

Oceans of data

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The conference theme of CAA2016 is “Exploring oceans of data”, hinting at the vast amount of digital data resulting from digitization projects and from all kind of electronic measuring gadgets used to document excavations and surveys. A quick look at this year’s conference book of abstracts will tell you that only a minority of the presentations actually address issues connected to curation, organization and use of the oceans of data. The majority of the presentations is, as at all CAA meetings, about innovative and experimental use of computer in archaeology and about the application of existing technology to new scientific projects, that is, about activities producing even more data. This is not unexpected. The system for academic credits gives little or no award for the use and development of research infrastructure.

My first CAA conference was in Iasi, Romania. Back then I lead a large digitization and database project for collections and archives build up by scholarly field work since the first part of the 19th century, including the collections of the archeological museums in Norway. The overarching data model was inspired by the event oriented model developed at the Danish National museum in 1988-89 and the data format was based on TEI (Text Encoding Initiative) developed by text philologists from 1987 onwards. As a natural consequence of this interdisciplinary modelling work I eventually got involved in the development of the CIDOC–CRM which is designed to be a conceptual model for data integration.

In 2012 CAA celebrated its 40th anniversary. The CAA2012 had a special session called “personal histories” where key members shared their CAA memories. The session was captured on video, can be viewed online and is highly recommended. Most of the memories are about social events and about the primitive state of computers back then, as it should be. However, there were a few caveats. In two of the 2012 “personal histories” it was stressed that we must not forget about proper archiving and that there is no point in storing your data in the cloud if you cannot read them after a few years.

Paper based data are voluminous and less accessible than digital data but are stable and can after years eventually find its way to collections and archives. Digital data are fragile and will usually not be readable after years in the attic. Without proper actions, the floods of digital data may evaporate and the oceans of data shrink as an Aral Sea.

Archaeology is neither library nor archival science. But a substantial part of archaeological training is how to do sound and accurate documentation of contexts. Methods for construction, curation and reuse of archaeological datasets should be in the central focus as well. Standardized conceptual data models can ease curation and secure long term reusability. Used for these purposes models will not put straitjackets on research.

Under the assumption that we manage to create and preserve the oceans of data, how can the data be utilized? A mechanical extension of our memory has been a dream since long. Vannavar Bush described in 1945 the MemEx machine in his famous paper *As We May Think*. In the 1980ies the hypertext was thought to do the job. The web in the 1990ies was an implementation of hypertext on a global scale. Linked data and the semantic web followed without really solving the problem.

The last decade we have been told to avoid information islands and the slogan has been “Open the data silos”. Is it easier to find a needle in an enormous haystack than in many small? If we are satisfied with the result lists of the google-type answer, it is a clear yes. If we want to build scientific datasets which may be aggregated into larger datasets, we need common authority systems and we need to impose some common structure on the data. To do this in a meaningful way, we have to do an ontological analysis of why and how data is produced in our disciplines. That is, we need to understand our data and establish consistent and well-founded data models or ontologies. On the basis of those we can see how our data may be mapped to a common model for integration. Well defined data models are necessary to define standards for storage formats and may help us to write the necessary specification for contract excavators.

In the CAA context the main focus will and should be on innovative ICT-applications and good practice. The methodology of common consistent but flexible models for data integration will be a relatively small, but important core activity. The data and the artefacts is all what remains from an excavation. They must be handled with care. We need to create accept among the stakeholders that data are at least as important as the artefacts and need long term curation. This is a task for the entire CAA community as well as for the cultural heritage sector as a whole.

S02 Using GIS modeling to solve real-world archaeological problems

Kelsey M Reese, Kathryn Harris, Jade d'Alpoim Guedes

The theme "Oceans of Data" is appropriate in addressing a fundamental disparity between modeling and the empirical world. Data is collected from every archaeological project, public or private, and stored with the intent of utilizing the myriad of information to solve a future question whether it broad- scale or finite. However many in the realm of dirt-archaeology are wary of using large-scale analyses that utilize computer modeling, and further wary to apply the results as legitimate answers for archaeological problems. This session aims to address those issues and provide several case studies in which large data is utilized by geographic information systems, network analysis, and other statistical analyses to help answer real-world archaeological problems, in a manner that is sufficient to withstand academic scrutiny, and present the range of computing power in geographic and spatial analyses that can be utilized by the larger archaeological discipline.

Cancelled S02-01 Constructing agricultural frames of reference: An example from Highland Southwest China

Jade d'Alpoim Guedes

The need to construct locally and historically contingent models of food resources was a central concern of "New Archaeology". However, data and computational limitations meant that archaeologists were unable to go beyond describing coarse patterns of effective temperature, rainfall and net primary production on a global scale. Advances in ecology and computational modeling mean that archaeologists have at their disposition new computational tools and big data that allows us to build frames of reference with a higher level of spatial and temporal precision. This paper describes the creation of ecological niche models for predicting the constraints placed on ancient agriculturalists as they moved crops outside of their homelands of domestication. Using the highland southwest China as a test case, describe how the use of these models has elucidated the reasons underlying a major transition in subsistence regimes during the second millennium cal. BC.

S02-02 Using geostatistical modeling to solve spatio—temporal questions

Katia Francesca Achino, Juan Antonio Barceló

Is it possible to infer where social agents performed their actions and work processes, on the basis of the observed relationships between the actual locations of archaeological material? This is an inverse problem with multiple solutions, and it is in no way simple how to decide between competing solutions. However, the fact that we cannot predict the place of past actions does not mean that social action is indeterministic at some spatial level. On the opposite, social actions should be analyzed as conditioned and/or determined by other actions, because they have been performed in an intrinsically better or worse spatial/temporal location for some purpose because of their position relative to some other location for another action or the reproduction of the same action. In this paper we use the spatial coordinates of different kinds of artifacts from the Early Bronze Age site of Villaggio delle Macine (Rome—Italy) to investigate the possible location of different activities (residence, production, use-consumption) and how the spatial distribution of an action has an influence over the spatial distribution of (an)other action(s). Intrasite spatial distributions are analyzed using variograms and related methods of spatial second-order analysis. Second order variation in a spatial pattern is that part of the pattern that may be attributed to interaction effects among elements in the pattern. Alternatively, it is what is left of the pattern once first order variation or trend effects have been removed. Against some back ground trend, the second order effects are more localized variations in pattern intensity. The problem is that each variogram refers to a single archaeological category. A still unresolved problem is how to integrate all we have

inferred from separate spatial patterns into a single model. In this paper we suggest using spatially constrained correspondence analysis to study possible communalities and spatial similarity relationships between spatial patterns of different artifact categories.

S02-03 Applied Agent-Based Modeling in archaeology: When and why?

Kathryn Harris, Iza Romanowska, Benjamin Davies, Stefani A Crabtree

Agent-based modeling is useful well beyond academia, but there is a lack of practical methodologies to guide the average archaeologist through the construction of an agent based model (ABM). Furthermore, the successful application of an ABM requires a thorough understanding of when it should be applied and why an ABM can be valuable to many different types of archaeologist. To this end, we developed a series of tutorials on agent-based modeling, walking the archaeologist through an agent-based model building process using a simple agent-based model and its application to an archaeological case study. This paper complements the tutorials by focusing on when and why an archaeologist should use an ABM. First, we discuss when to apply an abstract null model to an archaeological case study and discuss the potential difficulties and pitfalls of the method. Finally, we focus on exploring the epistemology of the agent based model and its potential within archaeology. Agent-based models can be helpful for disseminating information to government institutions and supporting a public archaeology. With the basic understanding developed through these tutorials and this paper, Agent-based modeling can aid in championing a better and deeper understanding of the past among the general public.

S02-04 Spatial analysis and predictive modelling and modern clandestine burials

Mike Groen

The use of spatial analysis and predictive modelling, with the aim to discover new sites, is widely applied in archaeology. However, this methods are sparsely known and hardly used within the judicial and police contexts. This paper presents a pioneering study of clandestine burials in the Netherlands between 1960 and 2015. The data set comes from known clandestine burial sites and integrates spatiotemporal patterns, criminological theories, and offender and victim characteristics, to predict where a clandestine burial can possibly be found, given a certain scenario. The study demonstrates that the clandestine grave locations are patterned and quantifiable, and that special analysis and predictive modelling should be used to help locate missing and presumably clandestinely buried persons.

S02-05 From the empirical to the conjectural: Settlement patterns on the Mesa Verde landform

Kelsey M. Reese

A consistent issue that arises in archaeological studies is the absence of a complete set of data on which to perform analyses. Data may be unavailable for a variety of reasons, but its absence often inhibits complete understanding of a population in a defined area. In southwestern Colorado, survey coverage on the Mesa Verde landform is limited to the extent of Mesa Verde National Park, and therefore settlement studies are limited to less than one third of the prominent landform. To fully understand the size and expanse of habitations that were present in this area, this case study extrapolates settlement information from the recorded area to help understand the settlements that could possibly lie in what is unrecorded. Utilizing geospatial analyses, multiple dimensions of settlement choices, and overarching settlement patterns, this paper will present potential demographic and settlement characteristics from A.D. 600–1280; and further include placement of habitation sites and various types of public architecture that may exist beyond the boundaries of Mesa Verde National Park.

S02-06 Studying site construction processes through visibility analyses: The case of Aguas Buenas, Nicaragua, a pre-Hispanic (400-1525 AD) mound complex

Dita Auziņa

Aguas Buenas is a mound and petroglyph site in Central Nicaragua, Chontales, which consists of 379 mounds with a diameter variation from 2 to 20 meters and a height that spans from 10 centimetres to 6 meters. These structures are organised in geometrical, circular configurations, and distributed over a 25 hectare area with complicated topography and vegetation. However, after several on and off mound excavations conducted in the past few years by the Proyecto Arqueológico Centro de Nicaragua (PACEN), the construction, use, and meaning of the site are still under debate.

This paper will focus on the application of visibility analyses and their potential contribution to answering construction related research questions. Apart from that, it will discuss the relationships and supplementing possibilities between GIS based visibility analyses and the phenomenological approach.

Therefore, this paper will present all different phases involved in visibility analyses:

- The development of a Digital Evaluation Model (DEM) from scratch - the challenge of mapping the site;
- The implementation of GIS based visibility and inter visibility analyses through Viewshed analysis or a Line of Sight (LOS) on the basis of a DEM using ArcGIS 10 and Viewshed, Skyline, or LOS tools within the 3D analyst extension. To evaluate viewpoints, observers will be assigned a height of 1.57 m, which reflects the average stature of Nicaraguan indigenous people. Based on visibility areas as well as points breaking the visibility lines, a preliminary model of the complex's construction phases will be presented.
- As a final step in visibility analyses, modelling results will be tested through a phenomenological approach.

S02-07 Assessing visibility and geomorphological biases in archaeological field surveys: a case study on an early Roman colonial landscape in Central-Southern Italy

Anita Casarotto, Tessa D. Stek, Ruud van Otterloo, Jan Sevink

There is general agreement amongst landscape archaeologists that survey data can be biased by many factors such as ground visibility conditions and geomorphological processes (erosion and deposition). The visibility conditions of investigated fields may play an important role in favoring or preventing the recognition of archaeological materials during field survey.

Moreover, erosive and sedimentary processes that occurred after the primary deposition of these materials, can delete or obscure part of the archaeological record. In due course, these factors are likely to distort the original settlement history in a landscape. Therefore, it is of vital importance that archaeologists check their legacy data obtained by surveys for potential biases, before they use these data to assess ancient settlement patterns and location preferences. This paper presents a GIS quantitative approach for the evaluation of visibility and geomorphological effects in large scale, site-oriented field surveys conducted in the early Roman colonial territory of Aesernia (Central-Southern Italy). By means of a combined application of statistical tests and geo-pedological analysis the extent and scale of these biases are translated into GIS maps indicating the likelihood that negative field survey observations (absence of sites), in specific parts of the landscape, are genuine or rather the result of the aforementioned biases. These 'archaeological detectability' maps allow researchers to formally highlight critical surveyed zones where the recording of evidence may be unreliable, and thus provide a filter through which archaeologists can calibrate their interpretations of legacy site distributions.

S02-08 Glacial Archaeology in the Austrian Alps (GAAA)

Stephanie E Metz, Harald Stadler, Thomas Bachnetzer

Due to the current rate of glacial erosion in the alpine region, more archaeological and organic remains are revealed than ever before. These finds span the last 10,000 years of human history, creating new and exciting datasets for not only archaeology, but other related subjects as well. Of particular interest have been prehistoric finds, notably at Similaun ("Ötzi the ice man") in 1991, and more recently at the Schnidejoch and Lätschenpass in the Bernese Oberland of Switzerland. The high level of preservation from having been encased in ice for thousands of years means that these examples and others have helped to shed light on the poorly understood early use of high-alpine landscapes. Thus, the data are of important value for multiple disciplines, namely Forensic Anthropology, Zooarchaeology, Archaeobotany, Glaciology, and Climatology. While the research potential in this field is clear, to date there has been little work done either to understand or protect these critically endangered cultural heritage assets. Indeed, previous academic work has highlighted just how important the development of a methodology is to systematically study the glacial archaeological data in the Austrian alpine region before it disappears. Thus, the aim of the GAAA Project will be the systematic identification of areas of high archaeological potential in the Tyrol and Vorarlberg regions of Austria. To this end, the project will work on a three-tiered level of engagement with the data via development of methodological practice and theory, fieldwork and community outreach/public relations. The very short window of maximum ice melt from August to September necessitates the development of a framework to be able to detect and evaluate potential findspots in advance. With the help of GIS, predictive models will be generated to identify areas of potential interest. These parameters of these models will be based on both cultural and environmental geospatial factors. The framework for these models will ultimately enable a targeted survey of potential findspots which will then be monitored for the appearance of archaeological material.

Cancelled S02-09 Look before you walk: Simulation and adaptive sampling in archaeological survey

Joe Roe, Olivia Mavrinac, Tobias Richter

Survey, as with many aspects of archaeological research, is a step into the unknown. Conventional sampling theory asks us to make a number of decisions before the survey begins. We are committed to a sample size, a transect spacing, and so on, before we know what we will find or how long it will take to record it. To compound the problem, small changes in sample parameters can have a large effect on both the resources needed to conduct a survey and the accuracy and precision it delivers. Previous work on optimising these parameters invokes long equations of probability and estimation theory - an unappealing prospect to most archaeologists. Adaptive sampling where the sample is adjusted based on initial findings' has been advocated as one solution to this problem, but it adds yet another parameter to be decided upon (the adaption criteria). This added complexity perhaps explains why adaptive sampling is seldom used in the real world of archaeological survey, and why the choice of sampling parameters is more often than not an ad hoc judgement.

In this paper, we argue that computer simulation is a more flexible and intuitive method for exploring and selecting sample parameters. Combined with adaptive sampling, it offers a way to maximise the chance of meeting the survey goals whilst making efficient use of the available resources. Using as a case study a recent survey in eastern Jordan, we demonstrate the use of a two-stage, adaptive sampling strategy to efficiently map very dense surface artefact scatters at three sites. We also show how, in retrospect, incorporating simulation into the research design, especially if informed by preliminary data, could have refined this

strategy further. Our experience demonstrates that simulation is not just a useful tool for interpreting archaeology, but also for doing it.

S02-10 New statistical tests determining the likely reality of a connection between stone circles and astronomical phenomena

Gail Michele Higginbottom, Roger Clay

Ruggles, in his major 1984 research project in Scotland chose to dismiss 'from further consideration any on-site indications involving stone rings' (C. Ruggles, *Megalithic astronomy* 1984: p. 61.). This was because astronomical hypotheses involving sightings across stone rings are dependent upon other variables, such as whether or not the 'site fits a particular geometrical construction' and therefore did not fit with his general research questions at the time. Further, no statistical test had yet been determined to deal with the associated probability issues connected to investigations of looking at orientations within a single circle. Such a test involves separate determinations of the likelihood of various statistical errors, including errors in orientation due to archaeological alignment uncertainties and the uncertainty of which part of the astronomical phenomenon was of interest as it crossed the horizon (e.g. when it first touches the horizon or its final disappearance; thus testing the intentions of the builders). Also, circles with large numbers of outer stones increased the likelihood of hitting an astronomical object by chance, increasing the statistical errors, and therefore reducing the level of probability at which one can reject the null hypothesis. No-one since then has tried to develop a purpose built statistic to deal with these issues until our own attempt. We have now created a test to empirically assess the possible astronomical associations of stone circles, which takes in account these concerns. This opens the way forward for more considered methodologies involving orientation issues connected to monuments, the landscape and/or astronomy and is thus this innovative statistic assists in ensuring more secure results for landscape archaeological research.

S02-11 Least cost path analysis and conditional perception of prehistoric travelers

Tsoni Kolev Tsonev

The present study focusses on the unexplored so far relation between the possibilities of Least Cost Path analyses (GIS) to explore higher order prehistoric human behaviour such as 'conditional' perception. It compares the least cost path relative to the slope of the terrain for supply with long blades of the Neolithic populations in Bulgaria to the most difficult one. It was found out that the easiest way for travelling encounters two anomalies (mismatch) of the symbolic complexes of foreign, public and private (house) domains of these prehistoric communities.

The explanations for this complex human behaviour are sought in the theory of perception. It helps to answer the question why in present day's countryside the old dirt roads tend to make unexpected turns when linking two adjacent small villages. My working hypothesis relies on the following steps of analysis based on theoretical understanding of human perception and establishing epistemic relations. First I will provide a formalized, ideal variant of establishing such a relation by the way of introducing an impossible world into the state of real ones (combining disjunctive and conditional options). On this ground I argue that a more realistic option is the use of absolute and conditional probabilities for reaching an agreement between two or more parties that use symbolic representations of various materials and objects. The next step is to fit the scatterplot between the values from the example with absolute and conditional probabilities with the corresponding values of scale dependent exponents which show explicitly a fractal-like behaviour.

On this ground I provide additional archaeological examples from Bulgarian Neolithic that show the distribution of various artefacts made of precious rocks. Unlike traditional

archaeological explanation schemes which state that within the territory of distribution of an archaeological culture the mismatch of symbolic representations is rare I find them that they are ubiquitous. These empirical data fit well with my theoretical considerations which open a real possibility for novel approach to studies of archaeological record that will help gaining better understanding of human behaviour from the remote past.

S03 Exploring maritime spaces with digital archaeology: Modelling navigation, seascapes and coastal spaces

Emma Slayton, Crystal Safadi

The use of GIS and modelling techniques for the study of maritime landscapes and seafaring is a growing theme in both maritime archaeology and in computational approaches to analyzing archaeological spaces. With the recent availability of large datasets, increasingly more detailed and accurate weather records, and advances in GIS applications and simulations, our understanding of seascapes, coastal landscapes, and navigation is expanding. Evaluating both the use of the water's surface and the interaction between seascapes and adjoining land based sites is essential for understanding the use and meaning of maritime spaces in the past. Digital archaeology is crucial to the investigation of these spaces, as the archaeological record supports the existence of sea travel without any clear evidence of the specifics of this movement and computer based analysis can be used to fill in these gaps. This session may also focus on the use of water-based navigation extending to the analysis of navigation of lakes or rivers. Similarly, coastal landscapes and harbour sites may be included as they provide essential archaeological information on the connection of seascapes and landscapes, through visibility studies, database records, or analysis of coastal mobility. This session welcomes papers on a variety of topics that make use of GIS and modelling methods to investigate these maritime spaces, e.g. seafaring and voyaging, harbour studies, coastal landscapes, seascapes and islandscapes, surveying techniques, maritime cultural landscapes, databases, web- applications, etc. Through this session we aim to share and explore different approaches to analyzing maritime spaces that would highlight their significance.

S03-01 Modeling prehistoric maritime interactions in East Polynesia

Melinda Allen, Benjamin Davies, Alex Morrison, Andrew McAllister

The islands of central East Polynesia were occupied from the end of the first millennium by people who maintained connections over large distances using a predominantly Neolithic technology. Beyond linguistic and cultural affinities among present day populations, evidence for these prehistoric interactions can be found in the distributions of artifacts that can be traced between island groups separated by thousands of kilometers. But despite the extensive nature of these interactions and the corroborating archaeological evidence, studies in prehistoric Polynesian voyaging have strongly emphasized voyages of discovery and colonization over later interactions. In the absence of material evidence for watercraft, archaeologists have relied heavily on ethnohistorical sources for interpreting the seafaring capabilities of Polynesia's ancient mariners, leading to numerous debates over the timing and direction of movements. The roles of climate, geography, and navigational skill in the maintenance of these interactions beyond the settlement period remain understudied. Our research explores how these elements may have combined to influence connectivity in the islands of central East Polynesia. We employ a two-stage process to modelling interactions: first, we establish optimal spatiotemporal corridors between Aitutaki, a volcanic island in the southern Cook group, and several regional targets based on a given voyaging "strategy" (e.g. with the wind, against the wind, etc.). This is used to establish baseline expectations for accessibility between islands and island groups. Following this, we use an agent-based model to simulate navigator responses to different conditions, in order to assess potential systematic deviations from optimal paths. Both the spatial and agent-based models are driven by probabilistic climatic configurations derived from a Markov Chain process using high-resolution palaeoclimate data. The objective of this is not to mimic presumed conditions operating in the past, but to explore a range of outcomes within a constrained set of possibilities. Results are then assessed using archaeological proxy data from Aitutaki and the surrounding area, with

the aim of determining likely candidate models for the position of Aitutaki within the greater interaction sphere of central East Polynesia.

S03-02 Reconstructing and modelling the Stone Age landscape in Southeastern Norway *Gjermund Steinskog*

During 2000-2015 the Museum of Cultural History carried out several large-scale excavation projects, instigated by major infrastructure projects. Combined, these projects have excavated c. 100 Stone Age sites. Of importance are also surveyed, but unexcavated sites which are registered in Askeladden, the Directorate for Cultural Heritage's national database of archaeological sites.

The region of Southeastern Norway is one of the few places in the world that has experienced continual coastal uplift since the end of the last Ice Age. Today, the Stone Age sites are situated at different heights within the landscape, from 20 to 150 meters above the present sea level. The sites are commonly located in remote hilly and woody inland areas, but when the sites were in use, they were situated close to the contemporary shoreline, in a landscape composed of large fjords and islands.

When working with Stone Age archaeology in Southeastern Norway, it is necessary to have tools for interpretation and reconstruction of the prehistoric coastal landscape, both on a local and regional scale. As such, GIS-based landscape models are essential tools for archaeological interpretations of these sites. This presentation will focus on how to use the different types of elevation data available from the Norwegian Mapping Authority, how to make palaeo-maps and different GIS-based models of the Stone Age coastal landscape, and finally demonstrate how this is integrated into the archaeologists work with the sites.

S03-03 Uncovering routes to Grenada: Exploring possible routes between mainland South America and the Southern Lesser Antilles

Emma Slayton, Jan Christoph Athenstädt, Jan Hildenbrand

Archaeologists have been attempting to uncover past sea routes through computer analysis since the early 1990s. Though the trend did not carry over into the Caribbean sphere until the turn of the century, many of the themes that had been established by the study of seafaring in the Pacific were applied to this region as well. One of these themes is the focus on the colonization of islands by early seafarers. While it is important to focus on initial connections, those voyages were only one way in which the sea was crossed by early seafarers. Reciprocal voyaging, or the process through which communities kept in contact over time through the act of canoeing, is equally as important, as it allows us to evaluate ongoing interactions that we see reflected in archaeological assemblages throughout the Caribbean. The interruption or adaption of these established reciprocal networks take are also of interest to archaeologists, to determine the affect Europeans on local social rhythms. From the time Grenada was first sighted by Columbus in 1498, the structure of social networks in Antilles had already begun to change due to the influx of new peoples, new technology, and new materials. To determine the effects on the relationship between mainland South America, in particular Guyana and Venezuela, and the Southern islands of the Lesser Antilles, in particular Grenada, pathways will be modelled to determine the ease of movement between these areas. This paper proposes to test links between sites using a new method of calculating isochrones taking into account both current and wind data. Through the use of this method, we will try to evaluate the effect of seasonal fluctuations on the model from a new perspective. Through this case study we hope to establish the benefits of using a directed ischrone method to understand and explore sea based pathways and uncovering the layout of past links between inter- island and inter-mainland communities.

S03-04 Looking for the lost harbor. Role of non-invasive archaeological methods in the reconstruction of the seascape of an ancient city Paphos

Paweł Ćwiakala, Kasper Jan Hanus, Karolina Matwij, Wojciech Matwij, Łukasz Miszk, Wojciech Ostrowski

Paphos, Hellenistic-Roman capital of Cyprus, was one of the most important trade centers in the East Mediterranean. Until recently, it was believed that only a singular harbor was located in Paphos in the east-south part of the city, the same place where the modern haven is now situated. When research on the Agora of the city has begun, the hypothesis about existence of the another harbor was formulated. It was primarily based on the analysis of the spatial organization of the city. Investigation of the layout of the city walls and gates gave assumptions that such hypothesis could be positively verified. The broad spectrum of non-invasive methods was implemented for reconstruction of the seascape of north-west part of the city where the harbor was expected to be found. At first, geoarchaeological research has proved that terrain behind the north-west wall had been silted by geologic material transported by Koskinas river after deforestation of the Troodos Mountains during the ancient times. It explains why there are no visible remains of the ancient harbor infrastructure. As the next step aerial prospection was conducted. The orthophotoplan and DTM of the Nea Paphos Archaeological Park was created using UAV. Obtained data were post-processed using Agisoft software. DTM allowed to register remains of the dock or shipyard outside the wall. 3D model of the research area was also created using TLS. The model was used to simulate sea level in ancient era which was two and a half meters higher than presently. All data gave a strong proves to confirm existing of the harbor in the north-west part of Paphos and allowed to reconstruct seascape of this part of the city. To final confirm these arrangements geophysical and archaeological research will be also conducted. In this paper, the role of integrated approach in extension of the range of digital tools for modelling and reconstruction of the past seascapes will be shown.

S03-05 Simulating Pre-Hispanic canoe navigation in Lake Cocibolca, Nicaragua

Adam Kevin Benfer

While the earliest computational method for modeling prehistoric human movement was developed during the late 1960s to simulate maritime voyages, other navigable bodies of water (e.g., lakes and rivers) have received very little attention in computational archaeology. Just as with the sea, the archaeological record supports the existence of travel on inland water bodies often without clear evidence of the specifics of this movement. Since the same environmental variables of surface current and wind patterns and cultural variables of navigator skill, vessel shape, and propulsion method are crucial to all aquatic travel simulations, the computational methods that were developed for simulating voyages in the open sea can be modified for lacustrine environments. As a case study, I focus on the largest lake in Central America, Nicaragua's Lake Cocibolca, which covers an area of about 8,264 square kilometers, but remains surprisingly shallow, with an average depth of 12.5 meters. Because the lake is subject to persistent, strong northeasterly winds, some archaeologists have claimed that pre-Hispanic navigation was infrequent due to rough waters. However, archaeological studies in the Lake Cocibolca region have documented an abundance of ceramics and worked stone that the past inhabitants produced and traded widely during the later pre-Hispanic periods (AD 300- 1550). This lake also features two large volcanic islands and hundreds of small islands, most of which contain archaeological sites with petroglyphs, monumental statuary, and mound architecture. Combined with the ethnohistoric record, it is clear that the pre-Hispanic inhabitants of the Lake Cocibolca region regularly navigated these waters using paddle-propelled dugout canoes. Computer- based voyage simulations in this

windy lacustrine environment reveal the actual navigability of Lake Cocibolca during the later pre-Hispanic periods.

S03-06 Evocative virtual exploration of underwater sites: Issues and approaches

Manuela Ritondale, Gaia Pavoni, Roberto Scopigno, Marco Callieri, Matteo Dellepiane

The preservation in-situ and the use of non-intrusive technologies are prior principles in the UNESCO Convention on the Protection of the Underwater Cultural Heritage of 2001, thus introducing new challenges for the management of the underwater sites. The latter include the need to reach a high quality level in the documentation using remote sensing techniques and the need to protect the sites although ensuring their full accessibility. Digital technologies have provided several solutions for the documentation, the visualization, the monitoring and the predictive analysis of CH sites. Nonetheless, a real time effective visualization of an underwater scene is much more complex than the navigation on the ground, due to the presence of all the light effects introduced by water as a transmission medium (absorption, turbidity, caustics, scattering...). The aforementioned technical constraints might affect the perception of the public. This work aims to summarize the main issues and directions for an effective (not necessarily naturalistic) virtual exploration of underwater sites, and to propose further options for a successful storytelling. In order to reach the goal, a number of aspects must be redesigned, thus taking also into account two different pivotal concepts which imply rather different approaches and solutions: that of immateriality and that of intangibility. Which kind of intangible relations are hidden behind archaeological objects? How can we display them? Is it possible to enable a material experience through virtual technologies? We try to face these issues and to propose solutions on a case-study related to a deep-water site.

S03-07 A space and time analysis of the Early Bronze Age Levantine Littoral

Crystal Safadi

Maritime spaces are endowed with a set of natural characteristics acting upon and beneath the water surface. They foster a home for the movement of winds, of water, of ships, and of people. Movement through these spaces is a function of a complex system of interaction between humans, the environment, and humans' perception of the environment. Yet Maritime spaces are not present in isolation or within demarcations. In fact, land and sea seamlessly merge shaping waterfronts and shores marked by human activities. The importance of these coastlines and their imbued heritage, is well paramount in maritime cultural landscapes studies. They form a substantial heritage record, a place of archaeological signature, and specialization. However, though our knowledge of maritime spaces is growing, much of their potential and affordances remain concealed. Through reconstructing, testing, and analysing, experimentally or digitally, we can reach a step closer to lived maritime spaces. The Early Bronze Age (EBA) in the Levant is recognised for marking the first urban period in the southern Levant, and the 'second urban revolution' in the northern Levant. It is characterised by significant changes, primarily a shift from village-like communities towards an urban mode of life. The Levantine littoral, particularly in the north, is known to have played a major role during the mid-third millennium, when maritime connections mainly with Egypt became vital. This has been considered one of the instigators of urban development. However, numerous hypotheses have attempted to explain the rise of social complexity and urbanism, yet most of these failed to consider the totality of the space over which change is occurring, and appraise the Levantine littoral in its full potentiality, as a seamless space of sea and land. This paper aims to study and analyse the littoral Levant during the EBA as a space of affordances, accessibility, and connectivity. It builds on a time-space analysis of traveling by sea and by land, and attempts to move beyond the representation of space towards spaces of representations which incorporates at its foundation social activities.

POSTER

Cancelled S03-P1 Changing coasts, changing worlds. A preliminary approach to the evolution of coastal landscapes at the Asón river basin (Cantabria, northern Spain) during the Pleistocene–Holocene transition

Alejandro García-Moreno, Manuel R. González-Morales, Igor Gutiérrez-Zugasti, Alejandro Cearreta, David Cuenca-Solana

The Late Pleistocene - Early Holocene transition changed the climate more profoundly than at any time in human history. This change was especially evident at coastal areas, due to a significant sea level rise. The influence of that environmental change on human societies has been largely addressed from an economic point of view, mainly related to changes in the availability of resources. However, little attention has been paid to how these changes transformed the landscape. By modelling changes in the landscape we can evaluate not only how coastal and maritime resources availability changed during the Pleistocene-Holocene transition, but also how the landscape evolved, due to the appearance of coastal environments such as marshes, estuaries, etc. In this paper, we present a case study from the Asón river mouth, in the Cantabrian coast (northern Iberia). Using GIS modelling, we analyse the evolution of this coastal area. Sea level rise was reconstructed, leading to the definition of past shorelines and coastal topography, while tree vegetation predictive models allow for the reconstruction of coastal forests. Modelling these two elements allows approaching the evolution of coastal landscapes during the Early Holocene, mainly by changes in coastal topography, the appearance and disappearance of coastal features (islands, bays, etc.), and the development of coastal environments, notably salt marshes and killing zones. The reconstruction of coastal landscapes is key to approach the historical dynamics of Late Palaeolithic - Early Mesolithic coastal hunter-gatherer societies, and allows for a better understanding on how environmental changes related to economic, social and cultural transformations.

S03-P2 Exploitation of prevailing winds and currents by the earliest known seafarers, reaching and colonizing Australasia c 50 000 years ago

Eveline Kiki Kuijjer, Rosemary Helen Farr, Robert Marsh, Ivan David Haigh, Erik van Sebille

Long-distance maritime migration can be seen as early as 60–50,000 years ago, with the movement of Anatomically Modern Humans from the Sunda basin (southeast Asia) to Sahul (Australasia). The archaeological record of early settlement is limited, but evidence suggests short crossings from southeast Asia to Papua New Guinea and northern Australia at a time when sea levels reached c.60 - 80 m lower than today.

The effects of the maritime environment and ocean drift on early seafaring is addressed with computer models and novel drift calculations. To demonstrate this method, a particle-tracking algorithm is used with high-resolution ocean model current data, to explore modern-day ocean drift between southeast Asia and Australia. The tracking algorithm is progressively developed to account for the "windage" effects of prevailing winds on a drifting body, such as a raft. Large ensembles of simulated drifts are thus calculated and further analysed to determine the most probable timescale and trajectory of drift between coastal departure and arrival points in present-day circumstances, and these will be assessed against observations of drifting buoy trajectories. The approach will ultimately be applied to ocean currents in simulations for the time-slices during the period of early migration.

S03-P3 Using GIS modeling to reconstruct the urban landscape of the Roman city of Ossonoba

Cátia Sofia Machado Teixeira, João Pedro Pereira da Costa Bernardes, Célia Maria Alves Gonçalves

The Algarve region in Portugal is an individualized and diverse geographical landscape, well defined by the sea to the south and the mountains to the north. The coastline is a key element that defines the region, not only for the resources available but also for shipping and maritime trade. It was not by chance that the structures in the city of Ossonoba were affected by the strategic position between the maritime routes of the Mediterranean and the Atlantic Ocean, which yielded several benefits, especially after the conquest of Britain in the mid-first century AD. This particular Roman city had an intense and dynamic economic system, promoted by the maritime trade in the Mediterranean during the Roman Empire. The archaeological findings, inscriptions and various field works carried out in the urban area of the city of Faro over more than a century, allow us to have an idea (albeit scarce), of the extent and topography of the Roman city of Ossonoba. This poster presents the first approach to the use of a digital support for spatial information, namely a GIS (Geographic Information System), specifically directed to the ancient Roman city in the current territory of Faro, in which the primary goal was to obtain a circuit of the former city of Ossonoba, by defining the city limits as well as the organization of Roman structures over time.

S03-P4 The first web based viewer for archaeological underwater sites in Europe: The Splashcos—Viewer

Moritz Mennenga, Hauke Jöns

During the last 6 years the EU-funded SPLASHCOS network has shed light on the discipline of 'Continental Shelf Prehistoric Research'. It is based on an interdisciplinary research approach combining archaeological, geophysical, geological, oceanographic and biological methods. Investigations so far have already enormously expanded the available knowledge about prehistoric life, especially the economic conditions and environments that these communities had to face. In many cases the excellent preservation conditions in waterlogged sediments for everyday objects, tools and structures made of organic materials have provided completely new insights into prehistoric life. The 25 member countries started to collect archaeological data from all over Europe in their national databases or publications and brought the data together. But not only the presence of archaeological sites is reported, also additional information like the type and dating of sites or the presence of organic material and the water depth is mentioned. The data gave first opportunities to compare the preservation and state of research in different European regions and to observe the distribution of sites in time, space and depth. Permanent access to the collected data is essential for safeguarding, investigating and researching these sites and landscapes, as well as for communicating and visualising results. The archaeological data is now accessible for free in the web viewer or as WMS via the Marine Information Service (Maris). Additional to this Maris is hosting bathymetrical, chemical, geological and a lot more data of the seas. Therefore the Splashcos—Viewer is not only a tool for the public to view the data, but a handy instrument to investigate the sites. Due to the WMS it is possible to combine it with external data and support the own research. The poster will present the project, the data range, the possibilities of access and first results of the evaluation of the data.

S04 Databases and archives: How do we handle the digital archives?

Evy Berg

As the databases grow old and mature, new versions have to be created and published. Often with different technologies than the previous version to enhance user experience. But what happens to the old versions are they dumped in a digital black hole? For some databases there are rules about how to treat an obsolete version. The National Archives in Norway is responsible for the caretaking of all written materiel, also in the form of digital archives, from the public sector. The deliverance of such data is mandatory. When it comes to a SMR (Sites and Monuments Register) the rules are less clear. Also, how should the vast amount of field data from collecting and analysing sites be treated? This includes both written reports, but also all files like GIS, pictures, photogrammetry etc. The file formats keeping the content can be very complex and software specific. How is this materiel archived for long term storage, and what are the chances that the files could ever be opened in 50 or 100 years' time? And who is responsible for taking care of them? The museum/research institution where the files were created? Or do they fall in under the responsibility of a National Archive? If so, what rules exist, or should be made, for taking care of the content regardless of file formats?

S04-01 No one's business: Negotiating the value of archiving archaeology in Sweden

Isto Huvila

Drawing from two empirical studies of the stakeholders of archaeological information in Sweden, this presentation discusses why the archiving of archaeology easily becomes no one's business. Comparing the Swedish situation to international examples of how mandatory depositing of various types of archaeological information has been organised and the interests of the stakeholders of archaeological archives, it is argued that the heterogeneity of archaeological information and the large spectrum of its potential stakeholders is a major, perhaps the most significant impediment of organising the management of archaeological archiving in a comprehensive manner even in cases where the situation is generally considered to be good. In Sweden, the stakeholders of the archaeological information process are focusing on different aspects of information (including various forms of tabular and geographic data, written documents, photographs, illustrations, objects, administrative documents) while no one has a comprehensive responsibility to manage the entire process. At the same time, on a practical level, the understanding of the information, how it is used and what are the responsibilities of other stakeholders varies considerably. An international comparison of archiving policies show that even if the Swedish situation can be characterised as problematic, it is far from being unique.

The presentation is bringing together findings from an interview study of Swedish professionals involved in the process of managing and archiving archaeological documentation and information, a survey study of the stakeholders of archaeological data outside of archaeology and an international comparison of the practices of managing archaeological data outside of Sweden. The work has been conducted as a part of the Swedish Research Council funded research project "Archaeological Information in the Digital Society".

S04-02 From active database to archive: Case of a Sites and Monuments Register

Evy Berg, Stian Finmark, Christer Vinje Gimse

The first version of the Sites and Monuments register "Askeladden" was released in 2004. In 2012 this version was replaced by a new, technologically updated version. Since then the old, and for management concerns, obsolete version has been running as an archive. The software it runs on is getting very old, and to preserve the content it is necessary to move to a platform better suited for long-time storage. The National Archive of Norway has decided this

collection of data is important enough to include in their digital archives as a deposition. The method used to take care of the content is to translate the table content to software designed for the purpose. The presentation will discuss the procedure and the results.

S04-03 Ensuring cultural heritage data longevity with the Arches Heritage Inventory and Management System

Annabel Lee Enriquez, Alison Dalgity, David Myers

A joint project of the Getty Conservation Institute and the World Monuments Fund, the Arches Heritage Inventory and Management System is an open source web-based geospatially enabled platform purpose built to inventory and manage immovable cultural heritage. Developed in direct response to the needs of both cultural heritage organizations worldwide as well as to the complex requirements of cultural heritage data, Arches incorporates concepts and features that help to ensure data quality and longevity. First, Arches integrates two CIDOC standards, the CIDOC-CRM (Conceptual Reference Model [ISO 21127:2006]) and the draft CIDOC International Core Data Standard for Archaeological and Architectural Heritage in order to optimize its data model and structure to be as generic and widely-applicable as possible, as well as generate standards-based self-describing data. By doing these things, Arches promotes data interoperability and portability; in other words, the data housed in the system is structured to actually outlive it. Second, Arches is able to accommodate the myriad ways in which cultural heritage data is recorded. The platform can accommodate multiple attributes and attribute values, grouped temporally, spatially, and thematically with relationships defined between various resources. This flexibility enables all data recorded throughout the lifespan of a cultural heritage resource to be maintained within the system. Third, the project adopted an open source development model using a license for free use with the intention that the Arches open source development community would sustain and improve upon the platform for as long as the system is viable. This allows heritage organizations to implement and develop their own Arches instance as economically as possible and with as much control over their system for as long as needed. In these three ways, combined with an easy to understand yet powerful interface, Arches promotes the longevity and quality of inventory data about cultural heritage places.

S04-04 Row, row, row your boat gently... upstream: A methodological approach to access Portuguese bioarchaeological data using a computer database

Cristina Barroso Cruz, Ana Seabra, Filipa Neto

In accordance with Portuguese Law, which holds the recording and inventory of information as the cornerstone for Heritage Protection and Safeguard, the DGPC - Directorate-General of Cultural Heritage in the capacity of being the state entity responsible for heritage management houses the main archive of Portuguese Archaeology, including fieldwork reports for storage, preservation and consultation. Since 1997 an increase of archaeological fieldwork in Portugal has led to a consequent increase of the number of reports (grey literature) produced. It is also during this exponential growth that the recording of human remains has evolved from a brief, footnote-like mention to more detailed records, due in part to a stricter demand for accountability concerning this kind of heritage. In an effort to overcome the absence of common standards for the production of anthropological field reports and also to minimize the discrepancies brought on by inter-observer error, in 2014 a legal recommendation was produced addressing the specificities of archaeological human remains and implementing a common core of ad minima procedures to be reported. In addition to the archive of written reports, the DGPC also develops and maintains a database for the recording of a wide spectrum of archaeological data Endovélico, which in recent years has been developing a module dedicated to register bioanthropological data, with the aim to constitute a

complementary record to the written reports, making their information more accessible for research.

In this poster communication we will present our experience with the implementation of the bioanthropological module and offer a reflection regarding the selection of the data to input and the best way to record it with the purpose of enabling access and potentiating research, therefore creating a valuable source of information for the improvement of knowledge.

S04-05 Digital archives: More than just a digital skeuomorph?

Emily Nimmo, Peter McKeague

Historic Environment Scotland (HES) continues the important functions of the Royal Commission on the Ancient and Historical Monuments of Scotland as the custodian of the national collection for archaeology and architecture of Scotland. Our Collections and inventory have built up over several decades and we have been collecting digital archive since the early 1990s. We have an established and mature approach to the long term care and dissemination of documentary archive in Scotland.. In this paper we will share our experience and expertise in providing for the long term preservation of digital archaeological archives and how this has to be a collaboration between the data creators and the archives if it is to succeed, not simply an activity at the end of a project or something 'the archive does'. However established approaches to digital archiving are essentially developing a skeuomorph of traditional analogue archives. This is the inevitable outcome of project-based deposition and established archival procedures from accessioning and cataloguing to publishing and reporting coupled with often chronic under-resourcing for the long-term preservation of the archive in all its guises. Issues over file formats and preservation only compound the approach.

Digital formats offer new opportunities and insights however we argue that current approaches to cataloguing and making project archives accessible prevent this material from reaching its full potential. Using examples from databases and GIS we question alternative approach to the way we catalogue and present aspects of the digital archive to our users. Digital archiving is not and should not be the continuation of existing archival practices but requires collaboration at an early stage to ensure consistency of approach, to deliver efficiencies and benefits beyond individual projects.

POSTER

S04-P1 Modelling between digital and humanities: Thinking in practice

Øyvind Eide, Arianna Ciula, Cristina Marras, Patrick Sahle

The proposed poster will present "Modelling between digital and humanities: thinking in practice," a newly started 18 month project with the aim of bringing together scientific and scholarly modelling with creative cognitive practices of coming to know. Modelling is a creative process of reasoning in which meaning is made and negotiated through the creation and manipulation of external representations. Making external representations to reason with has been part of the scholarly Western tradition at least since the Enlightenment; digital humanities extends this practice by actively creating digital artefacts in different media. To integrate these theories of how humans think through things with a practical dimension, the project will make use of digital humanities as an interdisciplinary departure to study modelling as anchored both to computer science and to the humanities. The project aims to link scholarly modelling as a formal and informal reasoning strategy across disciplinary boundaries, spanning also social, life and techno-sciences and culture heritage modelling, and bridging across modelling in research and in teaching.

Our working hypothesis is that in digital humanities research, implicit and explicit models of cultural phenomena are integrated into external metamodels, e.g. graphical representations, which often embed natural language and are informal. These metamodels can be iteratively translated towards computable implementations via a variety of more or less formal models: models for. The analysis of modelling practices in the areas outlined above will hence aim at gaining new insights in the epistemology of modelling.

While textuality mediates the world we live in, events are central to an epistemological perception and description of the processes shaping this world. In the proposed poster the links between the project and modelling in cultural heritage will be highlighted, with a focus on archaeology and with event modelling as the central case study.

S04-P2 Sustainability = separation: Keeping database structure, domain structure and interface independent

Ian Johnson

The conventional approach to relational databases implements the knowledge domain structure directly as database structure; tables represent entities and specific relationships between them, forms represent views which depend on specific joins, workflows and interfaces are customised through programming. This approach is inherently unsustainable due to dependence on specific software/versions and essential knowledge embedded in the custom programming rather than the database.

A number of archaeological databases, from IDEA in the 1990s through to FAIMS and Heurist today, use a fixed database structure across all applications, and represent the knowledge domain structure as data within the database. They generally incorporate documentation of the knowledge domain structure directly within the database.

In this poster I demonstrate the advantages of such an approach for long-term sustainability, since the only requirement for data accessibility is a database which can manage a set of SQL tables, against which a set of standard SQL queries can be issued to retrieve the knowledge domain structure and content. This requirement should be satisfied as long as SQL servers exist which, despite fierce competition from other models, show no signs of fading away. The poster will also argue that the original user-interface - so often confused with the database itself, due in part to desktop software where the interface is tightly integrated with the data storage infrastructure - is merely an end-user convenience and should be regarded as transitory; its value can be sustained with simple documentation such as an explanation of workflows accompanied by screenshots.

S04-P3 Bioarchaeology module—Loading please hold... Recording human bioarchaeological data from Portuguese archaeological field reports

Ana Seabra, Cristina Barroso-Cruz, Filipa Neto

In accordance with Portuguese Law, which holds the recording and inventory of information as the cornerstone for Heritage Protection and Safeguard, the DGPC – Directorate-General of Cultural Heritage in the capacity of being the state entity responsible for heritage management houses the main archive of Portuguese Archaeology, including fieldwork reports for storage, preservation and consultation.

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archaeological human remains and implementing a common core of ad minima procedures to be reported.

In addition to the archive of written reports, the DGPC also develops and maintains a database for the recording of a wide spectrum of archaeological data – Endovélico, which in recent years has been developing a module dedicated to register bioanthropological data, with the aim to constitute a complementary record to the written reports, making their information more accessible for research.

In this poster communication we will present our experience with the implementation of the bioanthropological module and offer a reflection regarding the selection of the data to input and the best way to record it with the purpose of enabling access and potentiating research, therefore creating a valuable source of information for the improvement of knowledge.

S05 Unstable futures/potential pasts: Scenarios for digital computing 2020

Gary Lock, Agiata Benardou, Costis Dallas, Paul Reilly, Jeremy Huggett

Building on the CAA Siena "Challenging Digital Archaeology" Round Table, the 'Open Archaeology' publications stemming from CAA Paris, and the recent Ariadne Expert Forum in Athens, we now ask "what are the plausible digital futures of our [digital] past and how might we prepare for them?"

This session will build on a series of stories or 'scenarios', developed using a technique called Scenario Planning, using an expert forum, to drive an action orientated agenda.

In this Round Table we do not attempt to forecast the impact of introducing any particular technology. Our aim is to direct attention to plausible future contexts in which digital technologies are likely to be introduced into archaeology. Scenario planning is not predictive, and unlike forecasting, in which the flow of time progresses linearly from the past through the present to predict a future, time flows can be multidirectional and iterative to reflect plausible, possible, anticipated and probable futures.

After inviting an expert panel to present some grounded scenarios, the key discussion point for this Round Table is: "what do we need to do now to be ready for all scenarios?"

Cancelled S05-01 Everyday reality and the multidirectional digital future in urban archaeology—The Brussels challenge

Ann Degraeve

Preventive urban archaeology in Brussels, Belgium, is, as elsewhere in the world, coping with a mass of (analogue, digitized and born-digital) data generated by the ever increasing pace of documenting the city's past before it disappears. While digital techniques offer archaeologists various possibilities of harvesting, producing and safeguarding data, an offer so wide some archaeologists feel completely lost, the next question already arises: how can we stay in control of this continuous flow of data? How can we share these primary data in an innovative way with researchers as well as the general public so as to give the possibility to generate new data? And how will this have an impact on the act of the preventive archaeology itself? This presentation brings a critical analysis of everyday reality vs a multidirectional and very uncertain future: a small but creative team wanting to use various techniques in the long process from gathering data up to sharing them and the reasons that drive or block them such as technological investment and quality of knowledge vs general politics, control of data and fear of loss of context vs open access, and fragility of transdisciplinary data vs standardization. The examples span the wide field of sometimes painstaking data capture in the field towards our first steps in a 4D GIS platform, the use of 3D visualization techniques for understanding data extracted from ancient drawings and maps and the resulting interpretations, the access to huge amounts of grey and often chaotic and unstructured data lingering in the cupboards, the tension arising around transforming standardized procedures to adapt to the new methods, and the sharing of data with the various stakeholders in such a way that archaeology as a whole gains added value in an everyday context and thus it's mere subsistence.

S06 Computer tools for depicting shape and detail in 3D archaeological models

Miguel Carrero-Pazos, Alia Vázquez-Martínez, Benito Vilas-Estévez, Miguel Busto-Zapico

Archaeology has been long characterized by the interdisciplinarity and the transversality of their approaches and methodologies. In this context, we strongly believe that a proposal of a session that considers the use of the New Technologies (NNTT) on the fields that deal with computer tools for depict shape and detail in 3D archaeological models, and their application in archaeology is necessary. At the same time, we might see the impact that other sciences could have into Archaeology and how it is seen through them. In the field of archaeological research, the use of the NNTT are widely spread due to their technical profits, as quicker methodologies to obtain archaeological data or carrying out some analysis that will be impossible to conduct manually. We should not forget that the use of these techniques allow us to get greater objectification of the archaeological record. From this perspective, the possibilities of the application of the NNTT to Archaeology are almost unlimited. In this sense, since its beginning, Processual and Post-processual Archaeology has been joining the benefits of the computer science advancements. Therefore, we are able to consider a strong consolidated research field. Since the beginning of Informatics' Era, different branches of archaeological research have been arisen. One of them has been the representation and study of archaeological elements by their virtual reconstruction (3D). From this view, different approaches have appeared, especially since the turn of the century, which put the attention on the development of visual techniques to implement archaeological 3D models. That is particularly the case regarding the Polynomial Texture Mapping technique, from RTI methodology -Reflection Transformation Imaging- (Malzbender et al., 2001). Or its counterpart, the virtual RTI, which combines reflection transformation techniques with photogrammetry and no intrusive digitalization, in order to create an advanced level of interaction with the 3D model, and to enhance the topographic surface (Earl, Beale, Martínez, Pagi, 2010). Moreover, the Morphological Residual Model (MRM), a recent technique (currently inaccessible) which also enables a better visualization of 3D model details has to be denoted (Pires et al., 2014; Correia Santos et al., 2014; Correia Santos et al., 2015; Pires et al., 2015). On the other hand, with the development of free and open access software like Meshlab, it has been multiplied the contributions to the creation of rendering plugins (or shaders), which analyse some characteristics of the 3D model to enhance them. Perhaps one of the most relevant is the Radiance Scaling (Vergne et al., 2010), an expressive rendering which enhance the 3D model concavities and convexities. The application of these techniques to the study of archaeological objects and structures is not new, but it has been steadily increasing since the last decade. Everything that has been said before show us the framework or context in which our session will take place. Our aim is to show different examples of 3D visual techniques, which have been planned or developed to use with computer tools. In this sense, we will be able to reflect about the advantages and the challenges of the interdisciplinarity and the transversality of our discipline and the use of NNTT in Archaeology. Nowadays the NNTT are a fundamental part of the development of the archaeological research. In many cases, the future of our discipline is to adapt and absorb new methods and models developed in other scientific fields. The purpose of our meeting will be to learn from those so heterogeneous experiences, and show how the use of other techniques can help Archaeology to plan and resolve different archaeological problems. Communications, posters and audio-visual material will be accepted, especially those that deal with new computer techniques, to depict shape and detail in 3D archaeological models.

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S06-01 Automated heritage monitoring software prototype implementing 3D technologies

Rimvydas Laužikas, Albinas Kuncevičius, Tadas Žižiūnas, Egidijus Žilinskas

Preservation of urban heritage is one of the main challenges for contemporary society. It's closely connected with several dimensions: Global-local rhetoric, cultural tourism, armed conflicts, immigration, cultural changes, investment flows, new transport infrastructures and etc. Nowadays very often organizations responsible for heritage management constantly have to deal with lack of resources, which are crucial for proper heritage preservation, maintaining and protection. Particularly it is problematic for countries with low GDP or unstable political situation. The possible solution of these problems could be automated heritage monitoring software system, based on the 3D technologies. The system prototype was developed and tested by Vilnius University and Terra Modus Ltd. in frame of project "Creation of automated urban heritage monitoring software prototype". Project financed by Lithuanian Council for Culture. At this paper will present the main results of the project. 3D scanning technology is the most accurate method to capture the situation of an evolving cultural heritage object or complex at a given time. As a cultural heritage object or complex is evolving continuously, two 3D point clouds created at different time allow to reliably trace potential changes. Monitoring of large scale heritage complexes such as urban heritage objects is a resource demanding task and in such cases automatic computer-based 3D visual analysis is appropriate. Comparison of 3D visual data captured in different time advances to next level when utilizing methods of 3D photogrammetry which make it possible (at least partially) to create 3D point clouds from old photos, giving us opportunities to expand research by adding

empirical data captured before 3D scanning equipment and also lowering costs to conduct such research.

S06-02 A machine learning approach for 3D shape analysis and recognition of archaeological objects

Diego Jiménez-Badillo, Mario Canul Ku, Salvador Ruiz-Correa, Rogelio Hasimoto-Beltrán

Museum professionals all over the world have always shown great interest in acquiring automatic methods to register and analyse the shape of cultural heritage artefacts. Thanks to recent advances in 3D scanning and photogrammetry techniques, it is now possible to model the surface of objects with very little effort and in a relatively short time. The continuous adoption of these techniques in cultural institutions has generated thousands if not millions of 3D digital models. Unfortunately, after these resources are produced, very little effort is spent in making them accessible to researchers or the general public. Part of the problem is a lack of efficient computer mechanisms to search, retrieve and classify 3D data. The conventional way to search and retrieve 3D models consists in composing a query based on text descriptions. However, textual annotations are necessarily constrained by the database application domain, ontology, etc., as well as by language and other factors. Consequently they are inadequate for shape oriented searches. This paper presents results of an on-going project focused on developing a computer platform to automatize the search, retrieval, recognition and analysis of 3D object models. The platform processes queries based on geometric properties instead of text. Simply stated, the computer program takes a 3D surface mesh as input (i.e. the query model). Then, a search engine compares it to hundreds or even thousands of 3D scanned objects stored in a repository identifying those that approximate the shape of the query model. Next, the matching models are retrieved, ranked by degree of similarity and displayed to the final user. Afterwards, additional tools can be deployed to perform some kind of analysis on the objects retrieved. A platform like this is much more powerful than a text search engine because it avoids mismatching situations, such as when a person queries the database looking up for "bowls" and retrieves nothing just because the bowls are labelled as "cuencos" (a Spanish term) or "cajetes" (i.e. a term common in Mesoamerican archaeology to described the same type of vessels). Moreover, the platform is able to exploit mathematical analysis algorithms for automatic classification of shapes. During the presentation, we discuss the specific requirements that a shape recognition platform must satisfy to be useful in museums and cultural heritage research. In archaeological projects, for example, we encounter objects that are not necessarily identical in terms of geometry and yet they are considered to belong to the same class. We also intent to show the first part of this platform, namely the search engine for matching and retrieval of 3D Objects.

S06-03 AsTrend: A las point based methodology for micro surfaces depicting

Miguel Carrero-Pazos, Benito Vilas-Estévez, Alia Vázquez-Martínez

The following work presents the AsTrend, a new methodology for enhance and depict details of 3D models. It is based on the extraction of las points from a tridimensional model, which are processed with the most common lidar techniques (Hesse 2010; Štular 2012). We propose a methodological approach, in which we have chosen some rock art carvings from megalithic sites and bronze age petroglyphs og Galicia (Northwest of Iberian Peninsula) to see the limits and possibilities of the methodology.

This technique is being revealed as an accurate method to study rock art carvings. We expect to test this technique in other supports like bones, wood, pottery and so on. We also think that this method could be used by everyone as the main study objects are based in low cost photogrammetry on the acquisition of 3D models.

S06-04 Application of Computer Vision algorithms for automatic classification of archaeological artefacts

Edgar Francisco Román-Rangel, Diego Jiménez-Badillo

The application of computer vision technologies for the analysis of cultural heritage artefacts has witnessed a rapid growth during the last decade. This is especially true with regard to the creation and use of digital 3D models, which enable capabilities that would not be available using the original artefacts, such as automatic and semi-automatic content analysis, virtual reconstructions, more efficient archiving, sharing documentation online, training of novel scholars, etc. An area of especial interest is the statistical analysis of shape features observed on 3D models of artefacts, especially ceramic vessels and pottery sherds, with the purpose of categorizing and classifying objects in an automatic way. In this paper we present new results of an on-going project focused on applying computer vision techniques for automatic classification of archaeological artefacts. We discuss some useful approaches that involve the extraction of shape descriptors (SIFT, Spin Images, etc.) within a Bag of Visual Words model and propose 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

S06-05 A comparison of methods for creating 3D models of obsidian artifacts

Samantha Thi Porter, Kele Missal

Within the discipline of lithic analysis, digital 3D artifact models are useful both as a means of augmenting traditional two-dimensional representations, and as a form of raw data for morphometric and technological analysis. Unfortunately, some raw materials are inherently more difficult to capture than others. Obsidian, specifically, is highly reflective, tends to have a visually homogenous surface, and is oftentimes transparent. All of these factors restrict a researcher's ability to capture images of obsidian objects that are of high enough quality for the construction of an accurate 3D model. In some parts of the world the vast majority of lithic artifacts are made of obsidian. Therefore, finding a way to systematically model obsidian artifacts with a high degree of precision would be extremely useful.

We compare the effectiveness of two different methods of capturing object morphology, (structured- light scanning using a DAVID SLS-2 system and close-range photogrammetry using the software Agisoft PhotoScan) in conjunction with several commonly used substances used to coat lithic artifacts for scanning, (brushed-on talc powder, talc-based developer spray, and chalk spray) on a sample of experimentally produced obsidian pieces of different shapes and sizes. Coatings are evaluated on their ease of use, the quality of scans that result from their use, and their impact on artifacts (e.g. difficulty of removal, and effects on artifact labels). The quality of the 3D models are evaluated on the accuracy of gross artifact morphology as well as success in capturing fine features commonly used in lithic analysis such as retouch, platform preparation removals, ripples, and lancets. We also discuss alternative methods of documenting obsidian artifacts that do not necessitate coating, such as Reflectance Transformation Imaging (RTI).

S06-06 Les gestes retrouvés: A 3D visualisation approach to the functional study of Early Upper Palaeolithic grinding stones

Sorin Hermon, Laura Longo, Dante Abate, Giusi Sorrentino, Natalia Skakun

The paper will present an innovative approach to the identification and characterization of use-wear traces on Aurignacian grinding stones used to processed plant in order to get staple food. Such a study is essential in reconstructing ancient dietary habits of humans at a crucial

stage of human colonization in Eurasia. The current study focuses on the potential contribution of 3D investigation, at various levels of detail and resolution, to the identification of such traces and residues. The working methodology is still under revision, but it includes the following steps, firstly applied on a grinding stone from the Upper Palaeolithic site of Surein, Crimean Peninsula:

1. An overall documentation of the grinding stone: 3D geometry and rectified macro-photography.
2. Rugosity analysis of the stone's surface, in order to identify anomalies relatable to human intentional intervention (grinding). This analysis is performed using two approaches: cloud compare and Meshlab filter functions of colorizing curvatures (several tests are currently performed, using different curvature types).
3. 3D documentation of molds taken in selected areas on the active surface of the grinding stone. These were 3D scanned using a shuttered light scanner and photogrammetry. Values had to be inversed along the Z axis, in order to correctly represent the surface micro-topography.
4. Rectified digital images taken with a digital microscope at various magnifications, at logarithmic steps from x25 to x2500. These were assembled together in a CAD system, each magnification being considered one layer, in order to create a mosaicking of the surface.
5. Measurements of the area of trace marks and characterization of their shape. Clustering of these marks along the working surface of the stone and associated starches.

Overall, more than 40 trace marks were observed and characterized. The rugosity analysis of the working surface of the grinding stone correctly identified areas that have been modified by intentional human intervention. The presence of wear-traces and adhering starches, identified under microscope, along with morphological characteristic of use marks, are among the earliest evidences for plant processing at the dawn of modern humans in Eurasia. Currently, other 10 stones related to plant grinding (both grinding stones and pestles) are under analysis, with very promising preliminary results. The integration of 3D documentation, macro-photography and digital microscopy provided an ideal set of 3D and 2D data that has been successfully used for the functional analysis of Aurigancian grinding stones.

S06-07 A methodological approach to the study of prehistoric cave engravings: The case of Cova Eirós (Lugo, Spain)

Alia Vázquez-Martínez, Benito Vilas-Estévez, Miguel Carrero-Pazos, Arturo de Lombera Hermida, Ramón Fábregas-Valcarce, Xosé Pedro Rodríguez-Álvarez

Near to the village of Triacastela in the province of Lugo, it is located Cova Eirós. Inside the cave, diverse engravings from Palaeolithic age are found; which are being studied at this moment.

Report these Palaeolithic engravings—narrow grooves and with less depth- which are disperse in the walls of the cave, it has not been an easy task. The characteristics that Cova Eirós presents, make them impossible the direct contact with the engraving panel because the contact is very harmful when studying it. Up to this moment, they were used different conventional methods to register the engravings, which were based on artificial light with grazing-light at the panel, to generate an effect of lights and shadows to get a better visualization of the motifs represented. Simultaneously, while the engravings are illuminated they are photographed from different viewpoints and through the photographs taken the motifs are drawn in a paper.

In order to generate a more precise documentation of the motifs, it is raised here the possibility of resorting to new methods of register that the more recent technologies offer. Thus, we make use of different techniques based on photogrammetry of near object, as for example, the Radiance Scaling, for trying to get a better visualization of the motifs, removing

part of subjective that the previous methods presented, and without direct contact with the panel in the moment of register.

S06-08 The digital ossuary: Rothwell (Northamptonshire, UK)

Elizabeth Craig-Atkins, Jenny Crangle, Dawn Hadley, Peter Heywood, Tom Hodgson, Steve Maddock, Robin Scott, Adam Wiles

Holy Trinity church, Rothwell (Northamptonshire) houses one of only two English medieval ossuaries with in situ charnel. Ossuaries were largely emptied and either demolished or allocated to other uses after the early sixteenth-century Reformation, and have accordingly attracted minimal scholarly attention, despite their important functions as places of pilgrimage and intercessory prayer. At Rothwell, osteological analysis is hampered by issues of access, preservation and requirement of the church authorities to retain the remains in situ. Our research project has four principal aims: i) to illuminate medieval use of the ossuary, through digital capturing of its spatial arrangements, and the range of medieval vantage points into the chapel; ii) to present this fragile, and largely inaccessible, heritage resource to the public in a sustainable manner; iii) to analyze the largely unstudied medieval human skeletal remains (which cannot be removed for standard osteological assessment) by collecting digital records of the charnel deposit, with a view to understanding the composition and stratigraphy of the assemblage; and iv) to facilitate digital preservation of the charnel, which is in a fragile state, with a view to informing conservation strategies (e.g. through recording of degradation and discolouration). This paper addresses the methodological challenges of working in this semi- subterranean environment, with restrictions on the handling of the osteological materials, and issues attendant on capturing the larger built environment alongside the finer detail of the charnel. A Leica P20 laser scanner was used to capture a 3D point cloud which is being processed to produce a 3D model. Interrelated research is addressing: i) how to produce a sufficiently accurate surface model; ii) the most appropriate computer graphics rendering; and iii) the kinds of interaction required to maximise accessibility to both the public and researchers.

S06-09 O brother, where art you? A quantitative approach using 3D models and geometric morphometrics: The case study of the Ayia Irini terracotta figurines

Vera Moitinho de Almeida, Valentina Vassallo

The Ayia Irini terracotta figurines are part of a collection found by a Swedish excavation in a rural open-air sanctuary in the north of Cyprus in 1929. It consists of a large number of statues different in size and in form representing human figures, animals, chariots, minotaurs. After the discovery, the archaeological mission received the permission to export more than half of the collection to Sweden, where is currently exhibited at the Medelhavsmuseet in Stockholm and a small set at the Historical Museum of Lund University. The rest of the collection is exhibited at the Cyprus museum in Nicosia. Traditionally, archaeological descriptions have either been based on qualitative assessments of morphologies and non-diagnostic techniques, or on the use of linear basic measurements and ratios to characterize figurines typologically, stylistically and morphologically. The current research aims at enhancing traditional studies and at exploring the range of variation that occurs in figurine form and size, and its potential contribution to their manufacturing taxonomy. Our approach includes the use of 3D scanning, three-dimensional models and Geometric Morphometrics (GM) techniques, to quantify and statistically analyse these archaeological objects. 3D scanning of archaeological materials has been widely used for artefact documentation. For this research, a set of human figures of small size were 3D scanned using a portable laser surface scanning system. Then, they were subjected to 3D GM techniques to quantify and analyse form variation and co-variation with other variables and factors. Thereafter, we

proceeded with multivariate statistical analysis to evaluate the morphological similarity/dissimilarity between the sampled set. We expect that the results of 3D GM and statistical analysis of these figurines may enhance discussions of technological studies and quantitatively improve our understanding of manufacturing techniques and procedures. This non-invasive approach has not been previously applied to terracotta figurines in Cyprus.

S06-10 From survey to 3D modeling to 3D printing: Bramante's Nymphaeum Colonna at Genazzano

Tommaso Empler, Adriana Caldarone

Today it's more and more widespread the use of new computer techniques applied to the field of archeology. Techniques are often heterogeneous, but organized in a right pipeline allow a good understanding of the archaeological heritage. In the study of the "Nymphaeum Colonna of Genazzano", attributed to Bramante, the integrated approach of systems such as photogrammetry, 3D modeling, virtual tour and 3D printing, allows to generate a scale model, with low margins of error, of the shape of the Nymphaeum at the beginning of the sixteenth century (researches until now were very limited). Initial activities are concentrated in the acquisition of data using a total station or TST (total station theodolite) and photographs, taken as multiple frames, recognizable in the coordinate system result from the survey with TST. A special software allows the georeferencing of the raster files with the captured data, allowing the generation of bitmap textures, used in the next step of 3D modeling and rendering. At this stage of 3D visualization it's possible to spot the differences between the Nymphaeum in the project of Bramante and the current status. The following step goes from the virtual 3D model to prototyping, through the realization of a real object by a 3D printing. The object, printed in two PLA parts, is then cleaned by the support materials and joined together. The methodology described revolutionizes and increases the "empathetic size" with the archaeological site, with its use, giving the opportunity to be better perceived either in its current state either in the historical reconstruction at the time of Bramante.

S06-11 3D Reconstruction of Koch, Russian rowing/sailing boat of the 17th century

Mikhail V. Vavulin, Olga V. Zaytceva, Andrei A. Pushkarev

Koch is a Russian rowing/sailing boat adapted for the heavy Arctic conditions. A virtual 3D reconstruction of a 17th-century koch commenced in 2014. Precise engineering drawings were unknown to Russian boat makers of the 17th century, while the few pictures of koch and inconsistent written sources do not allow for an authentic reconstruction of all details and specific features of the vessel. The original boat parts discovered during archaeological studies in Mangazeya, the first transpolar Russian town in Siberia, served the unique resource for the reconstruction. The area had no forests to provide wood for construction, so houses were built from dismantled boats. Structures built entirely from framings were surveyed in Mangazeya. Boat parts are perfectly preserved in the cultural layer of permafrost. For the purposes of reconstruction, we used the two best preserved koch framings dating back to the 17th century. We needed to perform 3D scanning of 293 boat parts. Those parts represented individual pieces of various forms and sizes (from 0.3m to 5.6m). This diversity was the key factor when choosing the equipment and elaborating scanning methods. We used scanners GoScan 3D and GoScan 50 by Creaform with the optimal resolution of 1mm. Textures were identified using photo camera Nikon D700 and the SfM (structure from motion) 3D model technique. Agisoft Photoscan Pro software was used to create low-poly models with applied textures. We used Geomagic Wrap software to perform the final processing of the scanned model and to copy the textures from low to high poly. 3D Studio max software was used to reproduce the original look of the parts by removing traces of secondary use and

natural wood deformation. The same software was used for virtual assembly of the parts and 3D reconstruction of the whole boat.

Cancelled S06-12 Structure from motion and post-processing. The application of the 3D techniques to rock art in Valcamonica

Paolo Medici, Giulia Rossi

In archaeology the use of 3D reconstruction is widely used for its ease of use, for being cheap and contactless, and, moreover, for the possibilities that the 3D technique offer to the archaeologists during the post-processing of the data. Also in the field of rock-art the use of the three-dimensional reconstructions is growing, in particular with the developing of the technology and the algorithms behind the software of 3D modelling and processing. In the recording of rock engravings the 3D can provide an important aid, first of all saving time and money for having a first sight objective documentation of an area available for all the scholars and interested (such as museum, operators in the valorisation and preservation, and others); furthermore it is useful for the tools (such as shaders, radiance scaling and others, provided by the enhancement software and for the microscale analysis. In our presentation we would like to show the use of the SfM technique on rock-art in Valcamonica and in particular the post-processing software like Mehslab, etc.. We will present different case of studies with different features, such as filiform (very tiny engravings around or below the millimetre), superimposed figures and other. Each of this case of study will be enhanced with different post- processing software and tools, in order to reach a comparison of these tools and understand which fit better for the different cases.

S07 Integrating 3D photogrammetric data in the field: Challenges, implications and solutions

Jens-Bjørn Riis Andresen

In recent years the proliferation of image based 3D techniques has enabled very detailed archaeological recording at greatly reduced time and cost. However, this requires extensive computation time, and as a consequence the processing and interpretation of the resultant models is often disconnected from the archaeologists on site. This is problematic, as the success of any recording technique is contingent on its ability to validate and interpret data while in the field. In this session we focus on solving the theoretical and methodological problems involved in closing the gap between excavators and their data. Contributions should explore how we can optimize workflows and enable archaeologists to meaningfully engage with and use 3D data on site

S07-01 RAPID Aerial Scanning of UNESCO cultural heritage sites in the Kingdom of Saudi Arabia

Mohamed al-Farhan, Ahmad al-Hasanat, Mohamed Shalaby, Luca Passone, Thomas Levy, Neil Smith

The rapid and extensive digital documentation of cultural heritage is now being made possible through the use of unmanned aerial vehicles and photogrammetry. A joint archaeological and computer vision project called RAPID was initiated in 2014 to digitally capture several of Saudi Arabia's major cultural heritage sites throughout the country. By using a combination of non-invasive aerial and terrestrial 3D scanning techniques, the UNESCO cultural heritage sites of Al-Hijr (Ancient Dedan, Madain Saleh), ad-Dariyah and Al-Balad Historic Jeddah were digitally recorded. A major obstacle faced for each of these sites was their sheer size and complexity. In particular, Historic Jeddah's dense urban cityscape consisting of hundreds of Rowshan tower houses spans an area of 250,000 m². Each site provided unique challenges in how UAVs and time-of-flight laser scanning were integrated. The project has resulted in massive datasets and ground-breaking software just to manage and visualize it. In this paper, we present the results, methodology, learned best practices, and integrated software and hardware developed to digitally document these massive areas of cultural significance.

S07-02 Digital workflow on a selection of Danish excavations in the Århus area—With special emphasis on the use of 3D recording

Carsten Meinertz Risager

In recent years the amount of digital data recorded by Danish museums with archaeological mitigation responsibilities has increased dramatically, especially with the increased use of 3D recording techniques. Handling these data is complex, and involves reconciling locally evolved, practice-led digital frameworks with mandatory national databases. This presentation will provide an overview of these frameworks, followed by an exploration of the digital workflow Moesgaard Museum uses for its excavations by providing case-based walkthroughs of the different steps involved in 3D documentation of excavations. This will include a live demonstration of the 3D documentation process.

S07-03 The 3D photogrammetry documentation of the Mesolithic grave from Brunstad, Norway

Kristin Eriksen, Almut Schülke

In 2014 archaeologists from the Museum of Cultural History, University of Oslo, found the remains of an inhumation burial with preserved human bone material on the Mesolithic site of Brunstad, Vestfold, Norway. Preserved bone material is seldom found in Norwegian Stone-Age contexts due to very acid soil conditions, and possible grave-finds that can be ascribed

the Mesolithic period are rare. Thus the documentation of the grave was of special importance. The grave was unearthed in several blocks for excavation in the laboratory. 3D-photogrammetry was used to document the situation in the field, but also under later excavation in the laboratory, where each block was singularly documented. The aim was to later compile the different datasets to reconstruct the components of the burial. We used the software Agisoft Photoscan and ArcScene for 3D-modelling and processing. In the talk we will focus on the challenges of documenting this find and the search for practicable solutions. This involves the excavation, documentation and preservation work in the lab. We will describe the workstation that was used for a well-functioning co-operation and work-flow between the osteo-archaeologist, conservator, and the GIS-expert. Several challenges will be pointed out, like the poor condition of the skeletal material, and the fact that the burial due to several reasons had to be split into several blocks before it could put together again digitally. We will also show how 3D photogrammetric data can contribute to the understanding and interpretation of the burial.

S07-04 Using 3D photogrammetry in the field: An example from Kvåle Sogndal, Norway
Cecilia Falkendal, Ingebjørg Njos Storvik, Kevin Wooldridge

During a small excavation project at Kvåle Sogndal in the Spring of 2015, archaeologists from the Universitetsmuseet i Bergen used a pole camera and Agisoft Photoscan 'structure through motion' software as a tool for basic site data capture. This was utilised along with the Intrasis archaeological GIS programme to record a complicated structural sequence of medieval and later buildings, associated with a possible church and later forming part of a farm complex. Processing of the geo-referenced 3-D orthoimages was achieved on site by the excavation team and the results used for the detailed recording of the structures and as the annotated record for entry into the site GIS. The geo-referenced orthoimages served as the basic on-site horizontal site plan and also the vertical profile record. This paper will detail the methodology used for the initial data capture and on-site processing and the practical applications of onsite 3-D imaging.

S07-05 Supercomputing at the trench edge: Expediting image based 3D recoding
David Stott, Matteo Pilati, Carsten Meinertz Risager, Peter Jensen, Casper Skaaning Andersen, Jens-Bjørn Riis Andresen

Image-based 3D reconstruction with Structure From Motion (SFM) techniques are increasingly used for documenting archaeological excavations. They afford an inexpensive means of recording accurate, detailed spatial and radiometric data, but there are a number of challenges presented by these methods. Foremost among these is the time it takes to produce a finished model. Due to the computationally intensive nature of these techniques processing often takes hours to complete. This is problematic, as archaeological excavation is by its nature a destructive practice where success is contingent on the quality of the record. Validating and interpreting these data in the field, while the subject still exists is essential. Thus, rapidly processing the models and making them available to archaeologists as they excavate is of crucial importance.

In this presentation we demonstrate how the process of model generation can be expedited to occur in near real-time, from the field. This is achieved using three approaches. First, by remotely processing the images over a 4G mobile internet connection to the High Performance Computing (HPC) cluster at DeIC Abacus 2.0 we can dramatically increase the computational power available on site. Second, we examine the effect different parameters have on processing speed and quality of the finished model. Third, we argue that data transfer and processing time can be further optimised by appropriately constraining image size to the scale of the objects being recorded.

S07-06 Creation of an Early 19th century Siberian ship 3D model

Andrei A. Pushkarev, Olga V. Zaytceva, Mikhail V. Vavulin, Anna Y. Skorobogatova

The Northeast Passage played a great role in the colonization of Siberia. However, we know almost nothing about design and specific features of Russian ships of the 17th–19th centuries that sailed through the Northeast Passage and gave rise to the very first Russian settlements on the Ob river. Due to the absence of drawings and the inadequacy of written sources, dependable reconstruction of historic vessels is virtually impossible if no archaeological data is used.

Archaeological investigation of a 19-century wooden ship was performed in 2015 on the bank of Kiryas, an arm of the Ob river. At the moment, this is the only large wooden ship in Siberia explored using archaeological methods. Another unique feature of the ship is its almost undamaged condition, which will ultimately allow for complete reconstruction.

The flat-bottomed ship measures 34 x 7 x 1,7 m. The planks of the bottom and the side slopes are connected with more than 50 frames made of stump wood.

In order to save as much information about the unique discovery as possible, a computer reconstruction project was developed. The first stage was launched in September 2015 and included two types of surveying:

1) Digital orthophotography of the ship location. The photos were made using Octocopter UAV Zala 421-22 and Sony RX1 camera.

2) High-precision digital photogrammetry of the wooden ship. Surveying was performed using Nikon D800 digital photo camera. The resulting photos were then processed with Agisoft Photoscan software. The works performed provided for:

- An overview ship location 3D model, 10 cm resolution;
- A textured ship 3D model, 0,4 cm resolution. In the course of works, the following new techniques were used:
 - Overlapping of land survey data and UAV images;
 - Survey of ill-lit areas;
 - Combining images of individual ship parts into a whole model;
 - Reconstruction of the missing ship elements using photos from earlier years.

S07-07 3D spatial analysis: Beyond extrusion and sectioning

Martijn van Leusen, Gary Nobles

Over the last 5 years, the fields of 3D archaeological data capture and visualisation have seen a quick development, both in terms of the technology involved (hardware and software) and in the numbers of groups involved and conference papers and articles produced. A similar development has been ongoing in many neighbouring disciplines. This paper, after briefly setting out the current state of the field, focuses on future needs and current limitations to the analytical use of 3D data in archaeology. It then sets out a proposal for an R&D agenda that aims to achieve mature 3D spatial analytical (GIS) functionality within 5 years.

S07-08 Enhancing evidence and re-evaluating interpretations with 3D GIS and image-based 3D replicas: The case of Borggade (Denmark)

Matteo Pilati

This paper illustrates a 3D GIS solution for the integration of image-based 3D recording in the investigation process at the medieval site of Borggade (Denmark). This experience reveals some methodological strengths and theoretical implications of using accurate and detailed 3D replicas of archaeological contexts for the managing of information in the field. Thanks to the reliance on a powerful offsite processing computer and a 4G data transfer connection, it has been possible to dispose of 3D replicas of the documentation surfaces and document them

contextually to the excavation process. An entire library of over 150 replicas could be visualized and databased in ESRI's ArcScene, reproducing documentation surfaces (plans and sections) the way they were shaped, perceived and initially interpreted by the archaeologists in the field. Furthermore, 3D GIS poses the archaeologist also in the position of representing, thus analyzing, the site as it never had existed in reality: the replicas can indeed be rearranged according analytical needs. As concluding remarks, given the accuracy and detail of true-to-reality 3D replicas their implementation can deliver a great amount of information about the site's structure and the onsite interpretation work; integrated in a 3D GIS environment, this information enhances the evidential and analytical value of documentation, promoting processes of data validation and re-evaluation of interpretations.

S07-09 In the fields and on the screens. 3D documentation for the excavations at Paphos Agora, Cyprus

Kasper Jan Hanus, Łukasz Misk, Wojciech Ostrowski, Weronika Winiarska

Paphos Agora Project's fieldwork revolve around (currently) four trenches. The nature of excavations at ancient classical city makes the documentation extremely challenging task due to vast quantity of unearthed portable antiquities, mostly pottery shreds and complicated stratigraphical relations of the architecture. There are some universal requirements for the field documentation: it should be as close to "the reality" as possible, yet the recording process can not be too time consuming. Furthermore, acknowledging the digital revolution in archaeology, the documentation shall be easily transferable to GIS software. Thus, in order to go "beyond" the limitations of drawing documentation we have decided to test the utility of close range photogrammetry while documenting successive stratigraphic lots. This approach was tested during the excavations at the site of Paphos, Western Cyprus.

The following pipeline was implemented: archaeological exploration - digital documentation - field interpretation. This workflow proved to be both accurate and time effective. Achieved accuracy of the models made out of close range photogrammetry were accurate enough to be directly imported to GIS software, furthermore the quickness of this method resolved the problem of the "bottleneck" - as usually drawing documentation is quite time consuming. 2D (orthophotoplans) and 2.5D (DEMs) documentation of every excavation lot was uploaded into GIS database, creating the base for further interpretation. As well the interpretation process can be supported by creation of textured 3D models of the trench, that could be prepared for every stage of the excavations. This integrated approach is in our opinion a powerful tool to create a digital representation of the archaeological site for documentation and interpretation purposes.

S07-10 Closing a gap with simple toy. How using a tablet affected documentation workflow on the Rozprza ring-fort excavation

Jerzy Sikora, Piotr Kittel

The use of digital documentation, including image-based 3D techniques allows to reduce the role of traditional and time-consuming manual drawings. However it significantly shortens the process of obtaining data in the field, it also need long time for digital processing of images. In fact, this situation is nothing new. Older researchers probably still remember that similar challenges were connected with a traditional archaeological photography of pre-digital era.

During the excavation on the medieval ring-fort and motte in Rozprza 2D and 3D photogrammetric documentation and integration of the results in GIS was widely used, eliminating traditional forms of field documentation. It was particularly important in extreme wet conditions of work in the bottom of Luciaża river valley. Popular Agisoft PhotoScan software and QGIS georeference module as well as a set of open source graphical raster and

vector applications were used.

The key role was the appropriate organization of the field work involving the parallel excavation of several sections by limited team. As a result, it was possible to flip explorers and equipment in situations where it was necessary to suspend work in the section, until the end of documentation process.

An important facilitation was to support the process by using popular tablet on Android OS. It allowed the application of interpretation layers directly onto earlier prepared orthophotos, with direct contact with documented structures. At the same time descriptive documentation and registration of stratigraphic relationships were performed, using a custom Strati5 app, based on a spreadsheet. This way the field documentation based on 3D techniques became a series of actions implemented routinely at the completion of the exploration of the another layer or preparation of the another cross-section. Simple and cheap tablet helped to close the gap between gathering of field data and later processing and interpretations.

S07-11 The documentation of Neolithic flint mines—An experimentation of methods

Åsa Berggren, Anders Gutehall

What is the best method to document a site of numerous pits, the result of a complex sequence of digging and filling, cutting and reopening holes in the ground in search of flint during the Early Neolithic?

During an excavation of Neolithic flint mines in 2014 in the area of Södra Sallerup in Malmö, Sweden, we experimented with various methods to document the mines in plan. These methods are now being evaluated. In addition a comparison to methods used to record the mines during the decades long history of excavations in the area is also executed.

The methods used were hand drawing on paper, digital planning with GPS, orthophotography, and photogrammetry. This paper discusses the evaluation of these methods and the impact of the methods on the process of interpretation.

Archaeological documentation methods have developed quickly during the last decades, digital techniques have become increasingly accessible and affordable. The increased use of these methods affects the prerequisites of archaeological interpretation and consequently the knowledge that is produced. However, this shift is seldom problematised or analysed.

The development of methods often takes place within research projects, with carefully chosen objects. However, we were able to use a choice of methods within a contract archaeology project, albeit with additional means from a research fund supporting the evaluation. The objects are typical of developer funded archaeology, not visible above ground, quite different from standing remains of architecture often regarded as suitable for research experiments of digital documentation.

In addition to adjusting the method to the recorded object, our results show that quite low tech digital solutions can go a long way towards achieving a detailed and relevant record. As each method seem to capture slightly different aspects, a combination of methods also seems preferable.

S07-12 Back and Forth through the contexts: 3D Geographic Information Systems in support of field documentation

Nicolo' Dell'Unto, Giacomo Landeschi, Jan Apel

The use of three-dimensional (3D) models in support of intra-site investigation activities represents an important novelty in archaeological practice. Unlike interpretative drawings, which provide a schematic and symbolic description of the site, three-dimensional models have the capacity to display the full qualities of a context immediately upon exposure, providing a high qualitative geometric description of the site at any specific time frame of the investigation activity. Among the different workflows of 3D data acquisition that have been

presented in literature, a very few case studies actually discussed the impact that this new typology of data has on archaeological practice. Since 2014, archaeological investigation activities have been carried out at the Mesolithic site of Kämpinge (Southern Sweden) by the department of Archaeology and Ancient History at Lund University. The documentation activity performed so far has been completely recorded in three dimensions and managed in the field by a 3D Geographic Information System (3D GIS).

In specific, by employing tablet PCs and field laptops, 3D models (as a result of image-based 3D modelling techniques) were georeferenced and used in the trench in aid of the field documentation. The possibility of taking advantage of a 3D real time platform capable of providing a spatio-temporal overview of the sequence of contexts retrieved at different stages of the investigation allowed the achievement of a completely different perception of the site. This paper will present and discuss the results of this experimentation, focusing on how the systematic use of a fully-3D visualization system in support of archaeological practice affects field interpretation, excavation strategies and knowledge production.

POSTER

S07-P1 Underwater archaeological remains open to the public diving –close range photogrammetry as a digital preservation and complex documentations of despairing relicts

Anna Maria Kubicka

During Underwater Research of Antalya Coast in Turkey directed by Assist. Prof. Dr. Hakan Öñiz close range photogrammetry was implemented during archaeological survey in 2015 in the maritime region of Kaş. Area covered by the survey was focus on non-archaeological zones but consisting ancient remains of shipwreck. In this water wood from ancient or medieval times does not preserve and only typical elements of a ship or its cargo could be recognizable. Standard tape of documentation as a drawing does not allow to make quick and detail plan of the remains which became a part of a landscape. This poster will present capabilities, limits and results of close range photogrammetry in underwater environment where time is extremely pressure not only for a diver. Access to an archeological remains could not be control in the same way like on the land so 3D photogrammetric data are exclusively useful for this reason.

S07-P2 Questions and bottlenecks: The precariousness of computation heavy documentation in the field

George Alexis Pantos

Archaeological excavation is often a complex business that requires constant interpretation and reappraisal that is well catered for by traditional documentation tools of the pen, pencil and eraser. While, photogrammetric recording methods offer many benefits, they currently lack the same immediacy, flexibility and adjustability of traditional methods. Furthermore these recording techniques promote a different way of interacting with the archaeological record during data capture and represent a fundamentally different record to traditional forms. The poster draws on the experiences and experiments with single context and multi-scale 3D recording - successful and otherwise - carried out as part of excavations at Shubayqa, Jordan. The poster seeks to emphasise the complex interrelated variables that can affect 3D recording and its use on site - from decisions on what and when to record (or re-record) to technical dependencies and environmental limitations that can lead to bottlenecks in workflow. While solutions to some problems have been overcome in the examples given, the main aim of the poster is to provide a frank account of the use of an imperfect technology in the field and to raise and to highlight important questions at each step of the process.

S08 Modelling approaches to analyse the socio-economic context in archaeology II: Defining the limits of production

Philip Verhagen, Monica de Cet

At CAA2015, we organized a fruitful and stimulating session on spatio-temporal modelling of socio-economic processes in archaeology. At this year's conference, we want to continue the debate, and in particular focus on the issue of establishing boundaries of production. Past societies, whether they were hunter-gatherers or complex state societies, were all forced to deal with the problem of producing sufficient food and other resources to meet economic as well as social demands.

The debate on the limitations of socio-economic systems for the production of resources is currently more often based on educated guesses than on a good understanding of the processes involved. The interplay between the (potential) availability of resources, and the necessary workforce, technology and socio-economic structures (like land ownership, taxation or access to markets) is a complex field of study, in which significant steps forward are being made through the combined use of GIS, statistical simulation and dynamical systems and agent-based modelling.

We are, however, still far removed from a common modelling approach to these issues that will allow us to easily make cross-regional, multi-scalar and diachronic comparisons. In this session, we want to address questions such as:

- what data sources and variables to include
- what modelling techniques and analysis protocols to use
- what theoretical frameworks to apply
- how to model at different scale levels
- and how to interpret the results of our models.

We therefore specifically want to invite papers dealing with one or more of the following issues:

- demographic processes and their socio-economic impact
- competition for resources at different scale levels, from the household to the state
- settlement patterns, territories, accessibility and control of resources
- the role of socio-economic and cultural constraints
- the utility of ethnographic data and comparisons
- sensitivity analysis of modelling approaches
- modelling with large data sets

S08-01 Putting production landscapes into context: A multi-faceted case study from Upper Mesopotamia during the Early Bronze Age

Tuna Kalayci

Second half of the Third Millennium BCE (mid-to-late Early Bronze Age) in Upper Mesopotamia was signified by a rapid urbanization period and intensification of agricultural production. Settlement nucleation in tell-based settlements evidently created a new form habitation. Furthermore, developments in the politico-economics (e.g. secondary state formation, textile production as a high-commodity) must have had considerable impacts on agricultural landscapes. In combination of these two events, it is possible that the main determinants of the change in food production were due to the increased demographic pressure and the systematic integration of animal husbandry -as the source of wool. In order to test this hypothesis, the study provides a quantitative model of the EBA agricultural production for highlighting the relationship between minimum biological requirements and estimates of food levels. Following this model, the discussion focuses on the anomalous variations in production levels under the axiom that high population levels required higher amount of foodstuffs, and thus, must have necessitated more input for the

sustainment. Next, it evaluates these variations for different planting strategies (e.g. fallowing) so that a more realistic picture can be drawn. Finally, the model results are re-assessed for its ethnographic corollaries for the issues of agricultural surplus, storage and social stratification.

S08-02 Quantifying change: An evolutionary approach to interpret the amphorae production in the Roman Empire

Maria Coto-Sarmiento, Xavier Rubio-Campillo, José Remesal

The aim of this study is to explore the dynamics of change in amphoric production within the Roman Empire. In particular, an evolutionary framework is applied to understand the mechanisms of changes in olive oil amphorae (Mesoudi 2015).

This analysis can be developed by the fact that we detect differences in the amphorae production through time that allow us to quantify the rates of change. One of the main challenges of this approach is the high level of uncertainty associated to the archaeological chronologies. In addition, this problem is combined with the lack of a formal framework to apply on the conventional techniques for the analysis of the amphorae dataset.

In order to achieve this goal the study uses a quantitative framework based on cultural evolution theory. It provides a set of methods that can be used to account these changes in the production of olive oil amphorae. In this context, it will be presented a research where this methodology has been used to show its capacity to detect the culture trajectories. In particular, our case study has been focused to understand the dynamics of change of olive oil amphora production found in Baetica (currently Andalusia) during the Roman Empire (1st-3rd century AD). Specifically phylogenetic approach has been applied to quantify the morphological distance between pottery assemblages in order to identify discontinuities in archaeological and historical sequences. The phylogenetic tree created with this method will then be used to explore rates of change detected in the amphorae. In particular, we want to identify if these changes were produced by cultural reasons as it may be economical, political and social changes.

The analysis explores how the framework provided by evolutionary archaeology can provide a useful base for understanding change in production processes using material culture.

Finally, the results suggest that different factors can influence rate of change and thus different speeds can be identified with distinguishable patterns of social behaviour.

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S08-03 Boundaries of agrarian production in the Bergisches Land in 1715 AD

Irmela Herzog

The boundaries of agrarian production for the Bergisches Land east of Cologne in 1715 AD can be deduced from historical sources including maps created in the years up to 1715 AD and modern topographic data. The historical maps indicate the settlement sizes ranging from mills and single farmsteads to towns with walls. The maps are complemented by images of the two towns in the study area and a text describing the economy of each administrative unit covered. According to this additional information, in 1715 AD the towns were quite small and the economy relied mostly on agriculture (oat, pigs, and cattle). This applies even to the town controlling a bridge of an important trade route. Moreover, the maps show a large proportion of today's settlements, hardly any additional settlement locations can be found in the maps created in 1848. For this reason it seems plausible to assume that the study area was nearly full in 1715 AD. Different approaches to allocate territories to the settlement locations shown on the 1715 AD maps are discussed, based both on straight-line and least-cost distances. For

allocation methods ignoring the settlement size the quality of the result is assessed by checking the relationship between territory size and settlement size. The paper also presents approaches for predicting the location of patches where additional settlements were founded after 1715 AD.

S08-04 Factors of production: Investigating land and labour as limiting factors in agricultural production in the Dutch Roman limes zone via agent-based modelling

Jamie Joyce, Philip Verhagen

In this paper, we investigate the role of land and labour availability in the rural economy of the Dutch Roman limes region via agent-based modelling. The availabilities of land and labour pose limits on agricultural production and are regarded in economics as two of the primary factors or inputs in the production process determining the quantity of output. Although recent research has now prompted a departure from the previously held view that surplus production in the region was not possible (see Kooistra et al. 2013; van Dinter et al. 2014), we still don't know how the shift from subsistence farming to surplus production occurred. The likely methods of surplus production undertaken by local farmers, the limiting factors in agricultural production within different temporal and geographic scales and possible mitigation strategies have hitherto only been dealt with in generalist terms. To investigate these topics, we have produced an agent-based model in NetLogo to simulate the rural economy of the region with land and labour costs as primary outputs. We have simulated methods and strategies in the three most significant elements of this economy: animal husbandry, arable farming and wood-fuel acquisition. By comparing the model results against archaeological data of the natural and cultural landscapes in the region, we are able to test the scenarios for plausibility. In addition, the model has enabled us to investigate the elements of the rural economy not only as separate activities but in combination, reflecting the mixed agriculture practiced in the region in this period. Lastly, we are able to simulate a dynamic economy both temporally and geographically by imposing on agents conditions known from the region. We present here therefore the initial results from the model and our conclusions in defining the limits of production in the Dutch Roman limes zone.

S08-05 Socio-economic analysis and GIS modelling: A pilot study from rural society in Northeastern Italy

Monica De Cet

Rural society from the second half of the XIX century CE in the mountain area of Northeastern Italy showed interesting dynamics of subsistence production. Products from land were one of the main sources of subsistence and cereals were largely consumed. This poster illustrates a pilot study of socio-economic analysis through GIS technology. It shows how a socio-economic approach, previously developed in De Cet, in press for the Mediterranean island of Menorca (Spain) can be reapplied in a mountain region. The study area is now the piedmont region of Alps, in the National Park of Dolomites-province of Belluno, Italy (Unesco site), characterized by an important natural and historic heritage. The geographical framework is a small scale area of around 150 hectares, nearby the city of Feltre and the chronology considers the second half of the XIX century CE.

This research illustrates the boundaries of subsistence production, where are involved the following variables: a. demographic sample (c. 1000 people), b. diet based on wheat and barley, c. rudimental technology, d. isolated mountain area, and d. political system focused on patriarchal structure. I illustrate the results as multi-scalar maps, where human exploitation of agrarian resources is observable. These outputs have been obtained from historical cadastral maps through spatial analysis techniques (e.g. Kernel densities) combined with palaeo-agrarian calculations (e.g. cereal harvest per person). Maps have highlighted an economic

strategy with self-sufficient families, land fragmentation, and direct political control of farmers on land (De Cet, in press-b). In fact, historical sources point out the difficulty of finding a balance between available land, subsistence needs, and manpower. The final aim is to contribute to the discussion on the resolution of socio-economic results obtained using GIS-based modelling, multiscalar approach, and ethnographic data.

S08-06 Co-evolution of culture and trade: Impact of cultural network topology on economic dynamics

Simon Carrignon, Jean-Marc Montanier, Jerome Michaud, Xavier Rubio-Campillo

Trace of the economic activity in the archaeological record are scarce which make the understanding of past economy difficult. Nowadays economic studies could bring new tools and models that could help to fill that gap, however such models badly incorporate cultural aspect of past society.

In this study we want to mix those approaches by mixing cultural and economical model to look at how the local cultural environment of individuals in a society could influence the global dynamics of the economy of this society.

To do so we use a trade model that has been shown to converge to an optimal market without central authority. In this model, individual have to trade a good they produce in order to get other goods they need, and can change their trading strategies by imitating the strategy of the most successful individuals.

In this previous model the cultural environment of the individual was made of every other agents in the system, i.e. all agents were able to know the success of all the other agents and imitate anyone of them. With this imitation mechanism and the simple trade system, all were quickly able to exchange the good they produce in a way that allows us to get the other goods, without the need of a central coordination.

In the current paper we want to study in what extend the capacity of this model to converge to an optimal and decentralized market depends on the properties of the cultural network of the individuals. To do so we change the cultural environment of the agents by creating a wide variety of different typologies of networks with different properties leading to different cultural environment. For each cultural environment, we then run simulations and observe and measure the properties of the resulting economic dynamics.

We thus aim to model the coevolution of both components (cultural and economic) and how different trade networks (based on knowledge of the Roman Empire) affect their dynamics. In coming study we hope to fruitfully apply this approach to evaluate the probability that this kind of economy evolved during the Roman Empire, using trade network reconstructed via Archaeological and Historical evidence.

S08-07 Defining boundaries: A GIS-based approach to the Sardinian Bronze Age

Francesca Cadeddu

This paper introduces a spatial statistical analysis in a GIS environment on the settlement patterns of the Nuragic civilisation, a long-lasting culture that existed in Sardinia (Italy) from the Middle Bronze Age (ca. 1600 BC) to the First Iron Age (ca 800 BC). The aim is to perform a test of the major theory proposed by scholars concerning the Nuragic civilisation, the cantonal system theory, a hierarchical settlement organisation according to which, during the Bronze Age, Sardinia was divided in regional polities, partitioned in districts called cantoni. In this paper the focus will be especially on settlement patterns with the purpose to assess the existence of these polities finding their territorial boundaries, as a necessary first step for the reconstruction of the socio-economic context of the Nuragic civilisation. GIS and spatial statistical analyses (i.e. Thiessen Polygons and Viewshed Analysis) are used to examine a sample area, represented by the historical region of Gallura, located in the

northeastern part of Sardinia. The method created allows for the first time to validate the existence, during the Sardinian Bronze Age, of territorial systems formed by interconnected communities, and to identify defined boundaries for these systems. The results provide new data on the Nuragic civilisation through the identification of overall common attributes in the settlement and economic strategies of these territorial systems, with some specific variances according to different environmental conditions. This research builds the foundation to analyse and reconstruct the exploitation strategies of the natural resources carried out by these Nuragic communities, creating also a provisional model of their demographic capacity.

S09 Archaeological Information Languages and Notations

César González-Pérez, Patricia Martín-Rodilla, Ruth Varela

Most of the efforts that are made in the realm of information technologies and archaeology are directly related to data or information. The way in which we represent archaeological information, the particular languages that we use, the formalisms that we employ to describe the archaeological record or to convey archaeological meaning, and the visual representations that we choose or construct, have a great impact on how knowledge is constructed at the other end of the communication process. This session aims to address this by, precisely, analyzing the languages and notations that we use in archaeology, i.e. by studying the vocabularies, conceptualizations, ontologies and graphical or textual representations that are involved in discussing the archaeological record and its interpretations from an abstract viewpoint and beyond anecdotal evidence. Major research areas that are welcome in the session include (but are not limited to) the following:

- What kind of natural language is being used to describe archaeological information? Is this language any different to regular language?
- What specific conceptualisations are we using to represent archaeological information? How are they developed? What are the key concepts on which the archaeological discourse relies?
- What formal systems, such as models or ontologies, are being used in archaeology? How are they useful? In what scenarios? Who develops and uses them?
- How is archaeological information conveyed between specialists in the field or the lab, while exploring hypotheses or developing arguments? What note taking, sketching, diagramming or other techniques are used?
- How is archaeological information presented in final form through publications or similar artefacts? What visual or textual notations are employed? What criteria are used to select the right presentation format?
- What kinds of actors are involved in the use of different languages and notations? Do specialists, amateurs and the general public, for example, use the same or different ones? What languages and notations mediate the communication between actor kinds?
- What software tools exist that facilitate the use of the above mentioned languages and notations? Who uses them and in which situations? How useful are them?
- How are these languages and notations useful for the development of computer systems such as databases or repositories?
- What reasoning and knowledge construction processes take place in relation to the languages and notations mentioned above?

Please bear in mind that the session is intended to focus on the theoretical and analytical study of archaeological languages and notations, rather than on the detailed account of specific case studies. The session will be of interest to people who:

- Participate in the development of models, ontologies, thesauri or other formal conceptualizations for archaeology.
- Have adopted, or are considering adoption of, a particular model or ontology for archaeological information.
- Believe that no particular conceptualization of archaeological information is especially better than others, or that no formal conceptualization can or should be used.
- Are interested in how archaeological knowledge is created, refined, visualized and shared.
- Are interested in the ways in which we interact among ourselves and with computer systems in relation to archaeological information.
- Need to assess the impact of the adoption of a tool or technique on the overall results of their work.
- Make decisions about standards adoption or methodological choices, either small- or large-scale.

- Are interested in the mechanisms by which meaning is constructed in archaeology, either individually or collectively.

S09-01 Is that a good concept?

Stephen Stead, Martin Doerr, George Bruseker, Maria Daskalaki

This paper draws on the experience of the 20 years of development of the CIDOC Conceptual Reference Model (now an ISO standard) to look at what constitutes a good concept. That is what are the characteristics of a concept that will form a robust part of a useful ontology. It first discusses the characteristics of Knowledge, Information and Data. From these characteristics it draws the conclusion that shared Interpretation Functions are required to induce Knowledge in an audience. Concepts act as such shared functions and so must have a solid definition. The paper continues by identifying and characterising the four foundational elements of such a definition: Arena, Purpose, Intension (spelt with an s!) and Potential. We then go on to describe the four components of the concepts Intension, namely Identity, Substance, Unity and Existence.

S09-02 Towards a formalisation of spatio—temporal relationships in chronometric databases

Igor Bogdanović, Capuzzo Giacomo, Berta Morell, Juan Antonio Barceló Álvarez

In this paper we address the possible ways to manage and explain spatio-temporal information to reconstruct the duration of historical events. The way in which we represent absolute dating and the formalisms that describe the stratigraphic relationships and spatial coordinates, have a great impact on how historical knowledge is constructed. In this paper we found a database model for radiocarbon dated and georeferenced archaeological contexts and findings, and we analyse the languages and notations, i.e. studying vocabularies, conceptualizations, ontologies and relationships. The paper is based on previous team-work on databases of radiocarbon dated archaeological contexts: Prehistory of Northeastern Iberian Peninsula (<http://www.mac.cat/eng/Research/Catalunya-C14>), Bronze Age of Southwestern Europe (the EUBAR—Capuzzo 2014) and other relevant case studies (Bogdanovic et al 2013, Morell et al., in press). To create an integrated data base in which chronometric dating of isotopic events are related with the archaeological contexts, we propose data model based on the inference chain: Isotopic event - Depositional event - Archaeological event - Historical event. In this way, each isotope event is related with its corresponding depositional events taking into account stratigraphic and taphonomic information of each dated sample. Defining context reliability is a fundamental step for obtaining a true relation between the radiocarbon probability intervals and the depositional event we are referring to. A particular logical connection should be found within the isotopically determined calendar dates of all determinable death events within the same depositional event. The estimated calendar date and duration of all depositional events within the same archaeological event will be used to measure the date and duration of events higher in the hierarchy. The calculated calendar date and duration of all archaeological events within a single historical event should be used to compute an estimation of the initial and final position of events within the historical period.

S10 Theorising the Digital: Digital Theoretical Archaeology Group (digiTAG) and the CAA

James Stuart Taylor, Sara Perry, Nicolò Del'Unto, Åsa Berggren

Computing and the application of new digital technologies in archaeology and the heritage sector more generally have been advancing rapidly in recent years. This 'digital turn' is reflected in the growth and success of the CAA international conference, and in the emergence of a range of dedicated interest groups and associated digital outputs around the world. In concert, pressure has been increasing to situate the application of digital technologies within a wider theoretical framework, and with a degree of critical self-awareness, thereby allowing for rigorous evaluation of impact and disciplinary change. This is something that the CAA, as a nexus for the discussion of applied digital technologies in archaeology, has explicitly addressed throughout its history, and particularly in recent meetings, with a range of round tables and theoretically-engaged sessions that have proved popular amongst the digital community.

TAG, another well-established conference, with a long history of fostering progressive and critical debate in archaeology, has never explicitly aimed to address the various theoretical consequences of the digital turn. As such, this session seeks both to broaden the TAG family to attend to the rapidly-growing computational sphere of archaeological practice, and to work with the CAA to consolidate its own efforts to theorise and encourage critique and evaluation of the effects of the digital turn.

We invite participants to deliver papers that question, challenge, appraise and reconceive the epistemological and research-oriented implications of the digital turn--as well as its larger social, political and economic consequences. In short, what is the actual impact of the digital turn upon archaeology and the wider heritage sector? The session will culminate in a chaired discussion amongst all contributors, with a focus on both debating the future of the concept of 'digiTAG' and rethinking critical engagement with digital practice in archaeology and heritage overall.

S10-01 Theorising the digital turn in archaeology

Sara Perry, James Taylor

"We are all digital archaeologists" is an increasingly common refrain amongst practitioners today. However, this ubiquity of computational approaches in archaeology seems hardly understood. Debates about the philosophical or cultural dimensions of digital technologies in the discipline have a deep legacy, yet the technical capacities of these tools still tend to eclipse meaningful critique of their implications. Problematically, it is usually the *applications* of computers that become the overwhelming focus of digital archaeological discussions at our conferences, in our written work, and often in our classrooms too.

This trend to value the technical above the theoretical is one that is seen across many fields ' and it is made worse by the fact that it tends to betray itself again and again as any new piece of gear is added to disciplinary toolkits. The Computer Applications and Quantitative Methods in Archaeology enterprise itself hints at the predicament, for applied methodology is foregrounded in the organisation's very name, with richer qualitative analyses of the digital seemingly consigned to the backstage. As an introduction to digiTAG, then, this paper makes a case for the necessity of reversing this situation, prioritizing critical engagement above practical exposition. To do so, we review the history of - and tensions between - digital methods in archaeology and the intellectual and social systems that shape (and are shaped by) them.

Ultimately, we aim here to broach a range of issues that habitually go unspoken: How do computer applications in archaeology intersect with local and global socio-political-economic complexes? How do they perpetuate or challenge structural inequalities? How do they

contribute to wider patterns of consumption, excess, loss and waste? How are they folded into the institutional status quo? And how do they shape not only our thinking and doing of archaeology, but so too our more intimate ways of being-in-the-world?

S10-02 A plea for (non-mathematical) reason. Rethinking the use of computational methods in archaeology

Catalin Nicolae Popa, Oliver Nakoinz

In this paper we argue that while computational methods offer exciting possibilities to archaeology, their large-scale unreflected use is making our discipline too mechanical and mathematical.

There is little doubt that many digital methods have made a positive contribution to our work. The use of digital techniques during and in combination with archaeological fieldwork has unquestionably given us more control over what we excavate. Such methods have also provided simpler and more interactive ways to explore our data and convey them to others. But they are no substitute to interpretation!

However, some computational methods are frequently employed as a means to explain the material record, with near total disregard of archaeological theory. Most of these approaches fall into the category of computer modelling and simulation. There are a plethora of studies and presentations utilizing such methods with little theoretical grounding. For example agent-based modelling papers, where theories of agency are rarely referred to. Additionally, results are often taken for granted, as if offering factual solutions, without critical evaluation and interpretation.

Such use of computational methods is damaging to the community employing them and to archaeology as a whole. The over-enthusiasm with these approaches, the belief in the objective nature of 'the machine' (i.e. computer), and the wish to transform archaeologists into applied mathematicians brings the dawn of a New New Archaeology (sic!). Currently, many scholars are still sceptical towards studies employing such methods, contributing to a division of the discipline. But archaeology does not need another theory war! We suggest an integrated approach, with balanced parts of method and theory. For archaeologists using computational methods this implies a wider integration of post-processual critique. In this manner, the full potential of these approaches can be realised as they would find their well-deserved place in archaeology.

Cancelled S10-03 The biography of a 3D print

Mhairi Maxwell

Over the past 5 years the digital has naturally crept into my work and subsequently influenced my practice. I have been digitally turned, but have not forgotten my roots. By June 2016 I will have attended my 12th TAG, but this will only be my 2nd CAA. I welcome this session and concept of 'digiTAG' as a conscious opportunity to reflect on this.

This paper will be a material culturist's take on the rise of the digital. This will be explored through the biography of a 3D print of an archaeological monument; its making, use and deposition (Appadurai, Kopytoff, Latour). Digitally created objects move in and out of different material and immaterial networks of engagement in which their value is re-negotiated. They are enchanted through these networks of engagement (Gell). I will reflect on the ACCORD project (in which I was the PDRA), which co-produced digital records with local communities in Scotland, and my own research in progress.

Critically studying the social biographies of digital artefacts has implications for how we can understand and re-imagine human social and political relationships with heritage and archaeology in our contemporary world, now so often enacted immaterially through fiber-optic cables and LCD screens, then materialised by Makerbots. Additionally, it will attempt to

explore whether established theories of the gift, and reciprocity and exchange (e.g. Mauss, Miller, Strathern), have merit for understanding how social relationships are built with archaeological artefacts and monuments in the digital era.

Arguably, without considering the social lives of digital objects more generally, we are risking their commodification. In such a future, the value of the digital artefact (including the born-digital) will be determined irrespective of who made them, how they were made and their cultural significance.

S10-04 Epistemological considerations on image-based 3D representations: Bridging the paradigms through the objectification of field interpretation

Matteo Pilati

This paper investigates what image-based 3D models are and what their contribution is for archaeological epistemology. Given that this particular form of digital representation is integrated in documentation work, data management systems, as well as in different analytical and interpretive contexts, several assumptions are made about their contribution to information generation. On these premises, the risk is that the epistemological affordance of image-based 3D models becomes regulated by methodological frameworks which may not acknowledge the full palette of heuristic, informative, and documentary values inherent to these representations. The first point to be discussed relates to the automatization of the image-based 3D reconstruction process, its dependence on raster data and use of algorithms, which simulate optic perception, meaning that image-based 3D models are profoundly mimetic, true to reality and un-interpreted representations of archaeological contexts. From a methodological point of view, these models reproduce situations precedent to their representation-based interpretation and provide objective evidence for contextual analytical work. Another point is that given the truthfulness of image-based 3D models to reality and their detail degree they do not simply represent the physical boundaries of an excavated context or unit. Image-based 3D recording captures the archaeological contexts in a broader context of documentation surfaces, features, alongside details, actions which may be considered marginalia, and often cropped. This visual information is a record of the historicity of the excavation work, revealing onsite interpretation dynamics; it can be employed to inform excavation strategies, evaluate analyses and interpretations, promote reflexivity and adaptive documentation strategies, and enhance the historical presence of the interpreting subjects in the digital archive. Based on these observations, this paper states the capability of image-based 3D representations in providing objective and detailed information of subjectively shaped material evidence, hence drawing closer epistemological positions traditionally perceived as reciprocally opposed.

S10-05 How raw is raw data?

Dominik Lukas

The biggest threshold to understand scientific knowledge, as it is stored in heterogeneous datasets today, is not the general availability of data, but the lack of transparency of its meaning and how datasets interrelate on the conceptual level. Moreover the increasing availability of research data has made it necessary to deal with a 'deluge' of information also in archaeology. Terms like 'big data', a proposed '4th paradigm' or simply the propagation of a 'digital turn' are used to describe this development. In fact, the modalities of data storage and its publication on the Internet make it possible to overlook the inherent dependencies that are part of the process from data generation to retrieval. The strangely externalized matter that data driven research seems to be confronted with, even allows for the postulation of a 'new empiricism' - a point of view that fails to acknowledge the theoretical implications of the generation of datasets and their forms of storage, assuming that the sheer quantity of data has

made scientific method obsolete.

In my paper I will examine the epistemological framework of data structures used in archaeological research, showing their theoretical and research strategic implications. I will argue that the relationship between archaeological data and its scientific interpretation, as reflected in the existing data models, must be understood as constituents of specific 'infrastructures of knowledge'. In consequence it is necessary to make scientific inference formally visible. The goal is the explication of semantic values embedded in the data structures and the mapping of provenance and inference. I will discuss whether this can be done through the implementation of existing ontologies or the development of specific micro ontologies, by presenting examples from the development of the Çatalhöyük Living Archive.

S10-06 Communication in archaeological fieldwork: Responses to a digital workflow

Leigh Anne Lieberman, Gregory Tucker

The emergence and adoption of convenient, reliable, and affordable technologies facilitates digital recording and processing in the course of field research, both improving the speed and quality of data entry and increasing access to data. This 'digital turn' in data collection and management has improved efficiency at the point of discovery, during secondary processing, and throughout later analyses. Consequently, much of the discussion surrounding the application of digital approaches in archaeology has focused on the data collection process and its subsequent impact on data dissemination. However, some of the secondary effects of this movement have not been fully evaluated, leaving us knowledgeable about the quantitative benefits of "going digital" but not about how this impacts researchers and how we conceptualize archaeological fieldwork and methodology.

Employing a completely digital workflow at the Pompeii Archaeological Research Project: Porta Stabia (PARP:PS) since 2010, we have observed that our approach has changed not only how we collect and employ data, but also how we interact with each other. We discuss results and interact with one another in different ways than before, with new expectations of what is possible in the field. Both specific details and synthetic ideas are able to be shared and collaboration takes place more quickly than ever thanks to our digital approach. Constant availability of digitally curated data has fostered an environment where asynchronous communication between team members is possible and, in many ways, preferred.

In this paper, we describe how the employment of tablets at the point of data collection, as the last link in an entirely digital workflow, has revolutionised not just the excavation, post-ex, and publication process, but also how we communicate at PARP:PS. Using our experiences as a case study, we aim to address not only the likely benefits that come out of our preference for asynchronous communication, but also the potential problems associated with this increased ease of contact as well as our experiences overcoming these issues. These concerns are not unique to PARP:PS, and thus, we hope to engage in a discussion of how the implementation of constantly evolving technologies influences archaeological practice, collaboration, and dialog in our discipline more broadly.

S10-07 The lives of digital machines: Evaluating the significance of historic computing machinery

Gareth Beale, John Schofield

Innovation has been a central concept in the formation of histories of digital technology. The significance of computing machinery is often defined in terms of innovation with comparatively little attention paid to the role which these technologies have played in the lives of users. The prevalence of this mode of historical narrative can at least in part be attributed to the tendency within a commercially motivated computing industry to place an emphasis on novelty and originality. The limitations of innovation-centric histories of

technology have been acknowledged within historical research (Edgerton 2006) and these critiques have sat alongside an increasingly critical approach to adoption of commercially derived technical concepts with academic research (Sterne 2003).

In this paper we will argue that archaeological approaches to the study of material culture can be utilised to build fuller accounts of the significance of digital technologies which are driven by use and impact as well as by innovation. The paper will describe the biographical and physical study of historical computers undertaken at the Jim Austin Computer Collection in collaboration with designers, engineers and users and will examine the interactions, modifications and experiences which help to define the significance and physical form of historical computing machinery.

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S10-08 Digital interpretive technologies: A way into difficult heritage in the Middle East and Central Asia?

Katie Campbell

Conflict, contested heritage and differing stakeholder interests have led to an increasing use of photogrammetry, remote sensing and 3D modelling techniques as the only means of recording, monitoring and interpreting historic monuments and archaeological sites across the Middle East and beyond. As a result, researchers are starting to make greater use of this digital data, for both academic and practical purposes. This paper aims to critically appraise the effect that the rapid transition from 'traditionally' to digitally collected field data is having both on our interpretation of these monuments and its role in informing conservation and heritage protection decisions in 'difficult' cases. The Great Kyz Kala, an early Islamic architectural monument that forms part of the UNESCO World Heritage site of Merv, in modern Turkmenistan, is a difficult monument. Not in the traditional sense that is associated with recent atrocities or ongoing tensions in the Middle East and Central Asia, but because of its iconic nature within the country and the crucial role that archaeology and historic monuments play in Turkmen narratives of a post-Soviet national identity. Discussions on how to interpret and conserve this rapidly deteriorating and enigmatic monument have been held over the last five years between various national and international organisations including UNESCO, the Ministry of Culture of Turkmenistan, and international collaborators including universities and embassies. These talks have, however, led to something of a stalemate in how to approach the monument in terms of its conservation and presentation, while academic research on the archaeology remains frustratingly limited. By combining qualitative feedback on the digital approach adopted by archaeologists from UCL, and a critical review of the decision-making processes behind actions at this monument, against the backdrop of a rapidly evolving political landscape in Turkmenistan, the wider consequences of this research strategy for the Great Kyz Kala will be assessed.

Cancelled S10-09 Trends in digitalisation of archaeology: Interdisciplinary and archaeological viewpoint

Teija Oikarinen

Currently digitalisation is changing societies and the sciences. A doctoral research by author focused to study the current state and characteristics of the digitalisation of both global and Finnish archaeology.

Archaeology was examined through an interdisciplinary conceptual (theoretical) framework originated from the field of socio-technical information systems research and the field of science and technology studies. The framework allowed comparison of the characteristics of digitalisation between global and Finnish archaeology. The aim was to recognise digital development goals that may be either shared between various disciplines or specific to the field of archaeology. Archaeology was studied by utilising different kinds of data sources and case examples. This study was the first doctoral dissertation that discusses the digitalisation of Finnish archaeology. The aim was to create a global-local overview to start to analyse a country-specific state of digitalisation of Finnish archaeology.

Research produced results related with both global and Finnish archaeology. The utilised interdisciplinary framework made possible to create a fresh insights from archaeology. The results implicated, for example, that technologisation and computerisation of archaeology have been going on for decades, but even in a global context, the concept of digitalisation as a global phenomenon (from the utilised interdisciplinary viewpoint) is rarely attached to archaeological discussion of these trends. Technological development is uneven at the global level: there are trailblazers who already utilise the latest technologies. These leaders are currently developing, for example, digital infrastructures of various sizes, even transnationally. This trend is common in various disciplines. The answers to questions regarding digital development needs can be generalised to Finnish archaeology in its entirety, even the focus was originally in the context of historical archaeological excavation process. In the future, digitalisation will increasingly affect archaeology as a cross-cutting factor for materials and work practices.

S10-10 The apparatus of digital archaeology

Jeremy Huggett

Digital Archaeology is predicated upon an ever-changing set of apparatuses – technological, methodological, software, hardware, material, immaterial – which in their own ways and to varying degrees shape the nature of Digital Archaeology. Our attention, however, is perhaps inevitably more closely focused on research questions, choice of data, and the kinds of analyses and outputs. In the process we tend to overlook the effect the tools themselves have on the archaeology we do beyond the immediate consequences of the digital. This paper seeks to address the apparatus more directly within the context of the developing archaeological digital ecosystem.

S10-11 Deep maps of digital, post-representational archaeology

Piraye Hacıgüzeller

Moving beyond the epistemological objectivity—subjectivity debate, post-representational thinking in archaeology has recently started to explicitly challenge the idea of a past reality that exists independently from the present and future. A post-representational archaeology, with its neo-empiricist ambitions, is to concentrate its efforts primarily and explicitly on the witnessable formations of the present. The past in post-representational thinking is therefore not an existing code to be cracked or reality to be discovered. Rather, it is creatively constructed here and now through a set of relations presented together insofar as such presentations are found relevant and acceptable by consensus.

Despite the increasing influence of such ideas in the discipline, the core business of archaeological practice today still largely remains focused on seeking knowledge that truthfully corresponds to the "archaeological past". Post-depositional processes and practices of archaeologists in this context are treated as of importance as far as they influence the processes of revealing or interpreting the past.

I will be arguing in the presentation that “deep archaeological maps” facilitated by the digital transition in archaeology can serve to further destabilise the ideas of and hopes for an independent past that can be known, understood and explained. Specifically, cartographic data visualisation in archaeology can be carried out with multimedia deep maps populated with narratives, videos, sound recordings, maps of emotions, hopes, fears, pictures, personal and material biographies, as well as links to conventional archaeological databases and Big Datasets. Such “thick” cartographic presentations of archaeological sites would act as a continuous reminder of the identity of archaeological places, processes and pasts as continuously becoming at present. I will describe the possibilities for such deep mapping applications at Çatalhöyük (Turkey) with the help of a multimedia deep map prepared with Prezi presentation software and in relation to the Çatalhöyük Living Archive project.

S10-12 Bringing digital sociology to digital archaeology

Lorna-Jane Richardson

Often, the practice of public engagement in digital environments with archaeological subjects is seen, from the professional perspective, as the need to attract presence, and the expectation that lay people are participating when they are simply being exposed to specific cultural information. Participation and consumption have become mercilessly conflated.

Whilst classical sociological theories can be brought to bear on the interactions and ‘social’ dimensions of the use of digital media between professional archaeologists and the non-professional lay person, digital interaction often moves beyond the theoretical possibilities offered to us by Marx, Weber, Durkheim or Törries. The work of Goffman, Bourdieu and other more recent theorists, and dramaturgy, the logic of practice and networked individualism are vital to our understanding of the potential for the replication of offline inequalities, the public display of expert knowledge, and the entanglement of social communication networks in the variety of digital environments provided by archaeological organisations.

This paper will explore the approaches that these sociologists can bring to an exploration of the digital turn in the archaeological profession, and examine what an in-depth understanding of digital sociology can offer the often ‘magpie’ discipline of archaeology.

S11 Supporting researchers in the use and re-use of archaeological data: Continuing the ARIADNE thread

Julian Richards, Franco Niccolucci, Holly Wright, Kate Fernie

Following on from the successful conversation begun at CAA Siena in 2015, this session seeks to further expand dialogue in this critical area. Ever-increasing amounts of data are available within data repositories in individual institutions, national infrastructures and international services. The EC Infrastructures funded ARIADNE project is working to bring together archaeological research data from across Europe, for use and re-use in new research. There are challenges, such as raising awareness about the available data, integrating datasets produced by very different projects using differing methodologies and various technologies. There are GIS, databases, 3D data, scientific datasets and more, all produced in a variety of languages. ARIADNE is building vital infrastructure to bring together, manage and provide access to these datasets. The project is embracing Linked Open Data, Natural Language Processing, deploying Web Services and new tools to provide enhanced access to researchers. ARIADNE is also offering training and opportunities for archaeologists to access the research infrastructure, and to share knowledge and expertise.

The aim of this session is to stimulate discussion between researchers and data specialists, and to:

- Showcase best practices and relevant work supporting access and use of digital archaeology from ARIADNE and other services
- Present case studies demonstrating innovative re-use of archaeological datasets
- Develop an understanding of the challenges in providing access to research data and the opportunities offered by ARIADNE and other services
- Discuss how these challenges can be addressed and how the opportunities can be maximized
- Generate ideas for future training, access and research

[Session themes]

The focus is on access, discovery and research reuse of archaeological datasets, and contributions are invited on the following (and related) topics:

- 3D and Visualization
- Remote Sensing and Spatial Data
- Excavation and Monument Data
- Scientific Datasets
- Grey Literature
- Linked Data
- Design of Archaeological Datasets
- Conversion of Legacy Datasets

S11-02 Methodological tips for mappings to CIDOC CRM

Maria Theodoridou, George Bruseker, Maria Daskalaki, Martin Doerr

The CIDOC Conceptual Reference Model (ISO 21127:2006) has been chosen as the core model for use in several Cultural Heritage projects including ARIADNE, ITN-DCH, PARTHENOS, and ResearchSpace. A foundational activity of these projects then has been the effort to convert the data stored in existing schemata to an expression in CIDOC-CRM and its extensions. The goal of the conversion process is to enable information exchange and integration between heterogeneous sources of cultural heritage information. In order to support the scalability of these activities, which entail careful analytic work by someone familiar both with the domain and with the ontology, a series of training events were initiated aimed at professionals who have an understanding of the CIDOC CRM and need to develop skills in data mapping techniques.

This paper will present some modelling principles and methodological good practices that we have empirically derived from the above exercises in the systematic mapping of diverse cultural data sets to CIDOC CRM and its extensions. This experience is specifically derived from mapping activities using the 3M (Mapping Memory Manager) tool in the above mentioned projects. In the paper we will address a number of fundamental issues. First, we look at the question of how to determine at the beginning of a mapping - the sufficiency of CIDOC-CRM and/or its extensions, for covering a given data set and when it would prove necessary to extend the model and introduce a new class, and how. We suggest practices related to the handling of identifiers that are local in the original source data set. We also treat some special issues of how to model the roles of people and organizations, including accidental roles, and present a methodology for introducing implicit contextual information. Finally we discuss issues related to the modeling of nationality, country and imaginary places.

S11-03 An essay of mapping archaeological land-record system used by Inrap with CIDOC—CRM and CIDOC—CRMarchaeo extension using 3M online tool

Christophe Tuffery, Achille Felicetti, Patrick Jard, Nicolas Holzem, Thomas Guillemard

During a summer school on the CIDOC-CRM organized by the PIN of 21 to 25 July 2015 in Prato for the ARIADNE program(1), we have had the opportunity to use the CIDOC-CRMarchaeo extension (2). The aim of the summer school was to work effectively with a set of our own data field and try to match fields between archaeological land registration systems used by Inrap and those of CIDOC- CRM. We had the opportunity to use the 3M application (Memory Mapping Manager), an online tool developed by ICS (3), which controls whether archaeological data can be matched with the CIDOC CRM model. We tested the matching process with two fields of archaeological land recording systems used by Inrap (one based on Access and another on FileMaker Pro). Then we did the same with a prototype application on development by Inrap. This is an interface using Google Chrome, SQLite, JavaScript and HTML5, and which aims to allow data exchange with the two previous land registration systems mentioned above. Working with the on-line application 3M (4) allowed assessing whether two of the main archaeological entities (the stratigraphic units and archaeological facts) can be matched with the CIDOC CRM model and CIDOC-CRMarchaeo extension. The work demonstrated the 3M on-line tool meets the needs of matching fields of archaeological recording systems tested with classes Model CIDOC-CRM and especially its CIDOC-CRMarchaeo extension. This matching procedure has demonstrated the ability to assess whether an archaeological land recording system may or may not be considered as matching with CIDOC-CRM models and how to adapt it to conform if it doesn't initially. Therefore new tests will soon be conducted with other land archaeological recording systems used by Inrap.

(1) <http://vast-lab.org/bando-summer-school-ariadne-2015/> (2)

http://www.ics.forth.gr/isl/index_main.php?l=e&c=711 (3) Institute of Computer Science (<http://www.ics.forth.gr>), Forth Foundation, Greece (4) <http://139.91.183.3/3M/>

S11-04 Formalisation and reuse of methodological knowledge on archaeology across European organisations

Cesar Gonzalez-Perez, Patricia Martín-Rodilla, Elena Epure

Archaeological projects vary greatly in size, complexity, object of study, timescale and other aspects. Finding the most suitable methodology for a project is often difficult, and an inadequate choice can ruin many months' worth of fieldwork, bias data interpretation, and slow down or impede cross-project comparison of results. An archaeological methodology should be as adjusted as possible to the project needs, take into consideration techniques and approaches successfully applied in the past, and clearly expressed for better understanding

and sharing among the involved agents. These goals are usually pursued informally through the application of tacit knowledge that exists within archaeology organisations, leading to situations where: 1) it is difficult to convey what is expected to be done, especially to new team members or external collaborators; 2) methodological knowledge is underutilised and rarely reused, especially across organisations; and 3) the improvement of methodologies over time is difficult since no explicit knowledge about them exists. As we have previously proposed [Gonzalez-Perez and Hug 2012, "Crafting Archaeological Methodologies"], situational method engineering (SME) can be used to mitigate these problems. SME does not conceive a methodology as a monolithic black box, but as an assembly of pre-existing components that are selected from a repository and composed together. Each component encapsulates a proven, reusable and self-contained "atom" of knowledge that can be reused, recombined in different situations, and improved over time. In the context of the FP7 ARIADNE project, we have applied an SME approach by which the informal methodological knowledge of seven European archaeological organisations (including university departments, research centres and museums) was formalised as discrete components, stored into a database, and linked to other components. Natural language processing techniques have been used to assist in the information extraction and formalisation process. The resulting repository has allowed us to obtain variations of established methodologies to cater for different project situations; combine different methodologies for collaborations and other hybrid scenarios; and carry out a comparative analysis of commonalities and differences between the archaeological practices of the selected organisations.

S11-05 Semantic database applications at the Samtavro Cemetery, Georgia

David Bader, Aleksandra Michalewicz, Oded Green, Jessie Birkett-Rees, Jason Riedy, James Fairbanks, Anita Zakrzewska

In 2013 a paper was offered to the CAA concerning archaeological legacy data and semantic database applications, with some preliminary results for a study conducted into the Samtavro cemetery, situated in the South Caucasus in the modern republic of Georgia. The present paper presents further research outcomes of data mining the Samtavro material. Over four thousand graves were excavated at this site, used most intensively during the Late Bronze and Iron Ages, and later in the Roman and Late Antique periods. The current project focuses on the latter period and the legacy of Soviet and post-Soviet excavations in a collaborative effort between computer scientists based at the Georgia Institute of Technology, USA, and archaeologists at the University of Melbourne and Monash University, Australia.

Data for 1075 tombs, 1249 individuals, and 5842 grave accoutrements were collected across 74 data fields, resulting in the identification of 9 tomb types, 37 artefact types and 320 artefact subtypes. Methods tested against the Samtavro material culture included the application of clustering techniques to understand associations of related items based on patterns of co-occurrence, using traditional data mining (hierarchical link clustering) and spectral graph theory focusing on tomb types in relation to artefact types. The other method calculated the probability of each event occurring and comparing this to what we would expect if these were truly random focusing on artefact types in relation to biological sex and age brackets.

In some instances, our work confirmed previously established relationships, but it likewise revealed new results concerning particular entities. The project demonstrates that although sites for which comprehensive archival records exist can benefit from these types of approaches, often the greatest limitation in taking a 'big data' approach is the relative scarcity of archaeological data.

S11-06 A catalog for archaeological resources

Franca Debole, Nicola Aloia, Christos Papatheodorou, Dimitris Gavrilis, Carlo Meghini

The European funded project Ariadne (<http://www.ariadne-infrastructure.eu/>) aims to develop an infrastructure to aggregate, enrich, integrate and make available the data and services so far developed by the international archaeology research communities. The project enriches and integrates data resources such as descriptions of datasets, collections, metadata schemas, vocabularies, etc. - and services in order to create a universally accessible shared knowledge base for the archaeology domain.

In the context of Ariadne a crucial concept to integrate and manage different resources is the catalog, or registry. The catalog of Ariadne lists and describes what is available from the project partners, and more generally the whole community of archaeologists, to identify, through refined search mechanisms, the candidate resources for integration. Data registries is in effect a well-known data organization and management approach that provides an environment in which datasets, collections, metadata schemas and vocabularies along with their mappings would be hosted and described by a common schema. Actually, the data registries enhance the accessibility and re-usability of the (research) data.

This paper presents the data model of the Ariadne catalog named Ariadne Catalog Data Model (ACDM) that extends the existing data registry standards. The central notion of the model is the class *ArchaeologicalResource*, specialized in the classes: (i) *DataResource*, whose instances represent the various types of data containers (e.g. collections, GIS, datasets) owned by the ARIADNE partners and lent to the project for integration; (ii) *LanguageResource*, having as instances vocabularies, metadata schemas, gazetteers and mappings (between language resources); (iii) *Services*, whose instances represent the services owned by the Ariadne partners and lent to the project for integration. The paper presents the aggregation service that is based on the ACDM model and enables the partners to upload huge volumes of metadata to the Catalog as well as the main functionalities of the Ariadne portal (<http://ariadne-portal.dcu.gr/>).

S11-07 Using semantic technologies for the deep integration of research items in ARIADNE

Philipp Gerth, Wolfgang Schmidle, Sebastian Cuy

One important goal of the EU-funded ARIADNE project is to integrate data originating in a variety of different disciplines in the archaeologies and connected subjects in order to facilitate access to heterogeneous data sources. This integration on the one hand happens on a large scale by incorporating descriptions of vast amounts of research resources into the ARIADNE catalog. On the other hand experiments on the tight integration of the detailed descriptions of single item of research investigates workflows and use-cases for semantically integrated data.

In this paper we will describe a practice-orientated approach on dealing with this problem with the help of Semantic Web Technologies. A specific use case on integrating finds from various databases will be presented. We will highlight the difficulties in integrating databases with differing genesis (museum catalog, object database, excavation database), therefore different terminology, focus and languages.

The integrated datasets will be accessible via a unified programming interface, which allows rich querying possibilities. This interface lays the groundwork for a user interface, which facilitates the intuitive formulation of queries for accessing the integrated data.

S11-08 Fasti surveys

Elizabeth Fentress, Michael Johnson, Florence Laino, Stuart Eve

Fasti Surveys The Fasti platform has proved so useful for the quick registration and retrieval of excavations in participating countries that we have decided to clone it for other types of data, creating a trinity of Fasti applications. Of these, Fasti Archaeological Conservation has been easily fit onto the original model, substituting conservation projects for objects and sites for the excavations. Fasti Survey presents other challenges, however, including the serving of polygons for regional surveys, crowd sourcing, and very unequal projects. We have thus devised a two-level site, in which the first, like the excavations, simply provides an overview of each project, complete with its bibliography. We have an enormous head start in the sharing of the data from 320 projects already compiled by the project MAGIS (Mediterranean Archaeology GIS, <http://www.iosa.it/2007/05/17/magis-mediterranean-archaeology-gis/>) generously shared with us by Pedar Foss and Rebecca Schindler. The second level will serve data from participating projects.

Cancelled S11-09 The advantages of integrated 3D photogrammetry and Reflectance Transformation Imaging empirical acquisition

Mark Mudge, Carla Schroer

Today, there is a convergence of recent advances in computer vision, computer graphics and computational photography technologies such as Reflectance Transformation Imaging (RTI) and 3D photogrammetry. New photogrammetric technologies using Structure from Motion (SfM), along with new understanding of the geometry of multiple photographs underlying Multi-viewpoint Stereo (MVS) are driving widespread adoption of these technologies. The software produced by this convergence, run on ever more powerful computing platforms, make it possible to derive densely sampled, low uncertainty, high quality 3D measurements. These advances have greatly improved both photogrammetric measurement quality and ease of use.

These photogrammetric advancements have enabled new synergies from the combined use of RTI and photogrammetry. This talk will offer an overview of the methodology used for this joint computational photography empirical acquisition. Using the procedures in the talk, RTI representations can be captured and spatially registered to the associated 3D geometry built with photogrammetry. This spatial registration dramatically increases the information available to RTI representations.

The photo sequence used to build the RTI can use the camera calibration(s) derived from the photogrammetric Structure from Motion algorithms. This permits the complete distortion correction of the RTI photo sequence. In turn, these undistorted photos can produce optical-distortion-free RTIs.

Using advanced photogrammetry software, the registration between the RTI and photogrammetry geometry can enable depth map generation of for each photo used in the photogrammetry project. This means that each registered RTI can have corresponding depth information. This undistorted RTI and depth map combination greatly increases the informational robustness of RTI imaging.

The combined use of the normal field and material reflectance information acquired by the RTI can also be used to improve the photogrammetry-based textured 3D model. Future work will exploit this relationship to produce material representations that more closely approximate the surface properties of the imaging subject.

S11-10 Best practices to re-use remote sensing data coming from marine geophysical surveys for the 3D reconstruction of underwater archaeological deep-sites

Manuela Ritondale, Gaia Pavoni, Roberto Scopigno, Marco Callieri, Matteo Dellepiane

Since several decades, underwater archaeology takes advantage of the tools available for marine geophysics to map, document and monitoring the seabed. Impressive levels of details have been reached in underwater photogrammetry. Nonetheless, a huge amount of data has been collected in the past with several different purposes and with rather different technologies. The aforementioned materials, particularly those coming from commercial archaeology, is underexplored and might be re- used and optimized by using digital technologies to enhance the accessibility of underwater sites through virtual reconstructions. Our goal is, on one hand, to investigate the technical and the legal/bureaucratic constraints that prevent the re-use of remote sensing data coming from geophysical marine surveys. On the other side, we propose a solution to reuse stills images and video data acquired with ROVs-based surveys of archaeological sites (characterized by non-homogeneous quality and resolution), aimed at obtaining 3D image-based models. Our approach uses standard photogrammetric solutions, but is based on specific pre-processing and enhancements of the input raw data. In the first pre-processing phase, we propose an automatic frame extraction algorithm working on video streams, able to reject the damaged or non-useful frames and to select the more proper for 3D reconstruction, taking into account all the best practices for an optimal photogrammetric reconstruction. In the second phase, we apply underwater-specific image enhancement filters to either images or video frames to sharpen useful details and to correct undesirable aspects for a good reconstruction like color absorption and blur. Practical examples and first results will be discussed.

S11-11 Digging into and re-using image data for archaeology

Christopher Power, Andrew Lewis, Helen Petrie, Julian Richards, Katie Green, Mark Eramian, Ekta Bhullar, Brittany Chan, Isaac Sijaranamual, Maarten de Rijke

Each year thousands of archaeological field studies are undertaken. One of the resources with the largest potential to help archaeologists in their work is the hundreds of photographs that are taken during field studies. These photos, which can now be labelled with captions and uploaded to repositories direct from the field, could open new possibilities for re-use in many research tasks. Unfortunately, the potential of these resources has not yet been realised. Due to time pressure and lack of personnel, most photos do not have appropriate content-related metadata associated with them. While it is possible to identify what collection an image is from, or where it was taken using GPS coordinates, knowing what is actually in the image is often impossible. Even if tools were available to provide such content-related metadata, it is unlikely that the person power would be available to provide this metadata for the thousands of photos that already exist in digital form. The DADAISM Project is addressing this issue by using a mixed-initiative approach, where the deep domain knowledge of the archaeologist can be used to identify a number of key features in an image, and then automated processing can identify images that are similar, digging into the image data and extracting relevant information from the content. These identified images can then be re-used by archaeologists for their research, or even automatically labelled with appropriate content-related metadata. The new data created from this labelling can then be published to improve the robustness of searches by other archaeologists during their research. This paper will present preliminary results from the DADAISM Project on the identification of images in two specific archaeological domains, flint tools and Anglo-Scandinavian brooches, and will also present the interactive system to enable archaeologists to work with the DADAISM image identification system.

S11-12 A data integration infrastructure for archaeology

Dimitris Gavrilis, Eleni Afiontzi, Johan Fihn, Olof Olsson, Sebastian Cuy, Achille Felicetti, Franco Niccolucci

Most infrastructure projects, both recent and ongoing, involve a data aggregation task in order to bring together the heterogeneous information one expects to see in a typical EU landscape. The main reason for this is the plethora of technologies, standards, languages and practices that is found in the EU. Data aggregation typically includes the homogenization of heterogeneous data through some kind of process that includes: ingestion, normalization, transformation and validation processes. The European funded project Ariadne (<http://www.ariadne-infrastructure.eu/>) aims at true integration of data by modelling the underlying domain and providing the technical framework for automatic integration of heterogeneous resources.

This infrastructure, comprises of a set of heterogeneous technologies such as: a metadata aggregator, including a set of enrichment and data integration micro-services, an RDF store with reasoning capabilities (through SPARQL), and a powerful indexing mechanism. The output of this process is published to a portal which can provide useful information to a variety of potential users ranging from simple visitors to domain researchers.

The data integration services can mine for links among resources, link them together and against language resources such as vocabularies. Complex records can be split into their individual components, represented, enriched and stored separately while maintaining their identity using semantic linking. These individual components are represented in the underlying model (ACDM) and include agents, language resources, datasets, collections, reports, databases, etc. Each integrated resource is assigned a URI and is published in RDF. This practice enables knowledge mining, semantic queries and reasoning engines which are provided within the project (e.g. SPARQL engine and Jena).

The technical infrastructure has been developed using various programming languages such as Java, PHP, Javascript, it is distributed spanning multiple virtual machines and brings together different established technologies and components. The portal is based on the Laravel PHP framework and uses Elasticsearch search engine to collect and browse through the data. Both the technical infrastructure and the portal will be presented and demonstrated in more detail.

POSTER

S11-P1 Combining analytical and digital data in archaeology: Towards a multidisciplinary ontological solution. The Salamis terracottas case study

Sorin Hermon, Valentina Vassallo, Giusi Sorrentino, Uros Damnjanovic

Multidisciplinary research produces heterogeneous data types, such as graphs, spectra, numbers and so on. Usually, what is presented to the research community is the interpretation of that scientific data. In a perspective of data transparency documentation, the auspicious solution would be to put at disposal all data and paradata that brought to that specific interpretation. How to make available and traceable these different kind of information? How to combine scientific, technological and archaeological data? This paper focuses on the ongoing multidisciplinary research, carried out within the frame of the EU funded projects ARIADNE and GRAVITATE, based on the integration of such data (e.g. archaeological, digital, chemical) and on the trace of the reasoning in scientific data documentation, analysis and interpretation. The organization of the information according to a rich and cross-domain metadata and to a standard conceptual reference model (CIDOC-CRMsci) will help towards the establishment of a multi-disciplinary research infrastructure. The research is applied within the terracotta figurines from Salamis-Toumba (Cyprus) project. The archaeological site

was excavated in the 19th century and the artefacts are currently stored in different museums. In the past the collection has been studied and the terracottas have been partially published along with their traditional stylistic description. Recently, within the GRAVITATE project, a further study of the collection has been undertaken. The project wants to identify and virtually reconstruct and re-unify parts of shattered or broken cultural objects with a multidisciplinary approach and integration of different digital analyses (e.g. 2D and 3D digital data acquisition, non-invasive and non-destructive chemical/physical analysis, 3D geometrical analysis).

Cancelled S11-P2 New tools for Digital Lab Notebook creation for use in Reflection Transformation Imaging

Mark Mudge, Carla Schroer

Scientific digital documentation of cultural heritage and natural science subjects can be a powerful tool for e-science and citizen scholarship. For centuries, the scientific method has required the recording of all empirical data's collection contexts and processes in a lab notebook, which provides informational transparency and enables informed reuse.

This talk will introduce two metadata and knowledge management software tools called Digital Lab Notebook: Capture Context (DLN:CC) and Digital Lab Notebook: Inspector (DLN:Inspector). These packages take the form of user-friendly toolkits that record the contexts in which the original photographic sets of empirical information were acquired and inspect these photographic datasets for successful processing.

This methodology is designed for digital representations that are built with computational photography technologies. While this software's first iteration is optimized for the computational photography technique Reflectance Transformation Imaging (RTI), the software is designed for easy adaptation to other computational photography technologies. The near-automatic nature of computational photography has advantages for the creation of scientific digital surrogates. A digital surrogate is a "stand-in" for "real world" subjects. They can be used for subsequent scientific or scholarly research.

Here's how it works. First, the DLN:CC harvests the capture context and process metadata associated with the empirical data and automatically maps this metadata to the CIDOC/CRMdig ontology. Next the processed photosets are inspected by DLN:Inspector to see if they will or will not successfully generate an RTI digital surrogate. When successful, the metadata is sent to the DLN. The metadata information in the DLN is then published as both XML and Research Description Framework (RDF) Linked Open Data files.

These DLN tools enable future evaluation of surrogate reliability and aids long-term archiving. When applied across the field of computational photography, the results of this strategic approach will be to enhance the digital data and knowledge sustainability of humankind's legacy.

S12 Documentation interpretation and communication of Digital Archaeological Heritage

Carlo Bianchini, Alfonso Ippolito, Carlo Inglese, Luca James Senatore

Any comprehensive knowledge concerning Archaeological Heritage can be reached only through the development of different investigation activities belonging to a very wide range of disciplines: archaeology of course, but also history, chemistry, physics, architecture, and so on. In the last two decades, this whole research field has experienced (like the majority of human activities) a massive transition from analogic to digital tools, data, information. While this transition can be considered by now almost concluded, nevertheless many problems remain unsolved especially concerning the way Archaeology is digitally documented, how this information is elaborated and finally how it is communicated. For instance, digital surveying technologies have produced important changes in the study, analysis, and interpretation of archaeological elements and the growing demand for realistic 3D models enabling the cognition and popularization of archaeology represents one of the most clear consequences of this process. Furthermore the opportunities disclosed by the digital revolution are deeply influencing even the management and preservation of Archaeological Heritage by now inextricably connected with the innovative processes of acquiring, organising and using digital information. In this framework, the multidisciplinary and multilevel approach that allows us to document, study, interpret, manage, preserve, and popularize archaeology implies the structuring of an innovative system of knowledge where all these phases are not only connected but also balanced among each other enlightening in this way a new image for Digital Archaeology itself. This session will thus not aim at focusing on a specific technique/technology but instead on state-of-the-art projects and investigations showing the integration of digital techniques, tools and methodologies necessary to understand, represent, spread, communicate and explore Archaeological Heritage. Contributions to this session will discuss the use of integrated and multidisciplinary approaches in archaeology, use of digital data acquisition technologies, data processing and communication. The focus will be on: 2D and 3D data capture methodologies and data processing in archaeology, 3D GIS, BIM, use of different system to document and explore archaeology, archaeological and historical research, standards, metadata, ontologies and semantic processing in cultural heritage, data management, archiving and presentation of archaeology content, innovative topics related to the current and future implementation, use, development and exploitation of the innovative technologies, on-site and remotely sensed data collection, innovative graphics applications and techniques, libraries and archives in archaeology, diagnoses and monitoring for the preventive conservation and maintenance of archaeology, information management systems in archaeology.

S12-01 Multi-shape archaeological modeling and communication

Carlo Bianchini, Giulia Pettoello

Fragmented, faceted and often even undisclosed, an archaeological site is perhaps one of the most heterogeneous piece of Cultural Heritage. Its multiple layers can be though classified into three main categories: completely visible, partially visible and not visible. The last one represents an element of special interest being related to the reading of an observer and his/her subjective background and ability in collecting, interpreting and elaborating a variety of data and information. Anastylis operations are thus the product of this process of merging/filtering of information: data coming from fieldwork, surveys, documental sources, comparative analysis and so on. Too often though the results seem to address exclusively scholar and experts while a wider communication of new information and content is neglected or underestimated. The project we are presenting, focusing on the archaeological site of Vulci in Tuscany, has instead tried to balance the two previous aspects (scientific consistency and

communication effectiveness) exploring the potential of several outputs: video trailer, smartphone application, real-time model, 3D PDF and digital brochure. The research has taken into account both the nature of the archaeological site and the generic visitor's need designing a tailor made communication project according to a specific object, the Great Temple in the Vulci site. Intangible aspects have besides taken into great account: while in fact the communication of tangible elements is easier, intangible is instead difficult to be analyzed and transmitted. Our research has tried also to deal with these issues not only providing a virtual reconstruction of something that actually is just a memory (the Great Temple) but also of the "overall picture" of the cultural landscape the building used to be part of: a work possible only analyzing and interpreting the existing traces "in situ". The result is a flexible communication grid which is at the same time very simple and intuitive. The cultural interaction between user and archaeological heritage becomes a mutual exchange. Memory "takes" shape to return to existence again virtually.

S12-02 A methodology for the analysis of graphical representations in archaeology and some preliminary results

Ruth Varela

Nowadays, archaeology and its related disciplines face interesting challenges from the graphical point of view. The most relevant of these challenges revolves around the visual language used in graphical expression, and aims at finding the most suitable system of representation for each form of representation and for each stage of the knowledge generation process, especially in those methodologies that generate or manage a large quantity of data. The main visual communication problem stems from the incorporation of visual languages linked to other disciplines with a lesser tradition of graphical expression, such as statistics, without a proper adaptation to the visual needs of archaeology and archaeologists. This results in much of the displayed graphic information being visually encrypted and, therefore, difficult to interpret. Additional problems exist in relation to the lack of expressive autonomy of many graphical representations.

With the aim to understand and solve these problems, a method of analysis has been designed where a systematic analysis and description can be carried out of graphical variables and graphic elements intervening in the construction of archaeological graphical representations, as well as of the elements employed for their interpretative support. Regarding the graphical variables, aspects such as the type of graphical process, the structure of the composition, the narrative structure, the level of abstraction, the viewing distance, the temporal treatment or the intentionality, etc. are studied. Within the graphic elements, the graphical representations are dissected in order to reveal the typological units and graphic objects with true expressive autonomy.

This approach was employed to analyse a sample of 1,200 images from 8 benchmark publications in archaeology and related disciplines. The obtained data provides a comprehensive view on the suitability of archaeological graphical representations with regard to issues such as information acquisition rate, legibility, visual cogency, the ability to generate meaning, and the symbolic or tropological potentiality.

In the next stage of our research, systematic criteria will be set to help us select or develop graphical representation systems for quantitative methodologies in archaeology.

S12-03 Developing a workflow for analysing and annotating reconstructed models of underwater sites

Vid Petrovic

The challenges inherent in the study of remote underwater sites require the development a systematic workflow to maximize the usefulness of the data collected on-site. In this work, we

investigate techniques for allowing researchers to work virtually 'hands-on' with the data collected, interactively exploring and elaborating the complete site model within a single virtual environment. Building on a software platform (developed in-house) enabling the visualization and manipulation of massive point clouds, we develop highly interactive tools for the virtual inspection and annotation of the site model. Finds within the site can be selected and marked up directly using programmable brushes—whose specific action is scriptable at run-time—allowing both qualitative and quantitative analyses to be performed conveniently within the virtual environment. Marked-up finds within the model can be extracted as sub-models for further study, or viewed and analysed in-place within their spatial context. We evaluate the results of these experiments and discuss planned future work.

S12-04 Emerging technologies for archaeological heritage: Knowledge, digital documentation, communication

Martina Attenni, Carlo Bianchini, Alfonso Ippolito

Knowledge of archaeological artefacts at various representation scales is today required of any three-dimensional models. The significance of constructing digital models in the domain of archaeology is a well-established idea and only reinforces the theoretical bases of survey and representation, conceived as structured systems for organizing and communicating information, and as the databases for critical analysis that optimize the results obtained from the concerted work of archaeologists, architects, informatics experts, etc. Presented here is a study of the Etruscan Sanctuary of Pyrgi (Santa Severa, Rome). Most of its archaeological material derives from ancient excavations. Only a few structural remnants have survived in loco, and numerous fragments of the decorative apparatus are partly exhibited in Museo Nazionale Etrusco at the Villa Giulia (Rome) and at the Antiquarium (Santa Severa). The aim is to start a process never applied to the data on the Sanctuary. The objectives have been the following: documenting and unifying information obtained from various excavation campaigns at different times with surveying techniques that ensure an a-critical cognition of the analyzed object; present a digital reconstruction of the sacred area based on philological analysis of data; apply digital technologies for dissemination of information. The core of the work is mainly based on the definition of 3D/2D/1D models based on several surveying and representation techniques (3D laser scanning, image-based modelling, semantic structuring). Attention has been focused on scientific advantages, costs, precision level guaranteed by various techniques as well as on digital visualization as the fundamental element of communication strategy. This research illustrates a complete methodology for the virtual assembling and the communicating of dismantled archaeological elements. The study includes a wide classification of elements of tangible and intangible heritage within a digital platform used as the place of expeditious consultation of heterogeneous data taking into consideration various user typologies.

12-05 Towards a European standard for spatial data management for archaeological heritage: Experiences in France and Italy

Anne Moreau, Federico Nurra

Archaeological heritage is most of the time linked to space. That is why this communication will focus on spatial data and the way we manage them for documentation interpretation and communication, through two European case studies. The issue of homogenization and harmonization of spatial data in archaeology has become by now central to the scientific debate. The explosion of GIS, first, and Web Mapping, later, requires constant reflection on the standards to be adopted. This paper aims to make a point about the situation of two European Countries, Italy and France, which have faced the problem in a different way, in the field of preventive archaeology: the first through the testing module SITAN/MODI of

MiBACT at the Department of Architecture, Design and Urbanism of the University of Sassari (DADU); the second through the structuring of a Spatial Data Catalog at the French National Institute for Preventive Archaeology (INRAP). INRAP has strengthened in recent years the use of GIS in archaeological practice; it has invested heavily in the training of archaeologists and has produced a considerable amount of data. The DADU has focused on the theoretical aspects functional to the construction of a metasystem able to dialogue with the several ongoing trials in Italy. The common attempt was to arrive at a minimal form of implementation, storage and representation of spatial and topographic data without losing the important informative supply related to the attributes. The informational architecture of the system will therefore be explained in the paper. Despite the obvious differences between the two contexts, the paper will seek the common meeting points that enable to launch a proposal for homogenization and standardization of production of spatial data in archaeology. The proposed challenge is in fact to overcome national boundaries, make borders permeable and work towards a common platform, open and shared, for the interchange of spatial data in archaeology. An important step towards a shared knowledge and an active protection of the European cultural heritage.

S12-06 Comprehensive field survey: Multidisciplinary approach for a field prospection

Julia Maria Chyla, Marzena Ozarek-Szilke, Wojciech Ejsmond

Since 2013 the goals of the Gebelein Archaeological Project are to recognize the potential of the site complex, to show the most threatened areas, to document the visible archaeological features and to summarize its more than 100 years old research history. Our aims lead us to the simultaneous management of different kinds of data, which were not only collected and post-processed but interpreted as well. The amount of information collected from different sources, resulted in the development of a new method for gathering information from the field, open source databases and archives. We would like to present the results of the past two years of testing this new approach on the examples of northern cemeteries of Gebelein. This area was chosen for several reasons. One of them is the tomb of Iti- a grave of a high official from the late 3rd millennium BC. Iti's tomb was excavated by the Italian mission at the beginning of the 20th century and its area was researched later on in 1990s. During our research we discovered numerous archaeological features unmentioned in earlier publications. This situation provided us with a suitable area for testing the new method comprising of: the gathering of archival data about the excavations previously conducted in this area, the analysis of the necropolis' destruction through satellite photos and a field survey with the use of mobile GIS focused on anthropological data (such as sex, age, paleopathology, osteometry), ceramic (type, part, dating) and archaeological data (type of feature, is it threaten, etc.). The results gained gave us a new view on the context that the Iti tomb was localized in and on the northern necropolis.

S12-07 New actualities for Mediterranean ancient theatres: The Athena Project lesson

Carlo Bianchini, Alfonso Ippolito, Carlo Inglese

Ancient Theatres are in many ways one of the most extraordinary legacies that past civilizations have left us: from a cultural standpoint, because of the importance that these monuments had in the social life of each community; from the environmental standpoint, because of the enormous skill that went into controlling the structures' territorial and urban impact; and finally, from a 'technological' and functional standpoint, because of the excellence of their distribution patterns and acoustics, hard to equal even today.

No less extraordinary is how well this architectural type is distributed around the entire Mediterranean basin, or the number of theatres that regularly host performances and shows. Prospectively, though, the survival of Ancient Theatres oscillates between a contemporary

reuse that keeps their functions alive along with their overall relevance (but in the long run will lead to decay) and an uncompromising conservation that by eliminating all manmade pressures would indeed be effective in preserving the structure but would nevertheless condemn it to an inexorable death, culturally, socially and economically.

A third factor, the widespread lack of awareness among the communities (local, but not only), has increasingly demonstrated its relevance in the process, pushing a number of activities to address not only the “knowledge” phase but also the issues related with communication and dissemination of content and information beyond the traditional cluster of experts.

In this framework we shall present the activities developed by the Ancient Theatres Enhancement for New Actualities (Athena) Project funded by the EU within the Euromed Heritage IV Program. A project addressing six famous sites on both shores of the Mediterranean (Mérida, Petra, Jerash, Carthage, Chérchell and Siracusa) providing a special focus both on the documentation, the reading and finally some innovative ways to involve also the general public through user-friendly instruments and outputs.

Cancelled S12-08 Handle digital data to turn them into immersive experience using the augmented reality

Donato Maniello, Valeria Amoretti

Thanks to the ease of use and dissemination of 3d scanning, are becoming increasingly popular cultural artifacts that appear on web platforms for free download. This allows to easily share online 3d models and create virtual galleries. Museums that are thinking of future, have departments dedicated of digital cataloging of their tridimensional collections. It often happens that the experience remains only virtual and you have a large amount of data, which are not used for anything real. It's possible to use this large amount of data in order to achieve a thematic collection, printing in 3d the collections when you do not have the archaeological pieces. The next step is the communication of the subject reconstructed through the use of augmented reality, understood as video mapping. A process entirely open source that can provide new avenues of study, preservation and use that see in this type of temporary collections a way not to replace the asset itself, but to strengthen it in its communicative aspect. This thing allows the visitor to be able to see live archaeological normally not visible because situated in other collections or museums. The use of a video mapping documentary on a perfect 3d printed copy underlines the great perspectives in museum communication and didactic. The aims of this article is to demonstrate the potential of this type of musealization through case studies carried out by the authors of this article.

Cancelled S12-09 Interpretative 3D mapping of large urban archaeological landscapes: The use of ESRI CityEngine for the interpretation of Ground Penetrating Radar data

Valeria Poscetti, Juan Torrejón Valdelomar, Alois Hinterleitner, Wolfgang Neubauer

Large scale archaeological prospection (i.e > 1 km²) using high resolution Ground Penetrating Radar (GPR) systems start to become a standard method for the investigation of archaeological sites and landscapes. By using motorized multi-channel GPR systems, several hectares per day can be prospected with a spatial resolution of few centimeters (e.g. 0.08 x 0.08 x 0.04 m) resulting in stacks of high definition images, which permit the detailed 3D interpretation of the buried remains. By interpreting the GPR data in a GIS environment, typically in ESRI ArcGIS, the creation of detailed 3D interpretation models, especially for large urban areas, is a time-consuming process. The ESRI CityEngine software based on procedural modeling is designed for the efficient 3D modeling of urban areas. In the presented work, we tested CityEngine for the interpretative mapping of a part of the Roman town Carnuntum (Austria), recently investigated with multichannel GPR systems by the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology. Compared to

methods we applied earlier, like the 3D editing in ArcScene involving the use of extruded polygons and multipatch features, the study applying CityEngine shows a great potential for respective applications. The possibility to extrude polygons interactively results for example in a more intuitive mapping process. The variability of file formats that can be imported, including the largely used OBJ file format, allows for a efficient combination of the 3D interpretation model derived from the GPR data with virtual reconstructions produced e.g. within 3D Studio Max in the GIS environment. Concerning the 3D virtual reconstruction within CityEngine, basic CGA rules were efficiently applied to generate reconstructed buildings from the buried Roman town. The present work has preliminary character and should be improved in the future, by focusing on the creation of custom rules for a more efficient 3D mapping and virtual reconstruction.

S12-10 Multimodal data fusion for the non-destructive assessment of the Baptistery di San Giovanni in Florence, Italy

Michael Hess

Three-dimensional data capture has long enabled visually compelling renderings of target environments, but in most cases the generated data are not utilized to their fullest potential for scientific analysis and interpretation. In addition to realistic rendering, 3D data streams from techniques like laser scanning and photogrammetry can be used for analysis of raw 3D point data and they can also serve as a digital scaffold which can be used to spatially anchor other data streams into one holistic model that serves as the digital surrogate. A case study at the Baptistery di San Giovanni in Florence, Italy is discussed here, wherein multiple 2D and 3D non-destructive techniques were used to digitally document the monument in order to study its construction. Terrestrial laser scanning (TLS) was used to measure accurate, high-resolution geometry throughout the structure. Portions of the raw data were analyzed in order to quantify and visualize the effects of centuries of structural changes and aging. The dense set of 3D coordinates also serves as the geometric scaffold used to anchor thermal imaging, ground penetrating radar and photogrammetry data. The analyzed point data as well as the data from the other imaging modalities can now be visualized together within the entire laser scanning model of the Baptistery. The utilized visualization environment allows for interactive exploration and manipulation of the holistic digital surrogate. Interactive visualization of the data enables more effective communication of the imaging results to stakeholders and facilitates collaboration with different domain experts for further analysis and interpretation of the multimodal data. The presented methodology for multimodal data fusion can be repeated to incorporate other data types and the flexible visualization environment supports the evolution and growth of input data.

S12-11 The Exedra of Goreme OAM: An ocean of points to be explored

Marco Carpiceci, Carlo Inglese, Fabio Colonnese

From 2013 the research unit of Rome has been developing the architectural survey of the Open Air Museum of Goreme in Cappadocia. After examining individual rock-cut complexes, this unit is currently focusing on the spatial and functional relationships of homogeneous structures. This paper deals with a specific area located in the southern part of the Museum: it is a semicircular rock cliff that separates the inhabited area from the plateau. This sort of natural exedra is characterized by the presence of several artificial cavities, including churches, refectories and service areas which by virtue of their typological variety, constitute autonomous groups and form a sort of urban settlement. The churches are the settlements' key elements around which communities built their meeting and shelter facilities. In many cases the identification of the functions and connections along the paths allows to mark sharp separations between the groups. This is the case of Cariali Kilise, the Karanlik Kilise and S.

Onofrio; in other cases, such as the Pantocrator Kilise and Malta Hacli Kilise, their widespread distribution tempers this separation. The tufa surface of the exedra has been surveyed through laser scans assembled into a single point cloud. The texture of the painted surfaces has been further surveyed by recording the reflectance value during the night time in order to prevent the chiaroscuro data distortion caused by sunlight variations. Downstream of the surveying activities, the group is working on specific representations, such as plans for contour lines and sections for equidistant plane curves. This kind of representations is particularly effective for the rock-cut habitat, because it allows an objective reading and clearly shows the constructive and distribution relations among the rooms separated by meters of rock.

S12-12 Enhancing archaeological interpretation with volume calculations. An integrated method of 3D recording and modeling

Giulio Poggi, Mirko Buono

Digital surveying technologies have nowadays found extensive application in Archaeology, enhancing the quantity and quality of data collected in the documentation of the archaeological assets. Besides the great communicative qualities, 3D data stores precisely the geometric information of a scene, enabling area and volume calculations.

In this paper we present two case studies in which area and volume calculations (on data from 3D survey and on 3D data processed and modeled through the tools and the principles of Virtual Archaeology) have achieved consistent results for the research and the archaeological interpretation. Moreover, the 3D modeling process creates virtual reconstructions that are essential to verify the likelihood of some hypotheses and represents a powerful means of communication for disclosure.

In the first case we studied a rocky outcrop by the medieval archaeological site of Canonica di San Niccoló (Montieri, Italy) where the particular shape of the context was, at first, interpreted as a mine entrance. The integration between different data coming from the 3D documentation of the outcrop, the excavation and the geological analysis has allowed the 3D reconstruction of the original shape of the outcrop, which must have looked like a wide rock shelter, today collapsed. This new interpretation was enhanced and confirmed by area and volume calculations, which have enabled the accurate quantification of the amount of space available for a living floor in the rock shelter.

In the second case the method was applied in order to study the relations between the collapsed parts of a productive building and the destruction layers in the deposit of an archaeological excavation. Without any archaeological comparison for this type of building, the volume of the layers was used to estimate the volume of the collapsed parts and to reconstruct in 3D the original height of the walls and their complete shape.

S12-13 A new approach for the study and presentation of an archaeological context not traditionally exploitable. Applying a fast but extensive 3D survey to the Bisarcio case study, a Medieval and Post-Medieval cemetery (Sardinia)

Paola Derudas, Maria Carla Sgarella

For some time, photogrammetry and 3D modelling have imposed themselves as prominent among the modern technologies applied to archaeology. Nevertheless, three-dimensional survey of the archaeological heritage hasn't reached, yet, its informative potential in the study phase, due to the fact that its use has been generally restricted to those cases characterized by their exceptionality and monumentality. Digging the Bisarcio (Sardinia) late- and post-medieval cemetery was an important opportunity to 3D survey experimentation as a daily instrument for documenting the stratigraphic sequence. Differently from what happens in the most common practical cases (where it is focused on specific findings or areas, or to a specific

time frame of the excavation), the 3D survey has been carried out extensively with respect to both space (covering the entire excavation area) and time (daily, throughout the excavation), with the main aim to totally substitute the two-dimensional survey.

3D modeling, which allows a very accurate and complete recording of the archaeological context, has been useful both in the documentation and analysis stage, and also in the interpretation stage. It has been complemented by the use of the 3DHOP presenter, a helpful tool for the visualization and web publishing of high resolution 3D models, connecting them to the large amount of data collected and interpreted during and after the excavation process. This tool gets an added value for the case study here presented: a cemetery context, for which it's not possible to imagine and define a "classic" musealization. Thanks to the presence of the 3D models, and the use of 3DHOP, it was possible to "re-use" the survey data to create an interactive web-based presentation aimed, this time, to the public, to provide a viable way to present and disseminate the results of the excavation to non-experts.

S12-14 Digital Archaeological Dissemination: Eleniana Domus in Rome

Tommaso Empler

The research project has the aim of a virtual reconstruction and dissemination of Eleniana Domus in Rome through the use of Digital Technologies. The historical site, associated to the excellent state of preservation and the musealization process, makes the Eleniana Domus a great subject for developing innovative research and applications of virtual reconstruction and interactive dissemination directly on the site. 3D modeling is done with Blender, an Open Source 3D modeling software, which has in its structure of programming a "game engine", that can simultaneously handle multiple events, which allow a display/navigation in "real time" of the Domus. Interaction enables new ways to visit and learn, through the use of instruments that can detect the actions and movements of the visitor/scholar himself, turning them into human/machine instructions. The procedure, developed in a digital way, allows multiple exploratory permutations/variations of informations on a single object, for a better understanding of the phenomena and/or nature of the object itself. The procedure at the base of this pipeline includes a series of transactions that are connected one to the other: 1) detection of the object or area of interest using a 3D laser scanning survey. 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, allow the use of Cartesian coordinates (x, y, z), of each point of the model, to plan the mode of interaction of the scholar on the site; 2) development of an interactive design application and set up an effective interface of interaction man/machine; 3) creation of human/machine interaction by the use of tools created for video game, as a Kinect or a leap motion; 4) preparation of a stage where occurs the release of the interactive information, defining the interactive area (box, corner, wall) and placing in tools of input/output (projector, kinect, Leap 3D motion).

S12-15 Integrated methodologies for knowledge and valorisation of the Roman Casinum city

Michela Cigola, Arturo Gallozzi, Leonardo Paris, Emanuela Chiavoni

Focus of this article is the documentation, interpretation, valorisation and communication of Archaeological Heritage of roman Casinum city site. Nowadays this important archaeological area is little known and appreciated. The city of Casinum is particularly flourishing in Republican and Imperial Roman period. From this period are the remains of the Roman via Appia, the Theatre (27 BC.—14 AC), the amphitheater (I century AC), the nymphaeum (I century BC-I century AC.) and the tomb of Ummidia Quadratilla (I century BC-I century AC) Casinum Archaeological Heritage includes tangible and intangible goods. Keeping this site from the present for the future is connected with actions such as Identification, Analysis,

Preservation, and Restoration, with specific technical meaning. Each of this area of intervention includes not only technical actions and expertise but require also of more cultural evaluations as in respect of the concept of Archeological heritage. Summarizing in short, Casinum Archaeological Area can be also understood as a complexity of activities in a very wide range of disciplines whose aim is to identify, evaluate, and preserve past achievements for the benefit of next generation in having memory of the past and inspiration from it for future enhancements and appreciation of current results. Our research includes several integrated methodologies. The main part involves a laser scanner survey of the whole area. There are many others steps that include digital processing about documentation, interpretation and communication of Casinum Archaeological Area. The research group is formed by DART: Laboratory of Documentation, Analysis, Survey of Architecture and Territory of University of Cassino and by LRA Laboratory of Architectural Survey, CRITEVAT Center in Riety, Sapienza University of Rome. The Cassino National Archaeological Museum "G. Carettoni" and the "Archaeological Park of Casinum" are involved and collaborate in the research.

S12-16 An exploratory use of 3D for investigating a prehistoric stratigraphic sequence

Giacomo Landeschi, Jan Apel, Stefan Lindgren, Nicolò Dell'Unto

Re-interpreting documentation that has been produced in the course of an archaeological excavation is always a challenging and tricky task. Several problems occur when archaeologists are dealing with datasets created by different authors at a different time in the past. As Shanks and Tilley recall (1992) the fullest understanding of an archaeological dataset is totally related to the context being investigated.

The purpose of a research recently started at Lund University was to test the use of 3D technology as an exploratory tool for data analysis. The combination of advanced 3D acquiring techniques and the setup of GIS systems capable to deal with geometrically-complex 3D information has been tested to investigate one of the most outstanding archaeological sites in Scandinavia, the cave of Stora Förvar in Stora Karlsö, Gotland (Sweden). The main part of the cave sequence was excavated between 1888 and 1894 but in the summer of 2013 the project conducted a small excavation of the cave floor and undisturbed cultural layers with flint tools, fish and marine mammal bones were recovered. We also recovered human remains in the form of a tooth, skull fragments and a foot bone. Unfortunately the original field report of the 19th-century excavation was written 50 years after the excavation by archaeologists not involved in the field work. However, unpublished photos and field documentation material is available at Antikvarisk Topografiska Arkivet in Stockholm. During the excavation in 2013 we collaborated with the Lund University Humanities Laboratory and 3D-scanned the complete cave with a high resolution scanner. The idea that has been developed was to integrate the 3D models of the cave in the GIS platform and to combine it with hand-made drawings made by archaeologists in the early 20th century. As a result, digital layers (that were excavated with the arbitrary layer method) were reconstructed in the form of three-dimensional vector features and the original stratigraphic sequence integrated in GIS based on the geometrical reference provided by the cave 3D model. As a future development, part of the artefacts documented during the early 20th Century excavation will be connected to their original stratigraphy. Hopefully, it will be possible to recreate a three-dimensional archaeological sequence in which the original spatial relations among the artifacts will be highlighted and possible patterns related to the Mesolithic occupation of the site put in light through the use of advanced analytic tools available in GIS environment.

S12-17 The building survey of Kaasan Church

James Miles, Hembo Pagi, Andres Uueni, Jüri Pärtna

Kaasan Church, in Tallinn, Estonia was built during the time of Peter the Great (1721) and is the oldest wooden sacral building in Tallinn. A building survey was conducted in January 2015 where a laser scan and photogrammetric survey was completed. One of the aims of the recording was to document the current situation of the building including the structure's interiors and exterior. The end product being a spatially georeferenced point cloud which was used for plans and drawings, as well as 3D modelling and other interactive outputs. The paper will discuss the advantages that laser scanning and photogrammetry offer when compared to traditional survey techniques. With both types of recording taking place, the combination of the data has allowed for a precise and accurate representation of the church that goes beyond any form of recording that has previously taken place. The paper will therefore discuss the digital applications that these different methods provide when combined and it will show their usefulness in recording historical structures for Building Information Model (BIM) extraction. Using digital frameworks has provided sufficient and adequate information for further reconstruction and conservation planning and has been used in addition to the previous work carried out on site, such as dendrochronological recording. As our models were combined, the results gathered were used as a basis for a BIM, CAD model, drawings, cross-sections and a video animation as well as panoramic photography to enable 360 degree views. Rather than limit ourselves to one technique, the combination of various methods has allowed all aspects of the church to be recorded and the data gathered will be used for future renovations. Each of the stages used will be discussed as will the difficulties associated with merging these data types. Particular attention will be given within the discussion of the production of the BIM model. This will develop into a further explanation of how BIM can be used within cultural heritage and it will point out the advantages that can be gained for future archaeological research. The paper will not only highlight the end results produced but it will also discuss the workflow methodology used in combining the different data types to extract the BIM.

S12-18 A virtual reconstruction of the sun temple of Niuserra: From scans to BIM

Angela Bosco, Andrea D'Andrea, Massimiliano Nuzzolo, Rosanna Pirelli, Patrizia Zanfagna

In 2010 an Italian team started new investigations in the Sun Temple of Niuserra at Abu Ghurab, south of Cairo, Egypt. The archaeological survey of the site was planned in order to re-examine the temple more than one hundred years on from the discovery by German archaeologist L. Borchardt in 1898. The investigation is mainly aimed at a general re-evaluation of the archaeological data still available on the site in order to establish a new plan of the temple by means of laser scanner and photogrammetry. The sun temple of Niuserra, sixth ruler of the fifth dynasty (about 2400 BC), covers an area of about 8800 sq m. More than 130 scans of the temple have been acquired so far. Some parts of the area have also been rendered by un-calibrate photogrammetry. At the beginning of the project a Zoller and Froilich Imager 5003 was used, while in 2014 the scans were acquired by Faro Focus 3D X130. In the last campaign also an image-based technique was tested. All data have been aligned and merged. The model has been referenced, firstly according to a local grid and then geo-referenced. In order to check the hypothesis made by Borchardt, the digital replica of the still visible rests of the monument have been processed by BIM (Build Information Modelling), an approach currently underdeveloped in archaeology. Thanks to this new methodology, it is possible to produce categories of environmental and technological objects and sub-systems, which represent the 3D semantic of the acquired model. The paper deals with all the recent achievements and technological issue, especially as concerns the analysis of the orientation, sun positioning and wind. Furthermore, the paper focuses on the analysis of the bearing structure and its components.

S12-19 Virtual Cilicia Project: Digital globes for communicating digital archaeological heritage

Susanne Rutishauser, Ralph Rosenbauer, Tim Arni, Fabienne Kilchör, Alexander Sollee

Surrounded by the Taurus and Amanus mountain ranges, the fertile alluvial plain of Cilicia Pedia in modern Turkey is a true treasury of important monuments from numerous ages. Hittite and Assyrian rock reliefs serve as representations of power at this connection between Anatolia and the Levant. Since it relies on Google Earth, the Virtual Cilicia Project is able to show these monuments as well as the ruins of Bronze and Iron Age settlements like e.g. Karatepe with its world-famous carved orthostats in their natural environments.

To visualize the development of this region during different epochs and to provide a better understanding for laypersons, new approaches are necessary. Virtual globes give users the chance to interactively explore different sites and the interplay between environment and settlement patterns. Since Google Earth uses KML 2.2, an open standard XML notation, it is simple to add one's own content. In addition, KML became an increasingly common standard within geographic information systems and online tools, therefore becoming a well-documented future-proof solution. The integration of a timeline directly into Google Earth makes it a perfect instrument for the visualization of historical developments.

The Virtual Cilicia Project's goal is to document the vast diversity of Cilicia's history and to present this cultural heritage in the context of its ancient and modern landscape to the expert and the layman.

S12-20 Representing Archaeological Architecture—RAA

Carlo Inglese, Mario Dozzi, Alfonso Ippolito

Representation analysis and interpretation of elements of archaeological heritage is a painstaking activity. It also includes a wide range of interdisciplinary subjects and competences. Innovative tools which are constantly being developed make it possible for the researcher to adopt an integrative approach favorable to all the figures involved in the whole process of documentation. Close collaboration of architects and archaeologists made it possible to understand the key elements of archaeological heritage based on considerations extracted from historical analysis and to have at disposal a large quantity of information gathered by taking advantage of the potentialities of technologically advanced tools (3d laser scanner, systems of massive acquisition of photographic data, modeling systems of image based, etc). The significance of constructing digital models in the domain of archaeology is already a well-established idea and only reinforces the theoretical bases of survey and representation. Unlike archaeologists - whose research is mainly aimed at reconstructing the historical process and collocating artifacts within a precise frame of reference - architects investigate the form, reconstruct the process of designing, and study formal, proportional laws and spatial aggregations of various elements. The interrelation between the two disciplines opens up the possibility to achieve complete results as far as documentation, analysis and interpretation of the so called archaeological architecture (AA) are concerned. On one hand, archaeologist can use explorable and measurable 2D and 3D high precision models, which realistically show surface qualities; on the other hand, architects can turn to advantage archaeologists' extensive knowledge to interpret correctly data in their historical and metric framework and to verify interpretative hypotheses. The proposed paper, starting with the integrated survey of archaeological structures of high historical and artistic importance, like Colosseum, Pantheon and Arch of Janus in Rome, analyzes the possibilities offered by the survey of archaeological architecture at different scales.

S12-21 Visual stratifications: Different levels of representation in relief of archaeological heritage

Paolo Di Pietro Martinelli, Valeria Valentini

The learning and the use of new survey technologies based on massive acquisition of metrical information, leads to a simple and immediate exploration of digital 3d models, like the first output about a new representation that leaves the quality reason in favour of a quantity reason. The temptation to identify the result of massive capturing data with the object of survey, is due to an apparent completeness of information of digital 3d model, obtained through digital representation techniques by Image Based Technologies (photo-modeling) or on Engineering Reverse (laser scanner), particularly in archaeology, where there is a high material decay and frequently shapes and volumes are unrecognizable. Considering the representation in a larger interdisciplinary work aimed at producing the knowledge of the archaeological heritage, only with the presence and the personal interpretation of a trained operator, it is possible to give a critical contribution to the survey, transforming discontinues information in efficient documentation, expendable in both the operative and communicative environment. The analysis of the current representation modalities leads to a consideration about the inversion of the following processes of capturing and working data:

- Two-dimensional measurements and processing that lead to three-dimensional objects through the construction of simplified geometric models;
- Simplification of complex geometric models to get a two-dimensional canonical representations;

The intent of this work is to analyse different levels of representation often used in archaeological studies corresponding to different objectives and exigencies, considering the advantages and disadvantages of each method.

S12-22 3D model of Roman architecture in Lusitania. Archaeology and classification of architectural heritage

Antonio Pizzo, Carlo Inglese

In recent years archeology tries to incorporate in to the traditional survey methods a set of tools from other disciplines to get more precise results and execution times smaller. In this sense, the use of different methods of investigation for the knowledge of architectural artifacts, such as 3D scanning, new surveying instruments (Range-based Modeling) and digital photogrammetry (Image-based Modeling), received a remarkable impulse, often with contradictory results. In recent years we have often questioned about the relationship between quantity and quality of data acquired with different instrumental survey methods and their interaction and integration through the all-digital procedures in continuous and rapid evolution. The recurrent use of new technologies in survey operations, has increased the separation between the objective step of acquisition of data, and a second, interpretative, of restitution of data through the creation of traditional or computer model. In our proposal we present the first results of a research project developed in collaboration between Institute of Archaeology (CSIC) and the "Sapienza" University of Rome on the digitization of the built heritage of the Roman period in Lusitania. Two are the objectives of the proposed research:

1. In the first phase in which we surveyed a series of complex buildings, the provincial Roman bridges, we obtained data that, in some cases, moving procedures of 3D Scan survey in the field of pure representation to the diagnostic analysis, increasing the possibilities of archaeological interpretation.

2. This research offers the possibility of establishing, at the management level of regional heritage, a standard protocol of survey and constructive analysis of the monuments to be included directly on a GIS platform managed by the institutions responsible for the heritage protection. The dissemination of a standardized survey and the precision obtained could

facilitate a correct presentation of data on the web and, above all, a greater diffusion of the architectural heritage of Roman region.

Cancelled S12-23 Virtual Reconstruction Information Management (VRIM): Some considerations on scientific 3D models

Fabrizio Ivan Apollonio, Elisabetta Caterina Giovannini

The large use of 3D models in Virtual Reconstructions of Archaeological Heritage artifacts is nowadays a common tool to communicate Archaeology. 3D models became a new tool to think, interpret and visualize knowledge. Academics and Scholars largely discuss about the need of new standards and scientific methodologies able to systematize the 3D Virtual Reconstruction process and its transparency. Even if some guidelines as the "London Charter for the Computer-based Visualization of Cultural Heritage" (2006) and "The Seville Charter: International Charter for Virtual Archaeology" (revised version, 2012) are available, the debate is still ongoing and shows the necessity to pass from the singular case study vision to a general one.

The problem of interpretation that characterizes reconstructions where multidisciplinary approaches are required, is crucial for the re-use of informations by users that own a different background and for next generations. The methodology proposed, "Virtual Reconstruction Information Management" (VRIM), has the intent to systematize some general processes related to 3D VR models construction data informations and their management. The Research Methodology is divided in five fundamentals phases:

- Collection
- Acquisition
- Analysis
- Interpretation
- Representation

For each phase, a set of procedures is proposed, following that approaches and concepts widely accepted and used by scholars in recent years of scientific debate: metadata, paradata, controlled vocabularies and notations, ontologies and a visualization tool to depict uncertainty. The 3D VR model structure follows the VRIM schema organization that clarifies the relationship between research sources (collection), implicit knowledge (acquisition and analysis), explicit reasoning (interpretation), and 3D visualization-based outcomes (representation).

The paper presents the use of VRIM on a case study: Porta Aurea in Ravenna. The Roman Gate, built in 43 A.D. with the behest of roman Emperor Tiberius Claudius, is a no longer extant monument that has always aroused the interest of many scholars and archaeologists. The existence of a large and not heterogeneous documentation available allows the possibility to investigate the theme of subjective processes and their management trying to close the gap between original data and associated interpretations.

S12-24 After the paper: Potential and problems in the documentation and communication of archaeology in the Information Age

Luca J. Senatore

The paper used as the traditional medium for the representation and communication of archaeology, today can potentially be replaced with digital media, offering the user a number of alternatives to the understanding of the objects of study.

The contribution focuses on this sensitive theme, through some examples of archaeological survey, highlighting the potential but also the limitations of this new approach to knowledge. Through a series of examples and related workflows, it will be analyzed the expressive possibilities offered by the digital medium and, a methodological approach in order to make

the processing represented digitally, scientifically valid and that can be immediately used by the researcher.

Due to the increasingly common use of image-based acquisition techniques and the implementation of real-based models used for a deep knowledge of the artifacts, the contribution it will analyze the new relationship of digital interface with the data. The interactive nature of the digital models highlighting a new approach to data acquisition and construction of models which requires the inclusion of the technical parameters, necessary for the correct reading of the models made for this purpose.

In particular the definition of the geometrical and perceptive limit of the model (the scale of the digital model) and some characteristics associated with the construction of the model become, in this new scenario, key elements necessary for the correct reading of the data, that can provide the researcher a coherent model of the reality.

POSTER

S12-P1 How to classification?—A trial examining the effectiveness of an elliptic Fourier descriptor for Japanese archaeological studies

Akihiro Kaneda

The purpose of this study is to examine the effectiveness of an elliptic Fourier descriptor (EFD) for archaeological studies. Typological study is essential to the classification of artifacts in archaeology. It is based on observed similarities in shape, color, etc. However, many Japanese archaeologists make use of a sensory classification system. This often creates confusion with archaeological classifications by other researchers, as the descriptions are often based on subjective observations. Thus, we must develop a method of reproducible classification for use with artifacts. Today, elliptic Fourier descriptors (EFD) are used as an effective method of classification in several fields, such as biology and medical science. This method can evaluate the shape of an artifact and is able to reconstruct the artifact's shape by the inverse Fourier transform. For this study, we examined Sue ware, a kind of Japanese stoneware. A common artifact from the eighth to the eleventh century, it can often be found at archaeological sites in the Japanese Archipelago. This type of ware was fired in a kiln with a large, long chamber. Many archaeologists, including the author, think Sue ware was made by specialized potters. Therefore, an examination of this type of artifact can reveal not only indicator dating, but also the spread of the potter groups and techniques in this era. Among Sue ware, the long-necked jar exhibits different characteristic styles depending on production area. It is therefore suitable for classification and examination to show the utility of EFD. This study demonstrates that EFD classification of jars shows a difference in shape by production area, and the technique can reconstruct modes of technological dissemination of Sue ware.

S12-P2 Urbanism in the Cilician Plain from Chalcolithic to Byzantine Period

Susanne Rutishauser

The fertile alluvial plain of the Cilicia Pedias is surrounded by the Taurus and Amanus mountain ranges in the West, North and East and the Mediterranean Sea in the South. Since the Neolithic period the Cilician Plain was an important connection between Anatolia and the Levant. This paper examines the settlement history with a focus on urbanism of the Cilician Plain based on survey and excavation data, written sources and remote sensing data. Thus, a database was built with up to 1000 sites from Neolithic to the Byzantine period. This dataset is combined in GIS with an analysis of remote sensing data such as Corona and TanDEM-X to reconstruct also the natural environment of the Cilician plain.

S13 Computational approaches to ancient urbanism: Documentation, analysis and interpretation

Johanna Stoeger, Eleftheria Paliou, Undine Lieberwirth

This session seeks to stimulate the discussion between different analytical approaches to the 'Ancient City', ranging from macro-scale analysis (including the exterior peripheral environment) to the micro-scale analysis of individual houses and interior spaces.

Since the 1990s archaeologists have been employing computer-based quantitative analysis tools to reconstruct not only cultural landscapes and rural settlements, but also urban built environments. These analysis tools and software solutions have been improved over the last decades, allowing us to advance our knowledge of the 'Ancient City' beyond descriptive digital models and constraining conceptional boundaries.

The aim of this session is to push the boundaries of current applications to open up new ways of studying and understanding Ancient Cities, and to work towards a shared set of analysis techniques and interpretative frameworks that can be applied to most past built environments across most time- scales.

We would like to invite contributions that discuss innovative aspects of computer applications to the research of past urban developments, which may include, among others, computer simulations of urban development in the past, 3D reconstructions of urban environments, large-scale analyses of urban social / cultural phenomena, innovative Building information Modeling applications (BIM), 3D/4D, and GIS. We particularly welcome papers that explore the interpretive potential of new computational approaches to ancient urbanism and encourage debate on the theoretical and methodological issues that come along with the application of digital technologies for the understanding of ancient cities.

S13-01 Digital archaeology and the science of cities: Some observations on the application of spatial interaction models to the study of Minoan urbanism

Eleftheria Paliou

A grand disciplinary challenge for Digital Archaeology is to increase its impact in society by partaking in a cross-disciplinary dialogue on contemporary issues, and in this way to contribute to advances both in archaeology and in other scientific disciplines. In recent years there is a steady increase in the number of published archaeological works that draw upon developments in contemporary urban geography, and in particular computational and mathematical modelling, to study a variety of past human and urban phenomena, such as settlement evolution, population movement and growth, the transmission of cultural traits, trade, economy and socio-political organisation. Such approaches are often the result of cross-disciplinary collaboration between archaeologists, physicists and urban geographers and have been encouraged by a growing realization that archaeology could constructively contribute to advances in a Science of Cities (Batty 2013), offering an abundance of material evidence against which contemporary scientific theories, concepts and methods can be evaluated and tested across time and space. Some of the methodologies that fall under the umbrella of this urban science, namely Space Syntax methods, have already met many applications in archaeology, while others, for example urban scaling, are only just emerging in archaeological studies. This paper will discuss briefly the reciprocal relationship between Digital Archaeology and the Science of Cities before focusing on a particular type of modelling that has attracted much attention in archaeological investigations in the last five years: simulations of spatial interaction that draw from "entropy maximising" approaches. By presenting applications of these models to the study of Minoan urbanism it will discuss the benefits and problems linked to their use in archaeology at various spatial scales.

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S13-02 A tale of two city blocks from Ostia, the port-town of Imperial Rome

Hanna Stöger

Neighbourhoods and the social use of urban space are areas of growing interest that concern both contemporary city planners and archaeologists. Based on a detailed examination of the archaeological remains of two distinct city blocks (IV ii and iv) from Ostia (Imperial Rome's principal port city), the proposed paper explores the spatial properties of these urban quarters and seeks to identify spaces which potentially fostered social cohesion and community building. By combining archaeological and syntactical methods of spatial analysis (space syntax), novel insights have been generated regarding the physical environment in which Roman city dwellers lived their daily lives. The shared courtyards and passage spaces of Block IV ii suggest a continuity of community focus over a period of almost four hundred years. In contrast, Block IV iv appears to lack shared spaces and revealed a spatial organisation of self-contained buildings focused on individual access to public space. Block IV ii is characterised by internal courtyards suggestive of collective use within its own perimeter; Block IV iv looks outward toward external community building with activities centred on the street confining the block. The space syntax tools allow us to reconstruct the generative processes active in neighbourhood development. The combined archaeological and syntactical analyses reveal insights into the flexibility of ancient Roman urban structures and offer several suggestive glimpses into the urban community that sustained these blocks and the wider city in the long-term.

S13-03 Kerkenes Dag: Materializing an Imaginary City

Scott Branting, Tuna Kalayci

Kerkenes is a massive pre-Hellenistic city in Anatolia. It covers 2.5 square kilometers and surrounded by a strong defensive wall, running for seven kilometers. The city was burnt down, sometime during the mid-first millennium BCE and no other extensive occupation disturbed archaeological remains, providing unique preservation conditions. Modern explorations in this Ancient City started in 1993, employing a wide range of innovative geospatial technologies. High resolution photographs from hot air balloons and tethered blimps, satellite imagery analysis, DGPS survey and especially geophysical prospection at the site already revealed numerous domestic structures, compounds, empty-spaces, courtyards, road systems and others; opening a new research frontier in the study of ancient studies. This study aims to highlight the importance of acquiring close-to-complete spatial datasets using multi-sensor technologies. To accomplish this, we suggest an extremely detailed city plan, draped over a very high resolution Digital Elevation Model, opening up possibilities for detailed 3D reconstructions of the built environment and testing of various archaeological hypotheses in the making of the city. Second, we reveal a pedestrian Transportation Geographical Information System (GIS-T) approach to model movement at this Iron Age city. The model incorporates models of human locomotion with a theoretical framework based on time-space continuum principles. Results from these models highlight movement densities, city neighborhoods; but also reveal variations in the agency of movement.

S13-04 From data visualization to hypothesis generation: An integrated approach for the study of past cityscapes

Chiara Piccoli

When it comes to the macro-scale analysis of past cityscapes, traditional 2D mapping presents limitations in grasping the complex relationship between landscape, built environment and find assemblages. A methodology that includes data recording, visualization and analysis in a 3D environment is better suited to pursue the study and interpretation of ancient cities from a holistic perspective. This paper discusses the methodology that we have applied to deal with

the survey data of the Graeco-Roman town of Koroneia, Greece. The adopted multidisciplinary approach is based on the creation of a 3D GIS that allows an intuitive data interpretation and an interactive formulation of reconstruction hypotheses on the town layout. Koroneia is used as a show case for the range of analyses and interpretations that are enabled in a 3D environment and that can be applied to similar datasets. The core of the methodology relates to the development of a library of procedural rules (i.e. customizable scripts) that are compiled using the software Esri CityEngine. The rules written for this project enable us 1) to make previously hidden patterns in the dataset more easily visible; 2) to automatically calculate the total built-up area and floor area of housing blocks, thus allowing the estimation of population size based on explicit assumptions; 3) to perform visibility analysis in the 3D GIS environment, in order to formulate hypotheses on the visual relationships between buildings, and on the planning choices made to negotiate between the hilly terrain morphology and the city layout. Finally, this paper discusses the development of a Unity3D based walk-through, which complements the quantitative visibility analysis performed in ArcGIS with an experiential navigation offering a pedestrian perspective into the virtual environment.

S13-05 On the attack of Constantinople! The Crusaders and the maritime walls of the Golden Horn: A matter of visibility?

Jacopo Turchetto, Giuseppe Salemi

In this paper three-dimensional visibility analysis, linking 3D modelling and GIS functionalities, is applied to a specific aspect of the urban topography of Constantinople in the 12th/13th centuries: The mitaton of the Saracens. The presence of this trading station, especially intended for Muslim merchants, is also suggested by the Byzantine historian Niketas Choniates, who describes its destruction during the Fourth Crusade in 1203. His reference has stimulated historical, philological and, more recently, topographical considerations, all this allowing to hypothesise, for this commercial building of which still no archaeological remains have been discovered, a possible localisation in the immediate vicinity of the port area of the Golden Horn, inside the belt of the maritime walls. It is necessary to bear in mind, anyway, that the Crusaders were on the opposite shore of the Golden Horn (in the area of Pera) and that, before setting forth on their ships directly towards the mitaton, they would have had to visualise and identify their final target. So, was the mitaton 'visible' from the northern shore of the Golden Horn? Was it not 'hidden' by the maritime walls of Constantinople? This paper will try and deal with these questions, following a computational approach, whose results will also be tested against those obtained so far on the basis of a more 'traditional' topographical research. In particular, the use of the 'third dimension' will contribute to add new value to this topic, being crucial for the determination of the 'visual perception' of the Crusaders within the context of the Golden Horn. All this will shed new light on the urban topography of that sector of Constantinople, on the role of the mitaton within that area of the Byzantine capital and on the reasons which subtended its construction on that very spot.

S13-06 Computational approaches for studying cultural coexistence in Peru's urban landscape: Contributions and questions

Kayeleigh Sharp

New work on the north coast of Peru has produced a complex picture of ancient lifeways that challenges the wide-held conceptions of cultural coexistence in the region. Major decorated, funerary monuments and large-scale urban centers of a group known as the Mochica have received a lion's share of attention for over a century. As a result of this highly skewed sampling, very little is known about daily life and internal organization and dynamics at

smaller cities or non-monumental administrative centers. Recent research at the Songoy-Cojal site complex, a mid-sized center in the Zaña Valley, has taken major strides to overcome this lacuna. By applying a combination of image-based 3D modeling and spatial analysis techniques, this work has begun to transform the way quotidian relationships between the Gallinazo and Mochica civilizations are perceived and analyzed. In this micro-scale analysis of interior spaces, 3D models were used to create detailed maps and carry out in-depth architectural analysis, while high-powered spatial statistical analysis including geographically weighted regression, and multi-distance spatial cluster analysis was conducted to model spatial relationships, determine whether statistically significant clustering or dispersion of features and their attributes was observed over the site, and to explore spatial relationships between different types of activity areas. Combined, these techniques were useful for elucidating various aspects of Gallinazo and Mochica social differentiation and technological diversity that were nearly impossible to detect using non-computational strategies. Most importantly, it has been possible to challenge decades-old research that has served to inappropriately dichotomize the relationship (e.g., superordinate versus subordinate) between these groups, moving well beyond the use of computational tools for descriptive model building. While exploring the analytical potential that combined photogrammetric and spatial statistical approaches hold for the future of archaeological investigation, this work contributes significantly to our understanding of small-scale urbanism on Peru's north coast.

S13-07 On roof construction and wall strength: Non-Linear Structural Integrity Analysis of the Early Bronze Age Helike Corridor House

Mariza Christina Kormann, Stella Katsarou, Dora Katsonopoulou, Gary Lock

We have demonstrated [1] through Structural Integrity Analysis that the Adobe brick Early Helladic (EH II-III) Helike Corridor House design was sound and it was able to support a second floor. This paper furthers the research focusing on roof loads by performing non-linear and sensitivity analyses addressing two research questions: 1) Was the roof of a light tiled construction or was it heavy as described in [2] about four times heavier than a tiled roof; and 2) What would the behaviour of the structure be when subjected to adverse wet weather under light and heavy roof loads. Previous research has shown that Adobe bricks can absorb large quantities of water from 2 to 10kg/m² [3, 4]. Furthermore, if it absorbs 4kg/m² the overall strength of the wall is reduced by 50% [3]. Using mechanical properties of dry and wet Adobe bricks, we have performed non-linear analysis using ANSYS aimed at determining whether or not the structure would collapse under four conditions: LIGHT-DRY (light roof, dry Adobe), LIGHT-WET, HEAVY-DRY and HEAVY-WET. The results show that under a light roof the structure would stand. However, a heavy roof similar to early Minoan structures [2] would lead to total collapse of the house as the Yield Stress on the wall structure is greater than the maximum allowed for wet and for dry Adobe. This points to sophisticated construction techniques with tiled rooves and the possible use of stabilising materials such as lime, ash or organic to protect the tiles [5]. The theory that Helike builders were aware of such techniques could only be supported by planned forthcoming detailed soil analysis to identify possible stabilisers and this would raise further questions on wider interactions such as trade. This research offers new understandings of roof techniques and weight limitations for Adobe building Corridor Houses in a period where only scant evidence is available.

[References]

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S13-08 3D GIS in archaeology—A microscale analysis

Undine Lieberwirth, Axel Gering

3D models are nowadays fashionable and always an eye catcher on conferences. However, what data really hide is depending on the system and digital environment of the model.

Primarily, a 3D GIS environment offers the same possibilities as a 2D GIS extended in the third dimension.

The presentation gives an insight into these possibilities by using a prototype of a 3D GIS excavation model with data taken during an excavation at the Roman Forum of Ostia Antica in 2011. It introduces the processing pipeline from recording archaeological data in a CAD environment, using a laser scanner and the structure-from-motion method until the final 3D GIS model. The latter contains all acquired quantified data including geophysical and pedological data. Furthermore, lab analysis values stored in an external PostgreSQL-database are included. Hence, the final model contains not only acquired data but also analysis values that are stored and analysed as attributes. These data enrich the model and improve the opportunities for post-excavation spatial analysis as in 2D GIS.

The 3D GIS model tries to reconstruct stratigraphical features in a quantitative way for further 3D analysis. 3D rasters (volume pixel) are used to describe continuous values inside a volume, 2.5D rasters are used for continuous surfaces and 3D vectors represent features with clear boundaries.

The presentation shows a solution of a digital infrastructure for archaeological needs by using a 3D GIS environment to model and analyse archaeological structures. The model focuses on archaeological trench analysis on micro-scale. Further developments might consider the incorporation of more structures and their comparison.

The aim of this approach is not only to combine all digital 3D data of an archaeological excavation but also to gain new results from the 3D perspective. For this objective, the free and open source software GRASS GIS was used for calculations, the only OS GIS software which can create voxel. The OS software ParaView, a scientific 3D GUI with various analysis functionalities, serves as a 3D viewer.

An archaeological excavation is by its nature three-dimensional. Therefore, we think the application might be useful for a greater community not only to store and organise excavation data and their attributes but also to gain new insight into the data structure due to a change of perspective.

S13-09 Understanding a Roman insula by the aid of GIS—The Insula 30 in Augusta Raurica (CH)

Sven Straumann

In a PhD-project at the University of Basel (CH) the completely excavated Insula 30 of the roman colonial town Augusta Raurica (CH) is in the focus of an archaeological interpretation. GIS is being employed from the very start of this post-excavation analysis. The introduced project shows the method and procedure how archaeological records can be extrapolated as a source with the aid of GIS. Digitising completely the analogue records (photos, drawings,

descriptions etc.) and integrating them into the GIS system allows the potential of old excavation documentation to be much better and more efficiently exploited. This computer application facilitates the handling of "oceans of data". Because all the data and contents of the excavation documentation are available in digital form via the GIS, work can be done on the evaluation from any location. The data can be used for doing research on different topics in various scales, from the micro-scale of the roman insula (building development, architecture, functionality) to the macro-scale focus of the city (urbanism). This will finally lead to a 3D/4D visualization of the building development. Within the many advantages and possibilities of this innovative method the long-term sustainability has to be emphasized. The digitally extrapolated sources and the Data in the GIS are comprehensively available for anyone in the scientific community to use for his or her own investigations (<http://www.augustaraurica.ch/de/stadtplan>).

http://forschdb2.unibas.ch/inf2/rm_projects/object_view.php?r=303585

S13-10 Hand drawn section drawings analyzed in real 3D environment

Kristine Stub Precht

To answer questions on the urban development in Viking Age and Medieval Odense, we have been experimenting with 3D GIS modeling on Odense City Museums. In this work, our aim is to estimate the volume of the medieval culture layers in the city center, as well as to make a (realistic) topographical model of the Viking Age surface. In our latest experiments, we have been using large-scale geological 3D tools to handle and analyze the data from section drawings. Many archaeological departments have an endless number of hand drawn section drawings in their archives. These drawings are difficult to reuse for analysis on their own. However, since the section drawings from old city centers contains data on many formation processes in an urban context, it is worthwhile to pay them extra attention. In a small-scale investigation, we use Discover 3D to analyze the local topography based on these drawings alone. The anchor points are converted into fictional drill holes on which the drawings are fixed in three dimensions, and combined with the excavation database we can analyze the layers. In a later large-scale experiment, our aim is to combine the section drawings from other archaeological sites in Odense with drill hole data from the public drill hole database. This experiment is planned with assistance from geologists from Odense Municipality where we will use IGIS and Geoscene. In both cases, we use voxels to animate the important layers in 3D and hereby we are able to both visualize and calculate volumes on the most important features and layers. The use of these 3D tools opens up for a better reuse of the many hand drawn section drawings. In this particular case, it facilitates the handling of a big data set and thereby enables us to answer the many questions concerning the formation processes during the early development of Odense City.

S13-11 Liquid footprints: Water, urbanism, and sustainability in Roman Ostia

Mark A. Locicero

The city of Ostia acted as a vital harbor city for ancient Rome, and was situated on the Mediterranean coast of Italy. Over its lifetime (ca. 4th century BCE-6th century CE), the city reacted to the diverse needs of its population for water. A substantial section of the urban fabric of this ancient port city has been excavated, and more is coming to light through recent non-invasive prospection techniques. While the large urban water structures have been known for some time, their (inter)connection with many smaller ones have been viewed mainly from an architectural viewpoint. This study investigates not only the hydraulic system of the city and how it changed over time, but more importantly, seeks to identify the forces that caused these complex systems to change over time. On a theoretical and analytical level, this means applying the insights gained from the recent advances in the study of sustainable resource

usage to identify cultural, social, or economic factors that produced and influenced the city's hydraulic landscape.

However, to fully understand these factors, the system itself must be identified in its fragmented archaeological reality. Through the application of computational fluid-dynamic modeling software (SOBEK), this research aims to model the hydraulic system of a Roman city block (insula IV,ii), identifying how and why its water management changed over time. Additionally, this software, developed by the Dutch hydraulic management company Deltares, identifies where to look for undiscovered or lost components of this system. By combining the hydraulic system model with archaeological and historical information, we can gain a better picture into how a Roman harbor city managed its changing water needs over nearly a millennium of urban existence.

S13-12 The waters of life. Digital approach towards the reconstruction of the small scale water management of Angkor (Cambodia)

Kasper Jan Hanus

Angkor is recognized as one of the most extensive low-density urban complexes of the pre-industrial world. One of the most striking features in the landscape of Angkor is the enormous assemblage of hydraulic infrastructure, including two artificial reservoirs each covering around 15 km². However, in parallel to this massive, state-level system of water management, we also see evidence at Angkor of a smaller-scale system of household or community ponds in the urban core. These were described by the Chinese envoy Zhou Daguan, who visited Angkor in the late 13th century AD. His account includes the important information that each cistern was used by one to three families. The validity of this historical account can now be assessed using a precise map of the archaeological landscape that was created in 2012 using airborne laser scanning ("ALS" or "lidar"). The lidar data allow us to arrive at new insights into the demography of medieval Angkor. Using an algorithm for semi-automatic pond detection in the ALS-derived data it was possible to map over three thousand cisterns and from this to make inferences about population density in central Angkor. The aim of paper is to present our methodology behind the paleodemographic estimations using lidar-derived data.

POSTER

S13-P1 Forum Boarium survey

Sabrina Amaducci

Forum Boarium was the original trade centre of Rome. From the beginning it has been a very important area of the city. It was studied for a long time, although there are issues to be clarified and investigated still today. This forum is the site of very important temples, the portus Tiberinus and the defensive structure of the city. This doctoral research project is the study of the relationship between the most important areas of this region. Realizing a 3D model of the structures of this area, I will explore and reconstruct this relationship and the real route of Triumphal procession in Forum Boarium. One of the well-known theories about the procession in this place and the localization of the porta Triumphalis, is that it maintains the structures discovered between Fortuna and Mater Matuta temples, belong to the ancient Porta Triumphalis. There are important architectural aspects of my thesis that are clearly visible in a 3D environment, but cannot be studied in a 2D maps. Effectively, thanks to 3D modelling, it is possible to evaluate a thesis and to understand if it is feasible or not, and I believe that this is a great support for archaeological research. In my Master's of Art thesis, during the realisation of a model of the structures in S. Omobono sanctuarial area, I could see that the space among the temples was not enough to house in a triumphal door. I am now developing

the S. Omobono twin temples reconstruction, basing on the recent archeological survey and studies, made from Sovrintendenza Capitolina and University of Michigan in collaboration. The scope is to obtain a quite truthful reconstruction, that can help us to understand those aspects of buildings and ancient life in Fortum Boarium that have not been completely explained yet.

S13-P2 Geographical and cultural networks to better understand urbanization processes in central Italy (1175/1150–500 BC ca)

Francesca Fulminante, Alessandro Guidi, Sergi Lozano, Luce Prignano, Ignacio Morer

Since the first pioneering application of the 1970' and 1980', during the last decade or 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 applications to the study of urbanization and state formation processes remain very few. By comparing Bronze and Iron Age Settlement terrestrial and fluvial Networks in Etruria and Latium vetus, this poster will show how a more compacted and hierarchical region as Latium vetus prevailed over the larger but more heterarchical Etruria. When cultural networks are considered the calculation of centralization measures on different networks through time shows clear trends which still need to be fully evaluated but are interesting in their distinctive trajectories.

S13-P3 Patterns and recognition: Mapping indigenous settlement topography in the Caribbean

Till Frieder Sonnemann

Amerindian settlements in the Caribbean have mostly been identified through the assemblage of artefacts; predominantly large conglomerations of shells, but also ceramics and lithics. The topography is another important aspect to consider. Small mounds are distributed between levelled areas where wooden house structures once stood. Modern ploughing and looting have often dispersed the material over a large area. Undamaged sites, where circular depressions surrounded by earthen walls show the location of the former buildings, however, present unique opportunities to investigate settlement dynamics through novel non-destructive approaches. Local scale UAS surveys have mapped several sites in high resolution, the outcome providing an overview of size and distribution of mounds and platforms. After digital clearance of vegetation, and extraction of the resulting DEM and orthophoto to GIS, filtering and enhancing the results provides an opportunity to perform spatial analysis approaches on the data set. From calculating the actual extent of living space and defining a likely zone of habitat, to understanding the relation of platforms to mounds within their environment may provide us with ideas on how and for what purpose the settlement was set up at this location, and if there was a e.g. hierarchical structure.

S14 Can you model that? Applications of complex systems simulation to explore the past

Iza Romanowska, Stefani Crabtree, Benjamin Davies

The large scale patterns that we commonly detect in the archaeological record are often not a simple sum of individual human interactions. Instead, they are a complex interwoven network of dependencies among individuals, groups, and the environment in which individuals live. Tools such as Agent-based Modelling, System Dynamics Models, Network Analysis and Equation-based Models are instrumental in unravelling some of this network and shedding light on the dynamic processes that occurred in the past.

In this session we invite case studies using computational approaches to understand past societies. This session will showcase the innovative ways archaeologists have used simulation and other model building techniques to understand the interactions between individuals and their social and natural environments. The session will also provide a platform to discuss both the potential and the limitations of computational modelling in archaeology and to highlight the range of possible applications.

S14-01 Agent-based modeling and complexity science: The next step in archaeological theory?

Stefani A Crabtree

Agent-based modeling is on the rise in archaeology; yet how do we decide what questions are appropriate to ask when using this tool? Are all study areas, and indeed all questions, best approached through an agent-based modeling framework? If not, which questions are best answered through this approach? In this paper I place complexity science approaches within the framework of canons of archaeological literature. I then explore which questions are best asked, and answered, through agent-based modeling approaches. Finally I demonstrate how a simple agent-based model of southern France helps clarify standing questions. Finally, I briefly introduce a more complex model to show how agent-based modeling can articulate with both simple theoretical models and complex realistic models. Processual archaeology favored an approach that looked at how variables, such as societies, or levels of hierarchy, or maximal size of community, led to the construction of the archaeological record. Post-processualism, on the other hand, favored exploring the individual experience in the past, which can confuse an understanding of overarching structures. Complexity approaches, however, honor the individual experience by showing how individual decisions do matter, yet allow these individuals to interact to create larger overarching structures. This articulation of the micro-scale to the macro-scale feeds into how to approach archaeology questions with complexity tools. I take a step-by-step approach to showing which questions agent-based modeling can directly examine, and how they can be useful for answering questions that had been posed by processualists and post-processualists alike. I then demonstrate these questions through two models: a simple model of resource trade in southern France, and a complex model of the development of hierarchy in the U.S. Southwest. These two models are on the opposite spectrum from each other in terms of intricacy, yet they succinctly demonstrate how ABM approaches can examine diverse questions.

S14-02 How agent-based models can be used to investigate the evolution of social complexity in the past: A test of circumscription theory in the Valley of Oaxaca

Alice Williams

Complex societies with multiple levels of hierarchy and extended populations of unrelated individuals emerged relatively recently in the human past. How and why these complex societies formed from small-scale groups of people are fundamental questions to ask in archaeology. Attempts to explain this shift have often been verbally argued without explicit

testing. The aim of this research is to test different hypotheses at a regional level by comparing the output from agent-based models with archaeological data. The emergence of increasingly complex social organisation as a beneficial trait at both the individual and group level will be understood within an evolutionary framework. Agent-based models will simulate the actions of individual villages (whether to move or accept a subordinate position) based on the costs and benefits of their situation. It is predicted that increasing the costs of moving (through increasing levels of environmental circumscription) will increase the rate at which hierarchical societies form as a successful strategy. In addition, it is predicted that a model based on real-world environmental data will be comparable with the archaeological record. Archaeological and environmental data from the Valley of Oaxaca in Mexico will be used to test these predictions. The data spans 3,000 years from early small-scale villages to the formation and collapse of the first state-level society in Mesoamerica, and is ideal to investigate changes in social complexity over time. This research shows how agent-based models can be used to link micro- with macro-level processes in the past to understand why some human societies evolved higher levels of social complexity than others.

14-03 Simulating archaeological landscape formation to understand late Holocene population dynamics and mobility in arid Australia

Benjamin Davies, Simon Holdaway, Patricia Fanning

Archaeological interpretation depends on the formation of patterns in the material record, but patterns are not always discernible as the outcomes of a single set of processes. In Australia's desert regions, interpretations of patterning in late Holocene deposits range from intermittent occupation by bands of hypermobile foragers to growing semi-resident populations of complex hunter-gatherers. In particular, archaeologists have focused on the temporal distribution of radiocarbon dates that show trends and gaps consistent with interpretations of population dynamics, periodicity in occupation, and time-dependent preservation. We constructed an exploratory agent-based model around the concept of the palimpsest to evaluate the ability of the coupled processes of cultural and sedimentary deposition and erosion to form these patterns in a surface record of heat-retainer hearths. Initial results suggest that explanations invoking population dynamics or geomorphic processes have the capacity to produce qualitatively similar outcomes. Models are then reconfigured to evaluate a second proxy: optically-stimulated luminescence dates obtained from hearth stones, in order to evaluate the differential influence of these formational processes on these two proxies. The results of the modelling exercises are discussed in relation to patterning observed in the archaeological landscape at Rutherfords Creek, New South Wales, and are used to argue that the record is consistent with neither intermittent occupation or appreciable population growth, but instead indicates regular visitation by groups performing a fairly consistent set of activities during the period of interest. This study demonstrates the suitability of agent-based models for studying archaeological formation, but also how simulations can be used as both 'tools to think with' and as mechanisms for developing tests of theoretical ideas.

S14-04 Reinforcement learning for decision making in agent-based models

Jean-Marc Montanier, Xavier Rubio-Campillo

Understanding the decision-making processes within past societies is a challenging aspect for archaeological research. In order to validate our understanding of these behaviours, an ideal workflow would be to simulate the behaviours that we imagine are correct. We can then observe, if the imagined behaviours reproduce the evidence collected from the terrain. ABM has proved to be an efficient approach toward the realisation of this vision. However, many of the phenomena we wish to study, require the adaptation of the agents to the context they live. For example, it would be interesting to study the behaviors of gatherer

agents in front of changing environments. To face this type of situations, there is a clear need for adaptation abilities. Unfortunately, most of the current behavioural architectures used in ABMs do not let the agent adapt continuously its behaviour so as to fit the environment, thus restricting the modeling possibilities.

Reinforcement learning algorithms have been proposed to address learning problems within multi-agent settings. Once applied to past-societies models, this learning method faces two main challenges: each agent observes only part of the world and the number of states and actions an agent can face is potentially extremely large. Similar challenges have been previously encountered by researcher applying reinforcement learning methods to multi-robots scenarios. Within this article we aim to present which of the solutions previously developed can be applied to create models of past societies.

Moreover, the use of a UCT architecture has been previously proposed to address the challenge of learning in past-societies models. We will draw a comparison between reinforcement learning and UCT approaches. This comparison will highlight the difficulties each approach is facing, specifically for an application to past-societies models

S14-05 An agent-based approach to weighted decision making in the spatially and temporally variable South African Palaeoscape

Colin D. Wren, Chloe Atwater, Kim Hill, Marco Janssen, Curtis Marean

Even a "simple" human foraging pattern has a large number of moving parts. This requires a complex decision making process to effectively exploit the spatially and temporally variable resources in an environment. Here we present a general framework, based in optimal foraging theory, for agent foragers to make mobility and foraging decisions by weighing expected caloric returns against geographic and social factors, and forecasted future return rates. We evaluate the effectiveness of this and alternative decision making strategies by comparing their caloric returns over the long-term.

During the early Holocene in South Africa, Later Stone Age (LSA) foragers systematically exploited a wide variety of flora and fauna in both terrestrial and inter-tidal environments. We first use a combination of modeling and field-based foraging experiments to rigorously reconstruct the spatially and temporally variable caloric returns of the South African Holocene resource environment. Next we apply our decision making system to this resource environment as a way of gaining greater insight into LSA foraging patterns. Finally, we discuss the implications of our study for the evolution of complex cognition.

S14-06 The versatile's story of human dispersal: Climate fluctuation, adaptation and the evolution of human uniqueness

Iza Romanowska

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 environmental conditions. This promoted adaptive changes leading to a higher level of behavioural plasticity and the evolution of organisms which can be described as 'versatilists', for example early hominins.

Here, we present an extension of the single locus model by Grove (2011) —the first successful formalisation of the Variability Selection Hypothesis into a mathematical framework. The current implementation aims to assess the implications of the Variability Selection Hypothesis on the agents 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 particular focus of this presentation is on the spatial structuring of the migration wave and the question of what characteristics of the original population play a role in its ability to disperse.

S14-07 Dates and dispersions: Examining the spatio—temporal boundaries of the Guaraní expansion into the La Plata basin with Monte Carlo methods

Phil Riris, Fabio Silva

The direction and timing of the Guaraní expansion into the La Plata basin from an Amazonian origin is a matter of no small debate in the study of South American indigenous cultures. The short timeframe of the Guaraní expansion (2000–500 BP) during the late Holocene, as well as the distances involved, are both used to explain it as the result of the migration of significant numbers of people in a classic “wave of advance”. The process is further broken down into “pulses” punctuated by periods of relative stasis in which colonization through the valleys of major rivers was halted or slowed. These factors, combined with a broad base of empirical data from decades of research, provide the impetus for refining established chronologies of the Guaraní dispersal.

We use a published database of georeferenced dates to model its spread at the beginning of the Common Era from a presumed entry point until the time of European contact at its known limits at the La Plata delta and Atlantic coast of Brazil. Using regression models and Monte Carlo methods, we examine the dispersal in order to constrain the probable start dates for entry into different zones. Additionally, we investigate the notion that Guaraní groups enveloped large sectors of terrain contiguously as the result of demographic pressures that were interspersed, as noted, with hiatuses of comparatively little movement.

We place our findings in the context of preceding archaeological, ethnographic, and ethnohistorical knowledge on this uniquely South American process of indigenous dispersal. Suggestions for further work to improve the scenarios we present are offered, following the note by Brochado (1984) that in the study of Guaraní archaeology, “computer modelling is probably the only way to achieve refined estimates of population growth” in the La Plata basin.

S14-08 An agent-based modelling approach to a complex problem: Economics and demography of the first farming expansion in the Balkans

Andrea Zanotti, Richard Moussa, Jean-Pierre Bocquet-Appel

How can we see demo-economic processes in the archaeological record? How is the pioneer front of a Neolithic farming society demographically and economically structured? What are the differences in the structure of the population between zones of expansion and zones of increasing density? These questions become especially difficult to answer the farther back in time we study. Here we use an agent-based modelling approach to examine the spread of the first farmers through the Balkans during the Early Neolithic, specifically focusing on the demo-economic impacts of the spread of agro- pastoralism in this region. In this model we combine archaeological records with ethnohistoric and paleodemographic inferences. These are layered on a realistic dataplane built by paleoclimate and soil fertility estimates. Agents interact on this landscape and follow a demographic and economic model in order to simulate the functioning of the Neolithic farming system. Our results provide possible scenarios for the expansion of the first farmers in the Balkans. The agent- based modelling approach permits the exploration of demo-economic structures that are unobservable in archeological record.

S14-09 An agent-based modeling framework for Out of Africa hypotheses

Ericson Hölzchen, Christine Hertler

The "Out of Africa" theory states that the genus *Homo* originated in Africa and from there dispersed across Eurasia. At least two different dispersal events can be distinguished. On the one hand there were the dispersals of archaic *Homo* such as *Homo ergaster/erectus* or even earlier forms which took place around 2 million years ago. We summarize these dispersals under "Out of Africa 1". The dispersals of modern humans took place around 130 thousand years ago. We summarize these dispersals under "Out of Africa 2". The underlying mechanisms for both dispersal events remain under debate. Currently, there are several hypotheses that try to explain these dispersal events with environmental, biological, or cognitive changes, resources and/or competition. There is currently no accepted formal representation of Out of Africa hypotheses which allows testing and comparing them on a quantitative basis. We propose agent-based modeling as an adequate method to explicitly represent Out of Africa hypotheses. An agent-based model consists of agents, an environment and rules of interaction. We apply this structure to model early hominins who interact with a Pleistocene environment. We present an agent-based modeling framework that is based on the most common Out of Africa hypotheses from literature and their associated driving factors. This framework allows the generation of testable and comparable agent-based models of various Out of Africa hypotheses and their subsequent quantification.

Cancelled S14-10 Testing archaeological narratives of the spread of rice cultivation in Asia

Fabio Silva

Often in archaeology, narratives are created based on a limited assessment of, or a qualitative take on, the data. This is the case when positing centres of technological or subsistence innovation, which often rely on the, limited and frequently biased, available archaeological evidence. Such approaches are prone to criticism by those who raise concerns that future archaeological finds, in less sampled regions, might completely disprove, or otherwise change, the archaeological story. One example of this is the debate over the origins of rice cultivation in Asia (cf. [1]). There is a need for a framework that can explicitly evaluate the proposed narratives against the wider archaeological record and weigh the evidence in favour of each, while, at the same time, penalise more complex narratives. Such a framework, based on the interface between Information Theory and Likelihood Statistics is here implemented. It is based on the numerical modelling of dispersals and subsequent comparison to the available (dated) archaeological data. Goodness-of-fit is obtained from a quantile regression [2] of the archaeologically inferred age versus a least-cost distance from the putative origin(s). The Fast Marching Method is used to model least-cost distances based on simple geographical features (cf. [3]) and the model's parameters are estimated using a Genetic Algorithm that maximizes the likelihood. Model selection is then conducted using Akaike's Information Criteria (cf. [4]) which allows for a quantification of the weight of evidence in favour of each model/narrative. As a case study, an extensive database of archaeological evidence for rice across Asia, including 400 sites from mainland East Asia, Southeast Asia and South Asia was used to compare several models for the geographical origins of rice cultivation and its subsequent spread. The results indicate that a model with two independent centres of innovation (in the Middle and Lower Yangtze) is supported by the entirety of available archaeobotanical evidence for the presence of cultivated rice in Asia (cf. [1]).

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S14-11 An agent-based empirical model of collective seasonal hunting

Florencia Del Castillo

This work presents an ethnoarchaeological model of collective seasonal hunting to track the interactions among hunters and guanacos-prey (one of the most abundant and ecologically important mammal species of Patagonian steppe) in a well-known ethnohistorical scenario of Patagonia hinterland. The conceptual model was developed based on ethnographical and historical data from an indigenous society from North Patagonia. We model a place of guanaco hunting named Yamnagoo by the ethnic group *gününa këna* during XIX century. The data used to design this complex space of hunting, come in part from the description made by European explorers from the XIX century and from ethnographic descriptions of one of the most uninhabited region of South America.

The model was developed to address the interactions between collective hunting organization and the guanaco's capacity to respond and react to it. Therefore, we design a model with collective hunting strategies based on search, stalk, chase, food processing, consume, and prey discard. With the model we experiment with a large number of hunting attacks to quantify how the environmental variables, geographical constrains and communication between hunters, affect density, speed and motion of hunter-agents and guanaco-agents. The aim of the model is analyse and explore how cooperation activities and the role of information transfer in hunting interactions works and how ethnoarchaeological data can be useful to understand social Dynamics in prehistory. The model is validated by comparing the simulation results with archaeological fieldwork and survey.

S14-12 The emergence and process of formation of the La Tène culture settlement system in Upper Silesia (Southern Poland and Northern Czech) in the light of the simulation modelling

Jan Zipser

The paper presents findings of research regarding recreation of the processes involved in the taking up of the Upper Silesian area (Southern Poland and Northern Czech) by the La Tène culture settlement, as well as in the formation of its structure, in the context of already existing theories.

Two diffusion simulation models were applied (Probabilistic Model for Residential Growth – also called UNC Model and Intervening Opportunities Model) in relation to the theories regarding the direction of the settlers' influx; the hypothesis referring to the reasons behind the emergence of the presently known settlement pattern; and the interactions between the potential environmental conditions and the detailed course of the settlement system expansion.

The introduction of the two simulation modelling procedures into the research of the La Tène culture settlement in the studied area demonstrated high statistical correlation with the mapped, prehistoric settlement system of the La Tène culture. It also brings respectable basis for interpretation of the settlement processes, not only in the studied case, but presumably also of other prehistoric cultures in different geographical conditions or cultural landscapes.

S14-13 Can you analyse that? Fitting simulations to idealised outcomes for the origins of farming

Elizabeth M Gallagher, Mark G Thomas, Stephen J Shennan

Monte-Carlo simulation is a powerful tool for exploring model behaviour and sharpening intuitions about prehistoric processes. Model-based inference requires empirical data, both to assess relative support for alternative models and to estimate model parameter values. However, inference on prehistoric processes is sometimes challenged by a lack of quantitative and ascertainment bias-free data, and often only general outcomes of past processes are known. In addition, when Monte-Carlo simulation is used to explore model behaviour, this is often done via a fix-all-but-one approach, whereby parameters are set at some default values and then varied one at a time. Such an approach will fail to capture many of the subtleties of parameter interactions.

In this study we examine the origins of agriculture by applying Monte-Carlo simulation to a model first proposed by Bowles and Choi [Bowles S, Choi J-K (2013) Proc Natl Acad Sci USA 110(22):8830–8835]. We vary 11 parameters simultaneously within defined ranges over 12 million simulations to ensure better exploration of parameter space. We also introduce a new method—fitting to idealized outcomes (FIO)—which permits identification of potential parameter interactions. Our FIO approach is analogous to approximate Bayesian computation and allows us to infer the optimum conditions under which farming would evolve, given our model. Our results reveal previously unidentified model behaviours. By setting our ‘ideal outcome’ as farming being fully established by 9,000 yBP, we show that the key factors for its emergence include farming-friendly property rights (supporting Bowles and Choi’s original work), group structuring and size, and conservatism. Furthermore we find that for farming to emerge it is not essential for farming productivity to be greater than that of foraging.

S14-14 Everything seems possible: Exploring the parametric space of a simulated prehistoric scenario

Juan Antonio Barceló, Florencia Del Castillo Bernal

Simulated scenarios allow exploring (by altering the variables) the entire possible range of outcomes for different past behaviors. Therefore, the starting point of the explanation of social systems by means of computer simulation is not the simulation of one particular system but the investigation of the mathematically possible development of specific classes of model systems (pure systems). As these pure systems usually generate a lot more different paths of development than are known from real human history, the automated archaeologist has to limit these possibilities by introducing known social constraints from social reality. The socially interesting question is then why these constraints appeared in reality. Each one of the resulting "simulations" of a historical trajectory of events can be used both to experiment with a theory of historical transition and social change (parameters are manipulated to test for predicted differences) and as a demonstration tool (parameters are manipulated to test for predicted robustness). In this paper we present a way of using experimentally a simulated universal model of a hunter-gatherer past, in which manipulations are allowed for agent-level parameters to test the global implications of behavioral assumptions in the case of small-scale prehistoric societies, but also it is allowed to manipulate global parameters to test a macro theory about the dynamical implications of social behavior assumptions in the case of more complex societies. Different initial parameters are fully explored, and all possible combinations between them (Initial number of households, household size, mean resource on patch, technological efficiency at start-up, mobility, internal change rate). The paper presents how variation in those parameters affect total survival, technology transfer, social interaction, intensity of cooperation, cultural diversity and social polarity.

S14-15 Evolving hominins in HomininSpace—Genetic Algorithms and the search for the perfect Neanderthal

Fulco Scherjon

Genetic Algorithms (GA) are evolutionary computational techniques inspired by natural selection in which individuals participate in a search for optimal results. HomininSpace (HS) is a large scale realistic agent-based modelling and simulation system exploring hominin dispersal through reconstructed landscapes in the deep past. A case study in HS implements Neanderthals moving through North-west Europe where simulated presence is scored against radiometrically dated archaeological sites (checkpoints). Model parameters influence agent behavior and GA are implemented in an automated scan for that specific parameter combination that produces a Neanderthal agent that best matches the archaeology.

The underlying research question for the implementation of HS is the characterization of the effects of the different parameters on hominin behavior in the landscape. 6000 simulations were run with randomly constructed parameter combinations. Statistical analysis (principal components analysis and cluster analysis) are used to determine the influence of each parameter in simulations with high scores. But the total dimensions of the parameter space (23 parameters) is simply too large for an exhaustive parameter sweep guaranteed to find the perfect Neanderthal.

In an effort to optimize that search GA techniques are applied against the set of simulated parameter combinations and their simulation results. Each unique combination of parameter settings is taken as an individual that participates in the automated search. Tournaments are organized to select high potentials, and randomly mixed pairs of successful parents produce hopefully more successful offspring (new combinations). Better scoring individuals are also point mutated on a single parameter to create even more new combinations. Simulation results for the new parameter combinations are added to the pool of individuals that participate in the following tournament rounds. This paper presents the preliminary results and the characterization of some very good Neanderthals.

S14-16 Content or context? Model selection of settlement growth models using entropy maximization

Xaver Rubio-Campillo, Rinse Willet

Entropy maximization is one of the most popular computer models used in archaeology. This family of simulations was designed to explore transport flows in urban and regional geography. The original model was transformed into a high-level methodology designed to explore any scenario where the size of a set of entities is related to spatial interaction. Several archaeological studies applied the methodology to settlement dynamics, thus exploring how geography and interaction could explain the observed size of sites. Recent developments have adapted the framework to the particularities of the field introducing concepts such as uncertainty, decision-making and the study of evolutionary trajectories.

These models characterize settlement growth as a combination of two factors: the intrinsic interest of the location and its relation within the network of settlements. The system is then iterated while updating the importance of each settlement until an equilibrium is reached. The main challenge of the model is to define parameter values for a) the hypothetical intrinsic interest of each site, b) the interaction decay over distance and c) the relative weight of the two components. Beyond the entropy- maximising approach, parameter estimation and comparison between competing hypotheses are two common challenges while evaluating how formal models match evidence under uncertainty.

This work evaluates the plausibility of different entropy-maximising models in the case study of Roman Asia Minor. A hierarchical model integrated the alternate hypotheses and data

uncertainty within the same framework. Parameter estimates and model comparison were then calculated applying Approximate Bayesian Computation. The application of this framework was used to infer new interaction dynamics between the settlements located in this region and improve our understanding of the underlying archaeological record.

POSTER

S14-P1 The origins of agriculture: Mathematical models, cooperation and the rise of social inequality

Elizabeth M Gallagher, Peter J Bentley, Stephen J Shennan, Mark G Thomas

The transition from hunting and gathering to farming was one of the most important events in human history; having major impacts on human demography, evolution, health, culture and technology, and coinciding with a switch from fairly egalitarian to hierarchical societies. The reasons why some societies switched to farming are still debated, with climate stabilization, population pressure and feasting, among others, as popular hypotheses. However, since these processes occurred so long ago and ethnographic studies may not always be comparable to ancient groups, investigating the transition can be difficult without the use of mathematical models.

We have developed a game theoretical agent-based model of social and environmental interactions during the late Pleistocene/early Holocene in order to investigate potential societal impacts of the transition to farming. Our model is used to test various popular hypotheses for the origins of farming (e.g. population and climate pressure). We also investigate the affect of changing levels of cooperation on both the transition to farming and the emergence of social inequality. Our model is conditioned with a proxy for the amount of farming in the Near East (the domestic-to-wild ratio from an archaeobotanical database), and we use a method analogous to approximate Bayesian computation to explore the model's parameter space and interactions in detail.

S15 Interpretations from digital sensations? Using the digital sensory turn to discover new things about the past

Stuart Eve, Catriona Cooper

We are at a turning point in development and thought about multi-sensorial engagement using digital mediation. From Oculus Rift VR goggles or noise-reducing headphones through to vibrating-haptic simulating gloves, smell generators and virtual treadmills, every week a new technology or software emerges that can be used to virtualise, augment or diminish our reality, across all of our senses. Digital archaeologists have always been at the forefront of using these new technologies and one glance at past proceedings of the CAA conferences show how enthusiastic and competent archaeologists are at deploying them in heritage applications.

These new technologies are very often used for the public presentation or exploration of archaeological sites. The technology is used as a way to broadcast interpretations, to present current thinking to an interested 'public' or to allow the sites to be experienced remotely. From the hundreds of virtual reconstructions of Rome, to the smelly galleries of the Jorvik centre multi-sensory applications are often used to simply evoke a feeling or to 'show' people what things looked like. Whilst this is, of course, an admirable and very important aim – this session instead seeks to explore the projects and applications where a multi-sensory approach has enabled a fundamentally different interpretation of a site or artefact.

Examples might include an acoustic model that demonstrates a new use of the public space or landscape, an exploration of smell that challenges the current view of town planning, a haptic interface that can be used to experiment with pottery fabrics or a visual analysis of movement through a prehistoric village.

The current theoretical sensory turn in archaeology allied with the availability of new multi-sensory technologies is the start of an exciting physical/digital era – but only if we use the technology and theory together sensibly and are not just creating new things because we can. This session then welcomes papers and presentations that don't simply claim “here is a cool model of X that I made”, but instead we encourage papers that shout firmly out loud, “here is something I made that tells us something new about my site and about the heritage and archaeology of the world”.

Traditional papers are welcomed, but more novel forms of presentation and demonstration are actively encouraged.

S15-01 Auralization: What can acoustics tell us about digital lived experience?

Catriona Cooper

The process of auralization has been a focus of acousticians for many years. As with early years of 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 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 or 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 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.

S15-02 From the largest to the smallest: The use of the latest technology in digitalization of the objects from the collection of the National Maritime Museum in Gdańsk

Piotr Dziewanowski, Janusz Różycki

In the collection of the National Maritime Museum in Gdańsk are both items that do not exceed 1 cm in length and objects measuring over 80 meters. With such diversity of objects sizes it becomes clear that there should be used different methods of documentation relevant to the object, data that we want to get and the way of later presentation.

In April of 2015 began the process of 3D scanning of the largest object in the collection of National Maritime Museum in Gdańsk - the museum ship "Sołdek". Scanning the object, which is available on a daily basis to the public turned out to be quite a logistical challenge. The construction of the ship, narrow corridors and cramped engine room caused many problems both for scanning and later processing of data.

On the other hand there are examples of tin bottle caps that have been collected in the current year while excavating the wreckage of F53.30 ship. On some of them are preserved tinker signs, and their correct reading was necessary to confirm the chronology of the artifacts and the place of their production. Correct reading of the information on the bottle caps, due to the small size of the objects and state of preservation, required the usage of different methods than in case of the museum ship "Sołdek".

Equally important as data collection, their processing and interpretation is opportunity to present in attractive way the results of work on the objects from our museum collection. By using appropriate methods we can present in the virtual space both objects presented in the museum every day, and those which for technical reasons are never shown to the public.

S15-03 More than just a pretty picture: A review of the use of 3D printing, touch tables and virtual environments to engage the public with Lidar and the archaeology of the New Forest, U.K.

Lawrence Shaw, David John, Harry Manley, Gary Underwood

Over the last five years, the New Forest Higher Level Stewardship (HLS) scheme has utilised remotely sensed data, including Lidar, to identify and record lost and forgotten archaeological monuments. Traditional processing techniques of these data, such as hill shade and slope analysis, allow archaeologists to identify 'lumps and bumps' in the landscape, created by human activity over thousands of years. Whilst great for prospection when analysed by professionals, these processed rasters only represent the original three dimensional data as a flat image. Consequently, when viewed by the general public, these interesting and engaging images are often dismissed as just 'pretty pictures', with little thought as to how they were produced or what they actually show.

In September 2015, to mark the mid-point of the New Forest HLS, a temporary exhibition was produced to share what had been discovered through this 3D recording technique. As part of this exhibition, researchers based at the New Forest National Park Authority and Bournemouth University looked at different ways they could represent the Lidar data to help the public understand how it was recorded and what it represents. Using developing technologies such as 3D printing, gaming engines and interactive touch tables, researchers produced a number of outputs that allowed visitors to engage with and interpret the 3D Lidar data in a number of multi-sensory ways.

This paper documents the different techniques used to produce multi-sensory outputs to teach the public about Lidar and assesses how effective these approaches are in helping people understand and interpret what they see.

S16 Networking the past: Towards best practice in archaeological network science

Tom Brughmans, Daniel Weidele

The full diversity of network perspectives has only been introduced in our discipline relatively recently. As a result we are still in the long-term process of evaluating which theories and methods are available, the 'fit' between particular network perspectives and particular research questions, and how to apply these critically. How can network science usefully contribute to archaeological research by enabling archaeologists to answer important questions they could not have answered through other approaches? In what circumstances is the use of network science techniques appropriate? There is a need to address these questions by working towards guidelines to best practice in archaeological network science. This is a goal that should be achieved by a community of scholars in collaboration, drawing on the lessons learned from applying network science critically and creatively in a diversity of archaeological research contexts.

This session aims to build on the growing interest in and maturity of archaeological networks science to lay the foundations of guidelines for best practice in archaeological network science. It invites papers debating best practice in archaeological network science, addressing methodological and theoretical challenges posed by the archaeological application of network science, or presenting archaeological case studies applying network science techniques. It particularly welcomes papers presenting work in which the use of network science techniques was necessary and well theoretically motivated, and papers applying network science to exploring 'oceans of data'.

S16-01 A guide to good practice for archaeological network science

Tom Brughmans

The use of network science techniques for the study of the past shows great potential and has recently become more common practice. However, this increased use of network science techniques has also led to the identification of particular challenges posed by their archaeological application, which deserve more critical attention. In order to overcome all these challenges and uncover new and useful archaeological uses of network science it is important that archaeological network science should be considered more than just a hype: archaeological network scientists should be cautious to make grand claims about the novelty of their methods and instead enable a larger body of archaeologists to critique their approaches.

In this talk I will argue there is a need for best practice guidelines for archaeological network science. I consider this a task that should be performed in collaboration with more mathematically- and computer-literate archaeologists, who should work towards a 'guide to good practice' accessible to all archaeologists, and provide critical applied case studies as examples. By doing so, archaeologists will be provided with the means to evaluate how and whether network science is a tool that can lead to innovative insights in their own research contexts, as well as enable a larger group of archaeologists to critique the ever increasing number of archaeological network science studies.

S16-02 Exploring formal SNA approaches to funerary contexts in Early Iron Age Italy

Lieve Donnellan

This paper explores various possible ways to analyse evidence from funerary contexts with formal SNA methods. Despite the availability of large datasets from grave yards of the Early Iron Age in the Mediterranean, formal SNA has hardly ever been applied to this type of data. Research of funerary contexts has traditionally focussed on typologies of objects and tombs, and the religious meanings of death, but a formal SNA has the potential to contribute

significantly to the scholarly understanding of a number of aspects, going from trends in the overall population, the evolution of such trends through time, to social stratification strategies, such as social distance through ritual performance, and intercultural interaction. The paper presents a summary of the analysis from two case-studies from Campania (the sites of Pithekoussai and Pontecagnano), whose funerary data sets have been digitised and subsequently analysed with SNA software. Various analytic tools, offered by standard SNA software packages, allow to ask and reassess several questions pertaining to the social make-up and interaction of the populations in question. The paper focusses especially on methodological questions and problems in translating conventionally-published excavation data, deriving from funerary contexts, to digital datasets that can be analysed with formal, quantitative methods. It also elaborates on some tools, available in standard SNA packages, which can be used to study social and cultural interaction in past populations.

S16-03 Wine trade from Roman Crete: Onomastic—geographic network analysis

Ignacio Morer, José Remesal, Albert Diaz-Guilera, Luce Prignano, Daniel Martin Arroyo

We present a case study developed within the EPNNet Project (ERC-2013-ADG 340828), whose main goal is to characterize the dynamics of the commercial trade system during the Roman Empire.

We analyse a subset of archaeological data found in Pompeii, namely, the Greek epigraphy (tituli picti) on the Cretan amphorae. It represents a promising dataset, given that Greek names can be crossed with the Lexicon of Greek Personal Names (LGPN) and linked to geographical data. Since we deal with two different kinds of entities, names and places, we represent the relations between them through a weighted bipartite network.

The bipartite network is built considering that the epigraphic data is incomplete and ambiguous, and foremost, that there are a few onomastic aspects to be taken into account. On the one hand, there are some very common names (homonimy) that don't provide significant information. On the other, there exist highly similar names that are likely to belong to the same families. Therefore, we introduce a set of probabilistic rules to weigh the links of our network that, together with the reference of the whole LGPN, allow us to:

Include the ambiguity of the data with very few assumptions.

Identify homonimy cases and remove its effect.

Check for family names grouping.

With the aim of detecting relevant trade-related information, we extract the community structure of the bipartite system. It is an appropriate baseline to detect different types of nodes according to their function in the network [1]. The goal is to identify possible roles for the names and places as a function of two topological variables in two-mode networks [2], by means of a functional cartography of families and places of different types (ports, production and consumption places, etc.).

[References]

[1] Guimerà & Nunes Amaral (2005)

[2] Saavedra et al (2009)

S16-04 Least-Cost Networks and Network Analysis: Modelling trade relations in early medieval East Central Europe

Donat Wehner

Medieval trade relations can be considered from many different angles. One can attend to the actors, their identities, motivations, manners and perception as well as the circumstances of travelling and equipment or one can deal with types and amount of traded goods, to name just a few of the possible aspects. The concern of this contribution is to reveal the structures, intensities and directions of commodity flows on different spatial and temporal scales in East

Central Europe in the Early Middle Ages. Networks of nodes and edges serve as visualizations of the economic relations. Sites with an increased density of interaction function as nodes, economic flows on transportation routes between these nodes serve as edges. The commodity flows can be weighted asymmetrically as well as differentially. Starting from networks created from least cost path routes and graph theoretical models network analysis and space syntax are used to obtain additional information on the structural characteristics and mechanisms of the networks. One issue is the network density. Are there many trade relations or rather few? Bridges and structural gaps are of interest as well. Do sites exist which connect economically densely entangled areas and where are such areas not connected? The importance of different sites in the exchange-networks is also relevant. It can be defined e.g. by the amount of relations (degree centrality), the closeness to other interaction hubs (closeness centrality) or in its strategical position between other interaction hubs (betweenness centrality). In order to achieve a dynamic and differentiated result, multiplex multimodal network analysis is used. Different artifact- groups like coins, so called imports, scales and weights as well as geographical distances and written sources of trade relations in diverse place-time-configurations are included as representatives and parts of trade. By combining various relevant models, data records, spatial layers (local, regional, supra-regional) and time slices, dynamic networks can be created and interpreted in a comparative and complementary way. This approach provides an opportunity for understanding the significance of relationships within and between past material culture, individuals, and groups. The alternating relation between physical distance, commodity distribution and contemporary perception of commodity flows can for example be identified by using affiliation-networks of Least-Cost Path relations, artifact-relations and trade relations known from written sources. One gets an idea of different types of linking in the context of trade activities, what they are good for and how they are related to each other. Thereby, connections in the network can be favored, created or handicapped and impeded by space. Complex feedback-loops between the creation of space through networks and the creation of networks through space can be observed. By doing so, mediation between physical and social space is created similarly.

S16-05 Geometrical and planar graphs in ancient iconography studies, a heuristic tool

Thomas Huet

By definition, Prehistory's symbolic systems are not readable; one of the main attributes of the writing - the syntactical axe- is lacking in almost all of ancient iconographical compositions (painted caves, engraved rocks, ceramic decorations, etc.). In those compositions, graphical units (GU) are commonly displayed with what Chippindale called a "weak tendency of avoidance" between each other. Therefore, despite the chrono-cultural attribution work (by comparison, study of superimpositions, seriation, etc.) of GU, recognition of associations and recurrent compositions (patterns) remains difficult. Furthermore, in almost all statistical analysis on ancient iconography, GU are quotes in term of presence/absence in data table and their proximity links are lost during the analysis process. We will present different cases studies showing how geometric and planar graphs, belonging to network analysis, are heuristic tools to manage "weak organised" compositions of graphical units.

POSTER

S16-P1 Artificial Neural Networks to estimate Paleotemperatures in North Patagonia (Argentina) based on micromammals sequences*Analia Andrade, Joan Anton Barceló, Florencia Del Castillo*

Small mammal's assemblages from archaeological sites were employed worldwide as proxy data to reconstruct paleoenvironments. However, the scope of these researches allow indirect paleoclimate inferences. The aim of this work is based on the use of neural networks (NN) to predict paleotemperatures during Middle and Late Holocene in northern Patagonia based on the presence/absence of rodent species from stratigraphical sequences. The study area is the Natural Protected Area of Somuncura, a massive volcanic plateau located in the Extra-Andean Patagonia, in which successive basaltic flows, step-like landform, set an elevational gradient between 600 and 1800 m a.s.l. At present, the annual average temperature decreases with the altitude (linear model, $r=-0.96376$, $m= -0.0061$, $b= 15.456$) but the annual average precipitation remains slow and constant (187 mm). This steep altitudinal gradient configures the assemblage composition of small mammals and plants along the gradient. Small mammals contained in diverse samples stem from owls' regurgitate balls and recovered along this gradient, and the temperature estimated at each locality by the regression model were employed as the actual correlate of the network. NN allowed discriminating species that distribute in colder environments (and upper levels) and those from warmer environments (and lower levels). The temperature parameters used to build the network were inferred from the sequence of micromammals with a predicted limit temperature of $9.5\pm 0.5^{\circ}\text{C}$. Results show that during colder periods micromammals from the current upper levels would have occupied lower levels, while the opposite would have happened in warmer times, micromammals from lower levels have occupied the upper plateau. The model reproduce well the temporal correlation of the observed data and indicates that the spatio- temporal informations and an accurate classification of micromammals is essential for NN predictive time series with incomplete data bases.

S17 The road not taken: Modelling approaches to transport on local and regional scales

Mark Groenhuijzen, Philip Verhagen

Research on transport systems thus far has largely focussed on the documented and partly surviving road systems, ranging from the Roman imperial road systems known from the itineraries and the Peutinger Table to the road systems documented by medieval cartographers, even when it is well known that secondary road systems were in use simultaneously. Empirical evidence for the existence, location and chronology, particularly for secondary roads, is however scarce in many cases. In addition, transport over water (both fluvial and coastal) is often not considered. In order to bridge the gap between our theoretical notions of short- to medium-distance transport and the surviving (archaeological and historical) evidence for transport systems, in this session we want to focus on the practical and theoretical implications of using spatial modelling and analysis techniques, such as GIS-based cost surface modelling and social network analysis, for better understanding transport at the local and regional scales. We want to explore in what way spatial modelling can provide more insight into the organisation of local and regional transport, as well as the implications it has for the interpretation of the position, function and potential for trade of settlements within the local and regional transport system. We specifically invite papers that deal with:

- 1) New approaches to modelling transport networks, including aspects of differential access to the system, different modes of (wheeled) transport and diverse cost considerations (energetic, economic etc.);
- 2) Studies that combine transport network modelling and quantitative analysis approaches such as social network analysis;
- 3) Studies that link transport networks to models of trade/exchange at the local and regional scale;
- 4) Applications of transport network modelling in different landscapes and environments.

S17-01 Transport and trade: An energyscape model and transport network approach for trade in Roman times

Devi Taelman, Dimitrij Mlekuž

Movement of goods is vital in all human societies. Complex societies are characterised by an increased importance of movement as the production of goods tends to be distributed geographically among all members/cities of the society. Roman society is particularly known for its well-developed trade systems where goods - such as food, wine, olive oil, pottery and stone - were moved in enormous quantities and over long distances.

We believe that the distribution of bulky and heavy goods is particularly related to the cost of their transport and that physical geography can be a major constraint to this transport. While Roman water transport has already received significant scholarly attention, land transport is studied only superficially. Many urban centres could, however, not be reached without land transport. Land transport was thus inevitable and formed an integral part of Roman trade. In this paper, we present different energyscape models for depicting the predicted energy costs of transporting heavy loads by land. The resulting energy networks are compared to identify differences in the structures and the focal points of the networks, such as changes in the location of distribution hubs or changes in the locations of critical intermediary sites that determine the direction, quantity and volume of flow and therefore critically contribute to the cost of moving and trading heavy loads. This approach allows for a better evaluation of how land transport could have acted as a structuring variable for the Roman landscape and the Roman economy. As a case study, the trade of marble 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. The marble assemblages of several Roman towns in the area are compared with the results of the energyscape models and transport networks.

S17-02 A network model for the evolution of terrestrial connections in Central Italy (1175/1150–500 BC ca)

Luce Prignano, Francesca Fulminante, Sergi Lozano, Ignacio Morer

The period between the Final Bronze Age and the Archaic Age is a time of changes and developments in the Italian Peninsula which led to the creation of regional ethnic and political groups and to the formation of the first city-states in Western Europe.

We study the evolution of the interaction patterns among settlements by analysing terrestrial communication networks in Latium Vetus (LV) and Southern Etruria (SE) in several time snapshots. At a first overall inspection, the two regions appear to be very similar, except for some interesting differences. In order to understand to what extent the observed results are a consequence of either differences on the spatial distribution of settlements, or dissimilarities in the process that generated those networks (cultural and political factors), we design a simple network model. After locating the nodes at the positions we know them from the archaeological record, we start adding links where they are more needed, according to a geographical criterion. The total link length is the only data-derived constraint. The model reproduces with good accuracy the features of every real network, except for LV in the Early Iron Age, where it systematically underestimate the average shortest path length while overestimating the local efficiency. Our hypothesis is that this model, that implements an optimal resources (new roads) distribution, cannot reproduce structures shaped by the unbalanced tensions of a harsh competition such as the Latin region of those times. On the contrary, it works fine in the case of a heterarchical system, such SE, or when considering a centralized, hierarchical one, as LV in the Archaic Period. We measured the hierarchicity (Trusina et al 2004) of both real and artificial networks as a preliminary test obtaining results compatible with this explanation.

Cancelled S17-03 Network analysis to understand the Roman commerce. Connectivity and transport costs of the Roman networks

Pau de Soto

In the last few years, the author has been working in the development of new technologies that let him calculate and visualise the configuration and performance of the Roman transport networks. This project is based on the analysis of Roman infrastructures to understand the transport costs and the best commercial routes. This is an indispensable way to know the benefits and shortcomings of the transportation system created in Roman times. It is well known that the Roman Empire built the first big transport network, combining roads, inland waterways and maritime connections. Such a huge effort aimed to create an integrated economy covering all the Roman provinces on the Mediterranean Sea and Atlantic Ocean. This paper will be focused in two main aspects of this project. Firstly, in the integration of very diverse data that allowed the recreation and analysis of the Roman transportation models. And secondly, the analysis realised and the most recent results obtained will be presented. In order to obtain successful results, the Roman transport conditions have been reconstructed by modelling travelling costs and times with the help of GIS and Network Analysis applications based in ancient sources and archaeological and ethnographical data. To explain the methodology of this part of the project and the integration of the data, this paper will be framed in the works realised in the NE of Hispania. It was necessary devote a significant effort to the gathering, documentation, analysis and digitisation of Roman communications with high precision. Later, to explain the analysis and the most recent results, this paper will expand the geographical scope to the entire Iberian Peninsula, Italy and Britain. It will allow

us to show very interesting patterns. The results of these applications provide us with new information to understand the distribution of commodities, product competition and problems of supplying in ancient economies.

Thanks to this project it has been possible to observe how the construction of a complex communication network, especially based on the creation of land routes, meant an important element for the integration of new territories into the Roman provincial organisation model. To understand the morphology of these networks, we have applied some personalised Centrality Degree analysis (Centrality, Betweenness and Closeness) in order to visualise the importance of the different settlements and territories depending of their weight and their position within the Roman transportation network. The calculations were designed applying different values of edges depending on the kind of transport that they represented. As a result, the edges representing roads had less value than other edges representing river or maritime routes.

Finally, the ability to see graphically and quantitative the morphology and the costs and time transportation values which until now they could only be guessed, can open new perspectives and justifications to the speeches made on this topic until today. In fact, the comparison between these results and the analysis of archaeological and historical interpretations should complement each other, clarifying and offering more elements for a global interpretation of the Roman transport and economy.

S17-04 Comparison of regional and local transport networks in 17th and 19th century AD pre-colonial stone-walled structures in the southern Gauteng Province, South Africa

Karim Sadr

Since 2008, as part of the South African National Research Foundation funded 'Southern Gauteng Stone Walled Structures' project a dozen postgraduate research assistants in Archaeology and Geography at Wits University, along with another dozen photo interpreters employed at SBL Geospatial Services in Cochin, India, have pored over freely available satellite images of an >8000 sq km study area between Johannesburg and the Vaal River using Google Earth software. Over 5000 pre-colonial stone-walled structures (SWS) have been detected and classified. This presentation focuses on the Group I and Group II pre-colonial SWS, comparing their distribution and probable transport networks within the 8000 square km study area. Group I structures date to the 16th and 17th centuries AD and represent the earliest Iron Age settlements in the study area. Previous studies on a restricted sample of Group I SWS suggest they represent a relatively egalitarian, more pastorally oriented society with a relatively dispersed settlement pattern. Group II structures date to the late 18th and early 19th centuries AD and are generally regarded as representing fairly complex and densely nucleated societies of Tswana-speakers in the immediately pre-colonial era. Using spatial modelling and analysis techniques, such as GIS-based cost surface and social network analysis, an attempt is made to compare the probable transport networks of Group I and II SWS at the local and regional scales. This involves the application of transport network modelling in the same landscape and environment but on two separate chronological periods. Combined with quantitative analysis, the aim is to see how the proposed differences in social, economic and political organization of Group I and II SWS that were ascertained through standard settlement pattern studies, might be reflected in their respective transport networks.

S17-05 Modelling the road network of central Cappadocia (Turkey): A matter of 'cost' and 'visibility'

Jacopo Turchetto

Analysing, reconstructing and modelling ancient road networks within a mountainous context is mostly a challenge. Often, several aspects and factors (both anthropic and natural) need to

be taken into consideration at the same time, in order to propose a plausible hypothesis as for the route of the roads. The exploitation of the potential of Cost Surfaces and the subsequent creation of Least Cost Pathways (LCP) can produce very interesting results, in particular if GIS-derived paths and historical/archaeological proved routes are compared in order to understand which factors could have played a major role in the definition of the layout of those same routes. In this paper, such a post-dictive approach has been applied to a specific case study, i.e. to the road system of central Cappadocia (Turkey), which is a semi-flat district strongly conditioned by the presence of the volcanic group formed by the Hasan Dağı, Göllü Dağı and Melendiz Dağları. Moreover, in any consideration of the morphological characters of that Cappadocian landscape, LCP are also combined with another factor, which surely played a central role in the itinerary choices adopted in that territory during the Byzantine era: visibility. In a period of instability, due to the different incursions which, between the 6th and the 9th centuries, made Cappadocia a strategic territory along the frontier line between the Byzantine Empire and its neighbours, the level of visibility (or invisibility) of the roads and from the roads really influenced the 'history' of those same ways of communication, together with the various settlements lying around them. The GIS-based modelling can reasonably explain the change which took place in the communication system of Cappadocia between the Roman and Byzantine periods, allowing to better understand the role and the functions of those road axes, and to evaluate the Byzantine military strategies in central Anatolia.

S17-06 Testing the validity of network analysis results in research on local transport networks

Mark Groenhuijzen, Philip Verhagen

Computational archaeology provides valuable tools for the reconstruction and analysis of transport networks. One such approach is a combination of a network constructed using least-cost paths and network analysis (Verhagen et al 2014, Groenhuijzen and Verhagen 2015), which can potentially provide valuable information regarding settlement location choice, site hierarchy, the role of settlements in transport networks and so on. However, testing the validity of the network analysis results and the archaeological interpretation thereof has so far been largely neglected. One of the key questions is thus: how reliant are the results of network analysis and their interpretation on nuances and uncertainties in the methodology and the dataset? This paper aims to test the robustness of network analysis results by measuring and analysing the development of local network statistics in randomly emerging transport networks. It is applied on a case study involving the Dutch part of the Roman limes, an area which is particularly interesting for research on local transport networks in the light of social and economic relations between the local rural population and the Roman military population, and an area for which a large amount of archaeological and palaeogeographical data is available.

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S17-07 The need of topographic restitution in local mobility analysis

Diego Torres-Iglesias

When we conduct a landscape archaeology study in a GIS environment (especially the analysis of mobility) we should be aware that any territory undergoes a transformation, especially in the last 50 years.

The Digital Terrain Models on which the study is based depart from the current topography (whether models from contours or the latest from LiDAR point clouds), so the lack of a correction and topographic restitution it can lead to certain errors, as can be the layout of an optimal path on a current road, an industrial area blocking sightlines or the impossibility of study a valley submerged in a dam. The probability of obtaining these errors increase in inverse proportion to the cell size of the digital model, and we need high resolution models if we want a higher accuracy in the calculations and results over the previous relief; the examples in this paragraph are evident when we work with a 5x5 m. DEM.

For all these reasons, it is essential to make a correction that brings us as closer as possible to a hypothetical paleotopography that allows us, among other things, know the evolution of a particular territory or calculate least cost paths avoiding "current interferences" such as the aforementioned actual roads, towns or, if we have the help of historical planimetry and orthophotos, opencast mines, dams and other significant alterations in the landscape.

S17-08 From sea to land: Reflections on freight traffic during the Iron Age of the Northeastern Iberian peninsula (6th to 1st centuries BC)

Joan Canela Gràcia, Núria Otero Herraiz

It is known that maritime and fluvial shipping were the most efficient means of transport for distributing freights during the Antiquity. However; the distribution of goods to certain inner cities or significant Iberian settlements raises many questions. In this regard the use of carts and pack animals was common, but the roads the Iberian people travelled are mostly unknown.

The objective of this paper is studying overland travels during the Second Iron Age in the northeast of the Iberian Peninsula. In this regard, the application of the least cost paths calculation methods should provide the opportunity to define the basis of a hypothetical Iberian road network during this period in the area. The results will be compared with the historic roads, in order to detect the presence or the lack of coincidences among them. This subject will be approached through two study cases, concerning two different political, ethnic and geographic territories. In one hand we have the Iberian Cessetània, located in the coastal area, which grosso modo coincides with the province of Tarragona. On the other we have the western Ilergetia, a territory wich is nowadays split among the provinces of Lleida and Huesca. This area has been from ancient times a well known communication hub towards the inner lands of the Iberian Peninsula and the Atlantic coast, due to the significance of its fluvial networks.

In conclusion with this work we pretend use the GIS least cost paths calculations in order to approach the Iberian terrestrial transport networks and their persistence over time and landscape.

S19 New technologies and archaeology: The impact of the digital revolution

Anne Moreau, Federico Nurra

The interest of digital technologies for archaeological data exploitation and analyse is well-known as shown by many papers at previous CAA conferences. The "new technologies" including photogrammetry, three-dimensional modeling, GIS (not so new), agent-based model, internet and its consequences—opendata, Openaccess, Geolinked data- are nowadays integrated within the archaeological research process and some of them are about to be the new tools of the archaeologist for his daily work. It is not over: we live in a time of technological transformation. What are the changes brought up by the introduction and the diffusion of the new technologies? How does it change our practices and our way of thinking archaeology? Is that better or only different? Accordingly, this session aims at focusing on the following issues:

- the consequences of the data digitalisation and the field data recording (efficiency? fiability?)
- the changes raised by the new technologies in the ways of working and the organisation of work
- the way of exploring the data : spatial analyses, statistical analyses, three-dimensional modelling etc
- relationships between the scientific problematic and the tool contrived and used
- the archiving of data
- the definition of data and metadata
- the sharing of data, the diffusion of knowledge
- the collaborative working
- the training of the archaeologists
- the definition of the professions involved in producing archaeological data
- ...

The session will explore the questions raised above through different cases studies exposing how the new technologies are used and what are the changes involved. One of the consequences of the widespread use of the new technologies is the ocean of data produced, forgetting sometimes that archaeology, even digital, is a human science.

S19-01 Towards a national infrastructure for semi-automatic mapping of cultural heritage in Norway

Martin Kermit, Øivind Due Trier

Recently, the Norwegian government decided to finance a new national digital terrain model (DTM) based on airborne laser scanning (ALS) at 2 pulses per m² in forested areas and automatic image matching above the tree line. This may open up for semi-automatic mapping of cultural heritage in any region of interest in Norway, provided that the cultural heritage being sought manifests itself in the DTM. However, this calls for the development of a national infrastructure combining the storage and retrieval of ALS data with automatic detection methods.

A pilot web portal for this infrastructure has been developed for use by archaeologists in some county administrations in Norway. The user specifies an area of interest, and selects which types of cultural heritage to look for. Since the new national DTM is not implemented yet, the user will need to upload an ALS data set. As the processing of large ALS data sets may be time consuming, the user will be notified when the task has been completed by an e-mail, which also contains a link where the processing result in the form of vector files may be downloaded.

Currently, semi-automatic detection of the following types of cultural heritage is supported: grave mound, pitfall trap, charcoal burning pit, and charcoal kiln. We plan to add semi-automatic detection of hollow ways and stone fences.

The output is one set of files for each type of cultural heritage. Within each type of cultural heritage, the detection results are grouped into six levels of confidence. The detections should be viewed and evaluated successively by an experienced archaeologist; starting with the highest confidence level.

The pilot portal is already a useful tool for archaeologists in the participating pilot counties in Norway, and demonstrates the need for a national infrastructure for processing of ALS data.

S19-02 Autonomous stereoscopic photosphere system for archaeological site virtualization

Dimitri Schreiber, Dominique Meyer, Dominique Rissolo, Falko Kuester

Over the last decade remote sensing has greatly improved in both its realism and coverage. Miniaturization and reduction in the cost of sensors, as well as game changing advances resulting from the development of new technologies have played a critical role in these improvements. This oral paper will explore an imaging technology, CaveCamX, that has been enabled as a result of these advances. CaveCamX is a small binocular two axis gimbal system used for creating high resolution 3D photospheres, combined with GPS and IMU data. This enables better coregistration internally within a single photosphere, and externally between heterogeneous datasets, including fusion with point clouds generated from Photogrammetry and Lidar. This decreases human processing time by automatically recording location and orientation of the dataset which would previously be recorded manually and therefore often left out or lost. The attitude data will hopefully enable fully automatic stitching of stereoscopic datasets without the commonly associated motion sickness by constraining the system, limiting how the software can warp the images. Its small size and low power consumption allow it to be easily taken with on field expeditions, without compromises in photo quality or excessive weight, like other systems. CaveCamX enables remote visualization of archaeological sites, allowing researchers to be virtually immersed in the captured scene without having to travel across the globe to be physically present, with high resolution (1GP sized datasets). It enables researchers to remotely view an area as if they were there (with the constraint that they are limited to a few locations in the area) with great detail, in contrast with other systems like LIDAR which provide different advantages.

S19-03 Systematic literature review on automated monument detection: A remote investigation on patterns within the field of automated monument detection

Karl Hjalte Maack Raun, Duncan Paterson

Automated procedures are necessary to cope with the vast amounts of digitized information within the field of cultural heritage. During the last 15 years, digital landscape analysis and detection of cultural heritage monuments developed rapidly especially due to the availability of LiDAR data. With the increasing amount of information, automated procedures are suitable for monitoring and surveying known monuments, as well as detecting unknown monuments. This study measures the state of automated procedures within cultural heritage detection and management, by correlating key terms for LiDAR data with academic citations of their use. Cross-referencing this impact measure with occurrences of "automated procedures" enhances our understanding of best practices. We analyze these results, using the methods of network analysis (NA) with respect to personal, institutional, and financial ties and actors involved in automated monument detection. In addition, a Systematic Literature Review (SLR) using standardized search structures on publications related to "automated monument detection" for LiDAR data from 2000 to 2015 reveals the evolution of the field. The observable trends and patterns within the combined results of (NA) and (SLR) allow for a critical assessment of current research practices. Based on these results we conclude by formulating recommendations for future implementations.

S19-04 Spatial analysis of Ancient Egyptian Monuments. Case study: Late Period private funerary monuments of Thebes

Anja Wutte, Peter Ferschin, Georg Suter

The term of rock-cut tombs describe a type of funerary monuments found all over Egyptian history. Their designs and building concepts show a strong coherency within their local occurrence, in a specific timeframe and even within a social status class. The chosen case study was analyzing private funerary rock-cut monuments of the Twenty-fifth and Twenty-sixth Egyptian dynasty, located in the Asasif, in Theben West, the modern Luxor. The major goal for this project was to obtain design principles of those rock-cut funerary architectures. The structures were digitalized and converted into a BIM (Building Information Modeling) model to be analyzed for certain architectural properties (e.g. accessibility of spaces and areas like semi-public offering places and non-public cult places, decoration positions and natural lighting). Social, local and chronological data was integrated and the models could be compared with each other on the basis of those informations. Questions like the relationship between different premises and natural lighting, the position of decoration categories or the differences of semi-public and non-public parts in ratio to their accessibility could be answered. These analytical methods offer insights into the design principals of the monuments. Additionally a Model Comparison Tool was implemented to offer interactive and visible information about the building typologies of the funerary monuments. This tool visualizes information about the buildings in combination with additional metadata (e.g. social parameters) within an abstracted spatial representation of the building. The monuments can be arranged by a set of parameters like social rank or sex of the owner, chronology of construction and land consumption. The developed tools are independent of archaeological content and type of buildings.

S19-05 Optimization in the co-registration of large point clouds for archaeological visualization

Dominique E Meyer, Jamie Hodgkins, Fabio Negrino, Christopher E Miller, Caley M Orr, Falko Kuester, Stefano Benazzi, Marco Peresani, Julien Riel-Salvatore, David Strait, Matthias Czechowski

Photogrammetry has been used in Archaeological studies to gather 3D data of sites and artifacts. Improvements in imaging systems, stitching algorithms and computation power has increased point cloud sizes and densities. Open-source and commercial softwares often cannot handle very large point clouds, making it cumbersome and difficult to combine large data sets. We propose a novel workflow to optimize the merging of large point clouds and visualizing them. Sites are often reconstructed at different scales ranging from square kilometers for environments to millimeter details on the ground. Aerial Surveys can be used to create large Digital Elevation Models (DEM) and they can contribute 3D models of buildings and architecture which is not easily accessible. Handheld photogrammetry and LIDAR scanning can be used on the ground to gather high accuracy models of structures, interiors and artifacts. A case study of the Arma Vairana Cave in Liguria, Italy, is presented where nine aerial and ground point clouds were merged into a fully immersive point cloud.

S19-06 3D survey for archaeology: When the solution can be a problem

Angela Bosco

The introduction of sophisticated survey techniques in archaeology has led to clear improvements in the acquisition process, making faster some operations and allowing unprecedented accuracy. But archaeology is really able to manage these oceans of data? Although the perspectives are very interesting and challenging for the research, the feeling of not having yet fully exploited the potential of this instrument is strong. Archaeology (among

other disciplines) insists to use the 3D as a kind of "advanced" 2D, thus losing its main benefit: the volume. On the other hand, research experience in Italian archaeological sites such as Pompeii, Herculaneum and nearby areas, allowed us to meet and deal with different issues. The article aims to address the problems of acquisition, processing and subsequent restitution of the extracted data of three-dimensional survey, whether by laser scanner or uncalibrated photogrammetry, both terrestrial and aerial. Also, issues relevant to the post-processing of the point clouds and the management of huge amounts of data are treated. Practical examples clearly show the need (i) to clarify what are the products that can be obtained from the application of each survey technique, (ii) to give information to correlate the products with the aims of the specific archaeological study, (iii) to give guidelines for the right integration of the different techniques in order to take full advantage of their potential and to allow that 3D survey will be seen not only as a container of infinite planes, sections and ortho-rectified photos, but as a real database itself, that can be queried to get 360-degree information.

S19-07 Interpolating 3D stratigraphic information from written excavation reports

Ana Predoi, Lutz Schubert, Keith Jeffery

Early excavation reports of around 1950 already employed meticulous recording techniques, yet fail to respect a lot of aspects concerning information that would help in generating relational information about a site's organization at different times, such as recurring occupation of sites during specific seasons. The interested archaeologists either have to rely on their ability to mentally visualize the information or painstakingly map it out on paper and try to generate some layout information this way. Such information is however typically not shared further and rarely takes additional concerns such as geological constraints into consideration. In this paper we present an approach that generates a rough / indicative 3d model of the stratigraphic layout of an excavation on the basis of stratigraphic profiles (along the excavation walls) and potential planar maps (insofar as they exist). The approach can take the location of finds into consideration, given that the according data (coordinates and stratigraphic layer they were found in) is reported. We propose and discuss different approaches to align the 3d model with the profile data. Obviously, the model will fail to reproduce any irregularities that were not recorded by the excavators, but we will show how geological information can be taken into consideration to improve the regular(!) properties of the stratigraphic layout, even without further information given. The paper discusses whether such models are sufficient for archaeological discussions with a particular reference to site occupation and usage.

S19-08 3D photogrammetric documentation in the archaeology of the contemporary past: Preserving the World War II landscape in North-West Sardinia (Italy)

Alessandro Panetta, Paola Derudas

Since the publication of Paul Virilio's "Bunker Archäologie" in 1975, there was an increasing interest in the archaeological study of the 20th century wars, especially WWII. This research takes into account a database of nearly 200 surveyed and inventoried military buildings and pillboxes built in 1943 for the coastal defense of the north-western Sardinia (Province of Sassari). Our aim is objectively documenting this particular archaeological record looking at its preservation both as a material and as a cultural heritage of European history, objectively, by the study of topographical organization of these buildings, their relationship with landscape and their internal space division according to their different tasks. We need to document this fragile heritage in his 'becoming archaeological', recognizing the historical and archaeological dimension of these often considered simply 'old' concrete buildings scattered in the countryside, before they become 'ruins', with their slow steady consumption. For this

reason the target of the research is the preservation of the memory of war, by the preserving and knowledge of its physical scars like these buildings are. To do that, we propose the use of 3d documentation technique, for the development of this 'en plein air' museum, making it accessible also by remote devices, due to the often difficult access to them on the ground. The 3DHOP presenter was chose to reach the goal. It is a flexible framework that allows to manage and handle 3D contents, also big ones, in a very easy way and through a series of ready-to- use templates. It will possible to take digital tours of the buildings, both outside and inside of them and the visit will be enriched by connecting multimedia data, such as related historical information and images. Some details will be highlighted through zooming tools, useful to catch and direct visitors' interest to the main contents.

Cancelled S19-09 Letter from the trenches: Challenges and strategies in the development of a digital collection management architecture

Torkel Johansen

The paper discusses current challenges and strategies being implemented in the ongoing renewal of the national, digital collection management infrastructure in Norway. For the past decades, the archaeological museums in Norway have cooperated in the development of digital solutions for collecting and managing archaeological data. Several projects have been conducted, renewed or replaced during this period, both at a local and a national level, rendering a complex inheritance of systems, practices and data-sets. Simultaneously, the rapid development of new documentation technologies and -practices are posing significant challenges to traditional curating practices, such as the systematical collection, management, preservation and dissemination of the source material involved. Arguably, these challenges cannot be solved through technology alone, but rather through the development of persistent enterprise- and information architectures that support traditional museum objectives.

S19-10 A proposal for a collaborative Web Mapping for archaeological spatial data: OpenArcheoMap

Federico Nurra

This contribution would present the results of a research project developed during a PhD thesis: an open and collaborative Web Mapping platform on a global scale based on XML interchange protocols and accepted standards, in cartographical terms but also from an archaeological point of view. The last thirty years of computer applications dedicated to the detection and positioning of archeological findings have produced a multitude of information systems for the storage, systematization, publication and sharing of spatial data. In this paper, we will focus on the minimum specifications that the archaeological data should have in order to be uniform and interoperable, and above all, on the geometric and cartographic characteristics that would allow the production of a homogeneous archaeological mapping. Until this moment, the proposals for the production of archaeological cartography have been developed at local, regional, national or, with rare exceptions, continental scale. Thanks to recent advances in information technology, it is now possible to create an open platform for the implementation, storage, exchange, discussion and verification of spatial archaeological data on a global scale. We will identify the primary categories for the acquisition of archaeological data, by defining the minimum standards of compliance of the data, without, however, trivialize the data themselves, with a consequent dangerous loss of historical-topographical information. It will be fundamental to identify the four coordinates of objects acquired and a minimum data set of attributes, plus a set of metadata, essential in order to recognize the origin of the data, their nature, their authorship, production, quality and reliability. The proposal will be therefore the development of a Web Mapping platform, open and collaborative, for positioning and representation of archaeological remains, a sort of

"cadaster", and an analytical and detailed knowledge base to assist, support and address each territorial study.

S19-11 HumanOS Project: A nomadic osteological inventory

Rozenn Colleter, Guillaume Roy, Thierry Gaugry, Jean-Baptiste Barreau

Three computer specialists and an anthropologist have created and developed an application called "HumanOs" to facilitate the registration of human bones from archaeological sites. This is a simple osteological data acquisition and management tool to deal with significant quantities of human skeletal remains, count and locate them.

An intuitive graphical user interface has been developed, allowing to add osteologic items in a dynamic and ergonomic way. The application is intended to be free, open source, nomadic, intuitive and suitable for any device support with an online version that operates on Google Chrome, Firefox, Internet Explorer and Safari. An offline version, that can run on any local web development environment, is also downloadable to work when the archaeological site has no network connection available. The Université Paul Sabatier - Toulouse III will host the source code.

Regarding the use and after filling out the name of the archaeological site, the number of burial and skeleton (if several are available), the operator can easily record the presence and state of conservation of each bone with a specific color code (green : preserved to over 50%, orange : less than 50%, red : undetermined or white : missing). The user can move or zoom on the skeleton to reveal underlying bones (cervical vertebrae under the skull and thoracic vertebrae under the sternum and the manubrium) with a mouse or with fingertips on tactile supports. The name of each bone appears as a banner on the support to confirm identification in order to help the operator, for example in the case of carpus bones. This application also allows to itemise the number of the skeleton conditioning bin and a commentary. All these information allow to rapidly process the material at the time of the study or delivery of collections to the State. The preservation schemas can be exported as vector image SVG files that can be used by all CAD softwares.

S19-12 Using GIS to study ancient landscapes. The case study of the Pisa centuriation (Italy)

Arianna Commodari

The utilisation of GIS and spatial analyses help answer the phenomenon of an ancient agrarian system's transmission from Roman period to ours days in the plain of Pisa. The paper, in the first section, describes the methodological approach used to collect, to manage and to explore the data base consisting of cartography, archaeological, geological and hydrological data, in a GIS system. The study of the form and structure of the agrarian landscape carried out on various documents (aerial photographs, modern and ancient cadastres, satellite images), and the analyses of hydrological and environmental characteristics realised with the utilisation of GIS permitted understand the conditions and the process of transmission of the centuriation (ancient agrarian system) over the centuries. In the second part are showed the spatial analyses (DTM and interpolation analyses) which bring new elements to the reconstruction of the ancient landscape. The last section focuses on the statistical analyses realized on the agrarian and urban parcels inside the centuries, to solve historical and morphological problems. In conclusion, the "new technologies" apply to the archaeological research permit to collect and manage different informations, to propose new interpretation and are fundamental tools for an interdisciplinary approach on the study of the ancient landscape.

S19-13 Discerning and explaining shape variations in Later Stone Age tanged arrowheads, South Africa

Ilan Ryan Smeyatsky, Karim Sadr, Patrick Randolph-Quinney

Over the past decade a new method of statistical shape analysis, geometric morphometrics, has been applied to the study of artefact shapes. Later Stone Age (LSA) tanged stone arrowheads have been analysed with geometric morphometrics and reveal spatially coherent variations in their shape. These spatial variations may indicate stylistic or other kinds of boundaries between different elements of prehistoric San populations, and understanding them can shed light on the social and economic organization of southern African hunter-gatherers during the later Holocene.

S19-14 Structuring data from documentary study and archives for spatial studies.

Examples from funerary archeology

Jean-Philippe Chimier, Matthieu Gaultier, Isabelle Pichon

Several archaeological studies have recently been conducted in the region of Tours (Val-de-Loire, France) on village cemeteries. They consist in assessments carried out through small excavations, mechanical test pits and construction monitoring. The field projects are associated with a study of archives (written and cartographic sources) and a documentary study (old excavations and discoveries, documents, local knowledge)

The usual documentary study aims at guiding the implementation of the excavation. The latter then provides most of the information. In certain cases, such as ours, the old documentation allows to understand the remains which result from limited observations.

The spatial study of these sites occupied in the long term requires the management of the archaeological documentation in a database or directly through the GIS software. This is also the case of the information given by archives and documentary studies that needs to be structured beforehand.

Nevertheless the structuring of the data is not an obvious fact. It only proves useful when georeferencing the information. The old documentary or archive studies performed without SIG locate the information in the form of a map while the current studies tend to spatial analysis.

This new approach requires the establishment of a catalog of datas aimed at their ranking according to their attributes, intended for analyse. The preliminary definition of attribute information is based on questions derived from a problem that must be mastered beforehand. Village funeral groups of the diocese of Tours are particularly well documented by the textual and archaeological sources and have been sufficiently studied for the last twenty years to introduce changes in the structuring of the data from archives and documentary studies toward the systematic use of GIS, particularly in preventive archaeology.

POSTER

S19-P1 From the field to the showroom: The Augmented—Reality Kilns ExhibitOn (ARKEO)

Alexis Gorgues, Florent Comte, Sonia Syllac

In 2015, the four years old LABEX Bordeaux Archaeological Sciences (LaScArBx) inaugurated an exhibition summing up its first and main results; among these, the results of the investigation project "The pottery in the Ancient Mediterranean: the Iberian Case". One of the main action of this program consisted on the excavation of the 3rd-1st cent BC Mas de Moreno (Teruel, Spain) potters' workshop. During this excavation, and since 2012, a 3D scanner was used for recording excavated structures (mainly kilns) as well as some artefacts (pots, loom weights, tools^{ÔÇª}), in order to optimize the quality of the archaeological data.

These data have been first used for scientific purposes (as support for virtual experiments), then for communicating scientific results in an academic context, and, least but not last, as a medium for augmenting an exhibition aimed at a wide audience, on the specific context of the exhibition we previously referred to. In this poster, we would like to present the process we used, from the field recording to the elaboration of easy-to-use 3D models. The presentation will be subdivided into 3 different parts. Part 1 will document the field recording with an Artec EVA scanner. Part 2 will analyze the data processing phase, and present the first experiments of field-data-based infography, aimed at a scientific public. Part 3 will consider how we "reconverted" these documents in interactive, augmented reality models within the exhibition. These models, imported as assets in Unity 3D, were accessible through tablets, thanks to the Vuforia Platform, and allowed the integration in a panel-based exhibition of "virtual objects" (a kiln, a potter's stamp, a pot, a tool), that could be manipulated and closely examined by the visitors, thus enhancing their experience.

S19-P2 Roman archaeology and GIS visibility studies

Mar Zamora Merchán

Since the introduction of Geographic Information Systems (GIS) in archaeology, the study of visibility from (and around) a particular viewpoint has been one of the most popular GIS applications. This poster deals with the study of visibility through GIS in Roman archaeology. The poster will show a numerical (and graphical) review of GIS visibility applications in roman archaeology (viewshed, Line of sight (LOS) and related tools). The main aims pursued are as follows: - identifying preferred application contexts; - to assess the impact of this kind of GIS tools in the research of the Roman period.

Papers published on the past CAA proceedings will have a particular treatment.

The poster is intended for researchers interested on viewshed and related tools, specially for those working on Roman archaeology, and also for students involved with GIS learning (since an array of different GIS applications related to visibility studies will be mentioned).

Cancelled S19-P3 Digital strategies and workflow. Case studies from large scale excavations in Central Norway

Raymond Sauvage, Magnar Mojaren Gran

Ever since the typewriter gave way to the PC, there has been a rapid increase in new digital ways to produce, record and process archaeological data. We now seem to have reached the point where the analogue way of doing things has become a major speed bump in the workflow of archaeological excavations. One example is digitalization of analogue data, which makes for double work hours and illustrates the need for a total digital strategy and workflow, for on site as well as off site work.

To develop new strategies and better workflows for digital documentation, we need to recognize not only the potential for use of new technology, but also its limitations. We need to consider the level of quality we wish to achieve as the end result of our excavations — not only the efficiency compared to already established methods.

S19-P4 Why 3D printing technique is the useful tool for artifact conservation

Wuyang Shui

Artifact was one of most important and valuable resource of cultural heritage. Only a limited number of artifacts were exhibition in other museums considering safety and precious, therefore it was a good solution to provide replicates for publics visit. Many of artifacts were still broken and needed artifact conservators restoration, therefore the new techniques should be considered to improvement the restoration speed and reduce prevented further damages. Hence, artifact conservators faced two tasks: how to easily and accurately to replicate artifacts

and how to produce physical model of missing region to restore the damaged artifact. In last two decades, 3D laser scanning technique has acquired both geometry and texture information of object and three-dimensional printing technique (3DP) has successfully converted the digital model to lifelike physical model. Therefore, the hybrid technique combining digital modeling, geometry computation and 3DP has gradually application in various applications. In this paper, we firstly reviewed the laser scanning and 3DP techniques, and analyzed the advantage and weakness of 3DP. Then, we described the technique pipelines of geometry computation and 3DP applications, especially the computation of missing region in detail. Finally, three case studies were illustrated, including artifact replicates(such as Wa dang, Chinese architecture), guiding heavy fractures reassembling (Terra Cotta Warriors and horses) and missing regions production(damaged bronze Gu of the Forbidden city), which described how laser scanning and 3DP techniques were implemented to support artifact conservators to overcome the limitation of traditional manual technique. With the cost of 3D printer and printing materials falling, printing precision improving and printing materials developing, we considered more and more artifact group require 3DP to help them.

S20 Computer vision vs human perception in remote sensing image analysis: Time to move on

Arianna Traviglia, Karsten Lambers

The (slow) emergence of semi-automated or supervised detection techniques to identify anthropogenic features over remote sensing imagery have received mixed reception in the past decade, with critics stressing the superiority of human vision and the irreplaceability of human judgement in recognising archaeological features, and supporters working toward the development of (semi)automated computer vision methodologies to streamline the screening of aerial/satellite imagery. This limited development has been due to a number of reasons, of which probably the most relevant are, on one side, an uneasiness of archaeologists in handing over—even partially—the interpretation process to machine-based judgment and, on the other, the fact that archaeological features can assume a near-unlimited assortment of shapes, sizes and spectral properties, which makes particularly challenging their auto-extraction. Thus, while (semi)automated and supervised procedures for feature extraction and processing are flourishing in a variety of fields, allowing for large swathes of landscapes to be simultaneously investigated, their application to archaeological and, more generally, cultural landscapes is still in its infancy.

A number of approaches in Feature extraction, Pattern Recognition, Pattern Matching, to name a few, now offer the opportunity to adopt (semi)automated feature detection and processing methods to identify potential archaeological features. These approaches can overcome the previous limitations of spectral and object-based methods and enable recognition of landscape patterns/features produced by a variety of diverse natural or artificial elements.

This session invites presentations showcasing computer-vision methods that are being used or developed to automatically identify landscape features and/or patterns on remote sensing imagery and it is—purposely—open to research employing broadly defined 'remote sensing data'. The session also welcomes controversial papers examining more broadly the subject from a theoretical point of view and addressing the topic from an antagonist angle.

S20-01 Why, when and how? Context and computer vision in archaeological prospection and interpretation

Dave Cowley

As the session abstract identifies, the debate over applications of semi-automated or supervised feature extraction techniques in archaeology has tended to be polarised between believers and doubters. In large part the polarisation of discussion probably stems from a lack of explicitness about how archaeological feature identification is undertaken and how the processes, whether 'automated' or 'human', of identifying patterns, shapes and features interrelate with archaeological interpretation. Furthermore, the varying contexts of these processes in multi-scaled archaeological prospection have not necessarily been defined as fully as they might. Such ambiguity is unhelpful to exploration of the potential of new techniques, and the interfaces between traditional archaeological skills/knowledge and emergent tools. It also makes definition of common purpose difficult. This paper will explore these issues, looking to address the reasons why the application of computer vision to archaeological prospection is vital, but also examining the workflows and outcomes of different approaches and processes, both manual and automated. These are important steps in addressing some key questions, including: how can we create clarity about why and when automated approaches are desirable?; what are the roles of (traditional/manual) archaeological experience and skills in designing algorithms?; and how can automated/manual approaches be used iteratively to improve archaeological detection?

S20-02 Computer vision applied to historical air photos: The registration and object detection challenge

Sebastian Zambanini, Fabian Hollaus, Robert Sablatnig

This paper addresses the problem of automatically analyzing aerial photos taken during World War II air strikes. The goal of this work is to locate unexploded ordnances (UXOs) for risk assessments, enabled by the registration of the historical air photos to modern-day satellite images and the detection of military objects (e.g. bomb craters or trenches). The work is part of the DeVisOR project which aims at supporting the tedious task of creating UXO surveys in a semi-automatic manner by means of powerful image analysis methods and interactive visualization techniques.

In this paper we focus on the image analysis part and present the specific challenges that arise when working with this kind of data. For registration, the strong image changes caused by time spans of around 70 years hinder the reliable identification of correspondences between the old and new images, especially in non-urban areas. In combination with the generally low image quality of the old aerial photos and the appearance variations caused by illumination changes, a straightforward solution based on standard algorithms using key point matching and sample-based transformation estimation does not exist. The same problem appears for the detection task, which is additionally impeded by the absence of large amounts of training data. Consequently, innovative solutions are required that are tailored to the specific conditions of the problem.

S20-03 Semi-automatic detection of charcoal kilns from airborne laser scanning data

Øivind Due Trier, Arnt-Børre Salberg, Lars Holger Pilø

This paper presents new methods for the semi-automatic detection of charcoal kilns from airborne laser scanning (ALS) data.

The 17th century saw the establishment of a number of iron works in Norway, based on the need of the Danish king for iron for ships, armaments and other military purposes. The iron works at Lesja, Oppland County, was established 1660. Surveys in connection with cultural heritage management work have pointed to the presence of large numbers of charcoal kilns in the area surrounding the Lesja Iron Works. It was not known, however, what the total number of preserved kilns was, if they showed sign of reuse, and how they were distributed throughout the landscape.

In 2013 the entire forested valley in Lesja was mapped by ALS with five first returns per m². The initial visual interpretation of the ALS data, focusing on the central area, yielded about one thousand possible charcoal kilns. All were round, with a diameter between 10 and 20 m. However, the edge of the kilns had a varied topographical expression. Some kilns had a ditch surrounding them, some had pits, and some had a combination of the two. In addition some kilns had a low mound inside the ditch/pits or even pits inside the circumference.

In order to conduct a complete mapping, covering the different shapes of charcoal kiln, several detection methods are used: (1) mound detection, (2) pit detection, (3) circular ditch detection, and (4) partial ditch detection. Although many individual charcoal kilns are missed by the automatic detection methods, many are also detected, leading the archaeologist to look for additional charcoal kilns nearby. In conclusion, the automatic detection methods are improving the quality of visual interpretation of the ALS data, and make the field work more efficient.

S20-04 Two methods for semi-automated feature extraction from Lidar-derived DEM designed for cairn-fields and burial mounds

Benjamin Stular

We are in agreement with the session call that among others a reason hindering more efficient emergence of semi-automated or supervised detection techniques to identify anthropogenic features on remote-sensing data are critics stressing the irreplaceability of human judgement in recognising archaeological features. In the case of the Lidar-derived data, it seems, the prevailing reason is the fact that archaeological features come in a near-unlimited assortment of shapes and sizes, though. Thus, the successful efforts so far have been focused on a limited number of homogenous feature types that appear in great quantity, i.e. roads, open mining shafts or cairn-fields. We are presenting two methods developed for semi-automated detection of individual cairns within a cairn-field. The first method is based on the standard-deviation-of-elevation based local relief and subsequent classification of 2D shapes. The second method is based on peak finding algorithm. Both methods are implemented in existing free GIS software packages. The pipeline for the two methods will be presented. The results will be showcased and discussed on two different case studies aiming at providing not just an "ideal" condition but also a very demanding one.

S20-05 Using eCognition to improve feature recognition

Iris Caroline Kramer

While automated feature recognition is still in its infancy in archaeology, within the geosciences recent developments have allowed its application to much more irregular typology, such as the supervised classification of landslides. This success is largely due to the geographical object-based image analysis software TRIMBLE eCognition. In archaeology, this programme has been applied to some extent, yet new additions to the array of available methods require a re-evaluation of its potential for feature recognition. For instance, the ability to integrate LiDAR data and aerial photography has long been desired within archaeology. Additionally, the ability to transfer rulesets for the detection of common features can facilitate data and knowledge-sharing amongst researchers. The case study will present three different automated detection methods; using the well-known eCognition ruleset generation based on cognitive reasoning; self-learning algorithms; and adaptive template matching. These techniques are applied to round barrow detection in the Avebury region in southern England, specifically distinguishing between the known variations of barrow, bank and ditch. Each method is assessed according to its usability for large regions and its potential for detecting variable features and complex shapes. The algorithms are intended to prioritise cognitive aspects of human vision such as elevation, size, shape and texture, using the LiDAR data and aerial photography. It is also stressed that ruleset exchange for generally known features and processes is highly important for mapping large areas across borders and is intrinsically supported by eCognition.

S20-06 Automated detection of stone-walled ruins using based on support vector machine and histogram of oriented gradients

Amandine Robin, Karim Sadr

Aerial or satellite imagery allow archaeological surveys of large areas for a fraction of the time and cost of ground surveys. Nevertheless, the task of examining reams of air photographs or zooming into details on Google Earth is also a time consuming exercise. Therefore a desirable objective is to find a way of automating the detection of archaeological sites on remotely sensed imagery.

This new method proposes an autonomous approach to detect ruins, based on Histograms of Oriented Gradients for feature extraction and on a Support Vector Machine in order to

classify the extracted features into a ruin vs non-ruin class. The support vector machine uses a training set to learn to distinguish the ruins from the rest, and is then applied to a wide area without any a priori knowledge to detect the ruins. The approach is validated over the Suikerbostrand area in South Africa, to identify and classify pre-colonial stone-walled structures in an 8000 km² study area. Over 7000 structures have been identified by a team of research assistants and are used as ground truth. The main challenges specific to this context are that the structures we seek to detect are very subtle and made from locally available material, shapes are diverse and tend to be occluded by other features such as vegetation. Thus, ruins are difficult to differentiate from natural features.

The performances of the method are analyzed depending on the set used for training, and the use of satellite images (LANDSAT, from Google Earth) vs LIDAR images is discussed. In both cases, the results demonstrate the relevance of this approach with a very good level of accuracy (more than 85%) and a good control of the false detections.

S20-07 Experiments in the automatic detection of archaeological features in remotely sensed data from Great Plains USA villages

Kenneth L Kvamme

Numerous prehistoric villages associated with native farming tribes of the Great Plains, USA, have been investigated through ground-based geophysics and aerial remote sensing, including Lidar. These villages vary from 1-20 ha and contain a number of common features including houses of various forms and sizes, ceremonial structures, plazas, and fortification ditches linked with bastions. Within houses, hearths and food storage pits represent features of great interest, important for dating and gaining samples of artifacts, faunal, and botanical remains. Large features are visible to varying degrees in Lidar, normal light or thermal infrared aerial imagery, or in site-wide electrical resistivity data, while hearths and storage pits are detectable through magnetometry. This paper explores whether such features be extracted and automatically classified through computer operations alone. The GIS toolbox offers unrealized potential for the identification of archaeological features in such data, simply because few investigators have attempted to do so. The focus here is on how relatively common GIS tools can be employed for the identification of specific archaeological feature types that exist in Great Plains villages using remotely sensed data. Pre-processing employs image manipulation tools (low and high-pass filters) to simplify noisy data and remove local geological or topographical trends, while Fourier methods isolate and remove periodicities (e.g., plow marks that obscure the archaeological signal). Reclassification tools permit definitions of anomalous objects or potential features. Shape indices give their approximate shapes, their sizes may be calculated, and proximities between them may be determined (though "distance" modules); the last permits realizations of context. Custom filters may be designed to recognize complex shapes through pattern matching approaches. Using these tools, pathways are developed for each of the previously cited feature types of archaeological interest. Collectively, they offer a diverse array of decision making mechanisms for the identification and classification of complex archaeological features.

S20-08 Down to the last pixel: Multiband use for direct detection of Caribbean indigenous archaeology

Till Frieder Sonnemann, William Megarry, Eduardo Herrera Malatesta, Douglas Comer

The use of satellite imagery has been so far very limited in detecting pre-colonial settlement archaeology in the Caribbean. Most superficial evidence of building structures has long perished. What remains are slight topographic modifications, house platforms and small mounds predominantly made of midden and soil that also include ceramics and lithic assemblages. The altered topography together with the surface scatter may however serve as

quantifiable indicators to represent an archaeological site. With the precise location of known sample sites, and the information of areas with no archaeological evidence, the authors use a variety of available data sets, a combination of multispectral bands (Worldview-2, Aster, LandsAT) and SAR (UAVSAR L-band, TanDEM-X) to feed a direct detection algorithm developed at CSRM and Johns Hopkins University. The pre-processed very diverse data has to be exactly matching in resolution and location, feeding a semi-automatic process to cross-correlate the datasets that requires supercomputing. Resulting maps present quantifiable statistical results of areas with similar pixel value combinations, with high probability of archaeological evidence. Three trial areas with sufficient diverse image coverage were chosen on the island of Hispaniola, representing different types of environments and crossing country boundaries, situated in Dominican Republic and Haiti. All areas have a number of sites identified through non-systematic surveys. A fourth region where a systematic survey was performed over a smaller area is used as a reference to validate the method.

S21 Linked pasts: Connecting islands of content

Leif Isaksen, Keith May

While ever more archaeological and historical content is available online, direct connectivity between independent resources remains comparatively rare. Semantic Web and Linked Data approaches are just some of the possible mechanisms which can facilitate interconnections and this session will be dedicated to presenting concrete examples of any activities which promote cross-navigations, discovery and integration of heterogeneous content. Topics for papers may include, but are not restricted to:

- Interface development and user support for ingestion, annotation and consumption
- Management, publication and sustainability of Linked Data resources
- Building cross and inter-domain Linked Data communities
- Processes for establishing usage conventions of specific terms, vocabularies and ontologies
- Alignment processes for overlapping vocabularies
- Engage non-technical users with adopting semantic technologies
- Licensing and acknowledgment in distributed systems (especially those across multiple legal jurisdictions)
- Incorporation within other software paradigms: TEI, GIS, plain text, imaging software, VR, etc.
- Access implications of integrating open and private content
- Mapping the Field—what components are now properly in place? What remains to be done?

Papers should try to provide evidence of proposed approaches in use across multiple systems wherever possible. Purely theoretical papers and those dealing solely with a single data system are explicitly out of scope for this session. Papers which address both social and technical issues, or bridge between archaeology and other disciplines are especially welcome.

S21-01 An ontology for a numismatic island with bridges to others

Karsten Tolle, David Wigg-Wolf, Ethan Gruber

Nomisma.org is a collaborative project to provide stable digital representations of numismatic concepts according to the principles of Linked Open Data. These take the form of http URIs that also provide access to machine-readable information about those concepts, along with links to other resources. We have also constructed an ontology for representing concepts in our thesaurus, and this has been applied to digital representations of physical specimens, enabling linking between specimens in Nomisma-defined numismatic concepts. In our presentation we will describe the processes by which we designed this Ontology with a view to allowing the highest possible flexibility and therefore reducing the barriers to using it. It must be stressed that designing the Ontology was a long-lasting process and is still ongoing. It was often challenging to combine existing requirements and to solve misunderstandings between different parties. We will further present how the Nomisma.org Ontology is used from three different viewpoints. For each viewpoint we will also demonstrate how the numismatic data are already linked to other data sources, thesauri, gazetteers or systems, such as Zenon (<http://zenon.dainst.org/>), Geonames, or others. The goal here is to enable and show how this can be used to combine different archaeological areas with our numismatic data. The back-end system of Nomisma.org: We provide information how we handle data, imports and maintenance issues. Providers of numismatic datasets: Nomisma.org provides the ability to others to publish their RDF datasets (based on the Ontology and with additional modelling requirements) via the Nomisma.org site. For the maintenance of datasets we use Vocabulary of Interlinked Datasets (VoID). We will furthering addition present how the Ontology is currently used by actors outside Nomisma.org (Online Coins of the Roman Empire, Antike Fundmuenzen Europa, Portable Antiquities Scheme, and others) in order to connect numismatic data between different sources.

S21-02 A Linked (Open) Data hub at the Norwegian Directorate for Cultural Heritage: A case study

Carl Anders Olsson

The Norwegian Directorate for Cultural Heritage has since 2014 been working on establishing a centralized Linked (Open) Data hub for its own heritage related digital information. This RDF-hub, which contains content from seven separate databases, has a web based search interface on its top. There is also an associated SPARQL-endpoint which offers both the public and third party developers' access to the open part of this data. The technical infrastructure is built using a standard RDF approach using predominantly open source tools. This proposed presentation aims at giving an overview of the key components of this new infrastructure from both a technical and content wise point of view. It will also address issues concerning the further development of the data hub. Key concepts are issues relating to:

- The benefits or drawbacks of mapping parts of this data to other heritage vocabularies such as EDM, CIDOC CRM etc.
- Challenges with the ambition to share as much of the data as possible with both other governmental agencies and with the public
- New or other uses of the aggregated data in relation to reporting, planning or research
- Potential third party interest and use of the openly shared material in mobile or web based dissemination or in other revenue generating activities

S21-03 Linking periods: Modeling and utilizing spatio-temporal concepts in the chronOntology project

Sebastian Cuy, Wolfgang Schmidle, Florian Thiery

In the last years several web services emerged that manage and make accessible place thesauri for the archaeologies and historical sciences. By making use of semantic technologies these applications are able to act as linked data hubs thereby making possible the linkage of multiple datasets of varying thematic focus and of different structural properties. Another common denominator of archaeological data resources, besides geo-spatial properties, is the temporal classification of research objects. One of the applications that try to assume a role similar to that of gazetteers but for temporal concepts and cultural periods is developed in the chronOntology project.

In this project, funded by the German Research Foundation, the German Archaeological Institute (DAI) together with the i3mainz are developing a system for storing, managing, mapping and making accessible descriptions of temporal concepts. The core of this endeavor is a rich semantic modeling of various existing terminological systems for cultural periods using a data model based on the CIDOC- CRM and its extensions. The use of the rich ontological model provided by the CRM on the one hand permits representing the measurable temporal extent (with the possibility for fuzzy edges) while also making it possible to embed temporal concepts in a network of semantic relationships to other temporal concepts, connected historical regions and thematic contexts.

Besides documenting the general architecture and data model of the project the paper will present possibilities of querying different heterogeneous data resources collected throughout various digitization and digging activities inside the DAI with the help of concepts defined in chronOntology. We will also point out the potential and problems of reasoning over geographically and temporally connected datasets.

S21-04 The Matrix: Connecting time and space with archaeological research questions involving spatio-temporal phenomena and the conceptual relationships between them

Keith May

The most common type of record in archaeological recording systems is the spatial dimension. When recording new layers, buildings, or any physical objects, we measure height, width, depth and for archaeological features we will describe shape in plan and section as well as attributes like profile, diameter and breaks of slope. Recording of temporal information about similar features is far less prevalent, but is still an important (perhaps more crucial) part of the record, particularly for objects where the dates of coins, brooches, or pottery and other 'finds' objects (with relative chronologies) are used for temporal reasoning or inferences about deposition dates and sequences across archaeological stratigraphy. Having divided the archaeology into various units for recording purposes, we use stratigraphy, and associated temporal logical relationships between the physical materials recorded as the 'reasoning glue', in the form of Phases and Periods, to connect all these different spatial and temporal phenomena back together again with various narratives to explain our conclusions. For 'single context recording' most archaeological temporal reasoning is based on the principles of stratigraphic superposition, the "Above and Below relationship" (Harris). But further principles of temporal reasoning are also available (Allen). The CIDOC CRM uses the Allen operators to describe not just superposition but a set of more complex temporal logical relationships that can pertain between archaeological data. This paper will give an insight into how conceptual reference modeling can be used to explore these issues and how associated semantic technologies can enable semantically enriched deductions about the spatio-temporal relationships which fundamentally link such archaeological data together. It will also consider where further work is needed to deal with not just spatial or temporal records but to reason about wholly spatio-temporal phenomena and how this can form the basis for new linkages between archaeological information across space-time.

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S21-05 When data meets the enterprise. How we turned a merger of organisations into a confluence of information

Koen Van Daele, Maarten Vermeyen, Sophie Mortier, Leen Meganck

In 2012 Flanders Heritage Agency was created as a central agency dealing with immovable cultural heritage - broadly defined as archaeology, built heritage and cultural landscapes - in Flanders. Prior to this, tasks of this agency were carried out by several independent agencies. The merger created a very heterogenous set of business processes, IT-components and systems. This, together with a new heritage legislation, prompted a re-evaluation of these systems and their business processes.

This paper will delve into our system architecture, built on a core separation of concerns between data driven applications and proces driven applications. We will explain how we came to implement this in a service oriented architecture . We will detail how and why we chose to go with REST services instead of SOAP services.

The resource oriented focus of REST services has served us well in creating inter-linking data sources that are firmly grounded in the World Wide Web and the HTTP protocol. We will demonstrate how we link these resources by using cool URI's. While a majority of our links are between the resources we create and maintain ourselves, we will also look at how we

interact with external resources and services when it comes to specific domains such as vocabularies and GIS.

Finally we will look at how we are further enhancing our data by more formally publishing it through the use of semantic technologies such as RDF. We aim to create truly linked open data in this way. We will look at some of the stumbling blocks we have encountered along the way. The most significant one to date being the clash between open data and privacy regulations and how to implement access control on linked data.

S21-06 Where is the House of the Dwarves? Enhancing granularity in the Pleiades Gazetteer: The examples of ancient Sicily and Pompeii

Valeria Vitale, Jeffrey Becker, Jonathan Prag

Pleiades, the online gazetteer of ancient places, has, for several years, been a precious resource for classicists and historians. Assigning a stable URI to each ancient place has allowed a number of digital projects to build on top of this infrastructure, developing new tools and resources such as Pelagios.

We believe that Pleiades could stimulate and facilitate new and interesting applications by assigning URIs to geographical units smaller than cities. The aim of this paper is to support this idea discussing two examples:

The digital epigraphic project iSicily. This project involves the identification, locating and addition to Pleiades of various Sicilian contrade (an administrative unit that was common in rural southern Italy) and other sublocations that have been recorded in archaeological reports and previous bibliography as findspots of antiquities, or positions of ancient monuments (some of which no longer exist). The availability of these URIs allows a strong and informative synergy between academic research on those antiquities and museum metadata, expressed in linked data, showing relationships and suggesting potential patterns and future lines of enquiry.

The city of Pompeii. This project involves minting specific URIs for each Pompeian building. The Campanian city offers a unique case study due to the amount of information, bibliography, and often confusion, which orbits around many of the single buildings.

Assigning a URI to each of them will help grouping and disambiguating the names and the interpretations (sometimes dramatically different) assigned to the same building during the last 250 years. Secondly, it will facilitate dialogue between several existing and future digital projects about Pompeian buildings. Lastly, it will link the information about Pompeian artefacts stored in databases, digital repositories or museum archives with the exact building where the artefact was found, and not exclusively with the generic provenance "Pompeii", thus offering an immediate basic level of contextualisation and highlighting connections with other artefacts related to the same building.

S21-07 LOD for Numismatic LAM Integration

Ethan Gruber

The American Numismatic Society (ANS), founded in 1858, is a research institute focusing coins from all eras and regions. It owns one of the largest collections of coins in the world, one of the largest numismatic libraries, is a publisher of monographs and journals, and maintains an archive of research notes from scholars associated with the Society. The ANS has been involved in the publication of numismatic databases and dissemination of such materials following Linked Open Data (LOD) methodologies since 2011; aspects of these digital projects (from Nomisma.org to Online Coins of the Roman Empire, <http://numismatics.org/ocre/>) have been detailed at previous CAA conferences.

While these other projects have focused on implementing LOD techniques in the publication of coin hoard or typological databases, this paper focuses on applying open standards from

across the Library, Archive, and Museum domains to thoroughly integrate the ANS's numismatic collection, library, archive, scholarly publications, and typological and hoard databases. We have begun a new project to digitize nearly 100 monographs into TEI, inserting links to people or places defined on Nomisma or the Pleiades Gazetteer of Ancient Places, citations to books or archival materials held by the ANS, coins in our or other museum collections, and references to hoards or coin types published online. These digital monographs, in essence, become research gateways into similar topics in the larger ancient world linked data cloud. Furthermore, these TEI documents may be deconstructed into RDF. Passages about the Macedonian city of Amphipolis may be made available to researchers through the Pelagios Project. Similarly, a user viewing a particular coin in our collection database may be read a paragraph about the coin, extracted from a TEI document. Our ultimate goal is to create an improved research experience for our users, allowing them to traverse seamlessly from one service to another, whether they begin their search within the ANS project network or arrive from external sources, like Pelagios.

S21-08 Pelagios Commons: Decentralizing the Web of historical data

Leif Isaksen, Simon Rainer, Pau de Soto Cañamares, Elton T. E. Barker

Pelagios is an international initiative concerned with the development of Linked Open Data (LOD) methods, tools and services so as to better interconnect the vast and ever-growing range of historical resources online. In particular it associates place references within those resources to online gazetteers that offer URI-based identifiers for such places. Some of its major outputs have been the development of Recogito, a tool for semantically annotating place references in images and texts, and Peripleo, a service for visualizing and exploring the graph of data that these annotations form.

In parallel with these developments a community of practitioners has started to form with interests in a range of related activities: the annotation of curated or third-party content; the production of specialist gazetteers; the integration of place annotations with those of people, periods and things; and the visualization and analysis of graph-based data, to name but a few. Since its early stages Pelagios has made concerted efforts to consult and support such stakeholders, but as it has grown new opportunities and challenges have emerged. In particular we have established that within a heritage context, LOD's principal advantage is its ability to relate independently maintained projects without requiring centralization. But what are the social ramifications of such an approach? In a world in which funding, academic legitimacy, intellectual property, and even conference presentations assume the authority of individuals and institutions, can LOD communities ever scale effectively?

This paper reports on early developments within Pelagios Commons, a new phase of Pelagios which focuses explicitly on addressing technical and social decentralization within Web-based projects of this nature. It will present our experiences in establishing Special Interest Groups, and the different challenges faced in devolving LOD architectures. It will also seek to foster discussion and critique from those planning or implementing similar community-driven projects.

S22 Teaching archaeology in the digital age. UISPP official session*Karsten Lambers, Hans Kamermans*

This session builds on a well-received session at the 2015 conference in Siena, Italy, in which the topic of teaching was addressed for the first time after many years at CAA. As the Siena session showed, teaching archaeology in the digital age entails various challenges, e.g. to integrate new topics into proven degree programs, to employ new learning environments, to adapt degree programs to the requirements of rapidly changing labor markets, and not least to bridge the Digital Native / Digital Immigrant divide between teachers and students. These challenges are currently met in a variety of different ways and contexts. In many countries, digital archaeology as a teaching topic and/or digital teaching aids in archaeology degree programs are not yet widely common. Focusing on higher education teaching (undergraduate, graduate and continuing education programs), this session is intended as a forum for practitioners mainly from universities who design, implement and evaluate degree programs in archaeology that focus on digital archaeology and/or employ digital teaching environments for educational purposes. The aim is to exchange ideas and experiences and to give examples of good practice in order to encourage new approaches to teaching archaeology in the digital age.

S22-01 Dynamic process, static document. How to solve the teacher's baffling problem?*Alexis Gorgues, Florent Comte*

As Lewis Binford noticed a long time ago, the main issue when dealing with archaeological data is to understand dynamic processes (the way Ancient societies worked) through the use of a basically static documentation, i.e. the material record. As an archaeology teacher, one of us (AG) could observe that it is in no way easier to try to explain dynamic processes to students by using only a static graphic support (some PowerPoint slides) which is the standard practice in French academic teaching. To explain site formation processes, for instance, only through some slides, and armed with a marker and a blackboard, is possible, but will be time (and energy!) consuming and can be pedagogically poorly effective. This observation brought us to conceive dynamic pedagogical supports intended to be used in a context of direct interaction with the students. These supports were indeed animation videos, often based on real case studies. Their topics were quite diversified: the first we made was about site formation processes, another one allowed to explain how to draw a stratigraphic section and what phenomenon it allows to describe. One of the most successful is about archaeological sites detection. The constitution of the funerary record was also considered. This initiative took place with a very limited financial support. Yet, students' feedback is very positive, and the pedagogical efficiency of the teaching is improved: more complex ideas can be effectively transmitted in fewer times. In this presentation, we propose to show some of these videos as well as to present the comments made by our 2nd year undergraduate students, who are our main "target", in order to demonstrate the combination of digital technology on the one hand and old-fashioned, direct archaeology teaching can give convincing results.

S22-02 ArGO. Archaeological Geocaching Online. Teaching and learning archaeology with geocaching*Michael Remmy*

Digital media has influenced the viewing and learning habits of students for the past decades. At the same time teaching habits in archaeology have not changed to the same extent: frontal teaching and lectures are often seen as best practice. Therefore teachers in universities should also apply new methods and didactics to their curriculum to engage students in diverse learning settings.

One approach is ArGO (Archaeological Geocaching Online) - an e-learning tool for students of archaeology that is currently being developed at the Archaeological Institute and the Humanities Computer Science at the University of Cologne. The main goal is to design virtual geocaching quests that students have to solve by using mobile devices on an archaeological site. On the one hand this allows the students to use their expertise in digital media while learning archaeological facts. On the other hand new impulses are given through the change of the learning environment and the use of self-organized learning. Currently, students of both institutes are developing a prototype of this tool in a seminar. The topic is the Roman city of Cologne (Colonia Claudia Ara Agrippinensium). In different groups the students are researching various aspects of a Roman city (e.g. infrastructure, politics, religion) and find ways to transfer archaeological information into virtual caches. These caches can consist of tasks and games. Teaching methods such as clustering, project learning and evaluation of the different project sections are used to get the best possible learning outcome. A accompanying website documents the progression of the seminar and backs up all results including the code of the tool.

The final results of the seminar will be the foundation for further developments of ArGO. A user-friendly Gui for teachers and a basis layout of different tasks and games are the goals for a following seminar. The prototype of ArGO will be tested in summer 2016.

S22-03 When I was a child, I wanted to be an archaeologist. What about now? A French case study

Anne Moreau, Sylvain Badey

The development of digital technologies in archaeology brought up changes in the way of practicing archaeology, since the apparition of computers and even more with the internet. In the last few years, we have seen a multiplication of free software and the global movement of open data and open access involves a larger free diffusion of tools and data. This digital evolution has several consequences such as the erasure of the previous barriers between the different activities of the archaeological process (topography, archaeology, drawing...). On the one hand, it's a way of developing individual skills but on the other hand, it's shaking up the archaeological world: formerly, the skills and the tools used were linked to a well-identified activity or job. Currently some of the new tasks of the archeological process-related to the new technologies involved - are spread over several contributors who developed skills by themselves most of the time.

Three observations can be made:

- this situation is increasing the gap between the self-educated archaeologists and those who have more "traditional" ways of working
- we need to redefine the jobs in order to propose, if necessary, a better sharing of the tasks and a better identification of the skills
- we need to think about the training in archaeology taking the new skills needed into account.

The French National Institute for Preventive Archaeology is a public institution. It comprises around 2000 archaeologists who realize more than 2000 operations a year. In 2011, the institute has launched an important program to promote the use of GIS. In that perspective, means have been used for the definition of a further education programs: four different programs dedicated to the use of GIS (two levels), statistics and photogrammetry are offered. Nowadays, around 600 archaeologists have been trained. But the definition of the matter of the training sessions is based on a larger reflection about the digital technologies to be integrated. Choices have to be made.

S22-04 Towards the integration of green and cultural heritage management. Developing content for blended learning

Heleen Van Londen, Marjo Schlaman, Andrea Travaglia

The European Archaeological and Natural Heritage project (ANHER) focuses on increasing knowledge and skills for professionals working in the archaeological and natural heritage sectors in Europe. Facing social, economic and climate changes, the development and improvement of knowledge of landscape management and protection of the archaeological and natural heritage has become a necessity. Through an interdisciplinary approach to the landscape heritage, new knowledge, new methods and new policies can be developed which will improve and strength conventional approaches. The basic principle is that through a better understanding of the importance of archaeological heritage and natural heritage for the rural environment, sustainable management of the landscape can be realized.

Within the project, the six European partners develop a variety of integrated educational e-learning materials designed to treat important facets of both sectors. The project also contributes to the development of improved methods and content of higher education and vocational training in the field of heritage. The digital method ensures that education sectors can be connected to the continuous changes concerning the protection and management of archaeological and natural heritage. This includes the role of the built heritage in urban planning and local and regional heritage policy in Europe.

The project will result in European Centres of Integrated Heritage Teaching Excellence in view of preservation of knowledge, methods and policy. These centres will provide an organizational structure for continuous training and a technical infrastructure for blended learning that will benefit the various labour markets.

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A Rocha pt, Mexilhoeira Grande (Portugal)

Aranzadi Society of Sciences, San Sebastian (Spain)

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S22-05 Archaeological education for a digital world: Case studies from the contemporary and historical US

Anna S Agbe-Davies

This paper takes as its premises that 1) archaeological education extends beyond the university walls to embrace the needs of a wider public, and 2) archaeology is an integrated discipline that includes the analysis of not only material culture, but also texts and other models of human expression. The author discusses initiatives to use digital technologies and techniques to "teach" "archaeology" in the broadest sense of both words. Examples include using digital archaeological data from DAACS.org to teach analytical processes and the scientific method, the class-sourcing/crowd-sourcing of archival transcription using FromThePage.com, and building websites to teach both archaeological content and digital literacies. What some now call the digital humanities is not new to archaeology, but we will do well to embrace technological and methodological innovations in the realm of education, just as we have in our research.

S22-06 Digital data recording at Circus Maximus: A recent experience

Alessandro Vecchione, Domenica Dininno, Giulio Casazza

Between 2011 and 2014 a stratigraphic excavation was carried out in the area of the Circus Maximus in Rome by the Sovrintendenza Capitolina ai Beni Culturali in agreement with the Università Sapienza of Rome, chair of Ancient roman city planning. The excavation and the field data recording campaign were part of a large-scale project for the environmental requalification and promotion of the archaeological remains of the Circus Maximus.

The whole area is currently undergoing restoration works in preparation for the opening for the public fruition; the excavation, carried out at the same time, focused at the beginning on the external ambulatory and on the radial rooms facing the Palatine hill; later, the area where in roman times stood the arch of Titus was dug up.

The excavation involved 50 archaeology students of the ancient topography curriculum.

While working in the educational digging the young archaeologists were trained in the use of new technologies for the field data recording: above all this activity focused on the use of photogrammetry and image based modelling.

The methodological choice was motivated by the hybrid nature of the archaeological site – an educational excavation but also a public work of urgent nature: the restoration works were urgent and this forced to speed the archeological research and, subsequently, the graphic recording of the structures and findings. Digital photogrammetry, after comparing costs and benefits, proved to be the best solution for the archaeologists's needs.

At the end of the excavation, when the archaeologists completed the data digitalisation, the need to improve the student's knowledge of new technologies during university courses was clear.

This presentation aims to share our opinion on the reliability of the methodolgy that was used, the changes it brought to the organization of the team's work and the issues related whitth the archiving and sharing of data.

POSTER

S22-P1 Teaching GIS in archaeology: What Students focus on

Mar Zamora Merchán, Javier Baena Preysler

The future of GIS applications in Archaeology is developing among current students. For that reason, the postgraduate classroom can be an appropriate laboratory in order to know how GIS must be taught to the future researchers.

Both authors of this poster, teach together “GIS and territorial analysis” subject at Master Degree. The aim of our research has been to analyze students’ preferences when using GIS. The students’ course works from five consecutive academic years have been analyzed taking into account the following aspects:

- Main work lines (research, cultural resource management, tourism);
- Spatial scale (intrasite, territory, region,...);
- Location of study areas, and their spatial distribution;
- Chronological array of analyses;
- Particular GIS application (thematic maps, viewshed, shortest path, etc.);
- Students’ background (Graduate studies).

All students followed the Master in Archaeology and Heritage at the University Autónoma of Madrid (Spain). This Master is conducted by the Department of Prehistory and Archaeology, where GIS in Archaeology teaching has been implemented since the middle of the nineties.

S23 Needles in the haystack: Geophysical methods in challenging conditions

Lars Gustavsen, Christer Tonning, Arne Anderson Stamnes, Erich Nau, Monica Kristiansen

The development of geophysical techniques for archaeological purposes has largely taken place in areas where archaeological features tend to be pronounced, well-defined and, arguably, easily detected by geophysical instruments. Often, however, we are faced with archaeological features which do not readily lend themselves to detection by these methods. This is sometimes compounded by local geomorphological and pedological conditions, which may obscure or mask the archaeological features. This calls for different approaches to how geophysical methods are applied, and it requires comprehensive field observation regimes to verify and understand the geophysical properties of the archaeology.

In this session we wish to focus on projects where adverse geological, geomorphological, pedological and archaeological conditions have been encountered. We want to explore how these conditions have affected the geophysical survey results and their archaeological interpretability, to see how these phenomena have been observed through archaeological feedback, and how the results have influenced subsequent field procedures.

S23-01 Magnetic geophysical prospection on prehistoric iron production sites in cultivated contexts: The case of Ånestad, Hedmark in Norway

Christian Løchsen Rødsrud, Arne Anderson Stamnes, Kristin Eriksen

In 2010 Hedmark County Council uncovered ten furnaces at two sites, dated to the Merovingian period (600–800 AD) in a cultivated field at Ånestad, Løten, Hedmark. In 2015 the Museum of Cultural History conducted excavations of the sites. In a preliminary phase a geophysical survey was completed, using topsoil magnetic susceptibility mapping and gradiometer surveys, to clarify the extent of the production sites.

The geophysics resulted in many anomalies interpreted as possible furnaces. While several proved to be furnaces, a range of geophysical anomalies proved to be of a quite different nature (stones, clay, etc.) when compared with the excavation evidence.

In this paper we will discuss what was done methodically and present our experiences on how the geophysical data were put to use and affected the strategy of the excavation, as seen both from the geophysical surveyors and the excavator's point of view. We will also discuss how the archaeological feedback helped altering the initial archaeological interpretation of the geophysical data, and potentials and pitfalls associated with such a cross-disciplinary collaboration. Finally, we will see this survey from a heritage management and planning perspective, and discuss the value of the geophysical prospecting opposed to the "regular" survey of the County Council. Did the magnetic geophysical surveys contribute with additional data preliminary to the field work at this site? And generally; is more methodical work needed before geophysics is applicable in rescue archaeology of similar sites? We believe the Ånestad-results will act as a contribution to further refinement of the field methodologies and improved understanding of magnetic geophysical data of similar sites in the future.

S23-02 Understanding contrast at Busayra: Geophysical surveys of an Iron Age settlement in Southwest Jordan

Christine Markussen, Katie Simon, Benjamin Porter, Stephanie Brown

In 2014 geophysical surveys were conducted at Busayra, southwest Jordan, as part of collaboration between and the University of California, Berkeley and the University of Arkansas' SPARC (Spatial Archaeometry Research Collaborations) program. The settlement of Busayra is suspected of being the capital of the Iron Age polity of Edom. British excavations in the 1970s revealed monumental buildings, fortifications, and domestic residences on Busayra's acropolis that confirm the settlement's stature as an administrative

center. With the objective to further investigate Busayra's sub-surface features, Ground Penetrating Radar (GPR) and Magnetic Gradiometry were employed to survey the site's unexcavated areas and yielded interesting results about the settlement's layout and primary construction materials. While few Gradiometry surveys in southwest Jordan have yielded notable results or have even been attempted, the data from Busayra provides an understanding of the settlement's design and highlights the need for multi-method approaches in the region. Underlying limestone architecture contrasts strongly with surrounding soil in the magnetic data set, but the GPR varied in success in identifying the same architectural features. The differences between the results from the two methods can provide insight into the geologic and geomorphologic properties of the features and soils at the site. In addition to understanding soil contrasts at Busayra, questions regarding "empty spaces" where little to no contrast can be identified in the current geophysical data invites suggestions for what further methods could provide results at the site.

S23-03 Opportunities and limitations of archaeological geophysical prospection on the example Uppåkra in Sweden

Manuel Gabler

The archaeological site Uppåkra is Sweden's largest and long lasted Iron Age settlement. In the years 2010 – 2013 the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro) conducted large scale archaeological geophysical measurements with motorized magnetic systems and ground penetrating radar (GPR–MIRA from Malå). The Riksantikvarieämbetet and the University Lund conducted targeted excavations based on the prospection results. Although the underlying geology is the same, the results differ extremely within the investigated area. At the central part of the settlement the prospection data could be perfectly confirmed. Just a few hundred meters south from that place large magnetic anomalies could not be hit by excavations. At another place north of the central area a large amount of archaeological remains could not be located with magnetic at all.

Ghost features (anomalies in prospection data which could not be confirmed by excavation) or non-detectable features are known phenomena in archaeological prospection. Anyway the results from Uppåkra with different results within the same geological environment are a good example for the possibilities and limitations of archaeological prospection methods in Sweden. In many cases it is very complicated to distinguish between archaeological and geological structures and only additional information makes it possible to understand the data. As large areas have been investigated with magnetic GPR, a high amount of comparable data is available. It can be clear demonstrated that the interpretation and reliability with just one prospection method is limited and combined prospection methods should be applied wherever possible. The data which will be presented highlights the opportunities of large scale prospection as well the limitations which have to be taken in consideration when it comes to a planned investigation of archaeological landscapes.

S23-04 Looking through the rocks. Geophysical research on the agora of the ancient city: Nea Paphos—A case study

Martina Siefert, Ewdoksia Papuci-Władyka, Tomasz Kalicki, Sebastian Adlung, Michaelis Antonakis, Nikola Babucic, Joanna Krupa, Artur Buszek, Sławomir Chwałek, Dawid Świąch, Tomasz Herbich, Łukasz Misk

Ancient Paphos was given enhanced protection status in November 2010 by UNESCO's Committee for the Protection of Cultural Property. Sustaining the outstanding universal value of the site, the (re)construction of the cityscape for example is one of the prominent issues in archaeological fieldwork. Hard terrain, tightly compacted layers of rubble mixed with the

ground, stone debris, an unclarified modern context without a mapping of recent building activities and infrastructural supply are part of the complicated local setting. The paper under discussion will present a work-in-progress case study of a combined archaeological, geological and geophysical research at Nea Paphos in Cyprus. Special emphasis will be laid on the ongoing process of finding methods as well as practical solutions and outlining workflows in a surrounding of forced public and scientific interest. Due to permission, money and time, non-invasive geophysical methods get more and more important to calculate workloads and, at least, the financial budget for archaeological research. In 2011, the Jagiellonian University in Kraków, Poland, started the PAPHOS AGORA PROJECT aiming to work out the urban plan of the site mainly focusing e.g. on the localization and spatial organization of the ancient agora, both in Hellenistic and Roman times. For the present interdisciplinary work of an international team include the prospection of the terrain with geoelectricity, georadar and geomagnetic. One of the main problems is to separate stone structures—so artificial walls from the natural level of rocks on the bottom and the pebbles layers over the built structures in an area known for field cultivation and used for an English military road.

S23-05 A geoarchaeological approach to selected issues in Norwegian archaeological geophysical prospection

Petra Schneidhofer, Erich Nau, Christer Tønning, Immo Trinks

Until recently, large-scale, high-resolution geophysical archaeological prospection had not been applied in Norway, mostly due to the challenging environmental conditions. New developments regarding motorized data acquisition, data processing and visualisation as well as the use of complementary prospection techniques have been able to provide promising solutions to some of these issues. Since 2010, research and development carried out by the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro) and its Norwegian partners, Vestfold County Administration (Vestfold fylkeskommune) and the Norwegian Institute for Cultural Heritage Research (NIKU), have been focusing on selected Viking Age landscapes in Vestfold County (<http://lbi-archpro.org/cs/vestfold/>). The vast amount of geophysical archaeological prospection data collected during this period has highlighted a range of issues, including those caused by shallow magnetic bedrock and unsorted glacial and fine-grained marine sediments, which are inherent to the diverse and dynamic character of the Norwegian environment. These environmental characteristics considerably affect the interpretation of ground penetrating-radar and magnetometry data sets, prompting a more detailed investigation. Targeted in-situ measurements of physical properties of soils and sediments (dielectric permittivity, electrical conductivity, magnetic susceptibility) were conducted in order to enhance the quality of geophysical archaeological prospection data interpretation, to establish a comparative knowledge base for future investigations, and not least to render the large-scale prospection approach more reliable. Methodology and results of several geoarchaeological evaluation studies from Norway are presented.

S23-06 Picking needles from a magnet: Obstacles and (hidden) opportunities of magnetic prospection in challenging environments

Tuna Kalayci, Apostolos Sarris

Magnetic prospection can be considered as the main arsenal of archaeologists due to its sensitive response to anthropogenic variations. It is a rapid approach, becoming the fastest one compared to other techniques due to the multiple sensor arrays, enabling a landscape approach to archaeological problems. Nevertheless, the foundational physics behind this technique limits its use for particular conditions; e.g. magnetic clutter, magnetic contrast between background soil and material culture. Feasibility of the survey is also determined by

the conditions of the study area; e.g. lack of modern features, absence of diffused archaeological material and relatively smooth topography. Complex Mediterranean landscapes, however, provides immediate challenges, both for the physics and the feasibility of magnetic prospection.

Various parameters can influence the success of a magnetic survey and a number of magnetic anomalies either remain masked or are difficult to interpret. Dense distribution of tiles in the Roman Nikopolis (Epirus) severely hindered the actual archaeological targets (roads and structural remains). The hematite ores in the vicinity of the ancient settlement of Hyettos (Boeotia) were indicative of the parent soil deposits of the area that made the magnetic survey an impossible task. In Palaepaphos, Cyprus, extreme values of vertical magnetic gradient were encountered over large patches without being able to be further verified through GPR or soil magnetic susceptibility measurements. Drawing from the examples of Naxos, Sicily and Therasia Island, Cyclades, it becomes clear that volcanic and volcano–sedimentary formations present further challenges in data collection, processing, and interpretation efforts.

This paper is a manifestation of some of the problematic situations encountered in the magnetic prospection of archaeological sites in the Mediterranean region. However, other geophysical methods are also discussed for further illumination of the magnetic prospection in magnetically enriched contexts. Results of this comparison highlight the importance of a priori information on the archaeology of sites and the employment of multi–sensor approach.

POSTER

S23-P1 Comparing 3D Ground–Penetrating Radar visualization methods: A case study from Austria

Christine Markussen

Collecting, interpreting, and visualizing Ground–Penetrating Radar (GPR) data is fundamentally a three–dimensional process. Closely spaced GPR transects have the potential to be interpolated into a true three–dimensional data block placing archaeological features into near surface geologic context as well as identifying and recording strata within the archaeological context. However, most archaeological interpretation of GPR data is carried out in two dimensions on individual horizontal slices limited to a certain depth or range of depths. Archaeological interpretations of GPR data are also often limited to computer specifications and program capabilities. In 2012 the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro) collected high–resolution GPR data (8cm sample spacing) across approximately 10 hectares of the site Flavia Solva, a Roman town in Austria along the Mur River dating from the 1st to 5th centuries A.D. This high–resolution data set provides accurate details of sub–surface properties ideal for 3D visualizations of archaeological features. This project analyzes multiple methods of 3D visualizations including vector extrusions, time–slice animations, iso–surface renderings, and voxel and point–cloud representations for the high–resolution data set.

S24 Digital rock art documentations, new perceptions

David Vogt, Steinar Kristensen, Magne Samdal, Bjarte Aarseth

The documentation of rock art has a tradition that spans over one hundred years, during which several methods have been tried and tested. Today, the traditional tracing method is the most commonly used all over the world. Digital methods of documentation have, however, in more recent years begun to challenge and supplement the traditional methods for documenting rock art. Laser scanning, photogrammetry, and other digital methods, are providing new ways of recording and presenting rock art, and are better suited to web based or other digital presentation forms. This session will explore these new tools and discuss the results and challenges they present. Questions will be addressed, such as will digital methods improve the documentation of strongly weathered figures, will the results be transferrable to general publication forms, and will digital methods be able to compete in terms of cost?

S24-01 New eyes to old graphics. Rock art in the Emirate of Sharjah

Xosefina Otero

In this paper we present new methods of the documentation and registration of the petroglyphs of the exceptional archaeological site located on Khor Fakkan, emirate of Sharjah, on the east coast of the United Arab Emirates along the Gulf of Oman, and coordinates 24°59'06.06" N - 56°20'36.70" E.

The engravings on the surface of the serpentine rock fragments, of the Semail ophiolite complex that was generated when the Saud- plate was introduced under the Iran-Zagros, in the Cretaceous, are made with the technique and striped characteristic of the Bronze Age-2000 BC schematic style. We intend to elaborate on their study ensuring their conditions and perfect conservation using the latest technologies available and employing the working methods of the archaeology of the landscape, which analyses the spatial dimension of the human group that performed it.

One of the our new tools to be analysed is the EyesMap tablet, a new professional device that allows the measurement and real time 3D modelling and scanning the stone supports and recording them in three dimensions. The new equipment uses computer vision techniques fused with large and close range photogrammetry, infrared and stereoscopic RGB cameras, sensor calibration precision. The research focuses on advanced measurement techniques that allow to make the virtual reconstruction of the site and the petroglyphs details and fit it in its original landscape to reproduce the environmental conditions in which the authors of the petroglyphs and their communities lived.

S24-02 Documenting facades of Etruscan rock-cut tombs: From 3D recording to archaeological analysis

Tatiana Votroubeková

Etruscan rock-cut tombs with decorated facades are located only in area of inland southern Etruria, now region Tuscany and Lazio in Italy. These tombs were constructed from second quarter of the 6th century BC to the end of 3rd / beginning of the 2nd century BC in natural vertical tuff cliffs. Decoration of the facades is carved into the rock and reproduces architectural elements and in the Hellenistic period also floral and figural motifs. Due to the character of tuff stone, facades suffer from heavy erosion caused mainly by water and vegetation. Carved decoration as well as inscriptions are slowly vanishing. Paper examines multi-image photogrammetry as a tool for documentation, digital preservation and archaeological analysis, which is based on increased readability of worked surface, typological comparisons and other actions which allows virtual environment. Advantages, disadvantages, possibilities and limitations of multi-image photogrammetry technique used

for documenting this kind of rock art will be discussed, as well as ways of further use of acquired data in virtual reconstruction and virtual anastylosis.

S24-03 Ex-situ preservation of exposed painted rock art. Applying photogrammetry and color manipulation

Raymond Sauvage

Natural degradation of rock art sites possess a major challenge for cultural heritage management. This is especially true for exposed sites with painted art. Conservation measures are in some cases not able to fully stop or reverse continuing degradation, and we may have to accept that some sites will be lost in a near future. Preservation ex-situ in archives may be the only future for these sites. In this paper, we will explore the potential for digital photogrammetry in combination with color manipulation to replace the more traditional means of surveying localities of this type. Examples from the rock-art site at Honnhammer in Tingvoll, Møre og Romsdal County, Norway, will be presented and discussed. Here, digital photogrammetry has been applied for the past two years, as a cost-effective and accurate way to preserve three-dimensional information for the future.

24-04 Photogrammetric rock art detection: Assisting detection of rock art on lichen covered surfaces using photogrammetry and 3D modelling software

Erik Kjellman

This presentation aims to show how photogrammetry and simple 3D-modelling software techniques can aid in the detection of rock art in difficult natural conditions. The field of Rock art documentation has seen an increase in the use of digital recording methods, such as Reflectance Transformation Imaging (RTI) and digital photogrammetry. Detailed datasets means that new and novel methods for study are emerging and are making it possible to get better understanding and even making it possible to uncover previously unknown details in the rock art. In this paper, I will show how the knowledge about these methods would facilitate ad hoc primary documentation of a newly discovered rock art site in northern Norway. The author discovered the rock art site at Gamnes, Sør-Varanger municipality, Norway, during an archaeological excavation. Due to the circumstances of the discovery in connection to the excavation, it became paramount to get high quality detailed documentation of the rock carvings at a minimum of time. Photogrammetry was used to document the rock art and generated good datasets for disseminating the findings. Identifying each of the pictographs was not easy. This was mostly due to difficult lighting conditions, but also because of heavy lichen growth on the rock surfaces. Manipulating the datasets gathered from the initial photogrammetry unveiled some parts of pictographs that were otherwise almost invisible. This discovery made it possible to get even better preliminary estimates of the rock art sites extent, and thus create a better basis for further work on the site.

POSTER

S24-P1 New eyes to old graphics. Rock art in the Emirate of Sharjah

Xosefina Otero

For abstract, see S24-01.

S25 Public archaeology and the use of digital platforms

Ingvild Solberg Andreassen

The past decade or so has seen a great increase in the digitalization of archaeological materials. More data than ever before is being collected in the field. Archaeologists are online while excavating, blogging and tweeting, and all projects now have a Facebook page. For a while, accessibility has been a buzzword within the archaeological community. But what happens to all the digital efforts—all the databases, the Facebook pages, blogs and so on? How is it picked up, how is it received and perceived by the public? This session is particularly concerned with deep oceans of digital data and technology as point of departure for exploring learning, understanding and knowledge building in archaeology. How is data picked up and used by different public groups, why, and under what circumstances? How is data and technology used by institutions to create dialogues with the public, if at all? How is this problematized within the research community? Are data and portals customized with the public's interest in mind? What about the potential of technology in bridging the gaps between excavation and museum, excavation and school, and excavation and the private sphere? Is this explored? If yes—how, if not—why not? Have you done an interesting project using social media, GIS data or database information with a group of students, with a school, or with a local community? Come and tell us about it! We are interested in harvested experience from the practical side of things as well as theoretical reflections over the connections between archaeology, digital data, the public and society. We welcome contributions presenting and discussing outreach projects, public archaeology projects and theoretical contributions concerned with learning, mediation and public dialogue. Keywords for this session are: social media, learning, dialogue, public archaeology, data collection

S25-01 Co-designing digital community archaeologies: Experiences from the re-reading the British Memorial Project

Gareth Beale, Nicole Beale

The Re-Reading the British Memorial Project began as a small scale documentation project which aimed to share digital imaging expertise with community groups studying burial spaces. In response to the requirements of community groups and with their collaboration the project has now expanded to support community led research at every stage of the data lifecycle from creation to re-use. The project has also grown to incorporate an increasingly broad range of stakeholders including national organisations and university research clusters as well as community groups and volunteers.

This presentation will discuss some of the practical issues which arise out of the collaborative development of methodologies for digital archaeology and will explore the challenges and opportunities involved in moving from being a local project based on personal relationships to a national project working remotely with multiple partners. We will critically assess different methodological directions which have been trialled by the project and will describe our current strategies for community engagement and collaboration.

S25-02 Using Google Earth applications to enhance public engagement with cultural heritage: An evaluation of Seeing Beneath Stonehenge

Kate Welham, Lawrence Shaw, Mark Dover, Harry Manley, Mike Parker Pearson

This paper discusses the nature of public engagement with Google Earth based heritage applications, and considers whether the full potential of this media has yet been realised. It focuses on an evaluation of Seeing Beneath Stonehenge (<https://microsites.bournemouth.ac.uk/seeing-beneath-stonehenge/>), a free to use, Google Earth based application that was created from the wide variety of spatial data collated as part of the Stonehenge Riverside Project. The work was funded by Google, and aimed at creating a

public platform where users could travel around the Stonehenge landscape examining a broad range of research results in-situ. Trench locations, findings and excavation images were included, along with broader landscape studies such as geophysical surveys and narrated tours of key monuments.

We discuss the release, uptake and user feedback from Seeing Beneath Stonehenge. Web statistics are used to examine the use of social media in driving downloads, issues such as initial peak use and plateau, and the geographic distribution of users are considered. In particular we present the results of an online questionnaire that was aimed at examining how the application might have stimulated additional interest in the archaeology of Stonehenge and its wider landscape. Results were obtained from over 100 users, and the majority gave an overwhelming positive reaction to the application. Over 80% stated they were now more likely to visit the monument. We discuss the results, including 'experience limiting' factors such as technological familiarity. Finally we consider why Google Earth applications are yet to be fully utilised within archaeology, and their potential to appeal to a public with an insatiable demand for engaging and informative content.

S25-03 Rekrei: A public platform for digitally preserving lost heritage

Matthew Luke Vincent, Chance Coughenour, Fabio Remondino, Mariano Flores Gutierrez, Victor Manuel Lopez-Menchero Bendicho, Dieter Fritsch

Rekrei (rekrei.org), formerly Project Mosul, is one of those projects that grow out of a conversation between two friends. The co-founders, Matthew Vincent and Chance Coughenour, were discussing the destruction of heritage in the Middle East by extremist groups such as the self-proclaimed Islamic State when Coughenour suggested that they could begin to crowd-source images and photogrammetrically create digital reconstructions of the heritage that was being systematically destroyed. A week later, Rekrei was born. Neither ever imagined that it would get the public's attention, but such a project provides a very real and tangible response to the senseless loss of humanity's past. 6 months later, Project Mosul has continued to grow, shifting from a single focus in northern Iraq, to a global focus on lost heritage everywhere. The co-founders are exploring ways they can continue to build tools that help identify monuments in danger, areas that should be prioritised for scanning and preservation, and ways they can continue to connect the public with tangible means of preserving the heritage. This paper explores some of these new topics, dealing with authenticity of 3D reconstructions, while also at the same time looking at public, crowd-sourcing projects and the challenges that they present when you combine a group of non-experts and high-profile destructions. Future work is looking at how this platform can be applied towards risk assessment and management, as well as improving the available tools to empower the public to engage in such reconstruction efforts for the preservation and recovery of lost heritage.

S25-04 Photomodeling and webmapping on archeological site of Carthage (Tunisia) and data collection in the museum of Bardo (Tunisia)

Meriem Zammel

In the context of the project Hologramme: "Harmonize the opportunities related to new guidelines for the management of archaeological Mediterranean resources and development of a network of experiences" between Italy and Tunisia, a multidisciplinary team formed of archaeologists, architects, computer scientists worked together in order to showcase Tunisian and Sicilian Heritage by using new technologies. The aim of this paper is to present our contribution in this project by teaching digital archaeology at Tourath association, by Photo modeling objects and statues in site of Carthage and Museum of Bardo, and preparing social media to public in order to help him to understand the particularity of cultural heritage in this

area and history, through 3D modeling of monuments and videos. Those objects are witnesses of the past. The sponsor of this project for Tunisia is the cultural heritage agency (AMVPPC) which has chosen the society NGI (Maghreb) for the webmapping. Thereby, interactive maps using web mapping, 3D models of monuments and image based modeling of objects obtained from Autodesk 123 catch were made in order to show the historical stratification of Tunisia. Automatic image based modeling constitute an accurate and low cost technique. Multiple data sources (Photos, text, 3D model, Photo model...) are used and integrated in a web system in order to show to the visitor a way of understanding and documenting the past.

S25-05 Visualizing original sea level of Stone Age sites on location by means of mobile augmented reality

Gunnar Liestøl, Birgitte Bjørkli, Espen Uleberg

When understanding and informing about the localization of Stone Age sites along the rugged coast of Norway it is always pertinent to include information about the sea level at the time the site was in use. This is important for both archaeological surveying and excavation, as well as mediation to the public at large. When one finds oneself on a Stone Age site a kilometer inland in the thick of a dark forest it is not easy to imagine what the place actually looked like six thousand years earlier when the site was in use by Neolithic Man in Norway as part of the coastline and exposed to the open sea. How may we take advantage of the current state of the art in location-based media and mobile augmented reality in order to bring dynamic visualizations of the ancient landscape into the hands of both archaeologists and interested visitors? In this paper presentation we report on the development and testing of a situated simulation where the user can move around in a given landscape and view a parallel simulation of the sea level from pre-historic times until present on his or her smartphone or tablet. The application uses an indirect augmented reality approach and sea level/time-period can be altered continuously. When approaching a surveyed and/or excavated site one can also observe its extension and via spatially positioned hypertext links access the online databases for multimodal information about the findings, etc. The prototype runs on iOS and has been tested with a small group of visitors on location. The paper concludes with a discussion of the user evaluation and suggestions for further work.

S25-06 DOMUS: Cyber—archaeology and education

Alex da Silva Martire, Tatiana Bina

This presentation is focused on the development and implementation of the project elaborated by the Laboratory for Roman Provincial Archaeology (LARP—University of Sao Paulo) named DOMUS: the first online Brazilian cyber—archaeological application that enables users to navigate in three—dimensional virtual environment that simulates an ancient house during the Roman Empire.

It will be presented the application development process starting from its initial conception (based on archaeological remains of Pompeii and Herculaneum), through the complete modeling and texturing in Autodesk Maya software to the creation of real-time interactivity on the Unity engine.

We will focus on the implementation of our educational proposal in schools. DOMUS was applied for the very first time at Colégio Unidade Jardim (a high school in Sao Paulo). The activity consisted of asking the students (aged from 10 to 12 years) to navigate through the idealized three—dimensional Roman house in order to explore its rooms and objects, and also to perceive inherent subjects belonging to Pompeian domestic art and architecture. The main intended goals of our proposal were: a) enable an otherness experience for students (so they can reflect on the historical use of the house); b) make use of “L’histoire du quotidien” (a much more approachable way to present History to students); c) discuss the technological and

historical choices that were made during the development of the application; and d) evaluate the reception of the application. In this manner, it will be presented the stages involved in the implementation of the activity with students and how our cyber-archaeological application allowed them to establish the link between archaeological remains and their own daily lives through computer emulation.

S25-07 Democratising the digital: Sustaining community—sourcing platforms for heritage management and conservation by co-creation

Leif Harald Fredheim

While the rise of interactive digital networks and technology has challenged established societal and intellectual authorities, digital heritage often exacerbates perceptions of expertise and entrenched flows of information. This paper will explore one way in which the democratising potential of the digital can be used to empower communities without neutralising professional expertise. As heritage conservators and managers increasingly recognise the role of non-expert contributions to informed decision-making processes, the development of tools for generating and processing consultation data digitally is the logical next step. This paper reflects on lessons learned from developing a web-application for community—sourcing heritage interpretations at the Middle Temple and the ongoing process of co-creating a similar platform with, and for, community archaeological groups affiliated with the Council for British Archaeology (CBA). A common feature of the two platforms is the integration of ‘expert’ and ‘non-expert’ interpretations of heritage and the attribution of expert interpretations to identifiable individuals rather than anonymous and omniscient third parties. The development of a community-sourcing platform for the CBA is part of a project investigating the sustainability of community-led approaches to archaeological stewardship, in response to recent cuts to public spending in the UK. Co-creating the platform with potential user-communities is intended to ensure that the platform satisfies user-needs, not merely the needs of professionals and academics, and can be sustained by user-communities. Participation will be facilitated through training events and concerted efforts to raise levels of digital literacy in participating communities.

Cancelled S25-08 Breaking the mould: Why do we replicate objects of the past?

Michael Ann Bevivino

This paper will discuss some of the preliminary results of the 'Breaking the mould: Ireland's replicas of cultural objects from the historic to the digital' project that is funded by the Irish Research Council. The main goal of this project is to assess the benefits and long-term implications of advanced 3D replication technologies to cultural institutions in Ireland. It will achieve this through a study of the parallels between historic replicas and the current surge in digital replication.

As in many other parts of Europe and the world, Ireland holds a collection of ‘historic replicas’(such as plaster casts and marble copies) that were created in the eighteenth, nineteenth and twentieth centuries in order to display a canon of great works of art to museum visitors. These replicas were considered to be prime indicators of good ‘taste’; museums often created replica collections to teach visitors what they should know various cultural icons. Today, many cultural bodies are using digital methods to do the very same thing. Many of Ireland's ‘icons’ have been digitally recorded (using laser scanning or photography-based methods), both for conservation and dissemination purposes. The use of these new technologies is widespread, but perhaps the application of digital data to answer defined research questions is sometimes more difficult to ascertain. This paper will touch on some of the following research questions:

- Why do we replicate objects of the past?

- What are the benefits and challenges of using 3D digital replication techniques?
- How do we most effectively use the available technology?
- Why are we studying particular objects using particular methods?
- Will the proliferation (and democratisation) of digital technologies lead to more interest among visitors or cause fatigue?

POSTER

S25-P1 WW2 remains as cultural heritage

Evy Berg

In Norway, a country-wide registration of remaining sites from WW2 with special emphasis on the less-known stories has started in 2015. Some of these have left little or no material traces, and it is important to document events taking place during 1940–45. Daily life, economy, but also genocide, slavery and persecution are all important themes in the project. Maps structured according to themes have been produced as part of the project, based on the main systems owned by the Directorate: the sites and monuments register Askeladden, and the public web-page Kulturminnesøk. Analysis of the information registered has been performed, with regard to which themes are more easily found in the official database vs. the public version. The main bulk of WW2 sites remain unregistered in our systems, but more will come in in coming years. Unregistered does not mean unknown, a lot of the military sites are well-known and with organisations on the local level being interested in them. The more esoteric sites are more dependent on living memory and such memories being committed to text. The maps will be expanded as more sites are entered into systems, and then classified. In this project the data collected and registered by members of local communities is of great importance, data which the professional cultural heritage agencies depend on to get good data to select what should be preserved as cultural heritage. The project also uses Internet and social media to communicate in ways the directorate has not done before.

S25-P2 Archives, archaeology, and architecture: A multimedia approach for 3D reconstructions

Lauren Massari

In a few years, the University of Virginia, founded in 1819 by Thomas Jefferson, will be celebrating its bicentennial. One of the University's initiatives for this important event is the Jefferson's University, the Early Life (JUEL) Project (<http://juel.iath.virginia.edu/>), which is a digital collection of personal and administrative documents dating from the University's founding until the years after the American Civil War, as well as a digital reconstruction portraying Jefferson's original architectural vision and early changes. The main goal of the JUEL Project is to allow users to explore early documents and renderings to gain an understanding of the people, places, and operations that shaped the university we know today. One of the main issues the project aims to bring to light is the role slavery played in the construction and everyday operations of the early university. In the past, the university has downplayed its uncomfortable relationship with slavery. By digitizing early university records and making them searchable, and digitally reconstructing buildings associated with slavery that have long since been torn down, users will be able to delve deeper into the university's hidden past.

The digital reconstruction of Jefferson's University is the result of collaboration between IATH, the University Office of the Architect, Facilities Management, the University Library, and Rivanna Archaeological Services. The reconstruction is based on architectural documents, written descriptions, historical photographs, historic structure reports, archaeological reports, and the input of local experts (architectural conservators,

archaeologists, and historians, to name a few). Original architectural details such as column capitals and crown molding are also being laser scanned, both to use in the digital reconstruction as well as to create a database of details that can be used for education and conservation. The end result will be a 3D model that shows the university in a way that has not been seen for over a hundred years—both the original Neoclassical buildings that still stand today as well as the countless outbuildings that cropped up to support early university life.

S25-P3 Doha Online Historical Atlas—GIS interactive mapping of space and time in a pearling town

Michal Michalski, Robert Carter, Daniel Eddisford, Richard Fletcher, Colleen Morgan

Since 2012, the Origins of Doha Project (University College London–Qatar) has investigated the foundations and historic growth of Doha, Qatar through archaeology, history, and oral testimony. As part of the digital public outreach for the project, Doha Online Historical Atlas (DOHA), a Historical Geographical Information Science web application has been developed to disseminate the live, multimedia results of Doha's transformation from a pearling town into a modern city.

DOHA was built using Open Source Software and utilises cutting edge web and geospatial technologies. The design allows for the efficient, flexible representation of an interactive timeline with geolocated maps, aerial images, videos, historic records, building recording, and archaeological investigation. This information explored on the web, or on mobile devices that bring the history and archaeology of local places to the user's location.

DOHA provides also users with opportunity to actively participate in development of the content which is crowdsourced using geotagged Wikipedia articles as well as by filling a report on historic event and adding a geolocated media. The popularity of the application will be evaluated using feedback provided through email, social media sharing buttons as well as analytic software for web maps that give insight into user interaction with map.

The poster will showcase the design, architecture and implementation of the application which has been unique in its nature and scope.

S26 The portable XRF revolution: Elemental analysis for all?

Kate Welham, Paul Cheetham, Derek Pitman, Rebecca Cannell

The recent surge of popularity in the use of portable XRF in archaeology has been felt across all spheres of the discipline. Applications of the technique are now wide and varied, and the affordability, flexibility, and non-destructive nature of this type of elemental analysis, together with easy to use software and internal calibration parameters have created an instrument that many new users are keen to embrace. Although portable XRF is being applied in increasingly novel and inventive ways, a commonality is the production of large datasets that must be statically treated and analysed. It is often at this point where interpretation begins and the many potential problems of integrating elemental data with archaeological research questions occur. This session invites contributions from all portable XRF users to discuss the advantages and disadvantages of the technique, the methods they have used, and the practical and technical opportunities and restrictions. We are keen to examine the different stages of a project where portable XRF can be applied, whether as a prospection method, to screen through stratigraphical layers on a site, or within the lab on artefacts with extensive sample processing. A particular focus will be the challenges within the analysis, data processing and interpretation stages. The aim is to cover a broad range of material types, in-situ and ex-situ analysis, and the wide range of archaeological research questions the instrument can help address. We hope to create a productive, inclusive discussion between both new and experienced users from all backgrounds.

S26-01 Seeing things differently. The use of combined geochemical and geophysical prospection techniques to investigate early Islamic town planning

Kate Welham, Derek Pitman, Chloe Duckworth, David Govantes - Edwards, Yvette Barbier, Ricardo Cordoba de Llave

This paper examines the combination of in-situ portable X-Ray Fluorescence (pXRF—Niton XL3TGOLDD+), and geophysical survey data obtained from the 10th century, early Islamic site of Madinat al-Zahra in Cordoba, Spain. The work presented here forms part of a larger research project that investigates the key role that glass, ceramic, and metal production had in the creation of urban centres, and the important question of technology transfer between Muslim, Christian and Jewish groups within Spain and in the wider Mediterranean at this time. Preliminary results are presented that demonstrate how this novel approach to site-wide prospection has identified a range of likely production areas within the medina (city) at Madinat al-Zahra. Elemental 'hotspots' obtained from a relatively coarse pXRF survey of the top-soil at the site are seen to be directly linked to substantive magnetic anomalies that have geophysical signatures suggestive of high-temperature activities. Iron working and probable ceramic production were located, and specifically areas of elevated lead, copper and manganese were found to be linked to the remains of furnaces that may have produced the famous glazed ceramics known to be manufactured on the site. The results move beyond enabling a more nuanced approach to the interpretation of geophysical datasets, and towards an integrated archaeological prospection tool on a site-wide level.

S26-02 Pipes, pedalis and portable X-ray fluorescence: New avenues for the study of Roman building materials

Derek Pitman, Mark Brisbane, Paul Cheetham, Miles Russell, John Beavis, Rob Symmons, Stephen Clews, Susan Fox, Maurice Tucker

This paper presents aspects of the 'Building Roman Britain' project which aims to use rapid, non-destructive chemical analysis to explore the procurement, production and use of building materials in early Roman Britain. Specifically, it focuses on the development of an analytical framework that employs portable X-ray fluorescence to target specific questions regarding the

production and use of ceramic building material (CBM) from Fishbourne Roman Palace and the Roman Bath Museum. In the context of Roman Britain, CBM production is a new technology practiced on an industrial scale. Its use could be considered a fundamental expression of Roman identity and the need for high volumes of material in a variety of forms presents interesting questions regarding how production was practiced and organised. CBM is one of the most abundant finds on many Roman sites and yet as an archaeological resource it is comparatively under researched. Its abundance coupled with its generally fragmented state can lead to inconsistent recovery and reporting practices, especially as single sites can produce literally tons of material. This can present significant problems for those tasked with interpreting and curating the material. On occasion, CBM may be preserved in-situ in the form of floors, hypocausts and foundations which represents a significant resource in the presentation of archaeology to the public. This leaves some of the most significant examples of CBM, from a public engagement perspective, inaccessible to lab-based study while there remains an abundance of accessible material that could serve to overwhelm traditional analytical methodologies. The work presented here explores these issues through the chemical analysis of samples of known date, form and fabric in order to explore the variation in production/raw material choices coupled with in-situ material in the two museums; giving a new avenue for the characterisation of archaeological material and the interpretation of museum exhibits.

POSTER

S26-P1 A multidisciplinary project for the study of historical landscapes: New archaeological and physicochemical data from the “Colline Metallifere” district

Luisa Dallai, Vanessa Volpi, Alessandro Donati

In the last years the Colline Metallifere district (southern Tuscany) has become a multidisciplinary study area. The territory is very well known for the presence of a large copper, silver, lead and iron sulfide deposit that was exploited over the centuries. A protocol for multiscale analysis of landscape and archaeological contexts has been developed and tested on different sites. The core of this protocol is a combination of archaeological, physicochemical and geological analysis, useful to describe and interpret the history of this peculiar region. The poster will illustrate the major results of pXRF analyses undertaken both on excavation sites and territorial samples; these data can be interpreted as possible traces of ancient human activities. In particular, it will be shown how this high throughput technique can be used in multi-scale investigations (intra-situ and medium-large territorial scale) with both predictive and descriptive goals, providing detailed chemical map helpful for excavation planning and historical evaluation of landscape changes. To validate pXRF data, a number of laboratory techniques (EDX, ICP-MS, GF-AA etc) have been applied on environmental matrices (soil, stream sediments), structures and findings. Moreover, preliminary results of pXRF analyses performed on new "key-sites" selected within a 5 years ERC project based in the University of Siena will be presented. The main object of this ERC project (NeuMed. Origins of a new economic union, 7th–12th centuries: resources, landscapes and political strategies in a Mediterranean region) is the study of the Colline Metallifere landscape features (coast, valley, hillsides and mountains), in order to reconstruct and understand the deep changes occurred in settlement patterns, trade routes and in the economical background of the area between Late Antiquity and the XIIth century.

S27 Revealing by visualising: Geographic relations in cultural heritage databases

Mieko Matsumoto, Michael Märker, Espen Uleberg, Volker Hochschild

Cultural heritage databases can easily accommodate, and are often required to contain large quantities of data. It is a challenge to present and convey this data in a manner which provides a comprehensive overview, whilst simultaneously promoting new interpretations and understanding. To continue from the CAA in Siena, we would like to bring together researchers working on varying issues connected to the geographical relationships in cultural heritage and archaeological data. This can include the technical prerequisites of database systems, such as interface solutions that transform geographic, geodetic and 3D data to visualisation tools. We welcome presentations of tools and interfaces that allow the visualisation of this data in web based services, GIS systems, etc. In addition, we also wish to discuss tools for the spatial assessment of data in terms of spatial descriptive statistics and modelling.

Examples of open source solutions are especially welcomed, along with applications that provide an overview of state of the art solutions. Further points of discussion include how to integrate the requirements of the target user and create sustainable systems— here questions of visualisation versus interaction might be relevant.

S27-01 GIS-based data integration for mapping paleoenvironments

Christian Willmes, Daniel Becker, Michael Märker, Volker Hochschild, G. Bareth

Maps depicting environments as they were in a certain time of the past, are very useful tools for researchers working on questions concerning these time periods. Those paleoenvironment maps contextualize data in a defined spatio-temporal frame. For example, to visualize an archaeological finds database containing data of the Alleröd–Interstadial time period, it is desirable to contextualize the find sites on a map displaying according topographic features like glaciation extends and coast lines, and if possible climatic and vegetation regimes of the given time in the region of interest.

Paleoenvironmental studies and according facts (data) are abundantly published in the scientific record. But GIS based paleoenvironmental datasets are relatively scarce. For the here presented project, we present how to acquire and produce GIS datasets from published non-GIS based facts and informations, such as analogous maps, textual informations or figures of scientific publications, and collect them in a database. This database consists of the metadata describing the paleoenvironmental data sources, that allows to query for spatial and temporal features.

This way we aim to make more paleoenvironmental data accessible for GIS based analyses and map creation. Another benefit of the GIS approach is the access to well developed data exchange and data integration techniques, known as Open Geospatial Consortium (OGC) Open Web Services (OWS).

Based on these OGC OWS collaboration (MÄRKER ET AL. 2015) between the CRC806-Database (WILLMES ET AL. 2014) and ROCEEH ROAD (MÄRKER ET AL. 2009) is setup, to exchange GIS data. The presentation will detail technicals of the collaboration between ROAD and CRC806-Database, and will show the data collection workflows and details of data management, as well as some paleoenvironment maps, which were produced in this endeavour.

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S27-02 Endangered archaeology in the Middle East and North Africa: The development of a spatial database

Richard Jennings

Archaeological sites across the Middle East and North Africa are under ever increasing risk from a range of threats such as growing population sizes, increased agricultural production, urban development, warfare and looting. The Endangered Archaeology in the Middle East and North Africa project (Eamena), which is based at the University of Oxford and the University of Leicester and is supported by the Arcadia Fund, is in the process of recording endangered sites, many of them unrecorded, from across this region using satellite imagery and aerial photography. The project collaborates with cultural heritage institutions in different countries as well as scientific researchers and all people with a strong interest in the preservation of its rich archaeological heritage.

In this presentation we discuss the development of the spatial database, which underpins the aims and objectives of the project. It is built using the Arches cultural heritage management system, a freely customisable open source software package that complies with to international recording standards. A number of key stages formed part of the database development, including setting out what types of data to record, what terms would make up the semantic vocabularies, ensuring that the structure conformed to CiDOC CRM standards, uploading of legacy datasets and the integration of satellite imagery. The aim is to produce a database that will be publically accessible and is designed to be used by a network of well trained staff in the region, with the skills to record and manage sensitive archaeological sites and landscapes, to ensure that the cultural heritage will be managed in the future.

S27-03 Management of raster data and their dynamic visualization within the ROCEEH–ROAD System

Michael Märker, Volker Hochschild

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. The main aim of the Heidelberg Academy of Sciences and Humanities project entitled "The role of culture in early human expansions (ROCEEH)" is to assess the spreading "out of Africa" in a spatial, cultural and biological context. Implicitly we suppose as working hypothesis that the influence of changing environmental conditions decreased as the importance of cultural and technological innovations grew. The ROCEEH project deals with a variety of variables and formats from geology, geomorphology, palaeontology and archaeology in vector, raster as well as text formats. To achieve the general objectives a georelational spatial information system was developed and implemented. The system is called "The ROCEEH Out of Africa Database (ROAD)". In this paper we focus especially on raster data and their dynamic visualization in order to assess landscape evolution. The ROAD georelational database was designed as flexible as possible to store manipulate and visualize geographic spatial data. Therefore open source software based on the OGC standards was implemented. Moreover, we provide several web map and web processing services based on a backbone structure with a specific raster data management. The latter allow the visualization of dynamic features in

landscape evolution such as topography changes or sea level changes. The acceptance of a database related to early human expansion studies depend very much on the capabilities to explore and visualize the data and to results in a dynamic way. Thus, different levels of interaction must be provided with the system in order to fulfil the manifold user requests.

S27-04 Vertical aspects of Stone Age distribution in Norwegian high mountains

Mieko Matsumoto, Espen Uleberg

This paper will show how the vertical aspects of Stone Age distribution in Norwegian mountains can be visualized through the museum database. This database system developed used by the Norwegian university museums is by now used for cataloguing all new acquisitions. It also contains metadata for the older parts of the collections. These archaeological collections are available through the website www.unimus.no as open data. As of November 2015, around 900 000 entries can be queried and presented. The majority of finds are geotagged, and some of the finds are related to posts in the national sites and monuments register, Askeladden. All finds are annotated with different precision levels ranging from precise location over cadastral unit to municipality and county. Some types of analyses can only be done with objects with precise provenience information, while analyses concerning trends within a larger area can use finds with lower precision levels. These precision levels are therefore decisive when choosing objects for the different analyses. Our project *Dynamic distributions* was concentrated on the visualization of large stone artefacts like axes, sickles and daggers in South-East Norway. These finds are mainly from valleys and agricultural areas. The vertical aspect should include the high mountains, and then it is necessary to take other material types into consideration. One important aspect for the find distribution in the high mountains is the fluctuating tree limit. Soon after the end of the Ice Age, the tree limit was much higher than today. Many of the Stone Age sites that today are interpreted as high mountain sites have been below the tree line in a birch and pine forest. The paper will present different visualizations of artefact type and site distribution across the high mountain region.

POSTER

Cancelled S27-P1 Distributions of Age at death from Roman Epitaph inscriptions in North Africa: An application of data mining

Peter Oskar Pflaumer

Thousands of age at death inscriptions from Roman epitaphs in North Africa 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 yields that the epigraphic sample is not representative for the mortality in North Africa. The results are compared with data from epitaphs from the European provinces. Africa is quite different. The general mortality level is much lower. The African cluster is much more homogenous than the European cluster. The distributions are determined by three factors: Mortality, levels, commemorative processes, and population growth rates.

S28 Methodology of archaeological simulation. Meeting of the Special Interest Group in Complex Systems Simulation

Iza Romanowska, Joan Anton Barceló, Florencia del Castillo

Following its creation at the CAA2014 in Siena the Special Interest Group in Complex Systems Simulation invites all researchers with an interest in computational modelling to join the discussion on the challenges and potential of simulation in archaeology.

This year the main focus of the meeting is on the methodology of simulation. Topics will include but are not limited to:

1. Model and Simulation: From Virtual Reality to Complex Systems Simulation.
2. Modelling Techniques: The world of options beyond Agent-based Modelling.
3. Constructing the Ontology: What goes in and what goes out in a model?
4. Testing and Validity of Simulations: How do we know which model to trust?
5. Best Practice in Model Design: ODD protocol, code sharing, replication.

The roundtable will consist of a series of lightning talks on the particular methodological challenges of modelling complex systems given by experts in archaeological simulation, followed by a roundtable discussion open to the audience.

S28-01 Why Model?

Juan Barceló

Modelling and simulation from an epistemological perspective. What is modelling, how does simulation differ from other types of modelling? What are the goals of simulation? What can we achieve with it? What are the strengths and limitations of the method.

S28-02 What is complexity theory and why should we care about it

Stefani Crabtree

What is complexity science? What is complexity? What is the difference between complex and complicated? Examples? What is the big deal of ‘emergence’ about? Isn’t complexity science just for physicist and mathematicians?

S28-03 Simulation as middle–range research

Ben Davies

How do we build the artificial society and the world around it? What do we include and what leave out of a model? How do we know that the model is a correct representation of the real–world system?

S28-04 Models: ‘Small and elegant’ or ‘complicated but realistic’?

Colin Wren

Theory driven and data driven models. Models that aim to emulate and models that aim to explain. Are these really two modelling paradigms or a gradient depending on the focus of different models? When do we use each type? How to struck a balance between generalist results and the need to validate the models against archaeological data?

S28-05 ABMs, because they’re worth it? Alternatives to our favourite method

Elizabeth Gallagher

Archaeologists LOVE agent–based modelling, but is it the only method? What other types of simulation are out there? Why and when we may prefer to use them?

S28-06 Fancy doing some networks?*Tom Brughmans*

What is network science? Are network science and complexity science related? What is network data? What can and what cannot (shouldn't) be represented as networks? Examples of archaeological networks.

S28-07 Building on expert advice to create an informed model*Philip Verhagen*

How to draw on expert knowledge to create an informed model? What are the challenges of translating 'what we already know' into realistic simulation setup? How do we get parameter values for things we cannot derive from the archaeological record?

S28-08 Lessons already learned: Drawing from the best software practice*Iza Romanowska*

The technical side of things. Different languages, which one to choose? What is 'good code'? The standards of development, testing, documenting and disseminating.

S28-09 Proof of concept: Verifying ABM with analytical methods*Irmela Herzog*

Using an analytical method to verify (check correctness) of a simulation. Bugs lurk in almost every code, testing results of ABMs against analytical methods (spatial analysis, statistics, etc) can help with detecting and correcting them. How to choose the right method? What type of 'artificial data' to compare and how?

S28-10 Validation: The painful moment when the model meets the data*Florencia del Castillo*

Validation is a big topic in simulation, what is it all about? Do all models need to be validated? How to choose which data to validate the model against? How to deal with uncertainties and biases of the data? Do we need to model taphonomic processes or biases caused by uneven history of research? What if the model does not agree with the data? What is 'overfitting'?

S28-11 Model selection: What is the 'best' model?*Xavi Rubio-Campillo*

Even if 'all models are wrong but some are useful' are some more wrong than other? Techniques used to determine which models fit the data better.