Schabenberger & Gotway, 2005). A case study is presented in order to analyse the benefits provided by our approach regarding previous statistical formulations. The example under study analyses the rural settlement pattern shown by an Islamic district in the lower course of the Ebre River, a riverside-mountainous area in south Catalonia, in the second half of the 12th century. Debate and external insights about this new method are expected to be very beneficial in order to implement this method, including the theoretical considerations that entails.

Authors Irene Ortiz Nieto-Márquez

Title *Dinamic processes of static objects. How and Why?*

Abstract Nowadays spatial analysis in Paleolithic sites is based mainly on georeferencing methods, GIS applications and three dimensional relations, that supply plenty of information, which can be used to investigate, among other aspects, on behavioral patterns as well as post-depositional and geomorphologic processes.

The aim of this research was the spatial analysis (intra-site) of an open air Middle Paleolithic site, El Cañaveral, Madrid, Spain. (Baena Preysler et al., 2011; Ortiz Nieto-Márquez, 2013). The objective was discriminate different archeological layers, reconstruct dispersal patterns taking in account the site formation processes, using refitting information and GIS applications inside the geoarchaeological interpretation of the site. It was also important to detect spatial social “structures” by analyzing artifacts distributions.

The focus of the study was to find a cause to explain the particular lithic industry distribution of the site. For that reason, a technological study of artifacts was made. At the same time, we tried to find all refits as possible between all remains. Refits data was used to get information about dynamic processes: anthropological and post-depositional ones. After that, thanks to GIS application, and the use of DTM analysis of the site, hydrographic analysis, geostatistical and spatial correlation processes (among others) to explain the specific distribution.

There were two layers on the site. The main differences between the lithic remains were external alterations like roundless, presence of carbo-silicates and the technology. Taking in account refits, one level had long join lines while the second level lines were very short, showing big knapping concentrations. Geostatistical analyses showed the relation of geological processes and lithic distribution.

The results suggest that anthropological action was the main reason of lithic movement and distribution patterns. However post-depositional processes were very important for the site conservation. Thanks to GIS applications and refits analysis we can reconstruct past activities taken by Neanderthals in a raw material quarrying site and meanwhile, possible post-depositional alterations.

CONTINUING THE REVOLUTION WITH SPATIAL METHODS & ARCHAEOLOGICAL INTERPRETATION:
THE HOW AND WHYS OF SPATIAL ANALYSIS**Authors** **Oliver Nakoinz****Title** *How to detect and interpret patterns in cultural landscapes?***Abstract** Points are one of the most important types of data which is used in archaeology. The distribution of sites and finds is used for many different interpretations. This paper is discussing different methods for the detection of patterns based on point distributions. The paper will explore limits and perspectives and questions the premisses of these approaches. We will for example employ point pattern analysis, density calculation, network analysis and different Voronoi techniques to determine the type of point patterns, to reconstruct the centres, linear structures and networks and borders.

The focus is on methodical details and pitfalls. Methodological competence allows a balanced view between naive application of quantitative methods and the rejection of positive concepts. In addition without a sound methodological knowledge, an integration of method and theory is not possible. We will address questions like: How can we distinguish random point patterns from clustered and regular point patterns? Which role play first and second order properties? Which methods are available for the reconstruction of linear structures?

Are there methods to establish interpretations for linear structures? Which technique of density calculation is useful for which purpose? Which role play metrics and which metric should be used in a certain context? Are Voronoi techniques still useful or outdated? Which interpretations are possible for point data?

Authors **John Pouncett, Christophe Snoeck, Rick Schulting****Title** *Coming to Knowth: Areal interpolation, strontium isotope analysis and Neolithic mobility***Abstract** One of the long-standing interpretations of the iconic passage tombs of the Brú na Bóinne involves the transport of stone from sources c.30-40km away. This has been documented geologically, and raises the question of whether people from communities near these sources were coming to the valley, bringing not only stone, but also their dead. Because the stones come from regions with distinct geologies, the bones and teeth of people from these areas should exhibit distinctive strontium isotope signatures. Strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) isotope analysis of cremated bone and tooth fragments from a number of passage and court tombs was carried out in order to explore the question of mobility in the Irish Neolithic. Modern plant samples (grass, bushes and trees) were used to establish a framework within which to contextualise the isotopic signatures from archaeological contexts. An isoscape of biologically available strontium, aggregated by rock type, was generated and cross-validated from the modern plant samples using areal interpolation. Weighted averages were subsequently calculated for each of the chambered tombs based on site catchments of varying sizes and compared against the isotope signatures of the cremated bone and tooth fragments. This paper presents the results of this analysis and discusses the problems and potentials of the application of geostatistics with regard to isotope analysis.

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Authors **Vincenzo Spagnolo, Daniele Aureli, Paolo Boscato, Francesco Boschin, Jacopo Crezzini, Giulia Marciani, Stefano Ricci, Annamaria Ronchitelli, Giulio Poggi**

Title *Integration between spatial analysis in a GIS environment and 3D models for the study of Middle Palaeolithic contexts: Molare Rockshelter (Scario – SA) and Oscurusciuto Rockshelter (Ginosa – TA)*

Abstract As part of the Paleolithic archeology, new research questions are focused on the reconstruction of the past activities at high spatial and temporal resolution, through the palimpsest dissection in their smallest time units. The analysis of the spatial dimension of data, collected and studied by specialists of different academic fields, is a key factor to understand these archaeological contexts. The current strategies of spatial archeology have led to the development of increasingly integrated analytical modules for the treatment of data achieved from these studies.

In this paper we submit the analytic model adopted for the study of two Middle Palaeolithic contexts in Southern Italy: Molare Rockshelter (Scario – SA) and Oscurusciuto Rockshelter (Ginosa – TA). We integrated data from GIS computations with 3D data elaborated using Image-based 3D modeling technique. The GIS is an essential tool, able to interface with each other different kinds of data, derived from interdisciplinary studies. First of all we have studied the taphonomic data, in order to demonstrate the non-random or anthropogenic nature of the spatial distribution of the archaeological finds, and the contexts good state of preservation (chi-square, physical state of the finds, refitting pattern, absence of water flow evidence, etc.). Then, we have studied these spatial arrangements (cluster analysis, kernel density analysis, correlation analysis, etc.) to identify the structures (both visible and latent).

Contextual analysis is therefore essential to reconstruct past ways of life, especially when dealing with the complex dynamics of the Paleolithic sites. An accurate documentation of the distinctive features of the context, including the morphology of the surfaces, contributes significantly to the understanding of these dynamics. Image-based 3D modeling technique allows to obtain 3D models of the investigated areas, achieving a high level of details and precision; these models can be imported into GIS platforms, enhancing its analytic potential. In particular, it is possible to deduce a number of traces of human activities, which can be recognized by centimeter-scale changes in the elevation of surfaces, as for example the arrangement of living floors and the accumulation of remains in different areas.

Authors **Kelin Flanagan, Walter R T Witschey, Clifford T Brown**

Title *The Fractal Topology of Archaeological Site Distributions: Killing the Spherical Chicken in the Vacuum*

Abstract Archaeological surveys are very common, they produce unique information critical to our interpretation of the archaeological record (Banning 2002: 10), and they are expensive. So, survey designs should be efficient and effective. Some simulations suggest that current survey techniques, specifically, systematic subsurface testing such as shovel testing, are neither effective nor efficient (Shott 1985, 1989). Paradoxically, in large parts of the U.S. and Europe (Verhagen et al. 2013), archaeologists continue to employ these methods and therefore must believe they are effective. If our survey techniques are effective, why do simulations suggest otherwise? If they are ineffective, how can we improve them?

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The answers to these questions depend on the topological characteristics of archaeological site distributions (Wobst 1983).

We thought that previous simulations (e.g., Kintigh 1988; Krakker et al. 1983; Shott 1985) might have underestimated site detection probabilities because of the simplifying assumptions they employed: that sites are circular, that sites have a single or a characteristic size, and that sites are randomly distributed. Are those assumptions reasonable simplifications or do they alter meaningful qualities of the distribution, creating a model that only works for the proverbial “spherical chicken in a vacuum?”

We hypothesized that archaeological site distributions might have fractal qualities, as some previous research has suggested (Brown and Liebovitch 2010; Brown et al. 2005; Brown and Witschey 2003; Cavanagh 2009; Cavanagh and Laxton 1994; Laxton and Cavanagh 1995; Oleschko 2000). Because of their highly irregular forms, fractal distributions might increase the detection probabilities of sites.

To test this hypothesis, we used data from the Monte Albán hinterland survey (Blanton et al. 1982; Kowalewski et al. 1989), a large and excellent survey that has previously been used to study survey effectiveness (Orton 2000; Plog 1976; Plog et al. 1978). We used the box-counting technique to evaluate whether the pattern was fractal and, if so, to estimate its fractal dimension. We analyzed 20 rectangular subregions from the eastern (Tlacolula) and southern (Ocotlán) clusters.

The box-counting technique shows quite clearly that the site distribution is fractal. The fractal dimensions for the subregions range from $D_f = 1.44$ to 1.79 with a well-defined central tendency between 1.5 and 1.6.

Our initial simulations of systematic subsurface testing suggest that the site detection rate is higher for the empirical fractal pattern of sites than for earlier simulations, which helps explain the paradox described above. We also found that the number of sites detected scales systematically as a power law with the shovel test interval. Therefore, as the interval between tests decreases, the number of sites detected increases in proportion to the characteristic exponent of a power law. Research designs and regulatory policies must take this into account: as the intensity of survey increases, the number of sites discovered will increase very rapidly. As there are certain fixed costs in recording sites, the time and effort required to perform survey will increase dramatically as a function of intensity. Archaeologists have long known this intuitively or anecdotally, but now we can quantify it.

SESSION 5C-
ARCHAEOLOGICAL THEORY
AND STATISTICAL MODELLING.
BRIDGING THE GAP

Authors

Tsoni Tsonev

Title

The concepts of 'cultural gradient' and 'central place' and their analytical and theoretical implications in archaeological interpretation

Abstract

Traditional archaeological interpretations are based almost exclusively on the concept of the existence of 'cultural gradient'. These understandings are mostly applicable to outlining the geographic spread of ceramic styles in prehistory. The process of spread itself starts from a central place and goes through the neighboring settlements with diminishing similarity of ceramic styles. It is these concepts that I am going to test analytically. For this purpose I made an extraction from the geographic distribution of the major early Neolithic sites in Bulgaria. In order to be able to test the efficiency of the concept of the central place I extracted the spatial distribution of the supermarkets in one present-day suburb in Sofia, Bulgaria. Both distributions are made as GIS databases using the ESRI digital map of Bulgaria, scale 1: 200 000 owned by the NIAM-BAS and the World Topographic map respectively. Both distributions are submitted to the following analyses: Directional Distribution, Central Feature, Mean and Median Center, and Standard Distance (Spatial Statistical Tools, ArcGIS Toolbox). The results are compared and analyzed. At practical and theoretical levels they show the insufficiency of the idea of 'cultural gradient' as a major explanatory factor for the geographic spread of "archaeological cultures". The results from the above analyses are surprising in that they show how this concept fragments the otherwise high adaptability of early farming communities to diverse habitats. Further it will be shown the efficiency of early farmers to choose the best places for their settlements that allow them to reach diverse habitats.

The results also raise theoretical questions about higher-order archaeological contexts that stay in relation to meaning making. It will be shown that the broader picture of the geographic spread of early farmers allows a uniform approach to study the abilities of these prehistoric communities to invent new symbolic system that increases their ability to communicate. In that respect few archaeological examples will be briefly presented. Based on these examples in the final part a summary will be made about the possibilities of the analytical power of GIS for bridging the gap between archaeological formal research and archaeological theory.

Authors

Juan A Barceló, Giacomo Capuzzo, Berta Morell, Agueda Lozano, Katia Achino

Title

The Statistics of Time-to-Event. Integrating the Bayesian Analysis of Radiocarbon data and Event History Analysis methods.

Abstract

Survival or Event History Analysis is a set of statistical methods for examining not only event occurrence but also the timing of events. These methods were developed for studying death – hence the name survival analysis – and have been used extensively for that purpose; however, they can also be successfully applied to archaeology. Examples include: how long it takes artifacts to be discarded after use; when will the next technological change succeed; what determines how long a settlement occupation will last; the timing of territorial hegemony drops – the list goes on. The underlying idea is pretty basic but fundamental for archaeological and historical purposes: understanding the pattern of events in time and what factors are associated with when those events occur. By incorporating time-to-event information, a survival analysis approach can be more powerful than simply examining whether or not a specific type of artifact occurs at some layer, site or region, and it has the added benefit of accounting for censoring, thus allowing inclusion of archaeological sites or regions who leave the study early.

We define the **duration** of an event is a mapping f from E to \mathbb{R} , which assigns a real number to the event measuring the time-span of the event, in terms of the difference between its beginning and end. In this case study we are measured the time-to-event (in centuries) for the occurrence

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of different pottery and metallurgical types from European Bronze Age, from the Alps to the Mediterranean. We use radiocarbon data to estimate the time span between the first and last occurrence of a distinctive artifact at one layer, site or region. Adding additional variables (covariates, regarding the nature of the archaeological deposition), we are interested in estimating the conditional probability that this kind of artifact occurs at a particular time interval (t) in relation with other events that may have been occurred at the same time, before or later. In other words, we intend to examine how long it takes at different regions until a new type occurred (technological or cultural change), and how different events correlate with the dependent variable. In fact this is a regression model with somewhat different likelihood estimators than ordinary least-squares regression.

Nevertheless it has for some time been accepted that the question “How long did this activity last?” cannot adequately be addressed by simply calibrating single radiocarbon determinations. We adopt a bayesian perspective to transform the confidence intervals of single isotopic events related with the event into a proper measurement of single episode data, Single episode data are then converted into a series of multiple episode data and the duration of the event is then estimated based on the difference

$$f(e) = \sup (d(e)) - \inf (d(e))$$

Once transformed the temporal data, we propose the use of non parametric temporal models using Kaplan-Meier estimates and other relevant statistical techniques of temporal data mining.

Authors**James R. Allison****Title*****Theories and Models of Prehistoric Exchange*****Abstract**

This paper explores the relationship between theories of exchange, prehistoric and ethnographic exchange systems, and archaeologists' attempts to model them. Since the 1970s, archaeologists have modeled exchange systems using either simple quantitative models or computer simulations, although these models have rarely done well at reflecting the wealth of data available on archaeological and ethnographic exchange systems, and have generally not engaged with anthropological theories of exchange. Early influential examples of archaeological exchange models include Renfrew's (1975, 1977) arguments connecting commodity fall-off curves with highly abstracted “modes” of exchange (such as down-the-line or directional trade), or Wright and Zeder's (1977) computer simulation, which was designed to explore the role of exchange of ritual items in “regulating” the production and exchange of subsistence goods. It is easy to criticize these early models of exchange for making overly simplified assumptions (such as assuming exclusively linear exchange between settlements, rather than more distributed exchange among individuals), they were valuable attempts to formalize the study of exchange systems that demonstrated the potential of modeling to help archaeologists better understand the implications of theories about exchange. This potential has gone largely unrealized, however. Advances in computer technology and modeling techniques over the last several decades, particularly the development of agent-based modeling, have created the possibility of creating more realistic exchange models that take into account exchange theory, ethnographic and archaeological data on exchange systems, and insights from network science. With only a few exceptions, however, exchange as incorporated into archaeological agent-based models has been limited to simple food sharing. One relevant exception is a recent publication by Ortega et al. (2014) of an agent-based simulation modeling obsidian exchange in the Neolithic Near East, which shows that creating a small-world network (rather than only allowing exchange among adjacent settlements) results in a better fit to the actual archaeological data. Nodes in that simulation are still settlements rather than people,

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however, and the long-distance links that create the small-world network are created randomly. My archaeological research has documented ceramic exchange networks in the North American Southwest in which the abundance of imported pottery generally declines with distance from the source zone, but households in consumer communities have greatly varying amounts of imported pottery (Allison 2000, 2008). The differential distribution of goods among spatially proximate households probably results from something like a small-world network, but one that links individuals, not entire settlements, across space. Exchange theory and ethnographic data suggest that kinship relations are important in forming these networks, and that rules about kinship obligations and patterns of post-marriage residence, as well as the size and spacing of settlements, should influence the form the exchange network takes (and therefore the distribution of exchanged goods). These variables must be important, although precisely how, and how strongly, they influence the distribution of goods is not obvious. But, as I will demonstrate with examples, agent-based modeling is ideally suited to exploring these theoretical issues.

Authors Kamila Olševičová, Alžběta Danielisová

Title *Towards shareable modeling outputs: CeltSIM case study*

Abstract Our research project was focused on explanation of cultural changes of the late Iron Age society in Central Europe. We designed the set of interconnected models, CeltSIM. This framework covers following demographical, environmental and economic issues:

Population Dynamics Model generates data on synthetic population.

Workforce Allocation Model is used to explore the maximum labour input with its consequences (sustainable yield and sizes of herds).

Livestock Model is used for experimenting with the population dynamics of livestock and its impact on the formation of landscape around the oppidum.

NCycle Model is designed to simulate the nutrient cycle in soil, caused by the presence of livestock and manuring.

Land Use Model is used to study the applicability of different agricultural practices.

Region Model is used to simulate the spatial dispersion of self-subsistent economic units in the region of the oppidum

Our idea was to decompose the task of simulation of complex society into sub-models, with clearly defined inputs and outputs. Models are specified using ODD protocol and implemented in NetLogo.

In this contribution we briefly present our modelling framework and we focus on methodological issues. We discuss (1) the process of transformation of archaeological hypotheses into scenarios, which are basis for simulation exercises and experiments, and (2) the importance of metadata description of both model and experiments for correct statistical analysis and interpretation of simulation results.

Authors Catalin Nicolae Popa, Peter Ramsel

Title *Iron Age Identity and Statistical Modelling. The Late Iron Age cemetery of Mannersdorf*

Abstract

The aim of the paper is to introduce a method of approaching group identity using statistical modelling and to discuss its results in the case of the Late Iron Age cemetery of Mannersdorf. The method is strongly rooted in identity theory and is developed around four main group identity principles: firstly, that group identities are constructed through practice; secondly, that group identities are based on a same-other opposition, thirdly that group identities are overdetermined and lastly that group identities are contextually catalysed.

The first principle serves to organise the data before the actual analysis. This involves characterising the funerary ritual and the grave-goods in a manner that is representative of the funerary practice and that allows for the identification of partial similarities. In the case of the grave-goods, it was necessary to characterise each objects according to a series of four hierarchically organised variables that went from general to particular. The first two variables related to object function, while the latter two characterised the shape of the object.

The second principle is implemented through a highly flexible, purposely developed similarity algorithm which is coupled with clustering procedures. Each grave is compared with every other grave using the previously defined variables. In the case of the grave-goods, the comparisons follow the hierarchical structure of the data which characterise the objects. All comparisons can be weighed, both on a variable and on a value level, which allows the researchers to feed into the algorithm observations or theories that they may have as well as any subjective ideas that they would like considered. The distance matrix that results from the comparisons is fed into several clustering procedures. Their outcome is both internally and especially externally validated.

The third principle, overdetermination, refers to the multidirectional character of group identity. Methodologically, this involves comparing the obtained clustering patterns with any available independent information (i.e. data not employed in the main analysis procedure). Examples of useful independent information are the age and sex of the deceased, the location of the graves (both on a cemetery and on a larger, regional level), settlement data of associated sites or written sources.

Finally, the contextually catalysed character of group identity is implemented at all stages of the analysis and refers to the idea that only similar contexts may be compared amongst themselves, though patterns from different contexts are comparable. However, because catalysts are not always present, group identity does not necessarily need to express itself in all contexts.

In the case of the Late Iron cemetery of Mannersdorf, the method revealed the existence of four strongly differentiated groups. The differentiation pattern seems to be a result of gender, age and social status distinctions. Of particular interest is the identification of burials belonging to regular community members, a group of people that was thought to be missing from the funerary record.

SESSION 5D-
PREDICTIVITY AND POSTDICTIVITY
IN ARCHAEOLOGY:
REFLECTING AND DISCUSSING
ABOUT THEORIES, METHODS,
AND TOOLS

Authors Carlo Citter, Antonia Arnoldus-Huyzendveld, Giovanna Pizziolo

Title *Predictivity-Postdictivity: a theoretical framework.*

Abstract Predictivity has a long lasting tradition in archaeology. However, it has been confined within a small courtyard by a theoretical framework that privileges an inductive approach, high mathematical skills, and the issue of cultural heritage management. It seems there is not much space for a deductive approach, fieldwork, historical issues, and digital tools other than some statistical algorithms. We wish to turn a specialized set of tools into a daily at hand package. We wish to start a lively debate on the theoretical framework upon which a wider approach should be based. Of course, it should not be restricted to the handful of specialists who already walk these paths. On the contrary, it is recommendable that field archaeologists do enliven the discussion with concrete questions. Which kind of data need to be collected to develop efficient predictive models? How can we face bias problems that affect landscape analyses and predicting procedures? In fact, a further weak point of the state of the art is the trend to be detached from the complexity of the material culture. How can we enrol predictivity into a wider theoretical, helpful context? We think we should put it into the daily toolbox of the archaeologist. Thus, predictivity, field work, and postdictivity are three stops along the same route. Prediction answers to the question “who?, where? what”, postdiction answers to the question “why?” They do not neutralize each other. On the contrary, they can be conceived as two different, but complementary, parts of the same procedure. The first one rests on a deductive top-down method, the second one on an inductive bottom-up approach. They both need a severe scrutiny of the archaeological dataset derived from intensive fieldwork. Thus, the theoretical framework we are going to introduce is all but a dogmatic point of view.

Authors Irmela Herzog

Title *Retrodicting the distribution of rural settlement locations recorded on a map created in 1715 AD*

Abstract A book on the Middle Ages in Central Europe describes the rural settlement pattern of the early Medieval period as follows: The farmers and their lords lived like on overcrowded islands within large unpopulated areas. It seems quite difficult to identify not only the islands but also likely farm house locations within the islands. In early Medieval times, one of the sparsely populated areas in Germany was the hilly region east of Cologne, the Bergisches Land. By 1715 AD, this picture had changed a lot, according to a map finished in that year. 82% of today's settlement locations were mentioned in historical sources before 1600 AD. There are only few abandoned settlement locations. So it seems that this region with fairly bad soils saw a development from empty to full within a few hundred years. This study tries to retrodict likely settlement locations in this rural area, i.e. the identification of the main factors governing the location of farms and villages. It turned out to be quite an unusual task due to the dense distribution of these locations. Simple statistics helped to identify some relevant variables. The result of this effort was a map consisting of a large number of small patches i.e. areas with high probability of farm house locations. The large number of known settlement locations also allowed a closer look at locations mentioned within certain time intervals in order to check if settlement patterns changed with time. Moreover, the size of the settlement locations as depicted on the map of 1715 was taken into account. It was found that some of the factors for settlement location were more relevant for large settlements than for small ones. However, the factors identifying possible settlement locations tell only part of the story. They do not take into account the settlement pattern, such as regular distances between settlements of similar sizes as proposed by Christaller's models. Each of the rural settlement locations was surrounded by gardens, ploughland, meadows and possibly forest areas and this should have some impact on the settlement pattern. In the study area considered, the single farm settlement locations are not

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as regularly distributed as Christaller's model would suggest. Christaller's models describe a full landscape, with no room for additional settlements. Although the settlement locations do not match Christaller's models there are some indications that the landscape was nearly full, with the area allocated to each settlement location being dependent on the size of the settlement.

Authors

Francesco Carrer

Title

Inductive models, deductive models and ethnoarchaeological models: strengths, weaknesses and new perspectives

Abstract

Two different types of predictive model are often used in archaeology: inductive and deductive. The former is based on a dataset (usually a sample of sites) that is taken as reference for evaluating the relationships between independent territorial variables and settlement patterns. This approach has been criticized because it lacks a behavioural context: it is based on the unverified assumption that the observed dataset mirrors an actual past settlement strategy. Deductive predictive model, instead, is based on behavioural rules, suggested by previous archaeological research and/or by ethnographic analogues, used to estimate the most suitable settlement locations. The problem of this second approach is usually its scarce predictive accuracy. Besides, these two models share a further theoretical problem: they originate from a preliminary selection of supposedly significant characteristics (independent variables in the inductive model and behavioural rules in the deductive model). In order to tackle these theoretical issues ethnoarchaeological analogy should be taken into account.

Ethnoarchaeology is a sub-discipline of archaeology that studies the relationships between human behaviour and material culture in ethnographic contexts in order to identify similar relationships in archaeological contexts. An ethnographic settlement pattern can be studied in order to understand how the locational strategy is constrained by specific environmental features, how the socio-economic framework influences landscape shaping and which role is played by immaterial elements, like ideological restrictions. GIS and statistical methods can provide a quantitative estimation of these interpretative relationships. The outcome is a probability surface that can be used for predicting the location of ancient sites. According to the analogic approach, given specific constants (environment, technological, etc.), similar settlement patterns can mirror a similar locational strategy, which in turn comes from a similar cultural and/or socio-economical context. And different settlement patterns, on the other hand, may suggest a different cultural and/or socio-economical context.

In this paper an ethnoarchaeological model is applied to a pastoral case study in the Italian Alps. One of the greatest archaeological problems of transhumant pastoralism is the low visibility of seasonal sites, and predictive modelling was considered an interesting tool to tackle this issue. Assuming similar locational strategies for herders in the present and in the past, an ethnoarchaeological study of pastoral settlement patterns in Val di Fiemme (Trentino province, eastern Italian Alps) was carried out. The model created was applied to another sample area (Val di Sole, Trentino province), and several pastoral sites were found inside and outside the areas indicated by the probability surface as more suitable. The study of current locational strategies of pastoral groups in Val di Fiemme was crucial to interpret this outcome, and it permitted to identify similarities and differences between current and historical/prehistoric pastoralism. Although the model had a predictive potential, it had also some theoretical and methodological weaknesses. Amendments and improvements were provided, and enabled an evaluation of the perspective of ethnoarchaeological modelling.

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Authors Philip Matthew Norman Hitchings, E B Banning

Title *Bayesian Optimal Allocation of Archaeological Survey Effort: A Case Study in Wadi Quseiba, Jordan*

Abstract

In 2012 and 2013, a team from the University of Toronto conducted survey of the Wadi Quseiba drainage in northwest Jordan. This survey's main goal was to discover evidence of Late Neolithic habitation and landscape use, which typical archaeological surveys in the region very rarely find. To improve the efficiency and frequency with which sites are located, we experimented with Bayesian optimal allocation methods, originally designed for naval searches during the 1940s. The survey's design began with a predictive model in a GIS environment in which we assigned prior probabilities to landscape elements thought most likely to have survived the severe alteration of the landscape that has occurred since the Neolithic in this highly eroded region.

Optimal-allocation algorithms, performed iteratively on the basis of each day's survey results, guided the allocation of survey effort to spaces with high probability densities, given past survey coverage.

After two survey seasons, we conducted small-scale excavations in 2014 on "candidate sites" located during survey.

This paper will discuss the survey methods and briefly touch on the results of these excavations, which verified that the "candidates" were Yarmoukian and Wadi Rabah Late Neolithic sites.

Authors Philip Verhagen, Laure Nuninger, Frédérique Bertonecello, Angelo Castrorao Barba

Title *Estimating the "memory of landscape" to predict changes in archaeological settlement patterns*

Abstract

Location preferences of rural settlements are not just linked to environmental factors. In this paper, we want to look at the influence of previous occupation of the landscape on settlement location. What would be the best suited location in a landscape?

- 1) An environment that was not settled before, offering the best soils and an advantageous topographic position?
- 2) A site that was occupied before, offering e.g. building materials that were left behind?
- 3) Or an environment that had already been adapted, e.g. by clearances, parcellation or soil improvements?

In order to study this effect, we developed a method to calculate a 'heritage map' based on the concept of 'memory of landscape'. Such a map can be seen as one variable among many others influencing site location preference, and can be used as input for predictive models. The computed values equate to an index of long-term land use intensity. In this paper, we will first discuss the method used for creating the heritage map, in particular the calculation of an optimal radius for the settlement surroundings that needs to be taken into account, for which kernel density estimates are used.

We will then present the results of using this heritage map for the analysis of location preferences for the Roman period in two different study areas in the southeast of France (Vaunage and Argens). From earlier analyses (Nuninger et al. 2012; Verhagen et al. 2013) it was clear that the influence of the natural environment on settlement location choice in the

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Roman period is limited. In contrast, the 'memory of landscape' seems to have a stronger influence on the placement of new settlements. We will discuss the implications of this for predictive modelling of settlement patterns.

- Authors** Kayt Armstrong, Christina Tsigonaki, Apostolos Sarris, Nadia Coutsinas
- Title** *Site Location Modelling and Prediction on Early Byzantine Crete: Methods employed, challenges encountered*
- Abstract** This paper will explore the pre- and post-dictive methods employed to model the locations of Early Byzantine Sites on Crete in the DynByzCrete project, which aims to examine changes in the inter- and intra- site record during the Early Byzantine period. This project is carried out under the framework of the Operational Programme «EDUCATION AND LIFELONG LEARNING» (NSRF 2007-2013) and specifically the action «ARISTEIA II», co-funded by the EU (European Social Fund) and national resources.
- The fragmented character of the landscape, with dominant mountain ranges isolating several areas, probably determined the organization of Cretan populations within several autonomous cities in antiquity. Crete emerged from late Antiquity as one of the most urbanized regions of the Byzantine Empire and fully integrated in the maritime military and trade routes in the unified Mediterranean Sea. Thanks to a combination of historical documents and field research, we are aware of approximately 80 settlements of the Early Byzantine period, about half of which can be securely identified with their historical name.
- There are two key questions issues within the project that GIS location modelling could assist with. Firstly, are there landscape factors involved in determining which sites survive from the Roman period to the Byzantine period? Location models can help with this, by firstly examining different geographical factors, such as geology, access to communication networks and visibility analysis, then seeing if they differ between the sites that survive and those that do not. Thus, our post-dictive model aims to identify not only the locational characteristics of the cretan settlements, but if there are any groupings within these that could be used to classify the sites. If classes of sites do emerge from the location factors, can they be related to the successful vs failed settlements? To address concerns about environmentally deterministic approaches, we will explore methodologies for modelling social, historical and economic factors within a GIS-based approach.
- Furthermore, such a post-dictive model can be used to explore the favoured conditions for a site location, and be turned into a predictive model, to suggest possible locations for the sites named in the historical record, but not yet identified on the ground. We can therefore use the historical data to constrain our predictive model. This paper will explore the methods we employed in the site location and predictive models, and the methodological and theoretical challenges we have encountered.

PREDICTIVITY AND POSTDICTIVITY IN ARCHAEOLOGY: REFLECTING AND DISCUSSING ABOUT THEORIES, METHODS, AND TOOLS

Authors **Antonio Porcheddu**

Title *Predicting and Postdicting a Roman road in the Pre-Pyrenees area of Lleida (Spain).*

Abstract

This work aims to discuss the results of a study carried out on an area located to the north of Lleida, in the Pre-Pyrenees, near the village of Àger (Spain). The object of study is a former Roman road, which remained in use partially until the first half of the twentieth century. During the building of a new road, the constructors rediscovered a piece of the ancient one, and the archaeologists excavated and interpreted it as of Roman origin. The questions I want to answer, on the base of my work, are twofold: a) what was the original path of the entire road, and how might we reconstruct this? and b) How did the landscape, the settlements, and other “attractors” influence the path of the road, and *vice versa*?

The methodology I will use to try to solve these problems is, firstly, a GIS Analysis with an algorithm known as Least Cost Path. It allows calculating the preferable path between two given points across a determined area in terms of cost-effectiveness. Even if this will not solve the whole problem, it will give a useful direction to further the investigation. The original path is approximated by adding other parameters to the analysis and considering the influence of some “attractors”, like settlements or sources of economic resources, as well as comparing it with archaeological data already known. The confirmation will come then from the ground, the so called “ground-truth procedure”, consists of the analysis validation through an intensive survey *in loco*. The second part of my work focuses on postdictivity. Interpreting the reconstructed path in order to find the real causes which may have influenced the road evolution and improve our understanding of the contextual area of the road. This will allow the discovery of new archaeological sites related to the road and, as a circuit, further improve the precision of the path determination.

Authors **Emeri Farinetti**

Title *Modelling regional landscape through the predictive and postdictive exploration of settlement choices: the theoretical framework and a case study*

Abstract

One of the challenges of regional landscape researches is to make the best use of the archaeological data sets available in different areas, setting up an environment within which heterogeneous legacy data, often incoherent and incomplete, could be integrated in a meaningful way, aiming at the modelling and the exploration of the past landscape dynamics.

In the paper, I will illustrate the theoretical approaches to the regional landscape that can interact, in particular the settlement chamber model, the community area theory and further implications, as well as the taskscape approach. Main goal is to set up a GIS-based meaningful framework for both predictive modelling and postdictive analyses, aiming at the long-term investigation of location choices and physical and cultural characteristics of landscape zones and settlement chambers. As a case study, the settlement dynamic approach applied for the definition of settlement chambers over the ancient Greek Boeotian landscape, at the 1st and 2nd settlement level, will be presented. It allowed to detect different areas with settlement potential in the long term, by analysing mainly the presence and location of known settlements in different periods. The methodology proved to be meaningful at the micro-regional level, provided the critical assessment of the archaeological record available, as well as in the comparative analysis in order to detect settlement trends and landscape choices in different

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parts of a region with specific environmental and cultural characters.

Moreover, the paper explores issues on data integration, on the involvement of historical sources, on the classification of environmental and cultural variables as well as on the feasible recording and management of the features representing social meanings and human choices over the landscape during time.

Authors Laura Soro, Loredana Francesca Tedeschi, Maurizio Minchilli

Title *N[Move - Spatial models of walking accessibility between nuragic sites*

Abstract This paper shows reflections and methods emerged from land analysis within the research project N[Move Spatial models of walking accessibility between nuragic sites.

The timeframe of reference starts from the Bronze Age, looks at the diachronic evolution of Sardinian land walkability afterwards and finally compares it with the current situation.

The objective is to explore, study in depth with multidisciplinary approach, and reconstruct the ancient networks of paths which connected nuraghi and nuragic sites (unique peculiarity of Sardinian landscape) and these historical landmarks with both territorial morphology and environmental resources (such as rivers, springs, coastal line etc).

The absence of animal-powered transport (horses and donkeys) during the Bronze Age inspired researchers and experts to focus on human walk movement and relative implications. However, these studies are often carried out through a modern point of view, influenced by the current way of conceiving transport in terms of means and routes. This is why the research work makes a further effort, that is constructing an operative survey method capable of considering all the variables which potentially interacted with the walk activity in the ancient age for creating more straightforward tools of land analysis.

In order to do this the work is organized through practical tests in the field and the use of technology; specifically divided in three main parallel modalities:

- Analytical modelling in GIS (modelling physical and environmental processes);
- Reconstruction of ancient paths through diachronic analysis inferred using the overlapping of historical maps;
- Exploration in the field by volunteers walkers equipped with technical devices for mapping physiological responses while walking (GNSS and heart rate monitor).

The expected outcome of this research work is the possibility of comparison between the three different approaches, in order to understand similarities in terms of analysis results and in particular for testing the reliability of GIS models.

SESSION 5E- HOMOLOGATION AND STANDARDIZATION OF ARCHAEOLOGICAL CARTOGRAPHIC DATA

Authors**Giovanni Azzena, Roberto Busonera, Federico Nurra, Enrico Petruzzi****Title*****Homogenization of the archaeological cartographic data on a national scale in Italy. The SITAN.*****Abstract**

Standardization, homogenization and harmonization of digital archaeological cartographic data in Italy is a major topic of debate for decades now. In particular, over the past five years, two interdepartmental committees (MiBACT and MIUR) were interviewed on the subject. The results of the work of the committees led to the definition of certain testing protocols.

In this context, the "Sardinian node of the national digital network for the collective construction of the Web GIS for the archaeological heritage - SITAN" is the extension of the national project "GIS website for research, protection, management and fruition of the archaeological Italian heritage" created within a network of universities and supported by MiBAC and ICCD. The project aims to: collaborate on the development of national standards with the highlight of the specific historic - archaeological context of Sardinia; identify and take a census of the "data producers" on the Island and consequently activate protocols of agreement for the exchange of information; experimentally apply the standard to the regional context; survey bibliography and archival data; popularize experimentally the database; test the connection to the National Network for the construction of Web GIS for the Italian archaeological heritage.

The paper intends to focus on the peculiarities of the "data producers", on the different types of data acquired and to be acquired, on the possibilities of utilization and on the forms of collaboration initiated or in the process of structuring with different actors operating in the region.

The complex articulation of state agencies, heterogeneously structured on different operational levels determines that disintegration of the archaeological georeferenced information that constitutes one of the main problems that the SITAN aims to simplify and to bring back to shared tools and languages.

State, Autonomous Region of Sardinia, Provinces, Municipalities, Mountain Communities, Archaeological Superintendence, universities are the main players in the production of information on the archaeological heritage. The creation of the Regional Landscape Plan, launched in Sardinia in 2006 and still in progress, is the perfect "battlefield" for experimenting the "engines of war" that can be functional for the knowledge and the protection of the evidences of our history. It is in this tumultuous environment, in which with greater strength is manifested the difference between protection of public property and benefit of private interests, even through a heated public debate, which develops the experimentation of SITAN.

The structuring of a Framework Agreement between the Archaeological Superintendence and the Department of Architecture, Design and Urban Planning in Alghero, allowed to establish and consolidate acquisition methods, analysis, classification and use of data. Are currently being implemented additional protocols with other parties, on the basis of a format of standard procedures to simplify and defines this pathway. The exemplification of the most important informatics steps through the use of Web GIS servers and clients, and especially the practical application of the tools and capabilities offered by data from different contexts, will allow to understand the activities taking place in Sardinia for the past two years and the perspectives for the near future.

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- Authors** Anne Moreau
- Title** *GIS, one of the answers to the challenge of preventive archaeology? : the attempts of the Inrap*
- Abstract** The French National Institute for Preventive Archaeological Research gathers over two thousand eight hundred archaeologists working on all archaeological periods from Paleolithic to the Modern times. The institute focuses on the detection and study the archaeological heritage threatened by development and infrastructural works – over two thousand operations are realised each year - , undertakes the study of the data collected, spreads the research results within the scientific community and introduces the archaeological knowledge to the general public.
- French preventive archaeology has to deal with several goals,
- as human science (research activity)
 - as patrimonial activity
 - as part of the planning process
 - as vector of cultural heritage
- To achieve the different aims above, archaeological data have to be manipulated, represented in different ways. Several restitutions of data have to be produced depending on the target public.
- In this context, GIS are a way of satisfying all the needs and obligations. The institute began considering the use of GIS in 2006. Since then, it has launched an unprecedented programme to promote the use of GIS and to train archaeologists in the new practices involved. Indeed, going from a local application of GIS to a rolling out of use to thousands of archaeological projects (trial trenching and excavations), for both research and management has brought up several questions as : the consequences of the data digitalisation and the field data recording the new graphic representations of archaeological data in the GIS compared with the traditional habits the aims of the systems used (management of the operation, data exploration, cartographic results...) the exploitation of stratigraphy linked with the data recording the need to find a common “language” for spatial data etc
- The variety of practices involves defining, on the one hand, a common part of data recorded and represented for all archaeological operations and, on the other hand, the part of data which is a matter for the archaeologists. Defining some standards while allowing some latitude : that is the aim of Inrap.
- Authors** Kamil Niedziółka
- Title** *Polish Archaeological Record and GIS: preparing data for settlement studies in Northern Poland*
- Abstract** The Polish Archaeological Record (PAR) is a unique research program initiated by Polish archaeologists in the second half of 70s. It was conducted for area of the whole country, which was divided into equal rectangles – so called PAR areas (7,5 x 5 km). The main aim of this project was to mark on a unitary maps (PAR sheets) all archaeological sites that were recorded during surface surveys which supposed to be conducted on each PAR area. Ready PAR sheet was to include all sites previously known from the literature and archives.

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This project has created a vast collection of standardized archaeological data that can be utilized by various academic and non academic fields. It is very useful especially for conducting settlement studies or other sorts of spatial analyses. Furthermore it also became a main database for Polish archaeological heritage protection. Unfortunately, because it was created „by archaeologist for archaeologist”, without any deeper consideration of cartographic methodology and knowledge, some serious difficulties occurred during local trials of introducing GIS into PAR archives.

The main aim of this paper is to show practical and methodological problems which emerged while digitalizing PAR archives of the area of Eastern Pomerania in Northern Poland. The reason for choosing this specific region was to create a database for further settlement studies focused on the Late Bronze Age and Early Iron Age. It was a period of significant cultural changes which later spread widely from Eastern Pomerania to the vast areas of contemporary Middle Europe. What is important - PAR for this region is completed only in about 50% and when compared with other regions of Poland gives the worst PAR availability score. This brings a lot of problems, combined with the fact that archaeological literature focused on this period is in most of the cases outdated. However this can also lead to introducing new solutions that may be useful in other examples of digitalization of archaeological facts with usage of the GIS based software.

Although Eastern Pomerania during the Late Bronze Age and Early Iron Age is a precise archaeological example, it seems that the problems connected with digitalization and standardization of archaeological data - and in wider perspective with implementation of GIS into archaeology - are similar in other regions of Poland and Europe, where analogical archaeological records are still awaiting to enter the XXI century.

Authors**Giorgia Leoni****Title*****Standardization for data "quality"? The experience of SITAR Project*****Abstract**

Since 2007 the *Special Superintendence for Archaeological Heritage of Rome* created the first "archaeological digital cadastre" of the entire metropolitan area, through the development of the platform webGIS SITAR, which uses open source software and open data format.

The main difficulties encountered during the implementation of the system were caused by the lack of standardized references about specific data. For the first time in Italy the Committees SITAN (within the MIBACT) provided guidance on the minimum requirements for the implementation of SIT (in Italian Territorial Information Systems). However, the complexity and variety of archaeological evidence as well as the need to align data produced in the past by means of different methodologies imposed a broader reflection on the minimum standards for the recording of archaeological data, and in particular of their content and their cartographic position.

The aim was thus to obtain a “minimum level of knowledge”, that is a given set of information for the recording of any historical and archaeological evidence, that could also be used for heritage protection and urban planning. All this is to contribute to the necessary alignment of operating and administrative processes of the *Superintendence*, as well as to the broader institutional, legal, methodological and technological framework that the Ministry of Cultural Heritage and Activities has been developing in recent years. The ability to store spatial information in a GIS, even with different degrees of detail for each object stimulates a preliminary discussion about the "quality" of the data stored. This in turn helps establishing from the beginning of the work which is the final scope of the SIT and which questions the system should be able to answer. These aspects are important both from the point of view of the

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"quality" of archaeological data and from the point of view of the different users of the data (local administrators, planners, citizens). Even more so today, considering the degree of shared information allowed and required by the network as well as the various forms of "openness" of the data.

Authors

Sergio Camiz, Paola Moscati

Title

Archaeology and GIS. Methodological and terminological issues

Abstract

The journal «Archeologia e Calcolatori» celebrates this year its 25th anniversary. Enriched by a new series of Supplements and by the challenging participation in the Open Archives Initiative, the journal offers today a comprehensive open access repository of electronic resources that allows readers to follow the twenty-year development of computer applications in the study of archaeological data, from fieldwork to laboratory investigations, from cultural heritage preservation to data dissemination and education.

In the early 1990s, the journal registered the first experiments in the use of digital mapping and the remarkable progress of Geographical Information Systems. Specific attention was soon paid to this new type of integrated platform on which methods and resources of different disciplines can be managed simultaneously, contributing to reconstruct, and therefore safeguard, the past through innovative tools.

In 1998 a special thematic issue was dedicated to "Methodological Problems and Future Perspectives in the Application of GIS in Archaeology" and the journal became an international arena for theoretical and methodological debates. The increasingly frequent application of GIS and the resulting introduction of spatial information, not only made the use of international geographic standards more urgent, but also modified the type of approach to the study of archaeological evidence, overcoming the traditional concepts of site, finds, and features and replacing them with the broader concepts of landscape and spatial entities.

Today, as part of a research project centred on the study of the evolution of computer applications through the textual markup and analysis of the articles published in the Journal, our scientific effort is addressed to apply multivariate exploratory data analysis procedures in order to locate simultaneous occurrences or sequences of word forms that can testify to the evolution of terminology in the field of archaeological computing and the semantic importance of specialised terms which derive both from the Humanities and Information Technology. Some examples will be illustrated specifically regarding the application of digital mapping and Geographical Information Systems in the context of excavations and urban planning studies.

SESSION 5G- HOW TO REVEAL
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Authors	Mieko Matsumoto, Espen Uleberg
Title	<i>Dynamic Distributions in macro and micro perspective</i>
Abstract	<p>The paper addresses how the online museum database can be used to reveal geographic relations of Norwegian Stone Age sites in macro and micro perspective. This is the third and final presentation of our project Dynamic Distributions on analysis of archaeological finds and landscape types.</p> <p>The archaeological collections at five Norwegian university museums are publicly available through the website www.unimus.no as open data. The open dataset is constantly maintained and updated as new finds are catalogued at the museums. As of November 2014, more than 866 000 geotagged entries can be queried. All finds are annotated with different accuracy levels ranging from precise location over cadastral unit to municipality or county. In addition to catalogue text and selective images, the website comprises interactive map and metadata including coordinates and accuracy levels. All these unfiltered raw data can be freely downloaded and used.</p> <p>We present two distribution analyses for Stone Age finds from the ten counties in East and South Norway; the museum district of Museum of Cultural History, the University of Oslo. The districts chosen cover varied landscapes with coast, fjords, high mountains, and agricultural areas. The major body of the archaeological finds is assembled in coastal areas and the distribution reflects the impact of the rapid isostatic uplift after the Ice Age, which was stronger in the inner Oslo Fjord than further south. To visualize the different land use patterns in the North, the material is clustered in several chronological phases based on typological dating.</p> <p>First, the distribution analysis at a macro perspective. The artefacts are in this broad perspective seen in relation to a few aggregated landscape categories. The main extent of different cultural groups is also discussed.</p> <p>Second, the distribution analysis at a micro perspective. Two smaller areas are chosen for more elaborate study. At this fine-scaled level, the periphery of landscapes and only finds with higher site accuracy levels are incorporated. The description of the landscape features will also be more detailed. The discussion on whether patterns observed at the macro perspective recur at this level is a focal point. The comparison of emerging patterns will illustrate how studies at different spatial and temporal levels can reveal new geographical relations.</p> <p>Our project has provided the museum database with a baseline of appropriate categorizations of Stone Age artefacts. New acquisition catalogues and updated interpretations are consecutively added, preserving earlier versions as historical data. This complete dataset contain a large number of geotagged artefacts, and is ready for unconditioned further use and reuse. Downloaded and combined with digital topographical and thematic maps and environmental data, it gives more opportunities to try out a number of diverse combinations and analyses. We believe that our work has provided a good starting point for unconventional research on the Norwegian Stone Age.</p>
Authors	Mirella Serlorenzi, Andrea De Tommasi, Cristiana Cordone, Federica Lamonaca, Stefania Picciola, Lino Traini, Andrea Varavallo
Title	<i>Cluster Analysis applications for SITAR Project open archaeological datasets</i>
Abstract	<p>Since 2007, Special Superintendence for Archaeological Heritage of Rome is implementing the <i>first digital archaeological cadastre</i> of entire metropolitan territory, through <i>SITAR Project AIS</i> web platform development. The underpinning logic architecture - already illustrated in several places - considers some primary information levels to translate material</p>

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field data/documents into spatial/descriptive metadata, digital objects and interactive maps, easily accessible via web for many users. Specifically, the so-called “*Archaeological Partitions*” level represents all investigated evidences or remote-sensed subsoil items with topographic value, and well demonstrates the typical “fragmentation phenomenon” of data and informations, to be obviously addressed within SITAR context, as well as in other similar systems.

This “physiologic” phenomenon is clearly due to different procedural approaches in data registering, formatting, georeferencing methods/technologies, strictly interrelated with many human actors, different “attitudes for completeness”, temporal/operational contexts, and theoretical/applicative evolution phases succeeded in the complex scenario of Public Archaeology at Rome.

With regard to SITAR digitizing activities, these “native elements” generate, more or less deeply and distinctly, some issues on precision/completeness at topographical/descriptive level of data, both old and new ones, motivating the implementation of a semi-automated workflow to compare and re-align fragmentary partitions each other. In this sense, the primary aim is to rapidly and massively identify *unitary analytical partitions*, indeed as *clusters* of basic data and as “digital abstractions” of *original/physical* archaeological objects “seen” and “fragmented”, time by time, through different investigations. So, the purposes are to correctly rectify final interpolated data and manage exponential increasing amount of thousands of *archaeological partitions*, due to the same dynamism of SITAR digital cadastre.

For this, *Cluster analysis* applications are expected to be successful in light of its variegated capabilities, notoriously based on *dissimilarity/distance* cross-analysis.

The most interesting opportunities to be investigated are: *unsupervised learning* and *hidden patterns* discovering paradigm; optional combination of hierarchical, flat, overlapping and fuzzy logic-based algorithms; processing of both quantitative and qualitative data; heuristic approach to avoid any deterministic output. So, it will be attempted to experiment some suitable “identification use cases” and specifically *clustering* procedures to be tailored on plano-altimetric values, semantic attributes and reflexive relationships between basic partitions, from a “single unitary analytical partition *subsumption*” (that could be based on hierarchical algorithms) up to multi-partition identification (that could be performed, e.g., with *k-medoids* based algorithms). A next development of a “3D geometry *subsumption* algorithm” should make possible to translate “spatial fragments” into new archaeological features more coherent with real territory topography.

Concrete purposes of these experimentations are to deeply know, as well as possible, inferences of field data on final affordability of SITAR *analytical partitions*, and to supply only well aligned and valuable *public open datasets* to users.

Authors

Christian Willmes, Daniel Becker, Georg Bareth

Title

Data integration for paleo environmental and archaeological GIS based analysis

Abstract

A spatio-temporal data base integrating paleo environmental and archaeological data is presented in this contribution. The data base is developed applying a collaborative prototyping approach based on Semantic Mediawiki (SMW, Krötzsch et al. 2006) and OGC standards based Spatial Data Infrastructure technology.

Time and space are the main integrating factors of the presented data base. The data is spatially integrated by its spatial extent. For GIS datasets this extent is present intrinsically. For data, not given in a GIS data format, or not containing explicit geo coordinates, the spatial integration is

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facilitated by annotating spatial attributes with predefined regions or sites, which translate to bounding boxes, polygons or point coordinates. The same is implemented for temporal data, where the data can be annotated with predefined periods and events, which translate into time-spans (periods) between a start and an end date, or into simple dates (events).

Developing the data base using a prototyping (Naumann & Jenkins 1982) approach means to develop the data model and the interface from the integrated data, and from demands of the users during internal use and operation of the data base application. SMW proves to be an ideal technology for implementing this approach, because model, data and interface are editable and combined in one application.

Based on some example use cases for integrated paleo environmental and archaeological GIS analysis, it will be shown how geographical and archaeological relations within the data base can be revealed. SMW allows to formulate complex queries and export the result in different formats. The complete process from query formulation, the query result export, the import of the data into a GIS, and an example GIS analysis based on the data will be explained.

Authors **Michael Märker, Christian Willmes, Volker Hochschild, Georg Bareth**

Title *How to exchange data between DB Systems on Early Humans. A case study based on the SFB 806 DB and the ROCEEH ROAD system*

Abstract In the recent past data base systems providing information on early humans and their environment are becoming more and more important and increase rapidly in number. However, this increase in different DB systems is concomitant with an increasing redundancy in the digital information stored in these database systems. Therefore, in this study we explore ways to reduce redundancies due to multiple storage of the same data and, hence, we show solutions to minimize the requirements to store and manage digital information.

The application example is based on the database systems of the DFG financed SFB 806: "Our Way to Europe" and the Heidelberg Academy of Sciences and Humanities project entitled: "The Role Of Culture in Early Expansion of Humans (ROCEEH). We focus especially on the spatial data available in both systems as well as on the environmental information. Therefore, we test exchange interfaces based on WebGIS technology and SQL Database queries on metadata.

Authors **Eric Andrew Rodriguez**

Title *Reconstructing "Cultural Wetlands": New Palaeogeographic Models for the Humber Estuary*

Abstract With the recent application of palaeogeographic modeling on prehistoric wetland environments, it is now possible to observe not only the landscapes of past peoples, but also the dynamic nature of these environs influencing the phenomenology and settlement patterns of these societies. Focusing on Northern England's Humber Estuary, this paper describes the re-modeling of the Humber Wetlands and its implications using recent glacial isostatic adjustment (GIA) models and borehole surveys, which are unaccounted for in previous attempts.

From these new palaeogeographic models, this paper discusses the implications and

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interactions between the re-modelled palaeolandscapes and the shifting settlement patterns observed in the archaeological record from the Late Neolithic to the Early Bronze Age. Given the rapid sea-level change of the period, this study offers a contribution to the dialogue concerning the correlation of climate change, dynamic landscapes and past societies. Furthermore, the application of palaeogeographic modeling for the Humber Wetlands in an archaeological framework encourages a rhythm-analytical understanding of wetland spaces as they carry their interagency from the physical into the cognitive realm, creating “cultural wetlands.”

The aims of this study are not solely situated on reconstructive modelling techniques, but rather, towards an investigation of Holocene phenomenologies and settlement patterning, which stem from this computational method. It is through this palaeosurface modeling approach that dynamic maritime cultural landscapes in the Humber Estuary can be understood.

Authors **Cristiano Benedetto De Vita, Vincenzo Amato, Francesca Filocamo, Alfonso Santoriello, Francesco Uliano Scelza, Francesco Mele**

Title *Archaeology, Geomorphology and Palaeosurfaces: studies: a multidisciplinary approach for understanding the ancient Laos territory.*

Abstract The paper describes the results of the project “Landscape archaeology in the territory of ancient Laos”, a collaboration between the Superintendency of Calabria, the University of Paris 1 Panthéon-Sorbonne, the Centre Jean Bérard in Naples (USR 3133 CNRS – École Française de Rome) and the Department of Heritage Science of University of Salerno. The aim of the project, started in the 2009, is to understand the ancient landscape dynamics in the coastal area of the northern Calabria. The territory is located between the Lao river and the Abatemarco stream. In the last two centuries the landscape has been deeply modified by the human contemporary activities. In this context many archaeological evidencies persist in a chaotic framework. The main problem is the localization of the Greek polis of Laos, cited from historical literature and still undiscovered. Moreover the organization of the ancient space is almost completely unknown. In such condition our first goal is to define several sample areas constituting the base for plausible evaluation of the use and territorial organization. For this purpose we defined a multidisciplinary research strategy. In particular a geomorphological and pedo-stratigraphical approach was applied to the archaeological survey. The study area is characterized by the presence of a wide alluvial-coastal plain, in which flows the Lao river and Abatemarco stream. The plain is landward bordered by hills, along which a stair of marine and fluvial terraces and referred to a time interval falling between the Early Pleistocene and the Middle Pleistocene. The terraces of greater width preserve, on the top, thick soil covers interpretable as relic paleosoils. During the archeological survey the collected data were related to other multidisciplinary informations, as the degree of visibility, the land-use, the state of soil covers and the main geomorphological processes. Such information has been used to build matrix-profiles aimed at the analysis of influencing factors regarding the presence of archaeological evidence on investigated surfaces. Such a representation of the information allows to consider the variety and the complexity of data. The most significant result show as the presence on surface of potteries and tiles is related to the presence of the palaeosurface and to the lack of the significant erosional or aggradational processes on surface. A detailed study of ground conditions can thus correct the alterations of the archaeological record and evaluate the features of material data in a less approximate way. It can be noted that, compared to a traditional reading of the archaeological data, this allows to bring out information of different entities in relation to the archaeological evidence. So, through the reconstruction of palaeosurfaces it has been possible to formulate some hypothesis about characteristics of the ancient territory organization.

SESSION 5G

HOW TO REVEAL GEOGRAPHIC RELATIONS IN DATABASES ON CULTURAL HERITAGE

SESSION 5H- GEOGRAPHICAL AND
TEMPORAL NETWORK SCIENCE IN
ARCHAEOLOGY

Authors**Peter Bikoulis****Title*****Hypothesis Testing and Validation in Archaeological Networks*****Abstract**

This paper reports a procedure for quantitative validation for the purpose of hypothesis testing between competing archaeological network models. Two ways of forming networks are compared using a case study situated in fourth-third millennia BC southern Turkey. The first is created using the principal of proximity, and connects network actors based on their geographical distance. This is a common approach used for networks that use locationP to connect actors. The second is created using the principal of effort costs, and uses Least Cost pathways between sites as a means of connecting them. These are employed as idealized routes connecting sites, taking into consideration movement between sites as the primary constraint in the formation to networks. A third set of random graphs generated using bootstrapping methods (Monte Carlo) are used to assess results between these two network creation strategies. Comparison and evaluation of the real-life network models indicates that large-scale or regional scale network models based on spatial proximity may not provide the best or ideal way of creating archaeological networks.

Authors**Daniel Weidele, Mereke van Garderen, Ulrik Brandes****Title*****Network Science in Archaeology: A Case Study Replication*****Abstract**

Because of its focus on relations and dependencies, *network science* is a promising addition to the data-analytic toolbox. It combines statistical, combinatorial, algorithmic, and graphical methods to address archaeological research questions that are amenable to a network perspective. Such approaches are becoming increasingly commonplace and a range of examples demonstrates that new insight can be obtained. Despite other claims, however, the methodology of network science is only in development and proper usage standards are the subject of debate.

We illustrate this point by replicating an application of network science in the study of Maya obsidian (Golitko et al., 2012). The original study considers networks in which nodes represent sites that are related by similarity of assemblages. To be able to apply certain methods for network layout and decomposition, the similarities are dichotomized via thresholding. Noting the differences in clustering over time the authors conclude that there was a shift from coastal to inland supply routes that contributed to a collapse of inland Maya urban centers.

In our replication, we use different methods that avoid the information loss incurred by thresholding and suggest extensions to the analysis. These combined lead to a slightly different interpretation of the data. A byproduct of our re-analysis is a visual representation for spatio-temporal archaeological data using custom-designed glyphs. We conclude by pointing out more general implications for the use of network science in archaeology.

Authors **Tom Brughmans**

Title ***MERCURY: an agent-based network model of tableware trade in the Roman East***

Abstract This paper presents the Market Economy and Roman Ceramics Redistribution model (MERCURY, after the Roman god of commerce), an agent-based network model of tableware trade in the Roman East, developed to illustrate the potential of computational modelling for the study of the Roman economy. It aims to abstract aspects of two conflicting descriptive models of the functioning of the Roman trade system using comparable network science concepts. This allows us to simulate the expected outcomes of the two descriptive models which can subsequently be compared with the observed tableware distribution pattern. The two conflicting descriptive models in question are Peter Bang's Roman bazaar (2008) and Peter Temin's Roman market economy (2013). Here we will focus in particular on the elements of these models that concern the flow of commercial information between traders, which will be conceptualised as different network structures.

MERCURY represents the structure of social networks between traders that act as the channels for the flow of commercial information and goods. When the model is initialised a social network is created between traders, who are distributed among sites. Four of these sites are production centres of four different tablewares, and traders located at these sites obtain a number of items of this locally produced ware in each turn. At each time step traders will determine the local demand for tableware they want to satisfy, and will estimate the price they believe an item of tableware is worth based on their knowledge of the supply and demand of the traders they are connected to. Every item of tableware is then put up for sale, and pairs of traders who are connected in the network can buy or sell an item. When an item is successfully traded, the buyer will decide to either sell it to a local consumer to lower the demand (in which case the item is taken out of the trade system and is deposited at that site), or to store it for redistribution in the following turn in case this promises a higher profit. Over time, this model therefore gives rise to distributions of four tablewares.

This paper will conclude by discussing the implications of using non-spatial network modelling to produce simulated tableware distributions that can be subsequently compared with the archaeologically observed distributions: does the model need to be spatially explicit? Is it even possible to be create a spatially explicit model whose outputs can be compared to the observed distributions?

Authors **Sébastien Plutniak, Joséphine Caro, Claire Manen**

Title ***Assessing the relevance of a stratigraphy by network analysis of conjoin relations between archaeological objects***

Abstract Considered at a fundamental level of analysis, the time dimension in archaeology is stated from an examination of spatial relations between material objects which are distributed into multiple spatial units (*e.g.* stratigraphic units). We propose a graph-based method to address these relations. We argue that the *structural* properties of a conjoin/refitting network can be a proxy to *measure* the admixture of materials between stratigraphic units and to assess the sediment dynamics and the validity of a stratigraphy.

In the last two decades, one can observe a renewed interest in analysis of archaeological object refitting [Cziesla & al. 1990; Hofman, Enloe 1992; Schurmans & De Bie 2007]. Multiple ways to define relations between fragmented pieces have been proposed, as Bollong's [1994] six items typology. However, most of these methods rely on a *count* of the number of relations and do not take into consideration the *structure* of a set of refitting links [see Vila 1982]. Network analysis is relevant to do so and has not yet been applied to this purpose [Brughman 2012].

Firstly, we consider the formalization of relations between fragments of a same object as a graph and the related issues. It is argued that archaeology can take advantage of the insights taken from formal ontology [Casati, Varzi 1999]. Two types of relations are defined and implemented in a graph formalism. Secondly, we discuss the relevant network measurements for both intra-level and inter-level analysis. Details concerning two cases studies are then given. Initially, our method was developed to answer the problems we encountered in Liang Abu Cave, Indonesia. We then perform our method on a bigger dataset taken from the Neolithic Taï Cave, South-east of France. All the functions we run have been written in R and built upon the *igraph* [Csardi & Nepusz 2006] and *tmet* packages [Opsahl 2009] in order to allow an easier application on other datasets.

Finally, we aim to emphasize some aspects of our approach with regard to the more general debates in archaeology. From actor-network theory to graph analysis, network-based approach in archaeology pushed archaeologists to encounter “ontological” issues. But ontology is then understood in two ways: either following the view developed by philosophical anthropology, as in works by T. Ingold or E. Viveiros de Castro [see Alberti, Marshall 2009] or in the perspective closer to what ontology means in computer science and formal ontology. We firmly consider our approach of fragmentation as a contribution to a human-decentralized [Lucas 2012] perspective in archaeology and a tool for an archaeology considered not only as the discipline of things [Olsen & al. 2012] but of *fragmented* things.

Authors Sergi Lozano , Luce Prignano, Alessandro Guidi, Francesca Fulminante

Title *Applying spectral analysis in archaeology. The urbanization process in Central Italy*

Abstract Despite formal network analysis is becoming increasingly common in archaeology, the measures and indices usually considered are just a small sample out of the actual toolbox at hand. Among the techniques that, as far as we now, have always gone unnoticed, there are those derived from the Spectral Graph Theory.

Such techniques (*spectral methods*) consist in the mathematical manipulation of matrices associated with the network. Spectral methods as a whole represent a way of distilling information (*spectral properties*) intermediating structural and dynamical properties. Indeed, even though spectral properties are directly derived from the network topology, they can provide details on processes underlying dynamics taking place on top of such network, like technology diffusion or information exchange.

Geographical networks represent a privileged application case due to the physical constraints applied to their evolution. If we want to characterize the time evolution of a network embedded in a geographic space, it is quite unlikely that we will observe important changes in the values of usual topological indexes (average degree, clustering coefficient, average betweenness centrality...). All of them are, generally speaking, bounded to undergo to local changes that do not affect their average values significantly. Hence, they cannot properly describe what occurs

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at the global scale. . On the contrary, spectral methods can allow revealing hidden but meaningful aspects of the transformation the system is experiencing.

We will show how spectral methods - that have been a part of graph theory for over a century and network researchers have used since the late 1960's- can be successfully applied to an archaeological case study. Specifically we address the urbanization process in Central Italy, through the analysis of the evolution of communication infrastructures' networks.

Analysing the evolution of rivers' and roads' transportation networks during the process, we observe no significant changes on 'usual' structural measures on either of the graphs. On the other hand, spectral analysis reveals significant differences between them. Specifically, while the fluvial network does stay almost the same, roads connections evolve in such way that the communication infrastructure becomes much more integrated (and efficient) at a systemic (global) scale. This result agrees with pre-existent hypotheses on the decreasing importance of the rivers network. Moreover, while empirically grounding the theory, spectral analysis also provides a new kind of explanation (i.e. in terms of the plasticity of roads and rivers as communication infrastructure) that is out of common measures' range. Concluding, we believe that spectral methods can make a great contribution to the analysis of geographical and temporal networks in general, and archaeological case studies in particular.

Authors

Pim van Bree, Geert Kessels

Title

Diachronic network analysis in nodegoat: a methodology to dynamically scrutinise, reconfigure and re-evaluate complex datasets

Abstract

In this session we propose the online research environment nodegoat for the exploration of long-term changes of socio-cultural systems and spatial phenomena in archeology. nodegoat allows scholars to build datasets based on their own data model and offers relational modes of analysis with spatial and chronological forms of contextualisation.

The explorative nature of nodegoat allows scholars to trailblaze through data; instead of working with static 'pushes' – or exports – of data, data is dynamically 'pulled' within its context each time a query is fired. nodegoat follows an object-oriented approach throughout its core functionalities. Borrowing from actor-network theory this means that people, events, artefacts, and sources are treated as equal: objects, and hierarchy depends solely on the composition of the network: relations.

This object-oriented approach advocates the self-identification of individual objects and maps the correlation of objects within the collective. nodegoat is used in various projects in the humanities throughout Europe (e.g. the analysis of correspondence networks, migration patterns of artists, networks of conference attendees, co-occurrence of literary tropes in poems, infrastructures of violence in post-conflict societies). Based on our experiences during the Connected Past sessions, we have recognised a number of potentially fruitful applications of the nodegoat methodology within the field of archeology. We would like to present the main concept of reversed classifications, extend the concept with cases of relativity in disconnected nearness, and expand by exploring the application of constraints and conditional logit.

In general, classifications emphasise a convention of value and vocabulary. The direction of a classification is outward, relating to the convention unidirectionally. In effect, the classification is unable to communicate/negotiate with the network it classifies. The reversal of classification opens up the convention by disclosing its parameters. Reversal allows the classification to be scrutinised, reconfigured and re-evaluate the objects it classifies.

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By making use of circumstances depending on time and location – defined by Sub-Objects in nodegoat, a reversed classification is able to accompany varying configurations relating to place and time (like an object). Reversed classifications can be employed to cluster people and organisations who are subject to considerable changes over time and in affiliation. Correspondingly, the location and date of a circumstance can also be reversely classified and retrieved from the configuration of the classification. Objects that match ('artifact excavated at a depth of X meters' AND 'in the region of Susa'), could for example be classified with Achaemenid Empire (depending on X) and use the date configured in that classification as its own. The same goes for locations (the domicile of a person can be assessed using titles a person may have had).

This reversal works well for concepts and periodisation. When dealing with concepts bound to change over time and space, a reversed classification can be configured to match 17th century objects differently than objects in the 18th century. To facilitate discussions on the definition of periodisations, instead of retagging objects, only the classification has to be reconfigured to match the latest consensus. Based on our experiences in working with historical, anthropological, and literary data, and observing the benefits of applying reversed classifications to deal with dynamic long-term phenomena, motivates us to discuss this concept within the realm of archeology.

Authors

Manuela Ritondale, Guido Caldarelli, Mauro Coletto

Title

Application of network analysis to the trade routes of antiquities passing through the pontine islands

Abstract

The organization and the mechanisms affecting the Roman trade system during time, shed light on a wide and complex range of social, political and economic dynamics that still leave open debates and unresolved questions. Considering such a complexity of archaeological data, historical events, economic theories and the multitude of actors involved, computational intelligence might be considered a powerful and useful tool although many archaeologists and historians still look at its application within social and historical sciences with skepticism.

Network analysis can be particularly useful in order to analyze the relationships between all the actors involved in Roman trades and routes: particularly the shipwrecks with their cargoes of amphorae and the production centers (considering both the products transported and the ceramic-production centers in which amphorae were produced)

Moreover, network analysis might be useful in order to predict routes and potential further dynamics, providing information about hubs and crucial relevant production centers or crucial crossroads.

Between 2008 and 2010 eleven ancient shipwrecks dating back to different phases of the Roman period were found by the Superintendence of Cultural Heritage of Lazio cooperating with the AURORA Trust, an international not-for-profit organization in the field of underwater archaeology

The final goal of our ongoing research is to apply network analysis in order to study and link the eleven shipwrecks within the general trade system of the period, highlighting the provenance of the cargoes, the production centers in which the amphorae were produced and the sites in which the same typologies are attested.

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In order to do this, several networks have been combined in order to create a multiple network, or so-called “multiplex”, able to investigate the transport system passing by Pontine Islands during the time providing also pieces of information about cargos composition over time, and further diachronic analysis.

In particular, a weighted projection on the products of the bipartite graph connecting products with shipwrecks, shows links among artefacts transported together, suggesting connections between the origins in the ship routes and exchanges.

Similarly the projection on the shipwrecks highlights isolate disconnected vertexes, namely peculiar rare cargos. This work shows how computer simulation and network analysis might be useful not only to support the visualization of already known routes and connections, but also to provide a better understanding of certain dynamics not easy to be disclosed.

Authors**Mu-Chun Wu****Title*****Wayfaring Social Relations: a spatial construct*****Abstract**

Recent research by social theorists has shown that not only is space a social construct, it is also a constituent of social relations. In terms of a spatial analysis in archaeology, most research has been focused on how social structure is reflected in spatial configuration, and how spatial layout supports and consolidates social order. However, the spatial construction of social relations is rarely discussed. In the light of Ingold’s ‘wayfaring theory’ (Ingold, 2012), researchers are equipped with an alternative thinking towards movement and social relations. This research argues that interpersonal relationships are not entirely based on social identities, and social relations should also be investigated, regardless of their hierarchical status, but through intimate human interaction. Echoing Wheatley’s suggestion (Wheatley, 2014) for adapting the concept of ‘social proxemics’ in the study of spatial structure, this research applies the same theoretical framework on a settlement scale and investigate the spatial construct of social relations. By applying both wayfaring theory and social proxemics, this research models human agency from a ‘meshworked’ perspective, and demonstrates how social interactions and relations are influenced through agents walking around a settlement. This bottom-up approach allows the examination of the allocated social relations as opposed to the delegated social identity, and benefits from understanding internal transformations. This research not only highlights the methodological approach of the model but also presents the results and potential interpretation of the subject.

SESSION 5I- INTERPRETING THE
UNSTRUCTURED: NEW METHODS AND
TOOLS FOR INTRASITE SPATIAL ANALYSIS
OF PALAEO SURFACES

Authors**Michal Birkenfeld, Nigel Adrian Goring-Morris****Title*****Stratigraphy and spatial analysis at the PPNB site of Kfar HaHoresh, Israel*****Abstract**

The Pre-Pottery Neolithic B period in the Southern Levant (PPNB; ca. 8,500-6,400 calBC) represents the culmination of the Neolithization process in the region. This process witnessed some of the more fundamental changes in human social and economic strategies: the emergence of large sedentary village communities, and the shift from food procurement to food production.

Other aspects of the material culture, such as mortuary customs supply further evidence for new social structures; variations in burial customs and the presence of grave goods, were suggested to reflect developments relating to increasing inequality and the possible emergence of social ranking.

The PPNB site of Kfar HaHoresh is located in the Nazareth Hills of the Lower Galilee. Fifteen field seasons at the site revealed a long and intricate stratigraphical sequence, and provided a uniquely rich and varied material record, including more than 65 human burials. These finds have led the excavators to hypothesise the site may have functioned as a mortuary site, a cult locale in which neighbouring villagers may have buried their dead and performed at least part of their ritual and ceremonial lives. The unique character of Kfar HaHoresh provides an opportunity to explore ritual aspects of Near Eastern PPNB society as a whole and of the Neolithic communities of the Lower Galilee in particular. Moreover, since the site's occupation persisted throughout the entire sequence of the PPNB (i.e. Early through Late PPNB, ~1750 years), it raises the possibility of evaluating how these processes of change developed.

During excavation it became apparent that several phases show clear spatial distributions of activities, including cemetery areas, cultic installations, production areas and midden deposits. However, shifts in the spatial organization of activities played a major role in shaping the stratigraphic sequence on-site: different areas were occupied more or less intensively at different stages, creating 'spiral' depositional processes, in which two immediately adjacent loci or artefact clusters can belong to very different stratigraphic contexts. This is compounded by later pits and erosion, by changes in the inclination of the slope during the occupation. All of these factors pose difficulties when looking for manifestations of human behavior, and require special methods and analytical tools.

In this paper we present a methodological approach aimed at dividing the bulk of the excavated features into analytical units. This approach allows us to recreate the spatial extent of each stratigraphic unit, even when visual identification of relatively featureless areas during excavation was difficult or not possible. Furthermore, it facilitates correlations of the stratigraphic and spatial data with the artefact datasets. This enables the creation of a more synthetic approach to stratigraphic analysis, allowing more detailed and cognizant spatial and contextual analyses.

This methodology, which is based on GIS applications, emphasizes a three-dimensional approach to the analysis of the spatial distributions of both the architectural remains and the small finds, facilitating subsequent contextual analyses and thus highlights new possibilities of using GIS in intra-site contexts.

INTERPRETING THE UNSTRUCTURED: NEW METHODS AND TOOLS FOR INTRASITE SPATIAL
ANALYSIS OF PALAEO SURFACES

- Authors** **Katia Francesca Achino, Juan Antonio Barceló**
- Title** *Predicting the accumulative consequences of abandonment processes. Intrasite analysis of lakeside settlements*
- Abstract** Over the past thirty years, predictive models have been almost always applied to an inter-site scale only, in order to detect the archaeological sites' locations and to predict the probabilities of occurrence for specific kinds of artefacts in areas where no archaeological surveys had been previously done. We believe that archaeologists can take full advantage of these statistical methods in an intra-site perspective.
- In this paper we suggest how to predict the spatiality post-depositional processes to understand abandonment dynamics in lakeside settlements, given their particular post-depositional processes that led to the partial emersion of the site (Menotti 1999). In such circumstances, surface surveys data are usually fragmentary and spatially incomplete. We have adopted a predictive approach based on the so-called "discard equation" (Cook 1972; Schiffer 1975; 1976; 1987; Schiffer et al 2010; Sullivan 2008; Varien & Mills 1997; Varien & Potter 1997) to discover the probability of the spatio-temporal uniformity and regularity of the deposition processes using a Poisson model and a Markov chain assumption. In case archaeological data do not fit the null hypothesis of uniformity in space and regularity across time, and given the assumed regularity of the main post-depositional process, we suggest the use of an alternative hypothetical model based on the binomial negative model of overdispersion and the relevance of Power laws to understand non-homogenous and irregular accumulative processes. In this last case, we expect to be able to determine the spatial areas where specific labour activities took place during the last occupation in terms of statistical differences in the nature of accumulation
- Authors** **Hans Peter Blankholm**
- Title** *Intrasite spatial analysis past and present: an overview*
- Abstract** This paper presents an outline of the history - from the past to the present - of intrasite spatial analytical research and interpretation. Contemporary theories, methods, and techniques will be elucidated according to their historical context and analytical perspectives and prospects for the future will be discussed.
- Authors** **Rebecca J S Cannell, Jan Bill**
- Title** *The geochemistry of deposition: functions and phases identified by geochemistry and spatial analysis in the proto-urban Viking Age settlement near Gokstad, Norway.*
- Abstract** Less than 500m from the monumental burial mound at Gokstad, Norway, in 2011 a proto-urban settlement from the Viking Age was discovered. The settlement extent, including an associated mound cemetery, was mapped in a survey by ground penetrating radar (GPR). Clearly visible

INTERPRETING THE UNSTRUCTURED: NEW METHODS AND TOOLS FOR INTRASITE SPATIAL
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was a road with plots, or parcels of land, facing the thorough-fare. Further, similar sized parcels stretch away from the road toward the then shoreline. Targeted excavation in 2012 and 2013 provided a rich finds assembly suggesting both local production and international trade. With the exception of the secondary backfills in the parcel ditches, much of the structural detail had been ploughed away from the settlement area, and the artefact distribution was disturbed. A combination of geochemical analysis using portable XRF and coring targeting by excavation and GPR data was used to help understand the use of space within the plots. Concentrating on what was best preserved, the backfills in the parcel ditches, geochemical stratigraphy was used to evidence phases and types of occupation. The results from a careful comparison between the geochemical traces, artefact and eco-fact distribution was further enhanced by spatial analysis. This produced a complex picture of a changing settlement over time and space, which the artefact distribution alone could not pinpoint with certainty.

Authors

Giovanna Pizziolo, Lucia Sarti, Nicoletta Volante

Title

Intrasite analysis in the Florentine Plain: from data integration to palaeosurfaces interpretation

Abstract

In the last thirty years the expansion of Sesto Fiorentino and Firenze urban belt, now stretching across the Florentine alluvial plain, has enabled archaeologists of the University of Siena and the University of Firenze in collaboration with the Soprintendenza ai Beni Archeologici della Toscana to discover a substantial body of evidence and to identify a wide temporal and spatial range of prehistoric contexts through systematic preliminary archaeological test pits. These specific monitoring conditions have allowed archaeologists to carry out several rescue excavations in the Sesto territory. Due to these existing circumstances, the thick clusters of small trenches have led, in an area of 20 square kilometres to more than 50 systematic excavations which have revealed prehistoric contexts.

The extension of the excavation areas is related to rescue excavation rules which often do not allow us to define the complete shape of the prehistoric structures and occupation areas. In fact GIS analysis performed at inter and intrasite scale suggests that different areas that are close to each other - but not in spatial continuity - may be part of the same "settlement unit".

This paper presents some intrasite analysis of possible prehistoric settlement units characterised by multiperiod occupation. The analysis attempts to connect different palaeosurfaces by mean of 3D visualisation and through the integration of ancillary topographic and palaeoenvironmental data. In this way it is possible to compare the stratigraphic sequences spanning from Neolithic to Bronze Age and analyse, in a wider perspective, the formation process of the site and settlement strategies occurred in the area. Erosion processes and post depositional effects have also been considered. Moreover intrasite analysis has been performed using different tools and spatial references in order to get a more comprehensive reading of the use of the space and the organisation of the living-floors. The analysis of palaeosurfaces has been conducted at different levels to increase the understanding of structures, latent structures and functional areas: their integration in a wider context helps in this interpretative process.

SESSION 5J- SPATIAL ANALYSIS IN
ETHNOARCHAEOLOGY AND
EXPERIMENTAL ARCHAEOLOGY

Authors **Jonas Alcaina-Mateos, Carla Lancelotti, Javier Ruiz-Perez**

Title ***Revisiting kriging methods for microspatial data: an ethnographical approach***

Abstract This paper intends to discuss the potential of advanced computational methods for the spatial analysis of ethnographic and ethnoarchaeological data. Particularly we will concentrate on the complexity of the construction of variogram models within kriging methods.

Kriging prediction is a commonly used method for interpolation of spatial data, employed in many technical applications and several areas of expertise. Unlike the deterministic methods, kriging interpolation assumes that it is possible to reconstruct the probability distribution of a random field using inferences through a stationarity hypothesis. For this purpose it is imperative to build a valid variogram model, which is the elementary tool of geostatistics for measuring the spatial dependence of the observed phenomenon. However, the user should be aware of the theoretical implications and subtleties of this tool, in order to create a suitable empirical variogram and overcome the difficulties of the process, such as the settings of parameters and the treatment of outliers. For these reasons, kriging is considered an interactive technique, where the user input is fundamental and where different levels of exploration of the model result in different prediction outcomes.

A relatively novel approach to the construction of variogram models, include the application of goodness-of-fit tests or Bayesian approximations, intending to automatize the procedure and consider the effects of uncertainty. In this paper we will apply these techniques to ethnographical data from a rural compound in North Gujarat (India). Finally, we will show the results of the different applications and propose a set of guidelines to treat spatial data in ethnographic and archaeological contexts. This will result in an improved method to answer questions related to the use of space and distribution of archaeological remains.

Authors **Joan Negre Pérez, Myrian Álvarez, Ivan Briz i Godino, Débora Zurro Hernández, Jorge Caro Saiz, Javier Ruiz Pérez**

Title ***The influence of spatial demarcations on the modelling of intra-site anthropic markers. An ethno-archaeological case study from Lanashuaia-II, a shell-midden in Tierra del Fuego (Argentina).***

Abstract Functional areas in hunter-gatherer sites constitute one of the most challenging issues in Archaeology. Identifying and even defining what the social use of space was in a specific archaeological site is a relevant matter in the study of prehistoric societies. Any archaeological inference that would aim at social and historical interpretation will depend on the correct identification and spatial modelling of the anthropic markers. These are the material consequence or human footprint of certain social actions that took place in the past. Chemical analysis of archaeological floors has become a fundamental tool to identify this kind of markers and their meaning regarding functional uses of space. Usually, several interpolation techniques and Geostatistics approaches have been used in order to model these trends and identify their significance (Rondelli et alii, 2014). Despite this remarkable improvement in data interpretation, some aspects of the analysis still need to be taken into evaluation. For example, one of the most important issues is to consider demarcations, such as walls or shell rings, into the spatial analysis of the chemical samples.

Archaeological shell-middens from Tierra del Fuego constitute an optimum arena for studying the spatial behaviour of certain anthropic markers in hunter-gatherer sites. Good preservation of archaeological remains as well as the rich ethnographic record about the hunter-fisher-gatherer

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societies who inhabited this region allow us to understand them accurately (Briz et alii, 2009). In addition, these conditions provide a perfect scenario to test new ways to model coordinated data into a continuous surface with spatial barriers. In our case study, these demarcations correspond to the characteristic ring structure formed as a result of the deposition of malacological residues around perishable huts

The aim of this work is, therefore, double. First, to present the results of an intra-site spatial analysis based on the distribution of different anthropic markers from the site Lanashuaia-II, a shell-midden located on the northern coast of the Beagle Channel (Tierra del Fuego, Argentina). On the other hand, introducing new elements of complexity, such as demarcations (López-Quilez & Muñoz, 2009), into geostatistical analysis of data coming from soils samples. Results are expected to be representative of different functional uses of space, allowing us to identify production and/or consumption areas within the habitat and its surroundings. Ethno-archaeology is used as a methodological tool to give content to the concept of anthropic marker by means of formulating archaeological hypothesis based on ethnological information.

Authors**Francesco Carrer****Title*****Interpreting intra-site activities and post-depositional processes: ethnoarchaeological case studies from the western Italian Alps*****Abstract**

The spatial organization of assemblages within structures is an issue that is often tackled by archaeologists. Cluster analysis and Principal Component Analysis (PCA) are commonly applied to archaeological case studies in order to identify specific intra-site activity areas. In some cases a number of post-depositional processes, such as trampling, have been assumed to explain the apparent displacement of objects from their primary position. However, the identification of activity areas and the effects of post-depositional processes in the archaeological record are complex and not easily identifiable. Analogical models are required to assess the reliability of the archaeological assumption; besides, statistical methods can be a useful tool to analyse complex and puzzling datasets. In order to inform these models, ethnoarchaeology and experimental archaeology have been used. While the former dealt mostly with the spatial patterning of assemblages in domestic structures and inhabited spaces, experimental archaeology provided interesting insights for investigating artefact/ecofact displacement in archaeological contexts. However, statistical methods are rarely applied in these studies.

This paper seeks to fill this theoretical and methodological gap through a focus on two dry-stone huts, seasonally used by a cattle herder, in the Val della Brignola (Cuneo province, western Italian Alps). The position and attributes (dimension, material, function) of all ecofacts and artefacts scattered on the internal surface of these huts were recorded. They were managed and analysed using R, a free software and environment for statistical computing. Different quantitative methods have been applied to these data. Cluster analysis on the entire dataset and on specific subsets has enabled to identify possible activity areas. Methods for assessing the spatial anisotropy of the artefacts/ecofacts were applied in order to identify directionality. Spatial autocorrelation was also estimated, in order to recognize spatial patterns in object attributes. Interviews with the herder provided the behavioural framework for interpreting and contesting the results of statistical analysis, providing explanations for the function of each part of the huts, the intra-site mobility and the maintenance strategy (sweeping the surface, removing the bulky waste, etc.). The spatial patterns identified were correlated with this information. The interplay between spatial statistics and ethnoarchaeology inference returned very significant data that will be of great interest for the interpretation of spatial patterns in archaeological sites, especially in seasonal contexts. Furthermore, it suggested that spatial analysis would improve the role of ethnoarchaeology as a tool for supporting not only archaeological interpretation but also archaeological fieldwork strategies.

SESSION 5J

SPATIAL ANALYSIS IN ETHNOARCHAEOLOGY AND EXPERIMENTAL ARCHAEOLOGY

SESSION 5K:- WHERE DO WE GO FROM HERE? LEAST COST PATHS REVISITED

Authors **Dimitrij Mlekuž, Devi Taelman**

Title *Energyscapes – An energy expenditure approach for the trade of ornamental stone in Central Adriatic Italy*

Abstract Movement is a fundamental way of how people interact with with places, things and other people. People move around, carry objects, moving them into new positional and relational contexts with other things, and they create new material encounters and new material traces through movement.

It is well-known that travelling over water is cheaper than over land, that moving around in mountainous areas is more difficult than in flat areas and that large loads can only be transported by harnessing the energy of draught animals using technology such as ox carts or sledges. Transport of building material constituted a major expense of a construction project, sometimes even exceeding the costs of the actual raw material and its quarrying. The distribution of bulky and heavy goods – such as ornamental stone – is therefore, at least partly, related to the cost of their transport. Deviating distribution patterns in relation to transport costs could indicate external intervention (e.g., by the state) in the prevailing market system.

We suggest that energetic considerations could be one of the main factors determining the availability of heavy and bulky material in a landscape. Physiological studies have proposed that the metabolic cost of moving is in direct proportion to the weight of carried loads. The transport of heavy loads thus requires a very different approach to the landscape than just traveling.

We created several “energyscape” models depicting the predicted costs of moving different loads and using different technologies (ox carts). We suggest that energetic considerations could be one of the main factors that determine the availability of heavy loads in a landscape. Another important question we address is the question of anisotropy. When transporting heavy loads, moving downhill require less energy, than moving uphill. For these reasons, the strategies adopted for ascending can be very different than those for descending.

The energyscape model presented in this paper offers an analytical tool for understanding the costs of movement and transport, and therefore allows a deeper understanding of the importance of the energy requirements as a variable for structuring the Roman economy. The approach identifies areas that are more accessible and so shows the structuring potential of the landscape itself on the transport and practices in landscape. Thus some areas could have functioned as low energy corridors where transport of heavy loads was facilitated by the landscape. Energyscapes can help us to understand the limits energy expenditure impose on transport of material.

As a case-study, the trade of ornamental stone in Central Adriatic Italy in Roman times is selected. Stone resources suitable for ornamental use did not occur in Central Adriatic Italy and thus had to be imported from more distant sources, notably Greece, Turkey, Egypt and North-Africa. The ornamental stone assemblages of five Roman towns (Potentia, Helvia Ricina, Trea, Forum Sempronii and Suasa) are compared with the results of the energyscape model.

Authors **Irmela Herzog**

Title *Dispersal versus optimal path calculation*

Abstract In the past, there has been some debate if standard GIS software is able to reconstruct the globally optimal path between two locations or if only a locally optimal path is generated. Nowadays, most least-cost path (LCP) software is based on a full implementation of Dijkstra’s algorithm and therefore calculates the globally optimal path with respect to the cost function chosen. The only drawback of this method is the fact that Dijkstra’s algorithm was designed for

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graphs, and the raster to graph conversion may introduce deviations from the optimal path. For calculating a globally optimal path complete knowledge of the landscape is required. But people spreading into unknown territory only see a small part of the landscape. This contribution introduces models for dispersal taking the costs of movement into account, i.e. discusses methods for creating locally optimal paths. A very simple algorithm is to apply some drainage procedure to the cost surface so that the path is constructed by successively choosing the next least costly step. In general, this procedure will only generate one path for each start location, and the path will change direction if this introduces minimal cost savings compared to continuing in the same direction. Maybe modern people spoiled by satellite navigating systems will walk like this but I assume that people in the past had some sense of direction and that some random influences play a role as well. For this reason, an agent-based approach was chosen where the agent's next move depends on the environment, i.e. the costs to be paid for the next step, the strength of the pull towards the preferred (initial) direction and the number of agents that already visited the possible target cells. The latter condition ensures that corridors rather than single cell paths are identified when tracking the dispersal of a large number of agents. Each agent moves until a predefined cost limit has expired. For this approach the raster to graph conversion, limiting the number of possible directions of movements, results in visible drawbacks. The presentation will discuss the methods, present some examples of agents' track images and compare these with least-cost radial networks for a given location. The examples are taken from the Bergisches Land, Germany, where the Medieval patterns of movement were derived from some known old trade routes.

Authors	Emma Slayton, Viviana Amati, Termeh Shafie, Ulrik Brandes, Menno Hoogland, Corinne Hofman
Title	<i>Least Cost Pathways and the Caribbean Sea: Using least cost pathway modeling to explore reciprocal connections between the Greater and Lesser Antilles.</i>
Abstract	The use of the sea as a surface for travel is still something which needs to be studied in more depth. In terms of computer modeling, there has been a great deal of work done on agents based modeling, but these efforts have often been directed towards modeling colonization movements or large scale migrations. However, when discussing regional mobility or exchange networks it may be a better approach to have analysis centered on more directed least-cost pathways.

Reachability is a prerequisite for the existence of interaction between sites. Ease of reachability affects access to specific resources and may moderate the strength of social ties between settlements. As we are generally interested in reconstructing interaction networks in the Greater and Lesser Antilles, we are also interested in analyzing plausible pathways that may have served as a transportation infrastructure.

Our approach is an adaptation of least-cost pathways common in landscape analysis to a maritime environment. Factors influencing the necessary effort to travel from one location to another thus include currents and winds as well as their seasonal variation. Combining these several factors together is difficult and new model may need to be explored to fully capture the total effects which a canoer must face when choosing to set out on an inter-island voyage.

The advantage in terms of using the environmental constraints mentioned above is the ability to observe acute changes in surface on which pathways are constructed. The seasonal fluctuation can also mean a stark difference in terms of which communities have the ability to exchange

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with others during specific times of the year. Focusing on the inter connections between the island chains, as showcased at the site of Kelby's Ridge² on Saba during the Late Ceramic Age, 1250-1400, may help to expose the construction of the mobility and exchange networks which existed over the course of several generations and expose possible key or central links between the two.

Authors

Mark Raymon Groenhuijzen, Philip Verhagen

Title

Through hell and high water: a multimodal transport network in the Dutch Roman limes

Abstract

Computational studies of movement in archaeology thus far largely focus on unimodal land-based movement or transport systems, in which natural terrain, visibility, social and cultural factors are seen as limitations or opportunities that determine the character of movement (Murrieta-Flores, 2010). Fairly little attention has been paid to water-based movement, and even less computational work has been performed on multimodal transport systems, which can potentially utilise both land-based and water-based transport modes. As a dynamic fluvial landscape, the Dutch river area is an excellent example of an environment where people would often require multimodal transport systems to exchange information, distribute resources and maintain social contacts. During the Roman period, the Dutch river area formed part of the Roman *limes* and witnessed the shift from subsistence to surplus agricultural production to at least partially supply the Roman military population, meaning that transport on local to regional scales must have intensified. Furthermore, the Dutch river area possesses extensive datasets from both archaeological as well as physical geographical research, which makes it an ideal testing ground for spatial computational approaches.

This paper aims to study the role of multimodal transport systems as part of the interconnections within the local population as well as between the local population and the Roman military population in the Dutch river area. The research forms part of the NWO-funded "Finding the limits of the *limes*" project, which aims to investigate the cultural landscape of the Dutch Roman *limes*, especially concerning the spatial and economic relations between the local and military populations, through spatial dynamical modelling.

To achieve this, a detailed palaeogeographic map is constructed for the study area that allows for least cost modelling of both land-based and water-based connections, as well as a combination of transport modes. Cumulative cost path networks (Verhagen, 2013) are then modelled for different scenarios that represent factors such as the (non-)availability of certain transport modes. Problems that arise and have to be overcome when modelling multimodal transport connections are the heterogeneity of energy consumption in land- and water-based transport, as well as the possibility that water-based transport has the capacity to carry multiple persons and goods, which can be remedied for instance by applying directional cost maps for water transport and using varying access costs for water transport modes. The resulting networks can be compared using network analysis (Verhagen et al., 2014), which can identify sites of central importance in (mass) transport networks and explain the position of military sites in transport networks. Accurate dating of archaeological sites also allows the study of the evolution of transport networks chronologically.

WHERE DO WE GO FROM HERE? LEAST COST PATHS REVISITED

Authors Sylviane Déderix

Title *Traveling across archaeological landscapes with the hierarchical communication network*

Abstract Least cost path analysis allows calculating the most cost-efficient way to reach a specific destination from a defined origin. But in archaeological contexts, where only partial data are available regarding the distribution of the sites, least cost paths can only offer limited insights into general patterns of movement. Furthermore, least cost path analysis assumes that each pair of sites was connected through a direct route, which was certainly not the case. In order to cope with such issues, GIS specialists such as Llobera, Murrieta-Flores, and Verhagen have approached accessibility and movement in a less archaeologically constrained manner, by attempting to model regional mobility potential instead of tracing discrete paths between known archaeological sites (Llobera 2000; Murrieta-Flores 2012; Verhagen 2013). Using Early Bronze Age south-central Crete as a case-study, this paper proposes to split the difference between cost surface analyses that are strictly constrained by the location of recorded archaeological sites and those that disregard available cultural data in the course of the computational process. It builds on the recently developed focal mobility network procedure (Fábrega-Álvarez 2006; Llobera, Fábrega-Álvarez and Parceró-Oubiña 2011) to model what can be described as a hierarchical communication network – i.e. a network in which the paths are ranked according to the relative importance they seem to have played in connecting the communities established in south-central Crete during the Early Bronze Age.

SESSION 5L- MODELLING LARGE-SCALE HUMAN DISPERSALS: DATA, PATTERN AND PROCESS

Authors

Benjamin Davies

Title

“Reediness is not a Polynesian character”: Modelling Pacific Island settlement and potential effects of spatiotemporal constraints on survival and human body dimensions

Abstract

Remote Oceanic peoples tend to be moderately tall and broad-bodied; traits not shared by probable source populations. Mitochondrial and chromosomal DNA evidence suggests that serial genetic bottlenecks occurred during the process of dispersal into the islands of the western Pacific, and this has been used to explain the prevalence of certain monogenic traits among Remote Oceanic populations. This study employs an individual-based demographic modelling approach to examine the prospect that these stochastic processes produced the morphological characteristics as well, using regional archaeological studies to provide spatiotemporal constraints for bottleneck events. Within the model, individuals age and are subject to age-and-sex-specific mortality and fertility profiles derived from a range of analogous populations. Anthropometric variability within and between populations is modelled using positively correlated simulated distributions of height, biiliac breadth, and biacromial breadth. These characteristics, along with a maternally-inherited genetic trait, are passed from parents to children in a biologically-consistent manner. Subsets of existing populations then disperse across biogeographic barriers, preventing any further admixture between parent and descendent populations. Our analyses confirm that repeated bottleneck events could very well explain the molecular genetic characteristics of Remote Oceanic populations; however, polygenic characteristics such as body size are not similarly affected. When the frequency of reaching the lowest mean value for the measured characteristics in Remote Oceania is used as a threshold, likelihoods of crossing that threshold under all scenarios considered are very low, and those scenarios which are the most likely to produce the body change during the time permitted by the chronometric window are assessed in terms of their demographic and cultural impacts. Alternative mechanisms for producing this change are proposed.

Authors

Fulco Scherjon

Title

Large scale population modelling in the deep past. Issues and concerns. HomininSpace, a case study in points.

Abstract

Genetic, morphological and archaeological research suggest that the Neandertal lineage disappeared around the time that modern humans arrived in Europe. The exact process, timing and causation are poorly understood. Landscape scale taphonomy and research intensity create a biased record. HomininSpace 2.0 is a modelling and simulation system for exploratory analysis of dispersal behaviour of hominin groups in large scale realistic landscapes and over long timescales. As a case study to validate the concept, an explicit Neandertal model is constructed and implemented. Simulation against the Neandertal archaeological record is used to identify the most likely values for key model parameters. The aim of this research is to quantitatively assess the importance of different parameters on the energy management of past hominins. As such HomininSpace offers an alternative approach to analysis of the past.

HomininSpace is an agent based modelling and simulation environment where a fluctuating carrying capacity in a reconstructed paleoenvironment is the key attractor for hominin dispersal. A year by year demographic model for Neandertal groups moving through North-west Europe is simulated from 131 ky BP to 50 ky BP. Presence and absence results are matched against the archaeological record which is stored in a comprehensive database of Checkpoints in Space and Time. These points store site name and GPS location, the archaeological material that is dated, chronometric dates assigned including accuracy and dating method, reference to the literature, and a confidence level. Each date translates into an interval that keeps track of foraging groups in the area.

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This paper discusses how important the availability of precise dating results can be, the issues when creating an explicit hominin model, and the concerns when evaluating simulation results. The discussion illustrates the deficiency in accurate chronological information for North-west Europe, arguably the most intensely studied Middle Paleolithic area. It will also address the unique possibilities that modelling and simulation efforts offer in using such limited amounts of data in hypothesis development and explorative analysis of large scale dispersal patterns.

Authors **Giacomo Capuzzo, Juan Antonio Barceló**

Title *Adoption of innovations and expansive phenomena in the 2nd millennium BC in Central and Western Europe.*

Abstract The 2nd millennium BC in Central and Western Europe represents a perfect case study to test different and competing hypotheses of social dynamics and economic changes in early-complex societies. Traditionally, for the European Bronze Age scholars have been able to detect the existence of macro-scale spreading phenomema whose material consequences have been recorded in the archaeological deposit. Among the most studied ones we can refer to the diffusion of cremation burials within the so called "Urnfield culture" and the introduction and spread of specific pottery and metal typologies (handles with vertical expansion, fluted pottery and bronze knives).

In this presentation, after having illustrated the theoretical aspects relating to the case study, we aim to quantify episodes of adoption of innovation which took place during the 2nd millennium BC in Prehistoric Europe. In particular, our study focuses on those characterized by an expansive behaviour.

In order to tackle this issue we present the results of a geostatistical analysis carried out through a computer programmed modeling of different space-time datasets. The data originate from the EUBAR database, which collects more than 1700 georeferenced and radiocarbon dated archaeological contexts of a period between the Early Bronze Age and the beginning of Iron Age from an area including the North-East of Iberian Peninsula, Southern France, Northern Italy, Switzerland, Austria and Southern Germany.

Authors **Michael Märker, Michael Bolus**

Title *What can we learn about the environmental preferences of Neanderthals and Modern Humans using stochastic modeling ?*

Abstract In this study we focus on the characterization of Neanderthals and Modern Human site locations using environmental data and different stochastic models. The models were trained using an unique spatial dataset of Neanderthal sites and a set of Modern Human find locations. We applied a boosted regression tree approach (TREENET) and a statistical mechanics approach (MAXENT) to test model robustness. As predictor variables a set of Terrain Indices based on digital elevation models and additional environmental information such as climatic and vegetational/ faunal information were utilized. A quantitative evaluation of the models was done using internal model performance indices such as the Receiver Operating Characteristics (ROC) curves for the train dataset and a validation test dataset. The dependent variable or target variable in this study are the locations of Neanderthal sites and Modern Human sites described

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by latitude and longitude. The information on the site location was collected from literature and own research. The study illustrates that the models are able to characterize the environmental preferences of Neanderthals and Modern Human expressed by a specific spatial distribution and a certain variable importance

Authors

Thomas G. Whitley, Geoff Avern, Christine Markussen, Katie Simon

Title

Modelling in Le Mandement: Using GIS and Geophysics to Examine Caesar's Campaign against the Helvetii in 58 BC

Abstract

In the first chapter of "Comentarii de Bello Gallico" Julius Caesar recounts his campaign against the Helvetii in 58 BC. He asserts that the forces arrayed against him included 92,000 warriors amongst a mobilised mass of about 368,000 Gauls. This far outnumbered his six legions of ~30,000 men. Other interpretations of the campaign calculate a much smaller Gaulish contingent; with as few as 16,000 warriors. But what were the actual numbers? The generally accepted view is that Caesar inflated them for political gain. Caesar also explains the Helvetian incursion as arising from the pressures of Germanic tribes north of the Rhine, and the constriction of the Alps and Jura on their available resources. Can we perhaps shed some light on these assertions? Were the pressures on the Helvetii due to stress on the regional carrying capacity? Or can we perceive other economic advantages behind their migration?

The aim of this paper is to examine a few of these issues using new techniques for modelling human energetics and dynamic mobility. This on-going three part project is aimed at developing: 1) a large-scale GIS simulation of the economic situation across all of the Helvetian territory as it existed just prior to the war, addressing the mechanisms of energy capture, exchange, storage, and loss in the context of the various population estimates; 2) a medium-scale model for kinetic energy expenditure by both groups specifically along the Rhône defences, and; 3) remotely sensing archaeological signatures in the small scale area known as Le Mandement (located just outside of Geneva, Switzerland). The specific landscape visualisations focus on the situation as it existed prior to the war across all of the Helvetian territory, and locally in the region of the Rhône between Lac Lemman and le Pas d'Ecluse. The former as an expression of potential energy sources (e.g. agricultural and pastoral productivity, plus wild and semi-domesticated resources), as well as systems of energy exchange, transport, storage, and loss. The latter is examined as a model for kinetic energy expenditure (e.g. the building and maintenance of the wall to dramatically increase the "friction" costs of the invasion), and the tenuous nature of long-range energy supply (i.e. the Roman supply lines).

Ultimately these examples provide ways of illustrating patterns of past human behaviour and movements that can be spatially quantified but are perhaps difficult to identify archaeologically. They can also be seen as insights into the cognitive processes employed by past people such as Julius Caesar, who did, in fact, keep track of, evaluate, and forecast the energy costs of politics, battles, and their future payoffs. Our goal in this presentation is to present the results of the large scale GIS landscape modelling, some preliminary geophysics findings and issues on both the medium and small scales, and to take a look forward to our proposed next steps in the process.

MODELLING LARGE-SCALE HUMAN DISPERSALS: DATA, PATTERN AND PROCESS

Authors **Andrea Zanotti, Jean-Pierre Bocquet-Appel**

Title *An Agent-based Model to Simulate the Balkan Neolithic Expansion*

Abstract Stochasticity and contingency make the simulation of the history of an archaeological society unlikely. However, the technique introduced by Braudel (1958) and the *Ecole des Annales*, in which the flow of historical information is broken down into temporal sequences of different durations (long, medium and short) allows modeling to focus on the fraction of total History where contingency and stochasticity will be at a minimum. This is the case with the "*longue durée*" of geohistory, that is to say the fraction of human activities that is mainly determined by the multi-secular (millennial) permanence of structural geo-environmental conditions. In the "*longue durée*" we find, in particular, the system of economic production (techniques and social relationships) that ensures the biological survival of a population and which can be summarized by the term "infrastructure". This is the general framework for this modeling study on the Balkan Neolithic expansion.

Reconstructed (estimated) geoenvironmental data (on climate and soil fertility) at the regional scale in the Balkans were incorporated into an agro-pastoral economic system obtained by ethno-archaeological inference, and into a Balkan-Anatolian anthropological model of the nuclear family. The process of Neolithic expansion in the Balkans was then simulated. What are the preferred settlement areas given by the simulation? Does the simulated pattern of expansion match the observed archaeological pattern?

Authors **Simone Callegari, John David Weissmann, George Lake, Christoph P. E. Zollikofer**

Title *High-performance agent-based models of worldwide human dispersals*

Abstract Recent advances in palaeoanthropology, archaeology, and ancient genomics, have yielded unprecedented insights into the prehistory of *Homo sapiens*. Worldwide spatial patterns of genetic and phenetic distance and variation, as well as archaeological findings, can be interpreted in the context of an African origin and out-of-Africa dispersal of our species during the late Pleistocene. However, quantitative tests of hypotheses about the population dynamics of the genus *Homo* are difficult to conduct, since models of large-scale human dispersals often neglect intrinsic stochasticity and environmental variability, and genetic patterns are modeled in terms of local populations or demes. Here we present an agent-based modeling framework for large-scale population dynamics that is able to handle millions of agents and timesteps in a geographically and ecologically structured environment. We show results from simulations of the out-of-Africa dispersal of *Homo sapiens* in which each agent can be thought of as a simplified, single individual. From these, we reconstruct the worldwide genetic history of our simulated populations, tracing back the complete ancestry of sample individuals. Finally, we show how large-scale parameters of population demography and diffusion affect the emerging spatiotemporal patterns and genetic signatures of the dispersal process.

Authors **Iza Romanowska, Seth Bullock**

Title *Testing the Variability Selection Hypothesis on Hominin Dispersals - an Agent-based Modelling Approach*

Abstract The Variability Selection Hypothesis proposed by Potts (1996; 1998) postulates the evolution of behavioural plasticity among early hominins arising during periods of strong environmental fluctuations in the last 6 million years. It argues that the inconsistency in selection regimes caused by the rapid environmental fluctuations produced particularly strong selection pressure on adapting to change rather than any particular set of conditions (termed 'adaptive complexity', 'adaptive flexibility', 'adaptive versatility', or simply 'versatilists organisms'). The work by Potts was further formalised by Grove (2011) in a single locus model and tested on the temperature curve spanning the last five million years. The current implementation aims to assess the implications of the Variability Selection Hypothesis on the agent's ability to disperse, a process that is visible in the archaeological record. The model was translated into a stochastic multi-agent simulation to investigate the dynamics between individuals with different positions and range on the adaptative spectrum (including the 'versatilist' individuals) within a non-homogenous population. The initial results shows that using heterogeneous multi-agent simulation can successfully replicate Grove's formal implementation but also sheds new light on how the pattern of dispersal unravels under different environmental regimes.

Authors **Penny Spikins, Andy Evans**

Title *The Dark Side of Dispersal: Modelling the effects of altruistic punishment, spite and vengeance on the spread of modern humans*

Abstract Ethnographically documented hunter-gatherers show unique patterns of social dynamics - unlike any other animal, fission-fusion societies in hunter-gatherers allow individuals to move freely between distant groups, moreover counter-dominance tactics actively promote expulsions, occasionally forcing potential founding populations into new regions. These dynamics are founded on uniquely human emotional capacities to forge new alliances or forcibly break old ones. However whilst attention is often focused on the biology of modern human populations or on human cognitive abilities the influence of emotional capacities on population movements has received little attention. Are expulsion events, driven by the very human emotions of altruistic punishment, spite and vengeance, the missing factor in modern human dispersal, motivating risk taking and distant colonisation events? Here we use agent based models to model different scenarios of dispersal and assess the potential impact of counter-dominance based expulsions on the global colonisation of our species.

- Authors** **Natalie Tkachenko, Simone Callegari, John David Weissmann, Wesley P. Petersen, George Lake, Christoph P. E. Zollikofer**
- Title** ***Individual-based modeling of population growth and dispersal in discrete time***
- Abstract** There is an increasing interest in spatio-temporal models of ecological dynamics and evolutionary processes that take into account the fact that populations consist of discrete entities, i.e., individuals. Such models allow to consider individual variation explicitly and are well-suited to the study of stochastic processes. Individual-based models (IBMs) that can be analyzed analytically and numerically are one type of such discrete models. IBMs represent thus an important approach for modeling (past) human population dynamics, especially when investigating large-scale emerging patterns.
- A common property of individual-based growth and growth-diffusion models is however the continuous-time implementation, in which individual “actions” happen one at a time. This approach does not scale well when simulating large number of individuals, and is not easily parallelizable on distributed memory machines.
- For this reason, in this work we describe an individual-based stochastic model of growth and diffusion with overlapping generations which is suitable for large-scale simulations in structured environments. The model uses a discrete-time paradigm with constant time step; as a consequence all agents act simultaneously based only on information from previous time step.
- By describing the system with a discrete-time Master equation we show that our stochastic model approaches the Fisher-Kolmogorov model in the continuum limit. The properties of the model at different discreteness levels are analyzed by means of numerical simulations as well as analytical approximations. We confirm qualitative trends found in previous works on stochastic birth-death models and growth-diffusion models, and find some novel and interesting features; in particular, the discrete-time algorithm shows different noise properties compared to continuous-time stochastic models. We show how these features affect emergent properties of the population such as the effective carrying capacity and the dispersal speed: both tend to decrease for high level of discreteness.
- Due to the simultaneous acting of all individuals, the model can be parallelized and is suited for High Performance Computing. This allows to increase the spatial and temporal resolution as well as to consider larger spatial domains and longer simulation times. Thus, the model is suited for the simulation of large populations expansions during human history. We discuss possible expansions of the model and the inclusion of real observational data.
- Authors** **Tarja Sundell, Martin Heger, Juhana Kammonen**
- Title** ***Reconstructing the boom of prehistoric hunter-gatherer population size in Finland by agent and equation-based modelling***
- Abstract** This paper discusses the boom of Finnish hunter-gatherer population size in the Neolithic. The marked increase in the size is based on the summed probability distribution of archaeological radiocarbon dates (Tallavaara & Seppä 2012) and the analyses of the Stone Artefact Database (Sundell et al. 2014). These provide clear evidence for a clear increase in the archaeological signal 4000-3500 cal BC followed by a distinct weakening.

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The spread of Typical Comb Ware culture into Finland c. 4000-3900 cal BC is apparent and coincides with the population size phenomenon. At the time, the climate was at its thermal maximum, which probably contributed positively to the resources available to inhabitation. In this paper we aim to find out the processes behind the human dispersals and the increasing size of the population by employing agent and equation-based modelling. Prehistoric population fluctuations also have consequences to the present day genetic diversity. These can be studied by population genetic simulations where evolutionary forces i.e. mutation, migration and genetic drift are incorporated. We employ population simulations to follow genetic changes over hundreds of generations and evaluate the effects of a Neolithic population size to the present day genetic diversity. A genetic simulation approach, including several separately simulated parameter combinations, enables us to evaluate which population scenarios are most likely to be true and, at the same time, exclude the least compatible scenarios when modelling past demographic events.

Authors **Stephanie R Rogers, Philippe Curdy, Muriel Eschmann Richon, Ralph Lugon**

Title *Modelling glacial archaeological potential in the Pennine Alps – A multidisciplinary approach*

Abstract This project integrated historical, archaeological, and geographical knowledge to analyse the glacial archaeological potential of the Pennine Alps, located in high altitude glaciated passes (3,000 to 3,500 m asl) between Switzerland and Italy. The results document site-based archaeological information that will disappear forever once the glaciers that preserve them have melted. Therefore, the main goal of the project was to preserve archaeological heritage threatened by melting ice around the passes and safeguard fundamental, but perishable, materials in vanishing ice fields.

The methods used included a historical archival text analysis, geospatial modelling, and archaeological prospection in the field. If the written sources did not provide exact information about the passes themselves or how frequently they were used in the past, the sources could still be used to demonstrate their regular usage thanks to related documentation linking political tensions or trade disputes between valleys. The information collected was used as a basis for conducting least cost path and locational analyses in GIS along with a regional scale glaciological modelling approach to determine where archaeological remains might be found in the future based on the principles of human accessibility and topographical characteristics of the terrain. One major scientific objective of this project was to use glaciological modelling to determine what the glaciers could look like in the future in this study area, in order to assess the degree of urgency for archaeological prospection. In collaboration with glaciologists, glaciers were modelled in 10-year stages from now until 2100. This information was used with results from the locational analysis in GIS to predict where archaeological remains could be found in the future based on future glacier geometries and the topography of the terrain. The results of the historical and geographical aspects were used as decision support tools for conducting archaeological prospection in the field. Archaeologists conducted 20 days of prospection at 13 different sites and collected over 100 pieces of wood deposited at the glaciers surface or in their glacial margins. As yet, 36 pieces have been dated using radiocarbon analysis; 19 were dated to modern time (later than 1600 AD), seven to the Middle Age (~500-1600 AD), six to Roman time (0-500 AD), and four to Prehistoric time (earlier than 1000 BC). The majority of the ancient wood pieces are non-worked stakes which were probably used as route markers. However, wood pieces were frequently highly distorted due to ice movement and their function cannot be interpreted. The results demonstrate that humans have crossed these glaciated high altitude passes for over 3,000 years and additionally can serve to protect the fragile archaeological heritage threatened by the melting of ice.

Authors **Guy De Mulder, Mark Van Strydonck**

Title ***Radiocarbon dates, cremations, flatgraves and the appearance of the urnfield cemeteries in Belgium***

Abstract Traditionally, the Late Bronze Age is seen as the period during which the urnfield cemeteries appeared in the funerary archaeological record in Belgium. Flatgraves were dominant and replaced in most cases the former barrow tradition. Inhumation was replaced by cremation of the deceased's body. This transition was dated around 1100 BC based on the typochronological study of the accompanying funerary goods in the burials

Radiocarbon dates on cremated bone offered new insights in the origin of the flatgraves and urnfield cemeteries. The appearance of cremations and flatgraves is according the present information a more complicated evolution with regional differences. This process started earlier than assumed before. Some dates are as old as the 15th-14th centuries cal BC. This new phenomenon clearly dominates the funerary ritual from 1200 cal BC onwards, but between 1500-1200 cal BC a co-existence of both traditions of barrows and flatgraves is evident. By using Bayesian analysis we want to try to refine the chronological information concerning flatgraves and the introduction of the cremation ritual in Belgium.

SESSION 5M- IMPROVING RESOLUTIONS:
USE AND POTENTIALS OF QUANTITATIVE
METHODS IN NEAR EASTERN
ARCHAEOLOGY

Authors **Simone Bonzano**

Title ***The Gis-Archaeologist: methodological and analytical remarks on ancient near eastern highlands.***

Abstract

In Near Eastern Archaeology highlands' study are definitely recent. This is a branch in constant and quick growth supported by a good number of new researches in Caucasus, Anatolian and Iran: it is almost possible to talk about the birth of a 'Landscape Archaeology of the highlands'.

However, there is not a specific methodology for this kind of studies are scanty and, often, archaeologists and landscape archeological in those area use adapted 'plain-based' techniques developed for the plain of Levant and Mesopotamia: and that is particularly true in the use of GIS, Remote Sensing and Spatial Analysis.

In comparison with plain environment, the study of the highlands requires a different and more contextualized approach, not only archaeological, but also able to address morphological and anthropological issues such as natural erosion, seasonal blocked communication, zonal farming and regional cohesion. One of keys to understand those environments is the study of the rural pathways among the mountains, the one that supports the developing and adapting of the regional social structure.

In this paper, I will present a specific GIS landscape modelling's methodology I used in Turkey and Iraq, based mostly on Weighted COST surfaces and Topographic Indexing able to outline the route's network of regions following archaeological, anthropological and/or historical parameters.

In the first case of study, the GIS model outlined the routes' and pathways system around first millennium BCE Lake Van and its entanglement with the coeval settlement patterns. The relationship between transhumant semi-nomads (who travels along the inland paths) and the Urartian central power (who uses the maion roads) was aimed.

The second case present an outline of the main communication axes crossing the district of Koya in Iraqi Kurdistan and, at the same time, the web of pathways entangled with them. The main aim has been an early understating of human movement in the area before any fieldwork to plan the scheduled archaeological survey. Archaeological data were paramount in the first case as well as anthropological and historical were here.

During these two tests, this interpretative methodology has shown his strengths and use, not only to obtain marvelous map but to actually support and push rural study in piedmont and mountain areas.

Authors **Nazarij Bulawka, Barbara Kaim**

Title ***The Iron Age in Serakhs oasis (Turkmenistan). The preliminary results of the application of Geographic Information System in the study of the settlement pattern of the earliest confirmed occupation of the oasis.***

Abstract

Almost twenty years, the Serakhs oasis, located in southern Turkmenistan, has been studied by Polish-Turkmen Archaeological Mission headed by Prof Barbara Kaim. The intensive field survey, conducted since 2007, resulted not only in a discovery of almost one hundred fifty sites of different periods, but also sheds light to the Yaz period earliest confirmed occupation of the oasis.

The Iron Age (Yaz I-III periods) archeological material, first abundantly described by V.M. Masson, have been discovered at above 500 sites situated in Central Asia, north-eastern Iran and Afghanistan by various studies carried on since the beginnings of the XX century. But, so far comparing to other areas, not much was known about the Yaz I-III settlement in the Serakhs

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oasis in Turkmenistan.

The analysis of settlement pattern and the topography, presented in the paper, makes it possible to assume the extent of irrigation system in Yaz periods in the Serakhs oasis and indicates the future areas of study.

The created ArcGIS database, which gathers satellite imagery, digital elevation data, topographic maps, the vector data related to hydrology, ancient and recent occupation are used as a tool to discuss some important questions in the settlement pattern on the oasis.

Authors

Tuna Kalayci

Title

Archaeological Sites and Site Territories: A Remote Sensing Approach for Modelling Production Landscapes

Abstract

This study investigates the relationship between settlement areas and food production levels in Upper Mesopotamia during the Early Bronze Age. Archaeological data from the area provide substantial information on the sizes of agricultural territories around tell-based nucleated settlements. First, we use CORONA imagery to document evidences of past production as well as the settlement areas. Second, we employ a crop-growth model using AVHRR-NDVI data, coupled with precipitation values from the region. This model generates a high resolution spatial time-series data of modern production levels. Finally, we use modern day production analogies in order to explore empirical data and to understand rain-fed agricultural strategies in the Early Bronze Age. CORONA remote sensing survey results reveal no significant relationship between archaeological sites and their production territories ($r^2=0.40$). Likewise, the relationship between site areas and estimated staples production is also a weak one ($r^2=0.30$). On the other hand, if we take in consideration biennial fallowing as a production strategy, the correlation becomes meaningful ($r^2=0.85$). Furthermore, model data suggests only settlements smaller than 50 hectares were potentially practicing biennial fallowing.

Authors

Vanessa Juloux

Title

New data mining approach to analyze male or female agency : inventory of action verbs

Abstract

During the “gender methodology” symposium in Helsinki, I introduced an innovating approach of data mining to study narrative texts: the inventory of verbs (IdV) ; its goal is to determine the agency of an entity or at least to give measurable indices, no matter whether biologically it is a male or a female.

The agency, in other words the capacity of each entity to act individually on his own initiative, is an extremely valuable tool to understand relations between two or more actors from social reality or fiction. Using it in studies of ANE civilizations, agency could be seen as a way for an ethnographical reading of understanding relations. The agency is especially true by looking at the actions verbs depending on the context, that is to say an IdV. Without data mining approach, it would be a daunting task. To get more relevant results, two more criteria

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complement the IdV : semantic comparison and images. How does all it inter-relate in an IT development project to be used by scholars in humanities ?

This project is divided in four steps: 1) to add data in a SQL database (DB) ; 2) to extract verbs from transcription in XML TEI format and to record them in a native XML DB ; 3) to import SQL data to XML DB ; 4) to do statistics.

1) There is a significant loss of informations contained in books. Beforehand it is useful to record all exploitable informations about verbs (verbal root, synonym, context, corpus, chronology, etc), particularly for the semantic comparison. At every opportunity, this informations will be added in SQL DB.

2) Transcription of text will be encoded in XML TEI where actions verbs, context, place (outside/inside), entity (assaulted/assailant), her name and “biological” sex (no matter whether human or divine origin) will be extracted to XML DB. Special attention will be devoted to inflectional as it shows gender.

3) The export of SQL data into the XML DB makes possible the semantic comparison between texts from same kingdom or not. During this step, images could be input relating to the verb.

4) Statistics of verbal occurrences should point out measurable indices for determining the male or female agency for each text.

A final step is the multi criteria engine to allow a sorting: *i.e.* entity assaulted outside (her palace) “biological” sex male or female ; the search result will appear in the form of a table with occurrences in ugaritic language, equivalence in other semitic languages (semantic comparison), result by “biological” sex only for assaulted entity outside her palace. While I focus on the ugaritic corpus, this methodological approach could be used for any language. This project has to be seen as a pilote project with open access in the future to add corpus from other civilizations. The final goal is to show the advantage of digital technics to analyse a text for studying anthropology by semantic comparisons and statistics of occurrences.

SESSION 6A- APPROACHES FOR SENSOR
DATA INTEGRATION FOR THE
INVESTIGATION OF ARCHAEOLOGICAL
LANDSCAPES

Authors Tuna Kalayci, Apostolos Sarris

Title *Sensor Data Integration: Concepts and Methods*

Abstract In this study, we first discuss pixel based (low level), feature based (intermediate level), and decision based (high level) fusion methods and explore their potentials in archaeological remote sensing. Next, we suggest workflows for each approach and highlight strengths and weaknesses in order to suggest a path for “a guide for good practice” in sensor-data integration in archaeology. In the second part of the study, we test the performance of various data integration methodologies on geophysical data, collected from structurally different sites (from Neolithic to Hellenistic) and provide a cross-comparative perspective. Finally, we contextualize these methodologies within abovementioned fusion methods.

Authors Nikos Papadopoulos, Meropi Manataki, Tuna Kalayci

Title *Sensor Fusion in Geophysics: A Synthetic Approach*

Abstract Fusion of diverse data obtained from different ground-based sensors is an emerging topic in archaeological prospection. Even though the “fusion concept” is well established in other disciplines and significant advancements have been achieved –especially in the satellite remote sensing- archaeologists remain reluctant to investigate further potentials of this methodological approach. To provide impetus for the scholarly community and to scientifically evaluate the potential of data fusion coming from ground-based in archaeology this work will focus on creating a fully controlled modelling environment for near surface geophysical sensors. In particular, synthetic models representing buried archaeological targets (e.g. walls) within a homogeneous environment will be simulated. Ground Penetrating Radar (GPR), magnetic and resistivity synthetic data will be generated by numerically solving the corresponding physical governing equations. The synthetic data will be treated with different fusion approaches and algorithms in an effort to evaluate their robustness and efficiency in enhancing the outline of the underground archaeological relics. Finally, the modelling results will form the foundations on reporting under which conditions sensors-data fusion approach may provide benefit over a single sensor data collection strategy.

Authors Enrique Cerrillo Cuenca, Adara López

Title *Recording the prehistoric landscapes of Inner Iberia through LiDAR data and Aerial Imagery Repositories (WMS)*

Abstract In this paper we deal with the application of spatial technologies and free data for the archaeological surveying of prehistoric landscapes in Extremadura region (Spain). Two main products are being utilized in this region: repositories of aerial orthophotographs served through web services (Web Map Services, WMS) and LiDAR data.

The study cases presented in this paper come from two independent areas: the drainages of Tagus and Guadiana Rivers. In the Tagus River survey we have put the stress on the identification of Neolithic barrows that are disseminated over an extensive territory, and in the Guadiana River in the patterns of settlement and the distribution of ditched enclosures and small fortifications from Late Neolithic to Copper Age periods. Due to the notorious extension

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of both study areas, a systematic approach needed to be designed.

Aerial ortophotographs are an essential source for the practice of Aerial Archaeology. The increasing number of available Web Map Services (WMS) allows the accessing to cartographic products with different spatial, temporal and radiometric resolutions. For this study cases, several WMS services have been tested, from Near Infrared colour compositions to Panchromatic images, and flights from 1945 to recent times, ranging their spatial resolution from 0.25 to 1 m. Otherwise, LiDAR data becomes an adequate complement for contrasting topographical information with images and, conversely, topographic anomalies can be better ratified after examining the ortho-images.

From the use of both types of data two procedures can be applied the classic photo-interpretation and the numerical analysis of DTMs for the detection of anomalies. As the volume of data can be extraordinary complex to deal with, a small piece of software was programmed in Python programming language. This software can be seen as a light client for accessing the WMS through a very simple interface that also allows the user to compare the information with DEM generated from LiDAR data.

The software incorporates the ability to create false colour compositions from Principal Components Analysis (PCA) of images downloaded from WMS servers, which becomes useful under certain circumstances for enhancing soil marks. Regarding to the processing of LiDAR data, the point-clouds have been filtered and cleaned of vegetation by an *ad hoc* algorithm, MCC-LiDAR, and several morphometric maps have been generated. Most of this work has been accomplished by the means of Python scripts, making use of scientific libraries like Numpy or Scipy.

By means of these procedures, different prehistoric sites have been detected and recorded in both studies areas. Some of the sites are well-known due to different archaeological investigations, while others are unpublished and recently identified thanks to these methods. That is why these techniques help to increase the knowledge about Neolithic and Cooper Age funerary monuments and patterns of settlement of Inner Iberia, an area traditionally considered as an empty space or corridor during this period. The results obtained confirm the ability of these tools for the practice of Remote Sensing, showing us a new perspective of prehistoric landscapes.

Authors

Benjamin Duce

Title

Conquering the point clouds: high-performance processing of multi-sensor data in free and open source GIS

Abstract

Due to their unmatched flexibility in integrating spatial data from a variety of sources, GIS are the most attractive platforms for processing multi-sensor data; assuming that they can actually handle the amounts of data produced by typical multi-sensor devices.

But as digital sensors and processor technology advance in parallel, the demand for computational power frequently exceeds the supply of affordable high-performance hardware. Thus, GIS programmers are pressed to seek creative software solutions for dealing with extreme amounts of high-density sensor data. With free and open source GIS (FOSS GIS) continuing to gain popularity in archaeology, their level of support for processing such data becomes an issue of great interest.

Recently, a number of FOSS GIS projects, such as GRASS GIS, SAGA GIS, QGIS and gvSIG CE, have started to converge on the common aim of processing very large datasets efficiently. Commonly implemented strategies include multi-threaded, parallel processing and rendering,

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tile-based data management and new efficient file formats, as well as improvements in the data processing tools themselves (such as rapid rasterization and interpolation of point data).

This contribution focuses on the issue of processing point clouds with hundreds of millions of points, coming from sources such as multi-sensor geophysical surveys (including marine environments) and UAV-mounted cameras (e.g. multi-view stereo reconstructions of DEMs). It discusses a variety of obstacles and limitations in generic GIS technology, as well as bleeding edge developments and achievements towards overcoming them. It also compares the basic architectures of several FOSS GIS, pointing out their individual merits and drawbacks when it comes to fast, reliable and flexible processing of multi-sensor data. Finally, there will be a (brief) discussion of selected data fusion methods available in current FOSS GIS that are suitable for the processing of very large and noisy datasets, such as belief-based inference (Dempster Shafer Theory) and multi-scalar object classification for machine learning.

The "conquest of the point clouds" is an important frontline in an effort that will give archaeologists free and powerful tools for working with enormous amounts of sensor data in user-friendly desktop GIS, the integrative platform where such diverse data naturally belongs. This contribution provides an insider's view, by an active FOSS GIS programmer, on the latest developments.

SESSION 6B- NEW ADVANCEMENTS IN COMPUTATIONAL IMAGING

Authors Scott Madry, Elizabeth Jones, Amanda Tickner

Title *Archaeological Public Outreach, Education, and Research using the Liquid Galaxy Display System*

Abstract The Liquid Galaxy display system was developed at Google to display Google Earth imagery and associated data in a ‘virtual globe’ environment that consists of seven large display screens configured in a semi-circle. This allows a high-resolution and immersive Google Earth experience, as well as viewing Google Earth imagery and .kmz files, GIS data, virtual reality, and other data. A Liquid Galaxy system was acquired by the Davis library at UNC-CH for their new Research Hub in 2014. It is primarily intended for public engagement in the library, and we seek to explore its potential application in archaeological research. The research hub is a new initiative to make the research cycle at UNC more collaborative and technologically enabled. The lab will provide related consulting, GIS data, software, data visualization and analysis support throughout the campus. This paper will consist of three parts. First, we will describe the Liquid Galaxy system, its configuration, strengths and weaknesses. The second aspect will be the library’s public access and public engagement goals and uses. The final topic will be the archaeological research potential of the system. Author Madry has been an early innovator in the use of Google Earth for the discovery and analysis of archaeological sites, and has presented papers and workshops at previous CAA sessions on this topic. We will present how this system compares with traditional Google Earth site prospection on personal computers. In conclusion, we will look at the future potential of this and related systems for both public engagement and archaeological research applications.

Authors Piotr Witkowski, Julia Maria Chyla, Wojciech Ejsmond, Dawid Feliks Wiczorek

Title *The Combination of the RTI techniques and DStretch algorithms and Near Infrared imagery in Gebelein Archaeological Project*

Abstract Popularization of digital photography and computers led to the development of new types of documentation, as well as the emergence of new ways of collecting data. During the “Gebelein Archaeological Project” we used both one-shot and multi-shot photographic techniques (HDR, Photogrammetry, *Super-Resolution* Photos etc.)

In this paper we would like to show how the use of RTI at Gebelein led to the discovery of an image of the god, Min. We will also talk about effects that we obtained by a combination of RTI techniques and set of algorithms called DStretch. The latter is a plugin to the software ImageJ. By default, it is used to enhance the hue differences between pixels on the rock art photos. We will present the advantages and pitfalls of this combination and the process of linking these two techniques.

In the Gebelein project we also utilize different imaging analysis with the use of Near Infrared satellite images. Contemporary satellite imagery is compared with archival maps and satellite images, ancient written sources and results of previous field works. Analysis showed specific features in the fields and areas surrounding the two rocks, which can be interpreted as traces of an old riverbed and channels, especially that written sources from Late and Greco-Roman Period describe numerous waterways in the Pathyris region (Greek name of the local city). Observed features were verified during field reconnaissance and helped to reconstruct the localisation of the waterways.

NEW ADVANCEMENTS IN COMPUTATIONAL IMAGING

Authors **George- Alexis Ioannakis, Anestis Koutsoudis, Blaž Vidmar, Fotis Arnaoutoglou, Christodoulos Chamzas**

Title ***Enhancing Multi- Image Photogrammetric 3d Reconstruction Performance on Low-Feature Surfaces***

Abstract The generation of 3D models with the *Structure-from-Motion* and *Multiple View Stereovision* (SFM-MVS) techniques is considered popular within the cultural heritage domain. The cost effectiveness in terms of hardware equipment and relatively low background knowledge requirements are two major SFM-MVS properties while the quality of the data produced composes a solution that may satisfy the requirements of a wide range of digitisation projects. Nevertheless, SFM-MVS belong to the targetless photogrammetric family methods and inevitably rely on the automated detection and matching of feature points on the surface of the object. However, many cultural heritage objects, such as marble statues, ceramic vases, e.t.c , present featureless surfaces. Using SFM-MVS on such featureless surfaces may result to camera calibration errors, image network spatial miscalculations (misalignment) and 3D data with severe noise due to the inability of MVS to accurately match neighbouring pixels.

In this work, we quantify the performance enhancement of SFM-MVS on featureless surfaces by introducing the projection of noise function-based patterns (NFBP) and thus overcome one of the method's primary limitations. NFBPs are known for their controlled randomness and irregularity. A total of eight well-known NFBPs were used to produce their bitmap representations which were then used for the SFM-MVS based 3D reconstruction of a Cycladic figurine replica artefact. We have implemented a two-stage evaluation experiment. In the first stage, we produced 3D reconstructions of the artefact's front part using all NFBPs in order to objectively quantify the performance of each NFBP.

In the second stage, the best performing NFBP found in the previous stage was used to create a complete 3D reconstruction of the artefact. In both stages we performed evaluation tests having as a ground truth the 3D data produced by scanning the same artefact with a 3D laser scanner. The Hausdorff distance metric was used to quantify the reconstruction's surface deviations. We provide objective comparisons between the 3D reconstructions produced with and without the use of each NFBP.

We determine that NFBPs with high local contrast and specific band limiting properties are able to provide better reconstruction results. We discuss on the practical side of introducing the NFBP projection in relation with the reduction of the initial automation level offered by the SFM-MVS, the 3D data quality enhancement and the introduction of 3D data processing procedures such as partial scan cleaning and alignment. We conclude on the previous trade-off by raising other issues such as projection surface focusing and actual surface colour projection.

Authors **Robert Bewley**

Title ***Endangered Archaeology in the Middle east and North Africa***

Abstract The purpose of this project is to document archaeology which is under threat in the Middle East and North Africa, using remote sensing and aerial photographs, beginning in January 2015, funded by the Arcadia Foundation at the School of Archaeology at Oxford University.

The archaeological heritage of the Middle East and North Africa is under increasing threat from massive and sustained population explosion, agricultural development, urban expansion,

SESSION 6B

NEW ADVANCEMENTS IN COMPUTATIONAL IMAGING

warfare, and looting. This project will provide the information required for effective protection of these sites to the relevant authorities.

The use of satellite and aerial imagery is especially important for those countries where access on the ground is either impossible or severely restricted (e.g. Syria and Iraq). The project will record and map unrecorded and endangered sites, to a uniform standard, and to evaluate and monitor their condition.

By understanding the extent of threat and damage to sites, and working with archaeological services in individual countries, the project will provide tools and strategies for the future conservation and management of threatened heritage, both individual sites and entire archaeological landscapes. Central to this objective is the creation of an open-access database of all visible sites. Only by knowing the nature of the threats to ancient sites can archaeologists advise national authorities to plan how to salvage a vital part of our shared human heritage.

Our experience in Jordan, Libya, Syria and Saudi Arabia, suggests that a conservative estimate of the number of sites in 'Arabia' alone is in the region of 1.5 million. Extrapolating from this the total for the whole of the Middle East and North Africa may be as much as 3–5 million archaeological sites. Not all of these are currently endangered, but a significant percentage will be, and many more will come under threat.

Important partners range from national agencies in individual countries to the International Committee for the Blue Shield, NATO, UNESCO and the British Museum.

SESSION 6C- SITES, LANDSCAPES AND
SURVEY: THE PAST, PRESENT AND FUTURE
OF NON-INTRUSIVE GEOPHYSICAL
SURVEY IN THE FIELD AND THE
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Authors KEN SAITO, Barbara Frezza, Stefano Campana

Title *LONG WALKS IN THE ITALIAN COUNTRYSIDE Large-scale geophysical prospection in rural and once-urban contexts in central Italy*

Abstract Geophysical prospection has long been recognized as one of the most effective forms of non-destructive archaeological investigation available for use within archaeology. Case studies from throughout the world are increasing in number, leading to a better understanding of the various geophysical methods and of the ways in which they can prove useful for exploratory survey and archaeological interpretation. Despite their wide use in archaeology geophysical methods have for the most part been applied until quite recently in ‘site-based’ projects of investigation. Technological advances, however, have in the last few years made possible the relatively rapid coverage of wider areas on a ‘landscape’ scale. That said, in the many archaeological projects undertaken each year in Italy, geophysical prospection has for the most part not yet been widely applied as an everyday investigative tool. For that reason the country has produced relatively few case-studies that publicly demonstrate the successful use of geophysical methods, least of all in contexts that encompass areas wider than the individual site or group of sites. In Italy the potential of geophysical prospection for the large-scale characterization of archaeological contexts, especially in previously-unexplored rural or formerly-urban areas, has remained largely unacknowledged or tested in the field. This contribution, however, will present the first results of a programme of large-scale multi-sensor magnetometry that has covered the whole of the Etruscan and Roman town of *Veii*, on a now-rural hilltop near Rome, as well as initial exploration of the lowland farming landscape of the Grosseto-Roselle valley in south-western Tuscany. Taken together, these two research projects aim at stimulating changes in the way in which archaeologists in Italy study the archaeology of landscapes, moving whenever the opportunity can be created from an essentially site-based approach to a truly ‘landscape’ perspective. Despite successful results of small scale geophysical survey, it is difficult to demonstrate the usefulness and reliability in the Italian context without clear supporting evidence. Therefore this kind of investigation, especially if combined with field-walking survey and aerial prospection, along with lidar imaging and test excavation wherever possible, could help to create an entirely new approach to the exploration of previously unconsidered rural and once-urban contexts in Italy and perhaps more broadly throughout the Mediterranean area.

If time allows, a few words will be added about the similar Etruscan and Roman town of *Vulci*, in northern Lazio, where magnetometry has so far failed to extend understanding of the urban pattern shown with remarkable clarity for parts of the town through aerial photographs from the 1940s onwards. It remains to be seen whether magnetometry, or geophysical prospection of other kinds, can extend the picture of the town’s urban character in the way that has already been demonstrated at *Veii*.

Authors Petra Schneidhofer, Erich Nau, Lars Gustavsen, Jessica Leigh McGraw, Christer Tønning, Terje Gansum, Jan Bill, Wolfgang Neubauer

Title *Interdisciplinary investigation of the burial mound at Rom in Vestfold County, Norway*

Abstract In September 2012, motorized magnetometry and ground-penetrating radar surveys were carried out by the Austrian Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI) in Slagendalen valley, Vestfold County, Norway for the archaeological prospection of Rom burial mound. The resulting high-resolution geophysical data sets showed interesting features inside the mound. Based on the prospection data, the mound was partially excavated in August 2013 by the Vestfold fylkeskommune and the Museum of Cultural History Oslo (UiO). In collaboration with the LBI, the excavation process was digitally documented using a 3D laser scanner for single surface planning. The three-

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dimensional documentation enabled the virtual reconstruction of the excavated part of the mound. Besides providing precise data for further archaeological investigations, the resulting volumetric data was used to evaluate the interpretation of the geophysical data. The exposure of soils and sediments during the excavation allowed for every stratigraphical unit to be targeted with in-situ geophysical measurements for correlation purposes, including magnetic susceptibility, electrical conductivity and water content measurements. Methodological approach and results of geophysical prospection, geoarchaeological evaluation and their impact on the archaeological investigation will be presented.

Authors**Brian Seymour, Paul Scerri****Title*****Robotic Watercraft and Archaeological Survey: A Cost Effective Approach.*****Abstract**

Underwater archaeological survey using remote sensing equipment is a costly and resource intensive enterprise. This often prevents surveys from being conducted due to “sticker shock” and safety concerns. As such, potentially significant underwater sites may be left undiscovered, or improperly studied and/or recorded as interested parties move project locations, look for less costly and resource intensive research possibilities, or develop alternative mitigation efforts. In an effort to reduce the cost and risk of underwater archaeological survey, our team has been developing a cost effective alternative using easily operated autonomous robotic watercraft outfitted with various sampling devices readily available through mainstream retail shops and software that requires minimal training to use and understand. Post-processed data can easily be exported to a variety of GIS type packages such as G.R.A.S.S., ESRI, and Google Earth for geo-referencing, analysis, and publication. The autonomous watercraft are particularly well suited for survey in rivers and lakes, and other shallow water environments or situations where the size and shape of the water body is restrictive to the maneuverability of larger vessels towing more conventional survey instruments. The advantageous compact size and increased maneuverability of the robotic watercraft, however, has also led to the challenge of adapting equipment that is conventionally designed for larger deployment systems to integrate seamlessly with a lighter, less powerful system of much lower displacement.

It is envisioned that, once perfected, these watercraft will also provide researchers the opportunity to survey in locations and situations that were previously inaccessible or too hazardous for “in person” investigation such as confined spaces (eg. underwater caves/caverns and cenotes) and heavily polluted rivers, harbours, and other water bodies. Surveys conducted autonomously by robots also have the advantage of being precisely repeatable and conducted at night in areas where, for example, commercial and recreational traffic may preclude survey during daylight hours.

In this paper, we present research designs and methodologies from several small experiments in the rivers around Pittsburgh, PA. These experiments include side-scan SONAR survey to locate several submerged objects whose locations are known, or where strong documentary or anecdotal evidence suggests a location. The watercraft are also outfitted with a depth-sounder and GPS equipment to provide as accurate position depth information as possible. It is hoped that in the future, the watercraft will be outfitted with sub-bottom profiling and swath bathymetry equipment in order to provide a full suite of remote sensing equipment; however, limited funding has not allowed for the integration of these systems to date.

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- Authors** Armin Schmidt, Kayt Armstrong, Martijn van Leusen
- Title** *Anomaly to Feature: Improving archaeological interpretation of magnetometer data through model-based inversion*
- Abstract** The archaeological interpretation of data from magnetometer surveys requires technical understanding of the underlying geophysical processes as well as insights into the archaeological context. Unlike GPR data, magnetometer measurements are only a two-dimensional projection of the three-dimensional subsurface. Nevertheless, they contain more information than just the location of anomalies and it is desirable to extract as much information as possible computationally. In contrast to geophysical inversion schemes that define generic optimisation functions (e.g. by specifying depth variability) we use archaeological models that are adjusted in the inversion process to create the best fit with selected anomalies. Using data gathered during the Rural Life in Protohistoric Italy project, which explores small-scale protohistoric settlement patterns in northern Calabria, this method allows us to distinguish between several alternative hypothetical models for the buried features. The value of the derived magnetic susceptibility, for example of a floor layer, may indicate whether a hut foundation is composed of compacted loam or burnt clay. For a pit-like anomaly it can be tested whether it is caused by a deep pit with homogeneous filling of low susceptibility (possibly a storage or rubbish pit) or by a layer of burnt material (as might be found in cremation burials). Through the inversion process parameters are also computed for the width and depth of the pit, aiding in its analysis. Although excavation would provide such information directly, it is destructive and expensive. By constraining inversion with hypothetical archaeological models and magnetic susceptibility data from test pits and corings we aid the interpretation of magnetometer data considerably, reducing the need for substantial invasive testing.
- Authors** Kate Welham, Jeffrey Fleisher, Federica Sulas, Charlene Steele, Stephanie Wynne-Jones
- Title** *An integrated approach to understanding Swahili archaeology. A case study from the UNESCO World Heritage Site of Songo Mnara, Tanzania.*
- Abstract** This paper focuses on research conducted at the UNESCO World Heritage Site of Songo Mnara, Tanzania. Located on the East African coast, the site contains substantial remains of a Swahili stonetown that was a major Islamic trading port during the fourteenth and fifteenth centuries. The presented work forms part of a multinational research project that explores the uses of space within and outside the structures of the town.
- Here we explore the integration of geophysical survey (fluxgate magnetometer and electromagnetic survey) with an extensive programme of geochemical analysis (ICP-AES), test pitting, and excavation. We discuss how the combination of approaches has enabled the full potential of the geophysical datasets to be realised through an improved understanding of the signatures obtained. We consider the potential for this integrated methodology to allow a more

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refined interpretation of multiple datasets, and how it might be used to identify the activities and practices at Swahili sites and the wider region where the use of archaeological prospection techniques are still in their infancy.

Authors **Meropi Manataki, Apostolos Sarris, Tuna Kalayci, Francois-Xavier Simon, Carmen Cuenca-Garcia, Jamieson C. Donati, Nikos Papadopoulos**

Title *Studying the Variation of Geophysical Signals of the Architectural Attributes of the Neolithic Tells and Landscape.*

Abstract Neolithic tell sites have been approached from various geophysical perspectives through the application of a large spectrum of geophysical techniques, spanning from ground penetrating radar (GPR) to electromagnetics (EM) and electrical resistivity tomography and magnetics. The success rate of these techniques varies considerably as the particular targets do not consist of massive architecture, they are poorly preserved and they are enclosed within multiple and usually disturbed soil strata.

A number of examples have been drawn in order to examine the behavior of the various geophysical techniques in surveying Neolithic tells under different soil and landscape conditions. The particular case studies are from Greece and Hungary and represent a group of sites with variable archaeological targets and environmental conditions. The result of those investigations has identified various features related to Neolithic settlements like ditches, enclosures, paleochannels, burnt structures, daub and stone structures, etc. A number of them manifest themselves as intense geophysical features, whereas in others are not able to register at all, either as a consequence of the local soil conditions or due to the nature of the targets themselves. This divergence is the particular topic of this presentation trying to address the causes of the disagreement among the methods and to suggest the most efficient way to survey a Neolithic tell.

Authors **Michael Märker, Ivano Rellini, Marco Firpo, Luigi Mucerino**

Title *Assessment of Subsurface Neolithic/ Palaeolithic sites in the Southern Gargano Area, Apulia, Italy using a 3D geo-electric resistivity approach*

Abstract Caves are important sediment traps both for sediment formed inside and for sediments transported from outside into the caves. The stratigraphic reconstruction of the cave's deposits combined with the study of the archaeological and biological contents (remains of plants or animals) provides an excellent record of the climatic changes happened in the cave and offers information about landscape evolution. Since the study area close to Manfredonia, Southern Gargano, Italy is characterized by important archaeological sites (Occhiopinto Cave) we investigated the area north of Manfredonia in order to get an idea of cavities and their spatial distribution in the ground.

In a previous work we tested a 2D approach based on 8 transects. In the present study we used

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a parallel setting of transects in order to perform a 3D model of the underground structures. Therefore three different arrays were tested, Dipol-Dipol; Wenner and Schlumberger. Schlumberger array is said to be superior in distinguishing lateral from vertical variations in resistivity in respect to Wenner. Whereas Dipol-Dipol array is especially useful for measuring lateral resistivity changes. The utilized electrode spacing for the surface transects was 2m. In order to calibrate and validate the analysis we made 2 core drillings yielding information on the stratigraphy and cavities in the underground. With the given value ranges and the respective electric resistivity arrays we were able to identify the location and depth of the major cavities in 3D for a ca. 25 ha test plot area.

Authors **Jan Bulas, Michał Kasiński, Piotr Wroniecki**

Title *Microregional studies of Iron Age landscape in the Michałowice region, woj. Świętokrzyskie, Poland.- Results of non-invasive investigations.*

Abstract The presentation concerns use of non-destructive methods on the Iron Age settlement site in Michałowice (woj. Świętokrzyskie, Poland), encompassing two settlement horizons: La Tene culture and Przeworsk culture (3rd century B.C. - 1st century AD). The main aim of the presentation is to show the effects of the geophysical surveys conducted on the site and to discuss possibilities and limitations of the method in the particular and specific geological background of the site. Discussion will include the results of small scale excavations which were aimed to verify the various geophysical anomalies.

What is worth mentioning is that there are only a few published results of the magnetic surveys of iron age settlement sites from Vistula basin and even fewer surveys that were tested by archaeological excavations. This is mainly the result of the scepticism of the researchers regarding the possibility of capturing prehistoric settlement features with non-invasive methods. The idea behind the excavations on the settlement in Michałowice was to empirically check the possibilities of using the magnetic method by combining different methods of research that beside magnetic survey and excavation process included analysis of the landscape, post-depositional processes that formed the site. One of the major factors that shapes the final result of the survey is the geological structure of the site. It is located at the bottom of the hill where since Neolithic thick layer of fertile soils was accumulated on top of less bedrock. In the presentation we will discuss the advantages for the magnetic method caused by the less bedrock present on the site and disadvantages caused by the thick layer of chernozem influencing results of the prospection. In the next part of the presentation the connection between geological structure of the site and the character of the particular anomalies will be discussed.

SESSION 6D- COLOUR AND SPACE IN
CULTURAL HERITAGE:
INTERDISCIPLINARY CONNECTIONS

Authors **Anna Bentkowska-Kafel**

Title *Colour and Space in Cultural Heritage in 6Ds. The interdisciplinary connections*

Abstract Documentation of material cultural objects is a core common interest to the participants of the network 'Colour and Space in Cultural Heritage (www.COSCH.info). COSCH is supported by the European Cooperation in Science and Technology and is a COST trans-domain Action in Materials, Physics and Nanosciences (TD1201). Many participants are scientists specialising in optical, spatial and spectral measurement techniques. Museum professionals, archaeologists, art historians and digital humanities scholars are also participating. Perspectives on the material cultural object are many within this diverse group. This paper shares some observations on this interdisciplinary communication, looking at the colour and space in cultural heritage in six dimensions: disciplines and digital technology, data, documentation, development and diffusion.

The focus is on an exploratory case study in 3D spatial and spectral documentation of ancient Roman coins. The study is being undertaken by a COSCH group of ten researchers from different academic institutions, scientific and museum laboratories in seven European countries. Participation of other researchers and subject specialists is anticipated. Despite this kind of collaborative research being well established, defining the basic terms of communication is far from being easy. Each discipline has its discrete cannons; they are being redefined through hybrid empirical work, experimentation and bridging a number of methodological and epistemological approaches.

Authors **Luca Cipriani, Filippo Fantini, Silvia Bertacchi**

Title *A novel method for shadow removal and BRDF simulation of texture from SfM applications*

Abstract The representation of colour and more in general optic behaviour of 3D digital assets has always been a complex matter, of primary importance especially when representing the descriptive features of archaeological and architectural heritage.

This topic involves different research fields, different ranging technologies (active and passive sensors) and different professional skills. In fact, time consuming techniques or expensive devices are not suitable for budgets and abilities that in general cannot be found in the field of documentation of Cultural Heritage. For this reason low-cost and rapid solution are in general most welcome, rather than sophisticated techniques that lead to reliable physical BRDF acquisition, with the disadvantage of being actually still very far from a true implementation in small or intermediate research projects, as well as in case of extensive documentation of archaeological areas.

The general purpose of this paper is the explanation of a pipeline aimed at converting apparent colour texture into diffuse maps starting from the output provided by Structure from Motion application, taking account of some case studies from historic centre of Ravenna.

A set of different materials, characterized by different optical behaviours, ranging from Lambertian surfaces to some dielectric specular materials have been surveyed using different devices (active and passive sensors) and then mapped with a set of different textures obtained from apparent colour. The workflow consists in a double data capture: on the one hand geometric aspects of archaeological remains (laser scanner and passive sensors for SfM applications), on the other hand a surveying of environmental illumination using HDR images.

This technique, developed in the frame of CGI and visual effects creation, is based on an

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extensive use of render-to-texture solutions (baking) implemented inside entertainment applications, whose function is to store indirect illumination solution from HDRI into (u,v) texturing system. This greyscale image provides an effective masking solution for a set of apparent colour textures of the same object resulting from different radiometric recovery.

Logistic aspects of the photographic campaign, frames pre-processing and texture post-processing form part of a pipeline aimed at converting apparent colour texture into a set of images able to generate a more natural and photo-realistic representation of 3D assets, since the typical “double shadow” effect from SfM generated models results mitigated.

Authors

Sarah Younan

Title

Museums, digital repositories and personal identities

Abstract

This paper examines recent developments in digital audience engagement with museum collections, with particular focus on the use of three-dimensional (3D) models of museum objects. Through a review of the field and case studies undertaken at the National Museum Cardiff this paper analyses the impact of the rise of digital 3D technologies on creative and self-directed visitor engagement with museum collections.

Recent popular interest in digital 3D scanning, editing and print technologies are giving rise to a number of unprecedented digital museum engagement practices, both fostered by museums and emerging outside the scope of these institutions.

3D models from museum collections hold a strong popular appeal. Museum visitors are increasingly using freely available software and photogrammetry techniques to experiment with the creation of digital 3D models of museum artefacts. Museums are embracing the popularity of 3D technologies through 'hackathons'. a vast number of 3D digital models of museum objects can be found across various file sharing websites, where they are added as user generated content (UGC).

Unlike their physical counterparts digital 3D models of museum objects can cross the threshold into the private sphere of individuals. 3D models of museum objects can be seen as things that are created as well as found. The digital 3D model of a museum object can be ‘poached’ in the museum or ‘found’ online. Creative engagement with digital 3D models of museums artefacts can transform them into personally charged artifacts with intimate meaning.

The fluidity and availability of digital 3D models of museum objects invites transformation and play. Creative engagement with digital 3D models of museum artefacts takes place on the boundary between culture and personal agency and challenges notions of originality, authenticity and ownership. At the same time, digital 3D models of museum objects and their creative use and trajectory online can provide insight into contemporary reinterpretations and use of museum collections.

In the light of historical and contemporary perspectives this paper investigates how young audiences are beginning to employ digital tools to engage with museums on their own terms, exploring themes of history, identity and access through creative engagement with digital museum objects.

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Authors **Marcello Picollo, Andrea Casini, Costanza Cucci, Marina Ginanni, Elena Prandi, Magnolia Scudieri, Tatiana Vitorino**

Title *The use of hyper-spectral imaging technique to reveal concealed layers: a key question for the study of paintings*

Abstract Hyper-spectral imaging, based on a high performance scanner operating at both high spectral and spatial resolution in the visible (Vis) and near-infrared (NIR) regions, has been applied as an *in situ* technique for the study and digital documentation of cultural heritage. When paintings are concerned, hyper-spectral imaging application in the NIR range is particularly important to provide essential information about the artworks' construction to museums professionals, conservators, and art historians. Paintings are frequently composed by different complex layers and those below the surface are usually invisible to the naked eye. Among these layers are the underdrawings that were generally created by the artists with different techniques and materials, typically charcoal and chalk, metalpoints, and inks. Since some of them absorb the NIR radiation it is possible to unveil and study what may be present under the visible coloured layers. However, the visualisation of these drawings may depend on the transparency of the coloured paint layers. Moreover a high spatial resolution is generally required in order to allow the discrimination between the multiple lines of the underdrawings. As such, the possibility to reconstruct highly resolved images at different wavelengths, which allows to go further into the different layers and obtain a higher degree of visualisation, is of great advantage. In this context, understanding which is the minimum spatial and spectral resolution needed for the spectral imaging systems to provide useful and accurate in-depth information is one of the questions addressed by COSCH Working Group 1 (WG1) and which will be discussed in the present work. Within an interdisciplinary collaboration between the WG1 community, museum professionals, conservation scientists, and technology specialists, a painted wood panel reconstructed according to a medieval technique described by Cennino Cennini was prepared and analysed with a push-broom hyper-spectral imaging scanner in the NIR range. On top of the panel's preparation layer, various lines and drawings were created with different materials (lead-based metalpoint, lead- and tin-based metalpoint, graphite, charcoal, and watercolour), which were then hidden by the coloured paint layers applied above. These underdrawings were used to assess the actual performances of the hyper-spectral imaging system and to evaluate its ability to discriminate between the patterns of lines underneath layers of variable thickness and diverse chemical composition.

Authors **Jonathan Roy Gratton, Douglas Alexander Cawthorne**

Title *Hidden but not lost; Exploring the Great Hall at Boughton House*

Abstract This paper describes preliminary doctoral research on the creation of high resolution, textured digital reconstructions and novel visualisations of several historical phases of the Great Hall of Boughton House in England.

Boughton House (1538-1910) is a sprawling country house built around 7 courtyards with twelve entrances, 52 chimney stacks and 365 windows. Its nickname "The English Versailles" is understandable. The focus of this paper is the Great Hall, which has been the central space of the house since its first establishment as a manor house on this site. The most eye catching

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element of the Great Hall is undoubtedly the wonderfully painted ceiling by Louis Chéron of 1705 depicting the Apotheosis of Hercules. The wainscoting panels appear to be of the same date, but are in fact additions of a restoration campaign in 1911. The panelling replaced a series of Corinthian pilasters of the same period as the painting by Chéron. The painted barrel vaulted ceiling however hides an earlier phase of this space, the Tudor Great Hall. The Tudor ceiling with its carved wind braces and quatrefoil patterns is still in a remarkable state of preservation although hidden behind its painted plaster successor. An original doorway dating to this period has also remained in situ. In addition there exist detailed inventories of furnishings many of which can be traced and there is also a valuable art collection which adorned the space and is still retained by the family.

Using these sources and a conservation level examination of the extant fabric including laser scanning, photogrammetry and HDR texture capturing it is possible to reconstruct the earlier phases of the architectural features of the Great Hall, its contents and furnishings. The paper examines the challenges of doing so, the creation of digital reconstructions of the phases in the history of the Great Hall and issues of diminishing levels of certainty achievable the further back in time one goes. It also examines comparisons of various forms of evidence that inform and influence the end result. The need to exercise balanced evaluation is examined when combining physical evidence and remains, such as tangible objects and textures that are preserved in situ and elements of which only intangible archival evidence remains. In order to create authenticated and trusted 3D digital reconstructions, particular research methodologies from the digital humanities have been combined with the practice based methodology of heritage conservation and restoration. Applying the rigorous standards of physical conservation and restoration to digital reconstructions is presented as a quality control measure that ensures all elements of the reconstructed 3D models can be authenticated, avoiding the temptation of modelling for effect instead of fact.

This ongoing project is presented as a specific example of the work that the Digital Building Heritage Group at De Montfort University undertakes, making the past of architectural heritage accessible through the creation of engaging digital reconstructions based on thorough academic research.



SESSION 6E: LOW ALTITUDE AERIAL
PHOTOGRAPHY FOR ARCHAEOLOGY –
WHERE IS THE REVOLUTION LEADING US?

Authors **Francesco Pericci, Matteo Sordini, Stefano Campana**

Title *UAV mapping of archaeological contexts*

Abstract UAVs (drones) are used in archeology mainly for the documentation and monitoring of archaeological contexts; the possibility of acquiring high resolution aerial images with photogrammetric characteristics makes drones a powerful tool for archaeological mapping. The most recent drones are less affected by atmospheric conditions, and the systems are designed to be ready to flight, without a long set-up time before take-off: this makes this kind of UAV more versatile for use in archaeological fieldwork. Automatic flight planning helps the user to acquire images which meet the requirements for photogrammetric processing, while manually controlled flights can be assisted by arrangements that help the user to perform flights with appropriate levels of safety and reliability. The level of detail in the recorded surfaces, the repeatability of flights with identical parameters and the high speed in acquiring photogrammetric coverage make this kind of instrument highly suitable for recording a variety of archaeological contexts. Photogrammetric techniques allow the archaeologist to create three-dimensional models that can be used for the mapping of archaeological excavations and historic buildings: the integration of topographic instruments with aerial and terrestrial images allows users to quickly record archaeological contexts with a good level of both geometric precision and accuracy at the same time. A wider use of drones in archaeology may allow us to improve knowledge of the landscape, undertaking the high resolution survey of chosen portions of the landscape: this in turn can help to create a better understanding of the landscape context, especially when considered alongside other remote-sensing techniques such as LIDAR or traditional aerial photography. UAV imagery can be used for DSM/DTM generation of specific areas: the archeological analysis and interpretation of DSM/DTM data can highlight micro-relief potentially related to archaeological features. Since early in 2014 ATS Archeo Tech and Survey, a spin-off company of the University of Siena, has started to employ the Aibotix UAV system for recording archaeological contexts: in this presentation we will show case studies involving archaeological excavations, historical buildings and DTM generation.

Authors **Nicolas Poirier, Florent Hautefeuille, Carine Calastrenc, Laurent Augereau**

Title *Low altitude thermal survey: determination of the best flight conditions to detect archaeological anomalies*

Abstract We can consider that the recent democratization of the use of Unmanned Aerial Systems (UAS) in archeology is a methodological break in terms of survey techniques (Eisenbeiss & Zang 2006, Everaerts 2008, Fernandez-Hernandez et al. 2014). Their relative low cost of operation, their flexibility of use and their ability to operate at low altitude renews the use of conventional sensors that are photographic cameras and pave the way for the use of many other now miniaturized sensors (infrared, Lidar, multispectral, etc.). From the scale of the site (identified or being excavated) to that of the micro-region, they allows the repetition of flights over the same areas with a variation of observation conditions.

We want to demonstrate this potential in the use of a thermal infrared camera. If experimental results had led in the 1970s to determine theoretically the best intervention conditions for the thermographic detection of buried remains (Tabbagh 1977), practical constraints related to the use of aircraft and unmanageable infrared sensitive films had failed to validate the potential of the method on a large scale. This is now possible thanks to the use of UAS and the availability of now miniaturized infrared digital camera.

In the framework of the "Archéodrone" program developed at the University of Toulouse (South of France) (Poirier et al. 2013), a set of observations was conducted in order to cross

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the information provided by archaeological ground surveys (fieldwalking) and from the aerial thermal surveys carried out by UAS. Contextualization of each of the flights in relation to temperature (air and soil), humidity, cloud cover and land cover has validated by field experience most of the theoretical results obtained in the laboratory (Augereau 2014), and especially permitted the creation of a useful reference for the planning of future missions.

Authors Wojciech Ostrowski, Kasper Jan Hanus, Łukasz Miszk, Mikołaj Kostyrko

Title *Is GoPro a hero? Limits, issues and perspectives of non-SLR cameras for LAAP.*

Abstract In the last few years we have witnessed a rapid development of UAV applications for archaeological prospection and documentation. In common opinion drones bring a new perspectives to both site- and landscape-scale research. However the main issues is the data quality. The price range of such equipment is very wide, starting from few hundred € kits for hobbyists to top-end geodetic systems based on DGPS and SLR cameras. As most of the archaeological projects or institutions have limited resources, the popular solution is application of non-SLR cameras, usually GoPro, in this paper we shall review the utility and accuracy of such systems.

The methodology of our research is based on comparison between models derived from remote controlled hexacopter armed with GoPro Hero 3 Black Edition camera and reference data set acquired by terrestrial laser scanner (Faro Focus 120). Three main parameters have been taken into account: a) cloud density b) points deviation c) orthophoto quality.

The study areas were three trenches on the Roman Agora (Fig. 1.) as well as surrounding archaeological landscape at World Heritage Site Paphos, NW Cyprus. The Vertical images of trenches was taken during five days of flying that resulted in more than 50 gb of data.

Processing of collected images were performed in Agisoft and Pix4D in order to obtain dense point cloud, ortophotomaps and digital elevation models, additionally GoPro Studio 2 was used to remove fisheye lens effect.

Our study shows that low cost UAV equipped with non-SLR could be successfully used for documentation and prospection. Obtained results clearly show the importance of Interior Orientation parameters, which usually are determined during self - calibration together with Exterior Orientation of images. Errors during determination of focal length might strongly influence on the obtained models (Fig. 2.), especially in the case of fish-eye lens cameras where even large number of images (200+) will not guarantee proper results of self - calibration. However, we still argue that the documentation based on such equipment could be accurate enough, as well prospection provide new information about the past landscape.



Fig. 01

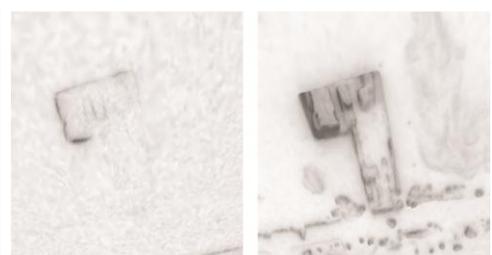


Fig. 02

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Authors Todd Brenningmeyer, Kostis Kourelis, Miltiadis Katsaros

Title *The Lidoriki Project - Low Altitude Aerial Photography, GIS, and Traditional Survey in Rural Greece*

Abstract Initiated in 2010, the Lidoriki project brings together an international team of scholars focused on an examination of the cultural and physical landscapes of the region surrounding the village of Lidoriki in the Province of Phocis, Greece. Since the 1960's, a series of modern interventions have radically altered the ancient topography of this region. The most visible example of these modern changes, the Mornos reservoir, occupies the valley that once served as a natural route of communication and transportation. Above the reservoir one can see craters from Bauxite mines that perforate the slopes of this mountainous region. The various topographic changes of the modern age fragmented the cultural landscape, separating and isolating villages through the flooding of the valley and the various mining operations that block traditional transportation networks.

Within this landscape exists a cultural topography and regional architectural history whose documentation is the focus of this project. In the summer of 2010, a team of scholars began compiling drawings, maps, photographs, and oral histories of the region, which supplement and inform ongoing surveys of vernacular architecture, buildings, infrastructure, and production areas dating from the Byzantine, Ottoman and Early Modern Periods. Current research involves the melding of traditional architectural practices with aerial photographic collection and photogrammetric documentation of landscapes and villages. Architects and surveyors enter sites, document architectural features and lay out a grid of ground control points for the aerial survey. Kites, helium aerostats, and UAV's are used to photograph the villages from the air. The overlapping images provide data for the generation of models of topography and buildings. This data is integrated into the project GIS and will form the foundation for a detailed documentation of the architectural features and history of the region.

This paper will discuss the project focusing specifically on the application of aerial survey techniques and technologies. The use of different methodologies will be discussed within the context of the advantages and disadvantages experienced by the team. The use of UAV's in the project survey has opened opportunities for rapidly gathering data across a diverse terrain that often poses difficulties when using tethered platforms. We have encountered our own set of issues in the use of UAVs however, including lens and camera constraints and environmental limitations. The paper will also discuss the post-processing of this data and the integration of this information with GIS.

Authors Gianluca Cantoro, Christina Tsigonaki, Kayt Armstrong, Apostolos Sarris

Title *Integrating low altitude with satellite and airborne aerial images: photogrammetric documentation of Early Byzantine settlements in Crete*

Abstract Photogrammetry is quite an old discipline and so is its digital version, with long tradition of studies and applications. Recently, thanks to the advent of free/affordable and easy to use amateur or professional applications, a number of scholars from various disciplines have

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adopted photogrammetry on large-scale artifacts in Cultural Heritage: vases and statues, historical buildings, arriving at the documentation of entire landscapes. The ease-of-use, affordability and flexibility of drones (also known as Unmanned Aerial Vehicles or Remotely Piloted Aerial Systems) considerably boost the potential of low altitude aerial photography, making it easier than ever to collect potentially endless numbers of overlapping photographs at variable altitude, with different light or soils conditions and for different purposes (and final ground resolution of the 3D model).

A combination of the two aforementioned hardware and software tools –the UAV system with onboard cameras and photogrammetric software for image matching, georeferencing and 3D model creation– have been exploited for the documentation and analysis of Early Byzantine settlements in Crete. Aerial photography through the use of UAVs is used:

- a) to refine the layout of Cretan Early-Byzantine settlements and identify further landscape elements, such land use patterns,
- b) to digitize the internal architectural features of them, to be used for the subsequent spatial analysis of the intra-space usage.

The combination of satellite imagery, newly acquired photographs and historical archive images aims at highlighting modifications in the physical environment and at helping to identify locations where differences may be enriched with archaeological / historical meaning.

The paper will present the current state of research with a showcase of significant settlements from Early Byzantine Crete with particular attention to those where a large set of different aerial images are available. Satellite imagery, historical photographs, airborne oblique images and UAV low altitude shots will be presented as integrated source of qualitative and quantitative information for the GIS analysis. The methodology developed is part of the project «Recapturing the Dynamics of the Early Byzantine Settlements in Crete: Old problems - New Interpretations through an Interdisciplinary Approach». The project is carried out under the framework of the Operational Programme «EDUCATION AND LIFELONG LEARNING» (NSRF 2007-2013) and specifically the action «ARISTEIA II», co-funded by the EU (European Social Fund) and national resources.

Authors

Matthias Lang, Thorsten Behrens, Karsten Schmidt

Title

A fully integrated UAV-system for archaeological prospection - Workflow and experiences on the Celtic oppidum Heidengraben

Abstract

The Celtic oppidum Heidengraben in the southwest of Germany is one of largest iron-age settlements in central Europe, it's outer fortification covers an area of 17 square kilometers. Since years the site is investigated by several field surveys, geomagnetic prospections and excavations by the University of Tübingen.

In the summer 2014 we started an aerial survey to generate an overview of the whole area with a small-scale and low-cost UAV-system, GPS-generated ground-control-points and structure-from-motion software, a setup that is currently used in many archaeological field-projects. First tests showed that this setup is limited in terms of flight time, accuracy and feasibility. Apart from flight time, the major limitation is that – depending on the model – the camera is triggered either manually or based on time intervals. Both is not precise and often results in either too high or too low overlap of the images. Precise geo-tagging as well as a consistently high image quality is only possible when using stabilized Nadir camera gimbals. This however, increases payload and thus further reduces flight time. Another drawback is that it is almost impossible to get a quick overview of the geo-location as well as the overall quality of the images in the field,

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which is of great importance in areas with limited access.

To overcome these problems we decided to test a UAV specifically designed for long endurance surveys. The system provides flight-times of up to 50 minutes with one battery-pack as well as an easy setup of automatic missions including GPS-based camera triggering. By using a stabilized Nadir gimbal and a high precision GPS-receiver direct geo-referencing and a high image quality are possible. The system has detachable arms and legs for a space saving transport. The setup in the field can be done within minutes. The software used for image processing is specifically designed for processing UAV imagery data and offers the user a seamless workflow from geo-tagging to post-processing of the resulting orthophoto. The application contains several image processing tools like color enhancement, on-the-fly projection, initial quick geo-referenced image overlays, and the analysis of blurriness for semi-automated image selection. These steps can be processed in the field for direct quality control. The postprocessing workflow comprises color scheme manipulation to support the identification of potential archaeological objects, image filters, overlay of RGB and IR orthophotos for generating vegetation indices as well as the generation of static html reports to provide easy access to the data.

In the paper we will discuss the workflow and the experiences we made so far. Moreover, we will show a comparison of the data recorded by both tested UAV-systems and the high-precision LIDAR-information available for the area.

Authors**Karim Sadr****Title**

A comparison of accuracy and precision in detecting stone-walled structures using satellite imagery, high resolution aerial photography and LiDAR; a case study from the South African Iron Age.

Abstract

The Southern Gauteng Stone-Walled Structures (SGSWS) project has been investigating the distribution of pre-colonial structures dating to the 17th-19th centuries AD in an over 8000 square kilometre study area in South Africa. Over 7000 such structures have been identified, classified and digitized on Google Earth satellite imagery by a dozen research assistants. Preliminary results indicate a socio-economic sequence from a more dispersed settlement pattern of relatively egalitarian and pastorally oriented communities in the 17th century AD to highly aggregated towns of ranked and more agriculturally oriented communities around the turn of the 19th century AD, followed by collapse and a return to simpler, smaller scale communities in the first half of the 19th century AD (Sadr & Rodier 2012). Understanding the forces that drove this sequence is the main aim of the SGSWS project. Several ancillary aims are methodological and include, for example, studies on how inter-analyst variability in identifying and classifying the structures affect the outcome of the analyses.

One such methodological side-project of the SGSWS is reported here: how do different approaches to data collection and processing affect the socio-economic interpretations. Specifically, do newer platforms and software for obtaining and processing aerial images translate into higher quality and more useful results than those so far obtained from relatively low resolution satellite imagery available through Google Earth. For this side-project, high resolution, relatively low-altitude aerial photography as well as LiDAR data has been obtained for a small portion of the SGSWS study area. The statistical comparison of accuracy and precision in detection, digitization and classification of the stone-walled structures using the three platforms (satellite imagery, aerial photography, LiDAR) is currently underway and suggests significant variations in the output using the different sources of data. This

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presentation compares the results in some detail and in general concludes that newer platforms and software undoubtedly produce more accurate and precise results; that this increase in accuracy and precision has measurable influence on the interpretations of the archaeological sequence; and that the SGSWS archaeological project will greatly benefit when the cost of obtaining and processing LiDAR data for large study areas drops to manageable levels.

- Authors** **Kate Welham, Lawrence Shaw, Adam Stanford**
- Title** *A comparison of data obtained from low altitude aerial imaging from remotely piloted aircraft, and Lidar. A case study from the New Forest National Park, UK.*
- Abstract** This research examines the recent rise in the use of remotely piloted aircraft for survey and landscape studies within archaeology. It evaluates the potential of images obtained from these vehicles to be used to create digital surface models suitable for prospection and recording purposes. In particular, it explores the use of structure from motion applications to offer potential alternatives to the products obtained from Lidar datasets. The work presented focuses on the results of a case study conducted within the New Forest National Park. Located in the south of England, the Park represents an ideal trial site due to the range of different environments and associated extant archaeological remains contained within it.
- High-resolution Lidar coverage, and comparative ground survey was undertaken across the case study area as part of an extensive Heritage Mapping programme funded by the New Forest Higher Level Stewardship scheme. Low altitude aerial images were obtained using a DJI S1000 Octocopter and Nikon D5300 SLR camera. Comparative ground control and baseline elevation data were recorded using a differential global positioning system, and Agisoft PhotoScan Pro software was used to process the aerial images. The results of the two approaches to archaeological monument and landscape recording are compared, and the outputs discussed with reference to resource requirements, resolution and quality of the end product. Consideration is given to how use of remotely piloted aircraft may impact on the future understanding, recording and monitoring of the historic environment within protected landscapes such as National Parks.
- Authors** **Diego Bellido Castañeda, Laura González López, Mercedes Farjas, Serafín López Cuervo, Julio Zancajo**
- Title** *UAV on the geometric documentation of archaeological sites: technology approach and analysis of products' accuracy. MLEIHA (UAE)*
- Abstract** During archaeological excavations, a suitable metric documentation of the site is completely needed and that the reason why topography has always been related with archaeology, providing a spatial reference of the site and objects which are in it. Nowadays, total Stations, GNSS (Global Navigation Satellite System) and GIS are classical technologies in the cultural

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heritage documentation process. Recently, new developments have allowed the use of new survey methodologies in the metric documentation. Aerial photogrammetric survey is one of them, due to the fact low cost UAV (Unmanned Aerial Vehicles) have made possible high-resolution images acquisition with a low cost.

To study the use of this promising technology, on the one hand we have the possibility to obtain real time data in order to monitoring the excavation, real images acquisition to create 3D models or the accuracy of products generated are some of the reasons. On the other hand, the length of batteries, the low accuracy of GPSS/INS systems, weather conditions and the accuracy in no-flats areas are some of the disadvantages.

The main goal of this paper is to make a detailed study about the metrical quality of the products we can obtain with airborne images. For this purpose, metrical data of several excavations sites in Mleiha (UAE) were taken with a small microdrone.

One of the challenges is to set up a procedure in data acquisition with UAV platforms, because of this is a recent technique and there are not enough information about it. Flight planning, suitable scale and ground control point distribution are specially focused.

In the same campaign, same areas are surveyed with classical topography instruments (GNSS and Total Stations) in order to compare this data with data acquired with UAV. It allows for comparing different parameters of the flight, looking for the most suitable scale depending on height flights.

Finally, photogrammetric products of excavations were produced, such as Digital Elevation Models (DEM), 3D models and orthoimages. The accuracy of these results has been compared with classical surveying data. A maximum scale of 1:200 orthoimages was obtained.

Definitely, digital elevation models generated with low cost UAV systems could be an interesting information source for archaeology works. Quality products were produced with high accuracy, especially in not very depths areas, as superficial structures or on the surface. A high density of GCP is required to achieve a good DEM.

However, weather conditions and battery limitations are determining in flight acquisition. Also, quality data is low in depth and in shadows areas, from where there is no information in images. Tombs and vertical walls need images with different angles in the acquisition. Accuracy could be improved joining data from other techniques, like or surveying.

In conclusion, despite the limitations, UAV are already a suitable tool to cultural heritage representation, although with platforms and software developing in the near future, accuracy will be even better.

Authors	Marco Block-Berlitz, Benjamin Ducke, Benjamin Gehmlich, Niklaas Görsch, Sören Stark
Title	<i>Thirteen desert castles: Towards best practice in 3D reconstruction from video streams with low-cost UAV kits</i>
Abstract	Using Structure from Motion (SfM) software and low-cost UAVs equipped with digital camera systems, archaeologists record high-resolution image series of sites and produce orthoimages, elevation models and textured 3D models. In practice, however, one of the biggest challenges in image-based 3D reconstruction remains ensuring that the image series contains sufficient overlap and full coverage of the site. In this respect, video streams are an intriguing alternative

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(or complementary) source of image data. Although each individual video frame has a relatively low resolution, the enormous number of frames and the almost complete overlap between consecutive frames provide ideal input for SfM reconstruction algorithms. Another attractive aspect is the sheer speed at which distortion free HD video can be recorded by current consumer cameras.

Our primary aim is the development of truly rapid and robust 3D recording technologies. We constrain ourselves to freely available software and low-cost consumer hardware. In October 2014 we put our ambitions to the test by documenting 13 monumental medieval fortresses in the harsh climate of Uzbekistan. The results are encouraging not only because they show how much can be achieved with very limited resources and in adverse environmental conditions, but also that current SfM and surface reconstruction algorithms are capable of handling the low-contrast, sparsely structured remains of typical mud brick architecture.

This paper discusses a number of key aspects and techniques to consider on the way to establishing a best-practice routine for SfM-based reconstruction using UAV-mounted cameras and video streams (as well as mixed video and image-based reconstructions). We discuss aspects ranging from pre-flight planning (weather and light conditions, operational safety, legal restrictions, etc.) to hardware selection, modification and maintenance (always focused on low-cost and sturdy consumer hardware), flight control software (including mobile applications) and data processing. Regarding the latter, we consider both on-site data processing of sparse preview models and off-site processing of complete, fully textured models.

Authors Emanuel Demetrescu, Enzo D'Annibale

Title *Massive archaeological 3D survey with UAV support for technical drawings production: the case study of Sarmizegetusa Ulpia Traiana.*

Abstract In the november 2014 the authors performed a massive acquisition in the Roumanian archaeological site of Sarmizegetusa Ulpia Traiana (ancient capital of the Roman Dacia) within the European Project 3D-ICONS.

The site is big (22 ha) with a large amount of areas unheated and there was not 3D survey before. This situation needs for customized survey solutions focused on speed, quantities and low-cost approaches. Our acquisition aims on the other hand to analyze and highlight possible future areas of the site to be excavated or researched with geological surveys. The chosen technology is the aerial photogrammetry with special attention to the speed of acquisition and flexibility: for that reason a Drone Phantom II equipped with a gopro Hero3Black camera has been used. The survey has been performed in four days, with a manual UAV drive and focusing in large architectural buildings (up to 11.500 squared meters for the forum). A topographical base with total station and DGPS has been made to georeference all the 3d models. The main goal of the 3D survey has been to obtain an extensive multi-scale technical documentation (up to 1:50 scale ratio precision) with the purpose to test the limits of accuracy of this kind of scenarios. The paper explains the whole process paying special attention to the relation between time of acquisition, resolution and post processing effort to define best-practices in a UAV based survey focused in speed and massive acquisition.

SESSION 7A- TEACHING DIGITAL
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Authors Ronald Visser, Pim Alders, Wilko van Zijverden

Title *Teaching digital archaeology digitally*

Abstract Digital archaeology is an integral part of the curriculum at Saxion – University of Applied Science. The students learn to work with software that is most often used by the companies and institutes in the Netherlands. The idea behind this is to enable to students to participate easily in the workproces during internships, but also after graduation. Teaching is not only focussed on learning to use the software, but it is also expected that the students are able to apply this knowledge in other courses. Furthermore, the teaching of digital tools is accompanied by courses where students learn the analogue counterpart. For example the students not only learn to document using RTS or RTK-GPS, but are also able to use conventional methods such as a measuring band. An interesting challenge is to teach students digital tools, while quite a few have the same aversion to these that can be found with many archaeologists. The first part of the paper will focus on the curriculum and more importantly what steps are taken to ensure that it is always actual and includes current technologies without too much changes.

A fascinating aspect of teaching in a world where everyone has a smartphone or uses various digital tools on a daily basis, is that most students have difficulties understanding the basics of computers and software. The more easy technology is available, the less it is understood. Therefore it is important not only to consider how to teach. Various digital tools are available to help us teaching digital archaeology, such as a digital learning platform, smartphones and an UAV. The second part of the paper will discuss several digital tools we are using for teaching (digital) archaeology.

Authors Doug Rocks-Macqueen

Title *Teaching Archaeology Online with Virtual Learning Environments*

Abstract Teaching Archaeology Online with Virtual Learning Environments Teaching archaeology online is becoming easier and easier with each year as content management systems (CMS) improve. Or as the Learning Management Systems/Virtual Learning Environments (VLE) improve, which are the educational sectors equivalent of a CMS for the virtual classroom. Even teachers in non-digital classes use these systems to supplement and support their teaching in the physical classroom.

This paper uses the cases study of landward.org to review setting up and implementing a VLE for archaeology audiences. It will discuss the challenges and best practices learned for implementing a VLE. Also, discussed will be the creation of e-learning modules in the form of SCORM packages and how the SCORM packages from the E-archaeology.org project were integrated into the landward.org VLE.

The goal of this paper is to provide insights into the creating and use of VLE and SCORM packages for archaeologists interested in teaching online using off the shelf software.

Authors Sorin Hermon, Kyprianos Kountouris, Panayotis Kyriakou

Title *Teaching or being taught? Experiences with digital archaeology at a primary school in Pyrga, Cyprus*

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Abstract

The paper reports on the (unexpected) developments in a project where the initial aims were to create a portfolio for the “wiki loves monuments” (<http://www.wikilovesmonuments.org/>) initiative, related to the heritage buildings in Pyrga, a village in the Larnaca district of Cyprus. The activity started as a straightforward action, where a team of researchers from our group formally trained teachers on how to 3D digitally documents heritage objects and monuments, in order to further supervise children performing the actual work. However, this approach returned modest initial results, and, together with the headmaster of the school we decided to change strategy. A new project was delineated, named “Pyrga: A time capsule. Discovering the key to unlock it”, to be coordinated by a joint team of researchers, pedagogical staff and community representatives (Turkish Cypriot, now residing in the Turkish side of the island, and Greek Cypriot). The emphasis this time was on looking for motivations beyond the “school obligations” or the “game” attitudes, focusing on encouragement of initiatives and broad community participation. The technologies involved were 3D data capture and processing, surveying, remote sensing (GPR), image processing and development of digital libraries. The initial results show that children were very perceptive to all technologies, as long as they understood the reason why operating them and as long as they were allowed to first hand experience them. The same model was later implemented at the “summer-school” program on digital heritage, aimed at students and young researchers at the beginning of their career. The course was built around participants’ interests and background knowledge, implementing various technological solutions to their own “projects”. Thus, teaching the technology, advantages / limitations and operability (fieldwork / laboratory work, software and analysis) was “customized” by the course participants. A main point here is that the primary focus was not on teaching the technology, but its potential contribution to advance an archaeological research project.

The paper reports on the results of these activities and their implications on “teaching digital archaeology”, in particular the importance of the concepts “learning by doing”, “motivation”, “identification with subject” and “community driven metadata”. Moreover, we will present initial ideas for developing a related curriculum addressing “digital archaeology” and its relation to “ancient” and “modern” history as locally perceived.

Authors

Matthias Lang, Dieta Svoboda, Jason T. Herrmann, Jörg Bofinger

Title

Teaching Digital Methods in the Field - The Tübingen approach

Abstract

Today, archaeological fieldwork is hardly imaginable without the use of IT-based methods. GPS, databases, geographic information science (GIS), aerial recording methods including data from UAVs and 3D-scanners are threatening to replace pen and ink and manual methods nearly completely. These new technologies have transformed the demands on the archaeologist. Now, they need the skills to handle a wide range of technical methods.

It is therefore no surprise that students of archaeology are actively seeking training in digital methods to be better positioned to find a post in a competitive labor market. Most students and professionals, however, develop their skills without advice or guidance from specialists. This is partly due to the fact that training in digital recording and analytical methods for archaeologists that would prepare students for a specialization in the field is generally not offered in German universities. What is offered is limited to basic topics that are outside of the established curriculum in archaeology and taught only sporadically in field-schools, often by archaeologists with a working knowledge of the subject rather than by specialists.

In this paper we will present the current state of a joint program established by the Landesamt für Denkmalpflege Baden-Württemberg and the University of Tübingen, established to train students of archaeology in digital methods. Our paper will highlight our experiences to date and

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our interest in developing further collaborative relationships on the national and international levels.

The presented program consists of three different elements: theoretical classes within the term, practical field lessons on some weekends, and a field school in the summer. Our emphasis is on the direct practical application of field methods and techniques learned in the classroom, as we believe that this is the best way that these skills are internalized by the students. We facilitate the students' ability to apply these skills in the field with the selection of a study area located in close proximity to Tübingen. This way, fieldwork is possible both during the term and during breaks in the academic calendar. Our study area, in the vicinity of Rottenburg on the Neckar, holds a wide range of archaeological remains, dating from the Paleolithic up until the Middle-Ages. This is important because our program is not designed as a separate course of studies where the fundamentals of regional and temporal specializations could be neglected, but rather as an extension that will augment the already robust archaeological programs offered at the University of Tübingen, Prehistoric archaeology, Classical Archaeology, Medieval Archaeology and Near Eastern Archaeology among them.

Authors

Herve Tronchere, Emma Bouvard, Stéphane Mor, Aude Fernagu

Title

From the Excavation to the Scale Model: a digital Approach

Abstract

The Lyon archaeological department took the opportunity of a recent rescue excavation to fulfil two purposes: improving (geo)archaeological knowledge of Lyon while developing a tool for scientific mediation.

The excavated site spanned 40000 years, from the Wurmian period to the 19th century. It also presented interesting fluvio-glacial geomorphological features. Both aspects justified a 3D diachronic reconstruction. The human story of the area, at the time quite remote from *Lugdunum*, the main settlement, began during the Roman period with two open quarries; it then went on with two graves (which probably belonged to a nearby larger necropolis) dating back to the 2nd to the 4th century. Afterwards, two medieval dwellings took place one after the other between the 6th and 8th century. After their abandonment, the area was used for agriculture for about 800 years. During the 19th century it finally became part of the city of Lyon, with large urban constructions which still characterize the district.

Stratigraphical and architectural data obtained from the field work were integrated into GIS and modelling software. This project is part of a wider program which aims at producing a 3D visualization of the Lyon landscape and its evolution on a long time scale. Stratigraphical data were interpolated in order to produce a series of digital elevation models. These were in turn converted into volumetric objects. Missing data such as the topography before the anthropic extractions (quarries) were also reconstructed. Medieval architectural elements have been processed as well in order to reconstruct the initial morphology of the buildings.

Then, these computer simulations were turned into educational media. We produced static renderings by processing the GIS and CAD files in a 3D scenery generator. We also worked with the local Fablab, whose 3D printer was used to build the tangible model from the same digital files. The goal was the construction of a scale model aimed at demonstrating the principles of stratigraphy to a broad audience. The singularity resides in mobile pieces: layers are represented by separated parts that can be assembled to tell the evolution of the landscape and its occupation, or disassembled to explain the work of the archaeologist. Using a representation of a "real" archaeological site instead of a purely theoretical model also allows the audience to easily identify with an area they know about and learn about the history of Lyon in an interactive way.

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Sticking from the beginning to the end to a wholly digital chain prevents information loss and guaranties the continuity from the scientific production to the educational discourse. Furthermore, it allows the easy testing of multiple research hypotheses on the base of objective but incomplete data.

Authors **Krzysztof Misiewicz, Wiesław Małkowski, Urszula Zawadzka-Pawlewska, Julia Maria Chyla**

Title *How to teach GIS to archaeologists*

Abstract The use of digital data in archeology courses is becoming more and more popular. It is interesting possibility to show pupils the results of research, development of studies, past cultures or architectural reconstruction. But before using digital data we must teach students how to gather, manipulate and use such information for their own purposes. At the University of Warsaw, "GIS for archaeologists" classes have been provided since 2008. Until this year they were presented in the form of lectures followed by exercises. This year we had to change the program because of the need of submitting the same exercises without the theoretical background of the lectures for BA students.

We would like to share our program, created on the basis of pedagogical rules for higher education. Also we would like to show our experience how to connected GIS theory and methodology, work in the office with archaeological field survey. First steps are to provide students with basic geographical, GIS terms and definitions. Additionally, every year students join field surveys which are part of the conservation program "Polish National Record of Archeological Sites". We explain to them how to prepare themselves for such research, how to act and collect data in the field and digitize results of their work. Part of the program is to understand and perform statistic analysis and present them as proper, cartographic and digital maps.

During the courses we have worked with students but also helped professors and doctors to present their own data and projects in interesting, open and understandable way with the use of available programs.

During presentations we would like to highlight problems connected with the use of different types of GIS and statistical software (open source and commercial), preparing exercises for different levels of students with and without theoretical knowledge. Also we would like to point out problems connected to data copyrights that might occur just as well as problems of obtaining data from national sources.

Authors **François Djindjian**

Title *3D Archaeology teaching at the Paris 1 Pantheon Sorbonne University*

Abstract The 3D archaeology course including seminar and practical works, created by myself in 2008, is now a part of the teaching of archaeology at the Master 2 level in the Institute of archaeology of the Paris 1 Pantheon Sorbonne University. The present paper is talking about the difficulties

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to create a new course in the context of a constant diminution of the number of students, to convince the other archaeologists of the University to promote the interest of the course to their students and the technical problems to develop a hardware and software platform of virtual reality and digital photogrammetry for the practical works and student projects. At the opposite, it must be pointed out the enthusiasm of the French specialist of the 3D archaeology to participate to the course and the motivation of the students at the origin of the creation of a student association for the promotion of 3D archaeology. Actually, the course of 3D archaeology is chosen by 25% of the students of Master 2, its main competitor being actually the course of GIS, chosen by 70% of students.

Authors	Eva Pietroni, Daniele Ferdani, Augusto Palombini, Massimiliano Forlani, Claudio Rufa
Title	<i>Lucus Feroniae and Tiber Valley virtual museum: from documentation and 3D reconstruction, up to a novel approach in storytelling, combining virtual reality, cinematographic rules, interaction and "ugmented" perception of the archaeological context</i>
Abstract	<p>The project "Virtual Museum of the Tiber Valley" lead by the ITABC-CNR aims at providing virtual reality applications, multimedia contents, together with a web site, for the enhancement and promotion of the natural and cultural heritage of the medium Tiber Valley north of Rome, from Monte Soratte to Fidene, crossed by the Tiber and by the ancient roman consular roads via Salaria and via Flaminia.</p> <p>These applications are accessible inside museums located in Rome (Villa Celimontana and National Etruscan Museum of Villa Giulia) and in the territory (museums of Nazzano, Lucus Feroniae, Villa dei Volusii) with the purpose to enhance the interest and curiosity of the public to know this suburban area, supporting the visit experience in its different phases.</p> <p>The project is quite original and ambitious for its multidisciplinary approach to the study of the landscape considered in its several cultural components: geological, natural, historical, archaeological, poetic, evocative and symbolic.</p> <p>The most spectacular installation is a Virtual Reality application based on the use of natural interaction interfaces (body movements instead of traditional devices) to explore the landscape in its interpretative and emotional dimensions. In it the visitor can experience four different sceneries migrating among different "avatars": he can fly over the landscape like a bird, or swim under the water of the Tiber like a fish, walk across the famous roman Villa dei Volusii like a freed slave, and finally visit the ancient roman site of Lucus Feroniae as a today foreigner.</p> <p>The paper will focus of this latter scenery. Lucus Feroniae was a very important Italic sanctuary dedicated to the Goddess Feronia, later transformed by the Romans in a colony, under Augustus. The site has been documented and represented in 3D through different technologies (topographical survey, UAV, photogrammetry and dense stereo marching techniques), and a 3D reconstruction in Tiberian and Trajan period has been realized adopting a proven methodology and a scientific approach developed by the scientific community and improved during past experiences.</p> <p>Later on, in the spectacular VR installation, it becomes a stage for interactive storytelling where a novel approach in combining different media and paradigms has been introduced: real time and gesture-based interaction, cinematographic paradigms and camera behaviors, virtual set practices, "augmented" reality. The visualization of the VR environment is distributed on three aligned large screens, where the user can experiment different representations of the space of Lucus Feroniae: the observed archaeological environment and the 3D reconstruction of the</p>

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past structures are shown in parallel, from the same points of view, in order to offer the visitor an "augmented" perception and a better comprehension of the site.

Moreover real actors have been filmed on a green screen and then integrated in the virtual scenery to represent the ancient characters performing their daily activities in the reconstructed site; they dialogue and interact among them and occasionally with the user. In this project the efforts have been oriented towards the creation of an emotional, multi-sensorial scenario, inside which visitors can feel immersed and involved and acquire cultural contents in a pleasant and not frustrating way. Narrative plots and non-linear interactive storytelling, interaction design, immersivity, soundscapes contribute to this result. In this perspective we tried to combine science, art and technology, to meet both museums and research needs.

SESSION 7B- NEW CULTURAL HERITAGE ECONOMIES IN THE DIGITAL ERA

Authors **Augusto Palombini**

Title *The bottom-up approach to project funding: an analytical overview of crowdfunding in archaeology.*

Abstract Among the effects of Digital revolution in archaeology, we can consider the spread of new economic models both for research activity and for promotion/conservation purposes. The perspectives offered by 3D printing and by the social networks- driven events and initiatives, are actually going to shape new job opportunities and expertise.

One of the most striking innovation in this domain has been the introduction of the bottom-up approach to project funding based on web services. The crowdfunding practice is today spreading in the archaeological community, and some tens of project campaigns have already been attempted. At the same time, we can rely on the earliest existing analytical work on such a topic.

Starting from the existing literature, and performing an analysis on the many aspects of each project (platform used, amount requested, rewards given to donors, communication approach, etc.), this work sets up a general breakdown of existing/existed crowdfunding projects (successful and unsuccessful) trying to trace some general observations on the possible winning strategies and on the problematic aspects.

Among the results, an interesting point seems to be the success of merely symbolic “perks” (the reward granted to the donors), as a sign to state the “participation” of the contributors to the archaeological experience, which leads back to the anthropological studies on the relevancy of the immaterial dimension of the gift, despite to its economic one.

Authors **Daria Hookk, Vladimir Opredelev, Tatiana Kharitonova**

Title *Modeling of a communication with virtual visitors of the museum web-site “Virtual archaeology”*

Abstract The promotion of a museum in virtual space requires solution of the same problem as any other commercial institution has: the necessity of marketing research, unique approach to specific audience, varying of methods in different cases. While the trade companies have enough facilities for it, the museums are only in the very beginning. It should be mentioned that mean value of cultural heritage thematic in global WWW-net is about 10%, in the Runet segment it is equal 1,2%. The analytical research on virtual visitors of museum web-site in the Internet provided by Pushkin art Museum encouraged us to continue develop modeling on a simple example of a museum web-site “Virtual archaeology”. The project started in 2011 aimed to support the 1st International conference on virtual archaeology and later became a source on special knowledge with its own public. We have applied Google.analytics and other web-instruments in order to demonstrate the use of the data. Preliminary we had to define the terms *virtual visitor, visit, new visitor, time of visit, user activity etc.*

The temporal exhibition on archaeological expeditions of the State Hermitage Museum has served the reason to study the structure of real and virtual museum visitors and their interaction with digital data and museum space. The virtual visitors were formed by specialists in the field of virtual archaeology and inquiring visitors of the exhibition, who used there a QR-code. The last category is “new visitors of the web-site” as a first time visitor of the museum. Time of a visit on the web-site is comparable with time of museum visit.

In last case, the museum archaeological exhibition gave us the possibility to compare analytical data on virtual visitors with questionnaire survey of the real museum visitors. Target group is similar in both cases, but there are some differences. Sociological study on archaeological exhibitions shows: 30% of visitors address to the Internet looking for professional consulting.

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That means, the communication museum-visitor extends from the exhibition space and forms special mixed target-group, simultaneously virtual and real. Sequence of visits (which one was first) has no meaning. Demographic composition of museum visitors is extended by the web-site visitors, particularly age distribution.

Increasing communication with virtual source of knowledge turned them to the permanent virtual visitors and stimulated to be interested in archaeology.

Then we have consequently used different methods increasing the number of visits: advertising in a social net, thematic contest for children, reference from Wikipedia, conference, weekly news, redesign, link from museum temporal exhibition. Finally analysed data gave us understanding of communication process, actual relations between events and reflections. The experience we have obtained can be useful for specialists in museum informatics and web-designers, as well as for museum personnel. It will help to optimize official web-site structure and content, to correspond to museum visitors' requirements and to improve the communication inside of the museum itself.

Authors

Francesco Uliano Scelza

Title

Archaeology, GIS and urban planning. Territorial polity and economy of cultural heritage

Abstract

The paper addresses some issues related to the implementation of archaeological cartography based on GIS technology. In particular, it starts from a PhD research project concerning the ancient population of a southern Italy area called Cilento, located in the current region of Campania. This portion of territory is the object of Greek colonization and the seat of well-organized indigenous communities. The tradition of the historical, topographical and archaeological studies is very wide and gives us a methodological framework of numerous systems, based, in most cases, on non-systematic investigations, without any analytical and quantitative level, with the exception of recent stratigraphic excavations and surveys. The common point is the absence of a general definition about what should be considered a site, an activity area, or a settlement. By adopting GIS software I have built a spatial base including all sources of ancient populations. In this territorial and historical context the main problem is the management of archaeological sources that testify of activities that take place in a portion of space, at a period and according to a function. The population pattern of the ancient landscape is the result of an ongoing relationship between different socio-political systems. After the review of the principles, the approach and the characteristics of the creation process of the archaeological map of Cilento, the paper will focus on instrumental and political aspects. First of all I will examine the GIS as a working tool. In this case the question is about the terms on which the GIS can be an efficient support to the archaeological activities: protection, research, conservation, restoration, fruition. Second, I will consider the issues of urban planning, with particular reference to the programs of each administrative authority. In the latter case, the question is: can the GIS constitute a common instrument through which the archaeological documents take an active role in urban and territorial planning? Above all, do the actual information systems provide the integration of protection, research and fruition? do they help the development of a territorial policy of Cultural Heritage? Starting from the definition of GIS as a working and planning tool, the last section of the contribution will describe the condition of the Cilento Archaeological Heritage, its needs, and the role that the introduction of an information system could have. In this final section, the topics discussed are: compared to a land with deep problems of abandonment, degradation and marginality, can the GIS have a decisive impact in the care and in the valorization of cultural heritage? And in general, can the archaeological knowledge contribute to the integrity and to the growth of the territory?

NEW CULTURAL HERITAGE ECONOMIES IN THE DIGITAL ERA

Authors Domenico Parisi, Lucina Giacomini, Cristina Delogu

Title *Simulating the role of the Tiber in ancient Rome*

Abstract Computer simulations are a new and promising tool to better understand the historical past and its archaeological record. If a computer simulation reproduces what we know about a certain historical phenomenon, we can reasonably claim that the model incorporated in the simulation captures the mechanisms and processes underlying this phenomenon and explains it.

We describe a computer simulation of the role played by the Tiber in the history of ancient Rome from the foundation of the city to the second century C.E., with reference to the river's mouth on the Tyrrhenian sea and to the archaeological remnants linked to the river both in the city of Rome and in Ostia. The simulation tries to understand this role by looking at the Tiber as a communications route and by considering the importance of communication routes for transporting things, people, and knowledge and for establishing contacts between places and cultures. Communication routes depend on both the physical environment and human technologies, and one significant factor that explains the history of ancient Rome is its physical location near the Tiber's mouth on the Tyrrhenian sea and its well-developed transportation technologies.

Our computer simulation includes historical comparisons making it possible to change the different factors and see the effects of these changes, in a sort of experimental laboratory. The simulation adopts two different models. The first is a network model in which nodes represent places and links between nodes represent communications routes between places. The second is a cellular automata model in which space is divided into squares and each square has some characteristics that explain how people living in one square influence or are influenced by people living in adjacent squares. (We have used both types of models in simulations of the expansion of the Assyrian Empire and of the formation of the historical tree of Indo-European languages. These simulations have been published and they are summarized in the book "Future Robots" by Domenico Parisi published by John Benjamins in 2014). We have also constructed a "digital environment", a version of the simulation endowed with a motivating, easy to understand, and active user interface that allows everyone to understand the role of the Tiber in ancient Rome. Unlike the already existing interfaces of virtual and augmented reality, the users don't interact with what they see on the screen but with the simulation which is behind what they see on the screen. In the digital environment by acting on the different variables that explain the historical processes, users understand these processes and its archaeological record. Digital environments are accessible on all sorts of devices and they may exist in different forms for different users. We believe they can greatly increase the cultural and economic value of the archaeological record.

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Authors **Rob Shaw, Michael Ann Bevino, Gary Devlin**

Title ***Replicating Replicas: from 19th Century plaster cast to 3D digital replica***

Abstract In recent years the Discovery Programme has been given the opportunity to laser scan a number of high profile stone-carved objects and monuments in Ireland, including some of the Irish High Crosses. The objective of this work has been to create 3D digital replicas of the objects, primarily to improve access and understanding through online dissemination; however some surveys have been undertaken as part of conservation projects, and others to enable the production of physical replicas of vulnerable objects for public display. The National Museum of Ireland holds an extensive collection of plaster-of-Paris casts produced in the 19th and 20th centuries, including copies of the some of the recently scanned objects, as well as the moulds used to create the physical replicas. In furthering our on-going research into 3D scanning and digital modelling the Discovery Programme approached the Museum to see whether the moulds (and the replicas they generated over 100 years ago) could be made available to be scanned themselves. What would such scan data offer in research terms? Could such data be analysed to give reliable and quantifiable assessments of the difference between recent and historic models? If so could this be used to enhance our understanding of the weathering processes active on such important objects? This paper discusses the issues involved in such a scanning project, considers what variables may be responsible for uncertainty in the model results, and whether changes can be quantified with sufficient reliability to draw any significant conclusions.

Authors **Maria Chiara Liguori**

Title ***Manifold digital applications for a multitarget communication: the Etruscan virtual experience***

Abstract A twin temporary exhibition opened at the end of October 2014 in Bologna and Rome celebrating the Etruscan world and, in particular, the journey towards the afterlife.

The project involves Villa Giulia National Etruscan Museum, the Museum of the History of Bologna Genus Bononiae, Bologna University, the Civic Archaeological Museum of Bologna and Cineca Supercomputing Interuniversity Consortium. The VisitLab (Visual Information Technology Laboratory) staff of Cineca was the creator and developer of all the technical solutions and final installations, ranging from a stand alone holographic display, to a computer graphics stereoscopic short documentary and a dramatized and scenically captivating virtual installation, merging 3D architectural mapping and holographic display.

In order to deliver historical or archaeological contents to as a wider audience as possible, virtual story-telling, declined in different ways, was used as a keystone in the creation of the present project. The aim was to mix outstanding Etruscan findings and state of the art virtual technology for bringing to Bologna (and to its recently opened city Museum) an unprecedented cultural event and for offering a crucial chance to enhance Villa Giulia collections and support a revitalization of the museum image upon the international panorama.

The main actions/elements of the project are:

the Sarcophagus of the Spouses - the most relevant artwork exhibited at the Villa Giulia Museum along with the statue of Apollo - has been transformed both into a digital representation and a 1:1 3D printing. The installation combines 3D architectural mapping, with 12 coordinated projectors and an holographic projection in a 10 minute show;

the bronze vase (the "Situla della Certosa") is on show at Villa Giulia as an holographic projection combined with a multimedia presentation;

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both at the History of Bologna Museum and at Villa Giulia is on show a new version of the 3D CG educational movie “Apa the Etruscan”, expressly developed by Cineca. This version merges the first 5 minute scenes, including the description of Felsina, the Etruscan city of Bologna, with new shootings about the site of Veii, near Rome, its temple and surroundings. The film introduces a new character called Ati, Apa’s cousin, voiced by the actress Sabrina Ferilli.

The realisation of each element has mixed an extensive process of digital acquisition, carried out with different technologies (photo-modelling, laser scanning, 3D stereo camera, etc.), and 3D modelling. The production pipeline was grounded mainly on Open Source, with Blender as the pivotal software. The outputs were conceived as a starting point for further developments. For example, the short movie can be considered as an introduction to the new Villa Giulia mascot: Ati. The show dedicated to the Sarcophagus of the Spouses will be adapted and presented at Expo Milano 2015 (Universal Exposition).

Authors **Paola Di Giuseppantonio Di Franco**

Title *The performance of heritage: manipulating 3D digital and printed replicas of artefacts inside museums*

Abstract In this paper I consider some of the possibilities offered by 3D digital and printed replicas to enhance engagement and understanding of artefacts inside museums. I stress that interaction with 3D digital replicas and tactile experience with 3D printed replicas give opportunities of engagement with ancient artifacts that go beyond sensing their physical characteristics and include *experience* and *performance* of museum visitors’ as a way to understanding heritage. This study builds on the results of recent surveys I conducted in collaboration with computer and cognitive scientists, aimed at exploring how people perceive ancient artifacts presented through different media (visual examination of original objects, interaction with 3D digital replicas, tactile experience with 3D prints). Results to these experiments revealed how our sample of participants favored interaction with 3D digital copies of artefacts and tactile experience with 3D prints over a visual non-manipulative experience with authentic objects, suggesting how museum visitors are willing to negotiate with replicas of artefacts for the sake of an active and more democratic experience with their material past. From these premises, the present paper can be positioned within recent debates in the wider field of heritage, which see heritage “as a process of engagement, an act of communication and an act of making meaning in and for the present” (Smith 2006: 1). I end this paper with offering ideas on alternative exhibition practices that integrate traditional museum settings and 3D replicas to increase museum experiences.

Authors **Stuart Jeffrey**

Title *Digital replication, aura and authenticity*

Abstract There are many parallels between the historic processes of replication in three dimensions, such as plaster casting, and the 3D digital documentation of heritage objects. However, recent changes in perception amongst some scholars regarding physical replicas, especially those of antiquarian origin, suggest that rather than simply inauthentic surrogates they are objects to be

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valued in their own right. These objects having a lot to tell us about earlier processes, earlier states of preservation and earlier conceptions of the authenticity of objects. Contrary to this change in perception for physical replicas, there still remains an ambiguity about the intrinsic value of digital objects. These forms of record are clearly valuable as tools for conservation, analysis, education or management, but do they also have value in themselves as objects through which people can meaningfully engage with the past? There is generally little consideration given to the future value of the records we create now and how they might be perceived in the long-term.

Using examples from the recent ACCORD project (<https://accordproject.wordpress.com/>) which developed community co-produced 3D digital replicas, and 3D printed versions of them, this paper will discuss the impact that the networks of relationships around replication have on their perceived aura and authenticity. Using further examples from the range of 3D recording and modelling projects undertaken by the GSA in the archaeology and heritage sectors it will discuss how an apparently immaterial and technical record may act as a focus for broader, more creative forms of engagement. The paper will situate digital records, as a form of 3D reproduction, in their broader context and argue that a clearer understanding of the ways in which such objects are received by their proposed audiences can imbue them with forms of value beyond simple documentation or representation.

Authors

Mhairi Maxwell, Jennifer Gray

Title

Digital-Design-Archaeology: integrating digital and traditional making in re-creating a Pictish drinking horn fitting.

Abstract

The Glenmorangie Early Medieval Research Project re-created objects from the period c.300-900AD in collaboration with artists, designers and makers. Contemporary digital techniques and traditional craft were integrated, our design informed directly from the archaeological evidence. This process of re-creation has brought these objects to life again, giving us insights into how they were made, experienced and used. This paper will present the processes involved in the re-creation of a silver terminal fitting for a large drinking horn.

Digital design and modelling processes were blended with traditional hand making techniques to re-create a silver zoomorphic fitting Inspired by a 2D image on an Early Medieval carved stone and contemporary pieces of Pictish and Anglo-Saxon metalwork. The final piece was displayed as a 'work in progress' (illustrating its conception from 3D modelling and printing through to the final silver cast object) in the National Museum of Scotland's 'Creative Spirit: Revealing Early Medieval Scotland' exhibition, from the 25th of October 2013 to the 23rd of February 2014.

Our design-archaeology approach towards material culture allows for a new way to re-evaluate craft. Jennifer Gray's work connects the innovative and traditional methods of re-creation; there has always been a tension between craft techniques available to Early Medieval people and new technologies available to us today. In this paper, together we will negotiate questions of authenticity, creativity and discovery that our particular approach combining 3D digital modelling and traditional hand-craft arose.

The process of designing and making in this way has added to our understanding of these types of fittings; highlighting the decisions made by the maker along the way, aesthetic qualities and probable functional features of Pictish drinking horn fittings. This project demonstrated that new technological approaches can be blended naturally to create an authentic replica, whilst also as a means of enhancing what's gone before - to bring the past alive.

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- Authors** Sofia Pescarin, Ivana Cerato
- Title** *Archaeological Museums: requirements, expectations, digital perspectives*
- Abstract** Communication is one of main scopes of a museum. Its importance has been recognised as going much beyond the simple display of objects, their conservation and study (ICOM 2007). We can count around 20,000 museums in Europe, among medium and big.
- Archaeological museums are a category with specific characteristics and set of problems, some of them connected with their collection, some with the related context. Examples of such problems are:
- Fragmentary nature of most of the objects
 - Scientific validation
 - Original color/aspect
 - Original context
 - Loan for exhibition purpose
 - Personalization of provided information
 - Impossibility to touch the objects
 - Cognitive distance between contents and visitors.
- The paper analyzes these characteristics and problems, taking in to account the results of a recent survey, carried out within V-Must.net activities (www.v-must.net). Around 50 archaeological museums curators have been contacted about their approach (required/expected) regarding communication, technological application integrated in their museums and economical model/management.
- Various virtual museums are presented, as possible digital solutions to curators requirements. Most of these technological applications have been included in “Keys to Rome” exhibition (www.keys2rome.eu) and Digital Museum Expo.

- Authors** Mercedes Farjas Abadía, Pablo Rocés Coto, Sabah Jasim
- Title** *Digital representation of archaeological pieces: 3D modelling, replicas and metrics*
- Abstract** In the field of digital documentation of archaeological pieces, 3D modelling has become a highly successful possibility that it is almost at its peak and extended worldwide. There are many different methodologies for 3D modelling of archaeological pieces or any other small size object, but the two main methodologies are close-range objects photogrammetry (by the shoot of converging photos) and the use of 3D laser scanning technology. Each of them, with their own and unique features, were used for obtaining 3D models of a group of pieces found in different archaeological sites in the emirate of Sharjah, United Arab Emirates. The aim was to study the differences between the models processed by the two methodologies, obtaining 3D maps of differences which show the most conflictive areas of the digital models between them.

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Even though the photogrammetric models showed optimal results, they had a lower quality than the models obtained by laser scanner. The ones, after the manual processing of the all the photos and final models, ensured an accuracy around 1 mm; while the others, guarantee 3D models with an accuracy of 0.2 mm or even lower. This accuracy is also the expected for replicas obtained by most of 3D printers in the market. 3D printing has lower costs everyday so it shows itself as a great solution for documentation of archaeological pieces, offering for instance the possibility of distributing a digital 3D model of piece to anywhere on the globe and printing a replica to study it. In order to know if a 3D printed replica is accurate enough to use it for a metric analysis, two printed replicas of the same piece (one with colour textures and the other one without them) were modelled by laser scanner technology and, as it was made to compare the 3D models obtained by different methodologies, maps of differences between the original digital models used for printing and the ones obtained after 3D printing were calculated. Results show that 3D printed replicas are not a perfect physical representation of the digital 3D models, as the colourless replica is around 0.1 mm bigger than its original model; happening the opposite for the replica in colour. Anyway, all differences are lower than 0.2 mm, expected accuracy for 3D laser scanner technology and for 3D printing as well, therefore, it can be concluded that 3D printing is a proper mean for metric analysis of archaeological pieces without physical manipulation of them.

Authors	Stefania Poesini, Lucia Sarti, Vincenzo de Troia, Paolo Machetti
Title	<i>Computer applications for multisensory communication on cultural heritage</i>
Abstract	<p>The paper aims to illustrate the design and implementation of subsidies for a multisensory communication of the cultural heritage for inclusive fruition through innovative processing techniques designed specifically with technological solutions.</p> <p>In our experience, some specific computer applications are important to improve the fruition of historical-artistic heritage also to people with sensory disabilities penalized by communications systems usually used in these contexts.</p> <p>In this paper we show some projects and solutions for museums and naturalistic- archaeological trails accessible to all sort of visitors.</p> <p>The purpose of this “cultural routes” is to remove barriers of various types, starting with the removal of sensorial barriers. We realised reproductions of some archaeological objects to be explored using one's hands with particular interest to communicate to the blind and visually impaired people. The graphic rendering of any object or location you want to reproduce begins with the acquisition by 3D laser scanner technology that returns a mathematical model to scale. The model, simplified, passes to the next stage of identifying the areas for tactile recognition, giving special 3D textures designed to be perceptible to the touch. Then a cutter and / or a 3D printer, conclude the work, giving the play adapted to the needs of the end user.</p>

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Authors **Teija Tuulia Oikarinen**

Title *Utilisation of a game engine for archaeological visualisation*

Abstract

A game engine is a software framework aimed at designing video games. Besides developing entertainment based applications a game engine can also be used for visualisation purposes thus providing improved access to scientific data and even presenting digital 3D replicas of real life objects to academics and also to the general public. However, game engines have thus far been used for archaeological visualisation only rarely. Therefore, relatively little information is available about the technical characteristics and demands for the use of a game engine from the archaeological point of view.

The potential and weaknesses of using a game engine for archaeological research and dissemination were analysed by developing a demonstration (a proof of concept) of an interactive virtual exhibition using Unity game engine. Besides testing the features and functionalities of Unity also the skill requirements related to the use of a game engine were studied from a practical archaeologist's viewpoint. In general, the work contributes, as a demonstration of virtual exhibition and simulation of the functionalities, to the field of Serious Games in cultural heritage game genre breakdown.

Development of the demo proved that a game engine can be used to implement a virtual exhibition with gamelike functionalities and interactive features. For example, Unity's visual and auditory features can be used to enhance the user experience. Unity's integrated game editor is user-friendly and Unity is free, which increases the potential for its exploitation in archaeology. Unity's graphical scene editor can be used to build a virtual exhibition, but the interactive functionalities of the exhibition will also require programming skills. Also basic 3D modelling and image editing skills were needed when creating the example exhibition. Unity, like most of the game engines, is not a 3D modelling software but utilises ready-made 3D objects, which can only be slightly modified within Unity editor.

The demo included also functionalities for viewing data of different kinds (visual, textual, web-links etc.). The data sources are realised as assets of Unity project and the related files can be prepared by persons without programming skills or knowledge about the features of the game engine itself. Therefore, within archaeological use of Unity, the technical implementation could also be outsourced. Visualisation of archaeological objects in three-dimensional game context requires use of 3D models that are based on archaeological information and documents / records. These models can be obtained via 3D scanning or created using 3D modelling software.

The analysis indicated that a game engine has potential for archaeological visualisation and also features that support design of a virtual exhibition to follow cultural heritage visualisation principles. Some technical features of a typical game engine, like e.g. the requirement of using simplified, so-called low-poly 3D objects, can also be seen as weaknesses from the archaeological scientific viewpoint.

SESSION 7D- WHAT CAME FIRST, THE
INTERFACE OR THE USER? ABOUT
REASONING AND THE ILLUSIVENESS OF
INTERFACES IN THE PRACTICE OF
DIGITAL AND VIRTUAL ARCHAEOLOGY

Authors**Javier Pereda****Title*****Enhancing Engagement with Online Cultural Heritage*****Abstract**

Cultural heritage organisations such as museums and public libraries have been undergoing a series of transformations in the way they store and manage their information. This has involved internal and external groups such as developers, information management specialists and designers to name a few. Moreover, a wide range of technologies has greatly altered the way in which cultural heritage knowledge is engaged by a wide range of users. Nowadays, computers are the main pathway to access information, acting as a gateway to knowledge, especially on the Web. There are vast sets of data and information widely distributed on the Web from a diverse number of groups that are directly and indirectly related to cultural heritage. Making sense of this wide diversity of data has become an active area of research in fields such as knowledge management, human information interaction and several information science fields among many others [1]. Currently, there has been substantial research focusing in the different ways that users can explore such data in a meaningful way through Semantic Web technologies [2]. Cultural heritage organisations, for instance, have adopted such technologies and provided users with several tools such as SPARQL endpoints and APIs offering entry to their data. Regardless of how robust and effective these technologies are, due to their complexity from a 'common' user experience or a non-technical audience, it can be said that there are still many limitations and constraints that end users might experience when trying to obtain information and learn about cultural heritage collections online.

This research studies how data can be facilitated to end users through interactive systems. Many of the interaction systems currently implemented to explore cultural heritage on the Web follow common approaches through graphic user interfaces and textual inputs. Nevertheless, these methods do not necessarily present the best knowledge acquisition platforms [3]. One of our aims is to provide an engagement platform for cultural heritage on the Web through Tangible User Interfaces (TUIs). It has been suggested that through the engagement with TUIs cognitive processes are promoted thus aiding with educational development [4, 5]. In this sense, our research aims to empower online users commonly deprived of this experience in relation to cultural heritage due to digital illiteracy, where TUIs have also been able to promote digital inclusion. TUIs present an environment where users can understand complex data relationships and retrieve data through a direct manipulation of physical objects [6, 7]. Online cultural heritage provides a structured intelligence playground through a wide range of Semantic Web technologies where exploration can be promoted in this way. This paper will present a novel approach to explore online cultural heritage once is incorporated on a data models such as Europeana, and will delve into the role that TUIs play on the empowerment of users and their learning activities on the Web.

Authors**Bruno Fanini, Alfonsina Pagano****Title*****Visual and rewarding strategies in gesture-based Serious Games*****Abstract**

This paper presents a new approach in the content-generated experience of users interacting with gesture-based interfaces.

Rich 3D environments in Virtual Archaeology involving large reconstructed urban areas always raise several challenges, especially when applied to interactive 3D applications using gesture-based approaches. Management of uncertainty, geometrical complexity, dynamic elements such as artificial crowds, interface and reliable communication of urban layers often introduce issues that must be addressed to provide users a positive successful experience.

Interface Design (ID) mostly focuses on predicting what users expect to see and do thus ensuring 3D interactive interfaces to have elements easy to access, navigable, and affordable.

WHAT CAME FIRST, THE INTERFACE OR THE USER? ABOUT REASONING AND THE ILLUSIVENESS OF INTERFACES IN THE PRACTICE OF DIGITAL AND VIRTUAL ARCHAEOLOGY

Likely, the study of User Interface (UI) brings together concepts from interaction design, information architecture and visual design applied to the Cultural Heritage domain. The most relevant aspects to take into account when designing interface elements include (a) Input Controls, (b) Navigational Components, (c) Informational Components.

Under the V-Must project, “Imago Bononiae” (2013) stands as a real example of how to build-up a reliable and efficient product caring about visual interface design and information architecture. The case study we propose is a 3D real-time application based on the interactive exploration of a large landscape reconstruction of the city of Bologna during the Roman age (1st century AD). Here, the user has the goal of discovering the future (our present times). The visitor is immersed into a complex 3D environment populated by a virtual crowd, evolving around ancient roads and architectures, influenced by urban chronotopoi.

Structured as a serious game, “Imago Bononiae” foresaw a user experience evaluation carried out in occasion of Digital Heritage Expo, held in Marseille, November 2013. During the event, “Imago Bononiae” was studied to understand more on the interaction’s aspects that take place between system and user; specifically, we wanted to deepen our knowledge on the design features that most influence the interaction such as navigation issues, visibility and efficacy of interface elements. Furthermore, we wanted to retrieve information regarding the interplay between the cognitive mechanisms involved during the interaction and the technical qualities of the system employed. Thanks to direct interviews and questionnaires, first analyses revealed that the impact of this interactive applications resulted highly positive and interface elements played a crucial role in the meaning-making of natural interaction gestures.

This paper focuses indeed on the user-centric gesture design, navigation system and progressive gestural skills (rewards) that user can acquire in order to gain a powerful engaging experience and a massive comprehension of urban contexts mediated by visual strategies, enabling spatial and volumetric comparisons. A large virtual environment that is evolved and enriched through clear semantical approaches such as overlapping architectures from different time-slices, visual trails, a linear interface and a gesture-based exploration model to provide a satisfactory 3D picture of the Evolutio Urbis.

Authors

Tommaso Empler, Fabio Quici

Title

Paleontology 2.0 - Public awareness of paleontological sites thorough new technologies

Abstract

Paleontology 2.0 is a new way to communicate Paleontology by the means of new technologies to communicate, disseminate and enhance the territory of ancient man: prehistoric habitat where man, fauna and flora were living a full sharing of the site.

The territory of ancient man is now made up by prehistoric "invisible" sites, “visible” sites and museums.

Prehistoric "invisible" sites are places where there are ruins and remains of fauna and flora which, due to the particular type of site, after being object of a campaign of excavation, are now covered and thus made invisible.

Prehistoric "visible" sites are those that, after an initial phase of the study, were subjected to a process of a musealization, where the artifacts are set back in the same place where they were found.

Traditional museums collect specimens in collections and are not always located in the area of the discovery.

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For each of these cases, the new technologies provide different tools for knowledge. APP are effective on prehistoric "invisible" sites and let you have a memory or "track" of what was experienced on land. APP are tools that, working with a virtual dimension, are able to give an image to the "invisibility" of the field, where there is no evidence of a paleontological existence.

Prehistoric "visible" sites allow you to make an interesting series of operations from the acquisition with 3D laser scanner, to interactive forms of knowledge of the finds, to 3D reconstruction of the habitat with the original flora and fauna of the past (3D modeling with the possibility of visualization and navigation in real time).

Museums allow you to use all the above procedures by integrating informations of a scientific nature with views that can make accessible to a wider audience data and specimens collected.

In the proposed case of study, new technologies are applied to Polledrara of Cecanibbio, a field of elephant fossils of 320,000 years ago.

The actions for the communication/disclosure are:

- Scan with 3D laser scanner to obtain a virtual reconstruction of the paleontological site; the model becomes the basis on which formulate different ways to display and to use the site and its artifacts;
- Creation of interactive installations that allow knowledge to a "participatory" action of the site;
- Creation of an APP to communicate and disclosure, at a distance, the history of the site and the value and consistency of its findings.

Authors

Tommaso Empleri, Mattia Fabrizi

Title

Interactive communication and Cultural Heritage

Abstract

New forms of cultural heritage's communication increasingly see the opportunity to the visitor to interact with the exhibit. The visitor does not incorporate any more information proposed in a passive and traditional way, but enters actively in the process of exploration and/or learning, deciding the path of communication/disclosure most congenial to him. With this new way of visiting and learning, are multiplying museological exhibitions in which scientific and educational content are structured so as to be received by the visitors in a "subjective" way, through the use of instruments that can detect the intentions/ actions/movements of the visitor himself, turning them into human/machine interactions. The developed application, in turn, allows multiple knowledge permutations/ variations on a single object, for a better understanding of the phenomena and/or nature of the same object.

The procedure at the base of this pipeline includes a series of chained actions:

- 1) recognition of an object or area of interest using a 3D laser scanning. In this way it is possible to obtain a 3D model with the double function of representing the object itself and, at the same time, allowing the use of the Cartesian coordinates (x, y, z) of each point of the 3D model to handle the mode of interaction of the visitor/scholar;
- 2) the development of an interactive application and the making of an effective interface interaction man/computer;

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3) making a human/computer interaction through the use of tools created for the video games, such as the Kinect and the leap motion 3D;

4) planning the exhibition set by defining the interactive area (box, corner, wall) and placing within the means input/output tools (projector, kinect, leap motion 3D).

A real application of the procedure described has been prepared for the area of the Forum of Nerva in Rome, located to the east of Via dei Fori Imperiali, where there are some columns and friezes remainings of the imperial period. The visitor has the opportunity to use, from a certain location, his finger as a pointer, in the natural gesture of "pointing out" the object of his interest, placed in front of him. On site the movement of the finger matches the lighting of the part indicated by a directional spotlight, thanks to the movement tracking of the finger obtained with a kinect or a leap motion 3D device. To the action of pointing the finger, corresponds from the point of view of the computer application, a detection by the Kinect of the position of the finger itself on the 3D model detected by the 3D laser scan procedure and now made "invisible". When the finger stops for more than 5 seconds on a point of interest starts a video explaining the history or nature of the part of the selected object. The video is projected on a portion of flooring placed in front of the visitor.

The same exploratory mode can be exported to the room on the Forum of Nerva present in the nearby Museum of the Imperial Forums.

During the paper session can be given a live performance of the above described application.

SESSION 8A- DIGITAL CITIES:
DOCUMENTING AND TRANSMITTING THE
ARCHAEOLOGICAL-ARCHITECTONICAL
RECORD

Authors **Bernard D. Frischer, Paolo Liverani, Matthew R. Brennan**

Title *Documenting and Restoring the Augusteum of Rusellae (Roselle, Italy)*

Abstract Rusellae (modern Roselle, province of Grosseto, Italy) was an ancient Etrusco-Roman town on the Tyrrhenian coast. Conquered by Rome in 294 BCE, the city underwent a significant renewal in the Julio-Claudian period. In particular, the forum was enlarged and completely rebuilt. Among the new structures on the south side of the town square was an Augusteum, or a building for honoring the imperial family with one of the best-preserved cycle of imperial portraits preserved in Italy. The Augusteum was excavated in the 1960s and is the focus of this talk. We report on a project to create state and restoration models of the urban context, the building, and the twenty imperial portraits discovered in and around the structure, now housed in the Civic Museum of Grosseto.

The project exploits new research on this important monument, which is still unpublished. The new studies undertaken by the University of Florence in collaboration with the Archaeological Superintendency for Tuscany and the Grosseto Museum have made it possible to reconstruct the interior décor of the Augusteum in great detail. New investigation of the polychromy of the imperial statues, undertaken by the Institute for the Conservation and Promotion of Cultural Heritage (CNR, Florence), has revealed important traces of the coloring of the statues, which is otherwise invisible to the naked eye.

The digital project integrates the various strands of research on this building and places it into the urban context. The resulting 3D interactive model serves as a tool of scientific discovery making it possible to confront the major issues raised by the Augusteum: why it was not located directly on the forum, and how was it approached by the ancient visitor? Finally, the 3D model also serves to make the building and the works of art found in it more accessible and comprehensible to the general public.

Authors **Francesca Anichini, Mara Febbraro, Gabriele Gattiglia, Fabiana Susini, Valerio Noti**

Title *The representation of archaeological-architectonical record of Pisa*

Abstract Built to last in time, buildings have a lifecycle that may span over many centuries. During this period, they are restored, modified, expanded or demolished. Each of these interventions inevitably leaves traces, which are identified and arranged in a chronological sequence by building archaeologists in order to retrace the history of a building – or of its remains – from the moment in which it was built to present day. In the case of buildings stratification is mainly “vertical”, but its representation through GIS is “horizontal”.

The study we propose was developed on the urban fabric of Pisa’s historical centre for the MAPPA project. The research started from a complete survey of the buildings, carried out using records that detailed the characteristics of the building through all the historical periods attested above ground, from Roman to Contemporary ages, allowing us to check the legibility and the transformations of the building structures. In order to collect the data, a database was created in which each record was defined on the basis of an Urban Architectural Unit (UAU) of belonging, i.e. an element that has its own identity and function in the present-day city. Every Unit is linked to the CAs (Architectural Building) and CFs (Construction) that eventually compose it. The former includes fields related to the name of the building, function, construction type, initial and final chronology and description of the building, the latter describes the function, construction type, and initial and final chronology. Both are linked to the Elevation Record and Building Phase Record. The former provides brief details and links to the drawn and photographic documents, whereas the latter describes each single construction phase in greater detail, through fields regarding construction materials, laying, building techniques, chronology, and description of brackets, putlog holes, supporting arches, portals

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and windows.

A first novelty is the use of the webGIS to visualise the evidences: UAU, CA and CF feature classes are described with a polygonal graph, and phases with a linear graph. This allowed us not only to compare and crosscheck the data on a larger scale than traditional research, but also to obtain new elements on the way the city has grown, useful to define the archaeological potential of the various areas.

The work carried out within the scope of the MAPPA project offers a second novelty which is currently at its start phase: building archaeology can provide data that are useful to determine buried artefacts. Specifically, they can reconstruct (at least from the late-medieval period) the original heights of the buildings and roads they overlooked, i.e. the height of the below ground level which has changed over the centuries due to the city's increasing growth.

Authors

José María Martín Civantos, Mérida Ramírez Burgos

Title

GIS and digital platform for Guadix (Granada, Spain)

Abstract

Guadix is a small town in the North-East of Granada. It's an old settlement first established in the Bronze Age that became a Roman Colony, the only one in the current provinces of Granada-Almeria. It is supposed to be one of the first bishoprics in the Iberian Peninsula, but the Roman fall made the city almost disappear. Guadix won't rebirth until the XIth century, during the Islamic period, founded as madina then conquered by the end of the XVth century by the Castillian army. The new political power began to transform the city with the novelty and the church settlement. An important part of the historical city is still preserved due to a marginalization process from the XVIIth century onwards.

Despite being a small town it has an impressive heritage. Since 1986 something more than 40 archaeological interventions have took place. Most of them have been rescue excavations or directly related to restoration processes of still standing historical buildings. Since 2000, there is an archaeological map risk and some of the main buildings are protected. Nevertheless we know very little about the history of Guadix. This kind of Archaeology has not been able to produce scientific knowledge or interpret the site in historical terms. Even more, Archaeology is viewed as a problem.

Guadix represent a good opportunity to rescue all the old information, read the building stratigraphy, join all the interventions, manage different kind of data, reinterpret historical processes and, finally try to communicate and disseminate the results, involving local communities and giving a real sense to the archaeological practice.

Computer applications have become an essential tool for managing and use the enormous potential of Guadix as an example. For three years we have been developing a GIS and some other digital tools for managing complexity and transmitting knowledge.

We have been able to collect an important amount of historical, graphical and technical information, including almost all the original data and reports from the archaeological interventions.

All this information has allowed us to start changing the History of the city, but also transmit part of this knowledge to the public creating a web site. The research is still in progress, as we will continue working in Guadix after the project renewal for three years more.

DIGITAL CITIES: DOCUMENTING AND TRANSMITTING THE
ARCHAEOLOGICAL-ARCHITECTONICAL RECORD

Authors **Alexandra Chavarria**

Title *Digital Padova: recording, analysing and telling stories of a medieval city*

Abstract During the last 6 years the team working in the ARMEP project (Architetture Residenziali Medievali di Padova, Chavarria 2011) has produced a great amount of data concerning Padua's historical centre and particularly photogrammetrical plans of the front buildings and their stratigraphical analysis, architectonic elements such as windows, doors, capitals and decorations, cadastral maps, written sources, ancient pictures and photographs among others. These data were managed using a sophisticated GIS database of primary importance for researches on both buildings and spatial analysis on cadastral units. We are now trying to develop new methods for the visualisation of the scientific results (diachronic thematic maps and chrono-corematique) and to communicate the research results to a non-academical audience through a digital-storytelling web application.

With these purposes, and in order to have a more friendly, simple-structured and easy to upgrade GIS, we decided to re-create the structure of the original ARMEP GIS entirely inside the ESRI Geodatabase, avoiding the support of an external DBMS. For the data communication and to share the research results, an application has been developed, that is easy to be explored and shared, and mainly suitable to satisfy the needs of many different kind of potential users. The main feature of the App is the story-telling technic, that increases the potential interaction between public and cultural heritage and generates new involving ways of use and exploitation.

SESSION 8B- URBAN DIGITAL-SCAPES:
COMPUTER APPLICATION TO THE STUDY
OF PAST URBAN DEVELOPMENTS

Authors

Gabriella Carpentiero, Leonardo Bigi, Carlo Tessaro

Title

Multi-scale approach for the reconstruction of past urban environment. From Remote Sensing to close range analysis: the case of Dionysias (Fayoum, Egypt)

Abstract

Traditional researches in the study of ancient cities give particular emphasis to the comprehension of construction's processes of past built environment and their development through the time, together with the study of infra-structural capacity and ability to adapt to dynamic urban process. Current approaches give evidence to the organisation and perception of space, in particular within small areas or portions of ancient cities.

These concepts have been applied throughout the "Dionysias Archaeological Project" (led by the University of Siena and directed by prof. E. Papi) in the investigation of the entire urban complex, giving a fundamental role to spatial characteristics of the city itself.

The conclusions that will be shown have been achieved through the study of the urban layout of the ancient settlement of Dionysias (Qasr Qarun), an Hellenistic foundation of the IIIrd/IIInd century B.C. in the Fayoum region (Egypt), where the lack of excavation data made necessary the integration of all possible techniques in order to overstress the information and to obtain new sources of knowledge.

The challenge of this approach has been focused on the exploitation and integration in a GIS environment of four different sources of data: remote sensing (Satellite Image interpretation and geophysical prospection); fieldwork techniques of investigation (survey of the surface artefacts and production materials, architectural survey, study of the building techniques); historical and papyrological sources; the application of Space Syntax and other kinds of spatial analysis on the entire urban complex.

In the first step of the research remote sensing and survey techniques gave the possibility to gain an impressive amount of data on the organisation of the whole settlement and on some aspects of the economic activities, such as the disposition of buildings, the geometric assessment, criteria of formality and monumentality, material and structural aspects of the entire urban layout and of specific contexts, the identification of productive compounds and their organisation.

The application of spatial analysis and Space Syntax was used in order to add new perspective to the study of the entire settlement and to test its effectiveness in the context of remote sensing and surface survey data. This case study and the importance of its results has been an excellent test-bed for the integration of these techniques and could be essential for further researches in the same or in other areas, helping to find new methodological approaches for the integration of remote sensing and spatial analysis to the study of the configuration of space in ancient cities and for the reconstruction of social, productive and economic history of the site.

Authors

Bartomeu Vallori-Márquez, Miguel Ángel Cau Ontiveros

Title

The Roman city of Palma (Mallorca, Balearic Islands). The use of rescue archaeology data to redefine a Roman city through a GIS project.

Abstract

The modern city of Palma (Mallorca, Balearic Islands) has its origins in a first Roman city that lies beneath the city centre, close to the cathedral. It probably corresponds to the city of *Palma* cited by Pliny and Strabo. The remains of this Roman city have been partially known since centuries ago thanks to casual finds such as coins, pottery and other

remains. Throughout the 19th and 20th centuries some attempts have been made to propose an urban shape for the Ancient city: extension, street layout, city walls and different areas (Cau 2004).

During the last 20 years, economic prosperity has promoted an increase of construction works in Spanish cities, which has led to an equal increase of archaeological rescue excavations. In Palma, this new set of information is controlled by the Regional Government and has a strong potentiality for the study of the Ancient city, sometimes helping to challenge previous hypotheses.

Thanks to a grant from the city council, we are currently studying the new and old archaeological finds, together with ancient cartography, architecture and written Medieval and Modern sources. All these elements are being introduced in a database, with their accurate coordinates, chronologies, and a reliability, among other data. These elements are being managed spatially through a GIS project (QGIS) in order to map features such as different kinds of structures, site dispersion or reliability indexes (Hermon and Nikodem 2008). One of the main points is to guarantee data transparency of any resulting graphic material. These maps will allow us to reformulate previous hypotheses and to explore new possibilities concerning the extension of the Roman city, its limits, function of different areas, ancient topography and orography, following some previous examples such as Florence (Scampoli 2010) and Seville (González Acuña 2011). Further social applications of this project will be a WebGIS showing its results, and an archaeological guide to the Roman city of Palma complemented with Augmented Reality. This project has to be a first step, a strong starting point, towards a 3D model of the Ancient city, that will be implemented to some extent as one of the results of this project as well.

Authors

Maura Medri, Valeria di Cola

Title

Baths of the Swimmer and Sanctuary of Bona Dea in Ostia (V, X,2): a Spatial Analysis application

Abstract

The Baths of the Swimmer are located in Ostia within Regio V, south-east of the Decumanus. They had been explored and excavated between 1960s and 1980s and recently published in the whole edition of the building. Six are the main constructive phases detected by the stratigraphical analysis, starting from the flavian age, when the Baths had been built, until the current time, when the last restorations occurred on the structures.

Besides, the architectural phases study of the adjoining sanctuary of Bona Dea, which shares an accessing route with the Baths, has been carried on.

Even if not all the relations among those buildings and the surrounding urban context are clear, it seemed worthy to analyse both internal and outgoing routes through the Spatial Analysis, used as a tool to display fruition dynamics.

In particular, concerning Roman Baths having a specific internal circulation, Spatial Analysis seemed to be really useful, as a experimental application, to define possible routing focuses and, consequently, which different architectural solutions had been provided in each phase to optimise size and organisation of inner spaces in relation with their use.

- Authors** **Hanna Stöger**
- Title** ***A Space Syntax enquiry into ancient Roman neighbourhoods: Can we measure community-building in Roman cities?***
- Abstract** The proposed paper presents the results of a comparative archaeological and Space Syntax study of three urban neighbourhoods from Roman Ostia: city blocks IV ii, IV iv and V ii. The blocks selected for close analysis are located in different areas of the city; they vary in layout and spatial composition and cover different time periods. In combination these blocks offer a long-term perspective on neighbourhood development from the Republican period to Late Antiquity.
- The selected blocks constitute a representative sample of the physical matrix within which the city's ancient inhabitants would have experienced daily life. This detailed architectural/archaeological and syntactic study sheds new light on the changing relationship between the 'physical' built environment and generative processes in neighbourhood development. Selected Space Syntax tool (access analysis and Visibility Graph Analysis) and Place Syntax (Mapinfo-based) will be used to identify spatial factors and spatial characteristics which are conducive to social interaction and hence are able to generate vitality and positive neighbourhood quality. These include shared inner courtyards, joint passage spaces, protecting porticoes and intersecting movement circles.
- The analytical tools offered by Space Syntax will be applied to investigate three interrelated research questions:
- 1) What constitutes Roman neighbourhoods spatially and syntactically?
 - 2) Which spatial factors impact the development of neighbourhoods and their potential for vitality and sustainability in the long-term?
 - 3) How do neighbourhoods relate to the spatial distribution of public facilities and affect the formation of the overall urban layout?
- Authors** **Chiara Piccoli, John Bintliff**
- Title** ***Enhancing GIS urban survey data with the 3rd dimension: a procedural modelling approach***
- Abstract** Urban surveys reconstruct past cityscapes by integrating heterogeneous data coming from e.g. architecture, pottery, and geophysical prospections. Handling such a complex data system and merging it to create a coherent picture of the ancient spatial structure is challenging. The creation of a GIS-based 3D reconstruction is a useful strategy to organize the available data and test alternative reconstruction hypotheses on the ancient urban landscape. Manual modelling is however not efficient for creating such broad virtual environments and optimizing the import of GIS data. Procedural modelling conversely represents a suitable modelling strategy that meets the requirements of an integrated approach towards 3D reconstructions of complex urban sites. This modelling technique allows the creation of large 3D scenes from a concise set of rules applied to GIS data.
- This paper discusses the application of procedural modelling to the reconstruction of the ancient city of Koroneia, Boeotia, Greece. This modelling approach was used to enhance the GIS-based

URBAN DIGITAL-SCAPES: COMPUTER APPLICATION TO THE STUDY OF PAST URBAN DEVELOPMENTS

data with a 3D reconstruction of Koroneia's urban layout in its historical phases. The software used was Esri CityEngine. Procedural rules were written for the Classical and Hellenistic housing and public architecture, city walls and vegetation. The rules describing the architecture were based on the finds from Koroneia and on published material from other Greek sites. Dimensions of buildings and the likelihood of occurrence of specific architectural features (e.g. an upper floor) were set by using attributes and parameters in the rules. By doing so, it was possible to quickly change the visualization in real time to test several hypothetical reconstructions. The rules have been annotated with comments on the modelling choices and citations from the sources that were used for comparison. In this way, the rules are intellectually transparent and can be assessed by the academic community. Mathematical functions were included in the rules to investigate spatial properties of the urban environment such as the distribution of housing quarters according to the terrain's slope.

Koroneia's reconstruction is available online and acts as a platform for discussion within the survey team and as a communication means for the broader public. All the rules that were written for Koroneia are publicly distributed to facilitate their reusability in other projects. By using this methodology we created a 3D visualization that integrates GIS and 3D modelling techniques and can be changed in real time to display and discuss different interpretations of the archaeological evidence. A basic network analysis was run to highlight integrated and segregated areas in the reconstructed street network to formulate hypotheses on the functional zoning of the city. The reconstructed cityscape can be furthermore exported to ArcGIS to perform visibility analysis on the 3D environment. This approach allowed us to use the 3D reconstruction not as a mere visualization aid but as a tool to investigate the city's spatial structure and gain a better understanding of the ancient urban landscape.

**Authors****Ermal Shpuza****Title*****The effect of gridiron street pattern on urban growth: evolution of Adriatic and Ionian coastal cities 1800-2010*****Abstract**

The study addresses the evolution of urban centers along the Adriatic and Ionian coastline, stretching six countries between Peloponnese and Sicily during the last two centuries. The cities and towns manifest the ambivalent role of the sea channel as divider and unifier over the centuries including the Theodosius Line, the Venetian maritime colonies, the western border of Ottoman Empire and the Iron Curtain. Urban expansion according to gridiron

street pattern was a defining urban planning event that followed the spread of Napoleonic influence in Italy after the fall of La Serenissima, and the attempt to de-Ottomanize cities after the independence in Greece. The application of nineteenth century gridiron extensions in the region was not universal. While it occurred in almost all Italian and Greek cities, it was not adopted in coastal cities in Albania, Montenegro, Croatia, and Slovenia, with the exception of Pula and Rijeka. Almost a century later, the application of gridiron streets during the early part of nineteenth century underlies the strongest bifurcation in urban evolution pattern in the region. The study inquires the effect of gridiron street patterns on two key characteristics of urban growth: the migration of the urban center from inside the historical center towards deeper in the newly accrued urban fabric; and the extent to which the original set of arterial roads connecting the historical center with neighboring cities maintains its role as the foreground network during the city's growth. Streets are the most important element of urban form, impacting many aspects of urban morphology, and social and economic life. Street networks in seventy cities and towns in the littoral region are studied according to three growth stages: nineteenth century, WW2, and present. The study is supported by an extensive research of historical maps and aerial photographs from more than twenty archives. Cities are analyzed according to manually drawn axial maps where the longest and the fewest segments that cover streets and open public space are represented as graph nodes, and intersections between them as graph links. The urban center is defined according to the geometric center of the region bound by the 10% most integrated lines; while the foreground network is defined according to the set of lines with 90% highest values of choice (betweenness centrality). The study combines the heuristic examination of the transition of urban center and change of foreground network over time with the statistical analysis of subsamples of cities with and without gridiron patterns. The research bridges between urban history, network analysis, statistical analysis and urban planning and design, and projects methods and tools in aid of computational quantitative archaeological and historical studies.

Authors**Benjamin N. Vis****Title*****Shaped by the Paths Shaping the City: Examples of BLT Mapping Maya Urban Circulation Space*****Abstract**

Boundary Line Type (BLT) Mapping is a recently developed method for studying the social functioning of cities by analytically mapping concepts capturing change in opportunities for interaction throughout the urban built environment. Its GIS based practice results in a very thick and complex dataset which retraces the outline base plan of urban built environments. Mapping technologies for analysing urban form often heavily depend on the existence of formal street networks. Instead, BLT Mapping reveals the outlines of subdivisions by which a city is inhabited; occupied and traversed. While space syntax analysis provides a probabilistic assessment resulting in a pattern of the likely frequency with which streets are used or the street preference to navigate urban space, BLT Mapping distinguishes how an individual's opportunities for interaction are contextualised as their position changes from space to space.

This paper uses examples from the ancient Maya city of Chunchucmil to discuss how its network of circulation spaces creates configurations of interaction opportunities that result in a very different experience of urban life than in cities with a formal and readily recognisable street network. The socio-spatial differentiations that structure the role of urban space close to Chunchucmil's city core, are suggestive of a radically different pulse to everyday pathways of social interaction within the city. By demonstrating some of BLT Mapping's abilities closely related to foundational features of other techniques in a challenging urban

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layout, a dialogue for methodological integration or structural correlation of results is sought.

Authors **Jeffrey Barron Glover, Robert Bryant, Brennan Collins, Tim Crimmins, Marni Davis, Joe Hurley, Ian Johnson, Michael Page**

Title *The digital Atlanta project: an interdisciplinary approach to remapping Atlanta's past*

Abstract In comparison to many Old World cities, the U.S. city of Atlanta is not that old, but the complexities of studying the urban environment is still evident in our efforts to interpret and tell the city's history. This paper brings together scholars from English, History, Archaeology, Library Sciences, and Urban Geography from Georgia State University and Emory University to discuss our initial efforts to create an integrated, digital project to study and recreate aspects of Atlanta's past. While we are early in this process, we hope to contribute to the on-going dialogue about studying past urban environments.

Atlanta is the largest metropolitan area in the southeastern United States, and its history might be most well known to outsiders thanks to the popular movie "Gone with the Wind." This classic movie, based on the novel by Margaret Mitchell, does highlight a transformative event in the history of Atlanta – its burning by Union Troops in 1864. In many ways it is the Civil War and this conflagration that marks the starting point for our historical investigations. In our own ways we have all been interested in studying the development of Atlanta from a ravaged, railway hub at the end of the Civil War into the major metropolis in the Southeast in the 20th century. What we are now trying to do is connect projects that all started as independent efforts – the creation of a georeferenced map of the city from 1930 with a linked geodatabase about the city's inhabitants; the creation of 3D environments of specific downtown buildings from the early 20th century; a study of urban planning principles through map data; the creation of microhistories of particular urban neighborhoods; and the investigation of archaeological collections recovered during a major urban infrastructure project conducted during the 1970s. To connect these projects we are creating a digital platform to enable us to engage in interdisciplinary collaboration with a regional focus on Atlanta's landscape. This platform must be useful for scholarly research as well as public engagement. Here we highlight our initial successes and failures as we cross disciplinary and university lines to integrate studies of material culture, history, and the built environment in an effort to better understand the city in which we all live and work.

Authors **Sorin Hermon, Georgios Artopoulos, Nikolas Bakirtzis**

Title *3D virtual environments for simulating past urban experiences in pluri-cultural spaces – the Pafos Gate, Nicosia as a case-study*

Abstract The experience of historic urban environments remains an ideal context to probe questions of urban identity. The Eastern Mediterranean preserves significant examples of cities whose continuous history can be traced all the way back to Prehistory. In particular, the capital of Cyprus is considered amongst the most contested urban environments having historically layered pasts and perplexing present-day realities. This paper proposes a methodology for the cross-disciplinary study of complex urban realities, with the use of advanced technological

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applications for the formulation of real-time virtual environments that create spatial data of user behaviour in and around monuments of cultural heritage. The presented digital methods focus on knowledge sharing and communicating experience. They are based on interdisciplinary collaborations between heritage, archaeology, architecture, urban studies and simulated environments. The paper suggests a new experience-centred method of site-explorations that facilitates data collection of mis-appropriated territories and challenged historical sites. The paper presents theoretical considerations and practical knowledge of the development of hybrid digital environments that stage urban narratives to study the role of monuments of cultural heritage on the development of historic cities. The proposed research framework is implemented in the on-going study of the infamous Green Line of Nicosia, Cyprus that still divides the city, and contributes to the analysis of the use of challenged public spaces in contested urban environments.

SESSION 8C- DIGITAL METHODS IN
EXPLORING AND EXPLAINING THE
DEVELOPMENT OF PROTOURBAN
CENTRES

Authors **Jorn Seubers**

Title *By the grace of the plough*

Abstract A GIS based cartographical analysis of changes in elevation due to erosion and sedimentation in the settlement area of ancient Crustumarium.

Obviously, surface archaeology is revealed to us by processes of post-deposition. However, these same processes move, abrade, disperse, obscure and can even change the composition of surface find assemblages, strongly biasing the interpretation of survey data in numerous unmeasurable ways. Ironically the plough that enables us to study surface archaeology in the first place is the same instrument that make its interpretation rather problematic, up to the point where even landscape archaeologists themselves question the value of their data.

The tuff bedrock that is characteristic for the geology of large parts of Central Italy is well known to be prone to erosion, which has only accelerated due to the long and intensive agricultural exploitation of the terrain. In the case of the ancient Latin settlement of Crustumarium (North-Rome) the adverse effects of erosion for the preservation of the archaeological record has been stressed for decades and on the basis of excavations soil-loss of several meters appears likely in specific locations. One of the objectives of the archaeological fieldwork on Crustumarium by the Groningen Institute of Archaeology, has been to investigate the nature and impact of these taphonomical processes for the archaeology of this ancient urban area.

The current paper investigates the history of land-use on the site of Crustumarium on the basis of elevation information in topographical maps covering a century. The authors will attempt to quantify the geomorphological changes to the terrain with a diachronical analysis of digital elevation models generated and compared in a GIS. This study will result in the creation of a map in which the degree of the expected preservation of subsurface archaeology can be specified for the entire settlement area. A map like this can help guide future research plans, but can also aid the interpretation of currently available data.

Authors **Angelo Amoroso**

Title *Markers to define the proto-urban centers and their territory in Latium Vetus*

Abstract During the advanced Early Iron Age on the left bank of the lower valley of the Tiber, in the ancient Latium Vetus, is documented a radical reorganization of the territory. The Latins adopt different strategies of land's occupation; and they go on, as since the Final Bronze Age, to keep settlements of the summit in a dominant position. They founded new proto-urban centers on big and structured plateaux, as the case of Rome. The proto-urban centers of the Latium Vetus replicate on a smaller scale the settlement model designed in southern Etruria since the Bronze Final - Ancient Iron Age; controlling territories considerably lower than those managed by the Villanovan hegemonic centers. This paper, using specific spatial analysis through the use of digital mapping, analyzes the characteristics of the proto-urban centers of Latium Vetus and attempts to define Their territories during the Iron Age. Six parameters sono stati taken as points of reference: the geomorphology of the territory and environment; the settlement position; the settlement morphology; the settlement size; the spatial relationship between settlement and related burial areas, the settlement territories. These six parameters allow detection of significant markers of distinction between the main centers and secondary centers in the Latium Vetus, as well as between proto-urban centers of Latium Vetus and those of southern Etruria. This paper also aims to reconstruct the area of influence of the main Latin centers, from the early Iron Age until the Archaic period. How can we calculate the extent of the territory controlled by any single center? Recently,

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scholars have been using different methods; many scholars have adopted Thiessen polygons to reconstruct the boundaries of the territories controlled by Etruscan centers and those in Latium Vetus. In this work we used the method of Thiessen polygons, but match the size of the settlements and adapted to the position of the main rivers of the region. Calibration allows you to attribute to major centers, characterized by a higher capacity demographic, territories proportionate to their size and their needs supply of resources, essential for the survival and development of the communities which will give rise to major cities of the ancient Latium.

Authors Ulla Maarit Rajala

Title *The Final Bronze Age – Early Iron Age transition in southern and northern Etruria: GIS, territories, agricultural production and settlement change*

Abstract In this paper I will return to the agricultural modelling I carried out earlier at Nepi (Rajala 2002). I will aim at examining the Final Bronze Age – Early Iron Age transition in southern and northern Etruria by comparing the situation at Veii in the south and Volterra in the north. I will briefly summarize the method used in my PhD where I applied GIS and agricultural modelling in order to suggest an interpretation for the reasons for change in settlement patterns between the two periods. The same method has been recently been used by Fulminante (2014) in order to study the extent of the territory of Archaic Rome.

The settlement histories of Veii and Volterra seem to differ slightly and their surroundings are visibly different. The plateau of Veii was not the main settlement at Veii until in the Early Iron Age, after the settlement relocated from the smaller hillock of Isola Farnese in the south (Boitani *et al.* 2002), whereas in Volterra the Acropolis seems to have been settled from the earlier part of the Bronze Age (Bonamici 2003, 174–183; 2009). Veii and Volterra were located at the southern and northern edge of Etruria respectively, the first in the inner rolling landscape of southern Etruria whereas the latter lies on a limestone rock with a sloping steeper northern side in a vast circular depression. Veii was the historic enemy of Rome that was defeated in 396 BC, whereas Volterra had probably the largest territory in Etruria (see Redhouse and Stoddart 2011) and it was independent almost until the last. In this paper I will discuss how GIS can potentially be used in explaining the potential differences in the political situation at the different boundary zones in Etruria.

Authors Alessandro Guidi, Francesca Fulminante, Sergi Lozano, Luce Prignano

Title *Networks and Urbanization in Etruria and Latium vetus (1175/1150-500 BC)*

Abstract Since the first pioneering application of the 1970' and 1980' during the last decade of so Network analysis has become more and more popular within the archaeological discipline.

In particular various scholars have emphasised the potential of Network Analysis for the study of emerging complex societies; however the application of Network Analysis for the study of urbanization and state formation processes remain very few.

By comparing Bronze and Early Iron Age settlement terrestrial and fluvial networks in Etruria and Latium vetus this paper will debate the contrasting trajectories toward higher complexity in these two regions. At the same time it will discuss advantages and issues related to the application of Network Analysis to Archaeology.

Authors Mariza Christina Kormann, Stella Katsarou, Dora Katsonopoulou, Gary Lock

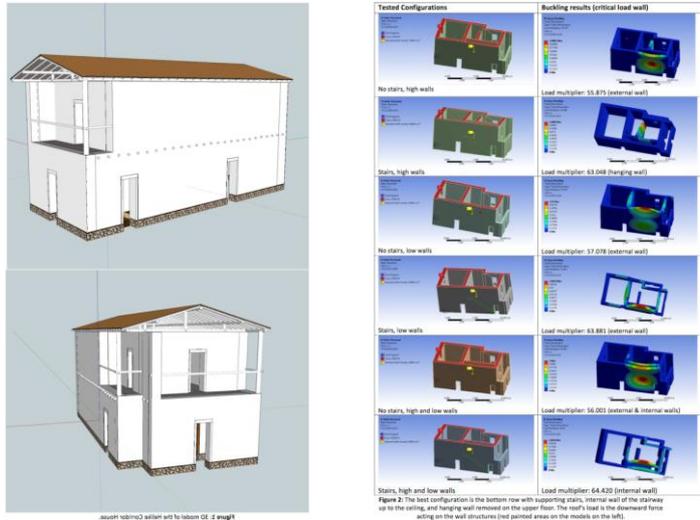
Title *Structural Integrity Modelling of an Early Bronze Age “Corridor House” in the Peloponnese*

Abstract

Structural integrity modelling and simulation studies were performed on the Helike Corridor House (HCH), an EBA monumental building excavated on the coast of the Corinthian Gulf, Southern Greece [1,2,3]. The hypothesis that an upper floor existed was tested to understand the function of innovative structural arrangements introduced during a period of sweeping social transformations during the third Millennium BC. The HCH is part of a proto-urban settlement with complex structures of houses facing paved streets. This work sheds light, from a structural integrity point of view, on the long-debated reconstructions of the so-called ‘Corridor’ EBA architecture by examining the modifications of old ground floor plans into two-storey buildings supporting a tiled roof, with specialized arrangements for high storage capacities [4], cooking facilities, and large living spaces with stairway access. These new structural arrangements with long and narrow corridors raise questions at the functional and structural levels addressed here by advanced computer simulations [5]. The methodology includes 3D solid modelling, material mechanical properties definition, mathematical modelling of the mechanical system, simulation and visualization.

ANSYS [6,7] is a sophisticated modelling and simulation platform for testing how structures behave in the real world based on finite element analysis and mechanical properties of materials. The building materials (unfired mudbrick, clay, pinus halepensis, twigs) and properties (density, modulus of elasticity, Poisson ratio, tensile and stress strength) were carefully defined [8,9,10]. The house geometry was derived from accurate measurements of the excavated foundation walls from the Helike site. The HCH was modelled in SketchUp (Fig 1) for use in ANSYS with the roof being replaced by its equivalent load. Static load analysis followed by buckling (failure) analysis clearly indicates that the long narrow corridors had a structural function. A number of scenarios were simulated including with and without stairs and internal walls on the first floor removed thus making possible provisions for larger rooms. Simulations demonstrate that whichever configuration is adopted buckling would develop in the walls of the narrow corridor area, this being the critical area of the structure due to its configuration of long, tall walls (Fig 2). However, when stairs are introduced the consequence is a more rigid structure less susceptible to buckling in all cases. The conclusion is that the building materials used and the new developed plan with double walls allowed for a second floor. Furthermore, the doubling of the outer walls forming narrow corridors with internal stairs had a clear structural function, a significant result in the context of understanding innovation in EBA architecture.

The results are interpreted through critical discussions in the context of emergent administrative authorities and centralized distribution systems occurring within the realm of the rising Eastern Mediterranean chiefdoms.

**Authors**

Andreas Viberg, Ulla Rajala, Arja Karivieri, Elena Sorge, Alessandro Furiesi, Lena Holmquist, Maria Lowe Fri

Title

The Stockholm Volterra Project—geophysics, photogrammetry and GIS mapping in exploring the historic centre of Volterra, Italy, from the Etruscan to the medieval period

Abstract

The Archaeological Research Laboratory and the Section of Classical Archaeology and Ancient History at the Stockholm University started in collaboration a field course entitled Field archaeology in land of the Etruscans in 2013. This course, on the undergraduate and master level, introduces the students to different geophysical prospection methods within an urban environment and gives an introduction to the Etruscan culture. The fieldwork takes place over a period of two weeks within the remit of a five-year research permit from the Soprintendenza per i beni archeologici della Toscana and the research is carried out in close collaboration with the city of Volterra, Italy. The methods taught and the studies executed have both educational and scientific aims, and the methods vary from year to year depending on the availability of specialists and results achieved during previous field campaigns. During 2014 the programme included surveys using Ground-penetrating Radar (GPR), RTK-GPS measurements, photogrammetric recording and data collection for a City GIS over Volterra. The 2013 surveys also included magnetometer prospection, continuous vertical electrical sounding (CVES), multi-antenna GPR surveys and terrestrial laser scanning of ancient monuments and buildings within the city. Different parts of the programme balance to a different degree the educational and scientific aims. The clearest geophysical results have been collected using GPR, which, to date, has been used at thirteen different locations in Volterra. The method has revealed new details of the Etruscan and Medieval monuments and provided new information regarding the city plan. All data will eventually be combined in a City GIS that makes use of the digital data provided by the Regione Toscana in the local Gauss-Boaga coordinate system. All data is measured in or transformed into this system. This presentation will focus on presenting new information about the Etruscan city walls of Volterra and the cemetery at the church of Santo Stefano.

Authors **Wojciech Ejsmond, Julia Maria Chyla, Teodozja Rzeuska, Dawid Feliks Wiczorek, Piotr Witkowski, Marcin Jakub Ordutowski, Marzena Ozarek-Szilke, Daniel Takacs**

Title ***Gebelein Archaeological Site Complex in Egypt – Shift from Capital of Predynastic, through Capital of Protostate to Administrative Centre in Dynastic Era***

Abstract Gebelein is located south-west of Luxor on the west bank of the Nile. Ancient remains at the site complex are representing all periods of Egyptian history. In the Predynastic Period it was a capital of protostate and an important administrative and trade centre in the following times.

How can we research the shift from Predynastic capital (c. 4000 - 3100 BC) to administrative centre of the Early dynastic period (c. 3100 – 2686 BC) and the Old Kingdom (c. 2868 - 2181 BC)? Recent research at Gebelein approach this question from various angles by analysing present local landscape and topography, archival maps and a contemporary satellite imagery, written sources and results of previous field works. The Archaeological Information System of the site consists of different kinds of data, which when analysed show significant progressive changes of the landscape in the Gebelein area and allow us to reconstruct the role and importance of the place in the past.

Purposive ceramic survey, undertaken in the season 2015, delivered new data that allowed dating and functional analysis of the surveyed area. NIR satellite image analysis revealed specific vegetation marks in fields surrounding the site. Those features might be interpreted as traces of an old riverbed and channels. The observed marks were verified during field reconnaissance. During the survey archaeological features observed previously on the satellite images were documented with the use of mobile GIS. In the city of el-Gherira we conducted geophysical survey to localise remains of Predynastic necropolis.

Gebelein is very rich in various archaeological sources. We discovered concentrations of graffiti from different periods. Part of them had been documented using Reflectance Transformation Imaging. This technique proved to be very useful in documenting graffiti located in the almost perpetual shadow as well as, in detecting poorly preserved ones. Also simple digital photos appeared to be a useful tool, paired with specialized software (such as image processing called "Decorrelation Stretch") allowed to obtain new information/data. The use of this algorithm on selected photographs of the last season led to the discovery of a new, previously untraceable hieroglyphic inscription. The results of multi-approach analysis of gathered data showed significant progressive changes of the landscape in the Gebelein area. Moreover, results of analysis provide new arguments for the discussion on the role, significance and evolution of Gebelein throughout history.

Authors **Lisa Frisher**

Title ***Creating Virtual Williamsburg: Modeling an Eighteenth-Century American City in 3D***

Abstract Modeling an entire historical city in 3D can provide many research and educational opportunities. Depicting a past cityscape can help audiences to visualize past landscapes as dynamic environments for better understanding the people who lived in them and the events that occurred there. Modeling of cities can also be valuable for research in better understanding

the relationships between sites and how wider landscapes functioned. However virtually recreating past cityscapes, even relatively small ones, can present challenges. As the number of buildings to be modeled increases, the greater the quantity and types of data required to reflect an accurate cityscape. Thus the analysis and interpretation must be more involved in order to look not just at individual sites in isolation, but how the built landscape functioned holistically. The modeling work also becomes more complex in virtually reconstructing hundreds or thousands of buildings as well as the surrounding landscape. The approach must also remain consistent throughout the development process so the end result appears cohesive. As more buildings and objects are added to a virtual environment, file sizes necessarily increase, which can affect rendering as well as delivery speeds and options. However if these challenges can be managed, then the resulting cityscape model can be a valuable research and educational tool. This paper will explore the approaches being used to develop Virtual Williamsburg, an interactive model of Virginia's second capital, as it looked on May 15, 1776. The date is significant because on this day the Fifth Virginia Convention, meeting in the Capitol, voted for its delegates to the Continental Congress to propose independence from Great Britain. The goal of the project is to use the virtual model of Williamsburg for a range of educational purposes for teaching guests, both online and onsite, about this important 18th-century capital. To model the whole city, more than five hundred buildings need to be recreated virtually. Our approach has involved creating a preliminary low level of detail (LOD) model showing the city and surrounding landscape based on existing interpretations as well as evidence from historical maps. Individual neighborhoods are then selected for high LOD modeling, in which all of the evidence for a site is reassessed and reinterpreted. When a high LOD model is completed, the reinterpreted building replaces the existing low LOD one. To date, eighty seven buildings—from complex structures, like the capitol and playhouse, to simpler outbuildings, such as smokehouses and dairies—have been modeled individually in high LOD. Twenty one of these high LOD buildings also include some or all of their interior spaces, and eleven have been modeled to multiple time periods. Having the low LOD model has also proven valuable for providing context to understand what structures look like as groups, not just in isolation, to better understand how the landscape functioned. This paper will present our approach to the modeling and discuss what we have learned as well as how we have managed the challenges in working to virtually reconstruct an entire eighteenth-century city.

SESSION 9A- TOWARDS A THEORY OF PRACTICE IN APPLIED DIGITAL FIELD METHODS

Authors Daniele Ferdani, Giovanna Bianchi

Title *Recording, preservation and interpretation of a medieval archaeological site integrating different 3d technologies.*

Abstract During the last years, the chair of Medieval Archaeology of the University of Siena, was involved in studying the archaeology and architecture of the medieval castle of Montieri (Grosseto-Italy). The castle was built by the Bishop of Volterra and thanks to its metalbearing ores, it was the focus of a complex history, which can still be read today in its well preserved remains.

The last survey campaign were focused on excavating “La Canonica”, an ecclesiastical complex dedicated to St. Nicolò. The excavations came up to light the existence of a church characterized by an unusual plan with six apses (the only example of its kind in Italy), and a number of buildings built pertaining to the ecclesiastical complex, linked to the bishop of Volterra and documented for the first time in the 1133 [Aranguren, Bianchi and Bruttini 2008]. During the research activities an innovative workflow for 3D documentation and analyses was tested. The successfully results shown how this approach can be adopted and fully integrated in the everyday archaeological practice thanks to its multiple advantages: fast acquisition and post-processing of the data, 3D textured models, low cost and post-excavation analyses. The workflow integrates different 3D modelling approaches in order to produce digital assets for three different research purposes:

1. **3D documentation.** Using Dense Image Matching techniques it was possible to process a detailed and textured digital model of the entire archaeological site. The model was used as base for post-excavation discussion and investigation and finally to easily derive technical archaeological documentation such as blueprints, sections, prospective and orthographic views.

2. **improved analyses.** Using computer graphics software, complex output were derived from the 3d models obtained. For instance the curved surface of the apses were rectified and developed. This allowed the facing stonework to be seen and measured without any distortion by archaeologists, improving their perception in analysing the construction phases and evaluating skills and capability of the builders.

3. **monitoring and preservation.** The site was under excavation and subject to a quick decay due to atmospheric agents and the excavation activity itself for a long period. This altered the state of preservation of the monument. However, since the 3D models were recorded once the architecture came up to light, "freezing" the remains at the discovering moment, it was possible to easily restore the monument using the digital model as reference.

4. **interpretation and 3D reconstruction.** Finally the 3D scanned model were used as reference for drawing up a virtual reconstruction of the medieval architectures using computer graphic approaches. The digital reconstruction process went hand in hand with interpretation activities improving researchers perception thanks to an immediate visual feedback and allowing hypotheses to be verified and refined when proved wrong.

In the paper, workflow, techniques and software used and result will be discussed and deepened.

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- Authors** Sorin Hermon, Lola Vico, Franco Niccolucci
- Title** *On the intricacies of scientifically 3D modelling a building from the past and formally representing its underlying reasoning process – The Santa Cristina sanctuary site (Sardegna, Italy) as a case-study*
- Abstract** 3D modelling is a commonly associated term with archaeology since more than two decades. Almost ten years ago a Charter (The London Charter) set up principles for the computer-based visualisation of cultural heritage. A diachronic survey of the archaeological scientific literatures reveals a fluctuating use of 3D modelling – while the initial thoughts of the early nineties aimed at developing an environment where “modelling” is the key aspect, consequent outcomes were related to “communication” aspects of archaeology / cultural heritage, “serious gaming”, “publication”, and so on, most claiming a “scientific foundation”, but often without a clear way to represent this. Another, more recent development branch regards the development of technologies and methodologies for 3D documentation and innovative methods of (3D) data capture, archiving and processing. There are still few papers in archaeology that demonstrate the utility of a 3D approach to the archaeological reasoning process, i.e. the use of 3D as a simulation and modelling environment, where hypotheses are tested and corroborated. The paper proposes to fill this gap, by presenting a proposal for a formal representation of a reasoning process, where the archaeological research question is answered through a 3D approach. The case-study analysed is the “sacred well” at the Santa Cristina archaeological site in Sardegna (OR), Italy. A major research question is related to understanding the human activities that occurred at the site, their nature and their implications to the related society. Consequently, several factors may elucidate this question: the shape of the building (exterior and interior), light and mobility paths in the investigated space, the perception of space, amount of energy invested in building it, etc. Such questions can be answered by understanding how the building was built, its lightning conditions, accessibility paths, etc., all includable into the 3D modelling concept. A parallel process to the above relates to “data transparency”, i.e. the ability of others to reproduce the simulation / modelling, access used data and, comprehensively, understand the reasoning process related to the published scientific outcome. The paper will present an example on the use of 3D as an archaeological simulation / modelling environment, with its related digital structure to support a scientific critique and deconstruction, by formally describing its reasoning process.
- Authors** Jeroen De Reu
- Title** *Image-based 3D reconstruction: the future of archaeological excavation practice?*
- Abstract** Image-based 3D reconstruction has the potential to revolutionise the practice of archaeological fieldwork. It holds great opportunities for increasing the quality of archaeological documentation, study and interpretation, but it also brings new challenges and risks.
- This paper will focus on the application of image-based 3D reconstruction for the documentation of archaeological excavations, with particular reference to its application within the framework of development-led archaeology. Based on a series of case studies, we will present how we try to systematically apply an image-based 3D recording workflow for the documentation of excavations, how we use the 3D data during the excavations and the post-excavation processing and how it aids the study, interpretation and understanding of the site. We will show that applying image-based 3D reconstruction, instead of traditional recording

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techniques, requires a complete change in the workflow of an excavations, but at the same time that the quality of the excavation documentation can be substantially increased when using this technology properly. Besides the opportunities, we will also highlight new challenges and risks encountered while applying this technology.

Authors**Fabrizio Galeazzi****Title*****Finding a Place for the New: Integrating 3D recording techniques with traditional practices of archaeological documentation.*****Abstract**

Advances in digital technologies over the last few decades have contributed to the diffusion of 3D documentation techniques in archaeological field practice, and is rapidly changing approaches to archaeological survey. To date, thanks to the use of different laser scanner techniques, it is now possible to acquire archaeological sites and monuments in all their aspects, from the small (artefacts and micro-stratigraphy) to the large scale (archaeological site context and landscape).

More recently researchers have turned their attention also to more usable and cost effective techniques, like Dense Stereo Matching (DSM). The possibility to acquire 3D models by just taking pictures makes DSM technique extremely flexible. Archaeological excavation is a destructive and unique process. When stratum are removed, it is not possible to “go back” and repeat the operation a second time. One of the most interesting aspects of this technique for the 3D documentation of archaeological stratigraphy lies in the possibility to revise acquired 3D models directly on site during the excavation process itself, because data processing time is reduced when compared to time needed using a laser scanner.

This paper will discuss the results of a fieldwork campaign at the Las Cuevas site (Western Belize) which aimed to develop a new recording methodology integrating DSM into day-to-day archaeological excavation practices. It will attempt to evaluate whether DSM allows the revising of final 3D models on site before strata are removed, and whether it offers reliable metric representation of stratigraphic unit information when compared to laser scanner technologies.

In conclusion this research demonstrates that the active integration of both traditional and innovative practices for archaeological documentation can be feasible when the use of 3D technologies does not affect the excavation process with regard to time or logistics. In this sense data acquisition has to be as fast as possible while simultaneously reducing invasiveness. Of additional importance is the time dedicated to data processing, giving researchers the opportunity to integrate 3D technologies effectively in the archaeological excavation process.

Furthermore, it is also critical to understand how the 3D data implemented for analysis and interpretation of specific projects can be re-used for the implementation of online platform that can provide access to data archived in a simple way for all kinds of users, including those who are unfamiliar with these technologies. For this reason the 3D data coming from this research has been re-used and integrated in the *ADS 3D Viewer*, a 3D online real-time visualization system for the management and analysis of archaeological data for ADS (Archaeology Data Service). This viewer gives the opportunity to multiple experts to interact and analyze 3D replicas of the excavation record promoting an unprecedented dissemination of multiple interpretations of the same archaeological context.

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- Authors** Luca Bezzi, Alessandro Bezzi, Rupert Gietl, Gianluca Fondriest, Giuseppe Naponiello, Mattia Segata
- Title** *Professional archaeology: innovations and best practices in digital methodologies. Through an Open Research*
- Abstract** This contribution tries to summarize the the ten-years experience of Arc-Team in professional archaeology, focusing the attention on the digital methodology with open tools (Free/Libre and Open Source software and hardware) and to analyze the concept of Open Research, through the exchange of informations, knowledge and data.
- During the presentation we will try to outline the best practices gradually evolved over the years in different archaeological fields, from remote sensing via DIY drones, to geodetic documentation (in 2D and 3D), from data management via database and GIS, to the dissemination of results through quadrimensional reconstructions. Particular attention will be pointed on archeometric techniques, analyzing the digital support in data collecting and comparison, with examples related to geoarchaeology (in situ and in laboratory), archaeobotany, archaeozoology and archaeoanthropology.
- Authors** Samantha Stout
- Title** *Cyberarchaeology and interdisciplinary collaboration – A critical analysis of the adoption of digital technologies in archaeology in the case of CISA3 fieldwork in Jordan*
- Abstract** Since the founding of the Center of Interdisciplinary Science in Art, Architecture and Archaeology (CISA3) in 2007 within the University of California, San Diego’s California Institute for Telecommunications and Information Technology (Calit2), the adoption of applied digital field methods within the Levantine Archaeology Lab has increased exponentially. CISA3 created a venue where engineers, software developers, and materials scientists, were tasked to work with the archaeologists and anthropologists, conducting joint field expeditions, where cutting edge technological tools were to be tested and developed. In theory, this was the exact sort of hotbed for fruitful collaboration, and rapid implementation of digitalisation tools ensued. One of the major contributing factors was that CISA3 became the recipient of a major grant from the National Science Foundation from 2009-2014, significantly fueling the technological “arms race” that began to occur as cyberarchaeology was emerging. Now, as this funding draws to a close, and the interdisciplinary team has transitioned from a novelty to a routine, it serves to examine the effects that the cyberarchaeology revolution has had on the Levantine Lab.
- Going digital has indubitably brought more press and recognition to the work of archaeologists in the lab. Immersive digital environments can bring the excavation site home, entrancing the public and attracting key donors to support the research. In this way, the field is likely enhanced. However, the barriers to communication across disciplines can also result in flashy models and data displays that fall flat when it comes to curated research practice. In addition, the hierarchy and structure of these dynamic teams, and the individual interests of academics who must still live in “silos” could undermine the real methodological progress interdisciplinary collaborations should in theory achieve.

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This paper seeks to examine ways in which caution can be exercised and improvements can be made when digital field methods are applied in an interdisciplinary team environment. Key points of discussion will be illustrated through critical analysis based on interviews of team members and faculty directors. This will be compared to relevant literature on the basic theories of practice employed in the past.

Authors**Colleen Morgan****Title*****The Death (and Afterlife) of Archaeological Photography*****Abstract**

The second wave of digital photography in archaeology, including HDR, photogrammetry, textures for 3D objects, time-lapse, drone photography, and screen-shots from google earth has destabilized notions of craft, authorship and the archive. Personal photography, taken with cellphones and curated on social media has created a substantial, expressive counter-archive that documents a more personal, experiential account of archaeological investigation. Digital manipulation of photographs has created a genre of hybrid images that combine past and present landscapes, to startling effect. While interplay between analog and digital photographs, inspiring innovation and stealing from one another, demonstrates that the digital age is still deeply embroiled with analog values and aesthetics, the second wave of digital photography in archaeology ventures into what J.T. Mitchell termed the “post-photographic” (1992:225).

While Mitchell characterized the post-photographic era as an “ineradicable fragility of our ontological distinctions between the imaginary and the real, and the tragic elusiveness of the Cartesian dream” (1992:225), this “loss of the real” has instead become a hyperreality wherein the imaginary is intimately linked to reality. The networked image has both decentered the “reality” of the photograph by hosting endless modifications and reproductions of the image while at the same time providing the ability to reference (or trace) the original “real” work. This “real” work is hosted next to the derivations, both de-centering its authority while also providing a citation for the modified images. The post-photographic era is generative, rendering the act of creation of the photograph as something that will be reproduced and modified, instead of creating a single artifact. The placement of digital photography within an “interactive, networked interplay of a larger metamedia” is termed “hyperphotography” by Fred Ritchin (2009:141). Metamedia can be conceived as a media ecology of “larger personal communication that will keep appointments, make calls, take visual notes, check calendars, order from restaurants, find out about sales in neighboring stores, check blood pressure, and tune in to television, radio and personal playlists” (Ritchin 2009:145). It is within this media ecology that we must understand archaeological photography, not simply as a separate methodology, but as part of a network of personal and professional digital practice.

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- Authors** Erik Kjellman, Anja Roth Niemi
- Title** *Lens distortion: perspectives on reflexivity and interpretation in digital field archaeology. Case studies from Northern Norway*
- Abstract** The process of archaeological fieldwork is often described as a hermeneutic circle, or spiral, where problems, strategies, methods, data and knowledge are recursively being produced and modified as the fieldwork progresses. The reflexivity that takes place on site, “at the trowel's edge” (Hodder 1999:92) is in this regard a central factor in the archaeological knowledge creation process.
- One way of meeting increasing demands of more cost-efficient project execution in Cultural Resource Management is to “go digital”. Digital field methods have definitively reduced the time spent on recording in the field, and increased the efficiency of post-excitation processing of archaeological data. The positive impact of digital field methods is legion: we can collect more data faster, a larger variety of data types is available, our data sets are more accurate, and the collected data can be more minutely scrutinized.
- What happens with the relationship between excavator, theory, method and data when field archeology “goes digital”? We assert that because of digitalization the archaeological material is today more often viewed through the lens of the camera or on the screen of the ipad, than through the naked eye. It is therefore pertinent to ask whether the camera and ipad enhances or rather distorts the view.
- Tromsø Museum has aimed to “go digital” in all aspects of field documentation. This implies the use of photogrammetry, total station and ipads for recording structures, relations, samples and finds in the field. All field personnel can quickly and accurately document layers and contexts, before these are physically destroyed in the excavation process. However, our experience is that compared to analogue field documentation, very little reflexivity takes place when digital methods are applied. It seems that the interpretation and reflection no longer takes place “at the trowel's edge”, but rather on the laptop in the field office.
- By presenting a few cases where excavation projects have “gone digital”, we wish to discuss the consequences of transferring reflexivity from the trench to the desk. How does this influence the ongoing excavation process, the recovery of data and the proceeding interpretation of past lives? Is there space for reflexivity in a digital field reality?
- Authors** Patricia Martín-Rodilla, Cesar Gonzalez-Perez, Patricia Mañana-Borrazás
- Title** *A conceptual and visual proposal to decouple material and interpretive information about stratigraphic data*
- Abstract** Within the context of archaeological information, the information related to stratigraphy is an important basis on which archaeologists document and infer about past events. Thus, the visualization of this information plays a fundamental role as a basis for generating knowledge in archaeological contexts. As a methodological construct, the conceptualization, management and visualization of stratigraphic information have traditionally been linked to the origin of stratigraphic documentation methods [1][2] keeping notations and visualization techniques that emerged all at once. In recent decades, some studies have progressively incorporated emerging trends that try to improve the visualization of the stratigraphic information obtained, with proposals of tools [3] and even changing the initial conception of the stratigraphic method, such as the incorporation of 3D approaches [4] on user interfaces to visualize stratigraphic

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sequences.

However, most of these innovative representations are only used to communicate results or disseminate archaeological knowledge to non-professionals, and traditional approaches are kept for research purposes. Still, it is research which usually presents the most demanding needs for information visualization and representation, and stratigraphic information, as shown in the literature, may benefit from new approaches to its conceptualization and display. Why not apply them as a support for the research process in archaeology?

We have performed a deep analysis of the representation and visualization techniques applied to stratigraphic information over time, with particular emphasis on how archaeologists visualize stratigraphic sequences during the research processes. In addition, we have identified some conceptual problems in the visualization of stratigraphic information that make the use of more innovative visualization techniques very difficult or impossible. In particular, we have identified as relevant the non-existence of a conceptual and visual separation between the material aspect (i.e. the material stratification found) and the outcomes of the interpretations that are based on the former (such as the archaeologist's conclusions about functional or chronological aspects of the material parts). This absence of separation create ambiguities and conflicts in the conceptualization and visualization of information, as some authors have pointed out [5][6].

This paper identifies the problems associated with this non-separation, and presents a conceptualization and visualization proposal for stratigraphic information as a result of joint work between archaeologists and specialists in information modelling and visualization. By using the proposed approach, the two aspects of information –material and interpretive– can be documented, processed and displayed separately but in an interconnected fashion, giving the researcher the power to view only one aspect, the other, or both at the same time. By using this approach, more precise information about stratigraphy can be handled with ease and communicated without ambiguity, thus helping the archaeological research process.

Authors

Heather Richards-Rissetto, Kristin Landau

Title

Lessons in Translation: From Analog to GeoDigital

Abstract

In this paper we discuss our “translations” of traditional analog datasets to digital formats, the lessons we learned in the process of so doing, and how they may be applied to archaeological practice. Analog data include paper maps, architectural drawings, or field notes, while geodigital data are spatially-referenced including GIS maps and 3D models. We address questions such as: What can we learn as we convert the two kinds of data formats? In the first part of this paper we discuss several examples of translating analog data to geodigital data including: (1) converting maps—originally generated with Alidade and plane table to Geographic Information Systems (GIS) data, (2) converting hand-written field notes on spatial location and notebook drawings of architectural groups and topography into GIS data, (3) integrating multi-source data collected at different times and with different instruments (e.g., GPS, GNSS, total station), (4) analog to geodigital conversion for 2.5D visibility analysis, (5) analog to geodigital to generate geo-referenced 3D models, and (6) data integration (tacking back and forth) from analog to GIS to Lidar.

In the second part of the paper, we summarize the lessons we have learned from our experiences in translating analog data to a geodigital format, through a recent case study at the ancient city of Copán, in the Maya area of western Honduras. We discuss what elements are lost and gained in the six translations described above. We then apply what we have learned to provide concrete insights that can be applied to archaeological practice in the Maya area and beyond. We contend that as we translate analog data into geodigital data, we acquire new

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knowledge about data collection, documentation, and interpretation. In turn, this knowledge encourages new archaeological questions and methodologies that can and should inform archaeological practice at all stages of research.

- Authors** Piraye Hacigüzeller
- Title** *The Archaeological Process and its Progress in the Age of Digital Cartography: a View from Çatalhöyük*
- Abstract** Despite the historically crucial role of maps in archaeology and the proliferation of digital cartography in the discipline since the 1990s, the archaeological effects of digital cartographic media are yet to be critically examined. An important question in this regard is whether the proliferation of digital cartographic practices has led to or can lead to “progress” in archaeological processes and, if so, of what type? The principal aim in this presentation will be to address this particular issue theoretically and empirically.
- As will be highlighted, “progress in archaeology” – when defined as “change in the discipline that brings improvement” – has often been measured in terms of innovation that clearly breaks with existing practices and traditions. This is especially the case today in the age of digital cartography when digital cartographic technologies (with their promise to increase speed, metric accuracy and ease of operation during fieldwork) are made to dislodge paper-based mapping practices at many archaeological sites. The argument in the presentation will be that even though this move from “paper to screen” in archaeology has been considered a form of improvement by many, there can be alternative understandings of progress in archaeological cartographic contexts that are at least as fruitful. Specifically, the suggestion will be made that maintaining paper-based mapping along with the digital in archaeological contexts is certainly not devoid of possibilities for disciplinary progress. This is because eradicating paper-based mapping processes in archaeology for the sake of digital mapping is not only about saving time and effort and creating metrically accurate representations with archaeo-cartographic verisimilitude. Rather, this eradication is also about “trimming the network” across which archaeological and cartographic knowledge generated at various parts of archaeological sites is assembled and moved (see Turnbull1996). As such, allowing paper and digital mapping processes to coexist at archaeological sites is essentially facilitating the assemblage of more “things” into this network, expanding the knowledge space and adding to the (variety of) relationships and, hence, experiences that archaeologists establish with their environment as part of cartographic processes. In short, letting paper-based mapping to coexist with digital mapping at archaeological sites is a way of enriching archaeological processes.
- The presentation will conclude by stressing that ultimately, it is us, archaeologists, who have to choose what constitutes progress in archaeological cartographic processes and act accordingly. Is archaeological progress in mapping about efficacy in which accuracy, speed and ease of operation are essential or is it rather about adding to archaeological relations and experiences? This point will be illustrated further by telling “small stories of mapping people” (see Lorimer 2003) from the 2013 fieldwork campaign at Çatalhöyük (Konya, Turkey).

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Authors Sara Perry

Title *Challenging the remit of applied digital field methods*

Abstract Digital methods for recording and analysing archaeological data tend to be used *by* disciplinary specialists *for* other specialist audiences. Although such application has meaningful implications for academic theorising about sites and associated material cultures, the impact upon their users and viewers, and their spread through all aspects of the archaeological project--out into the non-specialist world--is hardly understood.

For those of us who work on matters of general site interpretation - preparing exhibitionary resources and displays for varied international audiences - these methods tend to be harnessed as superficial modes of engagement; deployed purely to achieve a mindless 'wow' effect among non-specialist communities. Tablet recording, laser scanning, 'virtual digging', among other practices, are regularly presented without critical reflection, as though thoughtful appraisal and provocative consideration of their limits and prospects is impossible.

This predicament is not surprising, as heritage interpretation experts - despite translating archaeological practice for different publics - are often distanced from such practice themselves, shut out of the actual processes of planning, executing, and critically interrogating the raw data gathered via field methodologies. In other words, any existing theory of practice for applied digital methods has generally been formulated without concern for their relevance and epistemological repercussions across the entire cycle of archaeological knowledge production.

I call here for a rethinking of the remit of applied digital field methods. Their use has ramifications for a variety of interested parties (specialist and non-specialist alike), hence their deployment demands representation of such interests from the moment of conceptualisation. Heritage interpreters bring with them uniquely sensitive, cross-cutting perspectives on the nature of the archaeological record. Their direct involvement in digital methodological innovation from the outset, then, has the potential to transform the process and impact of archaeology overall.

Authors Matteo Sordini, Francesco Brogi, Stefano Campana

Title *3D recording of archaeological excavation: the case of study of Santa Marta, Tuscany, Italy*

Abstract Archaeological excavation is a destructive and non-repeatable process: the documentation of archaeological stratigraphy and relationships within and between layers and structural features is an essential component of the archaeologist's work in seeking understanding of the site under investigation. Traditional techniques of documentation, based on direct survey and manual drawing, are time-consuming in execution and are often characterized by poor levels of precision and accuracy that, over time, can lead to errors and misunderstandings. The use of traditional techniques of survey does not allow any margin of error in the interpretation: once the documentation has been produced the layers and other features are destroyed and it becomes difficult or impossible to make subsequent corrections in either the documentation or its interpretation. Over the last two decades technological innovations have progressively reduced the impact of these issues: survey techniques such the use of total stations and dGPS have gradually replaced direct survey and manual drawing.

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The introduction of digital SLR cameras has virtually eliminated the cost of photography, allowing the archaeologist to collect an almost inexhaustible mass of documentation, albeit mostly qualitative. Laser scanners have been tested within various excavation projects and the possibility of recording excavations in three dimensions has attracted great interest amongst archaeologists. But the high cost of instrumentation, along with the inherent complexity of the processing and management system for laser-acquired data, has limited its use and dissemination. In recent years, however, the advent of photogrammetric software based on multi-image photogrammetry (Structure from Motion) has gradually made three-dimensional digital recording accessible and practical within the excavation process. During the excavation of the Roman site at Santa Marta, in Cinigiano (GR), the Laboratory of Landscape Archaeology and Remote Sensing of the University of Siena has developed a pipeline for the rapid 3D recording of excavation evidence. Through an integrated approach to the use of topographic instruments, using both aerial and terrestrial images along with semi-automated photogrammetric packages and an appropriate GIS system, it has become possible to systematically record in three dimensions the structural and stratigraphical character of the site. This approach has reduced or eliminated issues relating to the precision and accuracy of the information within the differing datasets, which can as a result be integrated with one another to create diachronic 2D and 3D documentation. The high resolution and precision of the recorded surfaces increases both the quality and speed of documentation, optimizing the speed and cost-effectiveness of the work on site.

Authors**Amanda Clarke, Michael John Rains****Title*****The Use of Digital Technologies in the Silchester Town Life Project*****Abstract**

The Silchester Town Life Project was begun by the University of Reading in 1997 and held its final field season in 2014. Development of the Integrated Archaeological Database (IADB) began just before the start of the Silchester project, and it formed the core digital technology of the project throughout its eighteen years.

This paper will examine the stages in the development of the IADB and its use at Silchester over the course of the project. Key topics will include:

- Development of on-site data recording

- Systems for post-excavation analysis

- Extending IADB access to remote specialists

The IADB then and now: symbiosis and the key role Silchester has played in developing the IADB

Introduction and evaluation of “paperless” technologies into site recording (including PDAs, digital pens and notebooks, digital clipboards, GPS systems and, most recently, tablet computers).

- The importance of user needs analysis

- Evolution versus revolution

- Development of online database and report publication

- Use of the IADB and the Silchester data resource as a teaching tool

- Archiving the Silchester data

SESSION 9A

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In each of these areas the discussion will include an examination of why certain developments have been a great success and others less so.

SESSION 9C- MODELLING THE ARCHAEOLOGICAL PROCESS

Authors Sorin Hermon, Valentina Vassallo, Lola Vico, Elena Christophorou, Giancarlo Iannone

Title *A 3D visual and geometrical approach to epigraphic research; the Soli (Cyprus) inscription as a case study*

Abstract Within the framework of EAGLE (<http://www.eagle-network.eu/>), an EU funded project that aims at creating and providing multimedia digital content to the wide public through the Europeana portal (www.europeana.eu), we have 3D scanned an Ancient Greek inscription which is nowadays stored in the deposits of the Cyprus Department of Antiquities. The inscription originates from the archaeological site of Soli in Cyprus and it is tentatively dated to the first quarter of the IVth century B.C. Since there are still controversies among scholars on the full interpretation of the inscription, we have performed several attempts to improve the reading of the inscription with 3D measurements and visual investigation. The geometrical features of the inscription were recorded by means of a laser – scanner, with a sub-millimetre margin of error and a resolution of single mm. Our aim was to shed light in the reading of the inscription, in particular in its higher left corner, where damages are visible with a naked eye. Our secondary aim was to provide a rich description of the letters, in order to identify possible production patterns, techniques of engraving and the technologies involved. Therefore, we were interested in analysing and comparing the depth of carving of the various letters, their level of shape standardization and similarity among single types of letters and symmetry of the letter registers.

Our assumption was that by applying various visual filters and rendering options we will be able to enhance the reading of the inscription, particularly by enhancing the edges of the letters and their “separation” from the damaged area. For the second task, we proposed to use metrical analyses within a CAD environment for accurate measurements and geometry comparisons. We argue that the conclusion of the first analysis corroborates with most commonly accepted philological interpretations of the inscription, as published elsewhere (<http://akg.cyi.ac.cy/>). The conclusions from the second set of analyses are that several letters, especially the rounded ones (such as the Ω, the Greek Omega) were first drawn with a compass and then carved (given their almost identical shape). Other letters (such as Greek Σ, Sigma) were also drawn first with a straight line instrument on the stone and then carved, probably with the same instrument and style, as the high similarity in the depth of the carving throughout the analysed letters shows. The combined visual and metrical approaches proved to be extremely effective in supporting traditional epigraphic interpretation. At the same time they reveal new aspects related to the techniques of engraving. Important part of this work was to compile metadata which are mostly related to the acquisition and 3D post-processing of the 3D files.

Further research will include the analysis and comparison of other inscriptions of the same and related periods, in order to diachronically describe the engraving process and possibly identify scribes, workshops, etc. Finally, it will improve the metadata schema to include descriptions of the analysis and interpretation process of such 3D data.

Authors Isto Huvila, Daniel Löwenborg, Lisa Börjesson, Bodil Petersson, Nicolò dell’Unto, Per Stenborg

Title *What is archaeological information?*

Abstract Many things are informative in archaeology. The fundamental understanding of archaeology as a branch of scholarship studying past human activities based on their material traces captures the basic domain of interest of archaeology. At the same time, it fails to appreciate the diversity of material and intangible, written, drawn, emerged and produced types of artefacts, processes, feelings and practices informing archaeologists about the past and that archaeologists use to inform their colleagues and other stakeholders of their work (Huvila, 2006, 2014a). As, for

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instance, Thomas (2005) has underlined, it is necessary to dig deeper into the premises of the role of the material in archaeology as (one of the) fundaments of archaeological knowledge. A proper understanding of what is informative in archaeology is not only a rudimentary premise for unraveling the complexity of a simple typology of 'things' informing archaeologists and others about archaeology, but also an elementary step towards deconstructing the complexities of archaeological information processes and archaeological work.

The presentation reports on a collective effort of the researchers in the Swedish Research Council funded research project Archaeological Information in the Digital Society (ARKDIS) (Huvila, 2014b). ARKDIS focuses on mapping archaeological work and information process in the digital society, on creating an inventory and on developing a theoretical model of what archaeological information is and how 'things' become archaeologically informative. The study is based on a combination of empirical and theoretical work conducted as a part of the project. Changing technology is a significant aspect influencing the evolution of archaeological knowledge, for example, Evans and Daly (2006) emphasise. However, technologies is but one of the pertinent factors in addition to theoretical and methodological development (e.g., Hodder & Hutson, 2003; Jensen & Jensen 2012), and evolving societal conditions for archaeology as scholarship and profession (cf. Jensen 2012; Flatman, 2012). The aim of the presentation is to present results of this undertaking and to invite the audience to critically reflect on the questions of what is informative and by what means 'things' become informative in the rapidly digitising infrastructures of archaeological work and scholarship. The theoretical perspective combines insights from different areas of archaeology, information science, archival science, and cultural heritage studies.

Authors Matthias Lang, Christian Chiarcos, Philip Verhagen

Title *IT-assisted Exploration of Excavation Reports - Using Natural Language Processing in the archaeological research-process*

Abstract Almost every archaeological project begins with a review of literature, reports and other documents related to certain places, artifacts or periods. This is often very time consuming and it is difficult to document the results obtained. In our talk we want to present an interactive tool that extracts the information the researcher is interested in almost automatically. We will discuss the technical fundamentals as well as our first results.

The first challenge was to apply existing archaeological vocabularies and ontologies in SKOS-XML-format to the excavation reports. Most documents available come as (or can be converted to) PDF. Hence we set up a text-processing-pipeline to extract machine-readable text from any PDF-document with heuristic removal of non-textual content (e.g., page numbers) and text-structure-recognition.

With key concepts defined through an ontology, it is now possible to identify concepts using the label information which is stored within the ontology. This process extends beyond a trivial string match as it requires part-of-speech tagging, and lemmatization. Here, we also perform Named-Entity-Recognition to identify locations and persons automatically. These tasks are currently available for English only, for which we can rely on existing tools.

With keywords identified, we can now exploit the hierarchical structure of the underlying SKOS-formalization to search for a given concept in the excavation reports considered. In particular it is possible to retrieve a word based on its hypernyms.

The querying engine can also be used to automatically assess the content of a given text. With a small taxonomy on architectural features we can, for example, count the number of concepts and thus classify the relevance of a given document for inquiries on specific architectural features. Similarly, we can automatically identify the temporal scope of a report and the

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relevant cultural sphere with an ontological formalization of cultures and their temporal relations. This component, while being a near-trivial extension of the inference and querying engine, is, however, yet to be developed.

In the same way, our classification can be graphically visualized, as a means for distant reading, i.e., the development of user interfaces to enable the quick assessment of a report's relevance by the user. This builds on terminology management, inference and querying, and we would like to present and discuss recent visualization experiments.

Natural Language Processing is a key component of our system. Unlike conventional solutions for distant reading, we do not stick with keyword detection in plain text, but perform syntactic and semantic analyses. Such innovative techniques contribute to the semantic assessment of texts beyond pre-defined keywords. Instead, a semantic structure is built in a bottom-up fashion: Concepts and relations as formulated in the original text become available as formal structures and can be queried and visualized in the same way as information drawn from pre-defined vocabularies.

Authors

Anna Maria Marras

Title

Mind mapping and archaeological research. Concepts, themes and know-how dissemination

Abstract

What is it a map? A representative idea of the concept, a symbolic and iconographic image of the landscape. Maps are functional, intuitive, must be simple and easy to read, as a photo. Denis Wood in his book "The Power of the Maps" wrote: "Power is the ability to do a work. Which is what the maps do: they work." Inside the map there the knowledge of his maker.

What is it a mind map? It's a useful way to organize, for instance, a book chapters, to manage the work development step by step. Generally the layout is a sketch as tree scheme or logic chart. There are a lot of Mind Map software developed in the last years, some of them are Open Source. This kind of programs are very powerful and they give a chance to link to folders, share the documents in collaborative way.

The aim of this presentation is show how this kind of application can be used in archaeology in order to analyze and to compare the different survey methodologies used to collect the data.

The main topic is about how to deal the data and how these data were collected, in order to evaluate field projects or archaeological excavation data it. Is it more important to consider what kind of data that were collected or how they were collected? How could be useful for the archaeological dissemination follow a standard sketch that showing in easy way the development of the project step-by-step, how it was the gathering of data and how the data were planned, acquired and processed? It's a new approach and the argue to pay attention not only on the archaeological data themselves but also on the way that it was collected.

MODELLING THE ARCHAEOLOGICAL PROCESS

Authors Sveta Matskevich, Ilan Sharon

Title *Modelling the archaeological record: A look from the Levant – past and future approaches*

Abstract

The long-lived, intensely occupied, urban sites in the Near East and around the Mediterranean arguably present archaeology with its toughest riddles; combining problems of complex stratigraphy, complex societies, long and complex histories and—often—complex ideological baggage on the part of investigators and spectators. The history of Levantine archaeology is a story of methodological traditions of borrowed and developed techniques of excavation and recording. Today Near Eastern archaeologists use several relatively standardized recording systems that reflect different and, at the first glance, incompatible approaches: a form-driven *locus system* and *aspit system* based on an excavation journal—each of which has several variations. Yet, analysis of these systems on a conceptual level shows that both systems use two basic entities, a *spatial* (locational) unit and a *find*. Theoretically, both of these systems espouse a positivistic world-view, in which “the archaeological record” is deemed unitary and objective, and can be “read” unambiguously (e.g. by dividing it into precise depositional units or assigning deterministic attributes to artifacts).

In this presentation I shall define the *locus system* and its variations, and demonstrate how it can be mapped to a reference model (e.g. CRM EH) as a mean of integrating data from various recording systems.

Next, I will present a proposal for a radically new model of recording system, based on principles more in fitting with a post-processual / non-deterministic theoretical stance. This system is meant to stress the interpretative character of the archaeological record. The fundamental entity in it is an *observation event*. Post-factum, we can only look at the site (or any component of it) through the eyes of the beholder[s]. This also implies that even basic attributes of an entity (e.g. '[in X's opinion] this sherd belongs to type A') may acquire several values. i.e. the system is built to support different sets of observations on any entity. Next, we claim that *relations* (physical, stratigraphical, ontological) lie in the foundation of archaeological reasoning. [Observations about] relations should be epistemologically equivalent to [observations about] spatial entities and [observations about] objects found within them. Thus spatial units (loci or spits), finds, and relations form the next level in the proposed model. Finally, we observe that observations or relations may relate either to unitary entities (a single locus or a single find) or to composite entities (a “phase”, a “building”, a “type”). We thus define two types of *classes*: a ‘context’ is any [specifically named and defined] aggregate of atomic spatial units and an ‘assemblage’ is any [specifically named and defined] aggregate of finds. A ‘scenario’ therefore, is any arrangement of these classes that forms the outline of a ‘story of the site’ presented to a site-report reader. Such a system, we claim, can formally model a much wider swath of archaeological discourse than conventional site-recording systems.

MODELLING THE ARCHAEOLOGICAL PROCESS

Authors Stavros Angelis, Agiatis Benardou, Nephelie Chatzidiakou, Panos Constantopoulos, Costis Dallas, Lorna M. Hughes, Leonidas Papachristopoulos, Eliza Papaki, Vayianos Pertsas

Title *Documenting and reasoning about research on ancient Corinthia using the NeDiMAH Methods Ontology (NeMO)*

Abstract Analyzing and modeling research processes is a major component of the endeavor of understanding and charting the digital humanities practice, which broadly involves content, tools and methods. The need for a formal model of scholarly research activity was identified as early as the preparatory phase of DARIAH. An evidence-based model based on grounded theory analysis of researcher interviews was proposed, subsequently validated, and extended in EHRI (Benardou et al., 2013). This work is now taken forward in NeDiMAH, through development of the NeDiMAH Methods Ontology (NeMO). NeMO is CIDOC CRM - compliant, and represents explicitly dimensions of agency (actors and goals), process (activities and methods) and resources (information resources, tools, concepts) in scholarly research. It incorporates existing relevant taxonomies of scholarly methods and tools (TaDIRAH, Oxford ICT, DHCommons, CCC-IULA-UPF and DiRT) through appropriate mappings a semantic backbone of NeMO concepts. It thus enables integration of different perspectives, vocabularies and documentation on scholarly methods and practice (Hughes et al. forthcoming).

This paper introduces NeMO, applies it on the documentation of scholarly research conducted in the course of a synthetic study of the social and economic history of Classical Corinthia (Benardou 2007), and discusses how NeMO can support both a structured documentation of, and reasoning about, archaeological and historical research practice. The case study concerns the functions of the urban centre of Corinth as part of its surrounding countryside. It addresses Corinthian society throughout the 5th century BC. On the basis of geographical and temporal parameters, it examines settlement patterns and networks, and relates them with cultural and economic factors. Using NeMO, we demonstrate how research activities of specific types, organized in methodological steps, use, produce and curate specific information resources as they are carried out with specific methods and tools. Our study highlights the importance of overall goals and research questions in shaping scholarly process. Generation of semantic paths connecting concepts in NeMO enables support for associative queries and reasoning about the research activities, methods followed, and their context. Indexing terms are drawn from taxonomies incorporated in NeMO. This work contributes to methodological reflexivity, better understanding of the research process, and improved communication on research methods in archaeology. Future work includes the streamlining of interaction processes using NeMO and semantic publishing of related information.

Authors Igor Bogdanovic, Juan Antonio Barceló, Antoni Palomo, Raquel Piqué, Xavier Terradas

Title *From Data to Knowledge - telearchaeological approach*

Abstract The pursuit of knowledge about past social realities doubtlessly begins with archaeological fieldwork. Without claiming that “archaeology is exclusively about things”, we stress the unique value of material evidence observed and recorded in the field using formal and instrumental methods. This data record constitutes the basis for complex inferential processes in which a visual, spatial and temporal raw input should be transformed into data, and data into knowledge. Although analytical methods in archaeology, as well as knowledge creation procedures based on computer technologies are fast everywhere, there is still a gap between

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standard fieldwork and advanced formal methods of observation, recording and processing. To understand what men and women did in the past we need knowledge about social and natural agents that contributed in the formation of observed archaeological events, about relationships between them, and about relations between archaeological events (deposition) and historical events (the past realization of a social action).

Each archaeological site is a world *per se*; there is not a single standard recording technique which can be applied everywhere. In order to generate such a data structure, we present here on-going research on the Early Neolithic lakeside settlement of La Draga (Banyoles, Catalonia). The site has been excavated in several campaigns from 1990, thus we have to manage some different recording systems, different data formats, different documentation structures, thousands of maps, plans, drawings, photographs, and laser scan 3D models, analytical descriptions at different observation levels, from micro to macro, radiocarbon estimates of organic materials (seeds, wood), dendrochronological measurements, paleoclimatic and environmental data, archaeometric analysis of different artefacts and raw material sources, experimental replica and simulation models, and much more. La Draga is an archaeological site with an extraordinary wealth of finds made of organic materials (wood, vegetal, bone, etc.), and it is stratigraphically very complex due to the active geomorphology of its actual location and the amount and diversity of post depositional processes.

In this paper we describe knowledge creation process as a process of formal discovery of causal relationships in complex data structures. Attention will be paid to the configuration of ontological domains which represent a detailed instruction set about how to relate the data in order to discover causal relationships and generating a temporal network of archaeological events and their mutual dependencies. A general ontology for spatio-temporal data structures is presented. Emphasis is made on the use of Artificial Intelligence-based methods for converting data into knowledge and for archaeological knowledge processing.

Authors

Alberto Belussi, Sara Migliorini, Patrizia Basso, Piergiovanna Grossi

Title

The Archaeological Urban Information System of the Historical Heritage of Verona

Abstract

During the last 4 years the Archaeological Information System of Verona (SITAVR) has been implemented starting from the already existing and well consolidated SITAR project, that has been developed in Rome by the “*Soprintendenza speciale per i beni archeologici di Roma*”. The main objective of both projects is collecting all data about the archaeological findings and related information sources regarding the historical heritage of these two Italian urban Centres. The final goal is supporting full archaeological analysis and allowing for an easy reuse of all available data for various purposes (archaeological research, urban planning, safeguard and preservation...).

The first step of the project was the description of the conceptual schema of the database content by applying the GeoUML methodology and related tools. The result was a schema which can be easily understood also by non-technicians, but is also formal enough to allow the automatic generation of other information. In particular, a plug-in for the GeoUML Catalogue has been developed which produces the dataset metadata compliant with the Standard ISO 19115, using different abstraction level and languages. The definition of the conceptual schema and the metadata has supported and encouraged the cooperation and interoperability between the SITAVR and SITAR projects.

Moreover, the GeoUML Catalogue allows one to automatically generate the SQL code needed for creating a database corresponding to the conceptual specification, with the main aim to promote the correspondence between the abstract and the implementation level. In accordance

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with this principle, an additional plug-in for the GeoUML Catalogue has been implemented which automatically generates the JPA (Java Persistence API) classes needed for accessing and managing the database content. These classes represent the base layer for any application which uses the produced database.

From the modeling phase has emerged that time and space are two main characteristics of archaeological data, because they allow one to derive important relations between findings. For this reason, in the last years a 4D Geographical Information System (GIS) has been developed, in order to manage the SITAVR data, where the 4-th dimension is the temporal one. In particular, in the last year the problem of modeling temporal aspects in archaeology has been deeply studied, starting from the analysis of the applicability of the Standard ISO 19108, and ending with the definition of a framework which extends the Standard with fuzzy concepts, in order to represent the inherent uncertainty of the archaeological data, and uses consolidated reasoning techniques in order to reduce such uncertainty or support the interpretation process.

Moreover, a new web user interface is under development with the aim not only to collect the available data, but also to support and guide the activities performed by archaeologists during their interpretation process. In particular, it will make easy the definition of uncertain temporal dimensions and the execution of temporal and spatial queries. As regards to this last aspect, some efforts will be devoted to the definition of a framework for performing spatio-temporal queries with uncertainty.

SESSION 9E- MOVING THE FOCUS FROM
"KNOW HOW" TO "KNOW WHY" 3D
MODELING CULTURAL HERITAGE

Authors **Maurizio Cattani, Florencia Debandi, Andrea Fiorini**

Title ***3D documenting archaeological excavations: a case study with field operations and some considerations on the Bronze Age nuragic settlement of Tanca Manna (Nuoro - Sardinia)***

Abstract The paper presents a methodological approach and relative list of tools and protocols for a whole 3D documentation of the archaeological stratigraphy applied by the research group of the University of Bologna in the field activities at the nuraghe Tanca Manna, Nuoro. Current image-based 3D modeling methods are now able to acquire detailed and precise data similar to those obtained by laser scanner. The procedure is now mostly achieved with a simple protocol without requiring particular ability from operators both in the phase of field survey and in 3D modeling in laboratory. A continuous updating of software and hardware assures a permanent improvement of quality and friendly using of the system, leading to expect that in few years a 3D modeling will become the new required standard in documenting archaeological excavations. Instead we regard other aspects of the application during the daily field activities, that require some considerations. Among these we concern the general matter of utility of 3D models or methods of integration with other software dedicated to the management of archaeological excavation, like GIS, database and matrix builders. In any case we consider the 3D modeling as a starting point and not a final result of the analytical process dedicated to obtain and analyze the archaeological stratigraphy. More in particular we will talk about the role and skill of technicians or operators dedicated to record a 3D documentation, the rate of advantages respect to the traditional documentation, the ratio between optimum light conditions and scheduled time dedicated to the excavation and other aspects related to the ratio between time and results. The observations carried out on the site along single field activities and the estimation of the final results of 3D modeling will give an opportunity of discussion of practical and theoretical aspects of this methodology.

A further step concerns the use and dissemination of graphical products from the scientific level to the touristic valorization of the archaeological monument. The nuraghe of Tanca Manna is located in a public park and the 3d modeling of the excavations will become a fundamental part of a project of valorization to enhance research, education, and touristic attraction.

Authors **Lorenzo Teppati Losè**

Title ***Integrated survey techniques for the study of an archaeological site of medieval Morocco.***

Abstract During the 2014 the Laboratory of Classical Archaeology of the University of Siena has undertaken several missions of fieldwork on the archaeological site of Chellah, in the outskirts of Rabat. The site of Chellah, the roman city of *Sala Colonia*, has undergone various transformations during its history and became the marinid royal *necropoli* at the end of the XIII century A.D, a role that it maintained up to the end of XV century A.D.

In particular, this research was focused on the study of the building history of the marinid *madrasa*, that was a koranic school and a formation center of the state functionaries.

A first short mission on the site was dedicated to decide the buildings that would be the object of the research, and the survey strategy. The different survey techniques that was chosen and integrated are the following: total station, 2D and 3D photogrammetry.

Afterwards, in a 10 days mission of fieldwork, all the needed raw data were collected and in the following months they were postprocessed.

We choose to generate different output forms and create several elaborates:

MOVING THE FOCUS FROM "KNOW HOW" TO "KNOW WHY" 3D MODELING CULTURAL HERITAGE

a plan of the complex made using the total station and that was compared with another one that was extracted from the dense point cloud

all the wall was recorded using 2D photogrammetry and the ortophotos made with this technique were compared with the ones extracted from the point cloud

the point cloud was generated merging different models. The models has different density because they are generated using different steps. This choice is related to the LoD (level of detail) we decided to obtain for the different portions of the complex. The point cloud was the base for the analysis of building techniques and for the creation of an interpretative 3D models in CAD environment.

For this project we decided to work with both open source and proprietary software and testing pros and cons of the different solutions.

The final aims of this work were: creating a *corpus* of surveys of the *madrasa* that fit the needs of accuracy and precision but also the needs of the archaeologists, testing and integrating different techniques and producing the final elaborates for the analysis of building archaeology. The idea was to set a clear work flow for a fast acquisition of data, a quick postprocessing and the generation of useful final products at different levels of detail. Also the economic part of the overall process was really important, we needed to use low cost techniques and instruments, so the choice of photogrammetry was the one that best fitted our purposes. Finally, all the data we collected and elaborated will be the foundation for the writing of a restoration project that it's planned for the *madrasa*.

Authors	Marc Grellert, Mieke Pfarr-Harfst, Piotr Kuroczynski, Sander Münster
Title	<i>Virtual Reconstruction and Scientific/Academic 3D Models – Fundamental Considerations</i>
Abstract	<p>Long seen as a knowledge transfer tool, virtual reconstructions are increasingly used as research models. It becomes apparent that we have already gone beyond the scope of reconstruction, ad that digital models have begun to serve other functions within the sciences and the humanities. This poses fundamental questions and challenges that need to be considered and discussed. As part of the <i>Arbeitsgruppe Digitale Rekonstruktion</i>, founded in Germany, we have organised a series of workshops taking place in November 2014 and February 2015 to start the debate. This paper provides an account of the discussions and details the key questions, positions and challenges. It is intended to stimulate and establish international debate and exchange. We want to shed light on the following issues:</p> <p>1 Basic Principles</p> <p>What is the computer-assisted reconstruction of our material cultural heritage? What are the principles that should govern the discipline? What is digital reconstruction designed to achieve? What are the objectives and applications? What challenges do we face (in terms of content, methodology and technology)? Do we need standards and quality seals? Where do we situate ourselves in the scientific community and the digital humanities?</p>

2 Methodology

What does scientific reconstruction mean?

What does it require?

What should a scientific/academic methodology look like?

Three-dimensional digital models always have a graphic/aesthetic component. What are the challenges and opportunities this presents in the context of scientific methodology?

What are the limits and the potential of our software programs?

Which modelling method satisfies the demands of scientific methodology?

3 Documentation and Sustainability

The guidelines defined by the London Charter have not yet been widely implemented in digital reconstruction. Standards of documentation are yet to be established.

What standards of documentation ensure scientific methodology and sustainability?

What measures have to be taken, what demands need to be made?

What are the minimum requirements to follow up on existing reconstructions (both in terms of content and technically)?

Who is responsible for archiving and upgrading the data to the next generation of hard- and software?

4 Presentation of Knowledge and Virtual Research Environments

Many research projects seek to link models with information and to advance virtual research environments. What approaches, strategies and concepts (metadata, provenance and paradata, controlled vocabularies, ontologies) exist, particularly in view of the semantic web technologies?

How established and sustainable are the systems? What are the potential and the problems behind knowledge representation with regard to the documentation, generation and visualisation of knowledge?

5 Representation, Presentation and Knowledge Transfer

What aesthetic and didactic demands do we make on our models and presentations?

What are the different concepts?

What is the significance of the scientific basis, the finds, findings and data in the presentation of the models?

Which ends (presentation concepts) are justified by which means (technology and expenditure)?

6 Technology

What do we expect from the different technologies at our disposal?

- Authors** Federico Buccellati, Eric Kansa
- Title** *The Value of Energetic Analysis in Architecture as an Example for Data Sharing*
- Abstract** The process of construction of an ancient building can be broken down into a series of steps, and analyzed using tools such as the chaîne opératoire. This powerful methodology permits one to explore, in detail, the process of construction, allowing for a disarticulation of the process and leading thus to a more complete understanding.
- Such a method, however, cannot, in and of itself, explore the ‘cost’ of each of the steps, in terms of time, resources and energy. Drawing from diverse ethnographic sources, experimental archaeology and ancient textual material, one can derive sets of cost-calculation algorithms that can help calculate these costs – which in turn can help refine our understanding of broader concepts such as Monumentality or Prestige. These cost-calculation algorithms can then be applied to ancient architecture through the use of 3D models which define, with a high degree of precision, the volumes of built material in the archaeological record.
- Such an analysis can be applied to structures in any pre-industrial society, and, because of the nature of this analysis, cross-cultural comparisons can be as meaningful as intra-cultural studies. Open Context enables such studies because it provides access to the kinds of data needed for energetic analysis, as the examples from Tell Mozan/Urkes (Syria), Kenan Tepe (Turkey) and Poggio Civitate (Italy) show. By linking primary field data in Open Context and other repositories with cost-calculation algorithms, we enable greater openness and reproducibility in the study of prestige and monumentality. By architecting cost-calculation algorithms in a modular manner, researchers can explore different the impacts of choices in construction materials and production sequences. By making these cost-calculation algorithms open-source in public version control systems, we make modeling assumptions and other parameters explicit, contestable, and reusable for new research applications.
- Authors** Martin Unold, Freddie Kern, Kai-Christian Bruhn
- Title** *Annotating instead of Modelling*
- Abstract** Techniques to acquire 3D data, such as Structure from Motion (SfM) or Terrestrial Laser Scanning (TLS), are used more frequently. However, the process of creating models, i.e. determining surfaces in pointclouds, requires time and expertise in CAD. In all cases of 3D model generation, including those made for visualization purposes only, data distortions caused by human interpretation during the modeling process subtract from the overall accuracy of the underlying pointcloud. Beyond what is seen in a model, the true benefit for Archeological research is hidden behind the meaning of the items of investigation and its geometric

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properties.

With semantic annotations¹, one can enrich data by connecting an excerpt of a document to other data. Typically this enrichment happens collaboratively and online and is focussed on text and images. This paper describes a workflow and a web tool developed within the project „Inscriptions and their Spatial Context“² to annotate raw 3D pointcloud data and to gain potential relationships between items under consideration.

The workflow consists of three steps: Integrating, recording and interpreting of the data.

The first step has to be done at the beginning of a project. An integrator has to give both data from the survey (e.g. SfM, TLS) and an ontology describing the potential relations between items to the server.

The second step can be done throughout the duration of the project. Every user can contribute and add data, i.e. identify objects in space and tell something about these objects.

When there is enough data from step two, a researcher can export a subset of the content and do analysis.

The software shows panoramic images instead of a 3D space, so that users can navigate through the room by changing the viewpoint and can easily identify objects through simple mouse selection (point and click). The generated data describes objects in the space of the surveyed area in two ways: 1. The geometric description contains the position and topology of an object, and it can be accessed via a web feature service (WFS), and 2. The semantic description contains further expert data linked to an object, and this can be accessed via SPARQL-Endpoint. Through this approach, it is possible to exchange geometric and semantic information simultaneously and make it interoperable. It is possible to analyse the spatial relationships between semantically related objects.

While there are no walls without a model, it is rather difficult to do spacial syntax analysis. The paper discusses how alternative approaches to visibility or acessability can be computed on raw pointcloud data.

1Eyal Oren, Knud Hinnerk Möller, Simon Scerri, Siegfried Handschuh, Michael Sintek – What are Semantic Annotations?

2<http://www.spatialhumanities.de/ibr>

SESSION 9F- MACHINE LEARNING AND
PATTERN RECOGNITION FOR
ARCHAEOLOGICAL RESEARCH

Authors

Georg Roth

Title

Improving clustering: Using silhouettes to estimate the optimal number of clusters.

Abstract

Classical applications of clustering suffer from an indeterminacy in specifying the number of clusters. Neither agglomerative nor partitioning algorithms provide a solution. The dendrogram of an agglomerative approach still needs a decision on the number of clusters, while a partitioning method requires the number of clusters a priori. First attempts to overcome this problem have been made already 50 years ago (e. g. Ball and Hall 1965) by developing criteria to measure the quality of clusters in terms of intra-cluster homogeneity and/or inter-cluster heterogeneity to find estimates for the optimal cluster number. Meanwhile over 40 internal cluster validity criteria have been developed with a large simulation study (Arbelaitz et al. 2013) showing the silhouette criterion (Rousseeuw 1987) to be the most successful.

The paper starts with a short consideration on cluster quality introducing some common principles applied in validity criteria. The focus is then on the operating mode of the silhouette criterion explaining how it supports decisions on cluster numbers – and also on the choice of the clustering algorithm. Subsequently the use of silhouettes to evaluate single clusters and individual cases is discussed.

To exemplify the application two datasets from the Central European Neolithic are submitted to clustering using silhouettes to evaluate results. One represents tree ring width measurements from well sheetings excavated in Erkelenz-Kückhoven (Linear Pottery Culture: 5090 BC; Frank et al. in prep.) searching for an answer to “how many trees have been used to produce the timbers?” The second data set represents a situation more characteristic of archaeological group building: typological abundance data for pottery vessel classes of Younger Neolithic Michelsberg Culture (4400 – 3500 BC; Höhn 2002) are used to address the problem „how to cut a configuration dominated by a gradient?“

Free open source statistical programming software R (R Core Team 2014) was used applying package cluster (Maechler et al. 2014) for cluster and silhouette computations. R-code of the analysis can be provided by the author.

Authors

Diego Jimenez-Badillo, Sergio Mota-Gutierrez, Salvador Ruíz-Correa, Rogelio Hasimoto Beltran, Mario Canul Ku

Title

A new approach for classifying archaeological objects based on 3D shape similarity analysis

Abstract

In this paper we present a recently developed machine-learning approach called *metric-learning*, which shows great potential for shape-ranking and classification of archaeological objects. To the best of our knowledge, such approach has not been applied before in archaeology despite its prospective benefits.

The input data are standard 3D point-clouds acquired through a laser scanner or other vision sensors. Thus, the classification occurs in 3D space.

We consider classification as the problem of computing similarity between objects. For each object a similarity descriptor is computed by concatenating several simple geometric features extracted from its corresponding point-cloud. The descriptor of each object is a quantity that we can use to compare how similar or dissimilar this object is in relation to other objects. Intuitively, we can expect descriptors to be "close" for similar archaeological objects.

Some traditional approaches start the classification process without previous knowledge of the relative importance of each geometric feature included in the descriptor and consequently

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assign the same weight to all features. This constitutes what mathematicians called an “uninformed space”.

However, in most real-life situations similarity is a quantity that depends on the task at hand (i.e. the problem to be solved) and the data available. This means that certain features may be more important than others.

Therefore, a better classification approach is to figure out the relative weight of the features in a particular context. This is precisely what metric-learning helps to do. It achieves this goal by analysing examples of what archaeologists would consider “similar” within the context of the problem at hand. In other words, this new approach learns from examples a suitable similarity function specific for the application. This obviously is relevant in ranking and classification and its adoption in archaeology would bring many benefits.

To demonstrate the approach we applied it to a collection of Aztec archaeological objects from the Great Temple of Tenochtitlan (Mexico).

Authors Yuhe ZHANG, Pengbo ZHOU, Guohua GENG, Xianran WEI, Kang Li

Title *Virtual Restoration Method of Terracotta Warriors and Horses of Qin based on classified template registration in collections of 3D models*

Abstract In the past virtual restoration for large amounts of fragments in 3rd excavation of Pit 1 and excavation of Pit K9901 of Terra-cotta Warriors and Horses of Qin, about 100 Warriors and Horses was molded via computer-aided methods, while some of which still have defects in body. In the full analysis of the features of completed Warriors and Horses 3D models, a method based on classified template registration is proposed. It uses registration results of completed templates and the defect Terracotta models to get an template of the defect region, which will be used to inquiry the matching fragment in database. Finally, the matching fragment and the model can be precisely aligned to complete restoration. This method effectively solve the problem that traditional registration algorithm could not work well if the debris has defects in fracture surfaces.

From the actual stitching and recovering of the fragments of Terre-Cotta Warriors, we found three types of problems. The first is that the Terracotta has different postures. Terracotta having different postures plays different roles in the array, such as kneeling archers, standing warriors and standing archers. So they are diverse in local features due to different postures. The second is the large amounts of fragments. It is time-consuming and laborious to match every fragment with models. It is also difficult to distinguish the fragment affiliations merely based on their closely location in the array, because they might fall together when the Terracotta were broken. The third is that their body defects are not uniform. When aligning the fragments with the models to be restored, multiple fracture surfaces needed to be registered and it is a large calculation to recognize the defect region by features due to they might be diverse in location, size or shape.

In view of the three problems above, we propose a novel virtual restoration method based on classified template registration in collections of 3D models. Firstly, extract skeleton of all the completed Terracotta models and classify them according to their skeletons. We use *L1-medial* skeleton as a curve skeleton representation for 3D point cloud data. Then use an automatic extraction method based on shape segmentation to extract completed templates of each category of Terracotta models. Secondly, classify the defect model according to its skeleton and align it with the corresponding completed template, as the result, the original template of the defect region (the corresponding region on the completed template) was obtained and meanwhile the high matching fragments was gained by using the original

template to retrieval fragments in database. Finally, the restoration was completed by precisely aligning the high matching fragments with the model using ICPIF method.

Our restoration work of Terra-cotta Warriors and Horses proves that the proposed method is efficient and effective in classifying the Terra-cotta, extracting templates and obtaining the matching relations between models and fragments. The restoration results are satisfactory.

Authors **Stéphanie DUBOSCQ, Juan Antonio BARCELO, Katia Francesca ACHINO, Berta MORELL, Florence ALLIESE, Juan Francisco GIBAJA**

Title *Discovering prehistoric ritual norms. A machine learning approach.*

Abstract In this paper we will propose a computational approach, based on the application of supervised learning techniques, in order to explore prehistoric funerary practices. In particular we focus on the understanding of relevant ritual patterns from North-Eastern Iberian Peninsula Middle Neolithic burials (late V millennium-early IV millennium cal.BC).

The archaeological study of death and burial has changed considerably over recent decades in response to new and more articulated challenges: quantitative methods have been used to identify burial structures in the cultural and biological data.

Traditionally, mortuary practices have been studied through plain and basic similarities or differences between graves and artefacts within them. Statistical tools like Principal Component Analysis, Cluster Analysis and/or Correspondence Analysis have been used in order to build classifications of burials.

Although this approach allows us to quantify plain non-relational similarity, we need more complex relational once in order to understand the intrinsic variability of mortuary practices beyond the dissimilarities of graves and grave-goods. In other words, we need to consider not only variations in the presence/absence of descriptive features, but also the relational features between the different elements that make up the burial, their interdependence and their degree of significance. In this paper we compare standard statistical multidimensional approaches with machine learning methods: these are based on a supervised learning approach in which the relevant category to be formally induced is “gender”.

Different techniques will be explored, as Neuronal networks, Genetic Algorithms and Tree induction (C4.5 algorithm). They are useful to show how we can define social norms in the archaeological record based on detecting relevant differences between controlled categories. Of special relevance for our purposes is the comparison between “classical” Confirmatory Factor Analysis of burial similarities and a machine learning approach to conceptual induction

Authors **Elena Sizikova, Thomas Funkhouser**

Title *Automatically Assembling Frescos from Noisy Pairwise Fragment Measurements*

Abstract At archaeological sites around the world, many of the artefacts found are shattered into small fragments and archaeologists face a difficult task of reassembling the fragments to reconstruct the artefact, similarly as one would reassemble pieces of a jigsaw puzzle together. Combining

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fragments together manually is an extremely difficult task for several reasons. There could be many fragments that go to one artefact, and some could be missing. The artefact fragments are themselves fragile, and sometimes difficult to handle. Then, some fragments could have deteriorated over time, and it is not immediately clear whether two fragments should go together in the final puzzle. Finally, with a large number of fragments, there are simply too many combinations to test, especially without an automated system. Based on the above, it is reasonable to use computational methods correctly piece fragments together.

Most previous methods that can reconstruct the entire fresco rely on hierarchical clustering (e.g. [Castaneda 11]). In this technique, a greedy best-first approach iteratively merges pairs of clusters. Global relaxation needs to be applied to resulting clusters in order to find the best transformations to align fragments within clusters. Global relaxation uses least squares (LS) method to find the best rotations and translations for fragments in a cluster.

However, if a portion of the matches from a cluster are incorrect, least squares should not be used because the objective function becomes dominated by squared residuals [Singer 11]. A more robust method of finding optimal rotations and translations within the cluster should thus be used.

Our goal is to produce a set of globally consistent transformations given noisy pairwise fragment matches. We present a method based on [Singer 2011], which separates the problem into a first stage that uses an eigenvalue method to solve for rotations followed by a second stage that uses robust multilinear regression to solve for translations. The advantage of this approach is that a globally optimal set of rotations can be found by solving a convex optimization. It also can be applied iteratively by culling outlier matches according to how consistent they are with computed fragment rotations.

We test the rotation search algorithm on a set of 114 fragments which were obtained from a fresco created and shattered to test reconstruction techniques. A ground truth of 239 correct matches is available for this fresco. To test our algorithm, we add subsets of high scoring wrong matches obtained from [Funkhouser 11], and compare the resulting angles to manually created ground truth. When 30% of the matches are incorrect, least squares can recover at most 35% of angles within margin of error $\pi/16$, while our method recovers more than 70%.

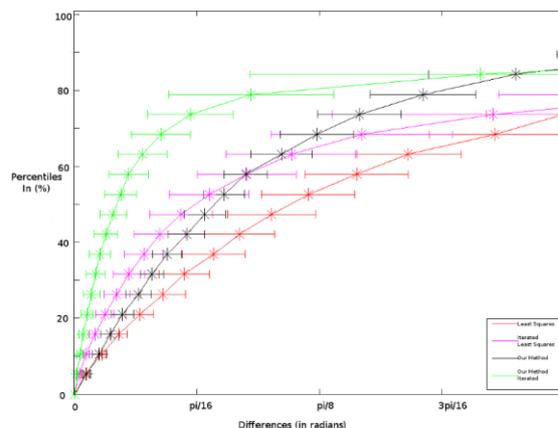


Figure 1: Percentiles of angular error achieved during a run of the methods with 114 fragments, 339 matches of which 239 are correct. The results are aggregated over 10 runs on different 100 wrong matches added.

The stars are the mean percentiles of the given error, and the horizontal lines represent standard

deviation.

Least squares (LS), performs poorly compared to other proposed methods. The method we propose, known as normalized eigenvector method (nEVM in the plot), finds more than 65% of the fragment angles within margin of error of $\pi/8$. Even better results are obtained when the methods (LS and nEVM) are iterated.

Authors

Diego Jimenez-Badillo, Edgar Roman-Rangel

Title

Application of the bag-of-words approach to the analysis of archaeological sherds and artefacts

Abstract

We introduce the bag-of-visual-words model (or bag-of-words for short, BOW) for the effective description and classification of archaeological sherds and artefacts.

Originally, the bag-of-words model was developed to statistically analyse textual documents with the intention of improving the browsing, classification and retrieval of its content.

The idea is that a document can be represented by a histogram that models the frequency of the most discriminative features of its content. In the case of text documents, a BOW model can be easily constructed by counting the frequency of certain words that are of high discriminative power (i.e. semantically important) given the topic of the document.

In the last decade the BOW model has gained popularity in the computer vision community as a method to compare 2D images and 3D point clouds, giving rise to the bag-of-visual-words approach. Instead of textual words, this version of BOW extracts and analyses visual patterns and local geometric features. This development offers great opportunities to analyse 3D shape data in many fields, including archaeology.

In this paper, we provide an intuitive but extensive explanation of the BOW model, and give details of two approaches that are popular in the computer vision literature to construct bag-of-visual-words representations: clustering and sparse coding. We evaluate the potential of these methods in the task of content-based retrieval of 3D models corresponding to a collection of sherds from Teotihuacan and Tenochtilan, two of the most important archaeological sites in Mexico.

Authors

Øyvind Ødegård, Stein M. Nornes, Thijs J. Maarleveld, Asgeir J. Sørensen

Title

Autonomy in Marine Archaeology

Abstract

After what oceanographers have called “a century of undersampling”, the marine sciences are now benefiting from tremendous technological advances in sensors and sensor platforms. Efficient exploration of the deep or remote marine environments depends on the use of underwater robotics, particularly untethered Autonomous Underwater Vehicles (AUVs) that can be sent out on missions covering large areas and return with data from multiple sensors. As technological developments allow AUVs to be deployed on long duration missions (months), the need for robust autonomous guidance, navigation and control systems become evident. The main concern is to have the robot plan and re-plan its mission to avoid damage in case of unexpected events, and to maintain safety while navigating in unknown environments. The

development of methods for Simultaneous Localization and Mapping (SLaM) is one of the key factors in resolving these problems and increasing the level of autonomy for AUVs. Robots' ability to deliberate and re-plan based on sensor data can be utilized for scientific purposes as well. Adaptive sampling and opportunistic decision making are methods that have already been used successfully by marine sciences and for military purposes. This paper will present some examples of these methods and discuss if and how they can be adapted and applied to archaeological purposes. Epistemological and ontological questions will be raised by integrating robots with artificial intelligence into the archaeological knowledge production. Can a robot be taught, or teach itself, to detect and recognize cultural heritage? Can a robot deliberate such recognition, and decide what next actions to take based on this deliberation? A research project on this topic has recently started, and there are few results available yet. This paper will mainly be concerned with identifying and defining problems regarding autonomy in marine archaeology, and demonstrating the importance of debating them.

Authors Vlad-Andrei Lăzărescu, Vincent Mom

Title *Pottery Studies of the 4th Century Necropolis at Bârlad-Valea Seacă, RO*

Abstract

Introduction

After decades of scientific studies, the Early Migration period (300 AD - 450 AD) is still one of the least studied fields in Romanian archaeology. Archaeological research related to pottery of this period is much behind and the existing gaps are only just beginning to be filled (Lăzărescu 2011).

Pottery

Pottery was only a minor topic in studies of important sites from that period. Paradoxically, the necropolis at Bârlad-Valea Seacă, which is one of the largest, is also one of the least studied (Palade 2004). The present paper gives a comprehensive analysis of the the pottery of this site. It is important that when dealing with a large collection of vessels (in our case over 600) to group similar items in meaningful categories in order to recognise patterns in the dataset as well as providing a framework to attach other information to (Orton, Tyres and Vince 1993). In our case, the first step was to establish shape categories and afterwards to attach to this classification structure other types of attributes relevant to pottery such as fabric, firing etc.

Secanto

The shape comparisons were done using Secanto, a computer program that calculates the dissimilarity of shapes of simple artefacts (like vessels, arrow points, axes) based on a numerical algorithm called the 'Slice method' (Shennan and Wilcock 1975). The dissimilarity is expressed as a 'distance' between the objects, and the resulting distance matrix is input for standard statistical packages to calculate clustering and to do Principal Coordinate Analysis.

Presentation

After a short introduction, the preliminary results will be discussed. A live demonstration of the Secanto program is part of the presentation.

SESSION 10A- ARCHEOFOSS: FREE/OPEN
SOURCE SOFTWARE AND
ARCHAEOLOGICAL RESEARCH, TEN
YEARS LATER

Authors **Alessandro Bezzi, Luca Bezzi, Fabrizio Furnari, Romain Janvier**

Title *ArcheOS Theodoric v. 5.0, ten years later.*

Abstract In 2005 ArcheOS Akhenaton v. 1.0 was the first main result of the OpArc project (OPEN ARChaeology), an initiative developed by the Arc-Team research group since summer 2003. The main focus of OpArc was to introduce and to spread the use of Free/Libre and Open Source Software and to apply the ideology of the “Free Software” movement to archaeology itself. The first results of our project were presented in the workshop “Open Source and Freeware Applications to the Archaeological Research” (L. Calori, S. Hermon, F. Niccolucci e S. Pescarin.) during the CAA 2004 of Prato. The year after we developed a first stable version of ArcheOS, a free/libre operating system based on GNU/Linux. The release was presented at the annual conference “Archaeologie und Computer - Kulturelles Erbe und Neue Technologien” in Vienna. Ten years later ArcheOS reached a new level in stability and reliability thanks to the joint effort of the new developers, who improved the distribution according to the GNU/Linux standard. Over the years, also the web-community feedbacks increased, with opinions and suggestions which helped us to affine the software selection.

ArcheOS' evolution is strictly connected to the digital archaeology's evolution itself. The first aim of this proposal is to analyze archaeological trends during the last ten years: we have enlarged the spectrum of applications, starting from Databases and GIS to Virtual Reality, from bi-dimensional data recording to three-dimensional documentation, and among much else, from sharing methods to opening access to data. The second aim of the presentation is to introduce the new release (codenamed Theodoric), based on the Debian stable “Wheezy”, and the status quo of the other projects connected to ArcheOS.

Authors **Luca Mandolesi**

Title *pyArchInit- python for archaeology - Part II*

Abstract “PyArchInit- python for archaeology”, presented in 2013 at the CAA of Southampton had reached an important goal: the birth of a new users and developers community. PyArchInit is a plug-in for the open source software Qgis, developed by archaeologists for archaeologists. The plugin allows any archaeologist to works in a single enviroment, using alphanumerical sheets and specifics geo-tables through specific GUI. Everyday we develop new part of the project, building routines that emulate the way of thinking of the archaeologist, and make faster, easy and precise the job for the researcher. One important innovation about PyArchInit is the Time-Factor: through a sperimental script we build a specific index to manage the position of any geometry in the temporal dimension, independently by elevation. Also we had augmented the way of exporting data in PDF formats and the system of the interaction on Qgis canvas with the stratigraphy directly through the Harris Matrix or the through the Stratigraphics rapport. Also the development of statistics and geostatistics about archaeological records continue. Infact has been improved the tool for spatial analysis with R softwere to make prediction map, graphics and statistics reports. Here we want to show all news of pyArchInit and to provide a tool for archaeological documentation and excavation management.

ARCHEOFOSS: FREE/OPEN SOURCE SOFTWARE AND ARCHAEOLOGICAL RESEARCH, TEN YEARS
LATER

Authors **Jerzy Sikora, Jacek Sroka, Jerzy Tyszkiewicz**

Title ***Strati5 - open mobile software for Harris matrix***

Abstract There are a number of software tools whose aim is to create and maintain Harris matrix data during fieldwork. They tend to be complicated and none of those we know of works on mobile devices.

Filling this gap, we present a very simple open software tool for recording Harris matrix data. It has all fundamental functionalities and, in addition to desktop and laptop computers, runs on mobile devices, almost irrespectively of the operating system.

Our tool is indeed a formula-only spreadsheet (i.e., one without macros or user-defined functions), in the older .xls format of Microsoft Excel. It can be therefore opened on most of spreadsheet software systems.

List of basic functionalities:

Recording data about contexts, groups, and their relations

Preventing duplicate context names

Preventing duplicate group names

Assigning contexts to already defined groups, only

Creating relations between already defined contexts, only

Detecting and preventing cycles in relations

Data exporting to *Stratify* format.

The least item above means that the data recorded in our spreadsheet can be saved in a format, which in turn the popular Imela Herzog's *Stratify* software for Harris matrix can import.

Offline version has been tested and works on:

Microsoft Windows (LibreOffice, WPS Office, MS Office)

Mac OS X (LibreOffice, MS Office)

Linux (LibreOffice)

iOS (WPS Office)

Android (WPS Office)

Windows Phone (MS Office)

In general, spreadsheet filled with data can be saved on one device and opened on another one, under different operating system and spreadsheet software, and will work properly.

Online version is available on:

Any system with Web access and ability to edit Google spreadsheets

Additional functionalities of online version

The data can be accessed and edited by many users simultaneously

Access administration via Google accounts

Tool for rendering the Harris matrix

Testing

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LATER

The offline version of the spreadsheet, scaled for 200 contexts and 500 relations, was tested in the field. J.Si. used it on SAMSUNG Galaxy Note 10.1 with Android and WPS Office. During excavations in Ostrowite and Obrowo (Pomerania, Poland) in 2014 initial bugs were eliminated. The tool was a little bit sluggish; a fully charged battery was more than sufficient for the whole day of operation. Mistakes in the data were caught: duplicates in context names, cyclic relations, references to undefined contexts.

Subsequently this mature offline version underwent simplified tests of correct operation under different spreadsheet software and operating systems, using the data collected during the field test.

The online version was subject to an incensed test with help of archaeology students from Lodz, with 7 people editing it concurrently. No problems were detected.

Availability

Strati5 is open software under BSD 2-Clause license.

It can be downloaded from the Google drive of the user strati.five@gmail.com:

<https://drive.google.com/folderview?id=0B-miB5pAbyRuSlg4RzhMRHdwWjg&usp=sharing>

Authors

Loup Bernard

Title

ArkeoGIS, merging European archaeological sites, artefacts and geographical datas online : state of art and further developments.

Abstract

ArkeoGIS software was incepted in 2009 in order to gather archeological and environmental datas regarding the Upper Rhine valley, an area providing a whole range of excellent research centres in archeology as well as geography, although they were not well connected. Besides linguistic problems, traditional research methods and archeology-linked legislations result in a state of datas particularly hard to merge with already existing digital tools. The original ERDF fouding helped us to develop ArkeoGIS (www.arkeogis.org), an *opensource online freeware*, for which users need only an Internet access and a navigator. The coding of up-to-date 3.0 version is available on github (<http://arkeogis.org/page/logiciel>). This latter version allowed us to adapt and develop a few more tools than the former versions (cf. Bernard 2012 and 2014) and it should not evolve before some time. Many difficulties regarding language, chronology, typology and map-designing traditions are now under control. Protected through a *login/password*, the website provides a sole demonstration version (<http://demo.arkeogis.org/login>) to the public at large, so as to prevent site-plunderers to access sensitive archeological data.

Today the tool expands towards other regions, new questions appear regarding more languages (only French and German are available for now), a non-relative chronological user-defined system and a user-defined level 3 and 4 characterizations. This paper will present the tool, discuss the user feed-backs and some of the results we had.

ARCHEOFOSS: FREE/OPEN SOURCE SOFTWARE AND ARCHAEOLOGICAL RESEARCH, TEN YEARS LATER

- Authors** Finnegan Pope-Carter, Chrys Harris, Thomas Sparrow, Chris Gaffney
- Title** *ArchaeoPY: Developing Open Source Software for Archaeological Geophysics*
- Abstract** Data are the building blocks for all archaeological geophysics research. As collected data forms the basis from which an archaeological interpretation is derived, proper handling, treatment, and display of data is crucial. Because archaeological geophysics is a small, dynamically evolving field, reasonably priced commercial software is not always available for handling the range of archaeological geophysics research. For instance, with recent trends towards mobile, multi-method, and large-area surveys; data processing, visualisation, and presentation may be too intensive to complete manually, or consist of repetitive tasks that can be automated. Few commercially available software packages can cope with these rapidly developing survey strategies and systems. These challenges have led to the creation of ArchaeoPY (<http://www.archaeopy.org>), a University of Bradford based community for the development of open source software for geospatial applications.
- ArchaeoPY's aim is simple: to foster a dynamic, supportive community for developing bespoke software. The ArchaeoPY community has open membership, and welcomes all interested users and developers. A problem with bespoke software is maintaining its usability through time, with issues such as obsolete programming languages, new or upgraded operating systems, and poorly documented code affecting the software's preservation with time. As a result, one of the key objectives of ArchaeoPY is to develop well documented, open-source code. The concept of being open requires the source being available for modification and improvement. This allows the users to take an active developer role as well, facilitating a dynamic relationship with the code they are using, which will help improve and maintain the code through time; furthermore, this dynamic relationship is not only opened between the user and the code, but the users to other users. This helps foster a collaborative effort, benefiting from the mixed backgrounds of the collective users.
- One of the key issues associated with software development across users with different programming experience is the maintenance of a common developer environment. This is especially complicated within the scientific python community due to the number of external modules utilised. To combat this, ArchaeoPY development is through the Anaconda Distribution, utilising a GitHub repository (<http://github.com/archaeopy>) for version control. This allows the maintenance on a common python environment on systems accessible while tracking changes to the code and utilising version control; so users should not worry about breaking or negatively impacting the code.
- Authors** Marco Callieri, Matteo Dellepiane, Marco Potenziani, Guido Ranzuglia, Roberto Scopigno
- Title** *Open source for CH: experience gained in ten years of service*
- Abstract** The evolution of computer graphics technologies in the last 20 years have been impressive. Digital Humanities (DH) have been a strong field of application right from the beginning. This is due to the large variation of interests: the subjects of study range from the small artwork to large buildings or even entire cities or territories; in terms of functionalities, the needs which range from historical research, fruition in museums, education, conservation, restoration,

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support to tourism, etc. At the same time, DH suffers from a scarcity of financial resources.

These factors originated the need to distribute tools to the community, to increase awareness and foster their deployment.

This distribution of software tools, however, was always carried out in an unsystematic way. Software releases were specifically connected with specific projects or collaborations, the distributed tools were scarcely documented and usually maintained only for a short time, and most of tools were extremely narrow in focus, e.g. solving a specific task in the 3D scanning pipeline or in 3D model processing and presentation. Despite these problems, this dissemination activity has proved fruitful in many interesting projects.

Since 2006, however, our effort has been redirected to the design of a single open-source tool, MeshLab. We decided to provide long-term support and continue the development of this tool, which replaced all of our single-purpose softwares (also for our internal use). MeshLab is an open-source mesh processing tool, oriented to the management of dense triangular meshes and 3D data coming from 3D scanning devices. Started as final project for a university course, it evolved into a powerful and advanced tool for mesh visualization and editing. MeshLab is distributed using GPL licence, and is available for Win32/64, and MacOS; officially supported by Ubuntu, Debian and other Linux distributions as packages. It has reached early in 2014 the 1 million download mark (with more than 350,000downloads in year 2013).

Recently (spring 2014) we have released another open-source tool, having a different focus than MeshLab: here the goal is to support easy publishing of visual media files on the web. This new resource, called 3DHOP (3D Heritage On-line Presenter) is a JavaScript component for the visualization on the web platform of high-resolution 3D models and the creation of complex interactive presentations. Though extremely young, this project has already received significant attention from the community and proved so far to be a successful initiative.

The maintenance of these tools is a cumbersome work, requiring regular development, debugging and maintenance, but also an effort of dissemination, documentation and teaching. For a research institution it is sometimes difficult to find resources for the continuous support of a tool (instead of concentrating our effort on basic research). Unfortunately, our national context does not offer funds for supporting the maintenance and evolution of open source resources. Our solution was initially to divert some of the funds secured on competitive EU calls for research projects or to use resources originated by third part contracts with industries or CH governing bodies. More recently, we are participating to infrastructure projects (both at the national and EC levels) which, on our opinion, are the ideal vehicle for both funding open source resources and for deploying the required training and dissemination actions.

In this presentation, we will describe our experience in developing and distributing open-source software for the CH community, detailing what we have done and what we have achieved in terms of relevance for the community, what we succeed in doing and, more important, what has not worked.

Authors**Ian Johnson****Title*****Building domain-agnostic databases using design patterns*****Abstract**

The conventional approach to designing SQL databases is tightly coupled to the specifics of the data to be recorded; tables typically reflect the entities modelled, the relationships between these entities and lookups for controlled values; the interface software is built to manage those structures. Consequently, this approach to managing data tends to generate problem-specific

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databases, which are tightly tied to a particular method of recording. The structure itself carries much of the semantic payload, which may also be embedded in locally programmed functions. While there are plenty of tools for streamlining development, from database wizards to UML and frameworks, this approach to database design is ultimately a programming approach with limited portability across projects.

At the other end of the spectrum, spreadsheets have a very low entry barrier and can be very efficient for handling structurally simple and repeatable datasets, such as specialist analyses involving samples, quantification and graphical display. However, when turned towards heterogenous collections which should be modelled as separate entities and relationships, they have encouraged unspeakable crimes against data modelling! Such spreadsheet 'databases' may end up a spaghetti soup of multiple entities per table, rampant redundancy, uncontrolled coding, multiple values per cell, positional significance, and cells blown out with discursive text. They are often a response to the mismatch between the data modelling required and the expertise and/or technical resources available.

In the mid 1990s, Jens Andressen and Torsten Madsen at Aarhus University developed an elegant model for their IDEA database system, which reduced the archaeological excavation landscape to just three main tables - deposits, finds and constructs - which could then be adapted to a wide range of different recording systems. A decade later I started designing Heurist (HeuristNetwork.org) based on an even simpler database construct of just two main tables - records and data values - which are agnostic on the nature of the entities recorded. The records table simply defines the record type and provides a foreign key value identifying the set of key-value pairs in the data values table which form an entity (as with IDEA, another 40 tables manage the coding and content of these tables). A further decade later, the FAIMS project (FedArch.org) is using an internal database with the same two main tables - entities and attributes - for their field data collection tablet app and synchronisation server.

In this paper I will show how widely disparate archaeological data can be modeled in such a meta-database hosted on top of a conventional relational database manager (Access for IDEA, MySQL for Heurist, SQLite for FAIMS). The key to these systems is not to deal directly with the structure of the data, but to identify commonly occurring database design patterns and to implement generic procedures to handle them independent of context. In the paper I will formally define a set of design patterns appropriate to archaeological data, and assess the Heurist and FAIMS applications against this set of patterns. By doing this we can identify opportunities for further development.

Authors Néhémie Strupler

Title *Archaeological science as community enterprise*

Abstract If 10 years ago it seemed largely irrelevant and out of scope to adopt FOSS (Free and Open-Source Software), the setting dramatically changed. Nowadays to address methodological and theoretical issues in archaeology, FOSS are attractive and promise access to powerful toolboxes accompanied with lifelong sustainability. An unexpected or unintended outgrowth of the adoption of FOSS is the interaction with FOSS Communities and the philosophy of software development. Such communities "are a global melting pot of diverse professions and skills that contribute to the progression of the goals represented by the software" (Wikipedia: The Free Encyclopedia, s.v. "Humanitarian-FOSS"). Thus, archaeologist adopting FOSS deals with free, informal and wider communities, so-called FOSS communities. Each software or a specific package develops a community maintaining the software, providing advices, case examples, advertising and developing new tools. Looking for help, new ideas, possibilities of new tasks,

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reading or collaborate in the development of FOSS give access for archaeologist to others, less formal, but scientific communities. Platforms like Wikipedia or Stack Overflow challenge scientific communication and the reward principle driven by the traditional academic. This paper addresses how FOSS and FOSS-communities provide a common language and goal through which foreign disciplines are revisited. It also takes this different perspectives to look how this framework could enrich and challenge science and more specifically archaeological research.

Authors **Gabriele Gattiglia, Francesca Anichini**

Title *#epicfail? Has Open Source in archaeology failed?*

Abstract

And then one day you find ten years have got behind you from the first ArcheoFOSS edition.

The impact of Open Source in archaeology has been surprisingly (?) limited, it have not been part of any radical development in how we conduct archaeology, and in the last years has suffered a loss of appeal among researchers and archaeologists.

The use of open source software should have overcome the limitations dictated by software currently used, leading the use of computer applications in archaeology to match with the goals, needs, and aspirations of archaeologists. Open Source has had the possibility to create computer application not simply derived from proprietary software, but applications create appositely by and for archaeologists. This path was too often neglected. Why?

Two main reasons can be identified.

The first can be viewed in theory ladennes. Open source was a computer science issue, the transposition to archaeology was not associated with a strong theoretical approach. Open Source was not able to propose new development, new forms of doing archaeology, that include new ways, and standards, of handling, processing and modeling information. This is related to the insufficient recognition that the intersection of computer application and archaeology provides new paradigms and/or research venues. Open Source in archaeology goes beyond the mere application of software, in fact, it represents an area where archaeologists can focus on discussion about the nature of archaeological data, their definition, representation and manipulation. ArcheoFOSS seems on the point of losing this battle, just when a new nourishment, in form of a more theoretical approach, is coming from the introduction of open access and open data instances.

The second reason is connected to education and formation. There is an absence of a proper academic curriculum: Open Source skills can't be relegate solely in post-graduate courses. On the contrary, it's necessary to provide future archaeologists with a level of competency both in archaeology and computer science such as to enable them to move from one discipline to another with ease, and to generate novel insight. Only proper training can permit them to engage in the development of new IT tools consonant with archaeological interests, and to foster a deeper conceptual understanding of how applications work as a necessary step towards the creation of new ones. The full benefits of Open Source would only be possible if such preparation is in place for archaeologists to reap the benefits themselves.

No one told us when to run, did we miss the starting gun?

SESSION 10B- ELECTRONIC RESOURCES
FOR ARCHAEOLOGY: FROM DATABASES
TO DIGITAL OPEN DATA

Authors **Doug Rocks-Macqueen**

Title *The Past and Future of Open Access in Archaeology*

Abstract This paper examines the work of the Open Access Archaeology project and its website OpenAccessArchaeology.org (OAA) over the last few years and future plans. A brief history of why the website was set up and its early development will be given. The successes and failures of some of the early initiatives will be reviewed like:

- The creation of a searchable database of OA Archaeology Journals.
- A custom search engine to search for OA Archaeology articles.
- Multiple web bots to disseminate OA publications on social media platforms.

However, the purpose of this paper is not to focus on the past of Open Access and Archaeology but its future together. With the very rapid expansion of OA through government mandates like those found in the US and UK the publishing environment is shifting very rapidly. Some of these changes have resulted in OAA reaching some of its initial goals. However, the rapid changes occurring in publishing has presented new challenges to Open Access and Archaeology. This paper will focus on what these challenges are and how archaeologists can deal with them. Ideally, presenting a roadmap to the future.

Authors **Francesca Anichini, Margherita Bartoli, Paola Liliana Buttiglione, Eleonora Delpozzo, Ilenia Galluccio, Gabriele Gattiglia, Clara Annarita Giannitrapani, Silvia Lischi, Saverio Giulio Malatesta, Flavia Morandini, Daniela Musmeci, Felice Perciante, Mariela Quartararo, Sara Linda Russo, Francesca Simi**

Title *Are the open archaeological data fashionable? The Italian Manifesto for Open Data in Archaeology (MODA)*

Abstract The Italian Manifesto for Open Data in Archaeology arose from the experience of the Open School of Archaeological Data, promoted by the MAPPALab of the University of Pisa, a free school conceived to foster open data literacy in archaeology. The school encourages a civic hacking approach to archaeology, an open data approach that we define as ha(r)ckeology, i.e. the act, conducted by archaeologists, of quickly improving the processes and systems of archaeology with new tools or approaches, or more simply the action of archaeologists working together quickly and creatively to improve archaeology. For reaching such a goal, the first step is to educate a new generation of archaeologists, a sharing generation able to work with a trowel, and to share and manipulate data, a generation that is aware that archaeological data must be open because they are public, and they must be reused.

The Manifesto is based on the idea that archaeological heritage is a public asset of all citizens, therefore the data describing them must be public, and that archaeology is a research activity, and if the research is free - as stated in the Italian Constitution - the data and the results derived from it should also be free, so an open access to data must be a right and is essential for the development of modern archaeology and for the enhancement of good archaeological practices. Open access to archaeological data will be the basis for a new, conscious and shared management of collective goods, and for giving the archaeologists the necessary awareness to regain a strong social relevance and to truly be culture makers and promoters.

As promoters of the Manifesto, we are aware that our society is gearing towards openness and sharing, so we decided no longer to limit ourselves to words, but commit ourselves concretely for the practical application of principles that are not mere statements of intent, in the name of a development of civic and cultural life. We are archaeologists, but basically crazy people. Crazy in wanting to propose a new approach to archaeology, to the point of putting us at the forefront

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to spread the idea of participative collaboration, because "Coming together is a beginning; keeping together is progress; working together is success" (H. Ford) and our aim is to succeed.

Authors **Alessandra Caravale, Alessandra Piergrossi**

Title *Digital resources for archaeology. The contribution of the on-line projects by ISMA-CNR.*

Abstract

Are digital resources now a real support to the work of the archaeologist? What assets on the network can benefit the scholar of antiquities in his patient work of classification and comparison? The paper discusses some examples of electronic resources for antiquity sciences, outlining briefly the lines of development and focusing on databases, on-line publishing, portals useful to carry out research into the history of ancient art and archeology. The paper refers to the activities carried out in this field of study by our Research Institute of the National Research Council, the Institute for the Study of the Ancient Mediterranean, whose ancient origins date back to the late Sixties. Since then specific attention to the so-called "ancillary sciences" of archaeology has been manifested and the CNR has paid particular attention to the methodological renewal concerning archaeology, which started applying new tools for research borrowed from natural and social sciences. With regard to the application of computer techniques for the study and classification of archaeological artefacts, in the early Eighties our Institute gave rise to a dedicated line of research, which found a stable editorial point of reference and a place of convergence for theoretical as well as methodological debate in the international journal "Archeologia e Calcolatori". As regards the data banks, the paper will focus in particular on the recent realization dedicated to the collection of bronzes Faina in the Orvieto Museum, realized using the Content Management System open source "Museo and Web". This is a system created by the Technological Observatory for Heritage and Cultural Activities of Italian Ministry for Cultural Heritage and Activities and Tourism in order to develop and manage high quality web sites devoted to museums or cultural institutions. This tool facilitates the creation of a database of the objects kept in museums and makes use of metadata for the retrieval and access management of digital resources. For the open access publishing policy, ISMA contributes with the "Archeologia e Calcolatori" case. The journal, directed by Paola Moscati, is a peer reviewed open access journal as, since 2005, in addition to the paper format, is also accessible on-line, providing all articles published since 1998 in pdf downloadable and printable. We present also two web sites examples implemented by ISMA researchers, on Cerveteri and the Virtual museum of archaeological computing. The website devoted to the Cerveteri necropolis, was realized in 2004 when the UNESCO declared the Etruscan necropolis of Cerveteri and Tarquinia world Heritage. In this website, apart from the data on the Etruscan town, the territory, the necropolis and the museum, you can consult some virtual itineraries inside the Banditaccia necropolis. The website of the Virtual museum of archaeological computing is managed by Paola Moscati in cooperation with the Centro Linceo Interdisciplinare "Beniamino Segre" of the Accademia Nazionale dei Lincei and some ISMA researchers. This website aims at showing the roots and the development of this discipline, by pointing out the related institutions, studies and main actors, at an international level.

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- Authors** Valeria Boi, Mirella Serlorenzi, Ilaria Jovine, Milena Stacca
- Title** *SITAR: starting point, challenges and future development of an archaeology data sharing platform*
- Abstract** The Geographic Archaeological Information System of Rome (SITAR) is a project of Ministry for Cultural Assets and Activities and for Tourism of Italy, developed since 2007 by the Special Superintendence for Archaeological Heritage of Rome. SITAR has the aim to create the first "archaeological digital cadastre" of the metropolitan area of Rome, in which archaeological data are integrated with the modern city, and in which every record provides the detailed topographic location of the archaeological finding, together with a descriptive sheet containing administrative informations (type of survey, commissioning body, executing company) and scientific ones (type/function, chronology, description, etc.). The informations provided correspond to a "minimum level of knowledge", which is adequate to allow an aware re-use of data for aims of research, conservation, urban planning, by both researchers, public bodies, professionals and citizens.
- The project data are accessible on the web through a webGIS platform, which allows the easy consultation and download of information to a wide range of users.
- From the outset, the project has been developed with a special regard to the open access to the information and to open data formats, in line with the european prescriptions for public data repositories.
- Thanks to the Special Superintendence for Archaeological Heritage of Rome, administrative and financial independence, public funding has guaranteed in the first seven years of the project the system design and development, as well as its implementation. For the future, public financing will ensure the economic sustainability of the project and will ensure future service efficiency and technology update, aiming to create a complete repository of the entire archaeological heritage of Rome.
- The SITAR contribution to Europeana and ARIADNE, in the prospect of sharing information with other european cultural databases, will provide mutual enrichment of knowledge; interoperability between databases, content sharing and knowledge are indeed the ultimate goal of the project.
- Authors** Federico Nurra
- Title** *Use of cartographical Open Data in the context of the project SITAN*
- Abstract** The aim of this paper is to take stock of the availability, integration and use of cartographic Open Data within the research project of the Department of Architecture, Design and Urbanism (DADU) of the University of Sassari named "Creation and activation of the Sardinian node of the national network for the collective construction of the Web GIS of the national archaeological heritage – SITAN".
- The research project was conceived within a national debate carried on by two Interdepartmental Commissions of the Ministry for Cultural Heritage and Activities and Tourism (MiBACT) and the Ministry for Instruction, University and Research (MIUR) over the past decade.
- Particularly, the second Commission, active from 2009 to 2011 and chaired by Giuseppe Sassatelli, issued a final document, still unedited, that dictates the directives for the definition

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of an archaeological Spatial Data Infrastructure (SDI) based on a national research network.

An experimentation was initiated in Sardinia from 2012, through an academic research project, involving different universities, the peripheral institutions of *MiBACT* (Superintendence for Cultural Heritage and Regional Directions) and Sardinia Autonomous Region (*RAS*).

Due to the great number of actors involved in the definition of a common project, the problem of the interoperability of the data, and of the need to get to a common reference cartographic base, arose.

In this sense, open cartographic bases provided by National Cartographic Portal (PCN) of the Ministry for Environment and by the Geoportal of the *RAS* were chosen.

The European Community established common rules in the field of Cartographic Open Data through the directive INSPIRE (2007/EC), directive transposed in Italy from 2010 (D.Lgs. 32/2010); particularly, the *RAS* provides its cartographic data through a distribution Italian Open Data License 2.0 (IODL).

All these data are published online according to the protocols defined by Open Geospatial Consortium (OGC) and they are usable regardless of available software and hardware architectures.

Particularly, reference is made to the use of the protocols Web Map Service (WMS), Web Map Tiled Service (WMTS), Web Feature Service (WFS) and to dedicated plug-ins on client platforms GIS Open Source for the structuring of client based GIS projects connected to the network of the *SITAN* experimentation, defined through OGC Standards.

The research project for experimentation of *SITAN* contemplates an architecture of storage of data on server based on RDBMS PostgreSQL with geographical interface PostGIS, and the use of GIS Open Source client qGIS for the implementation of the data by the different actors/users contributing to the production of the archaeological datum.

Particularly, the data interexchange between *DADU* and *Soprintendenza per i Beni archeologici per le Provincie di Sassari e Nuoro* was encoded through a framework agreement that standardizes all procedures relating the experimentation of the *SITAN*.

Finally, on the basis of Ministry directives, the project aims to realize a cartographical apparatus characterized by a minimum set of required standardized data, a "zero degree" of information, a geographical and alphanumeric "Greatest Common Denominator" contemplating an open distribution, complying with European and National directives.

Authors **Andrew Dufton, Michael Johnson, Elizabeth Fentress**

Title ***Exploring sustainable publication and the web: a case-study from the Villa Magna Project***

Abstract Within the past decade, new platforms for creating and managing archaeological data during fieldwork have seen both widespread adoption and increasing intricacy. Although effective data management is now a necessary component of most field projects, the lives of these complex systems after the project has ended are less certain. Institutional concerns including basic software requirements, system upgrades, and web security can derail digital publication and result in largely static, albeit sustainable, archives – downloadable CSV files, simple HTML pages, and, occasionally, PDFs. These formats are only one piece of the puzzle, a necessary aspect of sustainability that, when used alone, can limit the functionality of these data for future researchers. How can we ensure the open, online publication of archaeological data while also maintaining the complexity of original field systems? What steps can we take to address institutional concerns while publishing information in interactive formats that facilitate later

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use and reuse?

This paper considers some of these questions through the lens of a single case-study at the site of Villa Magna, Italy. A programme of fieldwork was completed at this Roman imperial villa and later medieval monastery from 2006-2010, and included geophysical survey, pedestrian survey, and open-area excavation. Complex data were managed on-site using the Archaeological Recording Kit (ARK), accessible to the project team during the off-season through the ARK system's online interface. The project is on schedule to publish these results in 2015 in a hybrid print/digital publication – a printed monograph containing site background and narrative interpretation, and an interactive online companion for stratigraphic reports and object catalogues. By looking at some of the difficulties the project has faced in finding a long-term home for its online component, and the steps toward automatic system updates and data security the project team has taken to ensure greater longevity, this discussion will explore some future options for the sustainability of digital data publications.

Authors **Stefano Costa, Alessandro Carabia, Enrico Zanini**

Title *GQBWiki goes open*

Abstract

In 2005 the team at the University of Siena working in Gortys started using wiki software as a digital documentation platform for the archaeological excavation and the broader research project. We chose MediaWiki, a fortunate choice in retrospect, with the aim of tackling two main problems: 1) all the 10-15 team members should be able to work on the same content platform at the same time 2) when fieldwork is over and everyone is in a different place, even country, we should be able to continue working seamlessly. This collaborative web-based approach is common, and perhaps just good practice in the mid '10s, but was admittedly experimental and, at times, problematic when we started to understand the routine of it.

Today GQBWiki is still our platform for the management of data and information, and it also keeps the historic memory of the archaeological interpretation and how it came into essence, thanks to page history. After more than ten years of research on the field, we are ready to publish our results and release our data alongside a traditional publication – that will be inevitably a synthetic and narrative one. In the meantime GQBWiki is the base of our knowledge and it will be published on its own as an open access repository (under a CC BY-SA license) where data and metadata are really the same.

From the point of view of digital data, the 2000+ pages in GQBWiki are a handbook case of linked data, with a unique URI for each stratigraphic unit, journal entry, archaeologist, and significant find. A thin ontology was created using Semantic MediaWiki: while this serves very practical purposes and bridges the gap between a wiki and a database for structured queries, it also helped us solving one of the main problems for publication, that is the accessibility of information for external users, both human and machine, by improving the ability to explore our knowledge base, through web browsing and state of the art linked open data practice.

Collaborative authorship has been a challenge both in the material practice of creating content and in the obvious distance from traditional academic publication when considering publication, peer review and attribution. A wiki is a different kind of “manuscript”, by definition a multivocal product, where every single page is built by many users, each one with a different background and level of commitment. While internal review of the content has worked well for us, an actual peer review process seems a daunting task and opening the wiki is likely going to spur only minor feedback in the near future. The very process of making our work open is one kind of alternate attribution mechanism, imperfect but appropriate since we're publishing a living body of knowledge that will continue to evolve.

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Authors **Monteil Aurélie, Bouletreau Viviane**

Title *Archaeological contents: from open access to open data*

Abstract

The activity of the researcher takes place within a global process of development of the scientific knowledge, which lies on data sharing. He needs both to access existing data (sources, publications), and to distribute his own production. Open access provides the suitable tool for reaching these two objectives.

Researchers must also overcome new challenges: selecting relevant information within the huge quantity of data and ensure optimal visibility and re-usability for the data they produce. In this context, open access is not sufficient, hence the emergence of the concept of open data, which deals with technical interoperability, quality of referencing and permanence of access.

Persée is a French, public-funded, program for the digitization and online publishing of printed academic journals in the field of Humanities and Social Sciences. Beyond the publication of a huge digital collection, Persée endorses the core principles of the open data movement (open access, handle/DOI, standard formats, SEO, interoperability, long term preservation).

The original mission of Persée is now expanded to a new project: producing and disseminating scientific content beyond published journals. Persée will apply its *savoir-faire* on corpus composed of heterogeneous material. A wide range of tools is being developed in order to process, disseminate, share, and allow scientific uses of these bodies of documents.

Among the collections that will be processed with these new tools in 2015, two are dedicated to archaeology:

- The collection "*Monuments of Cairo*" is about the the digital publication of the minutes and reports of the *Committee for the Conservation of the Monuments of Arab Art* (published from 1882 to 1953). We intend to enrich the original material with a multilingual index for toponyms and monuments. This index uses international standards and proposes to associate to each entry the several ways it is mentioned over the whole collection.

- The collection about the excavation of "*Salamine de Chypre*", is about the study of material and architectural remains. It aims at univoquely identifying artifacts and establishing links between several resources related to these objects: catalogs, photographs, publication, index cards.

These two projects will demonstrate the potential brought by an open data regarding the constitution of digital collections. One of our objectives is to build a large scale platform that will both federate data and be enriched, project after project, by a collection of tools addressing the researchers needs. Both data and tools will be fully and freely available to the community.

Authors **Finnegan Pope-Carter, Graeme Attwood**

Title *Legacy Data - Open strategies for closed data*

Abstract

Archaeological geophysics surveys have been conducted by groups based in Bradford for in excess of 40 years. GSB Prospection combined with the School of Archaeological Sciences at the University of Bradford have an archive of reports both analogue and digital stretching back this far, many of which have been viewed by only a select few. Spurred on by a project to catalogue the late Professor Arnold Aspinal's project archive and a need to update GSB's internal database and archiving systems, GSB and Postgraduate students in the school of Archaeological Sciences have embarked on a project to digitise, re-georeference and

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disseminate work that can be made available in the public domain. The project is built primarily on open source software and database systems and wherever possible will be made available to those seeking to replicate the work we are doing.

The Open aspects of the project break down into three key tasks, these are:

Bringing historic data into a format that can be utilised on current systems.

Batch Process historical word, CAD and data archives to ensure the contents are converted to and stored in freely available formats. Historic archives have been lost when proprietary formats become obsolete.

Salvage born digital data from archives only available in printed analogue formats. In salvaging archives that currently only exist in paper or legacy formats it safeguards the data for future use.

Ensuring the location of surveys can be easily determined from datasets

Compare digital mapping information with project metadata to verify georeferencing information in historical CAD archives.

If georeferencing information is incorrect automatically identify known features that correlate with open mapping data, to position the historic local grid within the world view.

If no automated georeferencing is possible flag the site for review

Make datasets available in the most appropriate way

Categorise surveys to determine those that are commercially sensitive and those that have previously migrated into the public domain.

If accurate georeferencing has been possible make data only previously available in printed form available on a google maps type service.

If only an approximate georeferencing has been possible add a Pin to a map linking to a web viewable report.

Undertake consultation to determine if the final display should contain data ‘tiers’ in order to protect uninvestigated archaeology. The first tier being an approximate location pin with basic survey details, leading to a final tier of fully georeferenced data and interpretive plots that can be accessed on request.

Authors

Anthony Corns, Louise Kennedy

Title

From Lamp-light to Laser-light: Opening access to the historic and contemporary imaging of monuments

Abstract

LoCloud is a 3 year co-funded EU project which aims to build on the achievements of CARARE in establishing a repository-based aggregator for Archaeological and Architectural heritage (and which will, by the end of 2012 have contributed some 3 million items to Europeana); and of Europeana Local in its work with local institutions and their regional and national aggregators, which resulted in the contribution to date of well over 5 million items.

The specific goals of LoCloud are to:

1. Ease the task of enabling heritage organisations in making their contents accessible via Europeana, by using the cloud to provide services and tools which help to reduce technical, semantic and skills barriers.

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2. Make it easier for digital content emerging from small and medium cultural institutions, and also through collaborative crowd-sourcing initiatives, to be made available to Europeana in order to increase the richness and representativeness of Europeana's record of local history.
3. Improve the interoperability of relevant content from localities across Europe from institutional domains which in some countries act separately: namely the 'heritage' sector and the MLA (museums, libraries, Archives) sectors, in order to provide a more coherent 'views' of the history and heritage of a given locality.
4. Enable smaller institution types such as house museums, which currently fall outside most aggregation infrastructures, to contribute their content to Europeana.
5. Explore the potential of cloud computing for aggregation, enrichment and re-use, with a special focus on geographic location.
6. Explore and trial a cloud based architecture as a scalable platform for Europeana metadata aggregation and harvesting with higher efficiency and reduced maintenance costs.
7. Develop a portal and support service to serve the needs of content providers.

Within Ireland, LoCloud is focusing its efforts on the assistance to small institutions which hold within their collection a range of historic and contemporary imagery which have recorded the monuments and archaeology of Ireland for more than 200 years. Some of the data sets which will be made available through LoCloud include:

the 19th Century watercolour illustrations of monuments created by DuNoyer,
 some of the earliest remaining lantern slides of important Irish archaeology sites,
 historic aerial photography utilised for archaeology survey,
 contemporary recording of ogham stones using close range laser scanning.

Before LoCloud, these archaeological resources were not available online, or not visible to the interested user. Through the activities of this project access through Europeana access will be made available for wider use. The project will also provide cloud based metadata enrichment services (Geolocation, vocabularies and languages, historic place names) which will enable those institutions providing the content create rich and detailed metadata records. LoCloud also offers those institutions with no dedicated repository for the online presentation of their digital assets with "LoCloud Online Collections" cloud based OMEKA service.

Authors	Nicholas Andre Holmer, Buck Benson, Jesse Pruitt, Robert Schlader, Nicholas Clement, Herbert D.G. Maschner, Corey Schou, Jonathan Holmes
Title	<i>From past to present: Reconciling years of Arctic archaeological data into a single visual database</i>
Abstract	Creating a database housing metadata on an archaeological site is a crucial yet daunting enterprise faced by many archaeologists. Problems associated with the creation of these databases can include: multiple investigators, the amount of time elapsed from excavation to completion of project, and the loss of context. Despite these issues the completion of a project is often followed by publications and in most cases the storage of data (both physical and digital). This is invariably followed by a lack of access or an overall degradation of data compounded by a lack of use and exposure. Many sites never see the 'light of day' following the publication stage making them invisible to the research realm. To combat this lethargy we have begun creating an online database housing 2D and 3D images, site data, excavation data and all other pertinent metadata of archaeological sites across the lower Alaska Peninsula. The beauty of this database is that it allows the researcher, educator, student or weekend observer to

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not only see these artifacts and data but perform research and analyses. Our process of data collection allows highly accurate (<0.01mm) metric analyses to be performed on both 2D and 3D images with the capability of exporting metrics directly into spreadsheets from online content. This database is also designed to be plastic, in that it is directly transferrable and malleable to any research area or time period. This paper discusses our process of data acquisition using 2D and 3D capture, data reconciliation, and the movement of data into an online digital database.

Authors Tamaki Suzuki, Ivan Vasiliev

Title *High-resolution Image Database for the Conservation of Cultural Heritage: Documentation of Architecture and Paintings of the Medieval Churches in the East Europe.*

Abstract In the middle of Balkan region, there are great numbers of medieval churches and monasteries with rich mural paintings. The author has been leading documentation of the cultural heritage in the project of Balkan Heritage Field School.

Documentation by digital method, such as high resolution photography, is one of the cutting-edge technique of recording current condition of the cultural heritage. In the recent conservation projects of the architectural heritage with mural paintings, high resolution image helps us to see both general view and detail condition of the painted surface by single image data. Despite its great merits, the cost, difficult operation of instruments and software, and huge amount of data have been nuisance for researchers and conservators. Therefore in this project, it is strongly desired to establish the costless and flexible methodology of documentation by the informatics approach.

The workshop of May 2012 and May 2013, targeted especially the church of St. Nicolae in Kalotina, 14th century church closely located to the Serbian border in the West Bulgaria. The paintings depict important historical background and Christianity at that period with highest technique. However the paintings were severely damaged by diverse mechanism on physical, environmental and biological aspects. In collaboration with local experts and international volunteers, the high resolution photography, measurement of the architecture, image processing and condition assessment of the paintings were done. The methodology and process of documentation is described below.

1) Photography of the paintings

Photography is conducted by setting the camera on tripod horizontally and paralleled to the wall painting. Depending on the dimension of wall paintings, the paintings were taken by several shots.

2) Measurement of the church and paintings

Rough measurement of the ground plan, section plans and especially elevation plans both inside and outside wall was done. The 3D model of the architecture was also created by photogrammetric measurement, by using software of Photo Modeler Scanner. The geographic information obtained by the total station, was added to the point cloud data.

3) Image processing

The photographs were merged into a single high resolution image by the “photo merge” function of Adobe Photoshop CS6. The merged image was rectified manually with the measurement data, resized into the exact scale and then set into the format of the base on the Adobe Illustrator CS6.

4) Condition assessment and recording

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Condition assessment was done directly on the base map by using Adobe Illustrator CS6. The damages of the painting were categorized into physical damage, environmental and biological aspects, and past restoration. The materials of architecture were divided into lime stone, sand stone tufa stone, brick and wood, and recorded on the digital map.

In this process, the high resolution database was achieved by the costless and flexible method. It is also remarkable to say that this database enables quantitative analysis of the architectural materials and damage of the paintings, which will be matched with actual needs of conservation planning.

POSTER SESSION

SESSION 1B: THE CHALLENGE OF THE
PREVENTIVE ARCHAEOLOGY :
EFFICIENCY AND QUALITY

POSTER

- Authors** **Jean-Philippe Chimier, Thomas Pouyet**
- Title** ***Working with preventive archeological data in the research program EVENA : an efficient case***
- Abstract** The research program called EVENA is managed by the Archéologie et Territoire Laboratory (LAT) wich belongs the CNRS/University of Tours. The purpose of this program is the archeological evaluation of Esvres-sur-Indre (Centre of France) and his surrounding landscape, whose origins go back at the Latenian period. However we work in a diachronic way, using old and new data. Several sources are used to gather archeological informations : historical archives, previous archeological records, preventive archeology operations (125 hectares in archeological surveys and six excavations) and one specific survey. When the program will be done, the new data will be release on a monographic issue for each site and will be used to work on a diachronic synthesis. All the spatial information is gathered in a Geographic Information System (GIS) specifically designed for the project EVENA.
- We developed this GIS to work on the city and territory's scale and with the possibility to integrate all the historical data, whatever they are. The scientific results of the preventive archeology (evaluations, excavations, pedestrian surveys) are used as documentary sources. We plan to analyze the digs's results of these specific operations and the data gathering by others kinds of historical surveys. This process will allow us to use spatial analysis concepts with solid and complementary data, in the long time and at multiple levels.
- Start a program like EVENA, using a wide range of documentary sources gives us the opportunity to investigate some new fields of research. We are no longer limited by the only vision offered by the preventive archeology. Of course, some parts of the study territory is inaccessible, frozen by the existing buildings or too far away from the dynamic development areas. But working with old documentary sources and collect new data each year with the specific survey allows us to give a better interpretation of the sites discovered with preventive archeology.
- Authors** **Frederic Audouit, Véronique Vachon**
- Title** ***Topography in preventive archaeology: operating mode integrated into GIS and archaeological information system.***
- Abstract** The topographer, a key player of preventive archaeology, guarantees thanks to its know-how a work of quality and precision and adapts his work to the requests of the archaeologists. A true dialog is developed between archaeologists and the topographer, security of efficiency and quality.
- The archaeologist makes land survey in certain circumstances. GIS, photogrammetry, Lidar, laser scanner 3D are new tools that appeared and the archaeologists can used these tools too. If the topographer does not master these new tools, he has to know the system used in order to advise the archaeologist and to guarantee the relationships between spatial data and descriptive data.
- GIS are more and more present in preventive archaeology, topography is the first tool that records spatial data from an excavation site. The topographer has to develop some methods of quickly and quality records that have to be integrated into GIS. The modus operandi has to optimize the rendering of the information: qualitative (topology, one ID by spatial object) and quantitative (quickly, precisely). Some standards have to been defined and respected, it is essential to have a good quality in topography to improve GIS. The current reflections within the framework Inrap GIS referents groups will help to present methods of land survey guaranteeing an optimization towards the GIS, a management of all the spatial data and create a

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ground to allow data transfers between technical teams and administrative teams. Finally an operating mode will be explain in order to define the relation between the participants (archaeologists, topographers, CAD drawers, specialists) and to optimize the management of different sources of spatial data.

All these methods and reflections should define some national standards to respect in management of data and archive system while allowing some latitude to archaeologists. This modus operandi will be a part of the “archaeologist pack” which contains some tools like archaeological data base too.

Authors

Sylvain Badey, Xavier Rodier

Title

Spatial analysis for an efficient use of data from trial trenching

Abstract

The practice of preventive archaeology in France takes place in two steps: first, preliminary survey (“diagnostic” in french) and second, excavations. The diagnostic consists in assessing the archaeological potential of an area impacted by development. In rural areas this means an opening in the form of trial trenches. This continuous trenching pattern is performed using mechanical devices. These trenches are evenly spaced so as to cover around 10% of the surface. This first phase aims to provide sufficient information -on the nature, extent, chronology and degree of preservation of the sites- to the competent authorities (in France, the Ministry of Culture) in view to prescribe or not an excavation. The areas affected by these archaeological surveys are considerable, in some cases tens or hundreds of hectares.

Beyond the assessment of archaeological potential, they deliver diachronic information on land-use whose exploitation is often restricted. In the case of large areas surveyed, we let’s suppose that the data mining is useful for archaeological interpretation of the site.

This paper presents the methods and results of an experiment based on data from a 226 ha archaeological survey performed at Etrechet in Indre (Centre of France). The aim was to evaluate the contribution of spatial analysis, on one hand to read the results of the trial trenching, secondly to understand the land-use in the studied area. The experiment focused on the use of exploratory spatial data analysis. The methods used are both cartographic with the grid analysis and statistic with data clustering. The aim of this methods is to overcome the division imposed by the trial trenches, and consider the whole area.

Results show that it is possible to test interpretive hypothesis on the distribution of the remains. Indeed spatial analysis reveals patterns by periods, confronted to the essential archaeological interpretation. The results meet the two objectives of an archaeological assessment. First, they are useful to interpret the remains and to understand the dynamics of land-use. Secondly, as decision-making tool, they provide elements for the authorities to deal with the archaeological sites (excavations or preservation).

Authors

Ellébore Segain, Véronique Vachon

Title

Recording data and managing the field: another use of the GIS-DBMS system in preventive archaeology

Abstract

In the rescue archaeology context in France, the preventive archaeologist must identify and analyse the archaeological information from sites concerned by development projects.

The collect of information mostly occurs during field intervention, and this is the most important step for recording and preserving spatial and descriptive data. All the future studies

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are determined by the system used during this phase. Archaeological information (spatial and descriptive) and eco- and artifact collected during the intervention will be the only remains left to document each site after its destruction. Therefore, it must be preserved, stored and archived for any future study. This archiving process must allow national exchange of the data, and comparison with others sites. The information also must be shared with the public.

In the rescue problematic, cost and time are important brakes to the collection of the data on the field. That's why the system used must be efficient, not only to allow studies, but also to help the archaeologist during his field work.

In Rhône-Alpes area, our team experiments a system based on collecting and archiving information into a database (DBMS), using PC-tablet on the field, in association with an open source GIS for the spatial information. The aim is to optimize the collection and investigation time on the field, but also to manage the team, during a rescue intervention, i.e. in a competitive business environment.

The result is a coherent system that helps the archaeologist to deepen his management and investigation, from the field to the exploitation of the data and the publication of the results. The study of data is optimized by standardization and early computerization thanks to the DBMS in the PC-tablet. The latest surveys are immediately transformed in GIS files in order to be used directly on the field, especially for managing the staff, the machine, and to evaluate the progression of work. This system is used for evaluation and excavation.

This presentation exposes in details the particular rescue problematic and this particular use of the GIS. It presents the operational scheme and process of the field work and the conception of the archaeological database up to the use of the GIS, as well as the type of tools used. The benefits and the issues of this system are also detailed.

This experimentation, still in progress, is an important step regarding the way of managing the archaeological intervention, but also the way of collecting information and working on the field as archaeologist.

- Authors** **Corina Ioana Bors, Luciana Adela Rumeaga-Irimus, Vlad Rumeaga-Irimus**
- Title** ***Large scale archaeological preventive excavations in Romania. The case study of the middle Hallstatt site Tărtăria – Podu Tărtăriei vest***
- Abstract** About 15 years ago a new reality emerged in Romania: the large-scale preventive archaeological excavations occasioned by the construction of the motorway networks developed along the Pan-European transport corridors. The National History Museum of Romania was involved since the beginning in coordinating the archaeological projects set in such circumstances. By analyzing the case of the middle Hallstatt site of Tărtăria –Podu Tărtăriei vest, the paper will discuss a series challenges encountered nowadays as regards efficiency and quality of large scale archaeological preventive excavations in Romania. Major. A series of topics will be considered, respectively the ones regarding the legal framework and constrains for such works, data management strategy and the associated GIS project, public archaeology aspects, post-excavation study and conservation of archaeological data and materials and publishing the data for research.
- The preventive archaeological research campaign 2012 on the site Tărtăria – Podu Tărtăriei vest was occasioned by the construction works of the A1 motorway, crossing the southern part of Transylvania from west to east. Throughout an open area archaeological excavation it was fully investigated an area of about 2ha, where 269 archaeological complexes (mostly from the middle Hallstatt period) were identified and excavated. From a functional point of view these were different and had particular features. There are also a series of particular discoveries,

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namely two ditches marking the southern and eastern limits of the site, two hoards comprising more than 400 bronze and iron objects (Ha B3–C) and a collective grave. It was uncovered a significant quantity of pottery characteristic for the so-called Basarabi pottery style, as well as a great number of metal objects (weapons, tools and adornment object made of bronze and iron). The post-exacavation preliminary analysis of the very rich archaeological finds indicates that the settlement from Tărtăria – Podu Tărtăriei vest represents a very important prehistoric of the middle Hallstatt period.

This work was supported by a grant of the Romanian National Authority for Scientific Research, CNDI– UEFISCDI, project number 2013-4-1022.

SESSION 2A: INTERDISCIPLINARY
METHODS OF DATA RECORDING,
MANAGEMENT AND PRESERVATION

POSTER

Authors **Domenico Cantone, Marianna Nicolosi-Asmundo, Daniele Francesco Santamaria, Francesca Trapani**

Title *An ontology for ceramics cataloguing*

Abstract

In the last decades, the need of efficiently organize the classification process of archaeological finds – with particular focus on ceramics – has become urgent for scholars and researchers in the field [6]. Currently, in fact, archaeological finds cataloguing and classification are mainly performed by traditional methods like hard-copy archives and standard digital techniques like relational databases. However, such methods have severe drawbacks. They are tools mainly developed and maintained in a local way and they usually store partial data, rarely shared with the whole scientific community, causing an incoherent use of information. Also, they do not support flexible data-management and information retrieval algorithms due to lack of advanced reasoning means.

Semantic web is a vision of the World Wide Web in which information carries an explicit meaning, so it can be automatically processed and integrated by machines, and data can be accessed and modified at a global level thus allowing coherence and dissemination of knowledge. Moreover, by means of automated reasoning procedures, it is possible to extract implicit information present in data, thus permitting to gain a deeper knowledge of the domain. The definition of a specific domain is widely called ontology. In the last years, potentiality of ontologies has been recognized by archaeologists [3,5]. Some projects have been undertaken concerning either single typologies of archaeological finds or several different materials related to each other.

In this contribution we briefly describe our work on Ontoceramic, a Semantic Web ontology for cataloguing and classifying ceramics. Ontoceramic is an OWL 2 (Ontology Web Language 2) ontology [11] designed on ICCD (Istituto Centrale per il Catalogo e la Documentazione) data sheets taking into account the most important papers in the field [1]. Ontoceramic consists of 90 classes, 33 object properties, and 20 data properties. It includes a number of SWRL (Semantic Web Rule Language) rules [12] allowing several reasoning tasks on the knowledge domain in a short time.

It has been developed using the Protégé editor [7,2] and classified by the Hermit [8], Pellet [9], and FaCT++ [10] reasoners.

Ontoceramic allows one to carry out many tasks such as associating fragments to a considered specimen according to its provenance, even indicating from which part of the vessel they come from, or by find place (i.e., nation, region, or province, and so on), or by measurements of their parts, or by their colours, or by other features (i.e., decoration) [4]. In particular, Ontoceramic allows one to specify shape and type of an object removing the redundancy of the nomenclature used, reducing ambiguous classifications of data.

We plan to include in the ontology support for stratigraphic excavations, bibliographic references management including authors and revisors, and identification of the production factory. We also aim at implementing an efficient parallelized decision procedure for the language of Ontoceramic that permits to reason with large data sets.

Authors **Monica Giuliano**

Title *A Multidisciplinary approach for virtual reconstruction*

Abstract

This research underlines the importance of a multidisciplinary approach and multi-technology application, describing the survey in the field of Cultural Heritage like a combination of different and related techniques. Furthermore it focuses on the identification of the best

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technique considering the monument studied and the required detail.

Planning the survey project has great importance and it requires actions based on the exact documentation of monuments or artifacts and on scientific and accurate management. These actions adopt all the instruments of knowledge, from historical analysis to metric survey, from topography and building materials study to their degradation, involving several expertises and backgrounds.

The first level of knowledge is the metric study of artifact collecting data. Acquired and processed data will be the basis of quantitative, historical, typological informations or they will be used for managing, with appropriate tools, the restoration project.

This work analyses and compares different survey systems as laser scanning and photogrammetry to identify the precision and the accuracy of models, the costs and time consuming assessment and to evaluate limits and applicability.

The tests are carried out on some of seventy-two limestone panels, the so-called Art of War Frieze, whose iconographic repertoire represents numerous war and building machines, as well as military and political symbols. The Art of War Frieze was commissioned by Federico da Montefeltro, Duke of Urbino, to decorate the back of the «wing façade» of the Ducal palace. The Frieze decorated the façade from the time it was done towards the end of the XVth century until 1756. Following it was moved in different rooms in the Palace but despite the many documentary records available, the question of the original sequence of the bas-reliefs has never been solved.

The second part of the work aims to create a virtual reconstruction of the original sequence of the bas-reliefs. The historical and the iconographic records are the first information that support following analysis of the back and the panels by geomatic approach based on laser scanner, structure from motion and image-based modeling technologies. Final step is the analyses of the state of conservation, type of degradation correlated to atmospheric parameters (sunlight, temperature, rain). The analysis of the state of conservation and the study of the artistic techniques, are some of the additional factors taken into account in recomposing the frieze.

The integration of these data allows to carry out tests on panels with different levels of degradation in order to verify best procedure to obtain accurate geometric reproduction for rapid prototyping.

SESSION 2B: INTEGRATING 3D DATA FROM FIELD ARCHAEOLOGY

INTEGRATING 3D DATA FROM FIELD ARCHAEOLOGY

POSTER

- Authors** **Simone Gianolio, Guglielmo Genovese, Francesca Mermati**
- Title** ***New data for the plan of Forum Boarium in Rome***
- Abstract** Starting in the summer of 2013, the ARESlab of “La Sapienza” University of Rome launched the “Insula Volusiana project”, concerning the dig, documentation and study of archaeological area. The Insula Volusiana complex is located inside Forum Boarium, a quartier of ancient Rome on the left side of Tiber, between Campidoglio and Aventino Hill. After two seasons of excavations, the Lab scheduled a new archaeological survey and relief of this important urban area: new research were carried out with the use of laser scanner, a Faro’s model, to obtain a comprehensive and accurate 3D model of this part of modern city from Theater of Marcellus and Forum Romanum to river to develop a new archaeological plan (after Coarelli 1988). The digital data will integrate with archives research (Pisani Sartorio 1995), to retrieve potentially valuable source of archaeological information which warrants further study. Many problems involved the Lab during this research: the issues associated with huge data, different types, different supports and softwares. These different approaches to 2D and 3D integrated data acquisition and analysis allowed not only archaeological data but new data on urban evolution, urban stratigraphy, that involved the Lab in the research to resolve the question “how to share these data with scholars and public” in an easy way. This paper aim to show how integrated data, new and already exists, multi-format and multi-scale, are required to understand a complex and modern urbanized ancient area and how new methodologies linked to traditional research providing a better informed understanding of archaeological landscape. Further more, one of the main focus of this research is the integration of data derived from renaissance drawing, modeled in computer graphic to superimposed on 3D scanning data to create a virtual timeline of this area through history.

- Authors** **Pat Thomas Tanner**
- Title** ***From initial site survey to 3D digital reconstruction***
- Abstract** Since its discovery in 2002, the remains of the mid 15th century clinker built Newport Medieval Ship have been excavated, cleaned, documented, modelled and are now midway through PEG and freeze-drying conservation treatment.
- On site recording documented the position and context of artefacts, disarticulated timbers and hull remains with traditional scaled drawings, photogrammetry, photography and videography. Plans were hand drawn, usually at a scale of 1:10, using an arbitrary site grid aligned with the centreline of the ship. These were annotated with spot heights relative to Ordnance Datum. Sections were hand drawn at the same scale, included running sections across the ship. These hand drawings were complemented by two phases of photogrammetric survey carried out when the ship was fully exposed, and later, after the removal of the majority of the framing timbers, using a dedicated photogrammetric camera to produce stereoscopic pairs of high-resolution photographs, followed by the extraction of 3D line data. Drawings were annotated with timber codes assigned to individual timbers, and timber record sheets were created for each individual timber.
- Post excavation documentation of the Newport Ship's 1,700 hull timbers, as well as over 600 associated timbers and small finds relating to the ship were comprehensively digitally documented using three dimensional contact digitisers and laser scanners. The resulting data, captured as full size 3D wire frame drawings of each timber, was then converted to digital solid models and finally physically manufactured at 1:10 scale using an additive manufacturing process called selective laser sintering. The resulting individual model parts when fastened together, formed a 1:10 scale model representing the recovered structural hull remains. The 1:10 scale physical model of the vessel remains has provided both construction sequence

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information and a suitable foundation from which to reconstruct the missing or damaged areas. The physical scale model was 3D laser scanned and a set of lines extracted and faired using Rhino3D software. The lines were turned into a digital hull model and analysed in a related software program called ORCA, which has been used to determine hydrostatic and seaworthiness characteristics.

By combining all of the recorded data into a single digital Rhino3D file allows objects to be analysed or modified in unison rather than working on isolated elements or sections of the vessel. As a result, when an individual component is twisted or reshaped, the associated original data can be modified in tandem, thereby repositioning recorded items, such as fastening locations, tool marks, intentional marks and any other relevant data which would be beneficial in the reconstruction process. This has the added benefit of displaying recorded elements such as tool mark, intentional marks and wear patterns within the actual digital reconstruction as opposed to being recorded separately and will aid, at an unprecedented level, in our understanding of the vessel as a whole, in areas such as construction sequence and techniques, as well as the society in which the vessel was built.

Authors**Meriem Zammel****Title*****Photomodeling and cloud computing application in the survey of the roman theater of Uthina architectural elements*****Abstract**

This paper aims to describe the results obtained concerning the archeological survey of architectural elements of the theater of Uthina by using new technologies. In particular image based modeling , ARC 3 D and cloud computing.

The representation of each architectural element of the roman theater of Uthina has been obtained since multiple data sources. The representation of architecture is no matter a two dimensional graph, it's now possible to represent and describe of each part using 3D modeling. Image based modeling of the principal elements of the building has been made in order to represent complex geometric surfaces texture, materials.

Image based modeling constitute an accurate and low cost technique. It's important to choose the right technique in relationship with the aim. An image based modeling of each element has been performed and then replaced on the point cloud survey. We notice that the point cloud survey is the interface access to multi scales representations and different information.

The archeological description has been made using a web system in which we can find multiple data sources: photographs, aerial photograph, image based modeling, and text. In this system exists a relationship between each component in the theater and its location, measuring and cataloguing, Interpretation doesn't consist on a single piece of data but from a set of data. These data are included in the system in which interactivity permits to have a relationship between different elements.

Representation serves not only for communication it's also a way to understand and study architectural structure. It's important to organize field data according to the objective and using the appropriate technique. It is to extract the right information from those multiple data. In synthesis we can talk about a chain composed by survey-representation-description, in which new technologies are situated across disciplines Computer science, architecture, archeology.

[1] PHD University Paris 1 Pantheon Sorbonne in Archeology Laboratory ARSCAN and MAP / GAMSAU with the professor Alain Schnapp on the 13th of September 2014.

http://www.map.archi.fr/3D-monuments/experience_oudhna-intro.php

[2] Patrimoine, Architecture, Environnement, Connaissance, Compréhension, Conservation

INTEGRATING 3D DATA FROM FIELD ARCHAEOLOGY

POSTER

Authors **Leonardo Baglioni, Carlo Inglese, Matteo Flavio Mancini**

Title ***Topography, Laser Scanning and Automated Photogrammetry for an Integrated Survey methodology: survey and modeling of the Roman amphitheater in Syracuse.***

Abstract The survey campaign conducted on Roman amphitheater in Syracuse on behalf of the Soprintendenza Beni Culturali ed Ambientali di Siracusa, is part of a line of research that aims to optimize the survey procedures in archeology, that until a few years ago, was based on topography and laser scanning; about the images we relied on texturing or, in more advanced procedures, the acquisition of digital photographs taken by replacing the laser scanner a digital camera (carefully calibrated) to reproduce the same center of projection; this operation allowed us to have images of greater resolution than the scanner data color.

Our work aims to overcome this methodology, through the integrated use of laser scanning and topography to create a numerical model of the building consists of the post-processed point cloud, integrated by the acquisition of Gigapixel images and panoramic photos in high resolution. The high-resolution panoramic images (Gigapixel) were carried out using a full-frame camera, fitted on a motorized panoramic head. The metric value Gigapixel image is ensured by calibration of the rotation center of the panoramic head with the lens center of projection (Entrance Pupil). The calibration of the E.P. was carried out with measurements, conducted in laboratory, on the lens set according to the focus distance used in the survey. The repeatability of the adopted procedures, provides higher accuracy than the most common calibration procedures based on control of the parallax. The Gigapixel obtained from equirectangular projection based on three main goals: creation of a repertory of the state of conservation of the archaeological heritage at the moment of acquisition; dissemination of the digital heritage (navigable images, augmented reality applications, etc.); creation of the data source for applications of digital photogrammetry.

In an effort to combine into a 3D integrated model the potentialities metrics of the topography with those descriptive of the quality and conservation status of the artefacts, we tested the possibility to create photogrammetric models automatically from the same panoramic images. This type of model provides automatic mapping of the model in which the geometry and textures match because they are both generated by the same set of initial data.

The particular shape of a Roman amphitheater, its state of conservation, and specific requirements of Soprintendenza aimed at the creation of architectural and characterized drawings (representing the current state for an intervention for the safety and renovation) were suitable to such a survey methodology. On this basis we set the integrated survey, also considering the intrinsic difficulty to represent some elements of the building (e.g. the cavea steps now only visible in the underlying inclined planes) through models that exceed a non-exhaustive processing based on point clouds, that keep their geometric and formal characteristics, and gave details of degradation and current state, as well as historical and archaeological information on which to base historical studies.

Authors **Yong Zhu**

Title ***3d interactive Terracotta Warriors site scene roaming system***

Abstract During the archaeological research and promotion of Emperor Qin Shihuang Terracotta Warriors, Warriors and troops array are displayed and represented statically. It is very important to show the living Terracotta Warriors, which is combined with the development of archaeological data, building and presenting the living Terracotta Warriors, reproducing the unstoppable Qin army. For this reason, we use the re-assembled Terracotta Warrior, the

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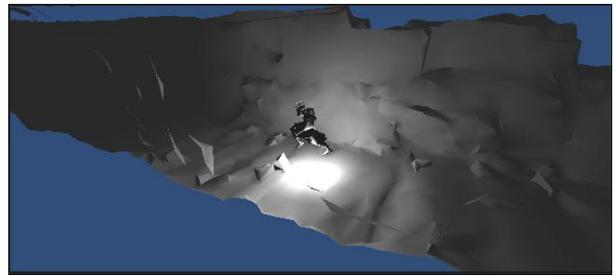
constructed Terracotta Warriors site and some animation skills developed the 3d interactive Terracotta Warriors site scene roaming system. We achieved the purpose of the representation of Terracotta Warriors troops array dynamically. Specific research contents include:

(1) Based on the Focus 3d virtual scene acquisition and modeling. Using three-dimensional laser scanner, we have scanned the Terracotta Warriors excavation site and built a 3d model of the site.

(2) Achieved the running animation design, which is based on real Terracotta Warrior figures model. Before this we have re-assembled some fragments virtually and recovered the three-dimensional model of the Terracotta Warriors, we have added a biped skeleton and designed an animation frame by frame. Finally, we have made the Terracotta Warrior run.

(3) Designed the virtual reality interactive Terracotta Warriors corps array scenario based on Unity3D. In the Unity3D, we have used c # script to design and implement the 3d interactive Terracotta Warriors site scene roaming system. Finally, we have represented the Terracotta Warriors arranged in the Terracotta Warriors site.

This system can be applied to the Terracotta Warriors array display. Also we can learn some historical knowledge. The representation of this system is good

**Authors**

Lukasz Miszk, Weronika Winiarska, Pawel Ćwiakala, Wojciech Matwij, Karolina Matwij

Title

3D database for Agora Nea Paphos. Case study.

Abstract

Department of Classical Archaeology of Jagiellonian University (Krakow, Poland) has started a research scheme Paphos Agora Project in 2011. A theme of the project was to understand an agora as a central place of a cityscape of Hellenistic and Roman town of Paphos (Cyprus). In order to provide an answer for the research questions the site was subjected to an extensive excavations backed by application of terrestrial and airborne remote sensing methods (GPR and UAV surveys) and modern documentation technologies (TLS). The project is financed by the National Science Centre, Poland.

Excavations on the Mediterranean ancient archaeological site, like Nea Paphos, provide a huge amount of data about registered structures, contexts or artefacts. The problem faced by the researchers of this part of fieldwork is the management of these data and the design of such a database, which in the highest degree would simplify the work with them.

In our paper we want to present the Archeological Information System, working under GIS software, which was created for management data which had been collected during excavation on the Nea Paphos Agora site.

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AIS for Agora Nea Paphos is based on a three-dimensional model of the exposed structures created by laser scanning using the scanner ground Faro Focus 120, combined with three-dimensional reconstruction of explored contexts created using a total station measurements within their tops and bottoms. 3D model is coupled with the data obtained in the research field, ie. architectural plans, maps, geophysical, ortophotomap of the entire site etc. With the implementation of the 3D model to EsriArcGIS software, it is also possible combination of graphical data with information on artefacts collected within contexts, as well as a management and filtering data, which facilitates the process of elaborating of the archaeological site. Finally result we want to achieve is reconstruction of the excavated site as the 3D database.

In our paper we want to present and emphasize new possibilities in creation of fieldwork database which are given by using new technologies of prospection and documentation.

Authors

Angela Bosco, Marco Barbarino, Rosario Valentini

Title

Pompei, Domus di Stallius Eros: a comparison between terrestrial and aerial low-cost surveys

Abstract

In the framework of the Project 3D-ICONS, addressed to digitize a series of architectural and archaeological masterpieces with particular reference to European cultural, different large archaeological models were acquired in the Pompeii. In particular the work focused on less known archaeological areas, but likewise relevant for the analysis of the different masonries and stratigraphical superimpositions. Among them a special attention has been dedicated to the House of Stallius Eros (Insula 1, RegioVI, 13 - 14), which conserves a rich vertical stratigraphy covering a large chronological period and offers interesting information about the development of this side of the ancient city. From June 2014, the team of University of Naples "L'Orientale", under the supervision of Fabrizio Pesando, started the cleaning of the domus with the aim to carry out a detailed survey of the house. In the framework of this intervention different surveys were made in order to provide the 3D model of the house. The domus is located among narrow streets which obstruct a complete vision of the archaeological monument. In order to overcome any possible problem in data-acquisition different technologies were tested with the aim to measure the accuracy, the efficacy and the velocity of the used methodologies. After surveying the domus by an electronic total station, two different interventions were planned to render with un-calibrated photogrammetry the 3D model of the house.

A first work was carried out with a terrestrial "traditional" approach. In one day many images (1.400) were acquired by Nikon D90 and some targets were measured by Total Station for the alignment of the final model and to define the geometry of the archaeological structure. In order to cover the top of the still existing wall of the Domus, a second intervention was realized with a low cost drone (Apollo IdeaFly) equipped with a small digital camera (Canon PowerShot SX 260). In order to gain time to have a longer flight, and consequently a major number of shots, the drone was lightened and equipments reduced. Also for the aerial intervention some targets were acquired by the total station to assure the superimposition and the integration among the different surveys. Each methodology has been applied following a well-consolidated pipeline as regards data-acquisition, processing and post-processing. The paper presents the results of the comparison and learned lesson mainly in terms of adaptability of the different methodologies and technologies to the different needs and requirements. No device can substitute the other one. Only in a framework of the data-integration is possible to achieve good results in the documenting process of archaeological monuments.

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Authors **Eneko Calonge Maestro, Pablo Romero Pellitero, José María Martín Civantos**

Title ***Archaeological 3D stratigraphic sequence modeling by structure from motion (SfM) techniques: practical experience in medieval sites***

Abstract

In recent years our research group has done an important effort to define the methods of digital documentation of the archaeological record. The development and experimentation of this procedure have been carried out at the archaeological intervention site to support the restoration of the castle of Íllora (Granada – Spain), the excavation of Jarafí site (Lanteira, Granada – Spain) and Pizzo Monaco (Custonaci, Trapani – Italy).

All these archaeological sites have been digitally recorded, showing significant differences that intervene in the overall implementation of the research. As a result, we introduced important changes during fieldwork and laboratory work, by implementing both 2D and 3D photogrammetry technics. These changes have enormously reduced the economic cost and time used for the data collection. The continuous development of new applications of structure from motion (SfM) and photogrammetry software has a direct impact on the strategies design for data collection and edition.

However, the implementation of these techniques also involves a series of new difficulties. The synchronized operation of alphanumeric information and 3D geometry is still one of the main issues that needs our special attention. Another challenge refers to the enormous amount of data gathered in the field that requires a great effort in terms of information management and selection of meaningful data.

Through the experience acquired at the mentioned archaeological sites, we have been able to approach some of these issues aiming to create new archaeological records that takes into account the whole 3D stratigraphic sequence of a site in a scientific way, minimizing the loss of information. At the same time, this register has also a great potential for the dissemination of the results, considering that the way of presenting them is totally intuitive.

All these aspects, based on the experiences of the group at the mentioned sites, will be presented during this session.

Authors **Eva Butina**

Title ***From historic data to representation of 3D models during archaeological excavation process: Benefits and limitations of use of proprietary software for archaeological data management***

Abstract

In the last few years a lot of historical documents in Slovenia have been digitized primarily with the intention of their preservation but consequently became valuable spatial data that can be integrated into the existing field data of a specific archaeological site. At the same time portions of Slovenia's landscape have been digitally documented for major construction projects using LiDAR. The availability of these new data to employees of the Institute for the protection of cultural heritage of Slovenia, Centre for preventive Archaeology (CPA), for archaeological research is of great importance.

However, the integration of these and other new digital sources that often come in a multitude of formats and scales as a coherent usable visualization that offers not only a visual display of different quantifiable data but also enables a better interpretation of the data, has become a challenge as well as necessary process of archaeological field documentation. Due to administrative issues regarding CPA, processing and management of digital field data has been

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restricted to proprietary software such as AutoCAD which enables management and processing of (most of) the above mentioned 2D and 3D digital data. Program module Skavt was developed as a program extension module inside AutoCAD for processing and managing of archaeological data gathered on an archaeological excavations conducted by CPA. It enables processing of increasingly large amount of gathered data (transformation of spatial data gathered with total station into CAD objects), fast and accurate creation of site plans and cross sections and digital photogrammetric drawings of specific features. It also provides archaeologists with an easy to use tool for searching specific entities within the site plan and to input observational and attribute data or creating additional data for each entity, making the site plan DWG drawing the data base of all gathered archaeological information of the site. With the use of Skavt, CAD software enables easy 3D visualization or search of spatial data, graphics, 3D models of specific features or contexts and other external references that may be used including creating and browsing through data base of spatial and observational data stored inside DWG file.

The paper presents a case study of a successful integration and management of different digital data using proprietary software on the Govče 2011 project that enabled not only a successful excavation of remains of a 16th century protestant church complex but also provided data for creating a more reliable 3D visualization of no longer existent church architecture and its adjoined cemetery.

Authors**Andrei Cîmpeanu, Ovidiu Țentea****Title*****Master Problems of a master plan*****Abstract**

Our project consists in creating a masterplan of Ulpia Traiana Sarmizegetusa (first roman town from Dacia) in order to understand the town's development. This masterplan has to integrate all the data published until now. Also we are considering a thorough interpretation of the functionality of the buildings and their possible (3D) reconstruction. This master plan will be very useful tool for inquiring specific professional information about the site, but also as a base for future excavation and 3D reconstructions. The research history of this site exceeds 100 years, of which the last 90 years consist in systematic excavations, so, the data available is in very large quantities and in various forms, bringing it all together in a coherent manner is a challenge. Linking almost all the pieces together is a topographic survey, done in one big session to eliminate errors and verified with other partial topographical surveys and plans. The shape of existing buildings do not correspond to the old drawings, so adjusting is needed. Some plans can be scaled only in reference to these rescaled and modified plans so their precision is not so great. The plan also integrates information from new excavations – new plans, small finds, cloud points from 3D scanners, very detailed topographical measurements and non-invasive surveys. All this information is carefully disposed into layers, and linked to a large organized file system in such manner that new renderings of just parts of the plan are always possible, with bibliographical references.

SESSION 2C: SUPPORTING
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Authors Victoria Donnelly**Title** *A Study in Grey: Grey literature and archaeology in England*

Abstract Grey literature is the repository for a vast amount of data generated by archaeological fieldwork in England. Practitioners in different arenas of English archaeology have diverse ideas of what the appropriate composition of grey literature should be; as it currently stands, the output is highly variable and in many ways incompatible. Alongside this critique, however, the significance of grey literature in terms of yielding fresh archaeological data long before it reaches circulation in the form of published monographs is receiving increasing recognition. Recent research projects have attempted to synthesise the evidence from and foreground the tremendous value of this body of literature. As of yet, however, no detailed study of the character and interpretative worth of grey literature has been undertaken. An investigation into the nature of archaeological grey literature and the processes and practices through which it is created is being undertaken as part of the English Landscapes and Identities Project based at the University of Oxford. This characterization of archaeological grey literature in England has benefitted from access to a variety of shared digital datasets including the English Heritage Excavation Index, the Archaeological Investigations Project and the Archaeological Data Services Grey Literature Library. The use of these digital datasets has at times proved challenging but addressing these issues has provided the opportunity to create a fuller understanding of archaeological grey literature in England and the factors influencing its production. Through a characterization of grey literature in England, this paper will consider how useful grey literature actually is, both for research purposes and more broadly, as well as considering the challenges and benefits of (re)using a variety of digital datasets in archaeological research.

Authors Elisabeth Gavignet, Eric Leclercq, Nadine Cullot, Marinette Savonnet, Laure Saligny**Title** *Logics and modalities for managing uncertainty in archaeological databases*

Abstract Computational archaeology must face several issues such as variability of data structures and knowledge as well as uncertainty of data. In previous works, we have developed an ontology-based annotation model that provides extensibility to traditional relational database [1]. This model has been implemented in a generic platform used for several projects (<http://care.tgeadonis.fr>, <http://lapierre.u-bourgogne.fr>). It provides users with tools to collaborate on the elaboration of digital corpora. In large scale collaborations, using different data sources and different ontological representation of knowledge, uncertainty must be modeled and managed to provide an accurate analysis. Some works have focused on adding annotations to relational database for managing uncertainty using probabilities [2,3] or fuzzy logic. Nevertheless, when different data sources are used together, a common representation is needed, ontologies are key enablers to solve this issue.

Starting from a typology of uncertainty, we propose an ontological representation of uncertainty and we show how our annotation model can be used to qualify the uncertainty of data. Next, we detail three kinds of reasoning, to deal with uncertainty.

First we will show how: 1) logic rules can be used to detect semantic inconsistency in data sets that can occur if two annotations are contradictory; and 2) description logic can be used to detect logic inconsistency that occurs if an annotation is not consistent with the ontological representation of domain knowledge (e.g. building's function in contradiction with its architecture). In result, uncertain data are automatically tagged with an annotation describing

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the type of uncertainty.

Second, we discuss how to model and reason on possible facts and necessity using modal logic. We introduce the modal logic operators and we detail some examples using MProlog [4] such as the study of possible states of ancient buildings.

Third, we discuss the problem of queries over multiple data sources defined using different knowledge. We use the modal logic with a belief calculus to reason on multiple data sources. We give examples in MProlog such as the different characterization/definition by properties of the concept of church in middle Ages across different sources that one user would like to be true in all the sources or just valid according to his definition.

Finally, we conclude the paper with the problem of integrating modal logics in a database query language.

Authors

Karl Grossner, Ian Hodder, Claudia Engel

Title

Towards a Living Archive for Çatalhöyük

Abstract

The Çatalhöyük Project has recently completed the pilot phase of a project aimed at developing a "living archive" of its data, which comprises tabular records, imagery, field diaries, and annual project reports. A primary goal of this project is to make 20+ years of project data more accessible for interpretation and re-interpretation during the remaining years of the present excavation and, through its transition to an archive, well into the future. In a living archive, researchers could 1) explore Çatalhöyük data via advanced search tools integrated with spatial temporal visualizations; 2) download subsets of data; and 3) store and annotate personal collections of records—kept either in a private user "workbench," or made public for interpretive argumentation. We anticipate such a system will greatly facilitate future comparative studies, laterally across Neolithic Anatolia and connected regions, and longitudinally, over time.

The Çatalhöyük Living Archive pilot project (<http://catalhoyuk.stanford.edu>) has completed some experimental first steps towards the aforementioned aims. We implemented a new spatial relational database with a graph like schema that better corresponds to the RDF model, and fully integrates spatial data from the project GIS. We developed a web-based application that reads from the new database, providing search and browsing capability integrated with spatial and temporal visualization in maps and timelines. We published a significant subset of excavation data in RDF format, with a SPARQL endpoint. Finally, we built a preliminary application programming interface (API) supporting RESTful URL-based queries on the database (<http://dh.stanford.edu/catal07/api/>).

The existing working Çatalhöyük database is a relational system developed a decade ago to bring together the disparate data records of about a dozen specialist teams within the larger project (e.g. Faunal, Human Remains, Clay, Groundstone, etc.). The database design has to some degree operationalized reflexive archaeological practice (Ridge 2005): by differentiating interpretive levels within team data, as for example "basic" versus "diagnostic;" by recording the history of changes to interpretive categories; by means of multiple specialist team tables holding extended attributes for subsets of artifacts in focus for some period of the excavation's long history; and by recording excavators' diary entries digitally, indexed to the spatial entities they reference. The current database system has been an effective tool for recording data and for team members to study finds in their own tables, however it is difficult to query across specialisms; asking for example, which units contain both human remains and anthropomorphic figurines or, where the highest concentrations of beads are, regardless of material. The graph structure of RDF has made such queries far easier.

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The work of our pilot phase has set the stage for a transformation of all Çatalhöyük tabular data and image metadata into the event-based and graph-like representation of CRM-EH, ultimately compatible with the model under development by ARIADNE partners. Its publication in that form will greatly enhance researchers' capability for integrative analyses, both within the Çatalhöyük data store and with other related and soon-to-be linkable projects.

Authors**Bruno Fanini, Sofia Pescarin****Title*****Cyber Archaeology in the Cloud*****Abstract**

The reconstruction of ancient landscape is a simulation process which requires the work of different professionals coming from different fields. Typically archaeologists, paleo-botanists, geologists, environmental experts, 3D modelers, photogrammetrists, historians, etc. need to work together in the same shared digital space. This digital space has certain requirements, such as the geospatial and 3D dimensions. In the past, several pilot projects and studies have explored the potentiality of cooperative environments for research, teaching and communication purposes.

In this paper we aim at presenting and discussing online cooperative environments, from two different perspectives:

1. Applications developed on this topic
2. Analysis from a cognitive and social perspective of the needs and requirements

What has been done about (1) and experimented recently in the field of online cooperative environments and cloud services? Examples of online collaborative creation of 3D territories, connected with digital libraries, will be described in this paper.

In order to reach an effective research and reconstruction work in (2), what researchers do, what do they need? to reach an effective knowledge increase which are best strategies to follow?

Although cloud computing solutions are mostly perceived for storage and large dataset analyses, these resulted in significant changes that are reshaping modalities through which institutions, companies and professionals manage different datasets. In this paper we investigate these solutions applied to large landscape and 3D archaeological hypotheses based on scene-graph mechanics. This integration not only applies to a scalable and robust organization of 3D data, but it also includes metadata and several dissemination outputs. Recent open-source platforms such as ownCloud allow great advantages within real-time collaborative scene composition tasks: these also include huge flexibility related to data access policies and distribution across multiple servers, allowing in 3D GIS-based projects a fine-grained per-node control and efficient sub-scene management. CloudComposer and other open-source web-based services alongside responsive web interfaces will be described with application to a landscape reconstruction case study, highlighting collaborative aspects and advantages through proposed approaches, including how these cloud-based services enable a distributed workflow across different professionals.

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Authors Uros Damnjanovic, Sorin Hermon, Valentina Vassallo, Kyriaki Yiakoupi, Giancarlo Iannone

Title *STARC repo, collaborative repository of digital heritage data*

Abstract In this paper we present a new version of a digital data repository of archaeological data developed at the STARC research centre of the Cyprus Institute. The repository is able to store and interact with most types of digital objects including 3D models. It provides rich set of tools for exploring and interacting with data. Important aspect of the repository is a set of collaborative tools used for sharing the ideas and insights related to the available content. The motivation for our work lays in the fact that the full potential of data can be used once we have the right tools to interact with this data.

The foundation of the repository is content management. At the moment repository accepts images, videos, texts, pdf, 3D(obj, wrl, ply) and xml files. The challenging part of the content management functionality was to make it possible to work with 3D data. Users can upload 3D models and once the conversion process is completed models can be displayed and used in browsers using the X3DOM visualization library.

Tools for exploratory content analysis include advanced search and search interpretation tool, geographical search, statistics and data visualization tool. Search interpretation tool help users explore search results. It help users easily examine the structure of the search results, enabling them to filter results and to easily move between different searches and compare and examine relations between different search results. Since most of our data is geographically referenced it was important to be able to show results on a map that will enable users to select objects based on their location. Interactive data visualizations of various properties and relations are used to help users better understand the structure of specific data sets.

Our idea was that digital data repositories should be used as channels of communication between its users. In order to achieve this, we developed number of tools that are used for sharing information. One such example is data annotation tool. It lets users add information to digital objects and share this information to the others. Another channel of communication are personal collections. While exploring data users can select any object and add it to a personal collection that can later be enriched with text and shared with others. Personal collection tool is closely related to the story-publishing tool, where users can create stories by combining text and digital object from the repository. Publishing of archaeological data involves a lot of processing. In order to be able to document the process of creation of a digital object from acquisition to its final version decision documentation tool is used. It helps users document each stage of the processing by describing decisions and related resources involved in the process.

Authors Kai-Christian Bruhn, Stefanie Wefers

Title *Salvaging TLS-Data from the terrace house 2 in Ephesos (Turkey) by annotating 3D-information and adopting a LOD approach*

Abstract Since the advent of terrestrial laser scanning systems (TLS) and its application in archaeological research, an ever increasing amount of 3D-Information complements the cultural heritage record. The initial processing of the data results in an unstructured set of point vectors referenced in a local xyz-coordinates and often supplemented by values representing the intensity of the reflected signal or the colour of the sampled surface. Although a few individual institutions, national infrastructures and international services provide access to preprocessed pointclouds, a number of restraints still detain the integration of pointclouds into a

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scientific research workflow.

The use of pointclouds is often limited to the creation of conventional 2D-representations, e.g. groundplans, sections and isometric or orthometric views usually processed in a CAD-environment. Other data products derived from pointclouds draw on the visual potential of coloured renderings or on the inherited information for modeling 3D-surfaces. None of these approaches offer later access to the original 3D-information; the derived products lose the connection to the underlying data. The pointcloud becomes a leftover full of valuable but unreferenced information.

A web-based application developed in the joint research project "Inscriptions in their Spatial Context (IBR)" of the i3mainz - Institute for Spatial Information and Surveying Technology at the Hochschule Mainz University of Applied Sciences and the Academy of Sciences and Literature in Mainz offers an approach to overcome these shortcomings.

The "GenericViewer" provides access to pointclouds through a panorama interface that allows for the 3-dimensional exploitation as well as the delineation of specific subsets of the data for partial extraction. Vector data created for outlining pointcloud snippets are accessible through a REST-API as a geometric resource. For specifying the content and/or meaning of the delineated pointcloud-snippet the "GenericViewer" includes a semantic annotation tool deploying technology of the Pundit project.

Although originating from a project focussing on a different research question, the application is geared for salvaging existing TLS-data, establishing persistent access to knowledge attached to pointcloud data and thereby demonstrating an innovative reuse of archaeological datasets.

The paper meets the challenge of providing access to 3D research data and the opportunities offered by strictly following the LOD approach in a case study. A set of 3D scans from the terrace house 2 in Ephesos, registered in 2009 and 2010, highlights the potential of the software's capabilities for semantically annotating 3D information. The northwestern part of the terrace house 2 was chosen as in this area the archaeological record is particularly complex with many intermingled building phases on a sloping site. By annotating knowledge to geometries directly linked to the underlying pointcloud it not only offers new insights into the building history but also tracks the archaeological perception and results in a semantic graph connectable to the LOD cloud.

Authors

Steinar Kristensen

Title

The Religion and money project; Coins found in medieval churches – the challenging GIS in a multidisciplinary project

Abstract

Organized at the Museum of Cultural history, Norway, the project "Religion and Money" will address the issue of religious thought and the perception and use of money in ancient and medieval societies by looking at religion, money and trust in relation to one another. In so doing the project aims to address people's interactions with religion, with language, with the economy, and with the material culture and physical environment in which they lived, and in their conception of life and afterlife.

The project will be carried out through an interdisciplinary approach, utilizing a considerable body of historical records and material culture interpreted in parallel with the methodological perspectives from archaeology, history, numismatics, theology and anthropology. Material derive from 19 medieval churches in Scandinavia; two from Finland, four from Denmark, six from Sweden and seven from Norway

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Digitizing historical documentation from surveys in medieval churches is one of key sources for the researchers in the project. Coins found in churches has a main focus with in the project as more than 70 000 medieval coins in total have been found in medieval churches in Norway, Denmark, Sweden and Finland. This paper will discuss the use and reuse of analog documentation in a digital perspective. It will address the approach, challenges and results of the GIS in the crossing of analog and digital datasets, analog and digital methods and analog and digital researchers.

SESSION 2D: LINKED DATA: FROM
INTEROPERABLE TO
INTEROPERATING

POSTER

- Authors** Rimvydas Laužikas, Justinas Jaronis, Ingrida Vosyliūtė
- Title** *Beyond the space: the LoCloud Historical Place Names microservice*
- Abstract**
- Space and time are considered to be the most important dimensions of reality. Much attention is paid to their scientific analysis in Natural Sciences. Moreover, these dimensions are very important in the conservation and research of cultural heritage (including history and archaeology).
- Historical space, usually, is considered as the sets of historical place names (which are fixed in historical sources). The transcoding of reality from analogue to digital system performed during the heritage and (or) scientific data digitisation affects the application of HPN used in the real world to artificial system. This way HPN becomes a link between reality and virtuality ensuring quality of digitisation, interoperability of reality and virtuality, internal interoperability within the information system and external interoperability of several systems, as well as efficient communication of digital data in general. However maximizing correctness in the perception of the historical space is important for preservation of HPN (as kind of intangible heritage) and participative interpretation of cultural heritage and for creation of the European narrative.
- Technically an HPN is considered to be a place appellation, which is used to refer to several places, because its application may change over time (similarly to E48 in CIDOC-CRM). On the other hand, the place as an object (similarly to E53 in CIDOC-CRM, excluding movable objects) is determined as GIS defined immovable geographic object: point, polygon or line (such as landscape, inhabited places, buildings, natural objects (mountains, rivers) and administrative areas). A place name can be understood as an historical identifier for several places (with the same meaning of E4 in CIDOC-CRM) and (or) as a kind of intangible heritage (“non-material products of our minds”, e.g. E28 Conceptual Object in CIDOC-CRM).
- At this paper will presented the HPN microservice. HPN microservice is the web service, which has been developed in frame of LoCloud (**Local content in a Europeana cloud**) project in collaboration between Project partners. The HPN microservice has been developed on the basis of HPN Thesaurus, which is intended for aggregation, storage and long-term preservation of historical geo-information. HPN Thesaurus is considered to be a qualification of the CARARE (Connecting Archaeology and Architecture in Europeana project) metadata schema at the conceptual level. HPN microservice perform the following functions: crowdsourcing and enrichment of provider’s and aggregator’s historical geodata, HPN geodata visualization and HPN interoperability provision.
- HPN microservice is accessible online via link: <<http://hpn.aksprendimai.lt/unitedgeo/>>.

- Authors** Matthew Luke Vincent
- Title** *OpenDig: Applying CIDOC-CRM and CRMarchaeo to in-field Data Recording*
- Abstract**
- Recent international recommendations and charters such as the London Charter and the Principles of Seville deal with the growing field of Digital Cultural Heritage, and more importantly, the need for careful documentation of sites to better enable the interpretation and dissemination of this knowledge to experts and public alike. To this end, standards have been developed to enable the intercommunication of the results from excavations, yet the challenge now seems to be to decide on the best standard to use. In some cases, rather than adopting an existing standard, some opt to simply create their own, thus adding yet one more standard to the

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mix. Unfortunately, with each addition standard, it only complicates matters more, pushing us farther from the goal of a common format for exchanging our data.

CIDOC-CRM's flexible expression model enables cultural heritage data from varying sub-disciplines to be combined and dealt with as a whole. The specific extension of CRMarchaeo provides the detail necessary to properly express archaeological data, while being able to harmonise it with the analytical data, bibliographic data, and the variety of other cultural heritage data that is related to the archaeological context. Recognised as an international standard (ISO 21127:2006), and supported by experts in the field of documentation and cultural heritage, it makes an excellent candidate for harmonising data across the entire discipline of cultural heritage.

OpenDig is an application that grew out of the excavations at the archaeological site of Tall al-'Umayri, Jordan. OpenDig is now as a framework that provides the archaeologist with the ability to record archaeological data in the field, with corresponding applications for processing the in the lab within the context of its permanent storage. OpenDig is now mapping data to CIDOC-CRM, specifically the archaeological extension, CRMarchaeo. The framework now represents a complete framework, from data recording in the field, to harmonising and disseminating the data to the public.

The application of CIDOC-CRM to the OpenDig archaeological data framework represents a holistic ecosystem for archaeological data recording, analysis and dissemination. Through the provision of an interface that resembles the traditional recording forms used in archaeological fieldwork, but at the same time, providing a transparent mapping layer that allows for data harmonisation through CIDOC-CRM without requiring the user to implement those requirements themselves. However, not all archaeological sites are the same, and therefore the project incorporates JSON definition files that allow the mappings to be adjusted on a project by project basis.

SESSION 3A: A DIALOGUE BETWEEN ARCHAEOLOGICAL SCIENCE AND COMPUTER VISUALIZATION

POSTER

Authors Ryan J Rabett, Paola Di Giuseppantonio Di Franco

Title *Digital fauna and zooarchaeological itunes*

Abstract In this brief presentation we consider some of the opportunities and challenges presented by fusing traditional zooarchaeological techniques with 3D digital technologies, such as 3D laser scanning and 3D rapid prototyping techniques. These techniques are well established in the field of archaeology today, and are capable of reproducing artefacts and human and faunal remains with a high level of accuracy, even if with some limitations. From the analyst's perspective, these benefits include the real prospect of scanning faunal remains in the field using portable and cost-effective devices, which will allow elements to be measured and, if necessary, 3D printed at a later date. Not only should this speed field collection, but also overcome the complexities of export and import protocols – particularly on sensitive material. Accumulating digital archives of specimens (both comparative and archaeological) that can be readily sourced and exchanged through online platforms between institutions, also presents a very effective way of democratising the depth and diversity of individual teaching and research collections, as well as facilitating cross-collection access. Remedies to the substantial digital storage requirements for collecting and archiving bone assemblages are now emerging with online infrastructures such as ARIADNE (<http://www.ariadne-infrastructure.eu/>), which allows online data-archiving and data-sharing; however other challenges remain to be addressed. Notable among these is the ability of digitization to capture the micro-terrain of bone surface modification features that are often critical to determining and assessing anthropogenic agency. The potential for portable and affordable 3D SEM scanning is probably some way off. From a wider perspective, we also consider the likelihood that in this kind of 'field fusion' within archaeology (and elsewhere) will lead to increasing attention on the matter of intellectual- or even heritage-property rights on scanned material. Who owns the rights to scans and who controls the number of 3D prints permitted on digitally archived specimens may become constraining factors to such expanding access.

Authors Daria Hookk, Nikolai Nikolaev

Title *Computer modelling for validation of a scientific hypothesis on narrative and archaeological sources: reconstruction of the wooden objects from frozen tombs*

Abstract The frozen tombs in Pazyryk valley have been found in 1927 and excavated by M.P.Gryaznov in 1929 (Griaznov, 1937) and S.I. Rudenko in 1948-49 (Rudenko, 1970). The extraordinary finds of organic materials (wood, wool, leather), which have been conserved in permafrost, are now in the collection of the State Hermitage Museum. Among them there were remains of wooden cart and fragments of big felt.

After the restoration the reconstructed cart was titled ritual "chariot", and according to the M.Gryaznov's conception the big ornamented felt covered a ceremonial tent based on wooden frame and decorated with felt figures of birds on the top. That hypothesis was discussed in some articles, because S.Rudenko, author of excavations marked the felt sculptures joined with details of the cart and supposed the felt covering it during funeral ceremony. Discussion between two scientists attracted our attention. We had only 2 photos of remains of cart in burial, published by S.Rudenko, and 2 photos of it before the restoration in museum archive. The next one photo – a renovated object at the exhibition in 1955. Big felt was fixed twice on the archive photos, and then after the restoration, prepared for the same museum exhibition. Three schemes in published material and field archaeologist's diaries were the important source for the verification. During the renovation of the exhibition in the museum, we tried to

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reconstruct the objects using the computer modelling (Hookk & Nikolaev, 2012).

Serious corrections in the tent construction were made after measurements had been taken of the angles between the sloped rectangle holes along the logs and the main hole at the end. The preserved pole, which was inserted into such a hole, forms an angle of 60° . The horizontal projection on the ground can be easily calculated $4,5 \text{ m} \cdot \cos 60^\circ = 2,25 \text{ m}$. So, the poles can be put into the logs only if the distance between the first pole hole and the corner is more than 2,25 m, otherwise the poles will form a palisade not suitable for the felt cover. Taking into account the length of our logs, only one pole can be placed into every log. These four poles will give us the central point to be used as a projection from the ground, where they are tied together with the help of the holes in their top ends. We have got a rectangle construction with an entrance at the corner, which was probably covered by felt. It is obvious, that there is no need for a wooden frame for such a construction. The measurements of all fragments with accuracy, geometric laws and computer modelling have shown, that original graphic M.Gryaznov's version cannot be proved. Thus, thanks to the *Pythagoras' Theorem* we successfully showed that ritual funeral tent has to be conic without flat walls, and felt birds had other location than on their top.

Authors

Juhana Kammonen, Tarja Sundell

Title

Principal component analysis of archaeological data

Abstract

Archaeological data often contains a large number of morphological and contextual features. In a large archaeological database the analysis and visualization of such multi-featured data may become increasingly difficult, as the raw data points cannot even be plotted unambiguously in a human-readable manner. This paper presents a computational method called principal component analysis (PCA) which can be used to analyze multidimensional data in order to visualize essential information regarding the data in two- or three-dimensional surfaces that are easier for the human eye and mind to understand. PCA is a method of optimization, as it finds in each case the most suitable surface that also minimizes the loss of resolution in the data. PCA has been used widely across many fields of science including genetics (Reich et al. 2008), computer science (e.g. Kim et al. 2002) as well as multidisciplinary studies (e.g. Cavalli-Sforza et al. 1988). For instance, many web services that contain recommender systems and advertisements often utilize PCA. So far PCA has seen only limited use in computational archaeology. Here, we apply the PCA method for a subset of multi-featured data from the Finnish Registry of Ancient Monuments (RAM). We show that PCA is a valid method for visualizing the data in the RAM and that it can outline patterns in the data subset that would be hard to detect otherwise. With ramifications reaching beyond this case study with the RAM, our results indicate that PCA could be a valuable supplement to the general analysis and maintenance of ever-growing archaeological databases.

Authors

Ilan Ryan Smeyatsky, Karim Sadr, Patrick Randolph-Quinney

Title

Stylistic variation in Later Stone Age tanged arrowheads: a pilot study using geometric morphometrics

Abstract

Geometric morphometrics is an effective tool for analysing differences in lithic shapes. The statistical accuracy achieved by employing this technique is significantly higher than previous forms of traditional morphometrics. When applied to images of Later Stone Age tanged arrowheads from southern Africa, this tool helped define stylistic boundaries. This study involved a sample of 72 tanged arrowheads from 22 sites, most of which are located in the

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upper Orange River Basin. Several analyses, including Principle Component Analysis and Canonical Variate Analysis, were conducted using the geometric morphometrics program “MorphoJ”. This particular free source software was especially useful in its ability to visualise the statistical results in numerous forms and from their interpretation in addition to drawing on the concepts of isochrestic and emblematic style, two major territorial units have been recognised in southern African pre-Colonial hunter-gatherer groups.

Authors**Luca Bezzi, Cicero Moraes****Title*****Archaeological forensic facial reconstruction with FLOSS*****Abstract**

The aim of this paper is to illustrate a protocol for forensic facial reconstruction, developed on the archaeological blog ATOR (<http://arc-team-open-research.blogspot.it/>).

The workflow is based on the use of Free/Libre and Open Source software (FLOSS), starting from the 3D documentation of the skull with Structure from Motion and Image-Based Modeling (Python Photogrammetry Toolbox) till the facial reconstruction in Blender. The whole protocol has been developed on ArcheOS, the free archaeological operating system, and can be integrated with the software InVesalius, in case of DICOM data. The validation has been performed with blind test on living person, turning the most advanced traditional forensic technique into digital methodologies. The actual development of the protocol will be also taken into consideration, analyzing the use of the suite MakeHuman to speed up and simplify the entire process.

During the presentation several case studies will be exposed, focusing the attention on the application of the protocol in archaeological projects oriented to the facial restitution of important personalities of the past, like St. Anthony or the poet Francesco Petrarca.

Beside the reconstruction of anatomically modern humans (AMH), in the field of paleoart another procedure will be presented to illustrate the facial reconstruction of hominids. Also in this case a new workflow has been elaborated using Free and Open Source Software and achieving a high level of reliability thanks to the technique of anatomical deformation. This methodology permits to reduce the artistic approach to the final reconstruction, balancing it with a congruent deformation of the anatomy of a primate very close to human (*pan troglodytes*). In this case the protocol has been validated using the DICOM data of a chimpanzee to reconstruct the head of a gorilla. An almost complete phylogenetic human tree has been illustrated with this technique and the results, which include also the *Australopithecus sediba* and the different individuals of the *Homo georgicus*, will be shown during the presentation.

SESSION 3B: OCCUPATION FLOORS OF
HUNTER-GATHERERS IN THE DIGITAL
ERA: IMPACT AND EXPECTATIONS
BEYOND GEOMATICS AND
COMPUTATIONAL PERSPECTIVE

SESSION 3B:

OCCUPATION FLOORS OF HUNTER-GATHERERS IN THE DIGITAL ERA: IMPACT AND EXPECTATIONS
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- Authors** Domenico Lo Vetro, Enrico Ortisi, Claudia Striuli, Giovanna Pizziolo, Michele De Silva, Pier Francesco Fabbri, Fabio Martini
- Title** *A new Palaeolithic burial from Grotta del Romito (Calabria, Italy). A digital restitution.*
- Abstract** The latest research carried out in Grotta del Romito, a Paleolithic site located in the northern Calabria, has brought a new Paleolithic burial (Romito 9). The complexity of this archaeological evidence, also affected by a breach of the burial pit that altered the deposition's context *ab antiquo*, required a suitable strategy of excavation and documentation for the funerary context in order to read the taphonomic and post-depositional processes.
- The burial, dating back to about 19,000 years cal. BP, belongs to a young individual laid supine on a red ochre bed and endowed with a rich ornamentation made of thousands of artefacts including red deer atrophic canines and drilled shells of marine molluscs. The breach of the burial disturbed the deposition setting about 1000 years after the closure of the original burial pit, causing a considerable displacement of the osteological and ornamental materials.
- The creation of a visual model representing the funerary evidence in a CAD vectorial environment has led to the virtual reproduction of the original archaeological context. This model, based on the processing of a very detailed graphic and photogrammetric documentation and linked to a database, provided an effective support to the interpretations and has allowed the reconstruction of the deposition context and the subsequent events connected to the breach of the burial.
- Authors** Giovanna Pizziolo, Carlo Tessaro, Nicoletta Volante
- Title** *Exploring a Copper Age funerary site: Intra-site analysis and 3D visualisation at 'Poggio di Spaccasasso' (Grosseto, Italy)*
- Abstract** The contribution presents the updated phases of a project on the Eneolithic funerary site at Spaccasasso Cave, a prehistoric site located on the calcareous hill of Poggio di Spaccasasso in The Maremma Regional Natural Park of Uccellina (Southern Tuscany, Grosseto, Italy). The cave is characterized by cinnabar veins which have been exploited through mining activities since prehistoric time. Moreover, during the Late Copper Age, the site was used as a funerary area, characterized by secondary deposition rituals. At Spaccasasso human bones and grave goods have consequently been displaced and arranged in the funerary chamber according to the different deposition processes, resulting in a chaotic displacement of bones. Due to the complexity of this context the project involves the implementation of an intra-site GIS based on photogrammetric methodologies. Beyond the approach adopted to obtain 3d photorealistic restitutions we discuss the elaboration of data acquired through this process in order to assess its effectiveness and to perform taphonomic analysis exploring spatial relationships inside and outside the funerary chamber. Particular attention is dedicated to the analysis of data in a 3D perspective.

SESSION 3C: COMPUTER AND ROCK
ART STUDIES: DATA COLLECTION,
INTERPRETATION AND
COMMUNICATION

Authors Larisa Vodolazhskaya, Artem Vodolazhskiy

Title *Journal AaATec - modern Internet-resource for communication in the field of archaeological studies*

Abstract Computer technology is used in archaeological research and in the study of rock art more and more every day. Many scientists are doing interesting studies, including with use of computer technology. However, researchers often publish research results in regional, small circulation books and scientific journals that do not have Internet copies. Access to such publications is very difficult for colleagues from other countries. Therefore in 2013 a team of researchers from Russia has created an electronic International Journal Archaeoastronomy and Ancient Technologies - AaATec (<http://aaatec.org>). Experts from Russia, Ukraine, Armenia, Bulgaria, and Italy entered the editorial board. The results of studies in the field of archeology and ancient technology, including related to the study and interpretation of rock art, published in the journal. During the existence of the journal articles related to the study of rock art, ancient symbols and drawings, amounted approximately 71% of the total number of published articles, and associated with the use of computer technology in archaeological researches, accounted for 67%.

The journal AaATec is a charity project. AaATec is an open access journal, and all publications are in it for the authors are free also. The journal was created by using the most economical and affordable technologies. The basis of the site of the journal was created using CSS. To create a menu using CSS and PHP - technology. The main part of the site was written in HTML with elements of PHP. In some cases, was used Java script. Availability and efficiency of the complex technology of the electronic journal, is designed by the authors site AaATec, makes it an extremely topical in today's world. Despite the simplicity and accessibility of used computer technology, the journal AaATec has been recognized as a full-fledged scientific electronic journal. International Standard Serial Number – ISSN has been assigned to it. Journal entered to the Directory of Open Access scholarly Resources (ROAD). The AaATec is included in the database Ulrich's Periodicals Directory and into the Russian National Bibliographic Database of Scientific Citation, and also included in the Scientific Electronic Library «eLIBRARY.RU». The Editorial Board is working to incorporate it in other international bibliographic and abstract databases.

For today AaATec is one of the most accessible and dynamic platforms in international scientific community, allowing to accumulate information and efficiently communicate in the field of archaeological research, including the study and interpretation of rock art, carried with the help of quantitative methods and computer technology.

Authors Benito Vilas, Alia Vázquez, Miguel Carrero

Title *A (re)view of the archaeoastronomical interpretations of the deer antlers in the Galician rock art: The case of Campo Lameiro, Pontevedra.*

Abstract In the last years, different authors have proposed that there exists a relation between the deer antlers in Galician rock art from Bronze Age with possible astronomical calendars. Most of these hypotheses focus on the big deer portrayals situated in prominent areas and that present a great number of antlers, forgetting those other deer representations in the area immediately around them. On the basis of that postulate and moving away from this fragmentary vision, we have decided to select the area of Campo Lameiro (Pontevedra) and study all the deer that are

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presented there. This area was not selected by chance; we resorted to statistical data and chose the area of Campo Lameiro for being the area depicting the most of this motif. Of the total percentage of these cervids currently in Galician Community, this area constitutes 24%. To study the quantification of the deer antlers we use a different number of tools of statistical nature including geographic information systems and photogrammetry. Photogrammetry is oriented to erase the different problems of subjectivity that are present in the old systems of registry, and to observe the possible existence of some new motifs that were almost invisible with the previous techniques. With this study is supposed to obtain a more accurate register of these motifs to analyse based on statistics, which helps to certify or deny if relations exist between the number of the deer antlers in a well-defined area with possible interpretations of lunar, solar, or lunisolar calendars.

Authors**Jorge Angas, Manuel Bea****Title*****Geometric documentation and diffusion of the rock-art in Spain: ARAM project*****Abstract**

Rock-art is one of the field's works that brings the most difficulties in its documentation, both geometric and graphic. The main difficulty is the importance of the objective register of each painted or engraved motif, as well as its relationship with the geometry of the place and substrate where they were created. This point is very important, because the reliable reproduction of the graphic and metric character allows us to research and explain the semiotics of each rock-art group.

In recent years, there have been important results that have enabled the improvement of the quality of graphic documentation of the decorated sites, with very notable progress in 3D documentation of rock-art. This improvement of data acquisition allows the perfect presentation and also a "real" perception of the represented works. Nevertheless, there is not yet a methodological standardization that we can use to document, to research, to spread and to preserve rock-art. On the other hand, the proliferation of new technologies and methodologies for document and spreading of Cultural Heritage in general has been quite relevant, and rock-art in particular, as a constant in the last few years, evolving in time with the available technology.

In the latest three years, we have applied our own documentation methodology over 45 rock-art shelters from different regions of Spain: Aragón, Castilla-la Mancha, Extremadura and Murcia, most of them inscribed in the World Heritage List. We developed a register system that combines the data acquired by 3D scanning technology (structured white light, time-of-flight, phase shift), photogrammetry, high-resolution spherical images both terrestrial and aerial and, finally, their organization by metadata.

The principal result of this research has been to contribute in a different concept for the registration, analysis and appreciation of rock-art allowing us a more exhaustive exploitation of the graphic and metric documentation. Additionally, it contributes to the gradual change towards the tridimensional graphic representation by using new digital supports.

By this registration system (combining 3D scanning technology, spherical ground and aerial photography, digital tracings and their organization through out digital access file-data) the obtained information has been processed in order to create new products to improve the impact of the spreading by using a web platform.

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The documentation generated has been transformed and uploaded to the *RAMA Project: Rock-Art and Multimedia Accessibility* web page (<http://proyectoaram.tecnitop.com/>), intending to serve as a link between the Rock Art and Society in general, with special attention to those groups with reduced mobility. The owners of this website want to open a digital platform (with open access archives, for whose inquiry it is not necessary the use of proprietary software or difficult to manage) where a large number of documented rock-art sites (Palaeolithic, Levantine and Schematic), as a nexus between different cultural areas in the Iberian Peninsula, can be exposed.

SESSION 4A: MANAGING ARCHAEOLOGICAL 3D MODELS

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Authors **Francesco Lella, Saverio Giulio Malatesta, Ilaria Baldini, Frances Pinnock, Davide Nadali**

Title ***Reconstructing a Lost Town: The Case Study of Ebla***

Abstract The use of technology to create potential synergies in archaeological field is the aim of the on-going joint project between the Italian Archaeological Expedition to Ebla (Syria) and the laboratory Archeo&Arte 3D of DigiLab of the Sapienza Università di Roma. The reconstruction of the Court of the Audiences of the Royal Palace G of Ebla (2450-2300 BC) has been chosen as pilot project. The large amount of photos can in fact allow a graphic 3D visualization of architectural structures through a careful elaboration of data. A digitalization and metadata of archive documents will be produced aiming at the presentation of different hypothetical reconstructions according to the principles of analogy and verisimilitude to integrate missing data and architectural features that have not been recovered in the archaeological excavation. Once the most suitable archaeological model has been created, the different hypotheses in reconstructions can be verified showing changes in a diachronic perspective, linking architectural data and the presence of objects and furniture and even suggesting the possible daily use of spaces by means of virtual re-enactment of activities and/or rites that were occurring in those spaces. Communication and popularization are just one of the recent trends of archaeology: virtual reconstructions, both restricted and free, provide a very useful and essential key for the comprehension and fruition of ancient spaces and cultures that once occupied those buildings and places. Furthermore, the present situation in Ebla as in all Syria offers the occasion for a fruitful debate on the protection of archaeological heritage, the fruition and elaboration of archaeological data: graphic processes and elaboration of old archaeological data and documents that imply hypotheses of reconstructions might in fact constitute the largest set of information for a scientific debate, on the one hand, and give the opportunity of continuing the research thinking of solutions that can then be adopted to recover the archaeological sites and integrate old data with the new post-war situations.

Partner

Italian Archaeological Expedition to Ebla (Syria): Frances Pinnock, Davide Nadali

Archeo&Arte3D Lab, DigiLab Sapienza: Ilaria Baldini, Francesco Lella, Saverio, Giulio Malatesta

Authors **Carlo Inglese, Antonio Pizzo**

Title ***The Integrated Digital Survey As a Form of Knowledge of the Roman Bridges in Lusitania***

Abstract The instruments and methods of investigation for the knowledge of architectural artefacts, thanks to the rapid evolution of technologies like the 3D laser scanner, new topographical tools (range-based modelling) and digital photogrammetry (image-based modelling) have seen considerable advances in the last decade. In particular the coordinated use of such technologies, by giving life to an integrated digital methodology, is capable of providing highly accurate three-dimensional architectural models.

In the last years many questions have been asked about the relationship between the quantity and the quality of the data obtained with the various instrumental survey methods, and about their interaction and integration through completely digital procedures in continuous and rapid evolution; the ever-more frequent use of the new technologies in survey operations has increased the separation between the (objective) phase of information acquisition and a second,

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interpretative phase of data restitution through the creation of traditional or I.T.-based models.

The acquisition phase, the survey's more scientific phase as it were, is often strongly conditioned, however, by a series of factors that we might label instrumental and environmental factors.

The former are those bound up with the knowledge of the operators of the tools and management software, while the latter are those linked to the object of the survey, to its internal and external conformation and its positioning in a specific context.

A particular area in which environmental factors have a significant weight is that related to the surveying of ancient bridges, the extant testimony to which ties them to archaeology, and the knowledge of which is pervaded by multiple meanings, from both the archaeological and the architectural perspectives, but also as strategic testimony of an environmental context almost always transformed in its outline but stable in its constitutive elements (the levels of foundation and connection).

The ancient bridge, and above all that connecting the two banks of a river, is often a difficult object to survey precisely for the specificity of the external environmental factors touched on above. The case studies examined in the Lusitania region – the bridges of Alconetar, Alcantara, Segura and Vila Formosa – represent unique instances for their current state of conservation and especially for the topographic and orographic complexity of their position, which makes the planning of the three-dimensional survey extremely complicated. In this sense, at present we do not have at our disposal architectural surveys of these edifices elaborated with a single methodology and with the same parameters of graphic feedback. The processing operations presented will be fundamental for the reconstruction of the historical processes of the bridges cited and for the archaeological study of the building technology employed in their construction.

In particular, the chance that the new I.T. systems offer to document, with remarkable accuracy, geometries that are highly complex and at times, as in these cases, not directly surveyable with traditional methods, enables an accurate stratigraphic reading of the building units, the identification and checking of the structural deformations, and the salvaging and conservation of the historical artefacts with potential simulations of virtual anastylosis.

Authors

Li Jijunnan, Geng Guohua, Jia Chao, Wang Xiaofeng

Title

Reappear the Qin Dynasty Architecture: Eaves Tiles Reconstruction

Abstract

As art works with unity of form and spirit, eaves tiles are the witnesses of Chinese early multiculturalism during the period of the Qin and the Han Dynasty. With today's widely spread of digital archaeological technology, the need of digitalization for eaves tiles became more and more urgent, which specifically instantiated in more efficient data collecting, from low level to high level modeling and processing, data driven analysis and retrieval. Compared with the 2-D information represented by images of eaves tiles, the 3-D information represented by models are difficult to obtain but scientifically reflect the whole picture of eaves tile system; and accompanied with the emergence of 3D printing technology, we can easily have the mass-produced reproductions of eaves tiles. Existing approaches for modeling and retrieval are either supervised requiring manual labeling; or labeling need tags for precise definition which are difficult obtained and thus are unsuited for analyzing large collections spanning many thousands of models. We propose an automatic pipeline that starts with the collection of eaves tiles' binary image and then jointly optimizes for modeling and symmetry based analysis for model repair to best translate the input image collection. As output, the pipeline produces a

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cluster of eaves tile models with a search engine for semantic-based or content-based image retrieval. We demonstrate our main contributions as follows: first, in order to obtain smooth convex edge and multilayer slice of the model, we implement image blurring on binary images, after that we can do linear interpolation by the gray information between the original image and what we called negative image, which generated for ground floor of eaves tiles model; second, we repair the generated models by symmetry based analysis and completion, further we propose an approach of constrained texture mapping by photograph of existed eaves tiles to strengthen the realism of the reconstruction results; at last, we build a search engine for model retrieval, using both semantic information we collected during 2-D images labeling and image information, for the models are generated from images, we have got the mapping relationship between them, the rest of the work is only to introduce the mature methods in field of content-based image retrieval. We evaluate our automatic pipeline on thousands of eaves tile binary images and demonstrate its general applicability and robustness by compare the generated models with models generated by real object photos; the result shows that our method has receptive precision of model. At the end of our work, we show the 3D printing object of eaves tile models which can only be found in museum nowadays.

Authors**Maurice de Kleijn, Rens de Hond****Title*****A 3D Information system for the Mapping the Via Appia project*****Abstract**

Over the last decades, the use of virtual 3D technologies in archaeology has increased tremendously. Projects in which scanning techniques are used to obtain 3D measurements or in which 3D modelling software is used to generate virtual reconstructions are numerous. However, applying 3D technologies to generate a complex 3D Geographic Information System (GIS) in which the data can be systematically queried and in which sophisticated 3D analyses can be conducted, have not yet been widespread. Especially for complex archaeological sites, in which structures and objects are scattered over the study area, a 3D GIS aids to structure and analyse the complex dataset.

This article discusses the development of a 3D Geographic Information System for the Mapping the Via Appia project in Rome. Based on an analysis of the user requirements, it presents the development pipeline in which the data structure and the functionalities are defined. The pipeline presented offers innovative functionalities for analysing the study area and aims to function as an example for other complex archaeological study areas.

Authors**Matteo Lorenzini, Renato Guerrucci****Title*****3D segmentation and semantical enrichment*****Abstract**

The application of 3D technologies to archaeological research has been the subject of intense experimentation carried out by different scientific groups. Activity has focused in particular on tools' use for acquisition and reconstruction of 3D archaeological features or sites. So far researcher's interest has been aimed mainly at exploitation of the potential of 3D technologies for virtual reality and visualization of archaeological features and artifacts, for which we have many good models, but we often lack the opportunity to fully understand the data which characterizes virtual objects. In that sense, this paper describes pipeline adopted during PreDigPi project -Preservation and Digitalization of Cultural Entities of Monte Pisano with the aim of creating a digital repositories for archaeological 3D entities of Monte Pisano area.

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In this paper we will present the common methodology adopted in our project from the photogrammetric acquisition of 3D archaeological and architectural feature to the development of OAI-PMH metadata repository for the interoperability with the other repositories.

Data Acquisition is done by photogrammetry, using Bundler algorithm for image processing. Bundler is a structure-from-motion (SfM) system and produces sparse point clouds. It's completely open source and guarantee good results with low budget. Point cloud processing is performed using MeshLab, the most famous and powerful open source software for 3D point cloud meshing. Generally unstructured point clouds are converted into structured polygonal models to digitally recreate the geometric shapes of the surveyed objects and allow better photo-realistic visualizations. The final steps are characterized by the development of our OAI-PMH repository and data mapping done using Europeana Data Model schema. The use of EDM and OAI-PMH protocol guarantee to our dataset a complete interoperability with other similar repositories such as Europeana and 3DICONs.

However, following EDM schema, we can find a huge limit about the definition of 3D objects that they are classified and categorized without any kind of segmentation between different parts that characterized the model. In this paper we will show our solution based on the integration of Europeana Data Model with AAT thesaurus from Getty in order to allow the semantical definition of each architectonic component.

In particular in this paper will be presented the 3D relief of the Church of San Jacopo in Lupeta founded during Lombards age. In origin the church was titled to bishop San Mamiliano and is know as monastery till 757 A.D.

We have chose this site from the moment in which represent one of the most ancient building of the area that is characterized by the presence of different kind of architectural elements that can be use as example for a semantical enrichment of 3D feature.

Authors**Francesca Carboni****Title*****Ostia, Domus Fulminata (III, VII, 3-5): from traditional survey to the virtual 3D model*****Abstract**

The Domus Fulminata at Ostia is located along the decumanus maximus, in the area outside Porta Marina. This architectural complex, characterized by a colonnaded courtyard, was mentioned for a long time as the first example of a 'peristyle' house in Ostia (Meiggs1973). It was also considered as a guild seat (CALZA,NASH 1959, BAKKER 1994). More recently it has been interpreted as a tripartite building with private, religious and commercial function and has been related to a possible owner, in connection with the adjacent mausoleum, probably dedicated to P. Lucilius Gamala (van der MEER 2005).The 3D models and the virtual animations here proposed are based on the extensive and detailed graphical documentation produced by direct traditional procedures in occasion of the BA thesis on this subject, which I conducted under the supervision of Cairoli Fulvio Giuliani (Sapienza University, Rome). In fact, despite its rather symmetrical current plan, the architectural complex resulted from a series of extensions, modifications and consolidations dated from the first century C.E. to the Late Roman Imperial period. The numerous plans, sections, elevations and 3D reconstructions, which were elaborated, have allowed a 3D virtual reconstruction of the building, which has proved to be incredibly useful for a better understanding of its different building phases, the possible function of the architectural complex and its connection with the surrounding monuments. Specifically:- 3D animations has contributed to clarify the articulation of the interior circulation system;- the comparison between the mapping of the cracks in the existing remains and the virtual reconstruction has provided insight into the static and structural

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behavior of the building over time, explaining some of its modifications;- the 3Dmodel has allowed a detailed simulation of the lighting distribution within the building;- the 3Dmodel has been used to simulate the thermal behavior of the building.

Authors

Peter Rauxloh, Moises Hernandez Cordero, Md Azizul Karim

Title

Beyond the academic – Photo modelling applied to complex commercial archaeology

Abstract

This paper will describe the actual application of photo modelling techniques within the work carried by one of the world's largest commercial archaeological firms. It will concentrate on the technique's application to the recording of excavations and standing building, and focus on how it enabled us to overcome some of the problems habitually faced on pressurized commercial projects. The paper will not simply describe how we applied a piece of software, and report that it worked as it should, but aims to demonstrate the benefits both in terms of time and costs, which it's use can deliver.

If the application of such techniques by the commercial sector can be demonstrated in a cost effective manner, then they have the potential to impact on most of the archaeological investigation carried out within Western Europe.

SESSION 4B: NEW TRENDS IN 3D
ARCHAEOLOGY: INNOVATIVE
TECHNIQUES AND METHODOLOGIES FOR
THE ACQUISITION, RETRIEVAL AND
ANALYSIS OF CULTURAL HERITAGE

: NEW TRENDS IN 3D ARCHAEOLOGY: INNOVATIVE TECHNIQUES AND METHODOLOGIES FOR THE ACQUISITION, RETRIEVAL AND ANALYSIS OF CULTURAL HERITAGE

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- Authors** Bernard D. Frischer
- Title** *Digitizing the West Pediment of the Temple of Zeus at Olympia: From 3D Data Capture to Online Publication*
- Abstract** This paper reports on a project of digitizing a significant cultural heritage monument, the west pediment of the Temple of Zeus at Olympia (Greece). Dating to the second quarter of the fifth century BCE, the pediment displayed twenty-one colossal statues illustrating the Battle of the Lapiths and Centaurs. Recent work by András Patay-Horváth on the east pediment of this temple shows how useful digital documentation can be in furthering scholarly understanding of the sculptural program of this central cult sanctuary of Greek culture. In particular, the 3D model allows one to study various hypotheses of positioning and restoring the individual statues in a way that is more efficient and precise than previous methods traditionally used by archaeologists since the temple was first excavated in the nineteenth century.
- In cooperation with Patay-Horváth the present team of authors undertook a project to digitize the west pediment of the temple in summer 2014. This paper will discuss the stages of the work from 3D data capture, to modeling and editing of the mesh, and, finally, to online publication.
- The project is most of interest because it entailed creation of the most massive model of a sculptural ensemble yet undertaken using the approach of Structure from Motion (SfM). The 3D data of the twenty-one colossal statues were captured in a photographic campaign that totaled over 3,800 24 megapixel photographs. The photographs were batch-processed over a period of one month to create the raw state model of the pedimental group, which consists of more than 1 billion polygons. The raw model was then edited to remove imperfections and irrelevant features such as the modern wall of the gallery where the statues are displayed. The full model plans is being used to pursue new archaeological studies of sculptural technique and interpretation. A reduced interactive version of the model will be freely viewed on the website of the Virtual World Heritage Laboratory.
- In the conclusion, we will present an assessment of the relative accuracy of a model made with traditional laser scanning as compared to one made through an approach utilizing Structure from Motion. Previous work by Guidi and Frischer suggesting that the results of SfM are reliable in terms of accurately representing the ground-truth geometry of the object scanned gain new confirmation through our study.
- Authors** Stefano Camporeale, Rossella Pansini
- Title** *The Capitolium of Sala (Rabat, Morocco): a new study and 3D reconstruction*
- Abstract** The Capitolium of Sala (II c. AD) is one of the most important temples of the province Mauretania Tingitana (Morocco). Nevertheless, after it was excavated during the 1960s it was never the object of a comprehensive study and this paper aims at presenting the results of a new analysis of this building combining different techniques and sources in order to demonstrate its cultural significance.
- The Capitolium was built on the slope of a hill in the centre of a small square surrounded by porticoes on a level 5 metres higher than the forum. The southern portico is no longer preserved but it is possible to demonstrate that it was supported by the barrel vaults of the tabernae opening towards the forum. This construction system was inferred thanks to a new laser scanner survey and 3D reconstruction as well as the study of unpublished documents and excavation reports of the 1960s preserved in archives at Aix-en-Provence. In particular a

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sophisticated system of building techniques is recognizable. The concrete barrel vaults of the tabernae were reinforced by three stone-voussoirs arches. The alignment of the southern portico of the upper piazza corresponds to that of the central arches of the tabernae vaults whose dividing walls were also reinforced with a stone pier supporting the central arch.

The reconstruction of the Capitolium itself as well as that of the porticoes and of the monumental façade towards the forum was achieved through the integration of different data, coming from archival records, analysis of building techniques, and the use of new technologies, as laser scanner and 3D photogrammetry of architectural decoration. The mesh obtained through laser scanner constituted the basis of the volumetric reconstruction of the whole complex, while the products of 3D photogrammetry were used as a starting point for the reconstruction of the capitals that decorated pilasters and columns. Measurements and proportions recorded in the point clouds were combined to the data contained in archive documents and used during the 3D modelling, performed through the open source software Blender. In particular a big pilaster capital could be attributed to the temple pronaos and its measures were useful for reconstructing the original height of the columns (8 metres). Smaller capitals belonged to the porticoes columns (5 metres) and their analysis allowed the regular spatial disposition of columns to be inferred.

3D modelling helped in solving some relevant questions: it allowed the whole complex to be visualized as it probably was in its first construction phase, and it was critical for reconstructing the architectural solutions used in some of its parts (vaulted tabernae, porticoes, pronaos). These results illuminate new aspects of local Romano-African architecture, and thus the historical significance of the building also for urban history of ancient Morocco.

Authors	Cristina Giancrifofaro, Emanuela Grifoni, Stefano Legnaioli, Giulia Lorenzetti, Stefano Pagnotta, Luciano Marras, Gianna Giachi, Pasquino Pallecchi, Vincenzo Palleschi
Title	<i>'Tomba della Scimmia' in Chiusi (SI). Photogrammetric 3D reconstruction, multispectral imaging and analysis of the painted surfaces</i>
Abstract	This project aims to demonstrate the usefulness of digital reconstructions in the visualization and interpretation of analytical data obtained in science conservation projects. The study was carried out in 'Tomba della Scimmia', one of the most important tomb of the Etruscan necropolis of Poggio Renzo, near Chiusi, dated around 480-470 BC. Photogrammetry survey method was used to generate a 3D model of the whole underground grave. The main advantage of this method, which is based on dense stereo matching tools, is the possibility to generate 3D reconstruction starting from a set of uncalibrated images, with non invasive and easy transportable hardware. Open source software is also used to integrate 3D wall painting data to the diagnostic researches: (I) Multispectral analysis, able to improve the readability of the painted scenes, detecting details otherwise invisible to the human eye, and (II) X-Ray Fluorescence data that give information on the elemental composition of materials and confirms the behavior of the multispectral signals collected on the wall painting surfaces.

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- Authors** Elena Biondi, Alessandro Bovero, Paolo Triolo
- Title** *Multispectral photogrammetric techniques and multispectral RTI in monitoring of surfaces in archeological and cultural heritages objects: the case study of sarcophagi from Egyptian Museum of Turin*
- Abstract** Volume and surface measuring and monitoring of cultural significance objects are indispensable in the correct evaluation of the state of conservation as well as the study of the objects themselves. The use of systems such as laser scanner may allow to obtain operative models, anyway limited under the point of view of the correct colour of the visual information of surfaces and resolution of the morphology. In order to optimize the production of high quality models consistent with the conservation needs a procedure has been developed combining surveys by means of photogrammetric and reflectance transformation imaging (RTI) techniques: the first technique allows to obtain 3D models - which must be metrically referenced by comparing to a 3D model obtained from a laser scanner data capture -, integrating the morphological and colorimetric data of the surface; the second technique captures a object's surface shape and colour and enables the interactive re-lighting of the surface from every direction. RTI also permits the mathematical enhancement of the surface shape and colour attributes, supporting in the perception of surface shape and detail, allowing a optically correct virtual relighting, obtaining graze light and zenithal illuminations in an interactive manner. The result of the RTI was again integrated into the 3D model derived from photogrammetry, selecting only the results that could be more descriptive of the conservative condition: incisions, areas of intervention, which often had different chronological layers and materials/techniques.
- While photogrammetry and RTI techniques are based on photographic captures, our data capture procedure is integrated by multispectral bands acquisition in the 365-1050 nm range, in order to consider degradation and conservation status, recognize pigments or dyes, locate restoration or underdrawings. Our procedure is suitable for archaeological, artistic and conservative field, both in monitoring and restoration (project for restoration, design of 3D printable integrations); it can be applied on small objects (, paintings, sculpture, sarcophagus, archaeological fragments - also made of metallic material -) and large ones (architecture, large statuary, archaeological excavation sites) and it is designed to be low-cost from the point of view of required technology and operating cost, allowing widespread application.
- For the specific case study of sarcophagi, visible-induced infrared luminescence (VIL) imaging was also integrate with multispectral photogrammetry and multispectral RTI to study Egyptian blue. It could be also a very changeling outcome for a complete imaging campaign for a in deep study of sarcophagi.
- Authors** Mehdi Belarbi, Aurelia Lureau
- Title** *The Gothic church Saint-Pierre et Saint-Paul of Gonesse, France : photogrammetric survey of preventive excavations and online presentation*
- Abstract** The Gothic church of Saint-Pierre et Saint-Paul in Gonesse is located in the French region Île-de-France, 25km North of Paris. The building is a Historic Monument of France since 1862 and was built between the end of the 12th century and the end of the 13th century above a Romanesque church.

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The INRAP (French National Institute of Researches in Preventive Archaeology) lead a campaign of preventive excavations in three phases during 2011, 2012 and 2013[1]. The church had the project of putting up an underfloor heating for the whole church and the preventive excavations were done piece by piece, following the work in progress. The INRAP excavated many graves from a necropolis used between the end of the 6th century and the 18th century, some tombstones, a negative of the former floor of the church, several sarcophagi, wells, a broken baptistery reused in a later water pipe and a very rare bell mould.

Photogrammetric surveys were done outside and inside the church during the various excavations. As the surveys were done while the archaeologists were working, some modern tools appear as witnesses of the excavations, and we can also observe the various phases of the excavations with the appearance of some structures little by little while they are being dug.

Some parts of the excavations were surveyed in detail: the graves and tombstones, and the various pieces of the baptistery. They appear on the general models while the rest is being dug around them and we also have the detailed models. The baptistery was completely dug and the various pieces composing it were surveyed separately and then assembled, but left as separate models to show the restoration work and propose an hypothesis of the broken stone.

The 3D models have followed the evolution of the photogrammetric software since 2011, with the acquisition and data treatment with OSM Bundler in 2011, with Visual SfM and SfM Georef in 2012 and with PhotoScan in 2013-2014. The 3D models were worked on MeshLab and georeferenced with SfM Georef, and now the work is done with PhotoScan.

Out of concern for the study and cultural diffusion these models were assembled and reduced in number of triangles to be easily manipulated and put online (but for the moment not available to the public) thanks to the X3DOM technology[2]. This programming language answered our peculiar needs: it is very fast, flexible and low-cost.

For more clarity, we propose two presentations: a chronology by year of excavation and a stratigraphic one. Tools were created in JavaScript to be able to take measurements and have the altitudes everywhere on the models. These tools allow the archaeologists to continue their work even if the archaeological remains are now destroyed.

We hope in the future to add our different versions of the 3D models to show the work being done in 3D and other tools to help the archaeologists in their work.

[1] <http://www.inrap.fr/archeologie-preventive/Actualites/Actualites-des-decouvertes/p-14253-1-000-ans-d-inhumations-dans-l-eglise-de-Gonesse.htm>

[2] <http://www.x3dom.org/>

Authors**Giulio Poggi****Title**

Documentation and analysis workflow for the on-going archaeological excavation with Images-Based 3D modeling technique: the case-study of the medieval site of Monteleo (Italy)

Abstract

Nowadays Image-Based 3D modeling techniques have been tested successfully in the documentation of archaeological contexts, both in terms of geometric precision and versatility to model many different archaeological elements. A preliminary evaluation of interactions and compatibility between the 3D model acquisition pipeline, proper of each technique, and the methodology of the archaeological research process in the field is a fundamental step. This analysis provides the basis for developing a reliable, flexible and accurate 3D documentation method based on high quality 3D data. A list of guidelines that enables the correct application

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of a 3D documentation and analysis method to most on-going excavations, independently from the different contexts, periods and the presence of expensive 3D modeling equipment or other supporting tools (i.e. total station, high-precision GPS) has been defined. The proposed method consists in a systematic 3D documentation of each archaeological stratigraphic unit, according to the methodology defined by the consolidated conventional documentation, and the development of a parallel management and analysis workflow, entirely based on 3D data. This operation is filtered by an accurate evaluation, that allows to calibrate the technique on the specific needs of each context and on timings and methods of the archaeological research. This method has been initially designed and developed to meet the quality requirements and to improve the informative potential of the documentation of the excavation of Monteleo (Italy), a late-medieval alum productive site, investigated by University of Siena since 2008. The sector documented in 3D is a fairly extensive context: in fact it measures 80mq and more than 100 stratigraphic units have been 3D modeled, geo-referenced and managed. The contextualization process of the models takes the form of a composite management and visualization system, where the cognitive significance of the single model is enhanced by the interaction between several 3D models and the interface with different types of data such as photographs, 2D images, geographical-spatial data and alphanumeric data. One of the most impressive example of that application, is the accurate three-dimensional reproduction of the complete archaeological stratigraphy in a visualization and management platform (3D GIS). Within this platform we can explore and manipulate the stratigraphy in three dimensions, measure distances between different units, take coordinates of any point, draw cross sections, compute area/volume automatically and perform spatial analysis. The distinctive feature of the proposed method, that takes into account the high standard of the most recent 3D modeling techniques, is the opportunity to obtain high quality results with economic equipment (a budget camera and a PC), and speeding up significantly the conventional documentation process. These factors expand the extent of application to most archaeological excavation projects, including those with low-budget.

Authors**Robert Schlader****Title*****Why pay to play? Comparison and contrast of Meshlab to commercial software for post processing of 3D scan data.*****Abstract**

Meshlab is a powerful software package with a great number of filters and plugins that allow for processing 3D data captured from a variety of different sources. For many in the Cultural Heritage sector this is the “go to” application for many reasons, not simply because of its price. Outside of the Cultural Heritage sector there are a large number of commercial packages that are being utilized to create and process 3D models such as ZBrush and Mudbox. In this poster we will compare and contrast these commercial software packages with Meshlab in the processing of 3D data. We will highlight areas where Meshlab excels, and where it is not so strong.

Authors**Nour Allah Munawar****Title*****Cultural Heritage Preservation in a Digital Context*****Abstract**

Since March 2011, the archaeological sites in Syria have suffered from the escalated violence of the recent armed conflict. Many sites have been damaged in different ways, such as looting, bombing, illegal excavations, terrorism actions and illicit trade. The armed conflict did not

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avoid the museums, as many museums all over Syria have been looted or bombed. Moreover, the monumental buildings such as citadels and castles have been used as military bases which have threaten the sites with being under the fire of bombs and artillery mortars.

In this research, the historical and comparative approaches have been extensively applied. Also, the researcher has invented a new tool in order to make this study more comprehensive which is the assessment tool of the damaged cultural heritage through looking into the details of damages of the cases of study, the purpose of this tool is to analyze each one of them and show/see how destructed they are? This tool will help the upcoming researchers in the process of rehabilitation of the damaged ruins and monuments, as it will illustrate what the percentage of the damages in the concerned buildings are, partially or completely?

Furthermore, some theories and concepts have been explored in this research. Showing the importance of the cultural heritage sites on different perspectives has required explaining the values and stakeholders of the cultural heritage site in general and for each case of study in particular. In parallel, the damages of the cultural heritage sites have been discussed in this thesis, also the division of each one of them has been fully described. In addition, the research has mentioned plenty of examples for each kind of damages by inserting them in special tables.

Authors **Giusi Sorrentino, Stefano Giuntoli, Stefano Valentini, Cristina Giancristofaro, Emanuela Grifoni, Stefano Legnaioli, Martina Leonardi, Giulia Lorenzetti, Stefano Pagnotta, Vincenzo Palleschi**

Title ***3D reconstruction and elemental analysis of the Etruscan 'Telephus mirror' of Tuscania***

Abstract In the framework of a collaboration between the Center for Ancient Mediterranean and Near Eastern Studies (CAMNES) in Florence and the Applied Laser and Spectroscopy Laboratory (ALS Lab) of CNR in Pisa, with the support of the Archaeological Superintendency of Southern Etruria, an extensive study of the findings of the excavation in the areas of 'Pian delle Rusciare' and 'Il Pratino' in the 'Macchia della Riserva' Hellenistic Age necropolis, in Tuscania (VT, Italy), has been realized. In this communication we will present the photogrammetric reconstruction of the 3D model of an Etruscan mirror, found in Tomb 1 of the 'Pian delle Rusciare' necropolis and depicting the scene of the Telephus myth; the results of the quantitative analysis of its composition, obtained through the Fundamental Parameters method from the X-Ray Fluorescence (XRF) spectra acquired at the National Archaeological Museum of Tuscania by the ALS Lab researchers, will be also presented. A particular attention will be given to the remote usability of the results and their contextualization in the tomb, which has also been reconstructed by the researchers of the ALS Lab with photogrammetric techniques.

Authors **Miguel Busto-Zapico, Miguel Carrero-Pazos**

Title ***3D technology applied to quantification studies of pottery: EVE 2.0***

Abstract In any archaeological excavation the pottery fragments are the most frequent quantitative remains. As a consequence, it seems right to propose a methodology that can help in their study. Therefore, we intend to expose a method that will lead us to know from a fragment of pottery the percentage of the pottery piece with respect to the total vessel which was part. This

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approach is not new, since between the eighties and nineties of the twentieth century, C. Orton, P. Tyers and A. Vince started talking about the *estimated vessel equivalent*(EVE). However, despite its advantages, it is a system little used. On this basis we have designed a reviewed EVE adapted to the new technologies (3D) that allow us to go further and talk of EVE 2.0. Not only is a change in form, but also a deep methodological revision.

Authors **Isidoro Campaña, Alfonso Benito-Calvo, Alfredo Pérez-González, José María Bermúdez de Castro, Eudald Carbonell**

Title ***Using 3D models to analyze stratigraphic and sedimentological contexts in archaeo-palaeoanthropological Pleistocene sites (Gran Dolina site, Sierra de Atapuerca)***

Abstract Gran Dolina is a key site to understand Early Pleistocene human evolution in Europe. It has three important Early and Middle Pleistocene archaeo-paleontological layers, where high densities of remains have been found, including hominid bones, fauna and lithic tools. Gran Dolina is a cavity belonging to the second level of the Sierra de Atapuerca multi-level karst system, which shows an Early and Middle Pleistocene sedimentary infilling 25 m thick, divided in eleven lithostratigraphic units.

The use of 3D models in stratigraphy and sedimentology is a new issue that allows new analyses and studies, increasing the knowledge of archaeological sites. In Gran Dolina site, the application of 3D laser scanning and photogrammetry techniques have allowed us to carry out 3D models, including RGB textures. The models were georeferenced in the excavation local coordinate system. From these 3D models, we identified and mapped the continuity and geometry of the sedimentary levels, reconstructing the stratigraphic architecture of the site. The 3D geometry of the levels was used to restore the original 3D morphologies of the excavated levels (e.g. TD4 and TD10), revealing the real post-depositional dip of the layers. The last helped us to infer input directions, their variations in each level, and to recognize older sedimentary entrances. With all these data we have elaborated palaeo-geographical reconstructions during the accumulation of the archaeological assemblages.

Authors **Ángela Crespo Fraguas, Miguel Ángel Díaz Moreno, Sergio Isabel Ludeña, Inés del Castillo Bargueño, Mercedes Farjas Abadía, Guillermo Martínez Pardo-Gil, Esther Alfonso Carbajosa, Carlos Ruíz Serrano**

Title ***Arqueología del Conflicto: Aplicación de nuevas tecnologías en el yacimiento de Los Yesares, Pinto (Madrid) [Archeology of Conflict: application of new technologies in the site of Los Yesares, Pinto (Madrid)]***

Abstract During the early months of 2014, an archaeological project has been carried out to locate and document the military fortifications distributed throughout the municipality of Pinto (Madrid, Spain). These archaeological remains are related to the military operations which took place during the Spanish Civil War (1936-1939). In one of the documented areas -Los Yesares- a wide set of techniques have been used to build a Digital Terrain Model (DTM) of the site and to produce 3D models the military structures built there in the aftermath of the Battle of

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Jarama.

The project has involved four different approaches to the study of the archaeological remains. Firstly, a very precise cartography (1:500 scale with a ± 10 cm accuracy) has been produced through the use of GPS. In addition, an orthophoto of the same area and an scale of 1:1000 has been obtained through the use of Unmanned Aerial Vehicles (UAV), complementing the aforementioned cartography and providing an excellent reference for the archaeological structures.

A third stage of the project has been focused on the tridimensional reconstruction of the Spanish Civil War structures, through the use of different techniques. A 3D scan has been used to produce a model of one of the four bunkers built in the position with a high accuracy of ± 2 cm. The model has been later geo-referred to the WGS84 system. Finally, a second group of structures of Los Yesares have also been reconstructed through the use of photogrammetric techniques and 3D modeling software, including a second bunker, a trench, a shelter and a firing position. The same technique has also been used to obtain 3D models of some of the objects found during the archaeological survey. Augmented reality has been used in this last group of images to compare the results with the actual, physical remains.

The present paper aims to show how the combination and merging of different 3D techniques can provide an insightful reconstruction of a complex site, not only from the most evident archaeological point of view but from the perspective of public outreach. Within the context of the so-called Conflict Archaeology, often controversial, the digital reconstruction of battle landscapes can prove a major role to raise the awareness about both these contemporary period objects and the collective memory they still represent.

Authors

Alba Masclans, Joan Anton Barceló, Maite Ventura, Juan Francisco Gibaja

Title

3D Geometric Morphometric Methodology applied to the Study of Neolithic Stone Axes.

Abstract

This paper will report the results of a combined approach of 3D Geometric Morphometric (GM) analysis of shape, surface texture and tribology, applied to the study of Neolithic Polished Stone Adzes and Axes.

The sample selected comes from the Neolithic site “Bobila Madurell-Can Gambús-1-2” (Catalonia, NE of the Iberian Peninsula), with a documented occupation during the early fourth millennium (between ca 4200-3600 cal ANE at 2 σ). We know from use-wear based functional analysis that these artifacts were used in a wide range of activities involving hide processing, butchering and different kind of woodworking. We should also take into account the probable symbolic use, as these artifacts are frequently found as grave goods. It also has been noticed that the accidental fracture pattern, the repair processes and the tool shaping are different depending on the raw material as well as on the activity in which it was involved as a mean of work.

This multiplicity of probable use functions is reflected in a very heterogeneous range of shapes, sizes and weighs. The problem we should solve lies in the fact that actual methodology used for archaeological shape description is clearly insufficient based on subjective analogies or reduced to size comparisons. We have extracted the shape and texture of polished lithic tools by means of a Breuckmann Smartsan 3D duo. Additional to the geometry revealed by 3D scanning, and analyzed using using OPTOCAT and Geomagic software, we have used 3D GM methods for quantifying the morphological differences between tools and parts of tools. Different shape parameters and surface texture indexes have been tested, including intensity of curvature, 3D sphericity, 2D roundness, 3D convexity, cubeness, irregularity, roughness, asymmetry, among

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others. The quantification of the edge bluntness, the edge scars morphology and the accidental fracture pattern also have given us valuable information for the worked material and repair processes identification. Measurements have been carried out with Fiji and ImageJ2.

Multidimensional statistical analysis of resulting measurements will help us to improve use-wear based functional estimations, opening the possibility of distinguishing between raw and altered-by-use surfaces.

- Authors** **Jorge Angas, Jacopo Bruttini, Federico Cantini**
- Title** ***Standardization of 3D data recording and management in the archaeological excavation of the Third Courtyard of Palazzo Vecchio (Florence. Italy)***
- Abstract**
- Florence is worldwide known for its Renaissance masterpieces, but it is often forgotten that it was founded during Roman times and remained as a village until the end of the early Middle Ages. Only after the end of the 10th century, the center moved toward a process of economic growth that led Florence to become the cradle of the Renaissance.
- Since 1997, an excavation has been achieved inside the Third Courtyard of Palazzo Vecchio. These surveys uncovered the Roman Theater, that was plundered during the Early Medieval period; then between the 11th and 13th centuries the most powerful families of the city built towers and buildings on the ruins of the ancient structure. Afterwards, in the 14th century, the construction of Palazzo Vecchio began, changing in depth the cityscape of this district. Finally, in the 16th century, the development of the area culminated in the final enlargement of Palazzo Vecchio, through the construction of the Third Courtyard, that lean against the ruins of the theater.
- The complexity of the layering found needed an in depth multidisciplinary approach, for a better understanding of the relationship between the theater and the medieval and renaissance buildings. For this reason, a survey, by means of 3D scanning, then linked with the archaeological data, has been recently achieved inside Palazzo Vecchio.
- Therefore the topic addressed in this paper is related to obtain an integration of 3D data acquired at the archaeological excavation with the goal of enhancing the urban reconstruction of this area throughout the centuries. To avoid the lack of a standardized or normalized process in the development and management of three-dimensional models this research was accomplished under the aims of different standards rules such as the London Chapter and the Seville Principles (International Principles of Virtual Archaeology). This standardization includes the following premises: accessibility, comprehension and geometric utility.
- The principal aim of this project was the combination of the 3D data registered from a different point of view: integrating the management of the 3D data in a multidisciplinary team to understand and to obtain the reconstruction of the different historical periods from the classical era until the final construction of the *Palazzo Vecchio*.
- The use of different types of 3D scanner (phase-shift, time of flight and structured light) and photogrammetric techniques in this project has allowed the precise and detailed reproduction of all kinds of personal and real property and their subsequent morphological analysis. The information generated by these different methods offers a totally accurate and precise 3D model, and it makes possible to carry out subsequent analyses that will increase the knowledge and the documentation of the monument. This technique enables us to confront new methodological focuses by the creation of 3D databases.

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The project has been developed since April of 2013 until nowadays, and it has been directed by the Soprintendenza Archeologica per la Toscana, the Town Hall of Florence, the University of Pisa (Italy) with the collaboration of the *Spin Off* of the University of Zaragoza (Spain) Scanner Patrimonio e Industria.

- Authors** **Bruno Fanini, Daniele Ferdani, Emanuel Demetrescu**
- Title** ***Serious games in Virtual Archaeology: a distributed workflow for 3D asset ingestion***
- Abstract** Within interactive serious gaming applied to Virtual Archaeology, 3D models validation and ingestion phases often present a wide range of issues, both for their iterative nature and specifically when dealing with different 3D modeling software products in a distributed workflow with remote professionals. Time constraints also require a well-organised pipeline and methodology in order to manage several 3D assets with different application requirements, including game items, user interface and scene dressing elements.
- In this paper, the case study of a natural interaction application “Admotum” will be presented: a serious game on show at “Keys to Rome” museum exhibition, that allows visitors to interact with virtual reconstructed archaeological environments. The game objective is to find and collect 3D items (museum objects seen in their original contexts), following the treasure hunting game model. The project required ad-hoc, efficient and modular workflow due to the amount of 3D virtual environments, items and artwork to be included in the game, due to the different skills and expertises of involved professionals. Particular attention was given to 3D assets creation and optimisation because of the different typologies of models used and game requirements. Indeed in the game we imported both models created using manual computer graphics modelling approaches and derived from 3D survey performed ad-hoc (laser scanning and/or photogrammetry).
- The range of 3D formats to manage and software used led to the development of open-source back-end tools, including real-time authoring tools, preview and object painting tools aimed at scene dressing tasks, integrated with versioning and cloud tools to control and manage distributed 3D asset collections. The paper will also describe steps involved into the definition of well-formed and re-usable guidelines aimed at smoothing all involved ingestion processes.

- Authors** **Mariusz Wiśniewski, Wojciech Ostrowski, Barry Molloy**
- Title** ***RAW file pre-processing and 3d model quality – archaeological perspective***
- Abstract** One of the vital requirements of a professional photographer’s routine is to capture images in the RAW file format. This can then be followed by careful development of files before exporting them to usable viewing formats like .jpg or .tiff.
- This is especially important for photographers who specialize in photographic documentation like archaeologists, because the RAW file format allows one to collect and store most of the information that the camera can capture. The .jpg format, on the other hand, compresses the file, which requires digital “decisions” by the onboard software. All RAW file formats allow

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greater control over post processing such as color control or detail recovery.

3D modeling using images is increasingly being used in archaeology, particularly using the cost-effective photogrammetric method. This raises methodological concerns, as there can be variable engagement with photographic best practice. We wish to ask in this paper if the use of RAW files during data capture for photogrammetric modeling improves the quality of final 3D model.

We aim to answer the question using following case studies:

- Large-scale models of medieval basements – complex objects consisting of rooms, recorded in RAW and then developed to jpg using automated and custom settings.
- Historical street lantern posts from Warsaw, Poland - medium size objects with homogeneous texture recorded in camera both in jpg and RAW.
- Small-scale metal objects recorded in camera both in jpg and RAW format, where customization of developing parameters was used to improve variable quality of original images.

We performed comparisons of quality of 3D modeling concerned not only the number of points generated for point-clouds, but also quality and accuracy of the model produced, particularly its texture.

The question we address is if we should be working towards forming best practice in archaeological 3D modeling based on image format and resolution, or do such issues really matter?

SESSION 4C: FORMAL APPROACHES TO VISIBILITY ANALYSIS IN ANCIENT ARCHITECTURAL SPACES AND CULTURAL LANDSCAPES

FORMAL APPROACHES TO VISIBILITY ANALYSIS IN ANCIENT ARCHITECTURAL SPACES
AND CULTURAL LANDSCAPES

POSTER

- Authors** **Michal Birkenfeld, Yiezhak Paz**
- Title** ***Seen and Unseen: Using View Shed Analysis to reconstruct socio-political relations between settlements in LBA Ramat Bet Shemesh, Israel***
- Abstract**
- The area of Ramat Bet Shemesh can be defined as a microcosmos, a closed ecological system in which human settlement flourished from prehistoric to modern times. During the Late Bronze Age, several small rural settlements, farmsteads and hamlets existed in this region. Located on commanding limestone hills, these settlements practiced agriculture, probably with close relation or as subjects of the urban centers that occupied the nearby mounds of Azeqah and Bet Shemesh.
- One of these small farmsteads, Site 82, located on the highest crest at Ramat Bet Shemesh, encompassed a unique feature: a cult locale in which a large standing stone was erected. This unusual feature raises important questions as to the connections and relationships between the Ramat Bet Shemesh sites themselves, and between them and the urban centers to which they relate, as well as to the nature and allocation of cultic activity in the area.
- In this paper we wish to present the results of a Viewshed analysis conducted, aimed at exploring the relationship between Site 82 and contemporaneous sites, with a special emphasis on the cultic locale, the standing stone and their visual qualities.
- Authors** **Anil Kumar, Neeti Anil Kumar**
- Title** ***Typo-technological aspects of rock-cut cave-temples in south India -with special reference to the Pallava Caves (data analysis and interpretation using digital applications in cave architecture)***
- Abstract**
- The present study is attempted to throw light on the architectural excellence and engineering skills of the Pallavas in its beginning and development of rock-cut cave temple architecture in South India as a whole and Tamil Nadu in particular. The Pallavas were one of the major dynasties that rose to prominence in the seventh century CE. They were the pioneers in the translation of the contemporary brick and timber architecture of the South India into more prominent stone and in the tackling of hard and less tractable rocks.
- The period between the latter half of the sixth and the first half of the tenth century, nearly four hundred years, is an important epoch in the history of south India and its culture. It coincides with the rise to power of three important dynasties, the Chalukya of the Vatapi (modern Badami, Karnataka), the Pallavas of Kanchi (modern Kanchipuram) and the Pandyas of Madurai. The rivalry and wars between the three for the status of imperial power in no way impeded the development of art, architecture, sculpture, painting and literature. In fact, there appears to have been a keen rivalry in the creation of artistic monuments in different parts of the country under these dynasties.
- The founders of the new Pallava dynasty of Kanchi were Simhavarma and his son Simhavishnuvarma alias Avanisimha. Among the Pallavas, four rulers, viz., Mahendravarman I, his son Narasimhhavarman I Mamalla, Paramesvaravarman I and Narasimhhavarman II Rajasimha were outstanding rulers not only for their political achievements, but also for their contribution in development of art, architecture, sculpture, painting, literature, etc.

FORMAL APPROACHES TO VISIBILITY ANALYSIS IN ANCIENT ARCHITECTURAL SPACES
AND CULTURAL LANDSCAPES

POSTER

Hypothesis

The present study is on the rock-cut cave temples at *Tondaimandalam* region and more emphasis is given on the rock-cut cave temples at Mamallapuram.

The Rock-Cut Cave-Temples have been finished in various stages and each of the stages and architectural components has been dealt with different groups of expert. All the stages and transformations would be taken into account.

Previously the inscriptions were taken in to account for fixing the date. In the present study the context as well as the architectural features as well iconographical, both would be studied in inter-alia.

Research Methodology:

For the study of architectural development the following application would be utilized:-

The application of Photogrammetry would be applied in which the digital photo documentation of all the images and caves.

The assimilated data would be compiled using Desktop Manager and a complete data base would be prepared for Analytical and comparative interpretation.

Authors

Michele De Silva

Title

Visual space, defence, control and communication: towers and fortresses system of the tuscan coastal belt

Abstract

Since the Late Mediaeval times to the end of the nineteenth century, coastal belt of Tuscany has been controlled by a towers and fortresses system. Main functions of these structures are the control of the shore lines, the defence of mainland from [dangers] pirates and enemies coming from the sea, control of maritime commerce and of smuggling. All these functions involve the priority of visibility issues, and underline the importance of investigating the visual space of this kind of military structures. In addition, the inter-visibility is fundamental in the communication system. In other words, visual space analysis seems to be one of the main keys to investigate this control system and to understand relationships between different military structures and between these and other elements of the landscape.

Due to the data collected by Anna Guarducci, Marco Piccardi and Leonardo Rombai in the context of the PERLA European Project, it has been possible to investigate the visual space of more than 160 structures such as fortified settlements, fortress, towers and military houses in the coastal belt of Tuscany. Inter-visibility, cumulative viewshed and other visual and spatial analysis has been carried out to investigate, in different periods, this ranked system and his relationship with other elements of the landscape. A further elaboration concerns the reconstruction, through the use of historical cartography, of the perceived landscape in different periods. Moreover 'holes' in the global visual space and inter-visibility network may indicate lacks in the documentation or the presence of unknown structures. In addition to the visual space of the structures, the visibility from/to the connecting military road network, derived from historical cartography, has been analysed.

FORMAL APPROACHES TO VISIBILITY ANALYSIS IN ANCIENT ARCHITECTURAL SPACES
AND CULTURAL LANDSCAPES

POSTER

- Authors** Ying Zhou, Mingquan Zhou, Wuyang Shui, Wei Wang, Zhongke Wu
- Title** *Segmentation of Ancient Chinese Architecture Point Cloud based on Parallel k-means Clustering*
- Abstract** Ancient Chinese architecture is one of the treasure of Chinese culture heritage, whose digital protection has drawn great attention to the Chinese society through the years. It is a common protection method to obtain point cloud data of ancient Chinese architecture by 3D scanners. Segmentation of the obtained point cloud is a key problem in the process of ancient Chinese architecture 3D point cloud data. Clustering is one of the most popular methods of point cloud segmentation, while k-means clustering is recognized as one of the most efficient algorithms of clustering. However, the scale of point cloud data of some specific ancient Chinese architecture could be rather large, such as Temple of Heaven and Potala Palace. Therefore, the traditional k-means clustering might fail in the efficiency of segmentation of point cloud and could not give out a satisfying result.
- This article presents a method of segmentation of ancient Chinese architecture point cloud based on parallel k-means clustering. The complexity of time and space has been the bottleneck of the traditional k-means clustering when dealing with a large scale of data. This article solves the problem by combining k-means clustering with the ideology of parallelism. With the application of parallel k-means clustering, the point cloud of ancient Chinese architecture, whose data scale is usually considerable large, can be segmented within an acceptable range of the expense of time and space. As a result, independent components, such as walls, door and windows, can be recognized from the entire architecture point cloud. This article proves the accuracy and effectiveness of the method by the means of experiments. The contrast between the performance of the traditional and parallel k-means clustering in the segmentation of ancient Chinese architecture point cloud shows the advantage and improvement of the latter. The result of segmentation will provide effective support for further process of ancient Chinese architecture point cloud, such as analysis and reconstruction.

SESSION 4D: 3D RECONSTRUCTION, ANALYSIS AND IMMERSIVE TELEPRESENCE AT ROCK-ART SITES

POSTER

Authors **Guoguang Du, Mingquan Zhou, Zhongke Wu, Wuyang Shui, Pengbo Zhou, Pu Ren**

Title ***Image aided repair for Tibetan Architecture Reconstruction***

Abstract

Tibetan Architecture is the unique architecture around the world, which is in coordinate with the religion and the climate there. It contains dwellings, manor, palace, temple, gardens and so on, of which regular windows, curtains, stairs, and pagodas are the remarkable features. In this paper, we focus on the need for obtaining complete architecture point cloud data for Tibetan Architecture. Our approach utilizes the full potential of patch-based Multi-view Stereo algorithm (PMVS), an outstanding state-of-art multi-view stereo reconstruction algorithm, by finding the relationship between the reconstructed 3d point cloud data and the 2d image pixel data. After mining the image segmentation and symmetry information, we can repair the 3D correspondence parts accordingly. The initial point cloud data, which is reconstructed using PMVS, contains some incomplete parts due to the symmetry and highlight regions that exist in the images since it will appear mistakes in the feature matching stage. Simply using PMVS can't get a perfect and complete model.

The structure of the paper is as follows. First, we take photos of Tibetan Architecture from multiple views and use PMVS to achieve initial dense point cloud data of Tibetan Architecture with some missing parts. Second, we calculated the relationship between the 3d point cloud data and the 3d image pixel data using the information PMVS generated, which contains every camera parameters and the 3d point's visible information in the images. After back projection, we can find which image's which pixel contributes to the reconstruction of one 3d point. Third, we manually do image segmentation on the photos used in reconstruction and obtain image regions where particular assets were found and acquire the pixel region that contains the particular asset. Finally, by finding the point cloud which is reconstructed from the selected image region and according to the unique symmetry characteristics of Tibetan Architecture and the symmetry characteristics detected in the images, we can make up for the missing parts in the point cloud and obtain the complete dense point cloud for the Tibetan Architecture.

Our method uses images as input and can get a considerably complete and dense point cloud instead using Li-DAR based scanning method. Using multi-view stereo method can easily find the relationship and assist a lot in the repair for the missing parts. We conduct experiments on several datasets which contains the forehead of famous architecture, the Potala Palace, Drepung Monastery, Sera Monastery and some civil houses. The repair results show that our repair pipeline can significantly improve the reconstruction result.

Authors **Pu Ren, Mingquan Zhou, Guohua Geng, Wuyang Shui, Chunhong Wang**

Title ***Rule-based Rapid Modeling Method for Chinese Pagodas***

Abstract

This paper presents an efficient method to create the 3D digital models of Chinese pagodas, which can be used in 3D printing. The Chinese pagoda is a tiered tower, built with specific forms and often found in Buddhist temples. Because of their beauty and historical value, modeling of Chinese pagodas is one of the most important works in the culture heritage digital protection areas.

There are two traditional methods of 3D modeling: manual modeling and automatic modeling. The manual modeling can generate accurate and complicated models, but it costs a lot of time and manual operation, which leads to a long cycle of engineering. The other method can automatically generate the models controlled by programs. However, there is few algorithms reach on the Chinese pagodas. Due to the regularity of Chinese pagodas, a rule-based rapid modeling method is proposed in this paper.

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To get the pagoda model rapidly, a system for 3D scene editing was implemented as a platform. The method consists of 4 steps: firstly, a component model library and a corresponding rule library are organized in the editing platform. Secondly, three kinds of retrieval methods are provided including direct searching, sketch retrieval and semantic retrieval. Thirdly, once the components we need (e.g. pedestals, walls and windows, brackets and roofs, beams and columns etc.) are chosen, a pagoda generating rule could be adopted to assemble these components by resetting their positions in 3D space. XML code was used to control the components with different semantic information to come to right positions, such as the roof must be on the top and the pedestal should be at the bottom. Some interactions can be adopted to optimize the components to fit the final model. Finally, the generated pagoda model can be exported for 3D printing. Because of the fast generating speed of our method, it can greatly shorten the cycle of model making and virtual scene building.

Above method has been applied to rapidly create the digital models of ancient Tongzhou, which is a district of Beijing, China now. This project mainly exhibits the scope of old areas of Tongzhou, including the grain transportation terminal area, some key relics (including a pagoda) and older streets. In addition to the digital virtual roaming in computer, all these models were printed out by 3D printer to form a sand table so as to be better displayed at the tourist attraction. Compared with the traditional modeling method, our method is faster with higher accuracy. The result of our method can be used to not only virtual roaming, but also 3D printing.

- Authors** Emanuel Demetrescu, Daniele Ferdani
- Title** *Best practices in archaeological 3D reconstruction: the case study of the Mausoleum of Romulus in Rome.*
- Abstract** In the summer 2013 the Institute for Technologies Applied to Cultural Heritage of the National Council of Research (CNR-ITABC) performed, within the 3D Icons European Project, an accurate 3D survey of the Mausoleum of Romulus placed along the ancient Appia road (Rome). The survey has integrated several scanning technologies, from laser scanner to photogrammetric solutions (both spherical and perspective photos) [Adami et Al. 2014].
- The building, one of the most impressive and complex funeral monument of the late roman period, has been surveyed using integrated 3D technologies for the first time, allowing an accurate geometrical documentation to be obtained.
- This gave research prospective a boost to new possibilities and reconstructive hypotheses. The paper will focus, with a critical approach, on current methods and practices in 3D reconstruction visualization. In particular the authors will highlight new possible ways to represent the processes involved in the hypothesis-making and validation.
- Furthermore, special attention will be paid to the interpretation workflow (data collection, management, sharing procedure inside the working team) and to iterative processes (from the archaeological record to the 3D representation and viceversa) as well as to the visualization of different hypothesis. Finally, the paper handles different approaches to publish the paradata of the archaeological reconstruction with special attention to formal solutions and online 3D digital libraries publishing.

POSTER

Authors Wei Wang, Mingquan Zhou, Wuyang Shui, Yi Zhou, Zhongke Wu, Ying Zhou, Kang Wang

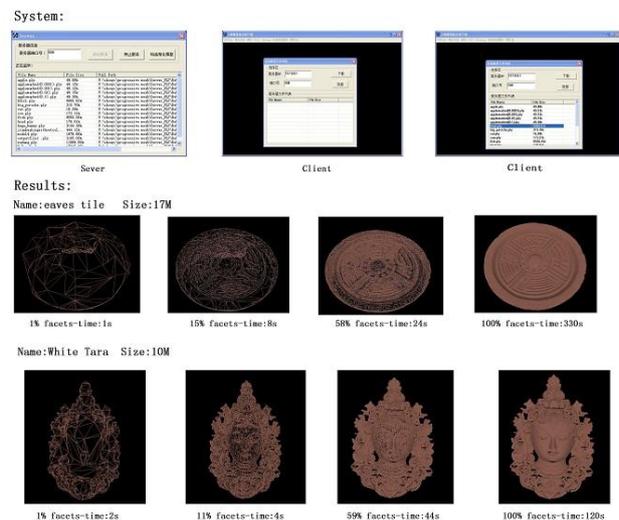
Title *Artifact models Simplification and progressive transmitted encoding*

Abstract

With the rapid development of computer graphics, the three-dimensional model processing technology draws increasing attention. Especially in the domains related to archaeology and heritage, the three-dimensional models technology plays a vital role. In order to maintain the reality of models, meshes with higher complexity and accuracy are in demand. Especially when it comes to 3D cultural heritage models, most of them are obtained by scanning which results in a large amount of data. In this way, there exist some restrictions among the protection, storage and transmission of 3D cultural heritage models. To solve these problems, we adopt level of details technology to perform the complexity artifact models remote under the remote narrow-bandwidth environment.

Aiming to simplify and transport 3D cultural heritage models, this paper propose a LOD method and develop a prototype software system. According to the characteristics of 3D cultural heritage models, and by analyzing and summarizing the existing algorithms of 3D mesh model simplification, an improved mesh simplification algorithm is proposed which is based of edge collapse and suitable for progressive transmission. Firstly, on the base of Garland's method, we import triangle importance degree as weight factor and define the cost of edge collapse. Secondly, for the purpose of keeping the outline features of cultural models, we further process the model with genus by increasing the boundary vertexs' weight. After that, we save the related information into two files. One file called base file is utilized to save the information of the most simplified model, and the other called collapse file is to save the collapse information of the model. In the collapse file, we record the start and end points of every deleted line, the number of triangles being impacted or deleted and these triangles' information including the index number of triangle and the index number of each vertex. When transmitting the models, we take advantage of LZ77 algorithm and Huffman code to compress the transmission data. As we reduce the amount of data, the transmission speed becomes faster. The system is on the foundation of TCP/IP transport protocol and C/S mode.

We apply this method to a lot of models, and the results show that the simplified algorithm and data compression method are very effective in presentation and transmission of 3D cultural heritage models.



POSTER

Authors **Jorge Angas, Manuel Bea**

Title ***Virtual restitution of the destroyed Levantine rock art shelters of Matarraña region (Teruel, Spain)***

Abstract

The Levantine rock art shelters of Roca dels Moros and Els Gascons (Cretas, Teruel, Spain), that initiated the official discovery of the Levantine style, were destroyed in the beginning of the XXth century. The splendid deer figures from the first site were sold to the Museum of Archaeology of Catalonia, where they are still exposed. The paintings from the second shelter were totally destroyed during the extraction works. Currently, in these rock art places it is only possible to see the extraction tracks on the walls.

The aim of the present project is to carry on a virtual reconstruction of the rock art shelters. We have scanned the shelters on the field and the paintings that remain in the Museum, by using different kind of scanners (phase-shift and structured light) and photogrammetry, in order to create a virtual 3D model of the sites identical to them before they have been removed.

We have also carried out digital tracings of the preserved paintings and also a digital restoration of the motifs. These works have been carried out by using digital tools, the final results have been applied to the 3D virtual model to obtained a photorealistic tridimensional model of the rock art shelters, having the look they had have at the moment they were made.

The final focus is to integrate all this graphical information in a web platform available both for computers and portable devices (smart-phones and tablets), in order to give people the possibility to make a virtual visit from anywhere, also in the field close to the rock art sites, having a real vision of the rock-art not just in its current state preservation but as if it had been recently depicted. In this way, the visitor can see the paintings in the same way as the prehistoric artist saw them.

SESSION 4E: FROM 3D SCANNING OF
OBJECTS AND MONUMENTS TO
AUGMENTED REALITY THEORETICAL
AND METHODOLOGICAL ISSUES OF
ADVANCED 3D IMAGING
TECHNOLOGIES

FROM 3D SCANNING OF OBJECTS AND MONUMENTS TO AUGMENTED REALITY THEORETICAL AND
METHODOLOGICAL ISSUES OF ADVANCED 3D IMAGING TECHNOLOGIES

POSTER

- Authors** **Mario Alaguero, David Checa, Andres Bustillo**
- Title** *Learning the lessons of history: the augmented reality of the Mosque of Burgos in the Spanish Civil War*
- Abstract** Historical perspectives have often imposed the values of one culture over another following strife and military conflict. Thus, history lessons may narrate only one side of the story, owing to the gap between historical narratives. One such example may be found in Burgos; the capital city of the Nationalist forces during the Spanish Civil War (1936-39). The Nationalist movement led by General Franco defended the Catholic religion as a basic tenet of Spanish culture, nonetheless it recruited many Muslims troops from the Spanish Sahara. In recognition of their services, an old hospice on the pilgrim's way to Santiago de Compostela that passes through Burgos, was converted into a hospital and mosque. Moreover, a sculpture of the apostle Saint James mounted on horseback, trampling Muslims underfoot, above the entrance to the hospice, was diplomatically hidden from sight during the years of the Spanish Civil War so as not to offend the Muslim population, in a city that came to symbolize the military prowess and the Catholic fervour of the Francoist regime. This topic serves to develop historical views on the manipulation of past events among secondary school students. The first step of the teaching activity proposes a virtual reconstruction of the mosque on a augmented reality platform, as younger generations are more open to visual concepts transmitted by new technologies than they are to traditional lectures. The visualization of the 3D model through augmented reality in its original situation is intended to bring home the events to students that took place 80 years ago. This temporal proximity stimulates the students to absorb abstract knowledge through virtual reality. The study seeks to measure whether the learning environment created with augmented reality affects learning rates. Students therefore attended two presentations: both groups listened to a talk on how history can be manipulated and distorted, only one of which went on to interact with the augmented reality platform following the same talk. The results of this study identify the advantages and critical points of this technology applied to stimulate the critical thinking of young students in relation to abstract historical concepts, through an example of local history from their own city.
- Authors** **Carlo Battini, Giovanni Landi**
- Title** *Augmented Reality e Virtual reality with mobile devices*
- Abstract** This work shows a Virtual Reality application obtained from 3d datas collected with a xxx laser scanner. Modern realtime 3d engine allow the researchers to manage complex three-dimensional models even on mobile devices, providing the ability to navigate these data interactively and immersively. The collected data are visualized immersively through to a GoogleCardboard head mounted display and a realtime 3d mobile VR application or augmented reality. The project examines the Cappellone degli Spagnoli in the Church of S.M.Novella in Florence. The user experience is designed to help the users to better understand the peculiarities of the frescos contained in the chapel. Users can turn their head around in 360 and examine every detail of the frescos as they were standing in the center of the chapel. Having no other input for the application apart from head orientation this work explores a particular selection mode: looking for more than 4 seconds in particular points of the environment gives acces to an extra layer of explanatory content about the represented episodes and the art of the frescos.

SESSION 4F: GEOMATICS APPROACHES IN LATIN AMERICAN ARCHAEOLOGY: THE STATE-OF-THE-ART IN SPATIAL ARCHAEOLOGY

GEOMATICS APPROACHES IN LATIN AMERICAN ARCHAEOLOGY: THE STATE-OF-THE-ART IN SPATIAL ARCHAEOLOGY

POSTER

- Authors** **Tiago Attorre, Paulo DeBlasis**
- Title** ***Ground Penetrating Radar and GNSS-RTK as tools for mapping, imaging and modeling large archaeological structures surrounding Coastal Shell Mounds in Southern Brazilian Coast***
- Abstract** The Southern State of Santa Catarina, in Brazil, contains the largest Shell Mounds found alongside the Brazilian Coast. These massive mounds, known as *sambaquis*, are actually burial grounds constructed between 7.500 to 2.000 years BP. As research developed in the last two decades, it became clear that such structures were the outcome of several activities that were taking place elsewhere. This perception led the investigations away from the mounds itself and into the very dynamic surrounding environment in which more conservative archaeological methods were not possible.
- By coupling a Leica Viva GS15 RTK and the GSSI Sir-3000 GPR we were able to detect, measure, map, and model buried archaeological structures within an active dunes field at the Figueirinha Region. These structures were not only made of shells, but of sand itself, as depicted in the clear stratigraphy captured in the GPR profiles. These sandworks seem to represent the various ways in which the mound builders dealt with the ever changing landscape present in the area.
- We will show how geomatics had a leading role, as well as implications, in how we managed to approach the geological and archaeological register at hand by proceeding with non-linear acquisitions within a linear represented space.
- Authors** **Daniel Alexander Contreras**
- Title** ***A history of digital data acquisition and analysis at Chavín de Huántar, Peru***
- Abstract** The monumental center of Chavín de Huántar in the Peruvian Central Andes has been the subject of mapping efforts for more than a century, and of digital mapping efforts since the mid-1990s. Spatial technology has been fundamental to significant revision of the site's construction sequence, definition and extent, and ultimately interpretation. This results from the site's complex, three-dimensional, and often-obscured architecture, mapping which has only become practical – and perhaps even possible – with digital tools. The array of technologies brought to bear over the last 15+ years (cf. Rick et al. 1998; Kembel 2008; Contreras 2009; Rick 2012) includes total station, high-precision GPS, satellite imagery, laser scanning, photogrammetry, near-surface geophysics, and kite aerial photography; data have been managed with *both* CAD and GIS. That rare duality resulted from the need to simultaneously manage complex, three-dimensional data and extensive, attribute-rich data, as well as distinct sets of research questions. This paper reflects on the respective contributions of these two strategies to the analysis of complex architecture, teasing apart the relative contributions of different strategies of digital data acquisition and considering what analyses they have enabled, before contemplating the risks of digital representation becoming an end unto itself and considering, from the point of view of Chavín, what could and should be the next digital steps.

GEOMATICS APPROACHES IN LATIN AMERICAN ARCHAEOLOGY: THE STATE-OF-THE-ART IN SPATIAL ARCHAEOLOGY

POSTER

- Authors** **Patricia Castillo-Peña, Krassimir Iankov**
- Title** *Application of LiDAR and Photogrammetry in a “World Heritage” Archaeological Site: El Tajín, Veracruz; México*
- Abstract** Application of LiDAR and photogrammetry technologies in a “World Heritage” archaeological site declared by UNESCO means a new perspective in regional studies. To this study it was used an airborne LiDAR with a repetition frequency of pulses of 300 khz (or 300,000 pulses per second) with a plow-camera. During post-process, high accuracy digital model was acquired and also contours each 20 cm. Based in this geodatabase, amazing and interesting discoveries were made in last four years (Castillo Peña 2011, 2011^a), later 70 years of research in this archaeological zone with traditional methods. In this way we discovered astronomical orientations of main buildings, digital reconstruction emblematic buildings were made, landscape analyses and event of descending light phenomenon through “Niches Building”. This building, the most important from the ritual and architectural viewpoint. It was a bridge between men and Quetzalcoátl, the most important god around 900 d.C. in Mesoamerica. This paper is focused in show how this new tecnologies are changing the way of study and interpreting an archeological site og Gulf Coast of México.

- Authors** **Alex Augustus Kara**
- Title** *Of PostGIS and Peteneros: finding the interface between geospatial technology and Maya Archaeology*
- Abstract** The area once inhabited by ancient Maya civilization features a long and prolific history of interdisciplinary archaeological research. However, the area's strong archaeological tradition and forested, tropical setting obstruct the archaeological application of geomatics: a growing suite of technology critical to both the discipline's own evolution and its applications to the contemporary world. The introduction of airborne lidar imagery has transformed the nature of reconnaissance in the area but does not obviate ground-based survey. Archaeologists continue to depend on total stations and GPS devices to georeference excavation data and map areas lacking luxurious lidar coverage. Using this equipment presents issues that include recording accurately in heavy vegetation, operating technology in hot, rainy conditions, and managing workers.
- In summer 2014, The Motul de San Jose Archaeological Project initiated excavations at Chachaklu'um, an archaeological site in central Peten, Guatemala. Both a Garmin handheld GPS receiver and Trimble GNSS Rover were used to map natural and archaeological features as well as the corners of excavations. A Windows Surface tablet functioned as a data collector for the Trimble Rover. Social and natural factors frustrated the operation of these technologies, and attempted solutions produced mixed results.
- A PostGIS spatial database was created to maximize the data's long-term accessibility and integrity. This paper presents the ontology of this system, which is optimized to interface current archaeological with political practices in Guatemala. Users currently update and analyze data through the QGIS desktop GIS application. An original QGIS extension written in python provides tools specific to both the project's data formats and archaeological inquiry. This approach is compared to that of similar software, and the project's future is discussed. In addition, a two-dimensional map of the site was created for the project's field report and upcoming publications. These figures depict the topography, ancient structures, and precise locations of individually labeled excavation units.

The database additionally features a diversity of images captured by aerospace remote sensing

SESSION 4F

GEOMATICS APPROACHES IN LATIN AMERICAN ARCHAEOLOGY: THE STATE-OF-THE-ART IN SPATIAL ARCHAEOLOGY

POSTER

platforms. Analyzing this gamut of geo-information illuminates how Chachaklu'um's ancient citizens selected and then manipulated their natural surroundings and how this center interacted with the broader region's political and economic system. This research demonstrates how geomatic techniques can effectively interface with traditional yet rigorous archaeological practice in a manner that enhances anthropological inquiry about the data. Finally this paper presents plans for the 2015 summer field season and suggestions for integrating geomatics and archaeology in tropically situated, developing countries.

SESSION 5A: MODELLING
APPROACHES TO ANALYSE THE
SOCIO-ECONOMIC CONTEXT IN
ARCHAEOLOGY

POSTER

- Authors** Karim Sadr
- Title** *Methodological issues in the classification of stone-walled structures and their effects on modelling the socio-economic organization of pre-colonial communities in the southern Gauteng Province, South Africa.*
- Abstract** The Southern Gauteng Stone-Walled Structures (SGSWS) project has been investigating the distribution of pre-colonial structures in a >8000 km² study area in South Africa. Over 7000 such structures have been identified, classified and digitized on satellite imagery by a dozen research assistants. Preliminary results indicate a socio-economic sequence from relatively dispersed, egalitarian and pastorally oriented communities in the 17th century AD to highly aggregated towns of ranked and more agriculturally oriented communities around the turn of the 19th century AD, followed by collapse and a return to simpler, smaller scale communities in the first half of the 19th century AD (Sadr & Rodier 2012). Understanding the forces that drove this sequence is the main aim of the SGSWS project.
- Several ancillary aims of SGSWS are methodological and this presentation concerns one such side-project: To what extent do the typology of stone-walled structures and the inter-analyst variability in identifying and classifying these structures affect the socio-economic interpretations? These are common issues faced in the methodological process of having several research assistants analyse remotely sensed data, and a host of geospatial techniques can be used to assess the accuracy and precision of their outputs. In this presentation, several questions are addressed specifically to the region-wide distribution of a particular type of pre-colonial stone-walled structure, the so-called Type N or Group I ruins dating to the 17th century AD. These questions include: How useful is the standard typological definition for Type N or Group I structures in view of the classification of actual data by several different research assistants? How well does a modification of the standard typological definition of Type N/Group I structures help to decrease inter-analyst variability in the identification and classification of these ruins? To what extent do the analysts' different outputs affect the validity of socio-economic interpretations of past communities? These questions are answered by using spatial statistical analyses to compare the different outputs and measure their similarities and differences.
- Currently the results of this on-going study suggest that even a high degree of inter-analyst variability at the level of identifying and classifying individual structures does not greatly affect the large scale interpretation of socio-economic organization of the past communities; that improved typologies help to reduce inter-analyst variability but prevent certain types of spatial analyses by drastically reducing the number of classified structures; and that studying such inherently 'fuzzy' data benefits from combining results from different approaches, in this case the results from the analysis based on the loose standard typology and those based on the stricter modified typology.
- Authors** Raffaella Da Vela
- Title** *The Romanization of Northern Etruria as a breakdown of the social network of the minor settlements*
- Abstract** The Romanization of Northern Etruria is a long and complex process that concerns the political organization of the Etruscan cities, their social structure, the local economy in relationship with the global one. The crucial questions I look forward to answer with the Social Network Analysis (SNA: Hennig et al. 2012; Wasserman – Faust 1994;) in these geographical and cultural area are the following: Which is the connecting role of the minor settlements and how

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do they participate in the circulation of goods, ideas and models? How does the perception of Etruscan cultural identity and the related affiliation among Etruscan cities interact with the economical and political needs (Straus – Hofer 2010, 201–203)? How do the Roman politics and economy interact with the network of the Etruscan minor settlements? Is it possible to describe the Romanization as a breakdown of ties between cities and minor centers? Aim of my research is the description of the chronological evolution of the longitudinal network of north Etruscan cities and minor settlements during the Romanization (Heidler 2010). As relational ties between these settlements I assume: transfer of material (coinage, ceramics, metal products: Ambrosini 2008) and immaterial (ideas, iconographies, models) resources and products; association or affiliation (in the social and in the civil wars); behavioural interaction (economical agreements, political pacts); mobility (migrations; marriages; familiar alliances through epigraphic records: Maggiani 2009); physical connections (route-systems, sea-ways, visual long-distance communication: Cresci – Viviani 1995; Cambi 2012). My analysis will observe the regional and local dimension of the longitudinal network of these cities and suggests a graphic interpretation of the historical and archaeological situation through the softwares Ucinet (Borgatti et al. 2002) and Cytoscape (Shannon et al. 2003). From the methodological point of view I look forward to present a topographical construction of the network graph and the possibilities and limits of the application of SNA to a dynamical archaeological context. In particular I am interested in the question which aspects are more conditioned from the choice of the level of observation (dyadic, triadic: Trappmann et al. 2011; ego-centered and full set level).

- Authors** Arne Anderson Stamnes
- Title** *Assessing the Effect of Temperature Change on Iron Age Crop Production and Settlement Patterns in Mid-Norway – a Geostatistical Model*
- Abstract** This paper will concern the relationship between available land for cultivation and settlement patterns, and the consequence and potential effect temperature changes had on the settlement pattern in the Iron Age of central Norway. Temperature, and more specifically the accumulated temperature sum (“*døgngrader*” in Norwegian, ACT abbreviated), is an important indicator for the potential of getting ripe crops. By calculating the ACT values at different locations, it is possible to geostatistically model and create maps in a GIS showing how varying temperature conditions affect the arable areas. The results of this can be drawn into a discussion concerning the effect of changing climate conditions on settlement patterns. What is the liminal zone for crop production at a specific time, in what regions would such a temperature change have the most effect, and would the effect of temperature change in have any effect on subsistence strategies? This paper will demonstrate how GIS-systems can be a powerful tool for analysing and model past climatic conditions, that could reveal important information which might not have been accessible in the same manner before.

- Authors** Craig Alexander
- Title** *Rock-art, land-use and settlement in Iron Age Valcamonica*
- Abstract** The likely population of Iron Age Valcamonica is estimated in a GIS environment on the basis of a land supply/demand model. Habitation locations are predicted on the basis of a rare-events logistic regression model. Given likely habitation sites, land-use patterns are determined on the

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basis of diet and land suitability to various activities (crops/pasture/hunting and gathering).

Rock-art sites are examined in terms of their position in the recreated socio-economic landscape. The implications for the significance and origin of the rock-art are discussed.

Authors

Valeria Acconcia, Serafino Lorenzo Ferreri

Title

GIS analysis for the identification of land use in inland Abruzzo from the Iron Age to the Romanization

Abstract

The inner regions of central Appenine range constitute a peculiar natural habitat, characterized by strong geomorphologic discontinuities. Here, ancient settlement was progressively adapted to exploit its resources and to reduce the effects of the environmental complexity. In this terms, the region gravitating around the Medieval and modern town of L'Aquila, in Abruzzo, formed by wide valleys delimited by the south-western slopes of the Gran Sasso range, represents an explanatory case-study for this topic, which can be applied also to other inner areas.

Still nowadays, the inner Abruzzo region preserves specific cultivations, more resistant to low temperature and poor terrains, selected from those prevalently diffused in plain and wide habitats, more productive but also hardly adaptive to mountainous lands. From Pre-roman times, this area also preserve a "pastoral" vocation, although relevant changes interested the ranges of transhumance processes: from a "short-distance" pattern, characterized by short seasonal moving of cattle from low to high lands of the same region, to a long distance one, moving from the Tyrrhenian side of the Appennine range to southern Adriatic low lands, from Roman times up to Middle Ages.

These characters first appeared at the end of Bronze Age, in coincidence with clear archaeological and cultural cuts in pre-existing settlement pattern developed from Neolithic period: characterized by the occupation of the valley floors by small open sites along waterways and around lakes.

From Final Bronze Age, local communities changed not only their settling strategies (moving from the valleys to the heights) or their internal organization, but also their production systems and exploitation strategy. The occupation of the mountain tops was functional to the control of the valleys, occupied by wide funerary areas and used as passage ways.

This phenomenon was connected to the growing of a new and clear social order, organized by medium-scale groups, representing themselves in an "eterarchic" way, as a rough and strict community of warriors.

The Roman conquest radically changed this framework, depopulating the heights and occupying with a nucleated settlement pattern organized around new cult and administrative places (the so-called "pagano-vicanico" system) the plain areas, better controlled by the central power of Rome.

Most of these problems should be defined by field research and excavations of inhabited sites and funerary areas, but at the moment we can suggest solid hypothesis about the settlement patterns in mountainous areas, in respect to landscape organization and to natural resources exploitation.

In this sense, we will try to apply GIS-based analysis models to this area, to implement the knowledge of this settlement basins, their control by local communities, the development of landscape towards natural geomorphologic characters and its productive potential. These models will be applied to Pre-roman and Roman times, to evidence changes and specific strategies in land use, connected to changes in political and social orders.

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- Authors** Giuseppe Muci
- Title** *Evaluating the crisis: population and land productivity in Late Medieval Salento (Southern Apulia)*
- Abstract** The paper illustrates a theoretical model designed to investigate the ongoing complex demographic and economic dynamics in the interval between Middle Ages and Early Modern period in southern Salento (almost corresponding to present days Lecce district in Apulia).
- Archaeological data and written sources show that in the period between the fourteenth and the first half of the fifteenth century Europe witnessed a period of massive economic and demographic crisis (see Russell 1985). For example, excavations and surveys in Greece show that the town of Corinth experienced a total decline and nearly all the small villages in existence during the eleventh to thirteenth centuries were abandoned in the fourteenth century (see Bintliff 2012). This “catastrophic” phase led to a large scale transformation in socio-economical systems, which opened the road to the European demographic growth of the sixteenth century.
- As happened in the rest of Europe, southern *Terra d’Otranto* underwent a large population decline and disintegration of the pre-existing early medieval settlement pattern: according to Visceglia (1988) the number of villages (*casalia*) decreased by 1/3 in the period between 1350 and 1450. The negative conjuncture seems to end around the middle fifteenth century, when a marked demographic and economic recovery, continued until the second half of the sixteenth century, is clearly evidenced by written fiscal documents (*focolaria*) (for example see Da Molin 1979).
- The proposed model, based on a large amount of data collected through archaeological excavations, surveys, historical sources and geographic datasets, all implemented in a GIS environment, tries to understand the “crisis and recovery” dynamics which characterized the transition from Medieval to Early Modern Salento (Arthur 2010). The performed spatial and quantitative analyses focuses on the relationship between population fluctuations and average productivity of cultivated land, estimated on the basis of Archaeological Land Suitability Classification derived from FAO Land Evaluation methodology (FAO 1976; for an archaeological application see Van Joolen 2003).
- The resulting theoretical model can be read through the lens of “resilience theory”, which provides a conceptual framework to understand transformations in socio-ecological systems (Holling 2001; Redman, Kinzig 2003). In this key “crisis and recoveries” may represent different phases of an “adaptive cycle”, and the new settlement pattern that emerged in Early Modern Salento could be the “tangible” effect of specific economic choices adopted as a response to late Medieval subsistence crisis.
- Authors** Andrea D'Andrea, Rodolfo Fattovich, Andrea Manzo, Luisa Sernicola, Gilda Ferrandino, Giuseppe Zollo, Antonella Palomba, Martina Graniglia
- Title** *Dynamics of the settlement pattern in the Aksum area (800-400 BC). An ABM preliminary approach*
- Abstract** From 1993 the Italian Mission to Ethiopia of the University “L’Orientale” (Naples, Italy) conducted a research project aimed at understanding the dynamics of man-environment interaction through the time. The main focus was also concerned with the process that led to the development of hierarchic societies and states, culminated with the rise of the kingdom of Aksum in the northern Ethiopia and Eritrea in the late 1st millennium BC. This goal resulted in intense research conducted from various perspectives: the collaboration of different specialists

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strand together in interdisciplinary and research field generated a huge amount of data, which is still increasing thanks to the ongoing investigations. The analysis and interpretation of data has brought to debates about the formation, consolidation and collapse of the hierarchic society in the Aksum region. Different factors have been considered as crucial for the explanation of the the environmental, social, economic and cultural transformations suggested by the archaeological evidence and hypothesis have been built to explain the process.

As the impressionistic comparison of qualitative and quantitative data demonstrated to be not fully satisfactory for the explanation of such a complex process, it is now time to address some important questions. Is a simple description of the possible hypothesis, data, factors and the events through time good enough to understand the human behaviour and human agency affecting the environment? How and why the man-environment interaction drove and constrained in a specific way the process and not in others? Is it possible to test the efficiencies of the prevailing hypothesis and theories? Moreover, in projects addressing these issues, it is difficult to take into consideration the lower levels that generate complexity: the behaviour of agents and the particular configuration of interactions between them. A crucial point of the question is how the data can be interpreted in this perspective.

Theoretically, such questions could be answered with the implementation of a model that could systematically take into consideration all the different kind of data and their systemic relationships. This model could highlight core dynamics, test the robustness of prevailing hypothesis, discover new aspects and even promote new questions by observing how simplicity could produce complexity. In this perspective, the collected data reveal a complex system, because they are the manifestation of a network of interactions. Finally, this model may also guide the data collection and a more problem-oriented future fieldwork.

In order to test the theories explaining the diachronic changes of the settlement pattern in the Aksum area, an interdisciplinary team, composed by African archaeologists from the University of Naples "L'Orientale" and engineers from University of Naples "Federico II", started a collaborative project of Agent Based Modelling simulation. Our team used the methodology of simulation at Agent Based Modelling, adopted since long time in the international scientific scenario, in order to create a dynamical settlement model of the earliest phases of development of the hierarchic societies in the region of Aksum (800-400 BC).

The model, based on paleoclimatic, paleoenvironmental, geological, archaeological and ethnographical data, simulates different settlement patterns describing the rate of growth of population, the demographic density and aggregation at a different scale also considering the real distribution of resources on the ground. This model demonstrated to be potentially useful for selecting the better interpretative hypothesis, as its outputs can be compared with real parameters observed in the available data. Moreover, new questions and issues emerged from the observation of tipping points which seem to determinate the rate and type of resilience of the simulated ecological system in the model.

Authors**Tim Murtha, Kirk French, Webster David, Chris Duffy****Title*****Landscape and Territory at Tikal, Guatemala*****Abstract**

This paper investigates the long-term spatial and temporal dynamics of land-use management, agricultural decision making and patterns of resource availability in the tropical lowlands of Central America, home to the Classic Maya. Combining diachronic environmental simulation with analysis of historic settlement patterns and environmental surveys, our new work is designed to address a series of long standing questions about the coupled natural and human history in the Central Maya lowlands, specifically at the UNESCO world heritage site of Tikal, Guatemala. We are examining changing patterns of land, water, population, settlement and political history for a 3, 000 year period using climate, soil, and hydrologic modeling and time-

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series spatial analysis of population and settlement.

For our project we are modeling the 3,000 year history of the region in five 100 year samples, comparing land and water availability to population distributions and examining what is known about political history in five 100 year time periods. The key issues we are studying is the role of niche construction during these periods and understanding the changing spatial and temporal dynamics of agrarian resource availability as compared to what we know about regional political and population history.

From what we've learned, early erosion initiated by the first settlements transformed the prehistoric environment, establishing resource patches that subsequent populations relied on, *i.e.*, pockets of soil adjacent to bajo (swamp) margins. Population size and density grew rapidly for 600 years (AD 250 to 850), while deforestation and erosion rates declined. During this period, a complex cultural and political system emerged and became tightly integrated to a carefully cultivated mosaic of environmental patches. There is striking evidence of political evolution, including the construction of monumental architecture, erection of hieroglyphic monuments detailing wars and alliances, and the construction of a regional territorial boundary, possibly delineating natural resource access. After this period of population growth and regional political stability, the political system fragmented, perhaps influenced by cultural niches or traditions of land use. This period was followed by population decline and reforestation in patterns now influenced by centuries of previous land use and landscape change.

By combining traditional archaeological approaches with formal environmental modeling, using SWAT and EPIC, we are beginning to reveal one of the world's most compelling landscape narratives of coupled natural and human systems dynamics.

SESSION 5B: CONTINUING THE
REVOLUTION WITH SPATIAL
METHODS & ARCHAEOLOGICAL
INTERPRETATION: THE HOW AND
WHYS OF SPATIAL ANALYSIS

CONTINUING THE REVOLUTION WITH SPATIAL METHODS & ARCHAEOLOGICAL INTERPRETATION:
THE HOW AND WHYS OF SPATIAL ANALYSIS

POSTER

Authors Karen Niskanen**Title** *Motifs in Finnish cliff paintings: distribution and contexts*

Abstract This research is a GIS study aimed at finding patterns in the distribution of the various motifs found in the Neolithic cliff paintings in Finland. Motifs found include anthropomorphs, zoomorphs, boats and a small number of abstract pictures. These motifs and their spatial distribution are examined in light of the archaeological contexts in which they are found. The associated sites and artefacts are considered to be integral aspects of the use of space and social structures. Of particular interest is the study of the archaeological contexts of sites with many motifs as compared with the contexts of sites with single motifs and the nature of the associated sites (e.g. burial sites, dwelling sites).

Authors Andrea Capecchi, Michele De Silva, Fabio Martini, Lucia Sarti**Title** *GIS applications and spatial analysis for the survey of the prehistoric northern Apennine context: the Mugello case study (Tuscany)*

Abstract This research is a study of territorial archaeology that takes advantage of information technology methods to examine the rich Tuscan context of Mugello area, on the Apennines mountains in the Florence province. This work intends to define a profile of the prehistoric settlement strategies in the area under discussion by the use of GIS based spatial analysis, starting from georeferencing published and unpublished data (coming from surveys by local archeological groups or from territorial museum and documentation centers).

The surveyed area is divided into higher Mugello, lower Mugello and the Sieve river Valley, for a total extension of 156 Km². The chronology includes all the evidences known on the territory from the lower Paleolithic to the final Bronze Age, counting 95 sites, corresponding to 114 chrono-cultural horizons.

The focal goal of the research is defining the main features of the prehistoric settlement strategies in the ancient Mugello region, highlighting the different dwelling choices diachronically and relating them with the climatic and environmental influences, the economical factors and the practical needs.

The methodology and the application of spatial analysis and statistic processing of the territorial data play an important role in this study. The following themes have been analyzed relating with their influence on the ancient settlement: altimetry, slope, orientation, yearly sun exposure, physiographic zones, geological classification, palaeoclimate, settlement typology, rank, chronology.

The creation of a relational database, along with the use of GIS applications, permitted an easy management of the large amount of data coming from a various, vast and ancient populated territory like Mugello, allowing the analysis of multiple features within a single interface. The work shows some originalities about the data archiving as well: the distinction between *site* and *horizon*, a new method for the chronology management based on increasing levels of accuracy and the insertion of a chronological assessment parameter.

The application of this methods finally brought to an overall understanding of the prehistoric dwelling dynamics in space and time, through a synthetic and relational description, by means of a characteristic analysis procedure.

The final framework defined by this research brings new elements of knowledge for the

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comprehension of the prehistoric Mugello, through an interpretation of the archaeological evidences supported by statistic and distributive data, able to outline the ancient settlement strategies and their development during the different ages of prehistory. A new point of view on the archaeological landscape of this area, no longer considered as series of isolated findings, but as the result of the peopling dynamics throughout the passage of prehistory.

SESSION 5C: ARCHAEOLOGICAL
THEORY AND STATISTICAL
MODELLING: BRIDGING THE GAP

POSTER

- Authors** Peter Oskar Pflaumer
- Title** *Distributions of Age and Death from Roman Epitaph Inscriptions: An Application of Data Mining*
- Abstract** Thousands of age at death inscriptions from Roman epitaphs are statistically analyzed. The Gompertz distribution is used to estimate survivor functions. The smoothed distributions are classified according to the estimation results. Similarities and differences can be detected more easily. Parameters, such as mean, mode, skew and kurtosis are calculated. Cluster analysis provides three typical distributions. The analysis of the force of mortality function of the three clusters yield that the epigraphic sample is not representative for the mortality in the Roman empire. But the data is not worthless. It can be used to show and to explain the differences in the burial and commemorative processes. Finally, the bias due to a growing population is discussed. A simple formula is proposed for estimating the growth rate. The paper discusses also some special parameter constellations of the Gompertz distribution, since in this special application it can not be approximated by the Gumbel distribution, which is often done in life table analysis.
- Authors** Elmar Schmaltz, Michael Märker, Felix Bachofer
- Title** *Stochastic modelling and comparison of fluvial landforming dynamics based on archaeological information of Palaeolithic sites in two intra-montane basins in the Northern Apennine*
- Abstract** The fluvial terrace landscape of the intra-montane Mugello basin in Northern Tuscany, Italy is characterized by three major Pleistocene terraces with Middle and Upper Palaeolithic artefacts. On the highest of these terrace, fresh artefact edges of the Middle and Upper Palaeolithic period can be found, which points to short transport distances of the material. In contrast, rounded material on the lower terraces indicates water related transport and hydro-erosive processes. Although, the middle find complex shows the lowest ratios of indeterminable artefacts, which leads to the assumption that these areas are not highly affected by hydro-erosive processes or long water related transport distances. Moreover, some of the find locations are characterized by loess deposits from glacial periods and/or a particular land use having a specific spectral reflectance.
- The spatial distribution of these three find complexes seems to be related to the topographic situation, the substrates and the respective hydro-erosive processes. This hypothesis was tested using a stochastic model simulating the spatial distribution of the three find complexes. The latter was used as dependent variable, whereas i) topographic indices, ii) results of hydro-erosive process models and iii) multispectral indices of ASTER-images were utilized as predictor variables.
- The model was validated internally and yield information on the most important triggering variables. Due to a good model performance also the spatial prognosis of find locations in similar environmental conditions is feasible. In this study we applied the model trained in the Mugello basin in another valley with similar environmental condition, the Casentino valley, which is also an intra-montane basin south-eastern of the Mugello valley.

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- Authors** Mauro Mazzei, Antonio Salvatori, Luciano Maria Rendina
- Title** *A Spatial Statistical Approach for the Territorial System of Marturanum Regional Park, Lazio (Italy)*
- Abstract** This work is based on an analysis of the main components derived from particular patterns of spatial statistical data referred to the Territorial System of Marturanum Regional Park in the Lazio Region (Italy). The reference models of spatial statistical analysis are extracted only from the data of bi-temporal aerial photographs. This methodological approach introduces a significant improvement in the evaluation of changes in the territorial archeology, providing a wider archaeological interpretation of problems of the area studied, encouraging a more analytical reading of complex archaeological and environmental phenomena. In order to improve reading and analysis of the territorial changes, it is necessary to compare the same geographical space in different moments that enclose a well-defined period of time.
- The territorial system of Marturanum Regional Park stretches from the North coast of Lazio to the ancient consular road Cassia. The Park is a territorial, sub-regional and interprovincial area that, since the past lived the Etrurian civilization, the Roman conquest, the medieval castling and the integration in the Pope State as administrative jurisdiction of the *Patrimonium beati Petri*.
- The Regional Park of Marturanum, established by Regional Law n. 41/84, has a surface of 1.240 ha. Its territory is characterized by the typical fluvial "forre", the landscape of hills, partially covered by oaks' wood. There are archaeological remains which: the Etrurian Necropolis of San Giuliano, with the the homonymous medieval settlement, and Caiolo, and other different locations identified with the name "Quarry of...". In particular, the San Giuliano Necropolis is the oldest and richest in rupestrian types tomb. The period of greatest flowering was in the VI century B.C. Tombs are therefore mainly of the Archaic period (VI - V. centuries B.C.), but there are also "tumuli" tombs of VII century. B.C. (Orientalising period) and tombs of the Hellenistic period.
- In addition to the "tumuli" tombs, other different types of tombs are visible as: cubes, with ridged ceiling, portico, hypogeal and niche tombs.

SESSION 5D: PREDICTIVITY AND
POSTDICTIVITY IN ARCHAEOLOGY:
REFLECTING AND DISCUSSING ABOUT
THEORIES, METHODS, AND TOOLS

PREDICTIVITY AND POSTDICTIVITY IN ARCHAEOLOGY: REFLECTING AND DISCUSSING ABOUT THEORIES, METHODS, AND TOOLS

POSTER

- Authors** Andrés Díez-Herrero, Luis M. Tanarro, David Álvarez-Alonso, María de Andrés-Herrero, Julio A. Rojo-Hernández
- Title** *A MCE-GIS based model for assessing the influence of abiotic factors on the spatial distribution of the paleolithic archaeo-sites in Central Spain*
- Abstract**
- The spatial distribution of human settlements and movement patterns during Palaeolithic times were mostly controlled by some environmental factors. Abiotic factors (e.g., geological, meteorological, hydrological) played a major role, because they conditioned the availability of refuge, water resources and raw materials for lithic industry; furthermore, abiotic factors controlled the biotic ones (flora and fauna), and then, the food resources. This work is focused on a detailed analysis of abiotic factors in Segovia (Central Spain) using multi-criteria evaluation (MCE) by means of geographical information systems (GIS).
- The analyzed factors were grouped in two objectives: a) abiotic factors that control the presence of settlements and movement patterns; and b) geodynamic factors. The first one (a), in turn, is developed in six geo-data sets: i) the relief and its anfractuosity (slope, aspect, mountain pass, fluvial corridors...); ii) the lithology and mineral resources (silica varieties-flint, hard rocks...); iii) the lithological geodiversity and its influence on soils, biodiversity and hunting resources; iv) active geodynamics (palaeofloods, glacial and periglacial processes, aeolian activity); v) the existence of caves and shelters (carbonatic and evaporitic rocks, granitic tors, conglomeratic overhangs...); and vi) the water resources availability (proximity of rivers, lakes, natural springs, shallow water table). The second group (b) is composed of two factor sets that govern archaeological site destruction or burial: 1) active geodynamic processes (e.g., fluvial, runoff, mass movements, glacial, aeolian, karstic); and 2) geomorphological stable areas or depositional zones (karstic filling, highlands, sedimentary basins...).
- Each factor was represented by a GIS layer, and all of them were integrated using map algebra (overlay) with the layer weights estimated using the Delphi method of expert polls (geoarchaeologists). The resulting map represents the potentiality of a given territory to contain Palaeolithic archaeological sites, depending on abiotic factors. This map has been compared with the location of known Paleolithic archaeological sites in order to calibrate the method. The substantial differences between the known positions of Paleolithic archaeological sites and the locations predicted by the proposed model will draw the need to reconsider the chosen factors and their weights; but subtle differences can be interpreted as the effect of other biotic or anthropic factors. To incorporate this later factors to the MCE-GIS based model, a third group of factors was added (c), focused on the possibility of the discovery of the archaeological sites, including: the degree of human disturbance (towns, infrastructures), the existence of specific studies (PhD dissertations, archaeological chart), and the possibility of site destruction (agricultural plowing, mining, urban growing).
- A new comparison of the modified map of potentiality of a given territory that contain Palaeolithic archaeological sites has let us to draw interesting conclusions on the method and its validity; at least when the model is enforced to the central part of Spain (Segovia district). The main applications of this model, besides of a better understanding of the spatial relations of the known archaeological sites, is that it serves to take predictive and protective measures for the heritage conservation in optimal areas before new infrastructure projects and plans are developed.

PREDICTIVITY AND POSTDICTIVITY IN ARCHAEOLOGY: REFLECTING AND DISCUSSING ABOUT THEORIES, METHODS, AND TOOLS

POSTER

- Authors** S. T. Stewart, Steven Edwards, Philip Hitchings, E. B. Banning
- Title** *Predicting Survey Coverage through Calibration: Sweep Widths and Survey in Cyprus and Jordan*
- Abstract** Many archaeological surveys make the assumption that a single fieldwalk by a survey team is sufficient to determine whether a space does or does not contain archaeological materials. Making retrodictive statements about site distributions or locational preferences relies on the accuracy of this assumption. We instead take the approach that the probability of detecting artifacts by fieldwalking is less than 1.0 and use calibration surveys to calculate survey teams' "sweep widths." Our calibrations took place in typical fields in which we "seeded" artifacts in known locations, but otherwise simulated actual survey conditions. Sweep widths, in combination with knowledge of the total length of transects walked, then allows us to calculate survey coverage. In prehistoric surveys in Tremithos Valley, Cyprus and Wadi Quseiba, Jordan, continually updated estimates of coverage and its effect on the probability that survey areas contained undetected sites were crucial elements in survey planning, execution and evaluation.
- Authors** Andrea Patacchini, Simone Moretti, Giulia Nicatore
- Title** *Potential paths and historical road network between Italy and Egypt: from predictive to postdictive approach.*
- Abstract** This paper focuses on a series of three case studies to evaluate the historical road network between two known centres, through the combinations of a predictive and a postdictive approach. We developed and tested the procedure in three different geographical areas: southern Tuscany, northern Lazio and the king's valley in Egypt. Our work consists of three main steps. The first one is predictive. We evaluated the movement in a given context and period. In this phase we produced several potential paths between two settlements, by changing the weight of the environmental and cultural factors. In the second step we verified the forecast directly on the field. The fieldwork is a crucial step to get the necessary information to establish the reliability of the simulations processed. The last step is postdictive. We change the question and we ask why they used exactly those paths. In these case studies we integrated all the available data, including those obtained during the survey. We modelled several cumulative cost surfaces to produce a simulation that overlaps as much as possible the historical paths. Thus, we can understand and evaluate which were the key factors that constrained the routes network.
- Authors** Nevio Dubbini, Gabriele Gattiglia
- Title** *What is the archaeological potential? A computational definition*
- Abstract** Archaeological potential is a term used to describe the likelihood that a more or less significant archaeological stratification is preserved in an area. The archaeological potential is given by a predictive model, where the outcome (the Map of Archaeological Potential) is a measure of the importance of the archaeological remains buried in areas where we have partial or no information available.
- By "projecting" information, through statistical and mathematical processing, on areas for which there are no available data, the map of archaeological potential make predictions about

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the greater or lower chance of human and environmental presences in these areas, and even on the type of presences. Archaeological potential is computed by studying and analysing a series of historical-archaeological and paleo-environmental data, with a degree of approximation that may vary according to the quantity and quality of the data provided, and their spatial and contextual relationships. Thus the archaeological potential makes use of predictive modelling, and it is a predictive model itself.

The aim of this work is to give an operational definition of archaeological potential. Namely, a definition explaining what are the parameters and how they contribute to the formation of the archaeological potential, but at the same time an operational procedure to define and combine those parameters, in order to be algorithmically implemented. To this aim, we define at a conceptual level what the archaeological potential is, and how it should be evaluated and measured.

Therefore, a setting to handle the problem of archaeological potential basically should contain the following main kind of information:

1. The characterization of the parameters influencing the archaeological potential, and a quantitative description of how the measure of the archaeological potential is created on the basis of these parameters. At this stage, it has to be considered that archaeological potential can be computed in different ways, depending on the aim of evaluation, and according to different philosophies of interpretation. An operational procedure must take into account all this flexibility together with rigorous algorithmic steps to follow, in order to let archaeologists to implement such a procedure.
2. A set of initial conditions, representing available data. Together with the description of the parameters influencing the archaeological potential, we have to quantify the available data, in the form of inputs for a predictive model.
3. A predictive model combining the available data and inductive/deductive rules, in order to produce as output the estimated archaeological potential. Whatever the model chosen, it has to be supposed that the output is an *estimate* of the archaeological potential. More precisely, only if all the data were available in all areas, one can compute the “true” value of the archaeological potential. Instead, in practical cases, the predictive model can only give an estimation of the “true” quantity, based on the available data.

Authors**Augusto Palombini, Cinzia Tavernari****Title*****On their way back home... Geostatistical analysis applied to medieval caravanserais distribution in the the Syrian region.*****Abstract**

The commonly diffused theories on caravanserais state they were usually built at about one-day march distance (30 km) each other.

Despite such a simple pattern may well fit to some situations, it does not reflect the situation in Syria during the Ayyubid (1174-1260) and Mamluk period (1260-1517), when most of the region's caravanserais were founded. Caravanserais built in this region during such period do not seem to follow a precise pattern of distribution along the communications axis that stretched all over Syria. Some caravanserais appear to be built only 10 km apart, while other stand at more that 40 km one from the other. Notwithstanding the on field researches

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undertaken in the last few years, the logic that underlines caravanserais' distribution in the Syrian region during the medieval period remains unclear.

The authors try to face the problem through a GIS-based geo-statistical approach taking into account the building period of each structure and the distance to its nearest neighbour also in relation to the closeness to large urban centers.

The results present interesting aspects both in terms of understanding of route organization and of predictive methods for focusing new areas where structures not yet located may be expected.

- Authors** **Marcus Asserstam**
- Title** ***Predictive modelling for pioneer settlements in eastern middle Sweden***
- Abstract**
- The Swedish area offers a unique environment for studying pioneer settlements during the Mesolithic. When the weichselian ice-sheet retreated, new uninhabited land opened up setting a terminus post quem for human exploitation. This provides an opportunity to identify migration routes, and times of areas being settled, through landscape reconstructions from the archaeological record. The area of focus in this study is Torsåker, Gästrikland, eastern middle Sweden. The first archaeological evidence of humans in this area is a handle core in quartz that is shore-line dated to the pioneering phase. This is evidence of the existence of pressure blade technology, an advanced technology seen to have only one innovation area, most probably in the Baltic/west Russian area. This means that it has spread through migration or diffusion, and since this is the earliest findings of humans in the area, it can be argued to have spread through migration.
- On this basis a predictive model for the area around Torsåker is constructed, from a database of the Swedish west coast and Norwegian south coast, which is the closest contemporary area where pressure blade technology is present, and possibly the origins of the first humans in Torsåker. Several of these sites have been heavily altered due to modern exploitation. To enhance the quality of the statistical analysis, the topography for the altered sites has been reconstructed before calculating the landscape topographic statistics, in order to get a more representative picture of the prehistoric landscape. The analysis will be made using a combination of ArcGIS and R.
- By using predictive modelling, the goal of this study is to identify possible new sites from the pioneering phase of eastern middle Sweden, that will be validated through ground truthing. By doing this, it might be possible to argue for potential migration routes and also to get a better understanding of the usage of landscape by the first humans in the area.

- Authors** **Laura Morabito, Giovanna Pizziolo**
- Title** ***Postdicting and predicting Proto-history: a case study from Central Italy***
- Abstract**
- In this contributions authors will present a workflow based on postdictive analysis as a foundation for future predictive verification on the field. The selected case study concerns the territorial context of Northern Tuscany and Emilia Romagna during the Bronze Age. One focal point of the contribution will be the analysis of possible ways of communication and cultural

SESSION 5D

PREDICTIVITY AND POSTDICTIVITY IN ARCHAEOLOGY: REFLECTING AND DISCUSSING ABOUT THEORIES, METHODS, AND TOOLS

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exchange between Tuscany and Emilia Romagna across the Apennines as one of the variables to understand settlement network. Considering the material culture data from both mountainsides, the watershed of the Apennines is to be analyzed not only as an element of separation but also as a hinge zone and, therefore, as an area of cultural exchange trough passes and inland valleys. This approach requires the use of GIS technology to support and verify the hypothetical models derived from literature through the construction of postdictive and predictive models. These interpretations will be integrated in a predictive model which will be verified through future analysis on the field.

SESSION 5E: HOMOLOGATION AND STANDARDIZATION OF ARCHAEOLOGICAL CARTOGRAPHIC DATA

HOMOLOGATION AND STANDARDIZATION OF ARCHAEOLOGICAL CARTOGRAPHIC DATA

POSTER

- Authors** **Stefano Campana, Matteo Sordini**
- Title** ***The Sitan project in the Province of Grosseto: a web-gis for landscape archaeology***
- Abstract** An archaeological context may be defined as a place or set of places where humans lived or where they carried out activities that have left material traces. The various research methodologies of landscape archaeology all contribute, in one way or another, to the highlighting of archaeological traces that contribute information for the reconstruction of individual contexts or broader ancient landscapes. The geographic information system for the Province of Grosseto has been designed to manage multisource datasets, from traditional methods such as field survey and the analysis of written sources to a range of remote sensing techniques – satellite imagery, LiDAR, vertical and oblique aerial photography and various geophysical techniques. All these sources of information, when spatially related to one another, contribute to the definition of archaeological contexts. Within the GIS system the definition of a context can be reduced to one or a set of spatially and chronologically coherent traces. The geographic database has been built using an open-source industrial database software, PostgreSQL – Postgis. The design, in the first instance, has been focused on producing a system compatible with the standards established within the Italian national programme for the development and implementation of geographoical information systems for archaeology. Secondly, the design has been aimed at producing a versatile system for managing information from all of the research activities undertaken by the Landscape Archaeology and Remote Sensing Laboratory of the University of Siena. The schemas implemented within the database have been divided into “macro classes” related to the method of acquisition of the data. An important aspect of the design has been the attempt to maximize standardization within and between the various datasets in order to produce, across the differing acquisition methods, comparable sets of information. Another aspect of the work has been focused on automating various aspects of the data entry process: some functions have been implemented through algorithms written using the plpgsql language. This kind of function allows users to improve both the productivity and reliability of data entry. Furthermore, particular attention has been paid to chronological modeling. To express the chronology of the various traces there has been devised the concept of the “chronological unit”, making it possible to create diachronic selections based on historical periods or phases through the use of sql queries. At the current stage of development the system has been tested with a local client, QGIS: a huge amount of data entry has been undertaken and some aspects of the database have been refined. The basic construction of the geographic system can now be considered as complete: further developments will focus on implementing web interfaces and publishing the system online.
- Authors** **Alfonso Santoriello, Amedeo Rossi, Luigina Tomay**
- Title** ***The SiUrBe project (Sistema Informativo del patrimonio archeologico Urbano di BENEVENTO: an Archaeological Information System as a tool for the definition of the archaeological evaluation***
- Abstract** The project SIUrBe (Information System of the Archaeological Heritage Urban Benevento) arises from a strong partnership between the Superintendence for Archaeological Heritage of Salerno, Avellino, Caserta and Benevento (Archaeological office of Benevento) and the Department of Cultural Heritage at the University of Salerno-Archaeological Laboratory “M.

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Napoli". The project aims to develop a system that, through expanded protocols and procedures for the acquisition and management of the archaeological record, according to the latest guidelines of the scientific discussion about the demand of a National Archaeological Information System (SITAN), respond to two main purposes: contributing to the scientific study of ancient Benevento through the elaboration of an Archaeological Map of the city and giving to the local administrations an easy instrument for the urban planning and cultural heritage of Benevento. The system, originally planned as local, has been translated into a DB WEB, using open source software. At the same time we have developed experimental solutions about the spacial database that allow to get over the current logics WEB> GIS and access to GIS> WEB platforms through protocols' semantics and OGC (Open Geospatial Consortium) procedures. The latter are aimed to develop and implement standards for the content, services and the exchange of geographic data that are "open and extensible". The project WebGIS is distinguished from a 'simple' GIS project for the specific purposes of communication and information sharing with other users. The WebGIS is made to the web server and to use MapServer development environment aimed at the representation of geo spatial data. The application for viewing and creating spatial data are made with pmaper and PosgresSQL DB (object-relational database with a free license) and with a spatial extension PostGIS db that can manage in the same layout both alphanumeric data and elements vector (geometric figures)

Authors**Serafino Lorenzo Ferreri****Title*****The 'Georeferenced archaeological census of Abruzzo': problems in the homologation and the repositioning of known archaeological data*****Abstract**

The Abruzzo region, although very advanced in the production of geographic databases, does not present corresponding layers dedicated to the mapping of archaeological evidences. The reasons are to be found in backwardness of Italian archeology for establishing guidelines compatible with 'Intesa GIS', then in the state of archaeological mapping in Abruzzo. This branch is, in fact, characterized by a lack of adequate instruments with normative value - as became evident during the 2009 L'Aquila earthquake - caused not only by the absence of a regional archaeological map, but also of a basic census of known archaeological heritage. Rather, there is a vast literature concerning different geographical areas and chronological range - with maps drawn up in the traditional form - and a bibliographical regional synthesis which, however, lacks of a cartographic counterpart. In this panorama, the same use of GIS is episodic and limited to small portions of the region.

With the aim to fill those gaps, the author has proposed, as dissertation in Ancient topography (AY 2012-2013, supervisor Prof. G. Iaculli, University of Chieti), a project for a georeferenced census including data from bibliography or documentation kept in the archives of the Archaeological Superintendence of Abruzzo. The project is designed in a modular form, providing for the gradual completion of sections defined by the IGM ED50 grid: the experimentation, applied so far in the section designated as '360-III (Capestrano)', highlighted the potential of this project but, at the same time, revealed problems concerning homologation and georeferencing of the archaeological data.

During the design phase, we tried to overcome the heterogeneity of the archaeological record through a rational and simplified modeling of the Shapefile layers, obtained with the distinction of three levels progressively more detailed, linked by topological or data-based relations: 'identification areas', 'planimetric characterization', 'archaeological element', consisting of polygon, polyline or point objects, catalogued using as much as possible entries taken from the catalog established by the ICCD, which sometimes needs additions. More details on the architecture of the project have been made available in the ASITA 2014 conference (Ferreri

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2014).

The other issue concerning the geo-referencing - and its reliability - in ETRF2000 of all the known data, has been achieved by comparing the various statements of location (cartographic, descriptive) for every archaeological element and, when possible, also making on-site controls with a mobile GIS device; the use of Abruzzo region WMS ortophotos proved to be very useful for relocation of visible archaeological features. Overall, these procedures evidenced some mapping errors for recent discoveries while, for findings documented in the past, sometimes totally erroneous localizations, going from hundreds of meters to a few kilometers.

Solving both problems is therefore crucial to obtain an archaeological Geographic Information System functional for the purpose of research, protection and enhancement: it is currently in use in landscape and excavation researches directed by Valeria Acconcia, Phd research fellow in Etruscology and Italic antiquities of University of Chieti.

Authors

Maria Assunta Papa, Aurelio Burgio

Title

The Cignana Project. Preliminary considerations on the settlement strategies during the Imperial Age from an archaeological, a geomorphological, and GIS perspective

Abstract

This paper presents a case-study related to the territory of Cignana (near Agrigento, Sicily), where archaeological excavations were carried out by Soprintendenza of Agrigento some years ago in the area of a Roman villa. The villa is located in an economically strategic location and in a productive district, where the spread of agriculture and sulphur used to be fundamental resources for the economy of that area. This favoured the growth and extension of a village during Late Antiquity and Byzantine ages.

The *Cignana Project*, which is based on an archaeological survey which the University of Palermo has been examining since 2007, focuses on the geographical context around the Roman villa. The Project is aimed at analysing both the economic district of the villa (where there exist numerous sites dating back from the Prehistory to the Middle Ages), and the human activities. Also, about 200 archaeological sites were identified in the project area. Many sites (farms, and perhaps also some villa) were inhabited from Late Hellenistic to Late Roman/Byzantine ages, and some became very large villages; also, many settlements are placed along the main rivers (Naro and Palma) and streams (Grancifone, Montechiaro), and they could configure a network, even if the function of some of these sites is not clear yet.

To sum up, this paper investigates the development of rural settlement in Romans times in order to detect the interrelationship between the most important and large sites (villas, villages, farms) that belong to the Roman and Byzantine periods, and also the communication network, the changes on trade and land-use, the transformations of settlement patterns, and finally the local communities' exploitation of natural resources. The interrelation existing among those sites (the most significant ones) will be scrutinized through systematic pottery sampling.

The archaeological data, which have been taken into account through the GIS methodologies (3D analysis, supply catchment, shortest path, Thiessen polygons, etc.), have put their emphasis on the connection between settlements and resource availability, sites in terms of diverse ranking and hierarchy and, finally, on the interconnected networks which politically controlled the territory.

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- Authors** **Maria Luisa Marchi, Giovanni Forte**
- Title** ***From the GIS of the Ager Venusinus project to the GIS of Ager Lucerinus Project: evolution of the system***
- Abstract** This paper presents the archaeological Map of Italy- "Forma Italiae" project, comprising to date the Ager Venusinus project (completed) and the Ager Lucerinus project (ongoing). The idea of an Archaeological Map of Italy dates back to 1889. Many decades later, with the advent of information technology and satellite observing system "new era" of archaeological mapping began and the "Forma Italiae", thank to these technological developments, began to develop the first Territorial Information System of archaeological matters in Italy. This project, represents one of the first applications of both GIS and GPS in archaeology. It was one of the first works with GPS. Between 1989 and 1992, studies and experiments were carried out on automatic systems for the acquisition, calculation and management of archaeological data relating to cartographic data of Italy. Currently we use GPS for all archaeological sites.
- It is important to keep in mind that in the GIS all archaeological elements, both monumental and structural as well as scatter of material on the surface are georeferenced their shapes and sizes perfectly represented. The current application of most advanced technologies enabled a precise referencing for each of these, along with a rapid creation of thematic cartographies. It is our hope that the data archive of this project may serve as a learning foundation and a strong basis for all those who work in the area and that it may contribute towards a greater efficiency of the preventive archaeology tools. For this purpose a computerized system for data management was used composed of a GIS platform associated with an alphanumeric archive and designed soon to become a webGIS.
- Authors** **Ilaria Di Cocco, Marco Edoardo Minoja, Renata Curina, Tiziano Trocchi**
- Title** ***Standardization and certification of archaeological data in the WebGIS of the protected cultural heritage of Emilia-Romagna***
- Abstract** The MiBACT Institutes of Emilia-Romagna created a geo-database of Emilia-Romagna's architectural heritage, developed entirely with open source technology. The data are made available to the public and to government bodies through an online cartographic portal (www.patrimonioculturale-er.it), developed even for mobile devices (smartphones and tablets).
- The work to incorporate the mapping of the archaeological heritage is at a very advanced stage, and for the first time will certify the cartographic data.

SESSION 5H: GEOGRAPHICAL AND TEMPORAL NETWORK SCIENCE IN ARCHAEOLOGY

POSTER

Authors Silke Vanbeselaere
Title *Durability of ties or Nero's frenemies*
Abstract Frenemy: NOUN (plural frenemies) *informal*

1. a person with whom one is friendly despite a fundamental dislike or rivalry
2. someone who is both friend and enemy, a relationship that is both mutually beneficial or dependent while being competitive, fraught with risk and mistrust

Nero, enfant terrible of the Roman principate, inherited the Roman imperium from his adoptive father Claudius in 54CE.

With that, he did not only inherit the vast Roman empire, but also part of his father's social network – or so it seems. His mother Agrippina's power over the imperial household, administration and Nero himself was so strong, that it may well have been her who orchestrated the links between her son and her former husband's allies. This makes one wonder whether the ties Claudius created and maintained during the last days of his life were actually transferable to his (adoptive) son or whether these ties die with the people who set them up. Indecisive about who actually were his friends and who were his frenemies, Nero executed everyone he became suspicious of. In doing so, he hoped to gain more control of Roman high society and its political network. But the question remains whether these executions really altered the network he found himself in. Did the structure change with people dying, or did these people have a remaining effect on the structure even after they passed away? And if the structure did change, did Nero improve his own position in the network by acting so cruelly? This research does not focus on a long-term phenomenon. Since Roman society was so turbulent in those days (or in other words: because Nero executed people like a raving madman), the structure of the community was always changing – or was it?

A change in ties does not always imply a change in network structure though. Social ties between people did not only change at the start of a new reign, here the power transition from Claudius to Nero, but rather were constantly altering because of deaths, conflicts and grudges. My aim is to assess whether this affected the structure of the network as well. Temporality of ties in social networks is one of the most interesting – if difficult – problems for researchers working with historical networks. By looking at the violent Roman society during Nero's reign we hope to get some insight in the changes that networks underwent and how the temporal aspect of personal ties had an impact on their structure. We also want to think about how this temporal aspect could best be visualized without losing sight of the macro-view of the network. In this respect we will take a look at the advantages and disadvantages of 3D visualisation and whether that could be an adequate tool for representing temporal data in historical networks.

SESSION 5I: INTERPRETING THE
UNSTRUCTURED: NEW METHODS AND
TOOLS FOR INTRASITE SPATIAL
ANALYSIS OF PALAEO SURFACES

INTERPRETING THE UNSTRUCTURED: NEW METHODS AND TOOLS FOR INTRASITE SPATIAL ANALYSIS OF PALAEO SURFACES

POSTER

- Authors** Miquel Roy Sunyer, Rafael Mora Torcal, Jorge Martínez Moreno
- Title** *Deconstructing palimpsests: Applicability of automated GIS algorithms*
- Abstract** Data management is a crucial point for the theoretical and methodological development in Archaeology. There have been many advances with the implementation of new techniques and instruments during last years. However, problems persist when analyzing the resolution of archaeological sites and particularly in low and medium resolution archaeological palimpsests.
- To overcome these limitations it is necessary to systematize the process of recovery and data management during and after excavations. From this perspective we have developed a Visual Basic 6.0 based-software called ArqueoUAB. Its structure integrates multiple tools that facilitate the systematic data management in five steps: Item recovery with laser theodolite (3D positioning), use of Personal Data Assistant (PDA) for contextual data recovery, labeling with Data Matrix Codes (DM), storage in georeferenced relational databases and data mining (Mora Torcal *et al.* 2010, Martínez-Moreno *et al.* 2011).
- We present the approach to the study of palimpsests by analyzing archaeo-stratigraphic cross-sections. The functionalities of current GIS software facilitates the exploitation of spatial information from archaeological datasets using automated routines, generating orthogonal and oblique cross-sections of the whole excavated volumes along user-specified intervals (Martínez-Moreno *et al.* 2010; Martínez-Moreno *et al.* 2011; de la Torre *et al.* 2012). This tool helps to analyze the archaeological levels, visualizing the geometry of the excavated surfaces and providing a better understanding of site formation processes, while helping in the decision-making directed to solve specific problems during the excavation.
- Authors** Gianna Gandossi
- Title** *A Chronology of Site Use: Quantifying Odd Deposits with GIS in Time and Space*
- Abstract** The field of archaeology is profoundly concerned with human beings in both time *and* space. Geographic Information Systems (GIS) have become an essential tool in analysing and understanding archaeological sites temporally. However as of yet, analysing change through time *in* space using quantitative GIS at the intra-site level is a severely limiting exercise. This research project examines a common type of spatiotemporal imprecision within the field of archaeology, in which an event occurs at a known spatial location but within an uncertain time range, in order to study and quantify the concept of structured deposition at the intra-site level. Statistical analysis provides a scaffolding from which quantitative investigation of an uncertain reality can be built in probabilistic terms.
- The research described in the following paper is designed to explore the temporality of site-use, occupation and the character of deposition using Hambledon Hill, a well-known and well-studied early Neolithic complex, as a case study to statistically quantify a faulty aspect of the concept of *structured deposition*: the lack of temporality in its analysis. I argue that looking at the spatial and temporal dynamics of deposited artefacts in detail can inform interpretations about the activities of people at a site in terms of a chronological framework.
- The goals of this project are to illuminate the potential of a spatiotemporal probabilistic framework in leading interpretations of temporality, structure and site-use when studying prehistoric material culture. As well as enhancing our understandings of one particularly important Neolithic site, it is hoped that this project may illuminate the potential that a

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spatiotemporal probabilistic framework has to offer to interpretations of temporality, structure and site-use when studying prehistoric material culture.

Taking into account recent developments in the theory of temporality and understanding the implications of using this method, perhaps others will incorporate this type of spatiotemporal analysis in present and future archaeological studies. In this adaptive age of science, I maintain that it is the vital merger of *actual* and *virtual* worlds that provides a compelling platform for analysis and public participation in archaeology.

Authors

Laura Morabito, Rosalba Aquino, Matteo Faraoni, Giovanna Pizziolo

Title

Living in a palaeoriverbed: intra-site analysis of two prehistoric sites in the Florentine alluvial plain.

Abstract

The paper will focus on the intra-site analysis of two case studies from the area of Sesto Fiorentino (Florence): S. Antonio and Cilea. Sesto Fiorentino is located in an alluvial plain affected by severe erosion/accumulation processes. Both sites are multi-stratified and present a complex interpretation due to the difficulty of reading stratigraphies in such a biased territorial context. In detail the two sites are both located in different palaeoriverbeds and present some temporal and structural differences.

S. Antonio shows a long frequentation from Middle Bronze age to Recent Bronze age. This site, as well as Cilea, is characterised by a specific settlement strategies widely documented in the Florentine area during Bell Beaker and Ancient Bronze age. With density analysis some functional areas have been recognized.

Cilea was occupied from Copper age to Final Bronze age with some interruptions in occupational phases. From the study of the morphology and analysis of the river banks it has been possible to distinguish the areas of the bed modified by human activities or by the natural processes.

The focus of the contribution will concern the bi-univocal dialogue between the analysis of archaeological materials and their distribution compared with the morphological and micro-morphological analysis of the sites. This kind of integrated analysis has been very useful in the case study of the Sesto Fiorentino plain, where the typical settlement strategy during Bell Beaker phases is the exploitation of already abandoned paleoriverbeds. The reading of such morphologies, often subjected to flooding and erosions as well as anthropic activities, can be very difficult especially concerning the natural or artificial origin of some shapes or of the more or less consistent spreads of materials in palaeoriverbeds. The interaction between Computer Aided Design and GIS systems has been of primary importance in the integration of archaeological and morphological data. Visual analysis, spatial analysis and 3D reconstruction of micro morphologies and structures helped us to test interpretation hypotheses emerged during the excavation as well as to identify possible 'latent structures' (*sensu* Leroi-Gourhan). Moreover, in some cases the integrated methodology and tools we used led us to propose new hypotheses on the reading of the stratigraphic sequence and on the chronological interpretation of some paleosurfaces.

With the application of intrasite analysis and micromorphological analysis it has been possible to recognize with more precision the anthropic modification of the palaeoriver morphologies and their opportunistic exploitation. The comparison between the two sites enabled us to emphasize differences and similarities of palaeoriver occupation through the use of the same analytic tools.

SESSION 5I

INTERPRETING THE UNSTRUCTURED: NEW METHODS AND TOOLS FOR INTRASITE SPATIAL
ANALYSIS OF PALAEO SURFACES

POSTER

Authors François Giligny

Title *Reconstruction of the domestic units by the data analysis of the ceramic reassemblies: the example of the lakeside dwellings*

Abstract A spatial analysis of pottery dumps is proposed on layers of dwelling Neolithic lakeshore sites of Jura (France and Switzerland). The method is based on diagonalization of presence/absence data table of square meters per vase. Then, through data analysis techniques, a co-occurrence matrix of the number of re-assemblages of pottery sherds within the square meters. The results show that dump areas are well correlated to the ancient buildings.

SESSION 5J: SPATIAL ANALYSIS IN
ETHNOARCHAEOLOGY AND
EXPERIMENTAL ARCHAEOLOGY

POSTER

Authors

Fabio Cavulli

Title

Sand trampling experiment: the effects of surface trampling on the archaeological record

Abstract

One of the main characteristics of the KHB-1 settlement (Sultanate of Oman) is the loose sediment upper sequence. During the excavation, even the simple stepping on the layer surface seemed to cause the mixing of stratigraphic units. The question about what the effect of the ancient trampling was on deposit arose naturally. An experiment has been carried out close to an excavation trench: sandy layers were overlaid and fake artefacts (shells, flints, stones, ...) catalogued and scattered in the stratification; their position was recorded. At the end of the campaign, after one month of trampling, the deposit was dug and the final position of the artefacts was recorded again. The results of spatial analysis, by the mean of scatter plots, basic statistics, and validation tests, on the experimental assemblage are presented in this paper and the effect of human (archaeologists and visitors) mobility are analysed; eventually, some considerations about possible comparisons in ancient times are formulated.

SESSION 5K: WHERE DO WE GO FROM HERE? LEAST COST PATHS REVISITED

WHERE DO WE GO FROM HERE? LEAST COST PATHS REVISITED

POSTER

Authors Michele Matteazzi
Title *Reconstructing Roman communication routes in the low Venetian plain with GIS*

Abstract The stretch of the Veneto plain that extends south of the city of Padua, today characterized by the presence of the southern basin of Venice Lagoon, has always been an important junction for communications between the center and the north-east of the Italian Peninsula. That was such also during Roman times, when the territory was under the control of the *municipia* of *Patavium* (Padova), *Ateste* (Este) and *Atria* (Adria).

Since their arrival between the late IIIrd and the early IInd century BC, Romans paid much attention to the creation of an efficient road network that allowed, beside connections among the main centers of the plain, even rapid communications between the southern strongholds of *Bononia* (Bologna) and *Ariminum* (Rimini) and the northernmost colony of Aquileia, extremely important centers for the expansionist policy of Rome toward North-East. We know about the existence of such routes from the sources, both written and epigraphic, but, despite the numerous studies about them, their real paths still remain rather uncertain or not unanimously accepted.

With this paper we want to further contribute to this issue, by addressing the question with the help of GIS and the computer simulations they allow to generate. In particular, for this study we made use of LCP analysis, thanks to which hypothetical paths can be created from cost and friction surfaces. Despite several applicable cost models available today in modern archaeological literature (De Silva and Pizziolo 2001; Van Leusen 2002; Fiz and Orengo 2008; Verhagen and Jensen 2012), nevertheless it was necessary to create a specific model that took into account the particular geomorphological features of the study area, an alluvial plain greatly influenced by fluvial and lagoon activity.

The created model seems work good, even if the fact we could only applied it to Digital Terrain Models generated from modern landscape data - because we don't know how exactly were the ancient surfaces of the plain (mostly from an hydrologic point of view) - has made it almost impossible to trustfully consider the simulations obtained. Very useful, in this sense, was the calibration of the model with all the archaeological, paleoenvironmental and historical available data: this allowed to reconstruct, with a high degree of probability, the main Roman routes that once went through the plain.

Authors Doug Rocks-Macqueen
Title *Least Cost Path- The Least Useful Tool?*

Abstract Since the beginning of least cost path analysis there have been many critiques of its use in Archaeology. Issues from how cost is calculated to how different GIS programs create different least cost paths for the same area have been raised. See (Herzog 2013, 2014) for a discussion of some of these issues. This paper will discuss efforts to tackle some of the problems with LCP caused by GIS programs, like single directional cost.

The solution investigated was the use of Agent Based Modelling (ABM) to undertake LCP. ABM allowed for the testing of different variables with LCP that have not been done with GIS.

While the results of this method solved some of the problems found with GIS and LCP the real interest is that this investigation raised more issues than it solved. In fact, many of these issues are serious enough to question if least cost path can be of any use to Archaeology. The result of

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this work suggests that for predicting routes LCP provides outcomes that are little better than looking at a map and guessing the routes past peoples may have taken. However, alternative uses were found for LCP.

Authors

Susanne Rutishauser

Title

Natural frontiers and paths in Cilicia

Abstract

Natural formations such as rivers, mountain ranges, deserts or the sea build natural frontiers. They are strategically important as it is more difficult for invading armies to cross such a border. Natural borders may be easily defended and allow to control who is passing the bridge/mountain pass. The Cilician Plain is surrounded by such natural frontiers: the Taurus mountain ranges in the west and north, the Amanus Mountains in the east and the Mediterranean Sea in the south. Additionally, the foothills of the Taurus and the Misis Mountains separate the Cilician Plain in two settlement cluster: the western Çukurova and the eastern Yukarıova.

Since the Neolithic period the Cilician plain forms an important passage between Anatolia and the Levant. Due to its natural frontiers there are limited passages through the Taurus and Amanus mountains.

This paper combines results of a study of ancient roads and itineraries from Hittite texts (Forlanini 2013) with Least Cost Paths.

SESSION 5L: MODELLING LARGE-SCALE HUMAN DISPERSALS: DATA, PATTERN AND PROCESS

POSTER

- Authors** Ericson Hölzchen
- Title** *Identification of Agent-based Modelling elements in “Out of Africa” Hypotheses*
- Abstract**
- The earliest fossil record of genus *Homo* is about 2.3 million years old (Antón 2012). With their origin in East Africa different early *Homo* species dispersed within Africa and all over Europe and Asia. Fossil discoveries of *Homo floresiensis* in Indonesia (Brown et al. 2004) or the Denisovan hominin in Siberia (Reich et al. 2010) illustrate that early hominins had large distribution ranges. “Out of Africa” can be divided in at least two separate dispersal events: “Out of Africa I” – the dispersal of early *Homo*, such as *Homo erectus* and “Out of Africa II” – the dispersal of *Homo sapiens*.
- We do not know the mechanisms behind hominin dispersal, besides the fact that it had happened and that it must have been at least two separate events. The main hypotheses that are suggested and discussed are climatic & vegetation changes (Agustí et al. 2009, Leroy et al. 2011, Van der Made 2011), demographic pressure (Klein 2008, Petraglia et al. 2009, Powell et al. 2009), biological & social evolution (Turner 1992, Carbonell et al. 1999, Templeton 2002, Derricourt 2005, Klein 2008, Tattersall 2009, Leroy et al. 2011, Van der Made 2011, Clobert 2012) and carnivore competition (Turner 1992, Rose and Marshall 1996, Leroy et al. 2011, Clobert 2012). Therefore we have to ask for the reasons why the “Out of Africa” events during the Pleistocene had happened.
- So the main question is: What were the mechanisms behind hominin dispersal?
- “Out of Africa” is a well-documented example that is studied under a variety of disciplines with different approaches and questions and thus provides us with a great pool of reference studies and reference data. This is crucial for modeling since the quality of the model results is strongly dependent on the quality of the input data. “Out of Africa” still has social relevance since it is the origin of our species.
- For modeling dynamical processes consisting of individual actors, ABM has been established as a suitable method. Thus ABM is a well suited method with which we model the hominin dispersal out of Africa emerging from autonomous components interacting with an environment.
- We have to identify the ABM-elements that correspond to agents, environments and rules of interaction. Additionally we have to define the data requirements.
- With the ABM method we want to test the hypotheses by formalizing them into an ABM structure and thus give us the opportunity to “observe” “Out of Africa” hypotheses *in silicio*.
- After formalizing the “Out of Africa” hypotheses we can start multiple simulation runs with different model configurations.
- We could compare the impact of the different factors that are proposed by “Out of Africa” hypotheses.
- For validation we have to define specific validation criteria that suit the hypothesis in addition to basic model criteria (e.g. transparency, identify range of possible model outcomes and limitations, check against empirical data, comparison with different model approaches).

POSTER

Authors **Chunyan Zhao**

Title *Strontium isotope analysis and human mobility from late Neolithic to early Bronze Age in the central plain of China*

Abstract Archaeological surveys a series of late neolithic to early bronze Age settlement in the central plain of China and provided useful data for understanding prehistoric period of increasing local social complexity. A combination of the modelling functions offered by Geographic Information Systems (GIS) and the data of strontium isotope ratios in human teeth from archaeological site allow us to explore possible relationships between human mobility and the natural environment. The results reveal complexities that in conjunction with other archaeological data can be correlated to social, political, or economic inequality in ancient sites.

SESSION 5M: IMPROVING
RESOLUTIONS: USE AND POTENTIALS
OF QUANTITATIVE METHODS
IN NEAR EASTERN ARCHAEOLOGY

SESSION 5M
IMPROVING RESOLUTIONS: USE AND POTENTIALS OF QUANTITATIVE METHODS
IN NEAR EASTERN ARCHAEOLOGY
POSTER

- Authors** **Arie Kai-Browne, Thomas Bremer, Susanne Brandhorst, Alexander Hennig, Felix Balda, David Strippgen, Sebastian Plesch, Arian Goren, Kay Kohlmeyer**
- Title** ***The potential of game engines in real-time simulation of archaeological scenarios***
- Abstract**
- Implementation of quantitative and computational applications in archaeological research facilitates experimenting with new methods and establishing interdisciplinary collaborations. Furthermore, growth in the amount of collected data and the large variation in the (re)sources it is collected by sets high standards for proper data management, sufficient processing power, efficient data processing, and insuring sustainability of data. Incorporating advanced tools and methods derived from computer-science related fields enables utilising legacy and newly acquired data in original and creative means, and opens exiting ways to address the process of contextualising archaeological assets.
- The Temple of the Storm God of Aleppo serves as a case study to explore the potential of game-engines and game design in simulating archaeological scenarios. 2D and 3D data collected from multiple sources and recorded in varying formats and scales, ranging from manual measuring devices to satellite imagery, was integrated into a comprehensive platform. Using methods taken from the world of game-design a realistic 3D visualisation of the temple and its environs was achieved. High level of precision and details was maintained even after a rigorous reduction in data volume took place.
- Generated in game-engine, a full-scale digital model of the temple's architecture complete with its reliefs and sculptures can be accessed and explored in a real-time virtual environment. When linked to an underlying database various spatio-temporal aspects as well as reconstruction scenarios can be tested and simulated. In the case of the Temple of the Storm God of Aleppo initial research applications address visibility analysis, modifications in the temple's floor-plan, and implications of stellar constellations to cultic spaces.
- Authors** **Alessandro Di Ludovico**
- Title** ***Working on Western Asiatic Artefacts: Values and Perspectives of Past and Present Experiences with Quantitative Methods***
- Abstract**
- The study of works of art and craftsmanship that are part of the ancient Near Eastern heritage often reveals complexities that can be primarily referred to the many gaps in the documentary material and the archaeological evidence.
- The combined interpretation of outcomes of researches that adopted interdisciplinary approaches and those based on quantitative methods can allow to make a picture of those gaps and at times provide elements that facilitate the look for a proper logical interpretation of the available materials.
- In some experiments quantitative methods have actually proved to be particularly helpful for exploring the material products of cultures of the pre-classic Western Asia, insofar as they permitted a correct logical contextualisation of the relevant features.
- In an explicit or implicit way those works were simultaneously raising the problem of the gaps in the documentation and the one of the cultural distance between the scholar and the authors of the artefacts with which he deals. In fact, the gaps cannot be really understood without an evaluation of some cognitive and technical issues that pertain to the way the artefacts were produced and planned.
- With reference to Near Eastern works of art and craft a not very huge number of experiences have been developed up to now, and mostly in the absence of an actual methodological debate through researchers. What they can represent for future studies and reflections, as well as what

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still deserves to be considered with respect to their in-depth comprehension, is the main topic of this contribution, while its basic proposal is the development of a multiform approach which could be adapted to the specific needs and aims of each research process and would also work as a tool for self-criticism.

Authors Cristina Baccarin, Antonietta Catanzariti

Title *Use of remote sensing in mapping the Qara Dagh valley, Iraqi-Kurdistan*

Abstract

The Qara Dagh Valley, located in the present day Iraqi-Kurdistan region, has been identified as an area of great historical significance. Based on ancient texts and archaeological finds there recovered, it is believed to be the territory where the so-called Mountain people, also known as Lullubis, lived. The valley is also famous for the so-called Naram-Sin stelae, which attracts many local people.

The area was first surveyed in the 1940's by Iraqi archaeologists who produced a map with circa 30 sites. Since then, only a few European explorers have documented the remains dated to the Antique period. The lack of information available on this area is due partly on the difficulties which the area's topography poses. The Qara Dagh Valley is bordered by the Baranad and the Qara Dagh Mountain chains and the valley itself is characterized by the presence of many hills. The Dalwan river and several seasonal wadi run through the valley from north to south and the sparse inhabitation is comprised in a few villages and a small district town.

Based on a short investigation conducted in November 2013, we were able to identify some of the sites recorded in the 1940's map. A systematic investigation of the region is needed and, for this reason, we will perform a preliminary study of the area by analyzing satellite images. The challenging topography of the valley offers an ideal situation for the use of remote sensing analysis, especially because a surface survey, in these circumstances, will not allow for a clear and rapid identification of the archaeologically relevant sites. The current availability of very high resolution satellite data facilitates the analysis of the area and makes possible the detection and observance of archaeological marks, more specifically, spectral and spatial anomalies linked to the presence of buried archaeological remains. Remote sensing will allow us to acquire information connected to the territory. Historical and contemporary maps will be overlaid, satellite images will be processed with GIS. The result of this study will result in the acquisition of information on past human activities, define the number of archaeological sites, create assumptions on site relationships, their change over time and their accessibility in relation to the possible presence of ancient routes.

The results of this work will be beneficial in several ways. Because of the presence of oil and gas pipe lines near the so-called relief of Naram-Sin, this area is in great danger of being damaged or destroyed. Thanks to the study of remote sensing images, we will provide the antiquity authorities with evidence of this area's historical and cultural importance and an incentive to protect the heritage of this area. Also, this data will promote the development of future cultural activities, such as workshops for the local communities.

SESSION 6A: APPROACHES FOR
SENSOR DATA INTEGRATION FOR THE
INVESTIGATION OF
ARCHAEOLOGICAL LANDSCAPES

APPROACHES FOR SENSOR DATA INTEGRATION FOR THE INVESTIGATION OF
ARCHAEOLOGICAL LANDSCAPES

POSTER

Authors Kasper Jan Hanus, Emilia Smagur

Title *Integrated prospection of the moated site Lovea, NW Cambodia.*

Abstract Our understanding of the medieval cityscapes of North-west Cambodia is well establish thanks to intensive remote sensing surveys and interpretation work. However the roots of urban tradition are obscured. The aim of our research scheme was to examine the proto-urban traits of early historic sites between northern shore of Tonlé Sap lake and Dângrêk Mountains. As the historic Khmer urban complexes, as Angkor or Koh Ker, have significant water management system, one of the features of our interests were the moats. Our assumption is that those circular ditches had not only defensive role, but were simple forms of water management infrastructure.

In order to test this supposition we have decided to investigate one of those sites. The case study was the archaeological site of Lovea, located in Pouk commune, Siem Reap province, excavated in recent years by the team of Australian archaeologists led by D. O'Reilly. To properly understand the past cultural landscape, focusing on water management-related landscape modifications, the integrated prospection was applied. Therefore the aim of this poster is to present how combining data from pedestrian survey, Airborne Laser Scanning done in 2012 by Khmer Archaeology LiDAR Consortium, satellite images and UAV could be used to interpret the moated sites.

Authors Miguel Carrero Pazos, Benito Vilas Estévez

Title *Limits and possibilities of LiDAR data application for the study of Galician megalithic culture*

Abstract Nowadays computer tools are a fundamental part in the training of an archaeologist, on both personal and academic levels. Indeed, Archaeology has been gradually incorporating the benefits of informatics since the 1960's. In this sense, Archaeology has adopted a wide range of computer tools into its daily practice at both theoretical-methodological and practical levels. Conceivably, one of the main tools are the Geographic Information Systems (GIS). This multiple tool software allows the archaeologist to not only do some very complex analytics, but also to consider new perspectives in the study of the past that were practically inaccessible before. The same is now happening with LiDAR (Light Detection and Ranging). This system provides clear advantages over the photogrammetry, such as the capacity to penetrate vegetation and therefore obtain information of the topographic surface.

The objective is not to explain how this technology works, but rather to provide an example of the possibilities that the case of the Galician Megalithism could have in terms of archaeological prospection. For this reason, we have chosen the megalithic necropolis of Santa Mariña (Province of Lugo, Galicia). This has so far presented a number of thirty burial mounds, some of them with dolmen.

For the topographical surface study, we have applied an archaeological prospection methodology based on LiDAR data, which, with different types of visualization techniques, has enabled us to identify the previously known monuments, and recognise new ones. However, we believe that it is necessary to design a "modus operandi" guide or handbook for the use of LiDAR data so that any archaeologist can use these available data. It is felt that this would lead to a more realistic way to approach the field and anticipate fieldwork.

SESSION 6B: NEW ADVANCEMENTS IN COMPUTATIONAL IMAGING

SESSION 6B
NEW ADVANCEMENTS IN COMPUTATIONAL IMAGING
POSTER

Authors

Eleni Kotoula

Title

Ultraviolet Reflectance Transformation Imaging

Abstract

Ultraviolet imaging provides an easy way to characterize materials and examine surfaces. Flaking losses and abrasions of an invisible transparent varnish, over-paintings and other modern repairs, and techniques of manufacture/application of materials can be easily investigated (Warda et al. 2011). In UV imaging and examination with UV handheld units the axial positioning of the radiation source is common practice. It facilitates improved examination of objects and better perception of features revealed. Nevertheless, the synergy of Reflectance Transformation Imaging (RTI) (Mudge et al. 2005) and/or Polynomial Texture Mapping (PTM) (Malzbender et al. 2001) remains largely unexplored.

This study serves to show the potential of UV RTI, using UV induced visible fluorescence and reflected UV datasets of a Gnathian skyphos, which possibly belongs to the middle-late Gnathian style, around 300 BC. The reflected UV RTI datasets were captured with a UV transmitter filter and an IR barrier. The UV induced visible fluorescence RTI datasets were captured with an IR and an UV barrier filter. The pot was irradiated by a UV flash from different angles. UV and RTI processing followed the common recommendations (CHI 2011).

The ultraviolet induced visible fluorescence image reveals the remains of conservation materials on the surface of the ceramic skyphos and the previous repairs, because of the visible fluorescence emission of common adhesives used. The UV induced visible fluorescence RTI enables the viewer to virtually move the radiation source around the object leading to numerous different visualizations. In that way the viewer can reach a better understanding about the morphology of the previous repairs. Furthermore, by applying different rendering modes, these features are emphasized. Reflected UV-RTI offers the opportunity for enhanced examination of subtle surface variations. In the case of the skyphos, these variations are the differentiations of the glaze due to its poor preservation and the efflorescence. By applying the specular enhancement rendering mode and additional setting of the parameters the findings appear emphasised. The normal maps produced are complete representations of the surface topography of the surface in the ultraviolet region.

In addition to normal RTI, the application of IR-RTI and UV-RTI techniques leads to a complete diagnostic examination methodology. This case study demonstrates the advantages of multispectral RTI instead of multispectral imaging, particularly in the ultraviolet spectral region.

SESSION 6C: SITES, LANDSCAPES AND
SURVEY. THE PAST, PRESENT AND
FUTURE OF NON-INTRUSIVE
GEOPHYSICAL SURVEY
IN THE FIELD AND THE LABORATORY

SITES, LANDSCAPES AND SURVEY. THE PAST, PRESENT AND FUTURE OF NON-INTRUSIVE
GEOPHYSICAL SURVEY IN THE FIELD AND THE LABORATORY

POSTER

Authors Luigi Capozzoli, Antonella Caputi, Gregory De Martino, Valeria Giampaolo, Raffaele Luongo, Felice Perciante, Enzo Rizzo

Title *Geophysical-archaeological experiments in controlled conditions at the Hydrogeosite Laboratory (CNR-IMAA)*

Abstract

An experimental activity has been performed in the Hydrogeosite laboratory, in order to assess the capability of geophysical techniques to detect archeological remains placed in the humid/saturated subsoil. The goal of this experimental activity is to reconstruct a buried small archaeological framework to enhance the ability to interpret geophysical data and refine field methods for application in archaeological investigation with an approach based on integration of electric and electromagnetics data.

The large scale Hydrogeosite Laboratory at CNR-IMAA consists on a pool shape structures of 230m³, where has been installed an analogue archaeological remains (walls, tombs, roads, harbour, etc.) buried by sediments with different humid condition in order to simulate lacustrine and wetland condition and to simulate extreme events (for example underwater landslide, fast natural erosion coast, etc.). In detailed, inside the Hydrogeosite laboratory pool, an archaeological evidences relative both to a living environment and burial of Roman times was built: representative elements of a building, defined by a "structural frame" consisting of two dividing walls joined at an angle; a flooring (Mosaic); a collapse with material uprooted and a column; a paved road; burial tombs with three different types of burial (a Capuchin, a case made with tiles, a enchytrismos) as showed in figure. For the definition of the structural types, construction techniques, the materials to be used, and especially for their installation, the dictates of architecture Vitruvius and different publications about that followed over time will be been taken into consideration.



The case study described is analyzed with two well-known techniques widely applied into the archeological research field: ground penetrating radar and electrical resistivity tomography. Their ability to individuate an archaeological target depends on the subsoil characteristics, on the water content and electrical properties. In both cases numerical simulations were carried out, then used for comparison with the real data collected in the field.

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POSTER

The objective was twofold: on the one hand we have tried through the integration of data to overcome the limits of each technique, especially in terms of resolution and depth, in humid/saturated conditions on the other hand the potential technological enhancement in the integrated use of GPR and ERT in three-dimensional mode was investigated.

Authors **Lucía Bermejo, Ana Isabel Ortega, Lawrence Conyers, Alfonso Benito-Calvo, Josep Maria Parés, Alfredo Pérez-González, José María Bermúdez de Castro, Eudald Carbonell**

Title ***Ground Penetrating Radar (GPR) for identifying the archeological caves of Trinchera (Sierra de Atapuerca, Burgos, Spain)***

Abstract The Sierra de Atapuerca sites located in the Trinchera area are ancient caves filled with sediments that were sectioned by a XIXth Century railroad trench. Sima del Elefante, Galería Complex and Gran Dolina sites have been studied for decades providing outstanding Early and Middle Pleistocene archaeo-palaeoanthropological remains (Bermúdez de Castro et al., 1997; Carbonell et al., 2008; Ortega et al., 2014). The understanding of these caves morphologies and the relationship between their infillings is thus one of the research team's priorities (Ortega et al., 2013). To that end, geophysical prospections are being applied to these sites having the Electrical Resistivity Tomography (ERT) already revealed its ability to characterize part of this karstic landscape sub-surface geometry (Ortega et al., 2010; Bermejo et al., 2014 a and b).

This work presents the Ground Penetrating Radar (GPR) prospections carried out for the first time on the Trinchera area. This method offered supplementary data to the previous ERT prospections as well as provided new information about unexplored areas where ERT was not performed. The singularity of Trinchera, where karstic features can be found less than 2 m underground, has also allowed to calibrate the method.

The result of this exploration, together with the previous topographic, archaeological, geological and geomorphological data, shows a larger complexity of the karstic system than previously thought, offering both a better understanding of the sites' formation processes and planning of the excavation and management strategies.

SESSION 6C

SITES, LANDSCAPES AND SURVEY. THE PAST, PRESENT AND FUTURE OF NON-INTRUSIVE
GEOPHYSICAL SURVEY IN THE FIELD AND THE LABORATORY

POSTER

SESSION 6D: COLOUR AND SPACE IN
CULTURAL HERITAGE:
INTERDISCIPLINARY CONNECTIONS

COLOUR AND SPACE IN CULTURAL HERITAGE: INTERDISCIPLINARY CONNECTIONS

This session is kindly supported by the COST Transdomain Action, Colour and Space in Cultural Heritage (COSCH)

POSTER

- Authors** **Dominique Lauvernier**
- Title** ***Virtualisation and restitution of Court theatres : from sources to space, sound, light.***
- Abstract**
- Surviving or vanished historic theatres have not yet been studied on a wide scale with modeling tools. The originality of our dissertation relies on the field studied and the methods used. Without funds neither integration in a team, we had to set a universal shareable method, based on software free for academic use.
- Our first results are destined to searchers and people in charge of inheritance, performers; integrating the models in a public museographic space is left to future, contracts and funds. Modeling historic scenic spaces asks for a dedicated protocol and methodology. If restituting architecture, or machines, is common today, working on these sources and transferring them into 3d models must be based upon creating a method for analyzing the sketches of stage decorations, as instance.
- For the arts of stage, and specifically opera, the widest interdisciplinarity is required, in order to get a pertinent lecture of the diverse datas collected. As a score gives us time and space, where a floorplan only gives space. Consequently we are sharing with performers of the so called baroque stage, dancers, singers, players, ...
- The project is clearly linked to the Digital Humanities field, but we always associate new tools and traditional efficient academic methods, set for the history of fine arts and historiography.
- We shall provide a few samples of this methodology and the specific problems we have to face, in a phase of systematic modeling for everything which gives data or belongs to the inheritance, with low textured models, in order to experiment.
- We create digital libraries of 3d components specific to our artefacts, to fasten the time of basic modeling and acquire a wider field of items. The necessary 48k visualisation and high end textured models will be engaged later.
- Stratification implies digital modeling. Computer visualization is an essential tool for scientists to understand how complex physical, biological and chemical phenomena work. What about Humanities ? as for geology or astrophysics, we find strata in our sources: archives, scores, artefacts, most time show the remnants of their reuse.
- Decimetre accuracy is inappropriate for baroque times. Also, 3D datas are accurate in the model, but the visualisation tools - virtual cameras - are not and simulate movie cameras. Latent picture (as in photography), hidden in scores, archives, are virtualised into 2d and 3d shapes.
- Colorimetry is a must for fine arts, and raises difficulties in our field. *lab format the only modelising the physic world - is not widely used; restitution of original lighting will not be possible without experimental archeology, and then will be applied to models. We insist on calibrating and pipeline, specifics to restoration and movie industry, basing our research on remains for painted props and samples of fabrics for costumes.
- In conclusion, among the multiple perspectives opened, we shall focus on three axes of our present and future experimentation :
- 1 virtual museum and serious games;
 - 2- acoustic simulation of virtual theatres;
 - 3 - transferring performers filmed with blue screen into 3d experimental virtual model

COLOUR AND SPACE IN CULTURAL HERITAGE: INTERDISCIPLINARY CONNECTIONS

This session is kindly supported by the COST Transdomain Action, Colour and Space in Cultural Heritage (COSCH)

POSTER

- Authors** Frank Boochs, Ashish Karmacharya, Stefanie Wefers
- Title** *Structuring 3D technologies through semantics for an optimized use in cultural heritage documentation*
- Abstract**
- Constant technological progress results in new possibilities to produce reliable and rich spatial data of cultural heritage objects: for instance, museums have started to digitize their collections, more and more archaeological excavations or features and entire CH buildings have been documented in 3D. It is now necessary to establish connections among different CH disciplines and several technical disciplines, and to work on collaborative projects.
- Technicians and CH experts together evaluate the best technique for specific CH object documentation, implementation and use. This discussion arises from the knowledge gaps of each counterpart in respect to the other discipline. Projects such as Agora 3D (see below) clearly demonstrate the need for an evaluation of the different available techniques.
- In order to make optimal use of these technological capabilities, it is important to identify and name the information required to best serve the reasoning processes in these application fields. Correspondingly it is necessary to know about the characteristics of digitization techniques producing the content adapted to the needs of the applications. Due to the considerable complexity of instruments and processes producing the data, it is helpful to have a clear structure which relates the capabilities of the instruments to the requirements of the applications.
- The COST Action TD1201 “Colour and Space in Cultural Heritage (COSCH)” takes this need into account, aiming to enhance the understanding among these disciplines. We will focus on the already listed, structured and evaluated available 3D technologies. At the same time, experts in spectral and CH research started to list, structure, and evaluate their knowledge. These evaluations yield a structure of technologies, and ultimately the techniques and instruments using their characteristics. The understanding of these characteristics provides insights for their potential applications. The ontology knowledge model accessible through so-called “COSCH^{KR}App” provides a knowledge structure. It benefits from the development of semantic technologies from the Semantic Web framework. Semantics, which provide meanings, are captured through the conceptual structure and are defined through the ontology. The overall aim of this ontology is the development of a software tool to enable a better understanding of data acquisition techniques and their support to optimally realize cultural heritage applications.

SESSION 6E: LOW ALTITUDE AERIAL
PHOTOGRAPHY FOR ARCHAEOLOGY –
WHERE IS THE REVOLUTION
LEADING US?

LOW ALTITUDE AERIAL PHOTOGRAPHY FOR ARCHAEOLOGY – WHERE IS THE REVOLUTION LEADING US?

POSTER

- Authors** **Tavernari Cinzia, Gillot Laurence, Bouet Olivier, Del André**
- Title** ***The uses of remote control drones in archaeological evaluation and assessment***
- Abstract** The University Paris Diderot and the School of Architecture Paris-Val-de-Seine have lead for several years a research program with a view to inventorying the cultural properties of the oasis of Figuig in Morocco. This program has been led in order to assist the local authorities in the preparation of the nomination file for the inscription of the oasis on the World Heritage List.
- The oasis represents a fertile ground for the archaeologists and historians of Morocco. The ruined ksar of the Ouled Jaber, situated between ksour Laabidate and Loudaghir is one example of the archaeological potential of the oasis. The ksar of Ouled Jaber formed a residential area surrounded by a rampart, by tours and by doors and constituted by houses. The ksar was implanted on water springs, of which the most known and most desired was that of Thaddert. The ksar is at present neglected and the major part of its structures are buried or degraded. Archaeological excavations scheduled since 2009 so aim at specifying the conditions of establishment of the ksar, the nature of the structures (religious buildings, houses, etc.), its functioning and its relation with the other ksour before understanding the conditions of its abandonment and destruction. In this context, excavations focused on the ruins of the three arches of a so-called « mosque » which has been identified by a French geographer F.-E. Gautier by the beginning of the XXth century.
- During the mission of October, 2013, in order to assess the full archaeological potential of the area and to achieve the geodatabase of the ksar (by completing the previous works of collection and georeferencing of planimetric maps and the photo-interpretation of the Google Earth image), we made several series of flights with a remote control drone at different heights. Shots were completed by a ground survey using GPS positioning.
- Several processings and assemblies were made with various results:
- Creation of one georeferenced orthophoto of the whole ksar
 - Link between this orthophoto and the topographic map of 1914 (realized by the French geographer F.-E. Gautier)
 - Creation of a photogrammetric 3D model by dense correlation of large-scale views
 - Creation of a large-scale orthophoto of the excavated zone and comparison between the measurements in the numerical model and the ground measurements
- Besides the satisfaction of the immediate needs of our researches, this experiment aims at estimating the potentialities of a device regarding archaeological assessment which is easy to implement, coupled with processing based as far as possible on freeware or affordable software. This communication thus aims at presenting the methodology and results of this work and at prospecting its material and technical reproducibility in other archaeological contexts.
- Authors** **Patrick Dresch**
- Title** ***Processing and presenting datasets acquired using UAVs for commercial landscape surveys.***
- Abstract** This paper will look at how multispectral datasets acquired using unmanned aerial vehicles (UAVs) can be used to produced photogrammetric models to be used for interpreting landscape archaeology. In addition to looking at the versatility and limitations of UAV platforms, the

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resolutions of the datasets obtained, how they are processed and what can be done with them will also be discussed.

The use of the Fledermaus software suite, primarily used in processing multibeam bathymetry data from the marine environment, to process the photogrammetric data and the production of 3D digital terrain models (DTMs) and associated workflows will be described. It is also hoped that this platform will act as a platform for discussion on presenting 3D data in reports and options available when producing digital deliverables.

Authors**Mikolaj Kostyrko****Title*****Obtaining a low cost DTM – a kite perspective*****Abstract**

A digital terrain model (DTM) to study archaeological sites can be obtained in different ways, but not all of them can be easily afforded by anyone, as they require technical knowledge and funds. In my poster I will present a case study of a medieval hill-fort from Poland. A DTM made by structure for motion and photos taken from a kite will be presented. I will compare the date with a DTM made with a GPS RTK and LiDAR-derived DTM obtained from the Polish national resources of “IT System of Country’s Protection against Extreme Hazards” project. The main goal of my study is to find a cheap, fast and effective way to map archaeological sites with their own form. I will compare each of the methods and describe it's defects and advantages.

Authors**Jason T. Herrmann, Benjamin Glissman, Matthias Lang****Title*****Low-Altitude Aerial Photography in an Archaeological Survey of Iraqi Kurdistan*****Abstract**

Close-range and low-altitude photography have emerged as an important tool for data collection in archaeology at a variety of scales, but most often for recording features at excavation level. Like other digital collection methods, the major advantage of this approach is that data are collected quite rapidly and are ‘born digital,’ enabling easy transfer to GIS and visualization software. Digital photogrammetry from unmanned aerial vehicles (UAVs) can now be carried out with relatively low-cost commercial-grade instruments, a factor that contributes to the widespread adoption of this technique by archaeologists.

In 2014 a UAV with a mounted camera was used to document sites recorded as part of the Eastern Ḥabur Archaeological Survey (EHAS) of Dohuk Province, Iraqi Kurdistan, a project of the University of Tübingen. The EHAS is part of a regional partnership of four adjacent archaeological surveys that cover a significant portion of Iraqi Kurdistan, the Assyrian Landscapes Project. While low-altitude photography and UAVs are not particularly new to archaeology, what is presented here is the first reported landscape-level application of low-altitude photography from UAVs in a large archaeological survey in this region. In the course of this survey, project members surveyed over 40 archaeological sites, many of which are stratified settlements with significant topographic variation (tells) that range in size from one to 30 hectares in area. A hand-held GPS was used to measure the location of ground-control points that would provide geographic position and guide photogrammetric image matching for site surveys. Photogrammetric processing and data filtering were carried out in AgiSoft Photoscan Pro. Output data include an orthophoto, a digital elevation model, and a digital surface model (estimated bare-earth). Output data were further analyzed in a GIS to produce a

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land use / land cover map for each site and integrated with data from the surface survey of each site. We believe that standardization of workflow, data output, and classification (e.g. in land use / land cover) will facilitate data archiving and publishing and encourage data sharing with related projects. We not only hope that our results and workflow can be shared with partner projects, but for one that we believe that this efficient method could potentially replace conventional surveying techniques for archaeological sites in Near Eastern archaeology.

Authors Ronny WeBling

Title *Mine is longer than yours – Pole Aerial Photography for the documentation of archaeological excavations and architectural remains*

Abstract Following Ansel Adams statement that “a good photograph is knowing where to stand”, archaeologist conducting daily field work often develop urgent needs to reach camera locations that are hard to get to. This need is highlighted by the fact that nowadays image based modelling approaches play an important role in the recording process of archaeological remains. As a conventional solution, ladders or sometimes scaffolds are being used as platforms to take photographs from an elevated point of view. As opposed to Pole Aerial Photography, such solutions are often rather inflexible and dangerous. Within archaeology, poles are probably the most underestimated kind of camera platform. Poles are cost efficient and easy to use tools. They drastically increase the activity radius of a photographer to an extent which outperforms most traditional platforms in respect to health and safety, mobility and efficiency. Pole Aerial Photography can be used to shoot vertical, oblique and horizontal imagery from an altitude of up to 15 m and is therefore ideally suited to bridge the elevation gap between handheld and UAV photography. As new technical systems allow to keep control of the image frame and the camera settings, poles are superior devices for the creation of high quality records of archaeological excavations and architectural remains. The paper will provide an overview of different poles available, will discuss their specific advantages and disadvantages and will depict their utilization within selected case studies. A special focus will be put on the use of poles on excavations as an every-day documentation tool.

SESSION 7A: TEACHING DIGITAL
ARCHAEOLOGY - DIGITALLY
TEACHING ARCHAEOLOGY

POSTER

- Authors** Kevin Kee
- Title** *Seeing the Past with Augmented Reality and Computer Vision in Schools, Universities and Museums*
- Abstract** It is the impossible dream of archaeologists and historians to see the past firsthand, to witness events as they happen, and remove the uncertainty of history. Though such aspirations remain a subject for science fiction writers, recent developments in augmented reality and computer vision are providing us with new ways to see, as well as touch, smell, and hear, traces of the past. These technologies are providing a new medium for archaeologists and historians to teach and share their knowledge in educational and museum settings.
- Augmented reality (AR), once the esoteric pursuit of engineers and computer scientists, is entering the mainstream as smartphones, tablets, and wearable computing become part of our daily routine. Place-based AR applications are a common feature at heritage sites and museums, and with the improved registering technology made possible by seeing computers, archaeologists and historians, in partnership with educators and museum staff, are creating immersive and multi-faceted learning experiences.
- Computer vision, which is also used in many AR applications, has been employed in a variety of endeavours from industrial production to the security sector. It is now being directed at archaeological and historic images and three-dimensional artifacts to find patterns, details, and discoveries that are beyond the capacity of the human eye. Research involving thousands of images can now be undertaken to recreate lost or destroyed environments, buildings, or even forgotten populations.
- Building and expanding on last year's presentation to CAA-2014: Paris, this paper focuses attention on six case studies (in Canada, the United States, and Great Britain) of AR and computer vision in historical and archaeological teaching and presentation. Drawing on the case studies, the paper: i. makes conclusions about best practices for design and development of these technologies; ii. outlines best practices for testing with users; iii. engages in a theoretical discussion of the implications and future possibilities of AR and computer vision in education and museums. In these ways the paper addresses how these technologies can be more effectively used as a means to teach our students, as well as visitors to museums and historic sites.

- Authors** Matteo Dellepiane
- Title** *3D acquisition technologies for Cultural Heritage: a course for Digital Humanities students*
- Abstract** In the last few years, 3D acquisition techniques have become available to the wide community. While in the past 3D data were demanded to expensive hardware or software, the decrease in hardware costs and the advancements in algorithms (i.e. multi-view stereo matching) have made 3D acquisition possible to everybody.
- This had an impact on both the professional community and the wide public. 3D acquisition techniques are becoming part of the workflow for documentation and interpretation for archeologists. At the same time, the wide public can be involved in the valorization and dissemination of local heritage.
- Starting in 2011, the "3D Graphics for Cultural heritage" (<http://vcg.isti.cnr.it/~dellepiane/Corso.html>) course has been proposed to the Humanistic Informatics students of University of Pisa. The students, while not coming from the archeological education, take part in courses related to humanistic subjects and Computer

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Science. Hence, while not having a strong technological background, they know the basics of Informatics and Data management.

The course is aimed at presenting four main 3D acquisition families of technologies: 3D Scanning, Assisted image modeling, Multi-view stereo matching, RTI Imaging. These technologies provide coverage for a wide range of possible objects, and all of them is presented and experimented with the use of open source or free software (i.e. MeshLab for 3D data processing, Photosynth Toolkit for Multi-view Stereo matching).

Authors

Giuliano De Felice

Title

The new trend of 3D archaeology is ... going 2D!

Abstract

Nowadays one cannot imagine any archaeological activity such as fieldwork, lab work or historical analysis and synthesis without the support of technologies. 3D is a relevant part of this scenario, considering that archaeology is a reality composed of 3D entities that have to be measured, analysed, understood and reconstructed.

No surprise then if 3D reconstruction of monuments and sites is one of the most important applications of IT to archaeology, considering the ability to measure and recreate, in a perfect and realistic form, something that does not exist anymore. Relying on this strength, 3D visualization is today the main medium also for archaeological communication. Its strong visual impact gives archaeologists the chance to visually realize their reconstructive thoughts and gives the wide audience a chance to interact with scientific process of research and interpretation.

But what if we move our focus from visualization techniques to content? Starting from the consideration that before determining the use of a peculiar technology it is always better to evaluate the communication aspects, we have to consider the fact that 3D sometimes could not be the right solution, considering that any archaeological site or object is more complex than its material aspect and that even the most accurate 3D survey or the most precise virtual reconstruction are nothing but parts of a research process, tools to help interpretation. If our goal is to make the real meaning of archaeology fully understandable to a wide audience a 3D model is not enough: we need a story.

As a matter of fact, 3D visualization is a branch of computer graphic, nothing but a tool coming from the world of film technique. And we must have a director, a plot, a screenplay, a script and maybe actors and so on, before choosing the tools. In other words, first comes the story: the good news is that archaeology is a story itself, and we only have to choose how to narrate it. So, the first questions to pose, starting a communication projects about archaeology should be "which story I am going to tell?" "Whom I am going to tell my story to?". Then, in a second moment we can ask ourselves "Which is the best tool to realize it?".

In this paper I will show the results of Living Heritage project, that led us to develop storytelling methodologies and techniques and to bind them with archaeological knowledge. The main result of the project has been the production of a prototype of a storytelling engine (swipe story) that can be easily used by authors to realize narrations about cultural communication, focusing on content and visual styles more than on technologies and tools. The engine can easily manage any kind of content, from texts to music to 2D and 3D computer graphic, but it needs a story to start!

SESSION 7B: NEW CULTURAL
HERITAGE ECONOMIES IN THE
DIGITAL ERA

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- Authors** **Marzia Breda, Anna Elisabetta Ziri, Michela Biancardi, Silvia Parenti**
- Title** ***WikiSauro: a wiki for museums***
- Abstract** The project is an initiative of TekneHub (laboratory of the Tecnopole of Ferrara, within the European Platform Construction of the High Technology Network of the Emilia Romagna Region) and the Italian software company Nemoris S.r.l of Bologna, and aims to create a WIKI for one or more museums of national relevance, still lacking a complete digitalization and on-line sharing of the information related to their Heritage.
- Through an incremental and collaborative approach, the project aims to build a single semantic wiki in which each participating museum owns pages recognizable thanks to personal graphical settings but whose information are shared and accessible as a whole, facilitating the development of cultural joint paths and amplifying their creative impact and visibility. The employment of semantics will allow a fruition from outside of the information accommodated in the different pages of the wiki and will thus advertise and promote the collections published in it.
- The project involves stakeholders of several institutions (museums, universities, schools, private companies, up to the whole citizenship), is easily transferable to different school and museum realities, and is addressed to the promotion of the local and national Cultural Heritage and to the spreading of culture on a global scale.
- The museums will exploit their Heritage in its scientific/artistic and historical value and, at the same time, they will hugely increase their presence on the web and thus their international renown. In particular, all those museums that do not possess an adequate web site, telling their history and advertising their paths through virtual tours, will particularly benefit from the WIKI.
- A pilot-project has started on the palaeontological collections of the Geological Museum “Giovanni Capellini” of the University of Bologna (Italy). From the nature of its collections, the name chosen for the project.
- Authors** **Chiara Feriotto, Giuseppe Mincoelli, Matteo Fabbri, Michela Biancardi, Alessandro Massarente, Stefano Munerato, Fabiana Raco**
- Title** ***QFD as an opportunity to drive innovation on the market. Living museum: education and active participation***
- Abstract** The crisis has impacted many sectors, enterprises have to deal with market change, the introduction of new technologies and the use of new ways and tools of communication. In the meanwhile, museums and cultural heritage sector are facing the maintenance of tradition and cultural values within new strategies for education, fruition and multimedia applications.
- To address this main problem TekneHub, a laboratory of the Emilia-Romagna High Technologies Network in cooperation with the creative enterprise Tryeco 2.0 and the enterprise TechSigno, developed a project based on technological transfer from enterprises to cultural heritage area. The knowledge based technique used to drive innovation is called Quality Function Deployment(QFD). It is a user interface design methodology that pointed out the features of the products and the main needs of museum public.
- The result is a product that can be sell on the market and it consists on a smartphones application with a user interface design that integrates QR code and Radio Frequency Identification technology (RFID) to engage museums public. It was tested on a case study, the

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Natural History Museum of Ferrara. During the museum visit, users can learn about collections, historical information and territorial links but the main important part is that public can interact and be active and customizes the visit with individual memories.

7C REPLICATION: FROM THE PAST TO THE DIGITAL AGE

POSTER

- Authors** **Blanca Guinea, Guillermo Puente, Andres Bustillo**
- Title** ***Using Rapid Prototyping and 3D renders to explain strong modified cultural heritage: the case of the Ducal Palace in Lerma (Spain)***
- Abstract** The passage of time and human activity can affect cultural and archaeological heritage in many different ways. Unfortunately, their consequences are often the complete destruction or a partial transformation of its original appearance. Dilapidation and deterioration of this kind hinders comprehension of cultural heritage and complicates the task of informing a non-specialised public about its past. In this study, an approach to the visualisation of the original morphology of the Ducal Palace of Lerma in Spain is proposed; a building left in disrepair for many centuries until its renovation involving significant alterations as a Parador Nacional or luxury hotel during the 1990s. The conversion of 3D models generated by CAD tools into digital images and the creation of physical prototypes with rapid prototyping techniques are proposed, to evoke the original appearance of this cultural heritage that has been substantially modified. Both techniques are especially useful for conveying the functional structure and the outer appearance of the heritage at the time of its construction to a non-specialised public. They illustrate the Ducal palace of Lerma and particularly two of its functional elements that been lost to time: the original structure of the 4 towers of the building and the network of passages that connected the main building with various churches and monasteries in the surrounding village. Moreover, a protocol is defined for the rapid prototyping of 3D models of buildings in a small working space, for their subsequent assembly. The two techniques yield 2D rendered images and 3D physical models that create a complete image of this architectural complex, so that its visitors may understand the objectives and ambitions that motivated its construction. Finally, groups of tourists shared their impressions, by means of a survey, of both the digital imagery and the 3D models in comparison with a standard visit to the palace. In the light of their responses, the advantages and disadvantages of these technologies for the interpretation of modified heritage assets are discussed.
- Authors** **Domenico Lo Vetro, Francesco Enrico Ortisi, Angelo Secci, Michele De Silva, Giovanna Pizziolo, Lucia Sarti, Fabio Martini**
- Title** ***Florence before Florentia. For the building up of a virtual Archaeological Museum of the Florentine area***
- Abstract** The archaeological researches carried out in the last 30 years in Florence and the surrounding area allowed us to get information about many sites related to the human presence during Prehistory. These discoveries refer to the first peopling process of the Florentine area spanning from Mesolithic to Bronze Age. Most of the findings from these excavations are preserved into the local Archaeological Superintendency 's warehouse and into the labs of the Universities of Florence and Siena. Consequently, such findings are available almost exclusively to experts.
- Today, modern digital technology and the web's widespread dissemination allow us to get an alternative strategy that can fulfill the needs of knowledge and the enjoyment of the local cultural heritage. For this aim, a model of "Virtual Archaeological Museum of the Florentine area" has been built up in order to fill a gap within the context of scientific and educational instruments related to the oldest peopling of the Florentine region.

SESSION 7D: WHAT CAME FIRST, THE
INTERFACE OR THE USER? ABOUT
REASONING AND THE ILLUSIVENESS OF
INTERFACES IN THE PRACTICE OF
DIGITAL AND VIRTUAL ARCHAEOLOGY

WHAT CAME FIRST, THE INTERFACE OR THE USER? ABOUT REASONING AND THE ILLUSIVENESS OF INTERFACES IN THE PRACTICE OF DIGITAL AND VIRTUAL ARCHAEOLOGY

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- Authors** **Andrea Fratta, Lorenzo Baldassarro, Fabio Giuseppe Antonio Gagliardi, Cristiano Moscaritolo**
- Title** *The Castle of Deliceto. Two proposals for archaeological knowledge sharing*
- Abstract** We want to introduce two digital archaeology projects conducted in the same context: the Castle of Deliceto (Province of Foggia, Southern Italy). The first, Deliceto History Hub, supported by the Municipality of Deliceto, started in December 2012. The purpose was to build a virtual environment that allowed users to visit the castle and learn about its history and the different uses of its buildings. Additionally, the project gave us the opportunity to integrate archaeological and digital data and to share archaeological knowledge with users. Three teams were involved in this project: archaeologists, topographers and CG experts. Archaeologists studied buildings, architectural elements and construction techniques. The topography team conducted a survey to collect spatial data both with total station and with 3D TOF laser scanner, with particular focus on contexts like underground rooms. The third group, composed of 3D modelling, virtual reality and level design experts created the whole virtual scene. Collaboration among these experts with different skills and ideas was very useful to reason out and to decide the type of contents that best fit with the virtual environment and with users' expectations. As in a videogame, users can move inside a 3D scene and read information every time they meet points of interest. They can also visit a virtual gallery of historical photographs of the castle from the beginning of 20th century. The second project, winner of "Principi Attivi 2012", a competition organized by the Department for Youth policies for the region of Puglia, is called Il castello di Deliceto. This is an app for mobile devices, similar to a e-book, which visitors can use for a guided tour in situ. The app is an interactive fairytale where the main character, Antonio Piccolomini, first marquis under the Aragonese crown, tells the story of the castle during the war against the Angevines in the second half of 15th century. Every scene is populated by 2D animation and, at the end of the tour, users can interact with a 3D gallery of archaeological finds. These projects focus on the importance of the relationship among archaeological research, digital technologies and communication with a large public.

- Authors** **Marco Orlandi, Simone Zambruno, Antonino Vazzana**
- Title** *One-to-one or one-to-many? An analysis of digital media for exploitation of academic outcomes*
- Abstract** The present paper will focus on the use and re-use of digital models for the communication of cultural heritage academic researches. It will demonstrate that the communication of the results is a very delicate process, often underestimated respect to the main operating tasks within the research pipeline.
- A proper communication process must take into account that users can be divided in different categories, each one with specific needs, experiences and expectations (e.g. academics, scholars, tourists, citizens etc.); different typologies of digital outputs then must be provided.
- The paper will show how virtual models can be experienced through different media; it will also highlight problems and opportunities of digital media for the exploitation of cultural contents.
- Some case studies will be shown, in which different typologies of media have been used according to different users. In particular, it will be presented the virtual historical

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reconstruction of San Giovanni Evangelista, the most ancient church in Ravenna, and the research about the mummies of Roccapelago (Modena), discovered under the medieval church of the ancient village in the northern Italy.

For each presented case, a different combination of web technologies, virtual reconstructions, semi-immersive environments and mobile technologies has been set up trying to reach different users' needs and expectations.

In particular it will be presented the use of Virtual Tours as a means to communicate the research outcomes to a wide public in a semi-immersive and interactive way; moreover it will be addressed the possibility to link the contents coming from different sources (e.g. external database, websites etc.), and the opportunity to navigate a Virtual Tour on different devices, whether desktop or mobile.



SESSION 8A: DIGITAL CITIES:
DOCUMENTING AND TRANSMITTING
THE
ARCHAEOLOGICAL-
ARCHITECTONICAL RECORD

DIGITAL CITIES: DOCUMENTING AND TRANSMITTING THE
ARCHAEOLOGICAL-ARCHITECTONICAL RECORD
POSTER

Authors

Alfonso Ippolito

Title

Archaeological data virtualization for the purpose of digital documentation and reconstruction

Abstract

The study aims at pointing out and examining the problems related to the new potentialities for documenting and sharing data from the whole spectrum of archaeological contexts. The interaction between the two separate fields - architecture and archaeology - allows us to take advantage of the potentialities of digital instruments and techniques. The information provided by archaeology – though metrically and historically reliable – presents various problems linked to object virtualization: accessibility of sources, prevalence of textual data with few graphic models, the tendency to separate the territorial scale from the architectonic one.

The objective of the research is the virtualization and communication of archaeological data through digital systems that will render it possible to systematize heterogeneous data within a single platform. Methodological and technical problems manifested themselves with the attempt at virtualizing the monumental Sanctuary at Pyrgi, an Etruscan city on the coast of Lazio, about 50 km from Rome. What remains now are the ruins of a sacred area and numerous fragments of architectonic terracotta belonging to the two huge Temples, called Temple A and Temple B.

The structure of the research centres around three main tasks: cognition and analysis of all the data relative to the existing and no longer existing elements of the Pyrgi Sanctuary; virtual reconstruction; heterogeneous data systematization within a single digital platform.

The cataloguing of available data proves to be necessary to maintain intact the informative content in the process of passing from archaeological documentation – mainly textual – to one with a high percentage of graphic models. Surveying campaigns of all structural remnants and fragments preserved on the site or/and in museums provided an additional instrument of cognition. The acquisition and elaboration of data have been conducted with low cost methodologies: photomodelling for the non-contact surveying operations, open source software for elaborating and editing of surveying results.

A complete and organized collection of graphic and textual archive documentation has been adopted as the point of departure and of reference for the virtual reconstruction. The latter will become the instrument of verification for hypotheses put forward to date and will moreover serve as the point of communication and confrontation for the scholars involved in the research.

Geometric and spacial data derived from reconstructed 3D models, together with archive documents, images, two-dimensional graphic models and videos will be systematized in a digital container. Usable together with physical archives, the digital container will provide a more articulate and “contemporary” knowledge of the case under study.

The unique feature of embracing and interconnecting heterogeneous data (archaeological, architectural, territorial, textual) makes the digital platform a valuable instrument for research and for evaluating cultural heritage.

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- Authors** Marco NEGRONI, Serena Dima, Rachele Zappa, Maria Clara Frosi, Monique Pasini
- Title** *Piazza dei Mercanti (Milano): Cardboard google's inexpensive virtual reality (VR) applied to cultural heritage promotion.*
- Abstract** The Google's experimental software toolkit makes possible to build inexpensive virtual reality headsets. You simply have to use viewers made of cardboard to transform your phone and enjoy an immersive digital experience (it works with most modern Android devices). The open source libraries, used in the software, are provided by the Google Cultural Institute of Paris. We want to apply this technology to an enhancement project about Piazza dei Mercanti, promoted by Milan's Chamber of Commerce during the 2015 Expo.

SESSION 8B: URBAN DIGITAL-SCAPES:
COMPUTER APPLICATION TO THE
STUDY OF PAST URBAN
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URBAN DIGITAL-SCAPES: COMPUTER APPLICATION TO THE STUDY OF PAST URBAN
DEVELOPMENTS
POSTER

Authors Paolo Buonora

Title *Descriptio Urbis – A WebGIS to reconstruct urban landscapes of Rome.*

Abstract

In 2014, the historical WebGis of Rome (CARIPLO project) released his final version. The final developments and enhancements, were presented together with similar project in Milano and Bologna in between December 2014 and January 2015.

Following former IT and GIS projects, mostly based on the Nolli map of Rome (1748), the project is now based on the detailed cadastral source of the Gregoriano cadastre (1824), and was founded by CARIPLO bank foundation since 2006.

Our research focused since more than ten years on an instrument able to relate each other different document sources concerning urban architecture, archeology and any possible field in urban studies. In this cross-domain work, archeologists became part of a true urban history team.

Project partners of the roman team come from several fields: historical archives, history of architecture, archeology. Archivists have been working together with archeologist and architecture historians to choose the historical cartography to create a GIS framework, and to analyze the typology of archival documents to implement it. Cataloguing maps and documents is not a trivial task in a multi-purpose context as an historical GIS can be, and several interoperability issues have to be defined.

A short survey of the available cartography for the city of Rome in between XVIIIth and XXth century will be given, together with a description of the archival sources for the history of the buildings.

The building of the WebGIS has been very complex by the technical side. A smart strategy has been applied in the progressive morphing of the original cartography to a vectorial/raster version, to improve GIS functionality without losing the value of an archival record. At the same time a long work was carried on to analyze the owners registers (“brogliardi”), to disambiguate data and to fit any information in a coherent database. Smart solutions has been adopted as well to merge in a unique database records coming from the indexing work made during years by different institutions and people, i.e. to implement our own concept of “interoperability” applied to the historical documents relating to the urban buildings.

SESSION 9A: TOWARDS A THEORY OF PRACTICE IN APPLIED DIGITAL FIELD METHODS

TOWARDS A THEORY OF PRACTICE IN APPLIED DIGITAL FIELD METHODS

POSTER

Authors Sorin Hermon, Elefterios Charalambous, Lola Vico, Nikolas Bakirtzis, Giancarlo Iannone

Title *Characterization of physical damages on ancient carved structures – a 3D quantitative and qualitative approach. Tomb 6 of the Pafos Tombs of the Kings complex as a case-study*

Abstract The paper presents the results of an initial campaign of 3D documentation and characterisation of types of physical damages observable along the surface of Tomb 6 of the monumental funerary complex known as “Pafos Tombs of the Kings”, a World Heritage Site in Cyprus. The complex includes several carved in the bedrock tombs, some extremely elaborated, with several chambers, columns, etc. Some of the tombs were consolidated during the sixties, others in later period, while many remained untouched. Recently, cracks were observed developing along the surface of several of them. A 3D data capture campaign resulted in obtaining a 3D model of Tomb 6, with a margin of error of a few mm. Such data was used to extract plans, sections and related measurements, but, above all, it allowed the extraction and characterisation of observed damages on the surface of the structure’s walls. The guiding hypothesis was that cracks can be geometrically characterised by several factors, such as: location, orientation, direction of propagation, shape, dimensions, etc. Consequently, the aim of the research is to evaluate the potential of 3D modelling as an environment for identifying physical damages along the surface of the carved areas, characterise, describe and classify types of damages, understand their origin, investigate which types of modern interventions are required and simulate the final results.

Authors Valentina Vassallo

Title *A virtual bridge between Sweden and Cyprus: the case study of Agia Irini*

Abstract The sanctuary of Agia Irini (Cyprus) was excavated by a Swedish archaeological mission in 1929 and its collection, famous for its large number of clay figurines, was divided between Sweden and Cyprus: more than half of the figurines were transferred to the Medelhavsmuseet in Stockholm, while the other half are exhibited in the Archaeological Museum of Nicosia. A small group of the archaeological collection is also conserved at the Historical Museum of Lund University (Sweden). Most of the terracottas represent male figures of small, medium and large size, including warriors and priests with helmet or conical caps and different attributes (votive offerings, arms, musical instruments).

The general aim of the ongoing doctoral research is the contribution of 3D documentation to the analysis of these terracotta artefacts and their archaeological context. The scopes, through the integration of digital technologies, are in fact the documentation of the archaeological material, its (re)interpretation, analysis, visualization and a digital unified access to the different collection parts. Specifically, the topic of this paper focuses on the methodology, the theoretical approach and the first results of the research, applied both to the collection and to its archaeological excavation documentation. In particular, this paper will focus on the pipeline and methodology developed for the choice of the sample, its digital acquisition and the analysis of the statues on the base of a semantic and standardized study of their three-dimensional elements. The first 3D acquisition test has been carried out on the collection conserved the Historical Museum of Lund University. Due to the size of the sample, the material, the shape, and surface characteristics of the artefacts, the geometry of the statues have been digitally acquired with a NextEngine 3D Desktop laser scanner. Moreover, in order to guarantee also a high definition quality texture, for the preservation of the visual characteristics (colors, material

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characteristics, micro elements, etc.), the statues have been also digitally acquired through image based modeling technique (post-processed with Agisoft PhotoScan). After this, the outcomes are integrated, in order to have high quality models both for their geometry and for their texture.

The geometrical representation of measurable 3D models (with millimetric precision), will allow to perform the extraction of the statues' elements as well as their characterization. Through that, it will be possible to identify technical/technological features such as the manufacture, use of standards, guidelines or rules (e.g. ratio between the parts, standard or fixed dimensions) in the production of these artefacts or to identify the workshop's methodologies and techniques (or different workshops and/or different artisans).

The research will further include the positioning of the statues' 3D models in a 3D GIS environment of the sanctuary, in order to have a unified access of the collection, a holistic vision of the archaeological discovery and to act as a virtual bridge between the different collection parts.

Authors

Arianna Traviglia, Stephen White, Andrew Wilson, Beatrice McLoughlin

Title

Digital practice in archaeological fieldwork: theoretical frameworks of 'going digital'.

Abstract

In light of the experience of two archaeological projects, the paper reflects on the relationship between theories of archaeological practice and aspects of digital archaeology including modelling, digitising, curating and integrating legacy and born digital data; managing the change to all digital data capture, including matching the way people work and standard archaeological practice with digital systems; management of volatile data in the field and long term sustainable management of digital records.

This paper presents two case studies in the application of digital technologies to archaeological investigation: the first based on the field survey of the landscape of Roman Aquileia, Italy and the second on the excavation experience at the Early Iron Age settlement of Zagora on Andros, Greece.

"Beyond the city walls: the landscapes of Aquileia" is a landscape archaeology project based in NE Italy and focused of the landscape transformations occurred in a large floodplain area as result of the Romanisation process from 2nd century BC onward. From 2010 the Aquileian landscapes has been investigated by an Australian team combining preliminary remote sensing analysis with verification through pedestrian survey. From the start the goal of the project was to automate the process by collecting survey and artefact catalogue data digitally for immediate integration into the research data management system.

Since 2012 the Zagora Archaeological Project (ZAP), based at the University of Sydney, has undertaken a broad, multi-disciplinary investigation of the site, including remote sensing, geophysical survey, spatial analysis using GIS, surface survey and excavation that had been previously excavated by a team from the University of Sydney in the 1960s and 1970s. A fundamental aim of the new project has been to use digital data capture and storage as much as possible and to integrate the new data with the extensive records from the earlier investigations within the existing database.

Field data collection was carried out using Android tablets running a variety of recording forms based on the Open Data Kit Collect xForms application. Field workflows for survey and excavation were analysed and codified and a suite of data collection forms developed to support them. A complex data model had been developed to support the analysis and publication of the legacy data and implemented in the server database. In order to integrate the new field data a two stage process was developed. Completed field forms were initially

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uploaded unaltered into the database and ingested as form records, these were then processed into the database as fully linked data.

Aspects of work in the field and in the laboratory, especially in excavation, require immediate feedback and reporting to support ongoing data collection on a daily basis. A system of digital summary reports, digests of daily field records and initial artefact analyses were implemented to provide team members with the data they needed each day.

Authors

Peter Jensen, Casper Skaaning Andersen

Title

3D Documentation Workflow of Archaeological Excavations

Abstract

For more than a decade Archaeological IT at Aarhus University has been using photogrammetric techniques for archaeological field documentation. However, photo-documentation often merely represents modern tools applied to traditional archaeology, rather than a re-thinking of the way we do archaeology. Recent research excavations at the Iron Age sacrificial bog at Alken Enge presented an exciting opportunity for developing methodologies for the recording of complex archaeology. The complex stratigraphy, huge quantity of human remains, and well preserved organic material encountered on the excavations are challenging to document effectively using conventional recording methods. As a result, 3D photo-documentation using Structure From Motion/Multi-View was adopted as the principal means of recording.

This presented a number of issues regarding the workflow of the digital documentation of archaeological excavations in general, and specifically the recording of complex 3-dimensional structures. For example, a significant challenge is the merging of data of differing complexity and origin into a common level of generalisation, which eventually leads to a re-evaluation of what the end-goal of archaeological documentation really is. Are we content with highly detailed 3D representations simply being reduced to something equivalent to a hand-drawn sketch, just because it must be compatible and comparable to existing data? Why not raise the bar of documentation quality and availability? Steps had to be taken to ensure that the detailed 3D representations were not reduced to a digital equivalent of analogue, traditional data types, but could be utilised as a new type of observational documentation with reduced interpretative bias. It is however extremely important to balance the documentation to focus on the element of archaeological interpretation and its level of authenticity and not merely strive for the objective 'truth'.

By working with concepts as Documentation Events and Data Collections a platform for handling diverse documentation has been established. This platform allows for the integration of new types of data into the archaeological record, and at the same time pushes the boundaries of documentation output.

The aim of this paper is to present the workflow and implementation of 3D documentation in archaeological excavation practice along with the methodological and theoretical challenges of generating and handling complex spatial data in relation to the archaeological process of interpretation.

SESSION 9C: MODELLING THE ARCHAEOLOGICAL PROCESS

MODELLING THE ARCHAEOLOGICAL PROCESS

POSTER

Authors Kaveh Yousef Pouran, Juan Anton Barceló, Maria Saña Seguí

Title *Extending Archaeozoology, from computer visualization to behavior dynamics: understanding early animal domestication through coupling functional morphology and locomotion Biomechanics*

Abstract Domestication can be defined as the adaptive dynamic process encompasses the genetic alteration as well as social-behavioral development toward living in captive environments. Comprehending the early steps of domestication process is not only vital for deeper insight into behavioral-anatomical evolution pathways of animals, but also crucial for understanding the early farmers' culture and socio-ecological boundaries; factors which motivated practicing animal husbandry and this might be the reason that studying transient stage of domestication has been appraised as the most determining yet most challenging chapter of zooarchaeological research. The challenge arose due to the lack of proper quantitative techniques facing archaeologists who strive for separating wild animals from their recently-domesticated descendants. Traditionally metric as well as morphometric approaches have been vastly used to separate wild and domestic animal bones in archaeological records though the results haven't been satisfactory enough for transitional episode.

Domestication process includes behavioral adaptive responses: keeping animals in captivity triggers behavioral changes. Knowing the behavior dynamics of wild-domestic evolution is necessary to comprehend domestication process. Combination of behavioral dynamics and functional morphology extends archaeology boundaries through biomechanics and robotics; provides new opportunities to overcome deficiency of traditional experiment designation for studying domestication and justifying consequences or even emergence of morphological divergence during the early stages of domestication process. Regulated by functional related mechanical forces, skeleton specifications are conditioned by biological process. Consequently, considering the significant impact of animal behavior on muscle activities and bone histomorphology, it is more pragmatic to first perceive the "mechano-behavioral" outcome of living a life controlled by human (domestication), then explore the resultant skeletal changes. Pursuing this idea, it might be possible to determine first attempts of canid, pig and cattle domestication and also explore the co-evolutionary anatomical-behavioral changes experienced by man and animal.

The proposed methodology can be separated into the two distinct steps: preparing mechano-behavioral database for target animals (i.e. pig, wild boar, dog, wolf and probably cattle) and estimation of mechanical loads experienced by each bones during animal lifespan. Loading estimation will be accomplished based on modeling functional morphology of archaeologic bones through finite element-based simulation of bone remodeling biomechanics. For this step, data acquisition includes micro CT scanning of archaeological bones. On the other hand mechano-behavioral database which encompasses estimated forces acting upon animal bones during different locomotory activities database, will be provided by simulating modern animal's locomotion implementing multibody dynamics and robotics. Data acquisition comprises CT-scanning of animal limbs (skin, muscle and bones) as well as measuring muscles biomechanical specifications. Comparing estimated loading with mechano-behavioral database reveals level of locomotory activity of animals (which can be considered as the animal behavior indicator) during favored era (e.g. Neolithic), makes it feasible to differentiate wild and domestic bone specimens.

MODELLING THE ARCHAEOLOGICAL PROCESS

POSTER

Authors Patrizia Gioia, Livia Riga, Rita Volpe

Title *How can the archaeologist “reconstruct” himself by “reconstructing” the ancient landscapes? Drawing and telling life in ancient suburbs of Rome*

Abstract

In the last years of the twentieth century wide archaeological investigations were carried out in the southeastern suburbs of Rome, in order to address the new urban planning of the so-called 'Sistema Direzionale Orientale' (SDO). The most widely investigated area was that of Centocelle, which is largely free of buildings because it includes a part of the former military airport. Therefore, since every part of this area had its peculiar history and required a different approach, the project was multidisciplinary and based on various methods: the wide extension of the area and the ongoing use of the plateau, required different kinds of investigations, including a systematic survey of the areas without modern landfills, core drillings (aimed both at drafting specific thematic maps and at producing a geomorphological reconstruction of the territory), geophysical research of the asphalted or cemented areas, trial trenches and open excavations. The data obtained entered into a GIS system: this was essential to link each other different scientific fields and their knowledge. The overall results allowed an extensive historical reconstruction of the settlement phases, with the sequence over time of different "landscapes": from the small houses / huts of the sixth century BC up to the first villas during the mid-republican age, with the intensive grape growing; subsequently the villas of the imperial age, extending over 10,000 square meters, provided with large thermal baths, extensive gardens adorned with statues, theaters and large pools, which however preserved income from valuable crops. On this occasion, we are going to present the multimedia project, based on a comparison of archaeological data, paleobotanical, paleozoological, geomorphological and others with the ancient sources, in order to revive the ancient suburban landscape of Rome in its changes over time, projecting the local data on a regional scale. Thanks to the interdisciplinary approach adopted since the beginning of the investigations in the 90s, we can now rethink about some aspects of the life and the environment that hardly fall into the normal routine of archaeological practice. In this context the use of new technologies has been a key tool to create new queries and find new interpretation meanings from the data already collected using the appropriate methods of field research. The ongoing study led so far to some visual imaging of ancient suburban landscapes, that will be part of a wider project of reconstruction for any occupation phases identified at Centocelle. Our experience shows that the professional profile and the know-how of the archaeologist is crucial in order to achieve significant scientific results, also in the field of virtual reconstructions. The archaeologist must be the leading actor, not only in the reconstruction choices, but already in the planning project and then in the improvement of the achievements.

SESSION 9E: MOVING THE FOCUS
FROM "KNOW HOW" TO "KNOW WHY"
3D MODELING CULTURAL HERITAGE

POSTER

Authors Eleonora Gandolfi, Grant Cox

Title *New techniques in archaeology: which is the most accurate?*

Abstract

In the past few years archaeology has seen an increase in the use of advanced technological recording methods, both in the field and post excavation. Most professionals are now familiar with techniques such as Photogrammetry and basic 3D reconstruction and these tools have become a common medium to engage local communities due to their efficiency in both speed and cost.

However, the availability of these techniques and their perceived ease of use has often arguably led to their inclusion into projects as a fulfillment of the current 'meta', rather than to directly answer questions, or overcome problems posed by the archaeology. Furthermore, their integration into an excavation workflow is often proposed by those without a background in the digital sphere or the wider commercial processes. Whilst this is not an issue, there is also a perceived fallacy that software and digital techniques are not just objective shortcuts to a perceived goal, but also automated processes where responsibility lies with the computer rather than the user. This phenomenon exists not just within archaeology but also on a wider scale within much of the artistic world and it will be argued in this paper that it is somewhat naive to use these software packages to perpetuate this fallacy and present objective authority.

Consequently, to assess exactly how accurate these techniques are, results will be compared between different technologies that have been applied to a single case study in Tunisia. These case studies will aim to deconstruct not only what is achievable through objective processes, but also how automatic those procedures truly are in comparison to what can be obtained by an informed user. It will also reintroduce the idea of the informed user within digital technologies, examining what tools are available and how they can be used in multiple situations and constraints to achieve very different subjective outcomes within the same packages.

SESSION 9F: MACHINE LEARNING AND PATTERN RECOGNITION FOR ARCHAEOLOGICAL RESEARCH

POSTER

Authors **Julia L Galliker**

Title *Application of computer vision to cross-collection characterisation of historic silk textiles attributed to Mediterranean production centres c. AD 600-1300*

Abstract

My research applies computer-based imaging technologies to examine historic silk production evidence more intensively than was formerly possible. My programme combines high-resolution images with a custom-developed computer vision software application to measure the quality and workshop characteristics of weft-faced compound weave figured silks attributed to Mediterranean and Near East workshops between c. AD 600-1300. Surviving complex figured silks are significant in both historical and technological terms. At the time, developments in complex pattern weaving had a profound effect on the organisation of work and the spread of weaving methods. In particular, drawlooms represented one of the first instances of mechanically sequenced and memorised work in history.

For a variety of reasons, research progress for this category of textiles has slowed in recent years with few scholars now active in the field. While essential to protect fragile textiles from damage, the practical consequence of strict museum conservation standards has been reduced collections access for textile scholars. Resource constraints and structural changes in museum practices mean that many institutions now focus on exhibitions rather than research. At some institutions, large textile collections gathered in the early 1900s now languish. Even at well-resourced institutions, there is little opportunity for incomplete or antiquated collections documentation to be updated.

In the face of these challenges, dramatic advances in digital imaging provide opportunities for the development of new methods for investigation and documentation. My research protocol combines a research grade digital microscope with a custom-built stand to perform precise digital 'sampling' for measurement of textile attributes including yarn characteristics, textile structure, density and pattern unit features. The computer vision application aids in error detection, providing a basic form of industrial inspection for ancient textiles. The outcome is a set of objective and reproducible measurements enabling specific comparison of attributes across different collections.

By using my portable equipment setup, I was able to record over 160 figured silk fragments held in North America and European collections. Analysis demonstrates patterns of work practices and imitative pattern reproduction among workshops. Results also help to re-unify textiles divided in antiquity or after excavation. In the future, this methodology could provide the basis for a shared database of images available to a broader community of researchers.

Authors **Hubert Mara, Bartosz Bogacz**

Title *A Bridge to Digital Humanities: From Geometric Methods to Machine Learning for Analyzing Ancient Script in 3D*

Abstract

Cuneiform tablets are one of oldest textual artifacts comparable in extent to texts written in Latin or ancient Greek. Since those tablets were used in all of the ancient Near East for over three thousand years [Sod94], many interesting research questions can be answered regarding the development of religion, politics, science, trade and climate change [Kan13]. These tablets were formed from clay and written on by impressing a rectangular stylus [Bor10], require novel methods different from methods used for flat objects i.e. ink on paper.

The digitization of cuneiform tablets and the development of respective databases, started in the same spirit as the *Open Data Initiative*, has already been initiated by the *Cuneiform Database*

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Library Initiative [GWL05]. At that point, usually, photos and images taken by flatbed scanners are used which are cheap and fast to create. This technique creates blurred and/or shadowed areas if the tablet is damaged or crooked, which is the case for most tablets. Therefore, modern 3D measuring instruments are employed in Jena, Würzburg [CMFW14] and in Heidelberg, Germany [MKJB10] to create highly exact digital replicas used to create appropriate visualizations.

Since the data basis does not consist of regular grids i.e. two dimensional bitmap images as used in the *Digital Humanities*, new methods for extraction of characters from the geometry of 3D models are required. For that reason, Integral Invariant Filters are applied using a multi-scale approach to extract distinct elements of a cuneiform character in vector representation [MK13]. The *Gigamesh Software Framework* exports these to the SVG file format. Software packages able to edit SVG files are employed in assyriology and for documentation of archaeological excavations. Therefore, it is already ensured that drawings computed from 3D models are compatible to drawings created by hand.

The representation as vectors as well as the complex 2D layout of cuneiform characters precludes the usage of common OCR methods that require characters to be represented as bitmaps [AGFV14] and/or to be sequentially ordered [RRF13]. The analysis of cuneiform characters requires the transformation of the SVG data into a simplified but mathematically usable representation as mathematical graphs of edges and vertices. Cuneiform characters are mostly identified by the placement of their wedges, a property exploitable by decomposing a graph into disconnected components corresponding to the wedges of a character. Furthermore the complete graphs are also being used to apply methods from the field of graph similarity, methods like graph kernels and spectral embedding [BR10]. The latter approach is especially advantageous if a complex pictorial character cannot be decomposed into sub-structures of features but still has to be compared to another character.

In summary, this work presents methods in the fields of geometry and pattern recognition free of lexicographic and linguistic assumptions. Hence, new approaches are created in which OCR for handwriting can be integrated, exceeding the sole application of cuneiform characters, which are handwritten in 3D. By steadily increasing our data basis for script in 3D the consequential next step will be the integration of machine learning methods. A direct application on epitaphs of medieval Europe is already part of respective online databases [Krö12]. Future application domains are e.g. Roman and Greek inscriptions or Linear B.

Authors**Michail Panagopoulos****Title*****Identifying patterns on prehistoric wall paintings: A new curve fitting approach*****Abstract**

Application of pattern recognition and image processing methods to archaeological finds has offered recently quite important results. More specifically, it has been demonstrated that the celebrated prehistoric wall paintings of Akrotiri (Thira, 1.650 BC) “Gathering of Crocus”, “The naked boys”, “Wild duck” etc., which belong to the building Xeste 3 and the famous wall-painting “Lady of Mycenae” from Mycenae, have been constructed by stencils and in particularly by geometric ones. In order to show that drawn parts of the wall paintings fit to specific geometric curves the method consists of a number of steps. The first step is the digitalization of the wall painting (high resolution digital images of the wall paintings) and the next one is the determination of its contour parts. Consequently, the determination of the curve family that will be tested needs to take place. More specifically, curves that can be chosen are conics (ellipses, hyperbolas etc.) and spirals. Then, the approach determines a curve fitting method that tries to optimally fit the drawn contour parts to the prototype curves based on the minimization of the fitting error in the least square sense. This will lead to a curve parameter

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set, so a clustering algorithm is applied and statistical methods provide the final set of parameters.

In this paper a curve fitting approach based on the curvature is presented and it is applied to the aforementioned wall paintings and to other wall paintings from Akrotiri, e.g from the other rooms of the site (“West House”, “House of the Ladies” etc.) and Minoan wall paintings as well. The error minimization is calculated by a curvature function and in consequently the refined parameters of the prototype curves are provided again by means of data clustering.

The fitting error between the original drawn contour parts and the prototype curves are extremely small, namely the average fitting error is 0.02 mm while the maximum fitting error is 0.06 mm. It is notable that there exist contour parts of length over 15 cm, which fit optimally the prototype curves and that there exist object parts of the same wall painting that perfectly fit to each other.

Finally, it is remarkable that the same group of geometric stencils is found to different locations.

Authors**Martina Trognitz****Title*****Computer based analysis of multi-sided Aegean seals*****Abstract**

There are known just over a thousand Minoan and Mycenaean seals with more than one seal face. The number of seal faces can go up to 14, but most common are two-, three- and four-sided seals, with about 370, 580 and 90 pieces respectively.

When contemplating these seals there soon arises the question whether there exist specific patterns for the combinations of different motives on the seal faces. Are there only patterns for some seal groups or none at all? If patterns exist, do they allow to draw conclusions about the function of the seals? Do they bear a meaning not yet known to us? Are there sequences that convey some kind of message? Are there sequences of motifs on multi-sided seals that are condensed on fewer seal faces? Does the place of origin play a role in the design of a seal?

In my ongoing doctoral thesis I will take into account all multi-sided seals, published in the „Corpus der minoischen und mykenischen Siegel“. As for today they are all recorded in the Arachne-database of the DAI and the University of Cologne. Considering material, provenance, number of seal faces and represented single or combined motifs, it may be possible, by means of clustering algorithms, to discover new seal groups, which then can be analysed from an archaeological point of view.

The talk will give an overview of the issues while preparing the data, and discuss advantages and disadvantages of the used algorithms for this task.

SESSION 10B: ELECTRONIC
RESOURCES FOR ARCHAEOLOGY:
FROM DATABASES TO DIGITAL OPEN
DATA

POSTER

- Authors** Yue Meng, MingQuan Zhou, WuYang Shui
- Title** *Tibet Cultural Resources Digital Network Exhibition Platform Based On Blog System*
- Abstract** The cultural resources of Tibet is unique in the world,they range from artistic relics and peculiar structure of architectures to religious traditions and national customs.As time passed by,the cultural and historical resources were fading away and people's desirability to accessing the real cultural resources is more and more difficult.We proposed a rapid,convenient and comprehensive way to construct a digital network exhibition platform.The blog system is graceful content management system,so we collected various types of resources which contain 2D(two dimensions) pictures,3D(three dimensions) models,videos and audios,then integrated them into Wordpress blog system.With a view to comprehensive exhibition and extended function of our platform,we designed the interactive exhibiting modules.One of them is that the 3D relic models can be rotated,scaled in webpage interactively using WebGL.User can also retrieve 3D models in a 3D retrieve sub-system and customize 3D print model.Furthermore,we designed panoramic roaming of scenic spots in order to viewing scenes from 360 degree.Users can visit and transfer different scenes interactively through clicking hot spot.This platform can manage and exhibit the Tibet cultural resources comprehensively.
- Authors** Bastien Varoutsikos
- Title** *Obsidatabase: a collaborative interdisciplinary platform on Near Eastern obsidian*
- Abstract** Obsidian in the Near East and the Caucasus has been the object of both archaeological and geological studies for more than a century (Cauvin et al. 1998). The role of this raw material in the identification of prehistoric processes (group interactions, exchange network, ...) is supported by a constant development of characterization techniques, and a growing number of analytical tools such as GIS (Chataigner and Barge 2005). However, the amount of research on this topic led to the production of an important quantity of data of various type (maps, pictures, provenance, provenience), and of different nature, geological and archaeological. Therefore, considering the amount of digital technology available to researchers, the only limit existing to the organization and sharing of this body of data is our desire to do so (Sterling and Weinkman 1990).
- Obsidatabase has been designed and programmed to create a space for scholars to access, edit, and share informations related to obsidian in the Near East and the Caucasus. It is, first and foremost, an online database compiling more than 2400 references, identifying and providing results for 47 geochemical sources, and 466 archaeological sites. The archaeological result can be accessed through a search engine allowing the creation of list following specific variables (site name, region, country, altitude, type of obsidian, etc...) that are directly exportable as sev or xls files to be integrated into any GIS software or database. The geological part of the website provides geological maps, detailed geochemical characterization associated with specific methods and publications, as well as pictures of obsidian samples. Finally, a page allows scholars to share their published data, that will be integrated into the database (after review).
- This database allows scholars to address obsidian from different perspectives and to produce different types of result. We therefore strongly encourage scholars to use Obsidatabase and to participate to this collaborative, interdisciplinary tool.

POSTER

- Authors** **Mariagrazia Galimberti, Nicholas George Wiltshire, Kyla Bluff**
- Title** ***Rolling Out Free And Open Source National Heritage Systems To Record Archaeological Sites***
- Abstract** Cedar Tower Services (CTS) and its non-profit branch, OpenHeritage, recently launched the national heritage management system for the National Heritage Council (NHC) of Namibia. This system is based on the same Drupal platform as the South African Heritage Resources Information System (SAHRIS). SAHRIS was developed in South Africa between 2012 and 2013 and is currently used as the main heritage management system in most of the country.
- In Namibia the system was launched in November 2014 and it is expected that more than 40 private and state funded museums will be positively engaged in the rollout of this national heritage platform, which will act as Namibian Heritage Register as required by the National Heritage Act, No 27 of 2004. Thousands of heritage site recordings, which fall within Namibia's borders, but reside in various collections around the world, will be fed into Namibia's system to integrate site management and protection by the NHC and their partners.
- The paper will reflect on how access to the information on archaeological sites was negotiated in the digital system, it will discuss the use of organic groups as a means to control this access to information and it will reflect on how the Namibian solution compares to its South African counterpart.
- Authors** **Matthias Lang, Manuel Abbt, Gerlinde Bigga, Jason T. Herrmann, Virginia Herrmann, Fabian Schwabe, Dieta Svoboda**
- Title** ***A Swabian in the Orient - in the footsteps of Julius Euting - Bridging the gap between Digital Humanities and Digital Archaeology***
- Abstract** At the end of the nineteenth century the Orientalist Julius Euting traveled several times to the Middle East to investigate and to record pre-Islamic monuments, artifacts, and inscriptions. In his journals he made countless descriptions, sketches, watercolors, and maps of the places and monuments he visited, many of which have been lost to time.
- On the occasion of the one hundredth anniversary of his death, the University Library of Tübingen has digitized all of Euting's journals and sketch books, preserved in the library's inventory. The aim of the presented project is to connect these texts with additional sources and data in a common interface.[1]
- This system is based on the web-framework *Neatline*, developed at the University of Virginia. *Neatline* is able to manage and visualize heterogeneous data in a common interface. We extended the system with a functionality to store and display XML-encoded texts according to the recommendations of the Text Encoding Initiative (TEI). Through the use of XML-TEI the text can easily be enriched by additional information in standardized way. So far, this utility has been implemented for persons and places. Furthermore, every entry in the journals is connected to a date or a time-span displayed in a timeline which could also be used to access the text. Beyond this, it is possible to upload or to link scientific articles to monuments, artifacts or archaeological sites mentioned by Euting.
- All geographical information in the diary can be directly connected to maps provided within the system. Besides a Google or a Bing map, it is possible to upload georeferenced historical maps to display them in the interface.

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This paper will focus on the technical underpinnings of this resource and our experiences in using a spatial and temporal digital text edition within an archaeological research project.

The enhanced edition of this text will be of interest to the public and scholars from a diverse array of fields. We have specifically enriched Euting's records with historical maps, pictures and scientific articles for use within the archaeological research process. The journals are snapshot of landscapes, archaeological sites, people and monuments that have all been transformed, displaced or destroyed over the last century, and are therefore of great interest to historians and archaeologists working in the regions described in the journals. In the context of the renewed archaeological project at Zincirli, Turkey (ancient Sam'al) by the Universities of Chicago and Tübingen, Euting's account of the months he spent at the excavations at Zincirli can provide new archaeological and epigraphic information, additional details of the pre-industrial landscape, and materials for the history of research and ethnohistory.

[1] <http://ecenter.uni-tuebingen.de:8012/neatline/fullscreen/start>

Authors

Silvia Lischi, Francesca Simi

Title

Open Data and Near Eastern Archaeology

Abstract

Cultural heritage preservation should be cared by everyone and less subjected to tourism industry speculation. The market dealing with cultural heritage is restricted to very few fields and it would have an economic yield only through tickets for highly attractive museums, exhibitions and monuments. This selection of highly interesting cultural heritage materials brings the tourists' attention only to few spectacular examples, leaving behind the objective need of wholly and systematically exploiting of what is believed to be part of a given territory heritage.

In this context Open Data, meant as free access to information, but mainly as direct access to data, deriving directly from excavations and not only from scientific researches, has the power to transform the way of carrying on investigations and scientific studies. Open Access, and furthermore Open Data, has the strength to maximize research investments, increase use and visibility of published researches, make data availability easier and then improve knowledge progress. This change is more and more felt necessary by those who study the field and everyone (research investors, academic institutions, researchers, scientists, teachers, students and community members) who actively support it.

For us this need is furthermore felt in a far and full of difficulties field such as the Oriental one. More and more often, countries culturally important also for our history, have been interested by critical social and political situations making difficult not only our access to them but also the preservation of what had been laboriously achieved until that moment. Furthermore, in these so far countries there have always been a lot of specialized experts. With no doubts this has enriched the quality of the obtained data but it has also made more difficult their circulation outside the specific circle. The progresses reached on Near and Middle East archeology are countless but the results known outside the scientific community are very little. In some cases, especially in certain niche fields, publications are very few and the reached progresses remain unknown even to the scientific community. The long lasting publication times instead seem universally spread. This leads to an inexorable aging of data, to a lack of coordination among the several research groups, to redundant researches and to waste of the already poor funds. With the purpose to clarify the situation and to establish a starting point to keep up with times, we decided to collect data on who is, or at least tries to be, Open Access or Open Data, as

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regard as Near East, trying to present the today situation and the possible future ways to be followed to aim funds and commitment not only to one researcher career, but to increase the whole community knowledge.

SESSION 11: OPEN SESSION

SESSION 11

OPEN SESSION

POSTER

Authors **Antonio García Castañeda, Tom Funkhouser, Benedict Brown, Szymon Rusinkiewicz, Tim Weyrich**

Title ***Verification-Minimal Assembly of Fragmented Frescoes***

Abstract Archaeological artefacts such as frescoes and pottery are typically found in a highly fragmented state, and thus require considerable effort on the part of conservators and archaeologists to reassemble. Despite much effort and research, assembly problems with large numbers of fragments remain impervious to fully-automatic reconstruction. This can be overcome by involving human experts to validate potential matches by physically testing them; however, this will require an ever-widening search, leading to an almost exhaustive search, making constant disambiguation through conservators intractable. We designed an algorithm that reaches high completion rates for very large problems, whilst minimising the physical match validations required. We achieve this by performing and combining numerous small, constrained local assemblies. We demonstrate our results using two data sets of real-world frescoes.

Authors **Fabián Ariel de Haro**

Title ***Archeology and GIS in the hills of Tandilia Buenos Aires Argentina***

Abstract The present work covers a research involving the study of spaces in a regional scale, through computing tools for the spatial information treatment. In this sense, the objective is to contribute to the general knowledge of the use of space providing new data about the different hunter-gatherer groups who inhabited the hill chain of Tandilia (Argentinian pampeana region), taking the geographical coordinates of the places as the main archeological fact. From these lines of research, it is possible to understand in depth the connection between the location of the archeological places and their surroundings. Therefore, it is possible to recognise the presence of distribution patterns by the archeological coordinates of the different places. Moreover, it is also possible to explore which environmental aspects had a mayor influence in the location of the different places. From this data, it is possible to point out and suggest new areas in which the same conditions are given, and therefore it is possible to generate expectations about new places to inhabit (Fernández Cacho 2009). This gives objectivity to the selection archeologists do of the places they choose to survey and establish a series of previous steps to the conventional surveys (Carmichael 1990). The area defining this work is the hill system of Tandilia located in the Province of Buenos Aires. It is an ancient geological formation with a large geological history which is characterised, among other things, by possessing vast igneo-metamorphic rock diversity. Its disposition heads northeast-southeast covering 350 km from the city Olavarria to Mar del Plata (Dalla Salda 1999; Dalla Salda et al. 2005). For this work, sixty six archeological places were used. They were taken as locations where hunter-gatherer groups inhabited from the Pleistocene-Holocene until the Late Holocene. The places where their geographical location was given were selected. This gave possibility to obtain a greater number of data in relation to the variable used in the present work (distance to water fountains, altitude amsl, position and gradient). These are distributed throughout the whole Tandilia, which was divided into three sections: northeast, central and south oriented. Through spatial analysis, using GIS and different statistic tools, it was possible to recognise, and at the same time distinguish how the different spatial variable influenced in the location and distribution of the archeological places. According to the results obtained from the research, the Gradient is the variable which best indicates the location patterns. It is followed by height and the remaining variable. At the same time, every step carried out in order to get to results, is explained in detail; and the use of certain tools for spatial analysis in general and in particular to the area involved in this work is discussed.

- Authors** **Rocío Gutiérrez González, Mercedes Farjas Abadía, Isabel Velázquez Soriano**
- Title** ***EPIARQ a step towards standardization and interoperability in the epigraphic cataloguing***
- Abstract** EPIARQ, methodology of cataloguing and spatial analysis of monumental and architectural epigraphy, It is created to implement any type of inscription, but especially the use case of building epigraphy in tardo-antigua Hispania (centuries V to VII). This methodology is born with the firm intention to fill the gap, through history, in data modeling standards relating to epigraphy. This lack of standards has made there is a lot of redundant information associated to the same element; distributed by different systems in distincts formats and media.
- The arrival of European Directive INSPIRE requires the government to take appropriate measures to ensure the sharing of their geographic data and geographic information services. Allowing easy access and interoperability with other data, facilitating the exchange and use by Spatial Data Infrastructure of Spain. All of this makes us to consider the need to create a new data model, supported in existing, covering the entire life cycle of an inscription since its discovery until its demise, including; the literature generated around it, carbon copies, photographs, videos and 3D representations if they exist.
- INSPIRE Annex I develops the theme "Protected Sites" from the point of view of nature, which makes it necessary to create a data model to take account of protected cultural sites. In which, in one way or another these inscriptions will manifest, as can be for example buildings, tombstones, etc.
- After investigating the composition of major epigraphic corpus existing and interviews with experts in the field, an initial conceptual model that contains the necessary classes to catalog entries of all types, identifying the attributes (required or optional) and methods that will get possible strict geographical analysis which will lead to future thematic maps made for our final study, epigraphy edilicia in late ancient Hispania (V to VII centuries).
- Authors** **Núria Otero**
- Title** ***Intervisibility analysis and the definition of the western Ilergete territory: the case of Monderes.***
- Abstract** The site of Monderes (Castillonroy, Aragón, Spain) is located on the top of an elevation 630 meters above the sea level at the Santa Anna's Gorge exit, at its feet runs the Noguera Ribagorçana River, a tributary of the River Segre. That gorge is nowadays closed by a dam built during the 1960's decade. At this strait's end the flat lands of the Ebro depression spread and descend until the 100m above the sea level, a point in which Segre and Cinca rivers join the Ebro. Monderes and its environment had been inhabited since prehistoric times, a fact proved by the presence of rock paintings and Prehistoric and Bronze Age dated cave occupations. In addition the finding of a bronze deposit shows the relevance of this spot and the Noguera Ribagorçana's valley route, which connected the Altantic area with the inner lands of the Iberian Peninsula during the Late Bronze Age (Domínguez & Maestro 1994: 33; Gallart 1991: 28-30; Montes *et al.* 2006: 103-109). The Ibero-Roman settlement in which we will focus (González 1986: 277; Garcés 1991: 222) is located over the hill's upper platform.
- The prominent position of this site and its strategic placement with respect to the surrounding areas makes it an optimal candidate for the application of the view shed and intervisibility

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analysis in order to exploit the potential of the GIS environments in researching the construction, the perception and the structure of cultural landscapes (Grau 2004: 61-75; Fiz *et al.* 2010: 97-122; Llobera 2001: 1005-1014; Llobera *et al.* 2010: 146-151). This case study revolves around: Monderes and its immediate environment, the definition of a northern frontier, and finally Monderes and the disintegration of the Ilergete state structures in the transition between the Late Iberic Period to the early Roman occupation of the area during the Roman Republic between the 3rd and the 1st centuries B.C.

Monderes visual range covers more than 3000 square kilometers controlling the eastern Aragonese and the western Catalan low lands; however, its relative isolation with respect the Iberic settlement network, its clear prominence and strategic position points out a possible functional specialization. The application of the viewshed and the intervisibility analysis allow us to investigate its role in the definition of the western Ilergetian territory during the Late Iberic Period and the early Roman occupation. It is through such methods possible to obtain clues about settlement patterns, landscape perception and structure, and even though about the social and territorial organization. The case of Monderes reveals a surveillance spot that could have performed a leading role in the definition of the Ilergetian territory, reinforced during the late Roman Republic in order to control its northern border, acting as an advanced outpost that kept visual control of the greater part of the territory.

Authors

Lana Melanie Ruck, Clifford Todd Brown

Title

Quantitative Analysis of Munsell Color Data in Ceramics

Abstract

The Munsell color system is almost universally used for measuring colors of archaeological artifacts. In addition to recording soil colors, many use the Munsell system to record the colors of ceramic attributes, such as pastes, slips, glazes, and paints. These data have typically been used in modal analyses of ceramic style. Most often, however, the Munsell color data are used in a purely descriptive fashion, and quantitative potential of the information is not fully exploited. We propose here a new protocol for manipulating, analyzing, and interpreting Munsell color data that permits the statistical manipulation of sets of Munsell observations as well as hypothesis testing. A Munsell color reading is composed of three continuous variables of at least interval scale. These data can be transformed into x, y, z coordinates that define a location in color space (D'Andrade and Romney 2003). Once transformed into spatial coordinates, Munsell data can be analyzed using spatial analysis techniques, such as k-means cluster analysis, as well as non-spatial statistical methods. In our case, we chose to use logistic regression to study the degree to which color could differentiate ceramic types and varieties as well as samples of the same varieties recovered from different contexts at a site. We performed exploratory binary logistic regressions on sets of Munsell data representing ceramic slip colors from Mayapán, Yucatán, México. We were able to show a clear separation between the Mamá (red) and Polbox (buff) types. However, the colors did not separate by houselot or cluster of houselot, suggesting that ceramics from this site were relatively continuously distributed by color. Using the techniques we suggest here, archaeologists can significantly expand their modal analyses of ceramics because color is a common and easily measured attribute in most ceramic assemblages.

Authors

Anders Hast, Andrea Marchetti

Title

Stereo Visualisation of Historical Aerial Photos as a Valuable Tool for Archeological Research

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Abstract

We demonstrate with several examples, how and why, stereo visualisation of historical aerial photos can be a valuable tool in the field of aerial archeology.

Historical aerial photographs offers a way to go back in time, exploring things as they were, while in the same time allowing to compare to the actual situation using modern photos. An archive with several millions of aerial photos is maintained by the AeroFototeca Nazionale (AFN) [AFN] of the Italian Ministry of Cultural Heritage in Rome. This extensive archive constitutes an important memory archive of the Italian territory since the end of the 19th century, before its transformation by the post-war reconstruction [Kirk2005].

The GeoMemories project [Geom] was launched in 2010 at the Institute of Informatics and Telematics of CNR in Pisa, with the aim of creating a web platform, making the AFN archive accessible via Internet. The resulting GeoMemories application covers spatial-temporal dimensions and also integrates multimedia data from other archives. The application is a tool, based on Google Earth, but oriented towards the management of the temporal variable, so that both geospatial changes and urban development can be monitored over time. The user can choose which map or maps that will be overlaid on the Google Earth maps and blended together using a slider.

The GeoMemories tool [Mar2011] has a great potential to become a valuable resource for both historians and archaeologists in the aerial archaeology field [Wil200] and cultural heritage. Thanks to the images provided by AFN in the application, archaeologists and historians, as well as geologists and geographers, can revisit the whole 20th century and study the changes that occurred in the country, due to human intervention or environmental phenomena, but also study crop marks etc on places that later was covered by buildings [Abr2013].

Visualising in stereo [Has2014] gives a much better understanding of the photos as the environment and buildings appear to be 3D. We demonstrate in several examples how this is beneficial for getting insight on what is actually seen, especially examples with an archeological value. It is much harder, and often impossible, to estimate heights of objects, such as trees and bushes, from single photos. In fact they often tend to look the same, which is detrimental for understanding the environment. The depth cue [Has2010] is very important for distinguishing between objects and background. Therefore, by viewing these photos in stereo, a better understanding of the content can be obtained, since the relative height of objects is discernible.

We intend to publish the “3D” content in the GeoMemories application and some technical problems in connection with this will be explained and solutions given. We also stress the importance of digitising similar archives and using them for aerial archeology in “3D”.

Authors

Maria Pia di Buono

Title

Entity Recognition for Archaeological Texts: an Ontology-based Su-pervised Approach

Abstract

In this paper we present our supervised approach to Entity Recognition (ER) task in the Archaeological Domain. Our framework is based on the development of labelled training data derived from consistent lexical analysis. Knowledge extraction is heavily based on terminology, therefore we apply our method to domain-specific texts.

In the last year many approaches to ER task has been developed. Some of these are concept-based systems which use a reduced number of characteristics in order to represent semantic content. On the other hand, some systems are based on term-representation. More recent

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techniques involve ontology-based approaches.

As for the Archeological Domain, information extraction (IE) outputs must be mainly focused on the rich sets of features which denote and connote any entity likely to be classified as an archeological object. Besides, such objects as for instance the *Partenone*, are often lexically referred to with capitalized proper nouns.

In this complex task, the first step to take is the locating of such entities inside texts, that is to say perform automatic entity recognition. This task can be achieved with a two-step procedure, which includes:

1. the creation of a domain electronic dictionary in which all entities are morphologically, terminologically and ontologically[1] tagged;
2. in NooJ[2], the creation and application of FSA/FSTs to specific corpora, in order to semantically locate and extract sentences or propositions in which named entities occur, and in which one or more of their features are explicated or referred to.

As we will see, apart from immediate IE, if applied to large corpora, such a procedure can lead to a more complex result, i.e. ontology-based named entity recognition, obtained applying inference during the extraction process, and coupling RDF triples to all the ontologically tagged declarative sentences located during the process of automatic textual analysis.

In order to develop our ER approach, we use the Archaeological Italian Dictionary[3] (AID). These linguistic resources represent our labelled training data.

Entities, organizations, persons, locations and time expressions, are recognized using local grammars, in the form of FSA.

Is-a hierarchical relationship is firstly defined by the domain labels applied to dictionary entries. In other words, we use the tag “+DOM” to indicate the taxonomic hierarchy. This label is also used to identify other constraints useful in entity recognition process.

We apply three types of rules:

1. Taxonomic rules (derived from MIBAC taxonomy prescriptions);
2. semantic rules (referred to CIDOC CRM);
3. selection restriction and co-occurrence rules (based on an accurate lexicon formalization).

The function of CIDOC tags differs from the function of classic semantic roles. While the last ones are exogenous – i.e. their nature and quality are governed by predicates by means of co-occurrence and selection restriction rules, CIDOC tags are endogenous, in the sense that they predicate something about the entity to which they are assigned.

[1] We refer to The CIDOC Conceptual Reference Model (CRM) which provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation.

[2] For more on NooJ, see www.nooj4nlp.net.

[3] For more information see di Buono M.P., Monteleone M. and Elia A. 2014. Terminology and Knowledge Representation. Italian Linguistic Resources for the Archeological Domain. In *Proceedings of the Workshop on Lexical and Grammatical Resources for Language Processing*, pages 24–29, Coling 2014, Dublin, Ireland, August 24 2014. ACL Web Anthology.

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Authors Eva Pietroni, Massimiliano Forlani, Claudio Rufa, Andrea Adami, Stefano Borghini, Raffaele Carlani

Title *The Villa dei Volusii and Tiber Valley Virtual Museum: from the digital acquisition on the field to the 3D reconstruction, up to a novel approach in interactive storytelling inside VR environment*

Abstract The Virtual Museum of the Tiber Valley has been conceived in order to increment and disseminate the knowledge and the interest towards the territory north of Rome, crossed by the Tiber river and by two important roman consular roads, via Salaria and via Flaminia, an area 40 km long x 60 km wide. To do this a digital platform has been created, including VR and multimedia installations placed in the archaeological sites and museums disseminated in the area and, at central level, in Rome inside more attended and important museums. Starting from a cross-disciplinary study and documentation of the territory and of its evolution across the time (from 3 million years ago until today), 3D representations at different scales have been realized, from the whole landscape, to specific sites.

One of the results of the project is a VR application characterized by gesture-based interaction, by an innovative approach in interactive storytelling and by an artistic and evocative style even if based on scientific contents. It has been presented as permanent installation in the National Etruscan Museum of Villa Giulia Museum, in Rome. This installation is very spectacular and consists of four different sceneries that are visualized on three aligned 80 inches screens.

This paper focuses on one of these sceneries: Villa dei Volusii. the most important roman villa of the area, belonged to one of the richest and most powerful families of Augustus' time and located near the ancient sanctuary of Lucus Feroniae, at around 30 km north from Rome.

It tries to explain the methodological approach followed along the complex pipeline leading from the digital acquisition on the field to the interpretative studies, preliminary to the 3D reconstruction of the villa as it could be in augustan age, up to real time optimization, the choice of narrative metaphors and the interaction design for the final communication.

One of the most innovative aspect of this scenery is the new approach in the interactive storytelling. We use the archaeological and historical context as scientific background to build an interactive and engaging story seen from the perspective of a freed slave living his own psychic drama inside the villa reconstructed in 3D. This character is imaginary but plausible because his profile has been created following several literary and historical sources related to freed slaves condition during Augustus' time and it is also historically connected to the presence of thousands of slaves working in the huge extensions of land owned by the Volusii around the villa.

Through natural gesture-based interaction, the visitor can navigate in the villa, visualizing at the same time the real and the reconstructed space on three large screens, living an immersive experience. The use of a so involving storytelling led us toward a new new approach in the virtual exploration, going beyond the traditional paradigms of virtual reality. We needed to create a "direction" of cameras to favour an emotional suspense (as it happens in movies), but keeping a certain degree of freedom for the user in the exploration of the 3D space. So a novel integration of different paradigms and media has been experimented, combining virtual reality, natural interaction and cinematographic rules. The paper will describe approaches, methods and results.

Authors Peter Anthony Inker

Title *Virtual Williamsburg - Contextualizing data to construct a multi-layered user experience*

Abstract Virtual reconstruction embedded in cultural heritage settings allows new ways to examine and present a diversity of data and the state of research, creating new paradigms for understanding the past. Virtual Williamsburg is one of these paradigms, a digital model of the city of Williamsburg on the eve of the American Revolution, in the culturally significant year of 1776. Significant amounts of archaeological research have been undertaken in Williamsburg over the past 80 years. These datasets are not always immediately compatible, or easily accessible to researchers and the public alike. The results exhibit a wide variety of quality, and at varying levels of resolution – from the topographic level, down to the level of the individual artifact. As part of the Virtual Williamsburg project, these diverse sets of data have been collated into a broad structure to be output through contextualized reconstruction. Virtual Williamsburg recreates the Colonial cityscape of Williamsburg as a way of contextualizing these data within a virtual environment, thereby allowing the rich and extensive archaeological datasets to be experienced through a single dynamic pedagogical model. Ultimately, the model expresses the 18th century cultural norms and behavior in an accessible way. Access to Virtual Williamsburg is through an immersive virtual environment that provides interactive web-based tools allowing data browsing, research, and connectivity with other Colonial Williamsburg digital initiatives. Not only does this provide the general public with an accessible way of understanding the data, it also presents the current state of archaeological research in Williamsburg through a virtual interface. The paper focuses on the development of the immerse environment, illustrating the methodology used in creating a diverse experience of the 18th Century city of Williamsburg, handling data, creating authenticity, and openness in reconstruction. It presents the audience with the potential for the presentation of varying levels of archaeological data through authentic digital reconstructions in an accessible and queryable environment. Finally, it will explore ways of developing this integrated approach into the future.

Authors Isto Huvila

Title *Chatting #fieldnotes : rethinking notetaking workflows in field archaeology*

Abstract The current forms-based paradigm of documenting observations in field has proved to be tenacious. The structured approach has many advantages. It helps to standardise documentation practices, it is easy to implement in paper-based document workflow and as the large majority of archeological database systems show, it has been easy to implement in digital systems as well. The approach has been criticised in several occasions as being inflexible and for giving precedence to formal and from interpretative and contentual perspectives impoverished documentation [Pavel2010]. More recently, for instance, the advocates of, for instance, semantic web, linked data and wiki-based database approaches (e.g. [Niccolucci2009]; [Huvila2012d]) have remarked that with the currently available technologies, there are no technical needs to deploy similarly rigid user interfaces as there can be argued to be in workflows based on paper-based documentation or relational data model. This presentation describes a new proposed model for interacting with an archaeological field documentation database. The presentation builds on an empirical analysis and formal description of archaeological field documentation work flows, and a small-scale action research project with an aim of developing a proof-of-concept of a new type of interface and documentation workflow model for documenting archaeological fieldwork. The approach is based on combination of the metaphor of a chat service (familiar to most of us from services like ICQ,

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AOL messenger, and iMessage) and a hashtag-based semantic annotation system. The presentation reports the results of work flow analysis and demonstrates the use of the new database interface design approach.

- Authors** Marco Minoja Gianfranca Salis
- Title** *Archaeological landscape safeguard and digital media. An example from Sardinia.*
- Abstract** The conservation of the archaeological landscape through digital technologies: Sardinia case history. In 2013 the Archaeological Superintendence for the provinces of Cagliari and Oristano, along with other peripheral organs of Mibact, has partnered with the Region of Sardinia to the adjustment of the Regional Landscape Plan adopted in 2006. This adjustment, however, provided by law every two years, it has become necessary as a result of legislative changes interventute in 2006 and 2008 and following the case law occurred. In particular, the activity of the Superintendence was aimed at the recognition and delimitation of areas of archaeological interest provided in D. Legs. 42, 2004 and subsequent amendments The areas of archaeological interest are property by operation of law, but that require for their identification technical and scientific skills that can not be specific to an ordinary citizen who therefore must be informed of the values and requirements in the area. For the procedure of identifying these landscaped goods, has been elaborated a digital form, which transposes in a concise, but complete way the next steps required by ministerial circulars for the recognition of the letters m), and the identification of the requirements of use aimed at tutelage. The activity carried out provides an opportunity to reflect on the sharing of landscape values with the citizens, on the clarity of the rules and their publication on the net, for the realization of a shared protection.

- Authors** John R Clarke
- Title** *The Unity Gaming Engine as a Tool for Scholarship: The 3D Model of Villa A at Oplontis*
- Abstract** This presentation demonstrates the utility of gaming engines for scholarship in the humanities and sciences, using the 3D model and associated database created by the Oplontis Project (University of Texas at Austin) and King's Visualisation Lab, King's College, London. The Roman villa known as Villa A at Oplontis (Torre Annunziata, Italy) is a UNESCO World Heritage site (Clarke 2014a). The 3D model of Villa A is fully navigable and interactive, using the Unity gaming platform, where the "first-person shooter" interface puts movement through the spaces of the Villa in the hands of the user. Its gaming platform makes our model different from existing 3D models of ancient architecture that tend to use interfaces almost exclusively as movies made in 3ds Max (3D Studio Max by Autodesk©). Because these movies employ virtual cameras placed at strategic positions in the model, they prescribe specific and unchangeable paths. The viewer is passive, unable to explore all the spaces in a continuum.
- In navigating the Villa A model, the user can explore every one of its 99 spaces, interior and exterior, at will. The user can toggle between actual state to accurate restored states that fill in the many puzzling gaps that prevent visitors from understanding the spaces and their decorations. He can experiment with changing lighting systems, and can understand how space and decoration function as hierarchical systems, ranging from imposing rooms paneled in marble and precious woods to simple striped systems marking out service quarters and passages. The model allows the user to click on the wall or floor of a space in order to connect

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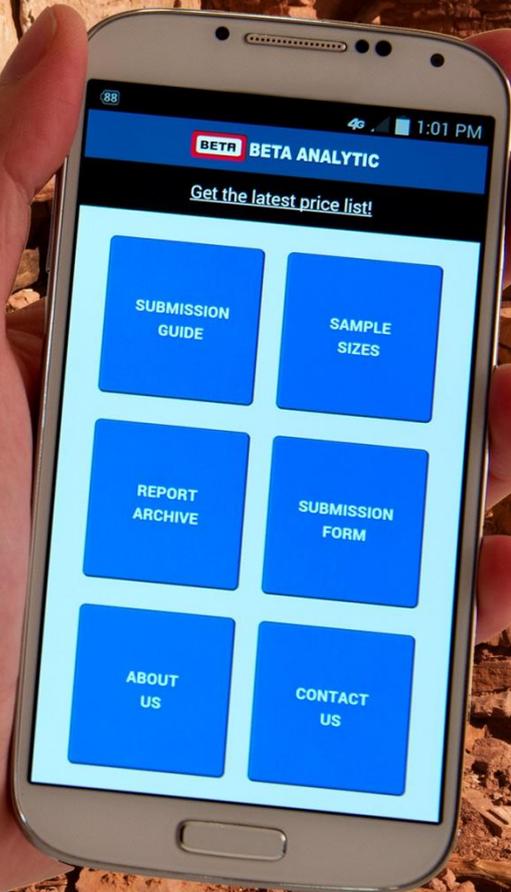
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to the database should she need more information about the wall paintings, the pavements, the masonry or artifacts found in the Villa. Because a scholar can locate the object of his inquiry spatially within the 3D model, this particular use of the Unity engine makes searches more efficient and effective than searches using a database without a spatial framework.

The most innovative feature of this project is the integration of various digital tools already in use among archaeologists and architectural historians, such as virtual reality walk-throughs and databases, to provide more effective means of knowledge acquisition and the creation of new knowledge.

The study of Villa A is intellectually significant because domestic architecture is fundamental for understanding the politics and society of ancient Rome. Recent scholarship has emphasized that the Roman luxury villa was a social, political and economic institution, a “powerhouse” that played a vital role in the dynamics of life in ancient Roman times. In addition to the 3D model, the Oplontis Project has made a commitment to advancing digital humanistic scholarship by publishing the Villa as a born-digital, open-access e-book in the ACLS Humanities E-Book series (Clarke 2014b).

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