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, Martinez, 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

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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 Ruíz-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 petrogliphs 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 retrouves: 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 intercessionary 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 0.3┬ám to 5.6┬ám). 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 1┬ámm. 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.