Abstracts CAA Tübingen 2018

UNIVERSITÄT TÜBINGEN

CAA
TÜBINGEN 2018

HUMAN HISTORY AND DIGITAL FUTURE

MARCH 19-23

Session 1
Creative Disruption in Archaeological Theory and Practice

Digital Creativity or Digital Dark Age? A scenario analysis of archaeological knowledge production in an insecure world

(Jeremy Huggett, Gary Lock, Paul Reilly)

Digital technology increasingly pervades all settings of archaeological practice (i.e., academic, contract, public, museum, and archive) and virtually every stage of knowledge production. Through the digital we create, develop, manage and share our disciplinary crown jewels. However, technology adoption and digital mediation has not been uniform across all settings or stages. This diversity might be celebrated as reflecting greater openness and multivocality in the discipline. Alternatively, it can be argued that such diversity is unsustainable, and that standards are insufficiently rigorous. However, all positions face the possibility of being severely tested by some large-scale external event: on every continent we witness economic and political upheaval, violence and social conflict. We ask how secure is the digitally mediated knowledge being produced by archaeologists today? To investigate this question we apply the futurity technique of scenario analysis to generate plausible scenarios and assess their strategic strengths and weaknesses. Based on this analysis we propose some measures to place archaeology in a more robust knowledgescape without stifling digitally creative disruption.

An antidote to the digital? Exploring the space between digital and non-digital in creative post-conflict reconstruction

(Zena Kamash)

In this paper, I will explore ways in which creative practice might be employed alongside or in combination with digital methods in finding solutions to post-conflict reconstruction in Syria and Iraq. Current propositions, such as the Institute for Digital Archaeology's replica arch from Palmyra, may appear shiny and exciting on the surface, but are lacking in numerous ways beneath that surface. This paper will demonstrate how other approaches, such as Michael Rakowitz's 'The Invisible Enemy Should Not Exist' and the 'Art from Zaatari' group, as well as my own 'Postcard to Palmyra' and 'Remembering the Romans in the Middle East and North Africa' projects, might disrupt the rhetoric and acceptance of the current propositions. In different ways, each of these creative projects seeks to refocus attention from the purely physical to the social relationships and networks of memories that are tied into the sites and monuments that have been destroyed. Harnessing the spirit of these more creative approaches might provide us with an antidote to the current propositions and suggest ways forward that might be more effective in helping communities and their cultural heritage to heal.

A Computational Decipherment of Linear B

(Katie Paxton-Fear)

The mystery of the world's undeciphered scripts continue to draw in amateurs and experts alike. Machine translation currently allows us to translate known languages and writing systems such as between English and French or between English and Greek but this technology could be used to unlock

the mysteries of the past and computers may hold the key to the understanding of these scripts. This project is a reconstruction of the decipherment of the Linear B script using computational techniques. Computational decipherment is a very important field; many ancient languages remain undeciphered such as Linear A, Etruscan, Rongo Rongo in addition to other ciphers or unknown writing system such as the Voynich Manuscript. Advances in decipherment could reveal more about the ancient world and answer key archaeological questions. In addition to deciphering more languages decipherment techniques can be used to further enhance machine translation by allowing translation with smaller corpuses. This project has deciphered Linear B in 3 stages, like the original decipherment, with the assumption that we have all tablets available in the dataset. In the first stage, an unsupervised algorithm will be used to automatically find inflected nouns. In the second phase, the results of this algorithm will be used to create a grid of values where signs share vowels or consonants. In the final phase, we will use a genetic algorithm to suggest possible values using evidence from statistics and known values of similar and related signs.

When Archaeological and Artistic Practices Meet Halfway: generative 'close encounters'
(*Paul Reilly*)

'Archaeological records' may be layers of material, artefact collections, and documents translating these deposits and artefacts into, nowadays, digital records. In traditional reports, the diggers, their tools and the encapsulating deposits, which together create an archaeological 'contact zone', are largely missing, anonymous and unacknowledged in the traditional 'hegemonic written accounts'. However, a plethora of low-cost digital devices capable of recording different modes of on-site intra-actions enable alternative field records. For both archaeologist and fine artist, the process of knowledge and learning develops through the act of doing - trowelling or drawing. Both practices intra-act through direct and repeated rhythmical contact and interconnection between practitioner, tools and deposits, and so dialogues develop. Gestures, tools, and deposit cyclically flow. Ultimately, such re-codings or translations generated through touch, mark and action intra-actively produce our findings. During these close encounters all actants leave visible, acoustic, haptic or olfactory traces or marks on one another. Now detectable and susceptible to analysis using standard digital video recording devices and computational imaging, these traces and marks can be conceived as signatures, each anonymous actant attesting for the other's presence and their modes of intra-action. Now, through experiential, shared and discrete dialogues involving the hand between collaborating field archaeologist and fine artist, new and expansive forms of digital recording can produce a new aesthetic of auto archived paradata and extended drawing practice, co-signed by excavator, tool and deposit, to disrupt the hegemony of the traditional written account.

"Not Just a Pretty Picture": Interpretive Visualisation as Design Practice in Archaeology.
(*Alice Watterson, Mhairi Maxwell*)

Archaeological visualisation, or the act of picturing the past in the present, is a complex area of research which exists at the convergence of evidence, interpretation, scientific data collection and artfully crafted storytelling. It is a process which relies on personal engagement between practitioner, practice and the archaeological record. Despite the ever present practice of image-making in archaeology, recurrent debates wrestle with a reluctance to engage with subjective methodologies

and the visual outputs of practice-based research. Design connects creativity and innovation, it is characterized by similar attributes to the interpretive process in archaeology: collaboration, intention, experimentation and discovery. Both design and interpretive visualization are a means of seeing and interacting with the world, they are a work in progress with a human perspective. As part of their visualization practice both archaeologists and designers imagine, research and problem solve. Reflecting upon the authors' shared experiences assuming dual identities between the fields of archaeology, art and design this paper considers the interdisciplinary building blocks which encourage innovation in practice. What vantage points have we been afforded by adopting transient roles as archaeologists, makers and storytellers? We argue that viewing the process of image-making in archaeology within the constructs of a design challenge could provide the field with the framework it badly needs to better understand the role of "creative disruption" in archaeology. Ultimately exploring how these shared perspectives might help develop creative methodologies and outputs which more meaningfully reflect the multi-layered, multi-vocal and ambiguous processes involved in archaeological interpretation.

Epoiesen and ODATE: Small Acts of Disruption in Archaeological Publishing
(*Shawn Graham*)

In this paper, I discuss the philosophy and disruptive methods behind two publishing projects with which I am involved. The first, 'Epoiesen: A Journal for Creative Engagement in History and Archaeology' makes a space for non-traditional (primarily, though not necessarily, digital) work in archaeology and heritage. It employs author-led licensing, markdown formats, ORCID & DOIs, and open source code, with an open peer review 'respondent' system. The second draws inspiration from open notebook science, literate programming, and git-enabled collaboration to create the 'Open Digital Archaeology Textbook Environment'. In this paper, I discuss how these two projects make operational ideals of open access research, and where they fit into a wider ecology of publishing, with reference to the work of such scholars as Ben Marwick. I discuss what's working, and what's not, and reflect on how these small acts of disruption could become much bigger acts of disruptions...

Design, Deployment and Dissection of an Archaeological Reconnaissance Robot at el-Hibeh, Egypt
(*Namir Ahmed, Jimmy Tran, Alex Ferworn, Jean Li, Carol Redmount, Michael Carter*)

In this paper we discuss our approach for the interdisciplinary use of robotic technology for the purposes of Archaeological reconnaissance. We will examine the creation and deployment of one of several Unmanned Ground Vehicles (UGVs) during the 2017 el-Hibeh field survey directed by Carol Redmount and Jean Li. Though the use of UGVs in Archaeological study is no longer novel (see Richardson's Giza pyramid exploration). We argue the field of robotics has reached an important juncture where a codified and procedural methodology is both possible and needed. Our case-study is divided into two sections. The first describes processes and decisions during the production of the el-Hibeh UGVs. Here we describe technical considerations, test protocols and design adaptations. We also explore how Cultural heritage experts inform these decisions while maintaining archaeological integrity and cultural sensitivity. Section two describes the UGVs deployment in the field, preparations

made, reconnaissance strategies and results. Here we also describe procedural field documents as well as a nascent MetaData framework for the use of robotics in the field. To date there is a paucity of direction in this regard through standard guides such as the Archaeology Data Service / Digital Antiquity: Guides to Good Practice. We believe the regular use of robotics in cultural data recovery is a necessary advancement of current practices, though aerial drones are becoming common the procedures needed for academic field research does not extend to UGVs. Our goal then is to offer this case-study as a potential way forward.

Digital Other: The Creative Use of Digital Avatars in Virtual Reconstructions

(*Kristian David Howald*)

As virtual reconstructions of archaeological landscapes have become more pervasive, it has became clear that there is a haunted emptiness to the virtual experience. Although highly charged in terms of the representation of the "other", digital avatars that represent ancient inhabitants of these landscapes we endeavour to envision, help to ground and situate not only the virtual archaeological interpretation, but our understanding of how these landscapes might have been inhabited. The use of digital avatars became a digital extension of dioramas being used around the world, such as those found at the Museum of Natural History in the Spitzer Hall of Human Origins, or Sterling Castle in Scotland, which effectively illustrate characters frozen within life moments. As part of recent research into the virtual (re)imagination of the ancient Middle Egyptian temple of Amun Great of Roaring at el-Hibeh, Egypt, I explored how a digital environment with this type visual representation of ancient characters and content could be pushed further. How would the addition of higher fidelity, lifelike avatars affect the virtual experience? Should these characters move and interact with objects in the environment, or even acknowledge a viewer's presence? How could advances in AI be utilized for these virtual humans, and should it? To create a greater phenomenological experience could these avatars be more than static video game characters? Through users engagement, I explore this creative disruption with jarring effect, suggesting that avatars both enhance and distract from the reconstructed archaeological landscape.

Towards an autoarchaeological archiving of practice within contextual and spatio-temporal meta-databases.

(*Andrew Gryf Paterson*)

This paper shares examples of the author's archival and artistic research method described by the author as autoarchaeologies. It faces an emerging research problem: How to represent and interpret practice, in this case, artist-organiser event-based activity and processes — that have happened in multiple contexts and locations, over time? The approach builds upon earlier practice-led research in virtual, augmented and mobile media environments (2002-2006), and reflections on charting 'artistic fieldwork' (2011) connecting authorship in spatio-temporal data structures, and borrows from archaeological and geological practice of stratigraphy, which records inter-related strata (or loci in time-space) to chart inter-related contexts and durations. Autoarchaeologies supports the charting of geneologies in open-ended processes, relative development and coherence of activities over time. In the context of increased meta-data-augmented documentation of practices and everyday life via

ubiquitous mobile computing and online publishing platforms, there is arguably increasing amounts of personal (small or big) data to interpret and analysis. This is especially interesting in the context of autoethnography, digital humanities, and media archaeological investigations into mobile and location-based media that is available in recent, current and future media landscapes. One archaeological theorist suggests, with access to multitude of data available about our own and others past activities, we are all (potentially) archaeologists now.

Lived lines: a lineological approach to network analysis

(*Gisli Palsson*)

Network analysis in archaeology is beginning to develop serious momentum. The practice has roots in processualism, but was somewhat pushed aside in the following years when archaeological theory was dominated by poststructural approaches. Since then, archaeologists have begun to adopt it widely, and in particular the methods collectively known as social network analysis. These, however, often lead to all-to-stable visualizations of relations between objects and things. This presentation aims to creatively engage with the way archaeologists currently practice network analysis by considering links between nodes not as straight lines, but storied lines. Lines that bend and knot as they are actualized and materialised; lines that often seem initially to connect A to B, but then begin to wander the landscape. The presentation draws on the author's dataset integrating Iceland's largest site record Ísleif with historical material (www.jardabok.com), and explores what a lineological approach to network analysis would constitute. Such an approach leans on both quantitative methods offered by spatial analysis, as well as qualitative methods, to arrive at a network of lived lines.

Chatbots for museums and heritage sites: all hype or promising strategy? A case study in building ChatÇat, a 'bot of conviction' for Çatalhöyük.

(*Angeliki Tzouganatou, Sierra McKinney, Sara Perry*)

Here we explore the feasibility of implementing chatbot technologies for museums and heritage sites by presenting ChatÇat, a provocative chatbot for the archaeological site of Çatalhöyük. Inspired by Shawn Graham's call for digital media that are able "to move us, to inspire us, to challenge us," and by his reference to Mark Sample's concept of "bots of conviction", this paper details the formative phases of constructing a Facebook Messenger-based automated conversational interface for Çatalhöyük that aims to compel critical reflection amongst its users. Increasingly adopted by cultural organisations within their digital strategies as means to attract and develop audiences, chatbot technologies are regularly proclaimed to offer novel engagement mechanisms that can empower participants. However, most Messenger bots in the museums and heritage sector are purely informative and object or exhibit centred, providing little opportunity for meaningful interactivity, creative expression, or critical engagement. Operating under the EU-funded EMOTIVE project (www.emotiveproject.eu), we describe our preliminary experiments in extending the 'traditional' canon of the museum/heritage bot into a challenging, provocative engine of social commentary and self-reflection. In this way, we aim to position the archaeological record of Çatalhöyük as the kick-off point for more emotive and probing human engagements with the world at large.

Documenting archaeological knowledge construction as distributed information practices

(*Zack Batist*)

Archaeology is a complex and communal undertaking that brings together people with varied backgrounds, who mobilize a wide range of tools and expert knowledge to assemble the archaeological record. In recognizing objects of interest and characterizing their significance through encoded disciplinary language (i.e. through data construction and other forms of scholarly communication), we situate our tacit, local experiences within an archaeological epistemic culture, or common modes of reasoning. Communication among archaeologists is therefore considered as a process of enculturation, whereby a shared understanding of the pragmatic conditions and expectations that underlie a record's construction facilitates its continued use by others. This paper presents the preliminary results from my doctoral research, which is an attempt to better understand this archaeological epistemic culture, and to develop information infrastructures that facilitate the interoperability of archaeological data across research contexts. By observing archaeologists as they work, which includes affixing GoPro action cameras to their foreheads in order to obtain first-person perspectives, the physical, cognitive and communicative processes that comprise common fieldwork practices are formally identified and related. These observations are integrated with interviews and analysis of recording practices in order to better understand individuals' affective roles within their socio-technical research environments, as well as the communicative processes (i.e. documentation, representation and mediation) that enable research to be distributed among archaeologists and across various settings. In sum, I trace the relationships among archaeologists, their tools, the ideas they draw from, and the archaeological record itself, as knowledge is constructed under realistic and social conditions.

Vampires vs Puffins: culture and nature on the Isle of Staffa

(*Stuart Jeffrey, Derek Alexander, Sian Jones, Daniel Rhodes, Shona Noble*)

This paper discusses the transformation of the Isle of Staffa, a small uninhabited island in the Inner Hebrides of Scotland, from a place famously 'burdened with culture' to a site primarily associated with the natural world, especially geology. For 150 years following Joseph Bank's 'discovery' of the island and its most notable feature, 'Fingal's Cave', in 1772, the site became central to the European romantic imagination. This is particularly apparent with regard to the relationship between nature and culture and the importance of solitude in its contemplation. The HARPS project (a collaboration between the Glasgow School of Art, The National Trust for Scotland and the University of Stirling) has been deploying multiple archaeological, digital recording, visualisation and auralisation techniques to understand the islands past, including early tourism, but also to realign our modern response to the site towards earlier conceptions of the 'sublime'. While Staffa was significant to visual and literary artists, from Turner to Wordsworth, Scott and Verne it is the importance of sound, which has inspired artists from Mendelsohn to Pink Floyd, that remains most challenging to represent. This presentation will describe new techniques for capturing the acoustic response of a dynamic and noisy site, and extracting an acoustic convolution that can be used for spatial auralisation in real-time, including in fully immersive VR environments. The value of this approach and the potential this has to help situate

new work, including digital visualisations and representations, within the existing rich continuum of creative response will also be discussed.

Creative disruption in Central European archaeology – reflexive or thoughtless?
(Jens Crueger)

Archaeology in its theory, method and practice is strongly influenced by general concepts and paradigms which are perpetuated by archaeological schools. The question whether or not archaeologists are aware of this influence is an important one, which has, for a long time, been completely underestimated. RĄCZKOWSKI recently introduced the classification of "thoughtless" archaeology and reflexive archaeology in order to emphasize the individual archaeologist behind the theories, paradigms and schools.* In which of these two categories will the archaeology, driven by creative disruption, fit? Will this be a new, more reflexive approach on archaeological theory and practice? One might assume this, since creativity and reflexivity are concepts that are linked with each other regularly in the innovation theory. But from the historical lessons we've learned in the past century, new methods and tools introduced to archaeology don't necessarily mean a shift of the scientific paradigms. So focusing especially on 3D documentation and visualizing technologies, used in Central European archaeology, we will have a closer look at how individual archaeologists handle the novel digital applications on the one hand and their theoretical background on the other hand. Does this happen in a reflexive or thoughtless way? *) RĄCZKOWSKI, WŁODZIMIERZ: The "German School of Archaeology" in its Central European Context: Sinful Thoughts, in: Gramsch, Alexander – Sommer, Ulrike (eds), A History Central European Archaeology. Theory, Methods, and Politics, Budapest 2011, 197-214.

A Conceptualization of Image-based 3D Recording in Field Archaeology
(Matteo Pilati)

This paper presents a conceptualization of image-based 3D recording. This initiative was finalized to the identification of the methodological and epistemological implications of integrating image-based 3D modelling for the mundane practice of documenting excavation sites. This conceptualization builds upon the acknowledgement of the methodological requirements of field documentation, the axiomatic nature and aims of photogrammetry and computer vision, and the interdisciplinary character of archaeological investigations. Aided by diverse theoretical resources on the question of objectivity and empirical observations in the field, the author describes how the production of representations, which do not require the archaeologist's subjective work of interpretation, characteristically impacts interpretation and unsettles traditional documentation practices. The results are a three-staged model of interpretive process where the subjective work of interpretation is split, but also unified, through the photo interpretation of computer-generated representations. In order to take advantage of image-based 3D recording in documentation practice, the new metadata object of "produced and recorded surface" is recognized as capable of linking information registered on a 3D representation to the related excavation events. This promotes practices of metadocumentation, that is, reflexive practices of recording and interpreting the task- and decision-based fieldwork environments. Thereby, the author proposes a theoretical strategy to reach introspection with

methodological innovations and to cope with the conundrum between objectivistic and constructivist views on method-led archaeology in the present theoretical debate.

Session 2
Islamic History and Archaeology: Linking Data and Ontologies

OpenOttoman and the Challenge of Building an Ottoman Gazetteer
(*Amy Singer*)

OpenOttoman is a transnational digital initiative for scholarship and public history focused on the Ottoman world. Its public face is openottoman.org, a portal to resources in Ottoman studies and the hub of collective initiatives like the gazetteer of the Ottoman world. A central challenges in Ottoman studies is to determine the correct name and location of a particular place. This is crucial for any study, professional or amateur, of the Ottoman world. Further, the chronological and geographic importance of such a gazetteer stretches beyond the formal definitions of the Ottoman state, as the same places were part of histories intertwined spatially and chronologically with those of the Ottomans. Moreover, the multiplicity of names as well as the disappearance of Ottoman sites – covered over the present, accidentally or willfully destroyed – can make the work of identifying locations of towns, buildings and activities quite difficult. Cooperations between historians and archaeologists are indispensable for sorting fact from fiction and recovering aspects of the Ottoman past. The study of the Ottoman world includes places incorporated into, disassociated from and connected to the Ottoman state for over 600 years. Important sources exist in at least twenty-five languages and eight alphabets, the result of the multi-lingual, multi-national and multi-confessional Ottoman population. The OpenOttoman initiated gazetteer aims to include locations as latitude and longitude coordinates, with dated and documented name variants, and eventually administrative associations at multiple levels. This paper will discuss the pilot initiatives in building this gazetteer.

Feature vs. Name? Identification and Localization Strategies for Linked Open Data on Islamic Places
(*Kurt Franz*)

This paper asks for the potential of digital gazetteers to connect the diverse evidences that are at the basis of historical-philological study on the one hand and archaeology and architectural history on the other. Seeing that lines of cultural transmission in the Arab-Islamic region often span from antiquity to the present day, the multi-linguistic record of historical place names provides outstanding markers of human development. Toponymy reveals tremendous continuity in some parts, while indicating shifts, transitions, or ruptures in others. This paper will make a point that whereas any single project-based gazetteer needs to keep within rather strict thematic, chronological, and geographical limits, a network of interlinked resources can go beyond. If a number of gazetteers or, more broadly speaking, spatially related databases create data according to open standards, this would multiply the opportunities to envisage the region's cultural dynamism. Therefore, this paper first points to the difference between names and places. The relevant tasks of identification and localization are affected not just by the

general issues of onomastics, but also by specific challenges that arise from the use of Arabic script. These will be discussed on the example of the Mamâlik web-GIS project and its geo-database. Second, the paper will reflect on how identification and localization can translate into an ontology that results in historically rich open data. Looking ahead, the ontological compatibility of gazetteers may facilitate researchers to capture human developments in spatial terms across periods and scholarly specializations.

Creating Thematic Layers on the Spatial History of Medieval Empires in the Levant: The GIS Mapping of the Network of Roads and Fortifications in the Syrian State of Nūr al-Dīn.
(*Mathias Piana*)

Due to the wealth of data provided, the manuscript BNF arabe 2281 offers a unique insight into the spatial framework of Nūr al-Dīn's Syrian state as of 1170. Combined with other textual and archaeological evidence, it allows creating not only a gazetteer of the significant sites and communication lines but also enables to provide well-based chronological entries for each site. The transfer of these data to a GIS environment will thus enable to illustrate the dynamics of territorial shifts in the area over time and, finally, the development of Nūr al-Dīn's state building in Syria. It may therefore be taken as a prime example to visualize settlement dy-namics, territorial shifts and state building processes. Along with other such layers covering the same period, their interaction in a GIS environment may lead to a new approach of visualizing intercultural developments in spatial terms.

Session 3
Digital Archaeology Scholars in a Changing World: Problems, Perspectives, and Challenges

Resilient Scholarship in the Digital Age
(*Jeremy Huggett*)

Is there a future for digital scholarship in archaeology? With all archaeologists becoming increasingly digital, where does that leave the digital archaeological scholar now and in coming years? Weller (2011) cites the novelist Martin Amis that, when facing a revolution: "You see what goes, you see what stays, you see what comes". What is important and necessary to us as digital scholars (what stays)? What changes lie ahead that we need to grasp (what comes)? And what practices and values will become vulnerable and threatened by the new technologies ahead (what goes)?

The Dark Side of Digital Archaeology
(*Juan Antonio Barceló*)

The dark side of Digital Archaeology. "Digital" is a fancy word that seems everywhere, but means very little. "Computer based reconstruction" is what archaeologists use to impose a particular view to wide audiences, even though the most archaeologists do not know how the reconstruction has been built using this magic machine. It seems as if the goal is just to visualize the past and offering a nice picture of an idealized past that anyone knows where it comes from. In this presentation, I argue in a very

different way. "Digital" has nothing to do with "images" nor reconstructions but with "numbers" and "formal logics". This is the "dark side" of Digital Archaeology: the computer method that allow us to convert data into explanation. We have to rebuild the way we think about the connection from the past to the present using a new language –mathematics, geometry- that should allow new explanations. The trouble is that most researchers do not know the language nor the tool, and they are still linked to a traditional way of doing things.

Against the wall of words: the last barricade before science

(*Iza Romanowska*)

"…sciences are those subjects in which the relative plausibility of rival hypotheses is capable of evaluation by some form of testing, and arts those in which subjective assessments are made. One might go further and claim that all science must be based upon mathematical principles, whereas in arts subjects this is not so." Dark (1992) Archaeology has a plethora of methods for evaluating rival hypotheses and building understanding using formal mathematical principles. From morphometrics, dating techniques, remote sensing to simulations, chemical analyses, text mining there is nothing inherently barring archaeological research from fulfilling these two necessary criteria to be a 'science'. However, in practice we all too often fall one tiny step short of getting there. Although the majority of archaeologists engage in heavy data lifting and jugglery and carefully use available evidence, once the data reveal the patterns we 'interpret' them using not-formal, not-quantitative and not-computational tool: words. In this presentation I will try to briefly diagnose this ill and put forward several possible cures for further discussion among the practitioners who are most suitably placed to deal with it - digital archaeologists. Dark, K. 1992. "The Science of Archaeology." Philosophy Now 3:21–22.

"…it's Animation…but for Archaeology!"

(*William Michael Carter*)

My paper will discuss the realities of digital archaeology from the perspective of an animation industry specialist and archaeologist, as someone trying to expand the discipline theoretically, methodologically and through practice, in what has traditionally been considered an ancillary addition to the data collection, data illustration or public engagement of archaeology. My archaeology, is the reflexive, virtual, representative, visualization of archaeological data by means of knowledge creation through the practice of making (see Ingold 2011), and is the culmination of related and non-related archaeological skills. As such, I find at times, strained reactions from the more traditional archaeological disciplines, as to the theoretical grounding and value of the practice of digital archaeology beyond providing illustrative or raw data representations. My path, as representative of Ingold's wayfaring points (2011) and Wylie's archaeological cording (1989) has had to include a deep commitment to a transdisciplinary, entrepreneurial and experiential generalist/specialist approach that has pushed my ability to think creatively and disruptively not only in the other disciplines in which I ply my skills, but more importantly in the archaeology I do. Mine is a wayfaring narrative, over 25 years long, in which I have recently witnessed a seismic shift within archaeology, that now values the scholarly research that enhances and creates new knowledge by virtual (digital) archaeological means. As such, there is a duty of care to theoretically ground a new generation of digitally born

archaeologists, as well as the digital archaeological assets and landscapes we now rush to capture, research and exploit.

Session 4
Close range 3D data acquisition, processing and querying in cultural heritage

A browser-based 3D scientific visualisation of the Keros excavations
(*Dante Abate, Marina Faka, Sorin Hermon, James Herbst, Evi Margaritis, Michael Boyd, Colin Renfrew*)

Excavations since 2007 at Dhaskalio, an islet off the west coast of the Cycladic island of Keros, have uncovered the world's earliest maritime sanctuary (ca. 2750-2300 BC). Current work highlights the monumentality of the proto-urban settlement adjacent to the sanctuary, with precocious evidence for metalworking and agricultural intensification. The paper-free digital recording strategy (to be described in full elsewhere) includes an iPad-based recording system (iDig), photogrammetry and terrestrial laser scanning. The latter aspect of the work is reported in detail here. In 2016 - 2017 eight excavation trenches were opened. Surveyed targets were established by the photogrammetry team to georeference their data. Two laser-scanning documentation campaigns used these targets to align and geo-reference high-detail 3D models of trenches at the end of each excavation season. The paper reports on the integration of a 3D model of the island (generated from drone photography) with the laser-scanner 3D models of trenches in a browser-based visualisation where users can visualise the entire island, select trenches and measure distances, depth, area, and volume at any scale, and compare cross-sections. Future work will adjoin photogrammetry 3D models, allowing users to virtually re-excavate the site by 3D visualising contexts, stratigraphic relationships, and sequences of context deposition (and removal). It is envisaged that as the GIS platform develops 3D models may be integrated within it.

Recreating an ancient marketplace with geophysical and topographical data
(*Jona Schlegel, Thomas Schenk, Kay Kohlmeyer, Bilge Hürmüzlü, Arie Kai-Browne*)

Through the use of different prospecting methods it is possible to arrive at an approximate conclusion about the appearance and condition of an archaeological site. In the campaigns in 2016 and 2017 at an ancient mound fortification in Central Anatolia (Turkey), students of the University of Applied Science Berlin and the Süleyman Demirel University collected 10 ha of geomagnetic data and 0,5 ha of georadar data and took around 10,000 pictures. The selected area for this purpose was a Roman delicacies market (Macellum), located at the archaeological site of Seleukeia Sidera. Various methods produced multiple types of data from the area. An intensive field survey provided data for a rough temporal classification. Geomagnetic measurements yielded a more or less exact positioning of features and offered insight into the material properties. Georadar data provided information about the dimensions as well as the depth. Image-based modeling created an extremely accurate topographic model. With this data a detailed current state of the documented area can be mapped as well as an interpretation of the anomalies and their purpose. Finally, these results provided the

foundation for a visualization of the Macellum, whereby neighboring sites such as Sagalassos also further influenced the recreation of the architectural design. The resulting three-dimensional model can provide an impression of the area and the people who lived at that place and time, in addition to directing the decision where to excavate. These techniques can lead to more reproducible results and international data exchange.

Close range photogrammetry for field documentation of the ongoing excavations - experiences from Paphos Agora Project

(Łukasz Miszk, Wojciech Ostrowski, Weronika Winiarska)

In 2016 at the CAA conference in Oslo we presented the methodological guidelines for the use of close range photogrammetry for ongoing documentation of the progress of archaeological work. This was the result of the tests carried out during excavations in Paphos (Cyprus), where technologies such as TLS, UAV or close-range (terrestrial) photogrammetry were used. Since 2016, during three excavation campaigns, close-range photogrammetry has become the main tool for obtaining graphical data during large scale and wide-ranging research. Over 300 models have been made, using almost 18,000 pictures for trenches. At the same time, a database was created using ArcGIS software which serves as a repository for all the data collected during excavation (from field and office work). In our presentation we would like to point out the changes in the management of fieldwork, which causes a wide introduction of photogrammetric documentation. We want to indicate positive features such as the uniformity of data acquired and the one software used for storing and analysing data. At the same time we pay attention to problems not only related to maintaining high quality accuracy, texture or point clouds details but also on aspects related to human factor, organization of work, software support or hardware availability. All that really influences the organization of work during excavations.

Lasergrammetry and high precision topography measurements to study a complex fortified building: Tour de la Pelote (Besançon, France)

(Thomas Chenal, Damien Vurpillot, Laure Nuninger, Marie-Laure Bassi, Amélie Berger, Laurent Desjardins)

As part of its Heritage Atlas project, the municipality of Besancon in partnership with MSHE C.N. Ledoux from the University of Franche-Comté, started a 3D data acquisition focused on a military building, the Tour de la Pelote. This late Middle Ages tower, subsequently included in Vauban's fortified architectural program (UNESCO world heritage) at the end of the seventeenth century, was ravaged by fire in 2013. An archaeological survey was then carried out to investigate the building evolution, prior to its complete restoration in accordance with the past construction. Despite great investment, the tower, remains inaccessible because of security issues. In order to ensure both general public access and research activities on this complex type of archaeological building, it was decided by the partners to acquire high resolution measurement series using a Riegl VZ400 T-Lidar Scanner. The inherent architectural complexity of the building, tied to narrow and steep stairs connections between each floor and a demanding surrounding, remains a challenge not reachable with conventional approaches. This presentation will focus on how to overcome those issues with acquisition methods developed by integrating 3D laser data and high precision topographic data (millimeter scale) indoor

and outdoor. Measurements quality and RMS errors will be discussed in order to observe the correlation between various phases of constructions and restorations more or less documented in previous archeological data. With the Tour de la Pelote example, we intend to show how an heritage project designed for public mediation can also contribute to interdisciplinary research.

The Application of Digital Survey Techniques to the Recording of Burials: A Reassessment of Standard Recording Practice
(*Damien Campbell-Bell*)

This paper details the methodology and results of an investigation which aimed to compare different methods of recording burials to ascertain which methods were the most accurate and, importantly for commercial practice, the most time and cost effective. This study was conducted after the discovery of an Anglo-Saxon cemetery of 150 burials on Salisbury Plain, Wiltshire, UK. Given the scale of the cemetery and recent developments in digital survey methods this was deemed the perfect opportunity for this type of analysis. Whilst everyone involved went into this study with various and sometimes differing preconceptions about the techniques and how they would perform, the results ended up surprising everyone and have since fundamentally changed how we deal with burials at Wessex Archaeology. The techniques compared were hand planning, rectified photography, photogrammetry and terrestrial laser scanning, using both tripod mounted and handheld scanners. The resultant digitised plans were compared for accuracy, positioning and completeness. As the traditional approach to recording burials hand drawings, produced with a planning frame, were the benchmark against which digital techniques were compared for completeness and appearance. Meanwhile laser scanning with its well understood accuracy tolerances was used as the benchmark for positioning and size accuracy. A number of different visual and statistical comparison techniques were used to ultimately determine what we now consider to be the best technique for recording burials.

Practical SfM Balancing: How Acquisition Parameters Affect Computation Time and Reconstruction Quality
(*Christian Seitz, Benjamin Reh, Silvan Lindner*)

Under perfect conditions, the best possible Structure from Motion (SfM) 3D model would be achieved by acquiring the largest number of photos using a camera of highest resolution. However, in reality the resolution is limited by the camera used and the time available onsite constrains the total number of images taken. Furthermore these constraints are directly linked to the computational time and quality of the SfM reconstruction. To determine the dependency between image resolution, number of images, computational time and accuracy of the resulting 3d model, we performed a series of a experiments, which can be categorized in two types: The first set under controlled conditions concerning constant lighting, precise movements between camera and object and accurately measured shapes of the latter to produce quantitatively reliable results. The second set of experiments features application-related objects, such as parts of historic monuments and archaeological small finds. We examine the relation of camera resolution and number of images taken with the reconstruction time and quality of the model quantitatively. For quality analysis, we use precise models

- obtained by a Breuckmann structured light scanner for small objects and a laser scanner for larger objects. Processing time is measured for a set of commercial and free SfM software.

Visualising Heat-Induced Change in Burned Bone: 3D data acquisition methods for novel surface analysis

(Priscilla Ferreira Ulguim)

Burned human remains are frequently encountered during archaeological investigations. Evidence of heat-induced changes in the hard tissues is highly significant in the interpretation of perimortem activity regarding these remains. The changes result from transformational, taphonomic effects of fire, and may indicate the state of the body, treatment and burning conditions. Research into 3D bioarchaeological data acquisition has focused on dimensional quantification, geometric morphometrics, species identification, as well as other surface changes such as cut marks and trauma. Fewer works have investigated 3D visualisation of heat-induced change, particularly surface change, but bioarchaeological data acquisition has the potential to enable remote, crowd-sourced analysis, open linked data, as well as engaging learning possibilities in burned bone surface research. To address this, the paper analyses methods for 3D data acquisition for the visualisation and interpretation of heat-induced surface change in human remains, and recommends best practices for bioarchaeological research. This focuses on the efficacy of digital methods for replicating 3D morphological features of burned bone; data quality requirements for accurate 3D quantification of heat-induced changes such as fracturing; the integration of surface colour data; and cost/benefit analyses, considering duration, complexity and storage. In addition, the paper considers the potential of digital 3D data to improve engagement with researchers and relevant audiences. Methods include structured light scanning, image-based modelling using structure from motion, as well as computational photography such as reflectance transformation imagery. Results indicate significant potential for improved visualisation, quantification and interpretation of heat-induced change in burned bone in particular for fragmented, complex assemblages.

A Multi-Scalar Approach to Structure-from-Motion Site Documentation at Crvena Stijena, Montenegro

(Samantha Thi Porter, Colin McFadden, Gilbert Tostevin)

Structure-from-motion (photogrammetry) is becoming an increasingly common practice on archaeological field sites. As is often the case, new adopters of this technology must work through a multitude of questions. In this instance, these include how 3D data may be able to enhance research, what level of data resolution is required to accomplish these goals, and how new forms of data collection can be integrated into current field practices. We present a case study of a multi-scalar approach to photogrammetric data collection and utilization at the Palaeolithic site of Crvena Stijena, Montenegro. Over the course of the 2017 field season we created 3D models of the site using a Phantom 4 drone, a custom-designed rig consisting of three GoPros on a zipline spanning the site, and a handheld compact digital camera. We will share details of our process (including designs for our self-built equipment) and discuss how the models generated from these approaches are being used to inform our research in different ways. We also explore the use of high-resolution 3D models to

streamline the collection of certain types of excavation data, such as the height of specific points of an excavation unit, and the volume of sediments vs. clasts. Finally, we consider things we could have done differently to improve our results and process, and future directions this work might take.

Is 3D scanning a suitable monitoring solution for supporting the lending management? – Recent projects, experiences and discussion

(*Thomas Reuter, Liane Albrecht*)

Since 2005, at the Archaeological Heritage Office of Saxony finds are digitised by high resolution 3D scanners. Until today more than 17500 objects were 3D scanned. A large number of finds are fragile and shifting organic objects. After documentation the finds will be treated and freeze dried to make them stable for future procedures. Ideally a find should not change in dimensions during the process of treatment and after drying. In reality partially massive changes were recorded which has to be quantified. Within the ongoing EU-funded binational project ArchaeoMontan more than 1000 wooden finds have been excavated, documented and digitised with 3D scanners, thus a reference measurement of all finds are existing in high detailed 3D models. In order to determine the amount of changes in volume and shape, all objects will be scanned again after the freeze drying process. Deviation analyses are showing detailed information about the success of the conservation. For now monitoring measurements with 3D scanners are also used for exhibition objects which are exposed to various additional influences too. The paper will demonstrate methods and experiences, and will present intermediate results of monitored measurements. The resulting applications relating to exhibition objects will lead to the discussion of further rewarding tasks supporting the lending management in museums.

Archaeology of Sicily in 3D: An interdisciplinary Italian-American collaborative research project

(*Michael Decker, Davide Tanasi, Elisa Bonacini, Cettina Santagati, Filippo Stanco, Mariarita Sgarlata*)

3D digital imaging for the study of archaeology and the global dissemination of knowledge is of growing relevance and has proven to be extremely beneficial in particular on cases study characterized by a poor digital accessibility. With seven Unesco World Heritage sites, Sicily has an extraordinary heritage perfectly representing the cultural achievements of many Mediterranean civilizations, but yet the digital presence of such heritage is rather limited. In order to bridge the digital divide and to share globally the archaeology of Sicily, a large scale digitization project has been undertaken, in the frame of a collaborative research agreement between the Center for Virtualization and Applied Spatial Technologies of the University of South Florida and three Departments of the University of Catania. The aim of this paper is to present the preliminary results of the first step of the research conducted in partnership with the Regional Department for Cultural Heritage and Sicilian Identity and specifically with the Regional Hub of Piazza Armerina, Aidone and Enna. In summer 2017, the interdisciplinary team focused on three cases study representing in different ways and on different scales the archaeological heritage of Sicily: terrestrial laserscanning and aerial photogrammetry of Villa del Casale at Piazza Armerina, one of the most important and better preserved Late Roman villa in the

Mediterranean and high quality micro-photogrammetry of its 3,500 m2 of mosaic floor; aerial photogrammetry of Greek city of Morgantina; virtualization of 250 Greek and Roman artefacts from collection of the Museum of Aidone.

Combination of color and 3D information
(*Dirk Rieke-Zapp, Erica Nocerino, Elisabeth Trinkl*)

A lot of research has been directed either towards color response or shape acquisition of objects. Information on a combined acquisition of both is hardly available, but would be useful for presentation and localization of visible and invisible features on 3D objects. In this contribution, we present data from a single object that was scanned with red, green, blue and visible (white) light using a structured light scanner. Texture information was acquired with monochrome scanner cameras under red, green, blue illumination. In addition to that a composite RGB image was calculated from the three images. In addition, an external camera was used to capture high-resolution RGB textures as well as to collect UV fluorescence imagery from the vase. Two different UV light sources were used for fluorescence imagery (366nm & 254nm). Data from the external camera were mapped on the 3D object using texture mapping software. Restauration marks on the vase are easily visible with UV fluorescence while RGB imagery can be utilized for data presentation. Data is available in digital format and the object can be presented and analyzed in the same viewer. Future work will include automatic alignment of 3D data with external camera data for automatic texture mapping for different camera/illumination sources.

Automatic Geometry, Metrology and Visualization Techniques for 3D Scanned Vessels
(*Claudia Lang-Auinger, Vera Moitinho de Almeida, Stefan Spelitz*)

The Corpus Vasorum Antiquorum (CVA) is an international project for the research and publication of ancient pottery. One of its goals is to present them in an accurate and standardized way, so as to provide a solid basis for distinct types of researches – namely, potters/painters and regional differentiation and development of vessel shapes and sizes, newly also filling volumes, pottery manufacturing and function, and economical networks. To this end and within CVA-Austria projects, more than 400 Greek (10th-4th c. BCE) vases have been 3D scanned (laser, structured light) and a small number CT scanned. In our ongoing project we use known and newly developed techniques to automatically process the 3D scans in the following way: using a vessel's weight and an estimate for its material density the missing interior geometry of the scan is reconstructed. Following this step, the filling capacity and wall thickness can be inferred. Reflective and rotational symmetric properties are determined and used to generate profiles and cross sections in vector graphics format. The gathered information and visualizations are stored in an open-access database for international collaboration. This is useful for archeologists to search and compare features of ancient vessels. We will further discuss the concerns related to accuracy, precision and resolution of 3D data necessary from different perspectives (e.g. for computation, metrology, archeology) and for distinct purposes. As well as the processing methods and techniques of 3D data, as these may determine the output of the data and, consequently, the interpretation of the archaeological object.

Beyond 3D Modelling: Analysis of archaeological artefacts based on a morphing algorithm

(Diego Jiménez-Badillo, Salvador Ruíz-Correa, Mario Canul Ku, Rogelio Hasimoto Beltrán)

Thanks to recent advances in scanning technologies there has been an increase in the number of methods developed for digitizing archaeological artefacts. Many of the resulting 3D models are used for visualization or archiving purposes. Unfortunately, there are still few projects oriented to gain archaeological knowledge from point clouds and triangular meshes. In this paper we present some results of an ongoing project focused on analyzing the shape of objects, focusing specifically on a new method to analyze variations of styles in archaeological artefacts. Such method is based on a 3D morphing algorithm that analyzes two objects whose shapes represent the canonical extremes of a continuum, that is, two objects that belong to two different "styles" within a cultural tradition. The purpose of the algorithm is taking these two extreme shapes as input in order to extract several 3D virtual models whose shape or "style" lies "in-between" the two extremes. This is useful in situations where archaeologists need to decide to which extreme a real artefact is more similar. The idea for this project came from the need to rank shape similarities in a collection of archaeological stone masks from Mexico. This includes masks belonging to several well-defined styles, but it also includes many others that cannot be positioned within a specific class because they share features of two or more canonic styles. These masks were found in the Sacred Precinct of Tenochtitlan, the main ceremonial Aztec complex, located in Mexico City.

Energetic Cost Calculator for Ancient Architecture (EnCAB) and Open Context – Combining a Digital Tool and Digital Data to Explore Ancient Architecture

(Federico Buccellati)

Architecture is one of the main elements of material culture that archaeologists find in the archaeological record, with the primary research focused on the typology, function, and the life of the building as shown in the stratigraphy. There is, however, another important aspect which is seldom explored: the process of construction leading up to the first use of the building. The chaîne opératoire methodology can be used to explore this process, allowing for its disarticulation into discrete steps. It cannot, however, explore the material, temporal, or energetic 'cost' of these steps; cost-calculation-algorithms are needed which can be applied to the volumes of ancient architecture. These algorithms attempt to answer specific questions regarding the cost (in time, material and/or energy) needed for the steps in the construction process on the basis of the actual (as present in the archaeological record) or estimated volumes of the building. The Energetic Cost Calculator for Ancient Architecture (EnCAB) Project builds on work done in analyzing the AP Palace of Tell Mozan, expanding the number of algorithms to allow for a broader range of architecture types to be examined. These algorithms are presented as a web-based calculator, allowing users to enter their own data, compare their results to a range of examples and explore the types of sources used in generating each algorithm. Hosting, documentation, and version control are all on Github to promote greater reproducibility, and the project will be published under an open access license to allow the calculator to expand as research in this field progresses. Used in collaboration with datasets from diverse contexts, EnCAB allows for a comparison of types of buildings across chronological and cultural boundaries. Questions such as: how

do building materials change the overall cost of monumental constructions? How much of a role does size play in the construction of monumental architecture? Apart from size, how do public buildings differ from vernacular architecture? How does the investment in building a palace compare to what is needed for a city wall? Does the palace/city-wall ratio change across cultures? Time periods? In order to answer questions like these, EnCAB requires a sufficiently rich and well documented body comparative data. To this end, EnCAB will draw on digital repositories and data publishing programs like Open Context; such a collaboration will also help inform and guide metadata requirements for programs such as Open Context. Thus approaches to computational modeling can play an important role understanding how our discipline can better curate primary data.

Architectural energetics with help of Virtual Reconstruction

(*Sebastian Hageneuer*)

Visual reconstructions of ancient architecture are an essential part of archaeological visualisation since the beginnings of the discipline itself. Since the late 20th century, virtual or computational reconstructions added a new dimension to the matter, as we are now able to render photo-realistically and construct the past in an interactive way. Virtual reconstructions are of course a tenuous matter, especially for periods of limited sources. As part of a research group of the Excellence Cluster TOPOI at the Freie Universität Berlin, I reconstructed selected architecture of Uruk (modern: Warka/Iraq), where the remains of these buildings are often incomplete and sparse. The implementation of a consistent reconstruction method helped to create a glance into the past of that city. Besides the visualisation, the differentiation of various building materials and the computational calculation of the individual volumes helped to render a kind of shopping list of required building materials. With the help of an example, I would like to present not only the visualisations, but also an useful way to work with these 3D models as well as combine them with archaeological knowledge in order to answer specific questions of labour, costs and organisation.

Close-range digital 3D data acquisition from UAV of a medieval keep in Montecorvino (Italy)

(*Luca d'Altilia, Pasquale Favia, Roberta Giuliani*)

Montecorvino is a deserted medieval settlement, located near Volturino (Foggia), in South – Eastern Italy. Archaeological investigations have been conducted on this site since 2006 by the University of Foggia (Department of Humanities), under the supervision of Prof. Pasquale Favia and Prof. Roberta Giuliani. Among the many research activities conducted on the site, in July 2017 a 3D data acquisition of the norman tower in Montecorvino has been performed by taking about 400 aerial images from an UAV (Unmanned Aerial Vehicle or "drone") and processing them in a dedicated software (Pix4D), using the "Structure from motion" technique. The UAV model used is a DJI Phantom 4 Pro Plus, equipped with a camera featuring a 1 inch, 20 megapixel CMOS sensor. The achieved resolution is 1.9 cm/pixel. The Norman keep in Montecorvino (then part of a more complex castle) is still standing today for 24 metres in height and 3 floors (originally 4). Images have been captured making several flight circles at different altitudes around the structure, with camera pointing to the ground at a 45 degree angle. A very high (around 85%, side and frontal) overlap between images has been applied. A sparse point

cloud, densified point cloud and a textured mesh have been generated through software processing. The generated 3D model has been uploaded in Sketchfab (an online 3D and VR model viewer) and integrated with historical and archaeological annotations about the structure of the keep. It is published at the following link: https://skfb.ly/68QJU

Hybrid Modelling Workflow for the Representation of Destroyed Heritage Monuments
(Wissam Wahbeh)

This study present different photogrammetric techniques to document the original situation of damaged or destroyed heritage monuments in three-dimensional digital form. The first part describes the reconstruction method integrating Spherical photogrammetry and dense matching, two interesting 3D reconstruction techniques. They are both used in architectural heritage applications. The second part of the article discusses the representation of the model and its accuracy, since it is almost impossible to have the same quality for an entire monument, overall when it is photogrammetric reconstruction with limited image resources. The workflow was applied to the Arch of Triumph which was destroyed by the so called "Islamic state" in September 2015. The photogrammetric reconstruction made use of touristic images collected from the web and panoramic professional images captured before the destruction of the monument. The relative accuracy is discussed and how the integration of the two photogrammetric techniques could be useful to obtain almost complete 3D model and explaining the used workflow to reach a worthy representation of the monuments.

Session 5
Exploring Digital Interpretation, Argumentation, Conflict

Explaining Archaeological 3D Visualisations from the perspectives of Polyrepresentation and Boundary Objects
(Isto Huvila)

Since their advent, two central challenges of working with archaeological 3D visualisations have been partly to provide hard evidence of their purported capability to contribute to archaeological interpretation and reasoning instead of functioning merely as pretty pictures, and partly, how to visualise uncertainties and conflicting interpretations instead of giving an impression of one authoritative truth. In contrast to the archaeological literature, in non-archaeological contexts, there is a large corpus of empirical and theoretical research on the collaborative and roles of various types of visualisations: both on their capabilities to make visible conflicting and dissimilar perspectives and interpretations, and their social role in the processes of negotiating and resolving indifferences. This presentation is based on an ethnographic observation study of an archaeological fieldwork project. During this particular field project, the participating archaeologists produced 3D visualisations of the excavated stratum directly in the field and used them as interpretative and communicative aids in their work in close-to-real-time. Referring to Ingwersen's theory of polyrepresentation and the notion of boundary objects coined by Star, this presentation discusses whether, when and how archaeological 3D visualisations are polyrepresentative (whether they can incorporate several perspectives and arguments), and whether, when and how they function as boundary objects ('things' that translate

understanding between different bordering communities). The findings show that the both notions are useful in explicating how the visualisations functioned in the studied contexts and how these insights can be useful in explicating the functioning of visualisations in other contexts of archaeological work.

Computer-Assisted Analysis of Combined Argumentation and Ontology in Archaeological Discourse

(*Cesar Gonzalez-Perez, Patricia Martín-Rodilla, Martín Pereira-Fariña*)

Archaeology constructs new knowledge by interpreting material evidence. Interpretation must be supported by arguments to be persuasive and accepted. Disagreements and conflicts usually arise on how different authors interpret facts or support their discourse. Therefore, new knowledge emerges in a dialogical rather than monological manner. Consequently, the study of argumentation processes is crucial to archaeology, especially when clashes occur. Discourse analysis has been barely applied in archaeology, although some natural processing language techniques have produced promising results. Also, it focuses on the utterances being spoken, paying little attention to the things being referred to. This latter aspect is usually left to be described by ontologies or conceptual models. In this paper, we propose a combined approach to capture both the dialogical argumentation and the things being referred to, so that both kinds of information can be extracted from transcripts and stored in an open-access repository for automatic processing. This is illustrated by a practical experiment in which a group of archaeologists were asked to debate about a controversial topic in archaeological heritage, the dialogue transcribed and analysed, and conclusions extracted. By using this approach, an open corpus of argumentation facts can be employed to obtain a better comprehension of why and how disagreements occur, how solidly each position is backed, and what facts are being used or ignored to construct a discourse. This can help us to design heritage policies, mediate between agents (such as citizens and government agencies) to reconcile diverging interests, or make decisions involving monuments at risk.

An experiment in multi-user linked system for the co-creation of environmental reconstruction and the documentation of the interpretative process.

(*George Alexis Pantos*)

Tools for recording, visualising and producing reconstructions from archaeological data abound. However, our visualisations, and the discursive process of their creation often remain separate, an adjunct to the original data in a way that often belies the significance and influence interpretive visualisation have on our perception of the original data. This talk presents a prototype multi-user system used to develop an environmental reconstruction based on archaeological fieldwork in northeast Jordan. It will illustrate the technical methods used to create a bi-directional link between GIS, Postgres and Unity and raise some of the broader theoretical considerations behind system choices and the way we might look to integrate data from a diverse array of sources in our interpretations. It will also encourage us to question how we value the interpretive process and what data we should seek to preserve and the possibility of integrating these interpretations as part of our primary data.

Exploratory and Comparative Analysis of Archaeological Excavation Databases
(*Fabian Riebschlaeger*)

Excavations are arguably one of the most important sources for archaeological data. Most excavations store their data as digital records in databases in a way that access to them could be provided easily. By the means of integration, it is now theoretically possible to compare different excavations at the level of its records. The analysis and comparison of those records is challenging. Excavation data is produced with nonrandom sampling methods and therefore has to be regarded as highly biased. Apart form this structural bias and the interpretative problems resulting from chronological and spatial uncertainty, further bias could be introduced by the design of the respective database itself (e.g. category bias). In addition to that, uncertainty can propagate through existing hierarchies within the data. Therefore, to facilitate the archaeological interpretation, robust methods are necessary to extract relevant, nontrivial patterns from such data, which do not hide this uncertainty. These algorithms such as clustering, frequent pattern mining or outlier detection demand decisions to be made regarding the necessary preprocessing, features selected or choice of parameters. These choices are an essential part of the interpretative process. Avoiding black boxing, identifying metadata which could be used for "Quellenkritik", interactive data visualization and the reproducibility of the achieved results are therefore an important part of this type of data analysis. Within my Ph.D. Thesis, working with excavation data of various excavations, stored in iDAI.field, i try to offer an epistemological framework within which these methods could be applied.

Session 6
Our little minions: small tools with major impact

Numismatic Reconciliation APIs for OpenRefine
(*Ethan Gruber*)

Since 2012, American Numismatic Society has published a variety of coin typology and hoard research databases that conform to the principles of Linked Open Data (LOD), as well as having undertaken the software development of Nomisma.org, an international collaboration that seeks to define the intellectual concepts of numismatics following the tenets of LOD. Nomisma is the foundation for other numismatic projects, such as the recently-completed Online Coins of the Roman Empire (OCRE: http://numismatics.org/ocre), which has published data for all typologies from the emperors Augustus to Zeno (31 B.C. to A.D. 491), and (so far) has aggregated more than 100,000 physical objects from more than 20 museum and archaeological datasets. Much of the mapping between physical objects and URIs for coin types has been undertaken by one-off PHP scripts featuring complex regular expression matching. However, OpenRefine reconciliation APIs have recently been built for the normalisation of numismatic data to Nomisma-defined concepts, as well as mapping reference fields to ID numbers for typologies published in OCRE. These APIs enable a much faster and more accurate reconciliation of spreadsheet data to standard identifiers, which then makes it easier for museums and archaeological projects to integrate their coins into the broader ancient world Linked Open Data cloud. This paper will detail these reconciliation APIs in Nomisma and OCRE—both their usage in OpenRefine and their underlying technical architecture.

Paperless mapping and Cave Archaeology: An application review.

(*Konstantinos Prokopios Trimmis*)

Caves' microenvironment is general a hostile place for archaeological research. The absolute darkness, the high humidity, the narrow passages and the high bioturbation factors, make subterranean archaeological survey a challenging situation for the researcher. As a consequence of the cave environment open-air site survey methods and tools (such as GPS/ EDMs) cannot be used in most of the underground occasions. Until 2011, a literature review (Stratford 2011) still suggested the 'compass and tape' technique as the best available option for archaeological survey in caves. Since then numerous applications and software for cave mapping have been introduced into archaeology, such as Quave, Abris, Pocket Topo, and Auriga. Most of these applications runs on smartphones and/or PDA and when combined with a modified Leica DistoX create a very usefull underground mapping set. This paper aims to review these available options, to list their advantages and disadvantages and to present field tests and evaluations. Main outcome is to suggest the best possible package that an archaeologist who works underground can use and also to explore further adaptations of these software solutions in photogrammetric and GIS approaches underground.

ProfileAAR – a small tool helping to rectify archaeological profiles in QGIS

(*Moritz Mennenga, Kay Schmütz, Nils Hempel, Christoph Rinne*)

Over years rectifying images of archaeological profiles became a standard procedure in archaeological field work. The time that is necessary in the field was greatly reduced, compared to on field drawings. But in most cases it was not possible to redraw the images in a geographic information system. Due to the lack of handling 3D-data, the points needed to be recalculated to the 2.5D world of the GIS in a very uncomfortable way or one was required to use proprietary CAD software. Very often the CAD solution is used but in most cases a 3D-view of the profiles is not important, because the drawings are mostly used for the documentation and printing only. For this scenario, the QGIS plugin was written by members of the Initiative for Statistical Analysis in Archaeology Kiel (ISAAK). Due to the tool, it is possible to rotate the measured 3D points, so that they will be displayed in the 2.5D view of QGIS. These points can be used to rectify the images with the georeferencer plugin. The profileAAR plugin provides the possibilities to transform the points in different ways and also calculates errors. These possibilities and the principle of operation as well as future ideas will be presented in the paper.

Session 7
What is the Value of Digitally Mediated Archaeology?

Making, Meaning-Making and Archaeological Cabling

(*William Michael Carter*)

Digital Archaeology is constantly challenged by the notion of being "under-theorized". As part of this round-table discussion, I would like to argue that Digital Archaeology is a unique, reflexive, multivocal,

disruptive and transdisciplinary approach to the construction of knowledge through the making process by means of cabling archaeological theory and method, through digital practice. It is neither elevated above or relegated below more traditional notions of archaeological practice, but equally sits among the multitude of theoretical, methodological approaches to construct meaning from the archaeological unknown.

Session 8
Untapping the potential of 3D Quantitative Analysis

The potential of multidimensional visualization in stratigraphic analysis
(*Vasiliki Andreaki, Juan Antonio Barceló Álvarez*)

Volumetric and 3D modelling analysis are quite popular techniques in archaeology, usually focusing on the reconstruction of artefacts and landscapes. In this paper, we discuss how they can be used to reconstruct the stratigraphy of the Neolithic lacustrine settlement of La Draga (Banyoles lake, NE Iberian peninsula). The site has a terrestrial and an underwater part, both with different sedimentation processes. The resulting stratigraphies are then hardly comparable when using traditional bidimensional graphical approaches (Wheeler stratigraphic diagram) or Harris matrix methods, lacking metrics and temporal information. In this paper, we present a volumetric global metric model of the stratigraphy, which has allowed to distinguish the different formation processes. An algorithm for volumetric interpolation is used to create a 3D representation of different layers and other stratigraphic and depositional units, based on x, y, z coordinates of the different stratigraphic interphases identified during excavation, and additional geological and archaeological information. Multidimensional visualization techniques are then use to overlay the geological and archaeological information to such a 3D model. The resulting visual model can be used to analyze the formation process of the archaeological record and the effects of the different sedimentary processes. We think that this procedure is not restricted to the present case study, and can be easily applicable to different archaeological excavations. Therefore, the paper makes emphasis on the nature of data necessary for this visualization, and on the algorithm for the volumetric interpolation of micro-topographic data.

Masterhand identification in 3D - Case studies from Archaic and Classical Greece
(*András Patay-Horváth*)

In order to arrive at a better understanding of ancient sculpture, it would be essential to determine which pieces were carved by the same workshop(s) or master(s). Reliable ancient evidence on this is quite rare and the masterhand attribution method, universally used for paintings, was applied only sporadically to sculptural works. After scanning (with Artec EVA and Spider) many pieces of archaic and classical Greek marble sculpture, an attempt is made to use these data for the identification of common traits and idisyncrasies in the treatment of frequently recurring details, e.g. drapery, facial features or locks of hair. Two different datasets (recorded with the same equipment) were selected for analysis: the sculptural decoration of the temple of Asclepius at Epidauros and the frieze of the Siphnian treasury at Delphi. They represent different stages of artistic development (from the 4th and

the 6th centuries BC respectively), are relatively well-preserved and are suitable for analysis mainly because each group constitutes a relatively large sample, within which comparisons can be made and because there is some documentary evidence (contemporary inscriptions) regarding the identity of the masters and the division of labour among them. The comparison of sculptural details is based on the methodology of geometric morphometrics used in paleontology for detecting and quantifying the similarities and differences of skeletal remains and thus enabling a detailed reconstruction of biological evolution. The same statistical analysis has been applied to comparable features extracted from 3D models of ancient sculpture. Some preliminary results of these comparisons will be presented with a discussion of possible interpretations.

A multidsciplinar survey of ground stone tools surface

(*Giusi Sorrentino, Martina Polig, Carole McCartney, Sorin Hermon*)

Stones were used since early stages of humankind as tools for pounding and grinding processes of various types of raw resources. Identifying this type of instruments and distinguishing them from manuports is not a simple task and a study of the entire surface with the traditional microscopic methods is usually not done because it is too time consuming. The aim of the study is to identify and quantitatively describe human inflicted alterations considering the entire surface of stones. We propose an integrated methodology for visual analysis of the tool's surface at various levels of resolution. The approach relies on high-resolution 3D documentation with a structured light scanner of a stone's surfaces and their post-processing, referring to them as micro-topography within a 3D GIS environment, as well as various approaches for the calculation of relative surface curvatures of selected areas. The identification of potential functional areas, identified as human inflicted anomalies due to irregularities in their surface rugosity, when compared to other areas, is corroborated with the use of a digital microscope to confirm the presence of use-wear traces and related residues. The methodology is applied on a sample of eleven ground stone tools from the late PPNA archaeological site of Ayia Varvara Asprokremnos, in central Cyprus. The site was in a strategic position for raw material exploitation especially connected to ochre, as demonstrated by numerous traces of ochre processing as well as an abundant number of ground stone tools most likely used for this purpose.

Death and decay in 3D: using 3D modelling for quantitative analysis, and as an educational and outreach tool in funerary archaeology

(*Hayley Mickleburgh, Sarah Gluschitz*)

3D applications are increasingly used in bioarchaeology and the study of death and burial. We present a study in which 3D data are used for quantitative analysis of human remains, in order to better distinguish between the effects of taphonomic processes and human actions on the body and grave. Currently, funerary taphonomy (i.e. reconstruction of grave formation processes), relies heavily on data from archaeological burials. These burials present a 'final snapshot' resulting from a sequence of unknown events. There is a lack of observational research on which factors determine the final position and condition of the bones within the grave. In an innovative cross-disciplinary study, we documented taphonomic processes affecting five donated human bodies at a forensic research facility during 2 years. 3D models were developed weekly using photogrammetry. By quantifying volume changes and

bone displacement patterns under controlled conditions, we can establish the relation between amount/direction of displacement and specific variables, such as body position, soil type, or the presence of open space around the body. This allows us to better understand how the body decomposes and interacts with environment to create static archaeological deposits. The sequential 3D models were also used to create a 3D animation, demonstrating the process of decomposition and skeletonization, for education of students in (forensic) archaeology/anthropology. The animation provides a means to visualize decomposition in a manner suitable for a non-specialist audience. It enables broad dissemination of results, drawing attention to the importance of experimental forensics/archaeology, while preserving anonymity of the body donor.

Point-based Visual Analytics and Virtual Taphonomy: A Case Study involving the Submerged Late Pleistocene Cave Site of Hoyo Negro, Mexico

(*Dominique Rissolo, Vid Petrovic, Alberto Nava Blank, James C. Chatters, Blaine W. Schubert, Patricia A. Beddows, Pilar Luna Erreguerena, Falko Kuester*)

A goal of the Hoyo Negro Project is to make this unique, submerged Paleoamerican cave site available for transdisciplinary, collaborative study and interpretation by a diverse group of scholars and stakeholders across borders and free of existing computing limitations. Recent efforts involve the development of an extraordinarily powerful, point-rendering and visualization software platform and multiuser cyber-infrastructure, which facilitates real-time analysis and annotation of image-derived point-data. Domain experts can conduct a range of deposit- and site-scale taphonomic or spatial analyses via a digital surrogate of the site. Rather than simply serving as models of the site and its ancient faunal and human remains to view and share, the full-resolution point-clouds can be manipulated by a variety of user-scripted tools. Archaeologists and paleontologists can, for example, marks points in 3D space and virtually extract skeletal elements or remove substrate to make necessary measurements or to better assess element articulation and distribution. Native image files corresponding to point regions can be readily called up for simultaneous viewing and evaluation. The interactive, point-based visual analytics workflow has proven to be especially empowering for researchers unable to otherwise access deep and remote underwater sites.

Mapping Skeletal Trauma: A Tour of Violence in 3D GIS

(*Julia Alyssa White, John Pouncett, Rick Schulting*)

Recording and analysing patterns of traumatic injuries in archaeological samples is complicated by several factors, including poor preservation, the likelihood of an injury impacting bone, and questions of the most likely causes of an injury. The creation of a 3D human model, including the skeleton and flesh, in GIS on which traumatic injuries can be mapped and the overall preservation of the skeletal elements can be accounted for offers an opportunity to not only visualize patterns of traumatic injury in a more sophisticated way, but also to quantify the errors associated with preservation, likelihood of injury to skeletal elements, likelihood of violent intent, and the dynamic movement of organs, tissue, and skeletal elements at the point of injury. Moreover, by treating the body as a map, this method provides the opportunity to compile the preservation and trauma data for cemeteries, regions, and larger units, which then can be explored through spatial queries. Currently, the viability and potential

of this approach to analysing skeletal trauma is being evaluated with remains from prehistoric hunter-gatherers and agriculturalists from the Japanese archipelago.

The 3D Survey of the Basilica of S. Apollinare in Classe

(Gianluca Foschi)

A 3D survey of the basilica of S. Apollinare in Classe, Italy, has been conducted by the School of History, Classics and Archaeology of Newcastle University in collaboration with the McCord Centre for Landscape and the National Museum of Ravenna. The data, obtained using a FARO Laser Scanner Focus3D X330, offer great potential to acquire new insights into the history of the basilica and its cultural background. Although considerable time was required to process the data, this is balanced by cost-effective acquisition in the field. The virtual replacement of moved elements in their original position and the integrations of archival material are being achieved using Autodesk software and Odeon Auditorium. Through the survey, the modular system of the basilica has been investigated to examine the scientific and philosophical principles underpinning its design. Multisensory analysis will also be conducted to address the control of light and sound from the past to the present. The objective is to obtain semantically annotated BIM and GIS-integrated models shared in interoperable formats with the Ministry of Cultural Heritage and Activities and Tourism, and suitable for multiple uses in the future. This digital approach aims to create new common ground between different disciplines and establish a solid link between archaeological and historical data. The high accuracy of the record allows investigation of how written sources relate to architecture and ultimately leads to new knowledge on intentionality and meaning in sacred spaces. Finally, the survey constitutes a primary reference for the conservation of the building.

Villa di Poggio a Caiano by Giuliano da Sangallo. 3D Reverse models for HBIM to study a witness of the Renaissance

(Cecilia Maria Bolognesi, Simone Garagnani)

When studying the morphology of historic buildings the acquisition of point cloud or polygonal mesh patterns coupled with the integration of traditional survey lay the basis for the formulation of a study integrating more skills that incorporates concepts of resolution, accuracy and precision with studies of alignment of scans, mesh creation, optimum decimation, texturization and extraction of the desired output. This precise 3D dataset brings the visible shape of the investigated monument but also it may become the stone of comparison for more in-depth studies. When real geometry can be superimposed to abstract parametric elements deeper analysis can be carried out about architectural or constructive choices. In the case study here proposed, Villa Medicea Poggio a Caiano this survey approach led to a specific BIM application, where the point cloud is the initial step of a much more articulated reverse assembling of building elements. The HBIM approach is mainly focused on comparison between surveys and a library of architectural components, deduced from other Sangallo architectures ; a digital representation of objects can likely validate or not decisions taken in order to generate specific portions of the building which are not probably preserved in their original configuration. All the sources available (contemporary literature and paintings, codes and treatises) have been used to find proper remodeling data. This explains why the scale of the monument is prevailing against the

territorial representation, whose advantages would be probably considered in future developments. Simulations were performed in order to evaluate many aspects of the original building design: from the overall proportion check of volumes to the analysis of modifications of specific elements such as porches, external stairs, the main vault. Also different building stages can be simulated and studied taking advantage of the produced BIM model. Manage wider datasets linked to digital models about the monument's lifecycle and its use over the years, paying attention to the initial building stage, simulations, analysis and virtual reconstruction of different architectural solutions can be shared, to better understand the legacy of the Renaissance.

The use of 3d modelling in the process of the reconstruction of the prehistoric wooden and clay architecture from the Roman Period settlement in Rzemienowice site 1, voiw. Świętokrzyskie, Poland

(Jan Bulas, Jędrzej Bulas)

The reconstruction process of wooden and clay architecture from the pre-history pose different problems than reconstruction process of the stone or brick architecture from ancient or medieval times. It is trivial to state that there are no sufficient analogies in preserved archaeology that would allow to propose a scientific, critical model of most types of buildings. Therefore there is a need to work out a "standard"? of the reconstruction process of the uncovered archaeological traces that would not be only artistic view of the prehistoric architecture but would also have scientific base. In the poster we will present a case study of the attempt of use of the 3d modelling and architectural analysis in the reconstruction process of the two Przeworsk culture pit-houses unearthed in Rzemienowice, in southern Poland. The poster aims in showing the problems and limitations of the reconstructions based solely on the archaeological record. The method used in the reconstruction is based on the critical discussion about possible use of different constructional solutions and the potential function of the buildings, in the context of the theirs location, orientation, size, possible interior lightning and warming. In the result of the presented reconstructions traditional understanding of the function of those types of buildings as the habitation spaces will be undermined.

Auralizing past places: Repurposing visual datasets

(Catriona Cooper)

A huge array of three dimensional (3D) techniques are currently employed in the study of buildings. Buildings can be recorded in 3D using total station, photogrammetry, and laser scanning; or modelled in 3D representing past spaces developed from maps, plans, historic research and excavation records. These models contain all kinds of information about the visual experience of these spaces but do not consider the wider multisensory or lived experience of those buildings in the past. This paper will discuss how these datasets can move beyond visualising the buildings and be repurposed to engage with the aural experience of the past. I will discuss the methodology for creating acoustic models, what quantitative data the models can provide, and how they can be used in the creation of auralizations; before considering a specific case study; Listening to the Commons. Listening to the Commons is a follow-on to the St Stephen's Project (https://www.virtualststephens.org.uk/). It takes a series of visualisations of the historic House of Commons, and coverts the dataset into an acoustic model, from

which a series of auralizations have be created. In doing so it explores particular experiences of the space, considers how different social groups engaged with the building, and allows a new understanding of political debate in the 18th century.

3D GIS: The road ahead (part 2)

(*Gary Nobles*)

n 2016 a R&D agenda was outlined which was aimed at the management and analysis of 3D archaeological data, the resulting paper will be available shortly in the Oslo CAA proceedings (van Leusen & Nobles). Initial tests of such an infrastructure reveal promising development but also highlight various obstacles, these are not restricted to technology but also to the quality of the archaeological data, the employed methodologies as well as the way archaeologists think about the data. This paper presents the first steps down the road to a 3D GIS from both a spatial theoretical and technological perspective, it highlights problems of working with point clouds, especially developed functionality to spatial libraries, and what needs to be resolved moving forward. This paper sits alongside an initiative to develop a 3D GIS Special Interest Group (SIG - to be announced at the AGM) to bring those active in its development together providing a platform for cross-method discussion and open the doors to greater collaborations.

Session 9
Show your code: task streamlining, reproducibility and replicability in archaeological computing

Not all data are born digital: Workflows to facilitate data integration and rapid 3D visualization of landscapes

(*Heather Richards-Rissetto, Zachary Day, Shane Bolan, Isaac Beddes*)

Born digital data are increasing in archaeology. RTK GPS and 3D surveying techniques such as laser scanning and photogrammetry allow "instantaneous" acquisition of high-resolution data of extant archaeological features. Digital tools such as GIS, 3DStudioMax, and Unity3D enable archaeologists to employ modeling and visualization as archaeological investigation. However, such archaeological investigation requires that we be able to efficiently integrate born digital field data with "digitized" legacy data such as architectural drawings, site maps, field notes, excavation profiles, or photographs. The problem is that digitized legacy data often come in a hodge-podge of file formats, generated without standards or according to best practices because they were created at different points in time using different software and to achieve diverse objectives. These various, and often incompatible formats, make data integration and interchange difficult, particularly for re-use purposes such as analysis and visualization. The MayaCityBuilder Project is creating a procedural modeling kit and digital lexicon of 2D and 3D data for ancient Maya architecture and workflows that will allow users to "rapidly" create 3D buildings in georeferenced landscapes in a web-based environment. In this paper, we present workflows and code we have developed to export/import 3D models derived from different formats and various sources into Unity3D and WebGL.

Streamlining 'big data' – adapting workflows for the extraction and management of large volumes of social media data for digital heritage research
(*Marta Krzyzanska, Chiara Bonacchi*)

Big data' is increasingly used in archaeology, heritage, providing new avenues for research and redefining methodological frameworks across disciplines. Recent scholarship has highlighted its profound impact on epistemological paradigms (e.g. Kitchin 2014, Bonacchi et al. forthcoming), but comparatively fewer studies discuss the practicalities of creating or adapting existing workflows for big data extraction, management and analysis. This paper proposes to present the workflows developed to streamline the extraction and management of millions of messages from social media. Such workflows were developed as part of the Digital Heritage strand of the 'Ancient Identities in Modern Britain' project (ancientidentities.org). The code was initially based on some well-known, very well-documented and almost fully reproducible studies (e.g. Marwick 2014), but was transformed considerably over the course of the research. The solutions that worked very well on the 'small' data for which they were originally designed were not sufficient to efficiently and support the analysis of a large-scale collection of unstructured digital data. The paper will thus present the initial code that we started to use, explain its shortcomings with regards to 'big data', and demonstrate how it was adapted for the purposes of examining public perceptions and experiences of the past in Britain. Finally, we will present and discuss the code developed to transform the data collected and store it in the non-relational Mongo Database. Bonacchi, C. et al. (forthcoming) The past in political identity construction. Kitchin, R. (2014) Big Data & Society 1(2). Marwick, B (2013) Data Mining Applications with R.

The Big Problem with Big Data: automating social media harvesting and interpretation for cultural heritage audience insight
(*Lawrence Shaw*)

In recent years the New Forest National Park, U.K, has facilitated a number of volunteer lead heritage recording programs. Overseen by project officers, these have not only helped to record and protect archaeological assets but also engage local residents with the heritage of this unique protected landscape. Whilst proven to be successful in their aims, these approaches have regularly missed out on the engagement of younger audiences. Much like the rest of the heritage sector, 12-24 year olds have rarely engaged with this work, yet its importance remains, not least because they will inherit these national assets in years to come. This research has looked to tackle this issue through the utilisation of Big Data, including social media and anonymised mobile data, to help officers understand how this hard to reach audience sees and uses this protected landscape and its heritage. By their very nature, these data are difficult and time consuming to gather and interpret, making automation essential. This paper will look to share the development of Python scripts that have harvested social media data, including Instagram and Twitter, into an analytical database, as well as the integration of deep learning when looking to rapidly identify what is contained within thousands of photographic records.

Standalone Photoscan VS Photoscan Cluster Processing

(*Jad Aboulhosn, Anais Guillem, Nicola Lercari*)

The field of archaeology uses photogrammetry more and more as a documentation recording technique. Photoscan has been widely adopted among archaeologists for its ease of use and quality of results. In its ordinary use scenario, Photoscan standalone supports the processing of up to a few hundred photos before overloading the system, even when running on a computer with a powerful CPU and sufficient memory. The nature of the most advanced single-PC hardware is that it is still fundamentally limited and can crash unexpectedly when the number of photos to be processed exceeds 500, or the quality of those photos is too high. For the mass collection of archaeological data, this quickly becomes an important bottleneck. We propose here to overcome this issue by exploiting the potentials of of cluster computing to deploy photoscan as a node-based system: Photoscan Cluster Processing (PCP). This enables the user to delegate processing tasks to several individual computers (nodes), and to significantly speed up the tasks performed. Furthermore, it overcomes the issue of losing data and time through crashes, as the loss of a single-node in a crash does not result in the loss of an entire stage of processing job. The method proposed overcomes the inherent drawbacks of the standalone Photoscan and provides a professional grade cluster solution which allows high quality and quick results for archaeological teams.

Towards 3D modelling as a replicable and intellectually transparent process: A rule-based approach to archaeological visualizations

(*Chiara Piccoli*)

This contribution demonstrates the capabilities of the Computer Generated Architecture (CGA) rule-based shape grammar. The main application of this scripting language is to (semi-)automatically generate 3D models of architecture in the software package CityEngine, but its recent integration with ArcGIS has enabled users also to automatize the visualization of specific properties of a GIS dataset. Although it is primarily targeted at modern urban planning and geodesign, this shape grammar has great potential also as a method for the interpretation and visualization of archaeological datasets. The archaeological case studies that will be discussed here will show how the CGA grammar can be used for the creation of a GIS-driven symbology and the modelling of 3D reconstructions of the past built environment. Moreover, I will focus on how this rule-based approach encourages the generation of reproducible and intellectually transparent 3D reconstructions that can be used as tools for real time simulation and analysis.

EDIT DISTANCE - Software tool for analysing epigraphic data

(*Iza Romanowska, Daniel Martín-Arroyo Sánchez*)

Imagine having 2000 inscriptions on roman amphora at your site. Each of them is unique but they do seem to follow some patterns. But how do you make any sense of them? Can these patterns be quantified? Do they group into possible 'cargos' or specific products? How are they related to the location of each amphora sherd? Here we present a Python-based software tool that compares epigraphic inscriptions to each other using the edit distance measure, calculates clusters based of this similarity and visualises them as cluster maps and dendrograms. It can also look for correlations

between the defined clusters and independent variables at different thresholds. In short, this is a tool that aids the analysis of written sources by quantifying their similarity and providing visual and statistical methods to aid the interpretation.

Defining archaeological Site Exploitation Territories (SET) using the open source statistical language R

(Jan Johannes Ahlrichs, Philipp Gries, Karsten Schmidt)

We present a seamless workflow for defining archaeological Site Exploitation Territories (SET) using the open source statistical language R. The concept was developed in the 1960s in order to study the cultural remains, botanical and zoological finds from archaeological sites in relation to their geographical environment. A SET designates a time-distance based area, which is visited on a daily basis by sedentary farmers or mobile groups as they deal with their subsistence. One of the main assumptions is that humans have a territorial behaviour and did not select sites at random. Accordingly, it is predominantly used to discuss economic questions, e.g. the availability of resources, the potentially available food or the function of a site within a larger settlement system. The form of a SET depends on the geography surrounding a site. In landscapes with a flat relief SET have an almost circular shape, in mountainous regions they are more distorted. Until recently, the determination of SET was performed manually based on experimental studies using the walking distance within a specific time frame. Today, these results are hardly reproducible. The increasing availability of spatial data and fast developments in computing technologies as well as geographical information systems (GIS) enable us to implement time-cost-functions in various ways. Our workflow enables researchers to calculate SET in a fast and reproducible way. So far, our R script takes into account walking speed and topography (slope) via Toblers Hiking Function.

Hypothesis modelling in R, using shared data

(Lizzie Scholtus, Loup Bernard)

This code has been written after a R training summerschool of the GSHDL in order to test hypothesis modelling with R. We also wanted to test both software and modelling in to convince the non-digital archaeologists of the interest of the tool. For these reasons, we chose to answer a question for which a consensus already exists and automated it by coding it for a large set of data. Furthermore, we wanted to use the different dataset extracts that are shared in the ArkeoGIS platform. We decided to work on how to recognize exceptional so called « princely » tombs in the upper Rhine valley during the late Hallstatt period. Indeed, the upper Rhine valley is an area for which exceptional sites are already known through the literature. Moreover, almost all the available data in the area (archaeological services, PHD Thesis, articles etc…) is encoded and characterized in the platform. We used the ontology that flattens data in 4 levels of depth in order to code them with hierarchization and complexity tools in R. This standardization of the data helped us to recode textual information in numerical values based on how exceptional the founds in the tumuli where. Finally, this code has been written on the free software R to be easily editable and accessible (FAIR). One only has to change the set of data in order to test the code of this hypothesis in some other regions where the graves or metal finds are already encoded in ArkeoGIS format.

Agent-based modelling for archaeology classes: sampling

(*Grégoire van Havre*)

Bringing agent-based modelling into undergraduate archaeology classes is a powerful mean to achieve a better comprehension of the role of computers in our field. Our NetLogo model was built to illustrate how sampling works in an excavation. Two options allow the user to choose between random and systematic methods of sampling. He can then compare the results on different kind of sites, where the artifacts have been more or less scattered. Yet, this project still needs a lot of code: we are particularly working on including a more random dispersion effect, as opposed to concentric, and a set of agents acting as archaeologists with different skills.

Automating heritage reporting tasks with R

(*Benjamin Davies*)

Heritage documentation often needs to fit particular formats based on legislative or corporate regulations. Having standardised formats is useful for comparison between reports, but creating them can sometimes be tedious and time-consuming. Large heritage organisations sometimes develop bespoke field recording solutions to streamline this process, but for independent heritage contractors or small university teams who may work for multiple organisations, these options may be either financially impractical or insufficiently flexible. In many cases, data is collected in multiple formats that need to be parsed and then recombined in a standardised way. In this presentation, I will demonstrate how different kinds of field data (GIS, spreadsheets, photographs, etc.) can be collated into pre-formatted documents using the free R statistical software platform. Making use of existing R libraries for creating rich text documents and manipulating different data formats, this workflow provides an inexpensive solution to standardised report generation that is flexible enough to be extended across many heritage settings

Session 10
Expanding horizons: confronting issues of scale, resolution, and representation in the study of human expansions

Modeling Movement on Water: Generating past mobility corridors on the sea

(*Emma Slayton*)

Seafaring is not a new concept, but modeling least-cost routes through maritime spaces has yet to be developed to the same extent as landscape modeling. Researchers have approached this issue through traditional least-cost pathway analysis run in ArcGIS using combined DEM and flat-cost sea surfaces, to the development of Agent Based Models specifically targeted to Polynesian sailing strategies. No matter the method used, these methods are often applied to the evaluating possible avenues of human expansion across oceans and onto islands. However, many of the researchers who study modeling movement through seascapes have developed their own models or methods for discussing

this issue on seascapes around the globe. Due to the regionally specific nature of this analysis, such as the change in current and wind patterns, each researcher has also had to adapt different data sets to meet their needs. This is compounded by the varied nature of seafaring technology, for example the sailing versus canoeing divide, which separates modeled routes in the Pacific from those in the Caribbean. Adding in the influence of the people in the vessel to the time cost for canoeing or sailing between coastlines can make the modeling of least-cost routes difficult. In my own research, I have applied a directed isochrone method to evaluate possible avenues of connection between mainland and Island communities as well as inter-island interaction in the Caribbean. In this presentation, I will discuss the history of GIS-based seascape route modeling and the issues I have faced.

No two ancient migrations are the same: constructing null models at different scales of analysis

(Iza Romanowska)

Ancient migration has been one of the fundamental research areas in archaeology since the dawn of the discipline. In the last few years new methods, in particular computational modelling techniques, moved the focus of these studies towards formal representations of complex dynamic hypotheses. These welcome advances are currently breaking the impasse caused by the dependence on verbal arguments and conceptual models expressed in informal language and are forcing researchers to provide explicit data predictions to their hypotheses. Thus, it is perhaps time to take a step back and think of an ontological framework for modelling ancient human migrations, which incorporates the inherent differences between global scale movements of hominins, habitat tracing by a single group in the face of changing environmental conditions or colonisation of previously uninhabited archipelago. Although no two ancient migrations are the same they can be considered to lie on a multidimensional spectrum between different social, environmental and spatio-temporal variables. In each case different mechanisms affect to varying degree the rate, shape and direction of the dispersal. From climate change to social fragmentation, from land dispersal following fertile soils to sea voyaging along favourable currents and wind patterns, from generational changes to individual decisions the ontologies of human migration models can be constructed in a myriad of ways. This contribution aims to bring some order in this chaos and provide a draft framework of the most important variable axes in the migratory processes for further consideration by specialists and general archaeological audience.

Route selection and number of exits: Quantifying "Out of Africa"

(Ericson Hölzchen, Christine Hertler)

The 'Out of Africa'-theory states that the earliest hominins originated in Africa and from there expanded across Eurasia. The fossil finds in Dmanisi point to a latest initial exit around 2 million years ago. But what happened afterwards remains under debate. On the one hand, it is unclear which route they took out of the African continent. Although the Levante is proposed as a most favoured corridor, other routes were also possible. On the other hand, we do not know how many times the earliest hominins left Africa. The hypotheses range from at least one, two or more exits. The answer to these questions has implications on our species definition of the genus Homo and the subsequent role of

Homo sapiens in comparison to other hominin species such as Neanderthals, Denisovans or Homo floresiensis. We use agent-based modeling to quantify the effects of 'Out of Africa' dispersal hypotheses on output variables, such as route selection and number of exits. In our talk, we present how we implemented the measuring of routes and the number of exits in an actual 'Out of Africa'-agent-based model. We show simulation results of different dispersal hypotheses on these output variables. We intend this talk, to open up a discussion about how and why using a certain output variable to quantify hominin dispersal events such as the earliest expansions out of Africa.

'Out of Site': Problems in Understanding Hominin Dispersal Caused by Site Centrism and Predictive Models
(*Patrick Cuthbertson*)

Discussions of Pleistocene hominin dispersal inevitably involve broad generalisations across vast spatio-temporal scales. As a result, the question of how we model movement in regions where there is a limited or fragmentary record becomes even more pertinent. Some of these regions are the most interesting from the perspective of global hominin dispersal. In such situations, pre-existing site location can become possibly our greatest clue, and inductive predictive models offer an attractive method for understanding and predicting site locations. However, I will argue that overreliance on such models could be holding back our understanding of key Pleistocene dispersal regions. Central to such a criticism is Foley's (1981a; 1981b) concept of 'off-site archaeology', which has previously called into question the use of sites as an analytical unit. When discrete sites are defined in opposition to the wider hominin landscape, it obscures the necessary fact that the hominin behavioural landscape was itself continuous with interconnected localities. Inductive predictive models exacerbate this issue by emphasising site location versus environmental variables, at the expense of a more nuanced understanding of hominin adaptation and subsistence in the landscape. Foley, R., 1981a. A Model of Regional Archaeological Structure. Proceedings of the Prehistoric Society, Volume 47, pp. 1-17. Foley, R., 1981b. Off-site archaeology: an alternative approach for the short-sighted. In: I. Hodder, G. Isaac & N. Hammond, eds. Pattern of the Past: Studies in Honour of David Clarke. Cambridge: Cambridge University Press, pp. 157-183.

Diffusion versus dispersal wave-of-advance models and Neolithic spread
(*Joaquim Fort*)

In this talk we recall that Fisher's speed, often used to model waves of advance, is only an approximation. Using parameter values for humans, obtained from ethnographic and archaeological observations, we show that using Fisher's speed introduces an error of up to 50%. This problem is solved using dispersal (instead of diffusion) equations. A second improvement is to use cohabitation equations. Finally, including also cultural transmission, cohabitation dispersal equations have been recently used to show that only about 2% of farmers were involved in cultural diffusion (interbreeding and/or acculturation) in the spread of the Neolithic in Europe.

Session 11
Untapping the value of old fieldwork records

Exploring the villa maritime of Sora (Torre del Greco - Italy) through the integration of old and new maps

(Angela Bosco, Andrea D'Andrea, Francesca Forte, Massimo Osanna, Fabrizio Pesando, Luana Toniolo, Rosario Valentini)

Recently the villa maritime of Sora at Torre del Greco (Italy), destroyed by the Vesuvius in 79 d. C, has been surveyed by laser scanner and close-range photogrammetry. After the data-processing, the digital replica has been cleaned of all the modern elements. Currently the 3D digital replica offers a view of the still existing buildings and the related archaeological levels. The villa, dated to the first century AD, included a large apsidal hall, a long peristyle, paved in polychrome marble, and other rooms richly decorated with frescoes. The area, explored since 1797, has been surveyed by several archaeologists or architects. Notwithstanding the site has not been the subject of a systematic excavation and much still remains buried. In order to integrate the 3D survey with the missing parts, all the old surveys have been digitized, scaled and overlapped. The integration shows that some archaeological features don't match probably because the maps refer to different levels in the investigations or in the interpretation of the archaeological finds. Unfortunately, the still visible buildings, recently surveyed, don't help to overcome those inconsistencies. Nevertheless, by starting from the 3D model and from the analysis of the masonry of the villa, two different reconstructions can be proposed on the arrangement of the area. The paper deals with the methodology followed by the archaeologists in the re-examination of the previous documentation, in the superimposition of the old and new surveys and in the virtual restoration of this important ancient maritime complex still insufficiently investigated.

Viability of Production and Implementation of Retrospective Photogrammetry in Archaeology

(Colin Allan Bruce Wallace, Dorina Moullou)

Retrospective photogrammetry is a novel approach to producing fully functional three-dimensional models using archival photographs, plans and drawings augmented with contemporary photogrammetry and surveying. This paper addresses the advantages as well as the difficulties in using retrospective photogrammetry and examines how the results can be put to use for further research, preservation, restoration, monitoring rates of deterioration and presentation to the public. We examine the approach to retrospective photogrammetry from the view points of both the photogrammetrist and the end user (ie. researcher, scholar or authority responsible for using or disseminating the resulting data). From the perspective of the photogrammetrist it is the nature and quality of the archival data that is of concern. Does the archival material meet the needs of 3D modelling and will the resulting models meet the needs of the end user? The end user is concerned with being able to store, access and utilize the results constructively. An impressive 3D model without detail or metrics is of little use apart from public presentation. We explain why the end user's goals must be addressed clearly prior to commencing the project. We will look at examples from the

Athenian Agora and Ancient Corinth to illustrate the methods required, limitations experienced and opportunities made possible with the resulting products.

Bad Photogrammetry: Using Nonoptimal or Archived Photographs for Constructing 3D Models
(*Robert J. Bischoff, James R. Allison*)

Archaeology frequently adopts new technology for fieldwork, but often this technology is of little use for prior fieldwork. One relatively new technology is using photogrammetry for constructing 3D models of features and artifacts. One of the many advantages of creating 3D models of archaeological features is the ability to merge models of multiple features to create a more complete view of an excavation. Often the excavation of sites occurs over multiple field seasons and occasionally different, adjacent features will not be open at the same time. Photogrammetry is limited by the quality of the photography, and there are several requirements for capturing optimal photographs. This paper explores the challenges and results of using nonoptimal photos from past excavations, including archived photographs, to create 3D models and produce useful results. We test the feasibility of attempting this process on several sites in the United States Southwest using relatively recent excavation photographs and with archived photographs from as far back as the 1930s. We focus on the workflow used to create the 3D models and discuss what situations failed to generate useful results and which were successful. We also discuss the benefits of creating 3D models from past excavations.

Getting the Measure of Brochs: Using survey records old and new to investigate Shetland's Iron Age archaeology
(*Li Sou, Julie Bond, Stephen Dockrill, Val Turner, Andrew Wilson, Lyn Wilson*)

This paper presents the on-going collaborative doctoral research project, Visualising the Crucible of Shetland's Broch Building. It aims to digitally document three significant broch sites in Shetland; Jarlshof, Mousa and Old Scatness, using terrestrial laser scanning and structure-from-motion photogrammetry, and to study this new data alongside existing archives of the sites. Brochs are prehistoric dry-stone towers or roundhouses, with massive double walls 3-6 metres thick and intramural galleries in between (Romankiewicz 2009). They are only found in Scotland, particularly in the Atlantic north and west, and were built in the Iron Age (c.400-200 BC). Whilst the structural layout of brochs has long been debated (for example MacKie 2002, Armit 2003), few measured surveys have been conducted at many sites (Cavers et al 2015). As part of this project, the first complete survey of Mousa Broch in recent times was undertaken in 2017, with similar plans for Jarlshof in 2018. Whilst this is the case, a range of archived records do exist, including; photos, plans and even earlier laser scans from 2002 and 2005 of Mousa. These provide comparable survey datasets through time. Old Scatness was only recently discovered, excavated and recorded to modern standards, providing a contrast to Mousa and Jarlshof who have been known since antiquity. The data acquired from these most recent surveys will produce the most detailed visualisations of the sites to date, and its analysis alongside historic site records will help to develop strategies to aid in understanding the history of their consolidation and their archaeology.

Reconstructing excavations ? Photogrammetry on 1980's Photos

(Thomas Wolter)

Two sites, both investigated by the CRC 806 „our way to Europe" are bearing archaeological context information from past excavations. In 2011 consecutive excavations were conducted at the site Madamagh (Jordan) by two different teams. Since the 1950s the site is known to yield stratigraphical issues regarding the identification and description of geological and archaeological layers. In order to test the in situ location of the archaeological material from past excavations, a geostatistical method for an intra site analysis had to be developed. At first methodological workflow categories were created to reclassify the layer packages. Hereby included information was extracted from the total station measurement data and the archaeological documentation including remarks, profile drawings, photos and layer descriptions. In a subsequent analytical process various congruent geological layers were merged by statistical comparison. Additionally, cultural layers were joined by single find parameters. A Photogrammetric 3D Model of the profile documentation helped to evaluate the results. The other site is located at Dibrës Region (Nezir Cave, Albania) within a karstic system. In order to obtain a complete scene of all excavations conducted at the site, documentation of the CRC 806 (2012 to 2015) and the Albanian campaigns (1970 to 1980s) had to be compared. By interlinking stratigraphical information between the trenches, we are now trying to build a referenced Photogrammetry Model from 1980's and 2015th campaign Photos and drawings. The operative focus of the talk is on the discussion of the methodological outcomes and issues at both case studies.

Utilising Text Mining to Unlock the Hidden Knowledge in Dutch Archaeological Reports

(Alex Brandsen, Milco Wansleeben, Suzan Verberne)

Over 60.000 Dutch archaeological research reports are available online, and this number is growing by around 4.000 a year. Much of this grey literature threatens to end up in a proverbial graveyard, unread and unknown. Currently it is only possible to search through the metadata of these documents, mainly via the Archis database and DANS repository. However, these metadata are often limited and sometimes inconsistent. To effectively index these texts, Named Entity Recognition (NER) is needed to correctly identify and distinguish between archaeological concepts. Standard approaches to NER are insufficient to deal with the peculiarities of these concepts. Some research has already been done on NER in archaeological texts, e.g. in the ARIADNE & Open Boek projects, but these are not combined with full-text search, or tend to focus on limited entity types, and not the full breadth of archaeological concepts. This paper will present the first phase of AGNES (Archaeological Grey literature Named Entity Search), in which machine learning is used to perform NER. The initial experiments use Conditional Random Fields and a feature set fine-tuned to archeological concepts. The identified entities are combined with a full-text index to create an effective online search, allowing researchers to answer research questions that are currently impossible to solve. The project is in cooperation with the Leiden Institute of Advanced Computer Science (LIACS), who provide a computer cluster with high computing power, allowing for the use of more resource intensive techniques and short iterative development cycles.

The Big Data Challenge. Integrative Big Data Approaches towards a Hybrid Archaeology in the Eastern Mediterranean

(Francesca Chelazzi, Simone Bonzano)

Archaeological data are what economists call a 'non-rivalrous' good: they can be processed again and again with no diminishing of their value. The recent embracement of digitalization in archaeology, coupled with the proliferation of archaeological projects over time, has dramatically multiplied the informative legacy at our disposal. In order to avoid the risk of isolated data silos, one of the current challenges is the correlation and aggregation of data in the 3V's perspective of Big Data: high volume, high velocity and high variety. Despite the traditional adoption of SQL relational database by archaeologists, the rising importance of Big Data in Computer Science has recently showcased a new typology of database: the NoSQL. This database can safeguard a 'more human' approach through dynamic queries and enhanced functions of data visualisation, so that NoSQL appears now to be a fundamental tool in moving from data silos to a 'brain-like' strategy of data management. This papers aims to illustrate the potential of a specific type of NoSQL graph database in handling archaeological Big Data, through the discussion of a tested case study in Bronze Age Cyprus.

Legacies Ancient and Modern: Hybrid Approaches to Digital Presentation of Legacy Data at Poggio Civitate and Sardis

(Theresa Huntsman, Eric Kansa)

Mediterranean and Near Eastern "Big Digs" of the 20th century are a significant source of information on the ancient world, but because of their broad scopes, managing and presenting their data is complicated. Recording and interpretive systems evolve over decades, and changes in personnel result in shifting priorities and the loss of project "oral histories." This paper will provide a comparative perspective on the challenges of digital documentation and data presentation from two sites: the Poggio Civitate Archaeological Project (1966-present) and the Archaeological Exploration of Sardis (1958-present). Both projects are lynchpin sites for the study of their respective cultures, ancient Etruria and Lydia, and their investigation has been crucial to shifting and enhancing the modern understanding of them. Due to the projects' consistent leadership and the prioritization of presenting information to scholarly and general audiences alike, they have been able to create digital presences that cope with the complexities of integrating legacy data with newly-discovered finds. This paper will outline the hybrid approaches used by the projects to automate some aspects of data standardization and the conversion of analog formats, while, by necessity, relying heavily on hand-curation by those intimately familiar with project histories. Even though both projects shifted to digital databases at around the same time and they share a core philosophy in making their data amenable for integration with other data sets, the way in which each has chosen to prioritize and present information differs, based on the nature of their original recording systems.

Synthesizing old excavation records and new archaeo-metallurgical data through functional, spatial and temporal dimensions
(Marion Berranger, Rémy Jeannot)

The ancient city of Epomanduodurum (Mandeure, France) was excavated in several areas since 1970, leading to reports of differing quality and important quantities of unstudied artifacts. A recent analysis of metallurgical slags of these old excavations motivated a new evaluation of the reports, in order to establish the contexts of the material. This presentation aims to discuss the application of a methodology, set by Lefebvre, Rodier and Saligny (2008) for urban archeology, to extract usable information from old and heterogenous field documentation, which is mainly composed of descriptions and drawings. We created a database that enables the use of statistical tools (SQLite, R, Qgis) to integrate the spatial, temporal and functional dimensions, the latest being based on the archaeometallurgical analysis. These three dimensions are considered as continuous spaces, to overcome the heterogeneity of precision of the data without loosing any information. The synthesis allows to better understand the organization of the iron metallurgy, its evolution and its relations with the dynamics of the city. Here, incomplete and imprecise old excavation reports have proven themselves a reliable material to emphasize the structure of craft activities. This methodology could therefore be an efficient tool to synthesize multiples excavation reports and compare the result with other social or environmental data.

A GIS procedure to study settlement patterns from site-based survey datasets
(Anita Casarotto)

This paper presents a GIS procedure to use (legacy) site-based survey datasets in settlement pattern analysis. Over the past few decades, an impressive quantity of archaeological data has been registered by field-survey projects. Large datasets have been produced, most notably in Mediterranean countries where field-survey has been widely applied for the study of regional landscapes. A majority of these datasets is site-based, which means that only well-defined surface concentrations of artifacts were recorded by surveyors, who usually registered them as dots on topographic maps. To realize the potential of these legacy site-based survey data, methodological procedures that cope with their limits, and more importantly with the distortions on data patterns caused by biasing factors, are necessary. By using these procedures, archaeologists can aim for correct interpretations of the past settlement behavior underlying the survey data. In this paper a GIS method is proposed consisting of a set of interrelated quantitative and qualitative approaches to infer significant settlement patterns from site-based survey datasets. Specifically the GIS procedure consists of two parts. One part regards the assessment of the effect of biases on the spatial pattern exhibited by legacy data. The other part aims to extract historical meaning from data patterning. To show how the proposed GIS research procedure works in practice, a case-study is employed. As part of the research by the Landscapes of Early Roman Colonization project (NWO, Leiden University, Royal Netherlands Institute in Rome), site-based datasets collected by previous survey projects in central-southern Italy are examined to investigate settlement patterns in the early Roman colonial period (3rd century BC).

The long-range record of the Temple of the Sun in Heliopolis (Egypt)

(*Kai-Christian Bruhn, Christopher Breninek, Klara Dietze, Dietrich Raue, Evgenia Tachatou*)

Since 2016 the "Heliopolis-Project", a cooperation between the University of Leipzig, the Egyptian Ministry of Antiquities and the University of Applied Sciences Mainz, systematically investigates the site of the "Temple of the Sun" complex in Matariya in the Northeast of modern Cairo. Abundant sources attest the significance of the sanctuary from the Old Kingdom to the Late Period. After the almost complete demolition in the Middle Ages, the vast area witnessed a few archaeological campaigns in the 19th and early 20th century. Only in the last decade, systematic investigations started to unscramble the complex building history of the sanctuary. One focus of the ongoing "Heliopolis-Project" is to digitally merge the widespread and heterogenous information to reconstruct its context and unlock the manifold interdependencies. The aim is not a complete visual reconstruction but rather a well modelled digital archive offering starting points for ongoing and future research. The paper will present results of the work of several excavation areas, including the findspot of the fragments of the colossus of Pharao Psamtik I recovered in 2017, and will demonstrate how the interpretation of the archaeological record is supported by archival data.

Assessing the value of legacy pre-digital landscape and survey data

(*Emeri Farinetti*)

The conversion into a digital environment and the digital elaboration and analysis of pre-digital survey and legacy landscape studies or site maps has proven to be a fruitful job with constantly improving results, although labour-consuming. Landscape studies are deeply concerned with the matter, as they deal usually with large areas where data from different sources, often collected in a long-term span, need to be analysed jointly in order to produce meaningful results. Reflexive approach on past surveyors' legacy and travellers' readings as well as a well-constructed 'source critique' to address information quality, along with the establishment of standards to digitally analyse heterogeneous old and new data in a feasible and reliable environment in order to assess past social behaviour, are the most essential issues to be addressed. A research framework and established methodologies, which would employ at the best digital opportunities and 2D-3D modelling, would be needed in order to fully assess the potential of aged information and legacy data. This way, new life could be given to Pausanias' walk through Roman Athens, for instance, or to the Greek medieval landscape mapped with the guide of the Ottoman archives, or to pre-digital paper based survey data in the Mediterranean landscape, inserted into GIS environments and jointly analysed with new digital data. In the paper possible digital ways of dealing with this kind of information will be discussed as well as the theoretical frameworks which would underpin them.

Digging in excavation diaries: digital re-assessment of stratigraphy in 3D GIS. The sanctuary of Ayia Irini, Cyprus

(*Valentina Vassallo, Giacomo Landeschi, Nicolò Dell'Unto, Sorin Hermon*)

The Ayia Irini (Cyprus) sanctuary was excavated by the Swedish Cyprus Expedition in 1929, who identified seven periods of use, from the end of Late Cypriot III (ca. 1200 BC) to the Cypro-Archaic II

(ca. 500 BC) periods, and suggested that the area was flooded several times. It consists of a temenos with small buildings around an open court where, around the altar and in semi-circular setting, more than 2000 terracotta statues and figurines of humans, animals, chariots, minotaurs, varying in size and shape, were found. The site is under Turkish military occupation since 1974 and thus inaccessible to further archaeological investigations. Scholars focus therefore on reviewing published and unpublished excavated material and analysis of artefacts and a better understanding of the site's stratigraphy and related chronological sequence. A recent effort concentrates on 3D semantic and shape based analysis of figurines. The current paper presents a digital reassessment of the site's stratigraphy using 3D GIS, by corroborating published material with data extracted from the original excavation diaries. The obtained maps question the positioning of finds and their setting within the sanctuary, the existence of natural versus human made features and the possible impact of flooding episodes. Such a stratigraphic re-assessment is based on the 3D re-alignment of statuettes, according to drawings and notes from the original excavation diaries, their location and orientation related to the other features of the sanctuary and a re-evaluation of the nature of features described in the excavation diaries and related to the statuettes.

Dirty Dishes for the WIn: Old museum collections as a source for new chemical analyses
(*Jennifer A. Loughmiller-Cardinal*)

Archaeologists have, for the past 150 years, collected and stored an enormous number of artifacts. The way they were analyzed has changed dramatically over this past century, with methodological changes as well as general practices of excavation. Meanwhile, most museum collections have remained underutilized and neglected. With the rapidly expanding analytical techniques designed to identify organic and inorganic food residues, the material housed in museums offer ideal study cases. For Mesoamerica, there are only a few positively identified foodstuffs. Among these are cacao and tobacco (the later identified by the author). Successful identification has been carried out for both substances on curated materials. What we lack in general is methods of identification for the vast range of other foodstuffs. Arguably museum materials are more difficult to analyze, as they are typically cleaned or repaired. They are not ideal, but with appropriate methods that target key areas of residue concentration – for instance the inner core of the ceramic fiber in low fired porous ceramics – archaeochemists open near infinite opportunities for analyses.

Session 12
Making the most of film and video in archaeology

Archaeological Documentaries from Scratch - Recording and Presentation of a research project
(*Till Frieder Sonnemann*)

The visual documentation of an archaeological research project is often not included in the project proposal's finances. Data collection is focussed on, and mostly limited to, academic research. However, there is an urge by publicly backed projects to reflect and present the outcome, to address the non-

scientific audience, and raising interest in the topic. The costs often prevent the archaeologists working with professional media specialists. In the here presented case of documenting archaeological surveys of the Nexus1492.eu project, data collection started, as so often randomly, with drone video shots, recorded for 3D-photogrammetry in 2014. Together with additional video recordings a set of short narrated videos were produced. The positive response from local screenings led to more sophisticated short films, new scripting and recording of footage, and interviews with team members and local stakeholders. A sensitive subject for filmmakers were topics such as looting or development threatening archaeological sites, raising questions regarding personal rights and source protection. A next step is to organize a seminar in which archaeology and communication students will together create short video clips on particular topics in archaeology. Questions to discuss in the talk are: Whom are we addressing with this video? What is the story we want to tell, and how can we achieve this? What should we record? What software provides the needed functions? What platforms are useful to give the public access to these stories? How can we reach a larger audience? What rights and laws need to be considered?

SCHARP Focus: film making as an integral part of a wider community based project
(*Tanya Kinston, Freke Venture*)

The SCAPE Trust has a long history of using film to record, interoperate and communicate many of its projects during the last 17 years. In 2012, SCAPE worked with citizen scientists and local community volunteers on the Scotland's Coastal Heritage at Risk Project (SCHARP), a four-year project designed to record and interpret archaeological sites around Scotland's dynamic coastline. Film was specifically built into the project to highlight each of the unique ShoreDIG's, independent community based projects that were completed alongside the larger coastal recording element of the project. A set of three complimentary films was also produced as part of its evaluation to tell the story of SCHARP and the people behind it. A wide variety of film techniques were utilised ranging from creating music videos, short documentaries, re-worked archive footage and interviews. This paper will discuss how the films were envisioned, produced and how challenges were overcome. It will highlight the key role of the local community, who provided content, took acting roles and sourced materials for several of the films. The talk will conclude with a showing of one of the short films, 'Standing on the Shoulders of Giants'. This stars many members of SWACS, a local community group in Fife, and details the history of antiquarian recording at the Wemyss Caves. It is part of a wider digital recording project combining film, 3D models, and RTI recording which reinforces a long tradition of research at an asset which is now in danger of being lost.

Low cost video making! Can it counter scarcity of resources while contributing to enhance visibility?
(*António Batarda Fernandes*)

The videos produced by the Côa Valley Museum and Archaeological Park team such as "O Que Aprendi - Fernando Barbosa e a Arte do Côa" (What I Have Learned – Fernando Barbosa and the Côa Art" - http://bit.ly/12DDdYC) or "Uma Visita ao Parque Arqueológico do Vale do Côa/A visit to the Côa Valley Archaeological Park" (http://bit.ly/1rULGd0) will be presented and discussed. These short movies,

directed and edited by author in partnership with Jaime António, were produced using semi-professional video editing software, widely available today. The production of these videos is a part of an overall communication strategy that aims to increase the visibility of the Côa Valley rock-art (www.arte-coa.pt) and reach wider audiences also resorting to social media, namely Facebook, Twitter, YouTube, or TripAdvisor. How can these be used to reach educational objectives within a fast evolving online environment? How to engage virtual audiences in significant learning experiences using time-limited windows of opportunity? How can dynamic and versatile synergies be created and implemented in online environments to involve the several vital areas to the sustainability of cultural institutions (marketing, education, entertainment, revenues…)? It is argued that low budget promotion video-making can play an important role in designing strategies that address these questions.

VR and the death of the frame: Filmmaking in an age of immersive technology

(*Kieran Baxter*)

New norms of immersion and interaction afforded by recent develops in head-mounted display technology appear to be - and have certainly been promised to be - a paradigm shifting development in new media. Against a background of 360° and 3D capture technologies, which give the end user retrospective control of the angle of viewing, the visual language of traditional filmmaking has been fundamentally disrupted. This paper expands upon the relationship between video and virtual reality (VR) in the context of heritage interpretation. It explores the continuity between the two, but also the disparate conventions and traditions that the two media draw upon. If we acknowledging that no medium is transparent then we must also consider how the practitioner's decision-making affects the creation of media content and its meaning. While in VR these decisions are more likely to define the ways in which the audience can interact with content, in video the composition of the frame plays a significant role in channeling the audience's attention in a predetermined way. The frame is an integral component of photography and filmmaking. The continued relevance of such filmic conventions in a time of technological upheaval is a key question here. It is suggested that both filmmaking and VR continue to offer unique and powerful tools for documentary storytelling in heritage interpretation, and that understanding the strengths of each will be important if we are to develop a well considered visual toolkit that goes beyond the technological hype.

Bringing Archaeology into the 21st century: social media and resource potential

(*Rachel Anne McMullan*)

It is widely acknowledged that people spend an increasingly large portion of their time online. Archaeology as a discipline has so far struggled to fully realise the potential benefits this form of communication has to offer through the sharing of interesting content with online content consumers. As the archaeology industry struggles to recruit graduates into the commercial sector in the UK, companies would benefit by understanding the value social media can provide. Increasing the online presence and popularity of archaeology can contribute to attracting new recruits to assist in the increasing number of UK infrastructure projects scheduled to start or already ongoing. The use of social media can also be valuable for boosting the general public image of the archaeology sector and a way to help guarantee that archaeology is viewed as a valuable heritage resource worth preserving. Lastly

it can be used to dispel myths, propagated through inaccurate portrayals in film and television, and provide education to a wide audience that are not normally accessible through traditional academic channels. This paper will discuss the pros and cons of archaeology themed social media accounts and the difficulties encountered with putting archaeological content online. It will present the case study of a Youtube channel run by a commercial archaeologist and present its demographic results with regard to: audience numbers, retention, and location. Lastly it will discuss social media's current role in archaeology and how it can be improved using effective strategies to boost the profiles of companies or individuals.

"Story first, technology second." Exploring the archaeological affordances of iDocs.

(*Kathryn Rogers*)

iDocs (interactive documentaries, web-docs, transmedia, docu-games, and interactive factuals) are taking the film industry by storm. Showcased at leading film festivals such as Tribeca, Cannes, Berlinale, Sheffield Doc/Fest and SXSW; increasingly adopted by broadcasters including Al Jazeera, ABC, and BBC; and operating in a media environment where video is predicted to account for 82% of consumer and business internet traffic by 2021 - the iDoc sector is about to boom. iDocs integrate actuality film, video, and audio, with text, images, data, infographics, VR, AR, and game logic into non-linear digital narratives. They can be experienced across multiple platforms from mobile phones, to digital TVs, to museum gallery installations. iDocs thus combine the strengths of traditional documentary storytelling (creative, truthful, and memorable treatments of reality) with the immersive power of new digital technologies (interactive, in-depth, complex, updateable content). iDocs transform audiences into participants, allowing them to not only explore and experience a story on their own terms, but to also remix, share, and contribute their own content and narratives to a story – arguably enabling a greater audience impact than multimedia websites or vlogs. Presenting a series of iDoc case studies, in this paper I explore the pros and cons of this new filmic medium for archaeological research design and dissemination. I propose that through immersive storytelling, iDocs might provide a solution to archaeologists' frustrations with traditional linear documentaries, such as concerns about information quality, depth, citability, research impact, and authorship.

Archiving film: what can we achieve?

(*James Miles*)

The production of film, as with other digital media, can produce an excessive amount of data. This data is usually represented through a finished product after having undergone several edits and removal of unwanted or unneeded content, leaving RAW footage and potential material unavailable to a wider audience. Sharing this data via online video websites such as Youtube and Vimeo provide access to this content, but what is found online is only a small proportion of video that exists. Hosting data online provides access, but there is a greater potential that can be achieved with this content, as highlighted through the interactive map display of the British Film Institute player. Archiving film and making this accessible are genuine concerns within film and archaeology and discussions are needed to highlight this major problem. Social media can provide scope to provide this data to a wider audience but this is often reduced in quality from the original. Archiving such large data is often unfeasible due to the cost factor, and integrating the data with archival solutions is not often possible, due in many respects

to the archival solutions that are centred on text and image based content. The paper that will discussed will highlight these problems in greater detail and will lead onto a larger discussion as to what can be achieved in film, and how this generation and generations to come can utilise the content that is produced, both within archaeological research and within future archaeological examinations.

Session 13
Digital Documentation Archaeological Ships. What do we do and what do we need?

Reconstructed one more time - The Bremen-Ship
(Pat Thomas Tanner)

The Bremen "Hanseatic Cog" currently on display in the German Maritime Museum (Deutches Schiffahrtsmuseum) in Bremerhaven, was discovered during October 1962 in the the Wesser river near Bremen Harbour. Dated to circa 1380, the remains were recovered, documented, conserved and reassembled for display in 1979. The vessel has been continuously monitored, analysed and subject to further research questions. This project did not begin with the intention of reconstructing an already reconstructed ship find, but rather to examine the overall hydrodynamic and seakeeping abilities of the ship. Was the Bremen Ship the oceangoing trading vessel of its time? Is this the ship that crossed the North Sea, and the Atlantic Ocean as part of the known Hanseatic trading routes to Iceland? In order to evaluate the complex concepts of seakeeping and oceangoing, a reliable hull form, as well as accurate construction details are required. Establishing the vessels overall hydrostatic characteristics, static and dynamic stability, and overall sailing abilities, requires detailed calculations using the centres of buoyancy, flotation and gravity. It is clear that the form and shape of the Bremen ship, as it currently stands, on display in the museum's ship hall, is not a true representation of hull shape. Data sets included the originally published two dimensional paper drawings, which also included a photogrammetric survey of the reconstructed vessel carried out in 1980. In addition, the data from three separate sessions of three dimensional digital documentation was available. This presentation will look at the methods and techniques employed in examining the current form of the vessel on display, as well as attempting to distil several apparently conflicting data sets into a valid hypothetical reconstruction to be used as the basis for further hydrodynamic analysis.

Monitoring concept for deformation estimation of the Bremen Cog
(Heidi Hastedt, Amandine Colson, Thomas Luhmann)

Long-term monitoring of processes on archaeological artefacts is an important issue in preserving their history and enabling their future presentation. The monitoring can be separated into 1) conservation and preservation aspects, 2) geometric deformation estimation and analysis and 3) documentation and long-life retention. Focussing on the geometric deformation estimation and its analysis of the conserved medieval ship "Bremen Cog" at the German Maritime Museum, a photogrammetric monitoring concept was developed, prototypical implemented and evaluated. In this case deformation estimation includes rigid-body motion of the artefact with respect to its stable surrounding as well as

the determination of strain, torsion or bending of the artefact itself. Deformation of 1mm has to be determined in order to provide information 1) about the size and direction of changes, 2) about critical sections in changes and 3) about interaction of sections. The goal is to deliver tangible data to plan a new support system. With respect to the motion estimation a stable ground control network was established and measured. For the long-term monitoring of deformation processes a photogrammetric measurement concept was chosen. The reasons are mainly due to: the size of the ship, the required high accuracy and financial and personal resources at hand. Targets were mounted to the Bremen Cog and measured with a photogrammetric triangulation method using a DSLR-camera. The prototypical implementation allows for the estimation of the specified deformation and different subsequent long-term analyses. Aspects on the concept, the implementation and first results will be presented.

Monitoring protocol for the preservation conditions of the barge Arles Rhône 3 (France)
(*Daniela Peloso*)

The experimental project of the barge monitoring is part of the preservation and conservation program of the Musée Départemental Arles Antique (MDAA). Since 2014, the museum is dealing with the long-term conservation challenges of a Roman barge of 31 meters in length displayed in its exhibition hall. The study of the conservation conditions and of the strains existing in the Roman maritime-fluvial barge Arles-Rhône 3 (AR3) showed the necessity to develop monitoring tools and a protocol. The monitoring tools gather a large amount of data among others: degradations, measurements between certain points or different observations linked to a localization. All this data allows to follow up on the barge's evolution and to plan future interventions more accurately, but also for further analysis. The development of a digital monitoring tool started in 2015, based on the technical expertise from the MDAA, Ipso Facto (archeological company) and the Centre Camille Julian (CNRS, Aix-Marseille University). The protocol is using a Geographical Information System (GIS) database platform to link the digital mapping (photogrammetry and orthophoto) with the observations. The resulting model can be consulted on a portable media device, such as tablet or smartphone, using an open-source application. The model allows also the recording of so called "incident" information, such as a mistake in the handling or during standard cleaning work. All available data are organized in a relational and searchable database management system. In the near future, the model will integrate climate information in the room and related weather condition reports, as well as public attendance. The aim is to be able to correlate the environmental parameters and the evolution of the barge's conservation. This tool has been specifically designed and developed for AR3, but will potentially be useful for other wrecks around the world or for similar wood artifacts.

From the Macro to the Micro; Digital shipwreck datasets and their inter-disciplinary application in managing potentially polluting shipwrecks
(*Camilla Moore*)

There are thousands of potentially polluting shipwrecks located on the seabed (Michel et al., 2005), as these wrecks degrade they pose a risk that they will release their pollutants into the environment. It is therefore important that we are able to identify, quantify, risk assess and remediate these wrecks. Investigating archaeological shipwrecks that pose a potentially polluting risk utilises an

interdisciplinary approach to understanding ship archaeology, employing a range of digital datasets from engineering, oceanography, archaeology, environmental sciences and data from socio-economic sources. These datasets range in scale from the macro to the micro, they are temporally diverse and vary in their applicable utility, accuracy and confidence. Many datasets offer conflicting information, offering substantial challenges to forming a coherent understanding of the risk posed by such shipwrecks. Examination and discussion of datasets used to investigate and monitor polluting wrecks will demonstrate the relative pitfalls and successes of these datasets. It is hoped that a greater understanding of these datasets will demonstrate the wider application of non-archaeological data to ship archaeology and vice-versa. Finally, this paper aims to provoke further discussion regarding what might be required in ship and shipwreck data collection, to facilitate the production of truly multi-use and inter-disciplinary data. References: Michel, et. al. (2005) Potentially Polluting Wrecks in Marine Waters: An Issue Paper, IOSC 2005.

New insights from the historical events in Nydam by 3D-GIS

(*Karin Göbel*)

The excavations in Nydam/ Denmark conducted by the Danish National Museum during the years from 1989 to 1999 are a very good example of how helpful the utilization of a Geographic Information System (GIS) even for old data could be. The modern excavation area was only about 500m², but the documentation includes 134 different handdrawn excavation plans with more than 10.000 features, a database with 13.387 items and countless photos and drawings of specific find details. Now all this information is gathered in one single GIS. In Nydam IV new photogrammetry based on old data recovered height values of the old stereo photography, which got lost during the years. In this way the three-dimensional view of the different features could be completed and facilitates the reconstruction of this famous Iron Age site. The fact that one is able to show how the different features are arranged is a considerable advantage in analysing this site, which would never have been achieved by ordinary studies. Furthermore all information about the features, like new research results, e.g. the varying ritual behaviour when depositing the items can be systematically collected into the database and afterwards visualized in its spatial context. This is always a thrilling moment and often it becomes the basis of new ideas and explanations.

A Comparative Structural Analysis of Shell-first and Frame-based Ship Hulls of the 1st Millennium AD

(*Nathan Helfman*)

The 1st millennium AD experienced significant change in ship construction. A slow transition evolved where ships built 'shell-first' were supplanted by 'frame-based' ships. Shell-first ships were constructed with strakes edge-jointed using pegged and later unpegged mortise-and-tenons joints, dowels or coaks, and at times, sewing, resulting in a strong and rigid hull. The strakes were then fitted with transverse frames independent of the keel. Frame-based ships were characterized by transverse frames fixed to the keel and reinforced by longitudinal components. The hull planks were later fastened to the pre-existing frames. The objective of this study was to examine whether mechanical factors contributed to the transition in ship construction. An initial comparative linear static FEA global

~~comparison analysis was conducted on CAD models reconstructed from two archaeological shipwreck findings: Ma'agan Mikhael (400 BC) and Dor 2001/1 (6th century AD). The Ma'agan Mikhael shipwreck was representative of the shell-first technique and the Dor 2001/1 shipwreck represented the frame-based technique. Standard global stillwater criteria revealed that both ships possessed high degrees of rigidity and low von Mises stress values. Further analyses were performed on two symmetrically identical archetypal quarter hulls while varying load and construction parameters. In all the archetypal load scenarios, the shell-first samples exhibited higher rigidity and less extreme von Mises stress differences than the frame-based samples. Frame-based rigidity and stress levels were directly dependent on the number of frames added to the structure. Further to be researched are the economic, engineering, social and ecological issues factors which contributed to the transition.~~

Session 14
Setting the automation agenda for Remote sensing: learning to see through a computer?

LiDAR-based automated detection of cultural heritage in Westphalia
(*M. Fabian Meyer, Ingo Pfeffer, Carsten Jürgens*)

While the LiDAR-technology solved some problems of archaeological prospection and different visualisation techniques have been developed, the automated detection of cultural heritage still poses a significant challenge. Therefore geographers from the Ruhr-Universität Bochum and archaeologists from the Landschaftsverband Westfalen-Lippe in Münster are developing workflows for the automatic detection of diverse types of field monuments. In 2016, a Master's thesis used object-based image analysis (OBIA, implemented in eCognition) for the detection of remains of burial mounds, motte-and-bailey castles and ridge and furrow field systems in a special terrain model named difference map, that was introduced by R. Hesse in 2010. The resulting areas of interest are available in shapefiles and manual interpretation is necessary, which still cannot and should not be done by a computer. However, this step is simplified because the results are classified by its condition. In this way, areas with probably well preserved field monuments are separated from others and can be interpreted at first without losing those that appear eroded. The results show, that all three types of field monuments are basically detectable with automated workflows and that the correctness can reach 75-90%. Furthermore, new field monuments were already found. After Celtic fields were found in Westphalia for the first time, research currently is expanded in order to develop a GIS-tool for calculating the required digital terrain models and searching for Celtic fields, by a template matching methodology integrated in Python.

Semi-automatic detection and extraction of complex burial monuments in Arabia from high-resolution multispectral satellite imagery
(*Giacomo Fontana*)

The use of semi-automatic methods to detect and extract archaeological objects in LIDAR data is providing outstanding results. For several large areas of the world, however, LIDAR data are not available, and satellite imagery is often the only source of information that archaeologists can use.

Therefore, it is necessary to develop new automatisms to analyse satellite imagery. This paper proposes a ruleset developed in eCognition to detect and extract complex burial monuments in Arabia from WorldView-2 satellite imagery. The ruleset is composed of three parts. The first part identifies candidate objects as single pixels using an adaptive template matching algorithm. The second part uses the identified candidate pixels as seeds for a region growing segmentation which creates the borders of the objects. This process is suitable to draw any object automatically because it does not consider any assumption regarding its shape. The third part of the ruleset classifies the candidate objects using a combination of thresholds and a random tree classifier. The adaptive template matching code has been trained using 130 burial monuments located across 3 km2. The same objects have been used to train the random tree classifier together with 200 negative samples. The ruleset was then applied on 100 km2 of terra incognita to test its efficiency. The results of this test are highly significant. This new method was able to detect and extract almost 80% of the burial monuments verified in the area, with an index of false positives equal to 30% of the total detections.

Extraction of linear structures from LIDAR images using a machine learning approach

(*Clément Laplaige, Xavier Rodier, Jean-Yves Ramel, Bai Shuo, Ronan Guillaume*)

In the context of the SOLiDAR program, which studies the dynamic of land use around Blois and Chambord (Loir-et-Cher, France), and collaboration between archaeologists and computer scientists, we develop a user-defined pattern extraction system dedicated to LIDAR images based on an interactive machine learning approach. After initial tests on linear structures, the system is currently used in some forest in Centre-Val de Loire on larger areas and on more varied remains (punctual structures by example). The goal of this step is to increase the recognition rate by integrating new features and more varied data The strengths of this system are, first, the ability to generate as results probability maps instead of binary decisions. Second, the software is designed to be free, open and easy to use in order to allow everyone to test it on their own data. We hope these originalities will allow the creation of new kind of databases and new ways to interpret archaeological data. This communication will be the occasion to present the framework (Selection of elements of interest, learning step, classification step, evaluation protocol) the data processing techniques and the features selected during this collaborative work. We will also take advantage of the event to make available the software developed as part of the SOLiDAR program.

Archaeological Object Detection in Airborne Laser Scanning Data Using Convolutional Neural Networks

(*Bashir Kazimi, Frank Thiemann, Katharina Malek, Monika Sester*)

Archaeological monuments need to be preserved and protected. A fundamental prerequisite for such a preservation is an adequate object acquisition and documentation. Some of the objects, however, such as archaeological objects visible in the terrain like ramparts, grave-mounds or traces of historic agriculture – even when covered by forest or bushes - are not even known. With airborne laser scanning in high resolution, the potential of detecting and measuring such terrain structures is growing. Still, doing it manually is a time-consuming process. The new data processing paradigm of deep learning has shown great potential in automatically detecting objects in images. Thus, in this

project, we use Convolutional Neural Networks (CNNs) to analyze the LIDAR data, and identify unknown archaeological objects. To this end, we first process the data to generate a height map of the region. Our study area is the Harz mining Region in Lower Saxony, where a high density of different archaeological monuments including the UNESCO world heritage site Historic Town of Goslar, Mines of Rammelsberg, and the Upper Harz Water Management System can be found. In this study area, ground truth data is available in terms of the locations of different types of archaeological structures. Then we train different CNN models with the labeled height map patches to classify archaeological objects. The learned models then scan through the whole height map and detect objects. Our results indicate that with enough training data, the proposed approach yields good performance and contributes to automated detection of archaeological objects.

Semi-automatic mapping of cultural heritage in Arran, Scotland, using deep neural networks on airborne laser scanning data

(Øivind Due Trier, David Cowley, Arnt-Børre Salberg)

This paper investigates the potential of deep learning for national mapping of cultural heritage from airborne laser scanning data. The island of Arran is a 'Scotland in miniature', representing the majority of landscape types and types of cultural heritage found elsewhere in Scotland. Airborne laser scanning data covering all of Arran, with an average of 2.8 ground points per square metre, was used to create a digital terrain model (DTM) with 20 cm pixel spacing. From accurate centre positions of known cultural heritage objects, or remains, that are visible in the DTM, 20 m × 20 m subimages were extracted. DTM subimages without cultural heritage remains were also extracted. The subimages were used for training the classifier. To increase the number of training images, flipped and rotated versions were created for each subimage. The main part of the classifier was a deep neural network that had already been pre-trained on one million images of natural scenes. The final layer of the neural network produces a vector of presence/absence of natural scene objects. This layer was replaced by a support vector machine (SVM) classifier. The SVM classifier was trained as follows. The labelled DTM image extracts, some of which were centred on a single cultural heritage object, were fed through the deep neural network to produce a 1000 element feature vector for each image extract. The labelled feature vectors were then used to train the SVM classifier. By cross-validation on the known cultural heritage remains, 90% of them were successfully detected.

The use of Convolutional Neural Networks in the automated detection of archaeological objects in remotely sensed data

(Wouter Baernd Verschoof-van der Vaart, Karsten Lambers)

Nowadays the surface of the earth is constantly being monitored by a multitude of airborne and satellite sensors that record a wide variety of environmental parameters. Over the last decade archaeologists have handled this ever-growing set of remotely sensed data by using computer-aided methods for the (semi-) automatic detection of archaeological objects. While successful, these handcrafted algorithms are highly specialized on specific object categories and data sources, which limits their use in different contexts. To overcome these limitations this research project will explore recent advancements in computer sciences in order to develop a generic, flexible and robust

automated detection method for archaeological objects in remotely sensed data. Deep learning, a machine learning approach built on Convolutional Neural Networks (CNNs) seems especially promising. In this paper a potential new technique for the automated detection of archaeological objects in airborne laser scanning data (ALS or LiDAR) will be presented. The technique is based on R-CNNs (Regions with CNN features). Unlike normal CNNs, that classify the entire input image, R-CNNs address the problem of object detection, which requires correctly localizing and classifying objects within a larger image. The proposed technique will be trained and tested on LiDAR data gathered from a forested area in the central part of the Netherlands. This area contains a multitude of archaeological objects, including (Prehistoric) barrows, Celtic fields and (Medieval) hollow roads. By implementing this new technique we will be able to develop a method to automatically detect and categorize these archaeological objects.

Detection of Bomb Craters in WW2 Aerial Images Using Convolutional Neural Nets

(*Sebastian Zambanini, Simon Brenner, Robert Sablatnig*)

This talk 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 detection of bomb craters in georeferenced aerial images taken after bombing. 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 talk, we present results and recent findings on training a convolutional neural net for the purpose of determining the image locations of bomb craters. We collected 85.000 samples of such bomb craters as data basis for training the network in the typical object detection scenario: the network is equipped with a softmax activation function in the final layer in order to infer the likelihood of patches to contain a crater. Localization of the craters is then achieved by evaluating a sliding window over the query image and thresholding the obtained likelihoods. For this work, we adopted a state-of-the-art densely connected convolutional network with 40 layers. In the talk we will present recent detection results and discuss specific failure cases of the final detector. The impact of non-maximum suppression and similar strategies to refine the detection result will also be addressed.

Tackling the Small Data Problem in Deep Learning with Multi-Sensor Approaches

(*Iris Kramer, Jonathon Hare, Adam Prugel-Bennett*)

Within data science, many problems are solved using machine learning. Recently, with the introduction of deep learning, we see this trend spread out across industries of which archaeological object detection on remote sensor data is a case in point. From the known case studies, we have identified the main issues and developed improvements accordingly. The main issue of archaeological datasets is that there are only a limited number of known sites which makes the networks prone to overfit. Overfitting happens when a network is trained on too few examples and learns patterns that do not generalize well to new data. To an extent, data augmentation can be used to prevent overfitting, however, the training images would still be highly correlated. Therefore, it is argued that the most effect can be gained by limiting storage of irrelevant features in networks. This can be done by optimising network architectures and additionally by using transfer learning in which pre-trained network are used to initialise training. Regardless of pre-training on datasets without archaeological

sites, its trained network can still be useful for the low-level features (including lines and edges). A downside of pre-trained networks is that they can only work with data in the same format as they had been trained with. Our main contribution is the research into including multi-sensor data. We will present approaches to train networks using images with stacks of data, apply fusion networks and by generating pre-trained networks for the available data of different sensors.

Deep learning for the benefit of archaeological remote sensing data interpretation?
(*Christopher Sevara, Geert Verhoeven*)

Although the concept of deep learning has been around for decades, its application has seen a recent surge in popularity. The enormous impact and state of the art performance of deep neural learning approaches in different domains like natural language processing, playing strategy games and self-driving cars occurred only during the past five years. The fantastic performance achieved in these fields notwithstanding, most deep learning approaches that deal with image classification seem to be proficient at comparatively simple tasks. Given the utter complexity of archaeological remote sensing data and the heterogeneity of archaeological features, it seems that deep learning applications still face many challenges in successfully identifying complex archaeological situations. Using various deep learning examples, this talk aims to discuss some of the current strengths and future challenges in deep learning for archaeological research. Should we focus on basic classification approaches or can we already aim further? How far can available tools bring us? Do we need to build national or international sets of remote sensing training data? Should we all use the same neural network and resort to transfer learning for particular tasks? Can other machine intelligence and image classification approaches potentially serve us better for specific purposes or complex feature identification? How can such approaches be connected to big data repositories in order to efficiently mine them for applicable data? This paper does not aim at providing finite answers; instead it tries to highlight some positive points and problematic issues in order to advance discussion of this topic.

Teaching a computer to 'see': training sets in Remote sensing archaeology
(*Arianna Traviglia*)

Recent upsurge in the applications of deep learning —characterised by neural networks— in a variety of image processing is determining an exponential advancement of the discipline, making it the fastest-growing trend in big data analysis. Deep neural networks make use of feature representations entirely learned from employed dataset and are therefore particularly relevant in the analysis of RS imagery where physical models can be extremely complex or cannot be generalised. Archaeological scholarship has been quick in understanding this potential, ultimately showing enthusiasm in a field (one of automation) otherwise characterised by tepid attempts of automating procedures for archaeological object detection based on a variety of 'classical' approaches (e.g. Supervised classification, object oriented image classification etc). This paper deals with training appropriate sets for detection of archaeological features on remotely sensed imagery. Specifically, sets refer to landscape arrangements determined by linear features (i.e. land divisions) rather than single objects, thus introducing a need for object patterning detection. The paper focuses also on pinpointing and acquiring the 'right' data, i.e. those that correlate with the outcomes intended to predict, and on their (often necessary) normalisation and standardisation to boost their suitability: typical RS datasets used in archaeology will be thus discussed. Accuracy of training and test sets is fundamental in deep learning as they act as

benchmarks against which deep neural networks get trained. Shortcoming and uncertainties linked to running the training set through a neural network will be then highlighted, pointing to challenges arising from the archaeological interpretation perspective during the overall process of prediction. The process is based on four steps: i) creation of the training pattern file; ii) network training; iii) creation of a "matrix" data file containing input values; iv) processing the matrix with trained network.

Session 15
Analysing Historical Transportation Systems from new applications and methodologies

GIS-based Spatial Analysis of the Defensive System of Juyongguang of the Great Wall of Ming Dynasty

(*Jie He, Wenpeng Song, Shanshan Liu*)

Juyongguan is one of the most important strategic point of the Great Wall which controlled the nearest shortcut to attacking Beijing, the capital of China in Ming Dynasty. Juyongguan is not only a single fortress, instead, it is a defensive system consisted by a series of fortresses which forms a defensive grid integrated with natural setting. The research paper introduces a GIS-based spatial analysis to simulate the original military functionality of the entire defensive system and evaluate its performance. Cost-surface analysis is operated to locate the possible invasion trails of Mongolian troops as well as the logistics network of the defence side in this region north to Beijing. The cost model introduced parameters in topography, historical land cover, defensive infrastructures and shooting ranges, and visibility as controlling, alerts and injury possibility during the wars. Firstly, computation of the least-cost paths in the original environment will identify the strategic points and illustrates the logics of site selection of the fortresses and defensive infrastructures, like beacons, boundary walls and artificial topographical treatments. Then by comparing the passing costs and path selection after the defensive system established, its defensive performance can be evaluated by the "spatial control capabilities" interpreted from the cost surface. Meanwhile, logistics convenience of the backside of the Great Wall defensive system will also demonstrate the system's performance from another perspective. This research will be benefit to in-depth understanding of the Great Wall heritage and its setting.

Understanding past territorial dynamics through the integrated study of movement, pathways and transport networks

(*Laure Nuninger, Philip Verhagen, Rachel Opitz, Damien Vurpillot, Frédérique Bertoncello, Zoran Cuckovic, Elise Fovet, Fruchart Catherine, Mark Groenhuijzen, Ziga Kokalj, Maurice de Kleijn, Benjamin Stular*)

Settlement patterns and path networks represent different but connected perspectives on human-environment interaction through movement, manifested through the appropriation and organisation of landscape by societies. Settlement patterns and path networks evolve with unharmonized temporalities, but in constant interaction which render the territorial studies very challenging. Remote

sensing, GIS and 3D modeling have greatly contributed to our knowledge and understanding of movement as encapsulated in routes, but the methods employed make it difficult to connect with theories of engagement through travel. Pragmatically, it is difficult to integrate LiDAR-detected traces of pathways, which conflate temporalities, with network analysis techniques and settlement pattern analysis which focus on changing patterns over time. This paper argues for an integrated approach. After a general review of the main methods developed to detect and model movement, pathways and networks of transportation, a conceptual framework will be presented that will enable us to make the connection between the material evidence of routes and various computer-based models of movement, and thus better understand territorial dynamics. This conceptual framework investigates connectivity at various spatio-temporal scales. Most importantly, it creates an explicit framework for research using both detection and modelling-led approaches. A comparison of regional case studies from the literature will be presented to discuss the balance between general models and specific contextualisation.

Dynamic Fastest Sea Route Computation in Support of Seafaring in the Ancient Eastern Mediterranean Serious Game

(*Elias Frentzos, Phaedon Kyriakidis, Dimitrios Skarlatos*)

Seafaring can be defined as the utilization of the sea for travel or transportation and constitutes an important research theme in maritime archaeology. Seafaring is broadly controlled by motivation (the objective of sea-born movement), environmental conditions, and marine technology. Seafaring modeling efforts within the context of Geographical Information Systems (GIS) have largely addressed the effects of environmental conditions on travel route choice and duration via the adoption of least cost path (LCP) analysis. Seafaring motivation is mostly restricted to a mere selection of origin-destination harbors depending on the time-period of interest and the type of trade postulated. Maritime technology is only scarcely taken into account, via often oversimplifying assumptions regarding the links between environmental conditions (largely wind speed and direction) and "velocity made good". In addition, existing LCP applications typically employ average wind and current conditions, and thus cannot be regarded as truly representative of the possibly extreme conditions that are encountered during sailing. This paper describes a LCP approach for dynamic fastest maritime route computation in the Eastern Mediterranean, employing time-varying wind speed and direction information (available at a spatial resolution of 12km and a temporal resolution of 3 hours), as well as accounting for user-provided ancient ship sailing diagrams (polar plots) postulating vessel response to wind conditions. The proposed LCP approach supports a seafaring-in-the-ancient-Mediterranean serious game being developed within the context of the H2020-funded i-MareCulture project: "Advanced Virtual Reality, Immersive Serious Games and Augmented Reality as tools to raise awareness and access to European Underwater Cultural Heritage".

Modelling spatial and quantitative aspects of the Roman military intervention to the Germanic territory during the Marcomannic wars

(Marek Vlach, Balázs Komoróczy)

Roman-Germanic relations in the Middle Danube region during the Roman Period are characterized by the wide range of forms of interaction, oscillating variously between violent conflicts and diplomatic relations. A distinctive group of direct and indirect evidence of the Roman military presence has been enriched during the last years. Amongst the large spectrum of applied field and laboratory methods counts also the digital modelling and simulation for testing of various theoretical models and assumptions within the issues. Due to geographical extent of the studied area the main modelled issues are concentrated to its supplying and logistics. Variable geomorphological context of the region provides opportunities to validate existing structures through the GIS spatial analyses, above all the army movement routes modeling. Besides the spatial statistics there was also established a simple emulative agent-based model with explicit geographic representation in order to test various dynamical aspects of realization of the Roman military intervention and occupation to the barbarian territory.

A comparison between network models for the calculation of least-cost paths: towards on open toolbox to facilitate future research

(Mark Groenhuijzen)

Least-cost path (LCP) modelling has become a consistent part of the archaeological study of movement, but the exact implementation varies throughout its application (e.g. Herzog 2014). Researchers often make implicit choices early in their studies using LCPs but fail to acknowledge the extent to which these choices influence their results. One of the issues raised is the manner in which LCP modelling is implemented in GIS applications, and the readily available GIS tools often operate as a black box. Another concern is that the direct use of rasters mostly allows only for the movement in eight directions (i.e. the neighbouring cells), while better results can be achieved from allowing 'knight's moves' or even more complex moves. White (2012) has developed a method to calculate LCPs over a network rather than a raster that would be able to overcome these and other issues, but that has not been developed further. This study aims to improve the application of LCP modelling by building upon the work of Herzog and White with the construction of an open toolbox. Using two case studies in the Netherlands, a comparison is made between LCPs calculated over a regular raster-based network (using eight directions), networks that include knight's and more complex moves, and a network based on a hexagonal grid (an approach more frequently used in ecological studies). This open toolbox will be expanded in the future with different path-finding algorithms and cost functions, to allow future research to include more conscious choices and robust results.

Session 16
Play, Process, and Procedure: An Experiential Digital Archaeology

A Hologram word: Process Drama and Performative Archaeology in the Digital Age

(*Konstantina Kalogirou, Konstantinos Prokopios Trimmis, Alexandra Kormari*)

As 3D models and holography gradually becoming mainstream in the archaeological research this paper aims to examine the possible adaptation of these techniques as interpretation tools combined with Process Drama. In our perception every human action is performed; thus as we are 'performing' with research, we can equally 'researching' with performance. Having a holographic projection of a possible gamestone and powns, as our only presentation slide, we are going to present an embodied Process Drama interpretation, using the technique of the "forum Theater" as this has been addressed by Augusto Boal. KK and AK two drama specialists and stage actors will "perform" the interpretation using the archaeologists (KPT) data and audiences ideas. The audience in this presentation is required to participate acting as Boal's "forum". As an outcome we would like to examine the possible use of 3D models/ holograms as fields "memorabilia". An archaeological team can create the model in the field and then having the model later can be engaged again with the object or structure. We suggest this re-engagement with the object to be more than a visual re-examination of the hologram, to be an active process – a performance – based not only on the experience that the researcher will acquire in the field, but also on the experiential relationship that the researcher will build with the hologram.

Beyond the Virtual Reconstruction of an Archaeological Settlement

(*Sergi Cebrián Gres, Núria Morera Noguer, Juan Antonio Barceló Álvarez, Igor Bogdanovic, Oriol Lopez Bultó, Ivan Campana, Antoni Palomo Pérez, Raquel Piqué Huerta, Jordi Revelles López, Xavier Terradas Batlle, Josep Lluis Arcos, Juan Antonio Rodríguez-Aguilar, Anton Bogdanovych, Simeon Simoff, Tomas Trescak, Inmaculada Rodríguez Santiago, Anna Puig Puig*)

In the frame of the research project undertaken in the site of La Draga, an Early Neolithic (ca. 5.300-4.800 cal BC) pile-dwelling settlement located at the North Eastern of the Iberian Peninsula, a virtual reconstruction of the settlement has been developed in order to show how did this Neolithic community live. This virtual reconstruction of the settlement has been made accessible to the public – since it is exhibited in a museum – as a 360º video, a virtual reality (VR) serious game, and a VR tour, hence offering different degrees of human-computer interaction. These technological results have been produced by means of a complex co-creation process involving archeologists, computer scientists, software developers, and designers. In this article, we present the methodology and tools employed to produce the 3D reconstruction of La Draga as well as the VR serious game and the VR tour. Furthermore, we also present some preliminary lessons on the role of VR and serious games that stem from analyzing the feedback provided by the museum audience. From this specific experience, we also extract some general conclusions towards the potential of VR and serious games as valuable technologies to engage children and teenagers in history and archaeology as sciences of the social past.

BibNum : reflections on a systematic approach to structure and disseminate archaeological digital data

(Quentin Verriez)

The European Archaeological Center of Bibracte, linked to the eponymous Iron Age site, is both a research entity and a museum since 1995. For the past 20 years, the unavoidable rise of digital technologies has led to radical transformations at each step of the archaeological process : field acquisitions, post-excavation tasks, data archiving, diffusion of the results (to all audiences), museographical purposes. This implies the implementation of treatment protocols and management increasingly heavy. Bibracte has just initiated a project dedicated to the structuring, integration and dissemination of new digital archaeological data, along three axes : - Engage in new documentary strategies to improve archiving and knowledge sharing among different audiences (researchers and general publics). - Equip excavation sites in digital tools to accelerate data recording and real-time consultation to improve in-situ control by archaeologists and provide access to some of these data to visitors. - Create new digital resources and new way of visualisation at the museum, online and on site. The aim of BibNum is to provide a complete workflow to manage the digital data from the field to the archiving, dissemination and valorization. The infrastructure Huma-Num (TGIR) provides a solid foundation for the project through the many resources and tools it offers. This project is developed in partnership with several French universities, archaeology actors and private firms in accordance with the project.

Advanced Visual Education in Archaeology using OpenSim: The Experience of the Time Maps Project

(Dragos Gheorghiu, Livia Stefan)

The present paper presents research work conducted within Time Maps, an experimental research project dedicated to the study of the Past, concerning the design and experimentation of a novel and advanced 3D online virtual learning environment on OpenSimulator, the open variant of Second Life metaverse and social platform. This environment allows the insertion of other, more "realistic", 3D virtual immersive systems, which makes possible a more complex approach to virtual reality, by transitioning from simpler to more advanced and hyper-realistic representations. The result of the experiments was an improvement of the educational process as a result of learning in realistically reconstructed historical contexts, by placing the student in an immersive and direct relation with the virtual environment consisting of 3D architectural reconstructions and multi-media learning resources.

Romans, Polar Bears, and Beach Huts: Crowd-imagining the Dutch Limes in RomeinCraft

(Angus A. A. Mol)

The VALUE foundation is currently running RoMeincraft (www.romeincraft.nl). RoMeincraft is a public outreach activity that combines archaeology, virtual reality, and the video game Minecraft. Through multiple events taking place in different municipalities of the province of Zuid Holland, we, together with the public, are reconstructing part of the Limes Germanicus, by building forts and other buildings located in or close to the various contemporary municipalities along the old Rhine river. At the same time, people attending our events have the possibility to enter VR and experience an in-person view

of the Roman forts in a 1 to 1 scale. Finally, the map is publicly available so those who wish to can keep working on their version of the Limes even after the end of the event and project. RomeinCraft is rooted in the idea that playful digital experiences enhance public engagement with the past. At the same time, the bottom-up, participatory approach of the activity creates a wide range of possible outcomes of re-construction projects, fueled by a (Dutch) popular view of Romanness. In this presentation we will be discussing the implementation of playful digital and archaeological experiences in Minecraft, by showcasing some of the landscape and building projects in the map. The project reaffirms that Minecraft is great as an outreach-tool but also shows that it affords archaeologist the possibility to see a crowd's imagination in action. It thereby shines a light on how our collective imaginations shape and are shaped by heritage.

Archaeogaming as Queergaming

(*Florence Claire Smith Nicholls*)

Archaeogaming can be broadly defined as the archaeological study of video games as artefacts, immaterial spaces and their programming. The discipline involves dismantling traditional ideas of archaeology exclusively as the study of tangible material culture, as well as engaging with, recording and occupying game spaces according to archaeological research aims. In short, archaeogaming can be considered as a discipline which disrupts established academic and ludic conventions. Queergaming, a term coined by Edmond Y. Chang, examines the nature of queer representation in games as well as queering game design, mechanics and experiential play. Queergaming challenges binary oppositions such as narrative versus gameplay and normative competitive and violent game mechanics. Archaeogaming has also sought to question these conventions, especially in terms of how game mechanics encourage the exploitation of immaterial artefacts and prescriptive interpretations of the past. Using a range of case studies, the parallels between archaeogaming and queergaming will be explored. It will be posited that this is a particularly productive exercise in terms of defining archaeogaming as a research praxis, and as a discipline with the potential to overturn hegemonic and heteronormative archaeological perspectives.

Objects, tangibility and immaterial space

(*Megan von Ackermann*)

This paper explores the ways in which objects bridge the divide between material and immaterial worlds, both facilitating access to imagined worlds and narratives and actively shaping the perception of those worlds. Using familiar objects in immaterial spaces adds verisimilitude, grounding the space in a shared cultural reality and blurring the conceptual divide between 'real' and 'imagined'. This movement between the tangible and the intangible is bi-directional not only through the authorised production and marketing of replicas but as extensions of active play by people in the COS-play and prop making communities. By exploring the role that objects have in this navigation between and among worlds we can better understand the ways in which objects serve as active participants in both material and immaterial spaces, creating, carrying, and changing the stories we tell.

Playing with Ethics: Preliminary Results of a Study of Public Perceptions of Archaeological Representation in Games Media

(*L. Meghan Dennis*)

As part of a larger research program into the potential real-world impacts of ethical and unethical archaeological practices via representations in games media, an internet-based survey was released to garner public comment. Participants were asked to self-identify as a member one of four categories; archeologists, archaeologists who play video-games, non-archaeologists who play video-games, and non-archaeologist non-game players. From the 532 responses, an application of open coding was employed to determine the major ethical concerns and areas of consideration for these publics when interacting with archaeology and heritage digitally in games-media. A selection of responses will be presented, along with potential mitigations for archaeologists and game developers.

The Game of Making an Archaeology Game: Proposing a Design Framework for Historical Game Design

(*Juan Francisco Hiriart*)

In the last years, game technologies have been increasingly raising the interest of archaeological communities as means to communicate the scientific data, process, interpretations, and findings from sites. This interest is evidenced by numerous examples of projects using game-type interactions and gaming technologies to communicate archaeological information. Although these projects have undoubtedly contributed to moving this discussion forward, still the problem of designing archaeological games able to mobilize the full potential of the medium remains a challenging task. In many cases, the preferred approach consists of "picking up" an existing game or game genre from the shelf of commercial titles, adapting their representational layers to fit the specifics goals of the project. In our view, this approach seriously limits the perspective of what games can do as a historical medium and excessively constraints their design space. In this presentation, I would like to propose a design framework developed to guide the effort of translating historical data and information into meaningful gaming experiences. In line with the spirit of this session, I will describe the ideas and functioning of the framework through a board game: the game of making an archaeological game. By playing this meta-game, participants will follow the decisional steps of the design framework, gradually moving from the messy tangle of initial game ideas, archaeological data, and interpretations, to a workable first definition of a game prototype.

Session 17
Early human land use strategies during Middle and Late Pleistocene glacial and interglacial times in Europe

Neanderthals on the move: An agent-based modeling approach to simulate Neanderthal migration

(Ericson Hölzchen, Philipp Mendgen, Christine Hertler, Christian Sommer, Michael Märker, Michael Bolus)

The question what caused the disappearance of Neanderthals around 30,000 years ago is still debated. The hypotheses include, but are not limited to, environmental changes, higher rates of mortality, lower birthrates, low population density and competitive disadvantage in comparison to modern humans. Certainly, the effects of those factors differ regionally. Therefore, the past distribution of Neanderthals determines the intensity of these effects on the actual populations. Knowing when and where they came in contact with these factors allows us to further examine the effects of those factors. Because movement is a process of space and time a dynamic simulation approach is required. Here, we present an agent-based model that allows quantifying movement patterns from different stages of Neanderthal development. The agents represent Neanderthal groups and move according to their topographic preferences and availability of resources. Furthermore, the Neanderthal agents can build permanent camps, hunting camps and show a seasonal hunting behavior. The effects of different behavioral patterns are compared in terms of effects on their mobility. We aim to detect differences in mobility behavior across different stages of Neanderthal evolution. The result is a range of mobility patterns that match the observed fossil and archaeological record of Neanderthal sites. On the basis of this model more precise defined hypotheses can be tested to further narrow the range of possible Neanderthal mobility behaviors. This will result in a deeper understanding of the behavior of Neanderthals and give hints about their extinction.

Expansions – How to create links between Neanderthal behavior, ecology and environment

(Christine Hertler, Susanne Haupt, Ericson Hölzchen, Angela Bruch)

With its concept for expansions, the ROCEEH research center examines links between hominin behavior, ecology and environment. As yet, we distinguished between cultural expansions on one hand and expansions in resource space and types of environments on the other in order to examine their geographical consequences in our concept of range expansions. We approached links among the three types of expansions on a quantitative basis only by studying correlations between the geographic range and spatial distributions of environmental variables. With our recent project on Neanderthals we would like to deepen our exploration of causal links between geographic space, resource space and dynamics in and/or variability of subsistence behavior. We use a wide array of statistical procedures in our models including boosted regression trees and GIS for spatial analyses, principal component and discriminant function analysis for an ecological classification of human ecosystems, and we perform proxy-based paleoclimate reconstructions. Results of such analyses are applied for simulations, for instance by agent-based modelling. Neanderthals show a variety of behavioral patterns contributing to subsistence. As is the case for environmental variables, behavioral patterns can be quantified and weighted by probabilities. Such patterns can be understood as expression of systems of provisioning, for instance for food supply. Various designs of such systems may be distinguished although all of them may serve the same purpose, for instance securing the food supply of a particular group. Depending on seasonality of ecosystems, the spectrum of acquired resources differs. Likewise, the level of

technology and common practices determines the composition of a basket of goods, including accessible resources. This approach permits us to identify and quantify crucial variables which exert major influence on the spatial behavior of Neanderthals. It guides the design of agent based models like the one introduced by Hölzchen and colleagues.

Tool Diversity and Mobility: Deducing Neanderthal Land Use Patterns from the Analysis of Lithic Assemblages

(*Michael Bolus, Knut Bretzke, Andrew W. Kandel*)

We hypothesize that the internal structure of a site changes during occupations of different lengths, and that the typological complexity of an assemblage increases as a site is occupied for a longer duration. In this study we use the Simpson's diversity index to compare the typological complexity among different cultural complexes and to evaluate the length of stay. If the calculated diversity index does reflect the duration of stay at a locality, then changes in the relative frequency of sites featuring low and high degrees of diversity can be interpreted as changes in land use patterns. Translating degree of diversity into a land use model, we associate high diversity with base camps and low diversity with task specific sites. An increase in diversity could be interpreted as a shift from a radiating to a circulating pattern of land use. The radiating pattern incorporates many task specific sites operated from relatively few base camps, while in a circulating pattern residential moves are more common, with relatively few, highly specialized sites and more base camps indicating a broader variety of tasks. The transport distance of lithic raw materials is another indicator of hominin mobility across the landscape, adding to the results obtained from the analysis of tool diversity. As a case study, we present data from Middle Paleolithic sites in Europe dating to MIS 6 and MIS 5e, testing the working hypothesis that changes in climate and environment influenced tool diversity and mobility and hence land use patterns of Neanderthals.

Session 19
Agents, networks and models: formal approaches to systems, relationships and change in archaeology

Agents, networks and complexity - an introduction to the session
(*Iza Romanowska, Tom Brughmans*)

In the last few years we have seen a surge in applications of two novel techniques in archaeology: agent-based modelling and network science. They seem to come with bold claims and a lot of promise but where exactly do we place them on the epistemological spectrum? Are they simply new tools for data analysis? Or perhaps they deal with previously overlooked data types? Surely they cannot be as important as is sometimes claimed if archaeology did just fine without them for so many years? In this introductory presentation we will define, explain, and discuss these and closely related methods, and show their place within the archaeological research process. We will sketch out the ways in which these methods have transformed other disciplines and how they relate to the larger field of complexity science. In doing so we will highlight the issues and challenges that archaeologist still need to overcome to unlock the full potential of agent-based modelling and network science for our discipline.

Simulating the past: From Virtual Reality to SocioPhysics
(*Juan Antonio Barceló, Florecnia Del Castillo Bernal*)

In this paper, we present a radical interpretation of the words "virtual" and "artificial", distinguishing "virtual realities" from "artificial societies", but insisting on their necessary interrelationships. Our approach relies on the assumption that we should explain past social events by showing how their results and consequences fit into a causal structure, that is to say, a vast network of interacting actions and entities. The potential of this theoretical framework is associated with the fact that we make emphasis on the production of very large numbers of alternatively possible "futures" (or "histories") can be produced by varying initial conditions or a specific parameter setting of interest or by subjecting the theoretically specified model to random perturbations. And those "possible" worlds are not "reconstructions" of what we know it may have happened, but formally testable hypothetical models. Some examples from the domain of social interaction and its effects on cultural identities will be used along the paper, and we will discuss how the physics of non-linear dynamics can be used to represent social change, avoiding the usual mistake of confounding social agents with atoms.

Explicit Knowledge Representation in Archaeological ABMs
(*Frederik Schaff*)

In current agent-based models (ABM) in archaeology individuals often do not interact directly. Instead, the environment acts as a mediator (Chliaoutakis and Chalkiadakis, 2016), similar to the price mechanism in neoclassical economics. In Schaff (2016) I analysed the consequences of such a representation and argued that an explicit knowledge representation would help to overcome these problems, because it allows to represent the distribution of individual knowledge and make it subject of the analysis, as argued for by von Hayek (1937). If we want to understand, e.g., settlement

phenomena in archaeology, we suggest that each software agent embodies its own representation (i.e. model) of the geophysical reality, but also social and other relevant reality and in turn bases its decisions only upon this internal model. Because this internal representation is a construction based on the personal history of the agent, sameness becomes an affair of the internal agent's "mind", as demanded by Georgescu-Roegen (1967, p. 37l). On the system level, we need to model agent communication and the general network of interaction to understand the propagation mechanisms for knowledge. The social network, as a consequence, cannot be fixed but must be emergent, too. In order to test the relevance of this idea for archaeological ABM we use the model of Janssen (2009, 2010), "Understanding Artificial Anasazi / Population Aggregation in Ancient Arid Environments" as a starting point. The model is exceptionally well documented (code published at openabm.org) and together with the original base-line model (Axtell et al., 2002), well-known between the community of archaeologists who work with ABM.

Predicting the Past: Computer Simulations in Archaeology
(*Fan Zhang*)

Can computer simulations find wide applications in archaeology as they have in many other disciplines? For the better part of the past few decades the question has been lingering on the margin of archaeology. In the 1970s and 1990s, simulative methods briefly enjoyed broader acceptance among archaeologists who used computer-constructed models to test hypotheses on settlement patterns, population growth and other phenomenon based on statistical sampling of archaeological remains. Such enthusiasm failed to arouse sustained and widespread interest until recently with archaeologists' adoption of emerging digital technologies and techniques from virtual reality, 3-D printing to agent-based modeling methods. A revolutionary new age for archaeological simulations was predicted. My research responds to this prediction. The primary objective of my paper is to examine the two earlier traditions of computer simulations in archaeology in order to explore the conditions for its future success. Specifically I will explore the possibility that archaeology's reluctant acceptance of computer simulations in the past was a result of insufficient engagement of simulative methods with theory building. The computer modeling and simulation were envisioned as mere scientific techniques and tools but were ineffectively contextualized to answer specific questions important to emerging archaeological interpretations and theorization, which in turn hindered their reception by a wider community of archaeologists beyond simulation enthusiasts. The significance of new simulative technologies and techniques, I suggest, lies in their ability to bridge a scientific archaeology and a value-laden interpretative archaeology.

Using ABM to explore the role of socio-environmental interactions on Ancient Settlement Dynamics
(*Frédérique Bertoncello, Marie-Jeanne Ouriachi, Célia Da Costa Pereira, Andrea Tettamanzi, Louise Purdue*)

This paper presents a work in progress within the project « Modeling the role of socio-environmental interactions on Ancient Settlement Dynamics - ModelAnSet » (UCA JEDI Academy 2 « Complex Systems ») developed by archaeologists, historians, palaeoenvironmentalists and computer scientists at

University Côte d'Azur (Nice). Agent-Based Modeling is used to explore the respective role of environmental and social factors in the evolution of the settlement pattern and dynamics during the Roman period in South-Eastern France. The model aims at simulating the impact of the climatic and macro-economical conditions on the behavior of Gallo-Roman landowners. According to the profit (both economical and symbolic) they derive from their rural exploitations, wich depends both on natural (soil fertility and changing climatic conditions) and socio-economical factors (social status and economical power of the landowner, macro-economical context), the landowners can decide to maintain without change, improve, enlarge or abandon their exploitations or to create a new one. The data (archaeological, epigraphical and palaeoenvironmental) collected and studied over more than 10 years in the territory of the Roman colony of Fréjus (Var, France) is used to define the model parameters and behavioral attributes of the cognitive agents. The paper will present the conceptual model and a first implemented version of the ABM.

Evaluating simulation platforms to describe ancient work processes

(*Florencia Del Castillo, Ivana González Bagur, Joan Anton Barceló*)

Computer simulation of ancient work processes has become central for the design of microsimulation models. Better computational methods and more efficient software tools are constantly being developed to provide more accurate archaeological inferences. Using analytical data from Patagonia ethnographical hunter gatherers work processes: hunting, processing, consumption and discard, we implemented this work flow on three different platforms: FlexSim, Netlogo and Repast. These simulations tools have been evaluated through the amount of data that they provided, their sequencing time and the cost of increased error rates. We proposed this platform comparison to highlight their distinct functionality, requirements and potential applications and to gain experience on which one can be useful to represents and fix better with real archaeological scenarios.

Simulating (In)experience at Sea: Building an Agent-based Model for Iron Age Channel Crossings

(*Karl Smith*)

By the end of the British Iron Age, historical sources report that mariners were crossing the English Channel at several points along its breadth, from the Strait of Dover to the much longer passage between Brittany and Cornwall. These voyagers would have had to make sense of currents, winds and tides, and would have had difficulty fixing their position without landmarks. To complete voyages successfully, sailors would have had to call upon experience and navigational skill. But how much skill would have been required in order to navigate across the Channel in the Iron Age? How would seasonal weather affect the risks involved? Would the use of a set of landmarks made the crossing less risky, or lessened the amount of experience necessary to succeed? To answer these questions, I propose considering navigation as a system in which variables relate to environmental conditions at sea, navigators' ability to assess those conditions, and navigators' prior knowledge (such as the location of landmarks). This paper describes an ABM in the conceptual phase of development that simulates Channel crossings under different combinations of these variables. By comparing the results of these simulations, I intend to use Complexity Science tools to evaluate how these variables contribute to the

success of Channel crossings. The results of this analysis should inform narratives that place the Channel in the centre of an Iron Age 'Atlantic Zone', or posit that contemporary coastal sites were situated in order to interact with mariners attempting the crossing.

Socio-Ecological Responses to a Changing Environment: The Mid-Holocene Elm Decline

(*Micheál Edmund Butler, Phil Murgatroyd, Vince Gaffney*)

The dramatic decline in Elm during the mid-Holocene of north-west Europe has remained a key area of study for archaeologists over the decades, as the mechanisms responsible for this change remain contentious. Current dates for the decline vary spatially, but tend to fall within a range between c.6500 BP and c.5100 BP, although possible isolated events have been dated to as early as c.7300 BP (Grosvenor et al, 2017). Whether the result of climate change, human activity, or disease, the decline occurred in close timing with the transition from hunter-gathering to farming, thus adding further complexity to our understanding of mid-Holocene vegetation changes. Using complexity science modelling techniques, the growth of individual Elm will be simulated within the context of mid-Holocene environments, while also being coupled with human agent interactions, in a suite of agent-based models (ABM's). These models will help to infer and test the mechanisms of such socio-ecological interactions, while also identifying suitable levels of abstraction for scalable ABM's. The construction of these socio-ecological models is integrated into the 'Europe's Lost Frontiers' program of simulation, and will form the basis for both human and ecological dynamics for large scale ABM's using the groups distributed simulation structure. The mechanisms of growth, and interaction will subsequently be parameterised by species, which will allow for the investigation of species interactions within mixed woodlands, coupled with the ever changing social and environmental factors of the early and mid-Holocene landscapes.

Transferring knowledge from locational predictive models into spatial Agent Based Models

(*Kaarel Sikk, Caruso Geoffrey*)

Predictive models have been used for finding potential archaeological site locations already for more than 40 years. In addition to their extensively used application in cultural heritage management they can also offer insights into past human behaviour in relation to environment. The proposed paper discusses how the information gathered from predictive modelling of archeological settlements, especially the revealed from location determinants, can be transferred to spatial Agent Based Models. We argue that spatial simulation models, especially those based on agents behaviour, above all aim to build theory and create generalisable knowledge. They therefore need to free themselves form local contexts and particular spatial heterogeneities, and automatically test the effect of agents behaviour on a wider range of spatial configurations. In cultural heritage management, models are usually created using geographical variables of existing settlement patterns (eg. water access and land formations). For finding archaeological sites the model needs to be calibrated for specific accuracy and precision. In this paper we focus on defining the potential residential space – an area that could be considered by people of the past as suitable for habitation or specific economic activities. We develop

a framework that links geographical variables and behaviour as extracted from empirical studies to the development of a theoretical spatial agent-based model.

The Emergence of the State in Predynastic Upper Egypt: An Agent-Based Approach

(Jessica Nitschke, Geoff Nitschke)

The archaeological record shows that from ca. 4000 BC onwards, Neolithic farming communities in Upper Egypt underwent a process of increasing social complexity. This included a rise in wealth inequality and hierarchy; settlement agglomeration; and the development of complex cultural ideology, culminating in the emergence of a unified territorial state encompassing the whole Nile Valley by ca. 3200-3100. The rise of the ancient Egyptian state has long been a point of fascination for scholars, but without a clear consensus on how or why this state emerged. Recently, several scholars have set aside the search for a grand unified explanation, acknowledging that the emergence of the Egyptian state was the result of overlapping complex social, economic, geographic factors. However, archaeologists still struggle to adequately narrate and understand this process. This paper will present what Agent Based Modeling (ABM) can contribute to the discussion, focusing on the early stage of the process: the transition from roughly egalitarian agri-communities to agglomerated settlements with pronounced social stratification. This paper will introduce some of the prevailing theoretical models in the Egyptological literature concerning the rise of polities and social complexity and show how ABM can be used to critically evaluate and refine these models. Specifically, we present an ABM (built using NetLogo) that explores how a combination of human-decision making, environmental/topographical factors, and chance all interconnect to result in the emergence of a settlement system and wealth hierarchy similar to that witnessed in the archaeological record of predynastic Upper Egypt.

Przeworsk Culture in Widawa Basin (South-Western Poland). Simulation Modelling and Probable Settlement Processes

(Jan Zipser)

The Przeworsk Culture is known, among others, for iron production. One of the Przeworsk Culture settlement regions bearing evidence of iron production is identified in the area of the Widawa Basin (Lower Silesia, south-western Poland) and consists of around 600 sites, although many of them are dated approximately and their functions are unspecified. Due to general chronology, it is possible to describe the overall dynamics of the Przeworsk Culture settlement phenomena there. However, questions about the reasons for emergence, dynamic and the accompanying changes in occurrence of the Przeworsk Culture settlements in Widawa Basin from the pre-Roman Iron Age to the early Migration period still remain unanswered. Have environmental conditions, particularly watercourses (due to the economic use of bog iron present only in the vicinity of wetlands), played a key role in shaping the strategy of land use by the Przeworsk Culture people and the detailed course of the settlement system's expansion? The Shifting Model procedure applied in the research is based on the "intervening opportunities" idea. The model mechanism of decision making, managed by the selectivity parameter (reflecting the human deliberative demand for the best settlement conditions), refers to the attractiveness of terrain features and is based on the apparatus of Bernoulli trials. The chosen method achieved satisfactory results demonstrating good correlations with the mapped,

archive settlement system. The paper presents general results of the research project aiming at a recreation of the Przeworsk Culture settlement emergence and expansion in the Widawa Basin by means of simulation modelling.

Do Conflicts Drive Urbanity? Spatial Modeling of Conflict and Flows in the Bronze Age
(*Lennart Linde*)

Hillforts are a long standing topic in Bronze and Iron Age archaeology. The fortifications are often dubbed as central places or proto urban centers and their appearance is often linked to a widespread rise of conflicts. Can we therefore identify conflict as a driving force of accumulation within settlement patterns by using hillforts as a proxy? And do they really emerge as a reaction to conflict? If they do conflicts can be counted as a driving force in social and spatial change. Within the archaeological narrative conflict is always dubbed as "crisis" leading to the devastation of a region. However they are a two sided phenomenon and might even have accelerated the rise of urbanity by involuntary redirecting flows of goods to new nodes in other regions. Studies of prehistoric places expressing grades of centrality and early urbanity seem to reveal that they are of low resilience. Our theoretical framework attributes this to the effects of conflicts on the various flows of goods and how they traverse through the landscape. The presentation will showcase an ABM that implements a spatial evolutionary game and a pathfinding algorithm to study the rise of hillforts, spread of conflicts, and their effect on flows in space.

The key lessons of complexity theory for Archaeology
(*Andre Costopoulos*)

Complexity theory has a few critical implications for archaeology. First, it teaches us that unusual or large scale effects do not require unusual or large scale causes. Second, it teaches us that initial conditions are extremely important to any evolutionary process. Third, it forces us to conclude that human intentions are only weakly connected with long-term historical developments. I will discuss how these insights affect agent-based computer simulation in archaeology.

Towards a conceptually-enhanced archaeological network analytic tool
(*Lieve Donnellan, Lutz Schubert*)

Network analysis is of growing interest for interpreting the archaeological data. However, even though several excellent applications for formal network analysis exist, they were generally not intended for analysis of archaeological data which leads to multiple serious concerns: 1) Theoretical: network analysis tools are written for sociologists and mathematicians and use terminology foreign to most archaeologists. Rewriting the terminology however also necessitates a more formal framework of when the methods are applicable and how to interpret the results (cf. 3) 2) Methodological: these programs were designed with other than archaeological scientific questions in mind. Many archaeological data are not taken into account when doing network analysis. A case in point is the complexity of entanglement between people and objects, as outlined by Hodder (2011, 2016). 3) Conceptual: in principle, archaeological data first needs to be adapted to the research questions posed

by network analysis tools, yet little information is available on how this can be achieved. Many archaeologists thus experience problems when converting their research question into a network model. To meet archaeological questions, the existing network analysis methods need to be reassessed on all levels, ranging from the way data is gathered and structured, up to how to deal with multi-parameter analysis over different statistical constraints. Specifically, more attention should be paid to ties between nodes in order to allow for a more qualitative network analysis. This paper will present a fist conceptual framework of how such an archaeology centered network analytic tool would look like.

Network approaches to the formation of artistic communities in the Orinoco Interaction Sphere
(*Phil Riris*)

It has long been observed that the Orinoco River unifies the cultures of the surrounding regions due to its geographic centrality in northern South America. However, the concept of the Orinoco as a mediator hinges not just on the cultural similarities, but also the crucial differences that have been identified the material, linguistic, and ethnographic records across time and space. Nonetheless, archaeological approaches seldom address this problem explicitly, and a challenge that remains is translating between highly particular local patterns and the mature models of diffusion, migration, and down-the-line trade that form an intricate and ever-present backdrop. Breaking from traditional interpretative focuses, this project aims to understand how artistic communities form and interact in this setting through the application of network methods. Mapping connectivity between rock art sites offers the opportunity to characterise the role of prehistoric art on an unprecedented scale. The combination of spatial, iconographic, and archaeological data will produce new insights into key questions facing archaeologists: do stylistic networks mirror prehistoric social structures or flow beyond known cultural and ethnolinguistic boundaries? Are sites highly interconnected or centred on few hubs with numerous satellites? What influence does geography have? This paper will report on the analysis of a pilot dataset collected in the Middle Orinoco, spanning nine millennia of occupation, as part of a project aiming to close a critical gap in our understanding of indigenous South American cultures.

The application of Network Science to the study of Atlantic Rock Art
(*Joana Valdez-Tullett, Tom Brughmans*)

Atlantic Art is a form of open-air prehistoric rock art of geometric and abstract design, typically carved on open-air outcrops and boulders. It has a wide geographic scope, being found in a number of modern countries of the Atlantic façade, such as Portugal, Spain, Ireland, England and Scotland. Although Atlantic Art has a long biography of research and an overwhelming presence, there is little understanding of the relationships responsible for the widespread iconography, although it has been suggested that the rock art of the various countries share a common origin. In this paper we will explore the similarities and differences between the rock art of five different study areas (one per mentioned country), analysed through the application network science, comprising a comprehensive dataset which includes the characteristics of the motifs' morphology, landscape setting, carving techniques, compositions, results of spatial analyses. This formal method enabled the development of

an effective relational analysis of the dataset encompassing all of the dataset by identifying relational patterning in a complete similarity network including all 100 recorded variables (i.e. without the need to remove any information). This was achieved by applying the Louvain modularity measure incorporating attribute presence/absence as edge values in the analysis. The data was analysed at different levels with different data selections. This approach allowed for the identification of regional preferences and contributed to a clearer insight into the connectivity and cultural transmission, emphasising meaningful relationships of attribute similarity and difference between the traditions of all countries could be identified.

Networks of things: mapping quantitative and qualitative variables of archaeological artifacts

(*Grégoire van Havre, Acilene Mota Sandes*)

Network Analysis in archaeology can be used as a spatial instrument of measure. In this regard, it has been applied to study diverse socio-economic systems through the ages. Clusters and measures indicate social and cultural phenomena that can directly be grasped in historical terms. Here, we propose to use network analysis as a non-spatial instrument of measure for material culture. In order to introduce this perspective, we applied it to two distinct sets of unrelated objects: rock art paintings from the state of Bahia, and lithic artifacts from the state of Piauí, both in Brazil. Two-mode networks are mounted on which different additional variables can be mapped and measured. The application of network analysis to archaeological artifacts also allow us to graphically study the concept of "chaîne opératoire". In this case, nodes are used as proxies for the study of flow and collective trajectories.

Virtual Kinship Networks

(*James R. Allison*)

This paper analyzes the structure of virtual kinship networks formed by an agent-based model that was originally designed to explore the relationships among kin networks, residence rules, settlement size, and the movement of exchange goods in a simulated exchange network. Following simple rules, agents in the model are born, die, find mates, establish post-marital residence, and exchange goods (which are conceptualized as pottery vessels) among close kin dispersed through a linear system of villages. Each run of the model produces a network that unites most agents, but each agent also has a personal network of close kin. Previous analysis of model output has focused on variation in the number of virtual pottery vessels obtained by agents, and on data averaged over large numbers of model runs, with only minimal analysis of the networks produced. But variation in network structure must underlie the variation in exchange success seen in the model runs. In this paper, the focus is on the characteristics of the virtual networks produced during individual runs of the model, including examining variation in measures of centrality and degree distribution. But, consistent with the original focus on the role of kinship in facilitating medium- or long-distance exchange, the spatial organization of kin networks is the most important component of the analysis. Variation among agents in a single run in path length from one end of the system to the other, and variation in the average path length between runs with different settlement sizes are of particular interest.

Christianization of the Roman Empire: Diffusion on a Settlement Network
(*Vojtech Kase, Jan Fousek, Eva Výtvarová, Adam Mertel*)

This paper analyzes the spread of Christianity through the area of ancient Mediterranean as a diffusion on spatial network. As the transmission of innovative ideas in the ancient world was dependent upon physical travel of people, we investigate the influence of the transportation network on the spatio-temporal pattern of gradually establishing Christian communities. We are working with three hypotheses. First, the time when Christianity reaches a settlement could relate to distance on the transportation network from Jerusalem. Second, we combine the distance on the transportation network with the population estimates of the major settlements to account for the expected amount of interaction between two settlements. Third, we evaluate the cultural factors as predictors of early arrival of Christianity, such as language and religious environment. The transportation network model is adopted from recently released platform ORBIS, incorporating both the road network and maritime travel model. To make the transportation model more useful for our purposes, we combine it with population estimates for major settlements of the Roman Empire based on other resources. To estimate the amount of interaction between two cities we employ the gravity model, which is used in transportation models to determine the origin-destination matrix. In short, it relates the interaction frequency as proportional to population sizes and inversely proportional to a function of distance. As a last step, we statistically evaluate the factors corresponding to all our three hypotheses with the dated presence of Christianity in particular settlements.

Epidemiological Modeling and Impact Evaluation of the Antonine Plague
(*Marek Vlach*)

Since the beginnings of the "3rd century crisis" discussions the infamous epidemic called Antonine or Galen plague has represented one of the featuring part within the whole process. During the crisis period various segments and regions of the Roman world experienced different forms of turmoil (social unrest and uprising, economic inflation, political instability etc.) and external incursions (warfare, barbarian raids). Present scientific knowledge encompasses considerable margins of estimated death toll cased by the epidemics. The main intention of the paper dwells is testing of possibilities of impact on the basis of emulative digital modeling and simulation. Simplified studied geographically explicit context of the cellular framework represents a workspace for spatio-temporal quantitative modelling. Model input data for such purpose include e.g. reconstructed distribution of population density, infrastructure, and clinical data. The vital part of simulation dynamics is defined through the epidemiology mathematics (a compartment model driven by differential equations). Coping with large array of input variables, which are known only up to the limited extent, has constrained establishment of testing scenarios for assessment of possible quantitative and spatial aspects of epidemic impact within the demographic context of the Roman Empire.

A Conceptual Model for Social Impact of Cultural Processes
(*Rimvydas Laužikas, Darius Plikynas, Leonidas Sakalauskas*)

The impact of dynamic cultural processes on personal and social change is one of important research questions not only in contemporary social sciences, but also for understanding of past societies. In

context of theoretical concept of culture values, based on systems theory and theory of social capital, the impact of cultural events could be analyzed and simulated through focusing on the construction / deconstruction of social capital, which takes place through the actor's engagement in the dynamic cultural processes. This papers was developed as the part of research project "Social impact of cultural processes: development of metrics, conceptual and simulation model". The project aims to create a model that would allow evaluating the impact of cultural processes on societal polarization and convergence. The aim of paper is to present a conceptual model of the social impact of cultural processes, based on CIDOC-CRM methodology. Three key components of cultural process are distinguished in the conceptual reference model (as CIDOC-CRM classes): events (CIDOC-CRM, E5 Event), actors (CIDOC-CRM, E39 Actor) and groups (CIDOC-CRM, E74 Group). In the model every component is described through the attributes (as basic features and changeable metrics). Processes, which take place during the event, may be defined as interactions, having impact on the actor and group's changeable metrics. The added value of social capital is generated during the course of events, which generates social impact of dynamic cultural processes and influent on societal polarization and convergence.

Identifying Late Chalcolithic and Early Bronze Age Metal Communities of Anatolia through Groups and Networks

(*Martina Massimino, Michelle de Gruchy, Jelena Grujić, Miljana Radivojević*)

There are two broad methodological approaches for identifying distinct communities in the archaeological record: groups and networks. Grouping methods divide objects into categories based on observed similarities, while networks map connections between objects. Archaeologists working in Europe have been advancing methods of both approaches, including Typenspektren to define groups without losing sight of the often fuzzy boundaries between them (Nakoinz 2013) and applying modularity maximization to network analysis (Radivojević and Grujić 2017). This paper applies and compares these new methods from both approaches and correspondence analysis to Late Chalcolithic and Early Bronze Age copper-based objects from Anatolia, for which metal compositional analysis are currently available. The resultant spatial clusters have implications for understanding regional and interregional patterns of production and exchange at a time when copper-using complex societies were first emerging in Anatolia. The remarkable abundance in Anatolia of poly-metallic ore deposits – including copper, iron, silver and lead - contributed to the early appearance - by the mid-4th millennium BC - of a wide range of copper-based alloys. These have been interpreted as resulting from different regionalised technological traditions, which possibly reflect large-scale interaction networks of production and exchange (Lehner and Yener 2014). Therefore, applying the grouping and network methods to the Anatolian data could enable to independently assess this archaeological interpretation and thus enhance our understanding of the socioeconomic structures and relations underlying the production, exchange and use of copper-based objects during the period under examination.

Reconstruction of Old Kingdom Administration using Data Mining

(Veronika Dulíková, Radek Marik)

The sophisticated administration in the age of the pyramid builders offers a remarkable time span for research and a unique opportunity to analyse the dynamics of a complex society in a diachronic perspective. Although scholarly interest in the Old Kingdom administration has always been relevant, the grasping of its complexity and the tracing of the particular processes which led to changes and innovations of the system have been missing. Contrary to traditional approaches relying on statistics and logic, we will present an overview of our achievements in society development reconstruction covering both structural and dynamic aspects using complex network analysis (CNA) and hidden Markov models (HMM). Our research is based on diachronic occurrences of titles held by officials of various social status. The presence of a social stratification structure can be demonstrated by specialized bipartite (people – titles) network visualizations, and by various data mining methods including classical categorical data clustering and bi-clustering techniques with similarities such as Jaccard index and mutual information. Great achievements regarding administrative development dynamics have been reached by applying a method based on HMM to sequences of titles held by viziers, the highest officials. The system is capable of automatic identification of major changes and transitions within society and the bureaucracy. We will present also results aimed at the recovery of the structure of Old Kingdom society obtained by the use of CNA, particularly of community detection methods. The approaches will be exemplified by selected case studies from the Fourth to Sixth Dynasties.

Chronological Network Analysis – A new methodical approach to the chronology of the Southwest German middle Neolithic (c. 4900-4500 BC)

(Stefan Suhrbier)

During the last decades, the relative chronology of the Southwest German Middle Neolithic was elaborated in various studies, based on correspondence analysis of pottery assemblages. However, this approach caused several problems. E.g., it was not possible to analyse the late middle Neolithic pots/sherds together with earlier pots/sherds since during Roessen various motives are bound to specific pottery shapes, which caused a chronological irrelevant sorting. The problem was solved by separate correspondence analyses of earlier (Hinkelstein-Grossgartach) and later (Roessen) pots. The results of both were compared and only argumentatively combined. Another problem was the rich decoration of late Grossgartach/Planig-Friedberg pottery. Due to a high variance of motives this phase was often divided into subphases which could not be tested empirically. Based on these problems, a new methodical approach is presented: "chronological network analysis". This rests upon the idea that analysis of relative chronology can be depicted as a network, i.e. two pots are connected by sharing the same motives or else motives are connected by their presence on the same pot. In contrast to the visualization of a correspondence analysis, the graph of a chronological network is a linear depiction. In order to redefine the relative chronology of the Southwest German middle Neolithic, modularity analysis was carried out. This results in a chronological division of phases that is no longer based on subjectively identified gaps in the visualization of the correspondence analysis but on empirically determined subgroups. Hence, this is a promising approach for analysis of relative chronology in general.

What's geography got to do with it? A networked, agent-based model of exchange in Polynesia

(Benjamin Davies)

Ancestral Polynesians settled the widely-dispersed islands of the Pacific Ocean through a series of purposeful voyages of discovery. These discoveries were followed by periods of maritime interaction, demonstrated by the presence of exotic stone artefacts in archaeological assemblages. It is often assumed that the presence of these exotic materials is evidence of exchange relationships between islands or island groups. Here we present on work simulating exchange across a spatial network in the central Pacific Ocean, with the goal of understanding how patterns in the distribution of lithic material sources might be influenced by the geography of the oceanic environment. First, a network between islands is generated where connections are mediated by geographic criteria (e.g. distance, size). Agents then move between points in the network, obtaining raw material at rocky islands and relocating it according to a neutral model of distribution. Results from the simulation demonstrate how frequencies of sources represented in archaeological assemblages can be approximated using a minimal set of constraints on networks, providing a set of baselines which can be used to assess any preferential exchange relationships. Recommendations are made for future work incorporating temporal changes in assemblage composition and the sailing environment.

Viewshed network analysis of the Cochasquí site, Ecuador

(Irmela Herzog, Alden Yépez)

The archaeological park of Cochasquí in the highlands of Ecuador includes 15 truncated pyramids and several mounds known as tolas, constructed before the advent of the Inca and the Spanish in this area. One of the aspects for choosing this location was probably the fantastic panoramic view down to the valleys and the high mountains at a distance of 8 km or more. If this site served a ritual purpose, visual relationships between agents on top of the pyramids were probably important. Moreover, the area surrounding the pyramids provides some space for spectators watching the ascent of the actors via the ramps to the top of the pyramids and any subsequent rituals on these tops. The network methods proposed by Brughmans and Brandes for studying visual relational phenomena in archaeology inspired the intrasite visibility research of the Cochasquí pyramids and their immediate surroundings. These methods allow reconstructing the visual communication of the agents on the pyramid tops for orchestrating a ritual. Moreover, network approaches support quantifying the visual relationships between the pyramid tops as well as between pyramid tops and possible spectators.

Networks of Meshworks: emerging social structure and communities in Kaushi, Taiwan

(Mu-Chun Wu, Tom Brughmans)

This paper presents a GIS implementation of Tim Ingold's concept of meshworks, and a subsequent representation of these meshworks as network data. This new method aims to formally represent possible interactions between households and to explore whether communities can be detected in a complete network of such potential interactions. The approach is applied to Kaushi settlements in

Southern Taiwan. The approach to constructing meshworks consists of calculating least-cost paths from each household's dwelling to every other household in the settlement (or between a subset of households) and representing the outcome as a set of rasters showing the potential for interaction at each part of the settlement. The modelling of social meshworks at Kaushi settlements renders the settlement layout as spatial potential for social encounter and enables archaeologists to examine the formation of social relations. In this paper we further demonstrate how network science can offer an alternative representation of such meshworks by representing households as nodes and connecting each pair of nodes with a directional strength equal to the probability of their interaction according to the meshwork. This complete weighted and directed network can subsequently be explored in its entirety (i.e. without throwing away any relationships by using a threshold edge strength value). We use modularity measures for weighted networks to identify communities of households with stronger probabilities of interaction. We argue that the exploration of such diverse representations of potential household interactions enables unique insights into the structures and communities that characterize the complexity of past social relations.

Analysing the effect of spatial distribution of two populations over the genetic composition of their hybrids

(Carolina Cucart-Mora, Sergi Lozano)

Hybridation is the subject of a growing interest in the literature about Human Evolution. Since the publication of the Neanderthal genome, nearly ten years ago numerous events of hybridation between different populations have been documented in Upper Pleistocene contexts. Hybridation processes are a newly opened door in the archaeological research, not only for geneticists but also for modellers. The process of hybridation between two populations is influenced by a wide range of parameters. Among them, the effect of the spatial distribution of the two initial populations over in the genetic composition of the resulting population has received little attention. Agent based modelling allows us to explicitly analyse the spatial dimension of a hybridation in a way no other approach does. This contribution takes advantage of this characteristic to explore the influence of the spatial distribution of the initial pure populations over the rates of introgression observed on the hybrid population resulting from their interaction. To do so, we perform computational experiments using a modified version of the model by Barton and Riel Salvatore of bio-cultural interactions between two populations (Cucart-Mora et al. 2017, Barton and Riel-Salvatore 2012). By means of such experiments, we analyse the effect of different spatial arrangements of the two populations over the genetic composition of the resulting hybrid population, the evolution of the size of each genotypic group, as well as, the final spatial distribution of the different groups.

Exploration of Hierarchical Prehistoric Settlement Networks - case study of late Iron Age settlements

(Betka Danielisová, Jan Procházka, Kamila Štekerová)

****POSTER***** We suggest a simple agent based model of gradual spatial dispersion of late Iron Age settlement network regarding the probable existence of central sites and settlement hierarchies. The aim of the model is to enable experimenting with relevant combinations of parameters and

triggers and to provide the dynamic picture of the emergence of the prehistoric settlement network. The model makes it possible to study the creation of the settlement structure in the broader region around an Iron Age oppidum. The model is based on a premise supported by archaeological finds that the oppidum was surrounded by a system of agricultural settlements that may have been in a mutual socio - economic relationship. The model is essentially conceived as emulative, as it is based on empirical data concerning the rules for the localisation and dating of settlements, however, the rules for the organisation of space in the creation of the settlement structure, their population dynamics and economic strategies are conceived in an explorative manner, as is the hypothetical relationship to the central site. The model is designed to enable experiments with the starting number and parameters of settlements, and the mechanisms of gradual growth, dispersal, fission and fusion. The settlement network and links between individual settlements use searching algorithms based on minimum spanning tree extension for Netlogo.

Session 20
Palaeo-GIS

Palaeolithic mining and processing complex in Orońsko (Masovian Voivodship, Poland) in the light of GIS analyses

(Sylwia Buławka, Katarzyna Kerneder-Gubała, Nazarij Buławka)

Orońsko is located in the Central-Southern part of Poland, in the most northern part of the "chocolate" flint outcrops. Chocolate flint has been distinguished in the 1920s by Stefan Krukowski and Jan Samsonowicz. In 1935, during the excavations, Stefan Krukowski discovered the remains of mining shafts, filled with flint artefacts, mostly dated to Palaeolithic. The mining landscape, however, was completely destroyed by the agriculture. In 2016 new research project has been conducted. The topic of the project is an "Exploitation and processing of chocolate flint during Palaeolithic and Mesolithic in the North-Western part of its deposits based on non-invasive archaeological and geophysical research and test-trenches". The project is financed by the National Science Centre in Poland (2015/17/N/HS3/01279). In the research we included archival documentation, topographic, geological and hydro-graphic maps, LIDAR, high-resolution aerial and satellite imagery. The analysis of mentioned data alongside with conducted field surveys allow us to locate the mining and processing complex at the site (Orońsko 2), which were chosen for verification. During the excavations we have found shafts over 3,5 m deep and sunk in carrstic clays and limestone bedrock, where clear traces of exploitation can be found. Radiocarbon dating of the charcoal yielded an age range of 12700-12800 +/-60 cal BP. It seems, that the assemblages found in the shafts are linked with the Arched Backed Pieces Technocomplex (probably the Federmesser culture). In order to document the complicated stratigraphy of the shafts different documentation techniques were used - i.a. high precision Total Station mapping of artefacts and photogrammetry. This paper focuses on the GIS methods used in the project in order to locate and study the mentioned mining areas. The recent results allowed us to verify the previous interpretations of the site and also indicate the future research directions.

Contribution of Geographic Information System in definition of human activity areas in Middle Palaeolithic. Examples of Caours and Beauvais (France)

(Gwénaëlle Moreau, Jean-Luc Locht, Marylène Patou-Mathis, Patrick Auguste)

During the Middle Palaeolithic, northern France was occupied only by Neanderthal. Confronted with an important climatic instability, they had to adapt their way of life and territorial and primary resources management. The study of human settlements and their function in a territory allow a better comprehension of this problematics, essential for this old periods. The intrasite spatial analysis will help us to answer those questions through the description of human activity areas and their interactions, witch lead to precise the site's function in a territory. However, for Middle Palaeolithic sites, we can't see systematically on the field the spatial organisation directly, we sometimes need modelization. Therefore, we started to build a spatial analysis protocol based on a Geographic Information System and rely on sites of Caours and Beauvais (France). They are two open air sites that are exceptionally well preserved and displaying a large amount of faunal and lithic rests. Our protocol's aim is showing the existence of a spatial organisation in form of artefacts concentration area. We first hypothesize with mesh analysis – or density, widely used in archaeology. Nevertheless, this method is limited by subjective choices like that of the mesh analysis. For that reason, we decided to use two other methodologies based on artefacts density but also on the distance between each other: The K-mean Clustering and The Kernel Density Estimation. Then, we will specified this areas function in a life space and their interactions through the spatial distribution of different lithic artefacts and faunal remains.

Palaeo-geography of the Channel Plain and its influence on Neanderthal lithic and landscape behaviour

(Samuel Griffiths)

The Channel Plain Region, now largely submerged by high sea-level, incorporates the UK Crown dependencies of the Channel Islands, Northern France (specifically Brittany and Normandy), and southern Britain. La Cotte de St Brelade sits at the centre of this landscape, and is pivotal in understanding the Early Middle Palaeolithic Neanderthal occupations of the area. My recently concluded PhD research investigated the lower, Saalian (c. 220 – 160 kya) deposits at La Cotte, and chronostratigraphic and technological relationship(s) across this region. This included a series of newly developed palaeo-geographic models (using ArcMap), aimed at understanding the influence of sea-level on Neanderthal landscape practices. Overall, this paper presents an up-to-date synthesis of Neanderthal behaviour between c. 220 – 160 kya within the region in question. Additionally, reviewing how these models have contributed greatly to this new understanding, I will highlight a series of apparently inherent floors and caveats to research undertaken in this way, in the hope of generating discussion around these practices for future investigations.

Using Taphonomy, GIS, and Photogrammetry to reconstruct site formation and carnivore-hominin interaction at Dmanisi, Georgia

(Reed Coil, Martha Tappen, C. Reid Ferring, Maia Bukhsianidze, David Lordkipanidze)

The Lower Paleolithic site of Dmanisi, Georgia, possesses rich archaeological and paleontological deposits, which include remains of at least five Homo erectus individuals. As with most rich archaeological sites, understanding the nature of the deposits, deconstructing complex stratigraphic sequences, and sorting through the palimpsest are integral to interpreting behaviorally driven site formation. In Block 2 at Dmanisi, the agents contributing to the accumulation of the deposits are mostly biotic (i.e. carnivores and hominins), but evidence from abiotic agents is not entirely absent. Pairing ArcGIS generated 3D spatial distributions and an Agisoft-Photoscan-created-photogrammetric model of the excavation provides support for these interpretations when examining the spatial patterning of fauna, stones, and taphonomic factors. Additionally, this 3D data and model effectively illustrate the location and nature of the physical constraints to biotic and abiotic site formation processes. Pseudo-karstic pipe and gully formations, along with the complex underlying basalt formation, appear to have differentially dictated site formation depending on stratigraphic layer, which is apparent when comparing stratigraphy to the 3D distributions. 3D bone orientations in some areas show directional preference, but this is generally correlated to the shape and dip of the basalt and pipe/gully formations, as illuminated by the 3D model. The spatial patterning of the lithic and faunal material also differs depending on the stratigraphic layer, with faunal remains being more densely distributed in the lower strata. The distribution of coprolites differs greatly from either of these patterns, possibly indicating spatially discrete carnivore activity.

The Last Interglacial period and its implications for AMH dispersal: GIS-based PalaeoMap of Egypt

(Felix Henselowsky, Christian Willmes, Christian Sommer, Dorothee Lammerich-Long, Karin Kindermann, Michael Märker, Olaf Bubenzer)

The question of Anatomically Modern Human (AMH) dispersal from Africa to Europe during the late Pleistocene is one major topic in Paleolithic research, where the use of GIS-techniques and integration of paleoenvironmental data, paleoclimate models and DEM´s has highly increased. However, the challenge remains to integrate data which exists often on a global to a continental scale, e.g. paleoclimate models, to a specific research region. We present a PaleoMap of Egypt for the last Interglacial period, where we combine climate, vegetation and relief, but also appropriate raw material sources as primary needs of hunter-gatherer societies. Input data for this map are produced from: (1) computation of a Paleo-Köppen-Geiger-climate and biomes from output variables of a global paleoclimate model (CCSM3, worldlcim.org) (2) scale-dependent relief analyses (3) geological maps for paleolake deposits and raw material sources (4) extensive literature survey for integration of proxy-records Existing models for North-Africa or the Arabian Peninsula show the general importance of the LIG as one window of opportunity for AMH to migrate throughout the nowadays desert belt. Our results highlight the strong need of the integration from different scale levels and manual modification of thresholds during the downscaling of large-scale data to the regional characteristics. Therefore it serves as a bridge between different heterogeneous regions in Egypt to the overall continental context in North Africa, which stands exemplary for challenges in GIS-based paleolithic research, as the up- and

downscaling of input and output data with regard to past human behavior is a major issue for future research.

Corridors or Barriers? A GIS model to classify biome distributions in the late Pleistocene Europe
(Christian Sommer, Christian Willmes, Ericson Hölzchen, Michael Märker, Volker Hochschild)

The expansion, migration and settlement of hominins, such as H. neanderthalensis and H. sapiens, during the late Pleistocene is strongly influenced by this period's changing environmental conditions. The cooling between the LIG and LGM resulted in the expansion of ice shields, the shift of vegetation zones and the increase of land masses due to falling sea level. In this study we present a GIS method to map biome distributions in order to evaluate their suitability as expansion routes and location preference for human settlement. The model is based on a classification scheme following Schultz (2016) and Bresinsky (2008), which allows to distinguish sixteen plant formations reaching from tropical rainforest to cold dessert, as well as eight characteristic vegetation forms. As input data we used climate variables such as the mean annual temperature (B1) and annual precipitation sum (B12) from the WorldClim Dataset (Hijmans et al. 2005). We also applied the biome model on an experimental climate dataset to simulate the transition from LIG to LGM in several time steps to trace the shift of biome zones. Furthermore, this model is also applied to validate the experimental climate data with bimozations derived from pollen records and other environmental datasets. Finally, we discuss the model results on several migration hotspots around Europe and the biome's effects as natural corridors and barriers. Therefore, we highlight their importance alongside other paleo data, like climate zones and terrain, for agent-based modelling of hominin dispersal.

Moving Around and Settling Down – Reconstructing Palaeolithic Land Use with GIS
(Taylor Otto)

Modelling mobility and land use has always been a challenge to Palaeolithic archaeologists. The complex relationships between subsistence, culture and environment are continuously discussed and modeled individually, but seldom are all these concepts brought together in a comprehensive characterization of hunter-gatherer land use. As these are inherently spatial concepts, multiple GIS methods are available to simulate mobility and subsistence behaviour, but no step-by-step workflow has been developed to combine the results and paint a detailed picture of Palaeolithic land use systems. With this project, I present such a methodology, which concentrates on site pattern analysis and cost-distance modelling, starting from straightforward GIS-analyses and ending with clear-cut expectations for hunter-gatherer land use patterns. I then test the methodology with a case study from the Eastern Rif in Northeast Morocco, on archaeological datasets spanning from the Middle Palaeolithic into the hunter-gatherer societies of the Holocene, discussing data acquisition methods and their influence on the end results. Here, I demonstrate the reliability and reproducibility of the application of spatial techniques to Palaeolithic archaeology, as well as the impact land use changes had on the hunter-gatherer societies.

Challenges in Palaeolithic Spatial Analysis: Two Eurasian Case Studies

(*Patrick Cuthbertson, Peny Tsakanikou*)

Geographic Information Systems (GIS) have proved to be an effective tool for Palaeolithic archaeologists, offering innovative approaches to landscape-related subjects. Multiple and variable GIS applications either desk-based and/or field-based have been widely used the past few decades in Palaeolithic research. However, there remains a notable lack of published literature addressing the integration of Palaeolithic archaeology with spatial analysis. The unique spatio-temporal scales involved in the study of the Palaeolithic require special consideration versus the study of later periods. Some forms of analysis used in historic and later prehistoric studies have a more complex relationship to the Palaeolithic record, or are of little or no relevance. Furthermore, some concepts in use in Palaeolithic studies, such as those modelling discrete habitats or biomes, are inherently anti-spatial. Two case studies from the Eurasian Palaeolithic will be used to illustrate these issues and discuss challenges, limitations and potentials. The first example uses environmental and geological data, and the concept of affordances, to look at dispersal through Lower-Middle Pleistocene Central Asia. The concept of affordances is suggested to challenge ED and site-centrism in the early Palaeolithic record. The second example explores opportunities and/or possibilities of hominin movement (routes) and survival (areas of activity) within the Lower – Middle Pleistocene Aegean 'dry land' (E-NE Mediterranean). The combination of archaeological evidence with the complex topography concept and spatial analysis is used here in order to develop a methodological approach to 'unlock' information kept in this type of dynamic contexts.

Session 21

Structural Analysis for Cultural Heritage: Tools and Methods for Assessing Heritage Monuments and Structures

Digitizing the heritage of Palmyra

(*Natalia Solovyova, Jegor Blochin, Sergei Solovyev*)

After the first liberation of Syrian Palmyra in March 2016 the 3D mapping of damaged sites has become one of the most important tasks for specialists in digital archaeology working in the region. In September 2016 the Institute for the History of Material Culture (Russian Academy of Sciences, Saint Petersburg) made an attempt to contribute to international efforts of digitizing the heritage of Palmyra on a macro-level and organised a large-scale aerial survey of the entire territory of the ancient city of Palmyra. During this survey we covered an area of ca. 14 sq.km and received more than 20000 aerial images (planar and oblique) with 2,5 to 7 cm/px resolution. The received photos were processed with Agisoft Photoscan and a detailed 3D model of ancient Palmyra was created. Based on this model we produced detailed geopositioned orthophotographs for the territory of the ancient city and nearby necropolis, as well as a detailed DEM. Currently we develop an archaeological GIS based on the imagery received – a multipurpose tool for damage assessment and cultural heritage management, for planning and conducting new research on the site and opening new insights in the understanding of the city infrastructure, topography and landscape development. Two versions are in construction - a desktop GIS to facilitate cultural heritage management for the Syrian ministry of culture and an online GIS to

give open access to all the collected data to the research community and to promote the knowledge about Syrian heritage in the world.

Utilization of Point Clouds for Quantitative Analysis of Heritage Structures: Challenges and Approaches

(*Michael Hess, Rebecca Napolitano, Vid Petrovic, Falko Kuester*)

In the field of Cultural Heritage, point clouds are increasingly used for applications ranging from digital preservation to structural analysis and at scales from a single pottery sherd to an entire city. Generated through spatial sensing techniques such as laser scanning or image based reconstruction and often augmented through computer aided design or simulation based modeling results, these point clouds are produced at ever higher detail and rates, all over the world. With the resulting data avalanche come unique challenges and the need to turn raw data into actionable data. The objectives of this work are to understand and discuss the challenges associated with point cloud density, complexity, size, accuracy and trust, as well as to illustrate how, after developing novel approaches to handle these challenges, point clouds can be an invaluable asset for health assessment of historical structures. The approaches presented here demonstrate how interactive analysis of full resolution point clouds further enables users to study construction techniques, detect and measure damages, perform point classification, and perform complex numerical simulations. Better utilization of the large amount of data within point clouds will equip professionals and stakeholders with vital information, which can lead to better decision making, preservation and restoration of the world's most precious structures.

Numerical methods for understanding and quantifying crack propagation in complex masonry constructions

(*Rebecca Napolitano, Michael Hess, Rachel Coe-Scharff, Branko Glisic*)

Before employing structural health monitoring systems or reinforcements on a heritage structure with known cracks, it is imperative to understand how the cracking patterns originated and how they affect the current capacity of the structure. This work outlines a mixed numerical approach for understanding the underlying causes of masonry cracking and the resulting effects on structural performance. By combining Finite Element Modeling (FEM) and Distinct Element Modeling (DEM), the structural response of an undamaged version of a building can be calculated for a combination of loading scenarios. The results of the loading simulations can be compared to the present state of the building for a probabilistic understanding of possible causes. This combined approach was used to examine the crack propagation in various historical structures such as the Baptistery of San Giovanni and Palazzo Vecchio in Florence. Both structures are masonry construction and cracks have been identified through visual inspection and thermal scanning. Several combinations of loading scenarios were run for pre-crack models of the structures. The results of the simulations were compared to the current state of the structures to assess the viability of the approach. Additionally, numerical analysis of the structures in their current state were performed. This aided in assessing the effects imposed by the existing crack pattern to their performance.

Proportion Analysis of Ancient Egyptian Funerary Monuments
(*Anja Wutte, Peter Ferschin*)

Mathematical texts such as the Rhind Mathematical Papyrus show that numbers and measurements played an important role for Ancient Egyptians. Most of these texts have a practical character and refer to daily problems but also address geometrical tasks. Theories claim that the ancient Egyptian architects knew about the Fibonacci series and the golden ratio or at least the idea of the concept of a periodical order of numbers and the appearance in geometry. It is probable that a grid was used to draw construction plans, as it is known for wall decorations. Egyptian Late Period rock-cut funerary monuments at Thebes were evaluated in term of a consistent proportion system for this type of tombs. So far no construction plans are discovered for these monuments and a possible distortion has to be considered due to the conservation status of the tombs. To study the proportions of the buildings the ancient Egyptian measuring unit cubit was used. Several tombs were modelled as HBIM models and the rooms were examined for a consistent proportion system by statistical methods. Furthermore, corresponding rooms (e.g. courtyard, pillared hall) of the monuments were compared in term of their room dimensions and spatial proportions. Additionally, a digital parametric cubit-grid was generated and oriented along a central axis. This allows to identify spatial qualities of room components and correlations between buildings. The understanding of the proportions enables new perspectives on design concepts of these funerary monuments.

A new methodology for the structural analysis of 3d digitized cultural heritage through FEA
(*Gabriele Guidi*)

Starting from the assumption that the conservation and restoration of Cultural Heritage is fundamental, especially nowadays when environmental agents such as earthquakes, pollution, wind, rain, or human factors like constructions in the surroundings, vehicular traffic, or heavy tourism are influencing the structural behaviour of ancient objects and buildings, it is mandatory to find the best pipeline to produce the most accurate structural analysis. Finite Element Analysis (FEA) has shown great potential applied to Cultural Heritage stress detection, combined with reality-based techniques for the survey of the object. The standard pipeline involves the use of CAD models to discretize and simplify the 3D reality-based models in order to import them into an FEA software and produce the analysis. This might be appropriate when the physical element to be simulated is very close to its ideal drawing. But, for Cultural Heritage objects, often altered by the time passed since their original creation, the simplification might introduce an approximation that can influence the accuracy of the results. The aim of this paper is to analyze a new methodology to directly transform the 3D reality-based meshed in NURBS and volumetric models suitable for FEA. The approach that is going to be experimented is based on a wise use of retopology procedures, coupled with a transformation of a simplified and retopologized model to a mathematical model made by NURBS surfaces, as close as possible to the real shape, but suitable to be transformed into reasonably complex volumetric 3D models through standard FEM packages. The methodology is applied to a statue held in the Uffizi Gallery and to the Baptistery in Florence.

Advanced Numerical Models for Seismic Evaluation of Masonry Heritage Monuments: The Case of Diocletian's Frigidarium in Rome, and Andahuaylillas Church, Cuzco

(Renato Perucchio, Christopher Muir, Raphael Aguilar)

The seismic assessment of masonry heritage monuments requires a combination of historical information, experimental tests, and numerical structural analysis. However, numerical modeling of masonry structures is a complex task due to the inhomogeneity, anisotropy and quasi-brittle behavior of masonry material. This paper presents the results of numerical studies conducted by a multidisciplinary research team for assessing the structural damage and seismic vulnerability of the Frigidarium of the Baths of Diocletian in Rome and of the Saint Peter Apostle church of Andahuaylillas, Cuzco. The analysis is performed via explicit nonlinear finite element modeling and rigid-body failure mechanism analysis. Concrete damaged plasticity formulation is adopted for representing the quasi-brittle behavior of masonry materials. The church of Andahuaylillas (late 16th or early 17th century) is a representative example of large colonial churches in the Andes, built primarily with adobe masonry and located in a region with high seismic hazard. Due to extensive damage of the triumphal arch, the present study is focused on assessing the lateral capacity of the arch under horizontal in-plane accelerations representing pushover conditions. Models are tested to evaluate how the arch, the tympanum, the lateral walls, and the building materials contribute to the lateral capacity. The Frigidarium of the Baths of Diocletian (298-306 AD) is one of the largest extant vaulted structures built with unreinforced pozzolanic concrete. The structural capacity of the Frigidarium to resist earthquake induced lateral accelerations is assessed by pushover analysis based on a 3D modified kinematic limit approach that takes into account compressive material strength.

Site Reconstruction from Partial Information

(Lutz Schubert, Robert Warden, Thomas Guderjan)

Environmental conditions change how structural elements wither and decay – e.g. by exposure to sun and wind. Depending on the local conditions, these will lead to different patterns of destructions, such as streaks of water cutting into lime stone depending on wind direction and strength, amount of water, duration of exposure etc. It is easy to derive sun exposure and / or wind exposition of a rock from this information and thus identify its spatial orientation. Shadows from trees and surrounding structures will thereby play an essential role, hence allowing assessment of orientation and inside / outside of building material relative to the architecture of the structure. Analysis of the remaining material thus provides information about its location and orientation relative to the surrounding. In this paper we will examine in how far the other way round holds true as well: by examining the patterns of destructions on ancient structures, we can determine the surrounding climate conditions. What is more, shadows, rainfall and wind force / direction are affected strongly by the surroundings, namely the layout of other structures and therefore the location and size of other buildings. Computational fluid dynamics will be used to simulate the exposure to wind and thus rain, whereas simple astronomical models can be used to simulate exposure to sun. By exploiting a knowledge base on material decomposition given different circumstances, we can attempt to reconstruct the city layout, respectively validate a layout against these patterns.

Session 22
Social theory after the spatial turn

Taking the Hobbits to Isengard': Testing common practices of spatial modelling in fictional worlds
(Chiara G. M. Girotto, Lennart Linde)

In recent years the inclusion of spatial data in archaeological behavioural modelling has offered new paths, possibilities and ideas. However, most models consider landscape to be a predominantly economic feature. But the differing perception of landscapes and the way meaning, importance, and dominance of a place are build in a cultural memory through people, their history, and agency with a place. Human societies are complex systems, not obliging to simple pay-out matrices and approaches dominated by game theory and economic determinisms. To believe so implies a world where everyone is either friend or foe, does rarely switch alliances, and conducts actions which might be questionable on the long term if they only adhere to a certain code. However characters in fictional worlds certainly do. In our talk we aim to demonstrate gains and pitfalls of spatial modelling by applying popular techniques to Middle-earth and Westeros. On the basis of these fantasy worlds and their inhabitants, which can be considered as examples for linear and complex models, we wish to exemplify how assumptions impact a model's applicability. Since archaeology is partly a narrated past these narratives can lead us down a spiral of assumptions and self-affirmation that are also immanent to fictional worlds. How apt are our models if we apply them to complex stories?

In the mind of a Roman farmer: social interaction and predictive modelling in Northern Gaul
(Nicolas Revert)

Our understanding of settlement patterns is generally biased by an environmental deterministic approach, which diminishes the role of social and economic choices. If the Roman Empire has always been considered as driven by economy and culture rather than ecological context, explanations and models of its settlements patterns generally failed to take these factors into consideration. Indeed, in archaeological practice the Roman rural settlement is often considered in 'pre-spatial turn' terms: its location is one of internal characteristics - sometimes the quality of its immediate neighbourhood - rather than its potential towards social interconnection, which is the topic of recent research on rural settlement patterns. This paper attempts to produce a more socially-dependent landscape through archaeological location predictive models, which include non-euclidian parameters such as the perceived accessibility of socio-economic central places. The area of study - The Somme (Northern France) - offers a very non-deterministic space: no variable, even social in nature, can be considered as determinant in site location. The gentleness of its topography may be the cause of that, as is the ease of access to social gathering places in nearly all areas. Nonetheless, multivariate models including socio-economic parameters display higher correlation and consistency than other factors. If these variables strongly distort our cartesian space, they provide - through their combination with the physical environment - a more accurate representation of the landscape as it could have been perceived by Roman landlords deciding where to set the site for a new farm.

Is 'culture' a buzzword? Ontological challenge of an interdisciplinary project on the cultural history of early modern humans in Asia
(Yasuhisa Kondo, Hideyuki Onishi, Yoko Iwamoto)

The PaleoAsia project aims to interpret the nature of distinct patterns in the formation of modern human cultures across Asia. To this end, over 50 researchers from diverse backgrounds such as archaeology, cultural anthropology, mathematical biology, and palaeoenvironmental sciences work in collaboration. Thus far, discussions in the project's meetings and workshops have revealed that the meaning of 'culture' (bunka in Japanese language) seems to mean different things to researchers from different backgrounds, and the term is often used without an explicit definition. This problem, left untreated, may negatively affect the interdisciplinary collaboration, and it is a serious concern for us. With this as our motivation, we envision discourses concerning 'culture' in the PaleoAsia project, which will build a baseline for the intra-project collaborative research on the quantification of culture and its diversity. We applied an ontological approach to this issue. First, we retrieved 486 sentences that included the word 'culture' from the full text of the project's conference proceedings, annual reports of sub-groups, and the project's website (https://paleoasia.jp). Co-occurring words, synonyms, and antonyms were listed, and the occurrence pattern was analysed with respect to the authors' backgrounds. No sentence directly defined the concept of culture, although it was observed that the term was used in the context of materials (e.g., lithic culture, ceramic culture, etc.), geography (e.g., cultural zones), temporality (e.g., Aurignacian culture) and dynamics (e.g., cultural ecology). Through dialogue between researchers from different backgrounds, we will attempt to develop a shared ontology of 'culture' in the project.

Dissecting the Neolithic Dwelling Through the Application of Geostatistics Techniques
(Nuria Morera, Juan Antonio Barceló, Antoni Palomo, Raquel Piqué)

La Draga is an early Neolithic (7270-6750 cal. BP) pile-dwelling settlement, located in the NE of the Iberian Peninsula. This site has provided an exceptional sample of organic remains that have been preserved in an anoxic environment. This paper presents the methodology we have followed to infer regarding the spatial dispersal of social activities from the observed distribution of refuse material. Our procedure selects only synchronous occupation layers using well-measured stratigraphic relationships and dendrochronological dating, and describes the variation in spatial frequencies for each archaeological category (pottery, lithic functional type, animal bones by taxa and skeletal part, etc.) using different geostatistical approaches. A null hypothesis of random distribution of spatial frequency per sampling unit is statistically rejected and a probabilistic map of the most probable location of the activity is calculated, in terms of the statistical relevant contribution in spatial autocorrelation at a local level (Local Moran's I, LISA) between "empty" and "full" places. A predictive model for each spatial variable is built performing a careful analysis of the semivariogram, adjusted for local anisotropy. The resulting model is visualized using kriging and inverse-distance weighting algorithms, and non-linear fit is calculated in each case to test spatial prediction even in the cases of departure from normality. A spatially constrained Correspondence Analysis and a matrix of spatial non-parametric correlations is given to test the possible relationships between the different categories of refuse material, and the prior hypothesis of the most probable position of habitat space (the "house"), and productive space

(activity areas related to subsistence management). Beyond the specific methods used, our approach offers the possibility of relating different social activities and different kinds of space (habitation, production, consumption, refuse), in order to infer the nature of social relations of production in the past.

Session 23
New Directions in Archaeological Aerial and Satellite Remote Sensing

Remote sensing analyses on Sentinel-2 images: looking for Roman roads in Srem region (Serbia)

(*Sara Zanni*)

The research presented is part of the project "From Aquileia to Singidunum: reconstructing the paths of the Roman travelers – RecRoad", developed at Université Bordeaux Montaigne thanks to a Marie Skłodowska-Curie fellowship. One of the goals of the project is the detection and reconstruction of the Roman viability connecting the Roman cities of Aquileia (Aquileia, Italy) and Singidunum (Belgrade, Serbia) using different sources and methods, one of which is satellite remote sensing. The research project analyzed, among other sources, the images produced by the Sentinel mission, funded by ESA and fully operative from March 2017: these images are freely available for scientific and commercial purposes and constitute a constantly updated gallery of the whole planet, with a revisit time of five days at Equator. Thanks to the technical specifications of the satellites' sensors, they are particularly suitable for archaeological mapping purposes, but their capacities in this field still needs to be fully explored. The project provided a useful testbed for the use of Sentinel-2A images in the archaeological field. The study compares traditional Vegetation Indices with experimental trials on Sentinel images applied to the Srem District in Serbia and offers a methodological proposal to use Sentinel-2A images to detect the presence of buried archaeological sites. The paper also compares the results obtained from the analysis of Sentinel-2 images and other kind of satellite multi-spectral imageries. The obtained results were verified with archaeological surface survey.

Towards an automated model for archaeological site detection in Eastern Botswana, an eCognition Model

(*Forrest Follett, Adam Barnes, Carla Klehm, Katie Simon*)

This paper is an effort to create a predictive model for archaeological sites in an area of Eastern Botswana. With a rather arid climate, much of Botswana's ground surface (and archaeology) is easily visible to airborne and spaceborne sensors. Without sufficient training data for supervised classification, an iterative spectral clustering method was used to group spectrally similar pixels from multispectral imagery into a large number of spectrally distinct but unknown classes. A field survey crew inspected known and prospective sites in an attempt to identify the pixel classes and their relationship to the archaeology. The results of this fieldwork have been used to create a ruleset for an Object Based Image Analysis package (eCognition) to automatically detect sites in the multispectral imagery.

Earth observation technologies and cultural heritage needs through the "ATHENA TWINNING PROJECT"

(*Andreas Christofe, Diofantos Hadjimitsis, Athos Agapiou, Vasiliki Lysandrou, Argyro Nisantzi, Marios Tzouvaras, Christiana Papoutsa, Rodanthi-Elisavet Mamouri, Christodoulos Mettas, Evagoras Evagorou, Kyriacos Themistocleous, Rosa Lasaponara, Nicola Masini, Gunter Schreier, Daniele Cerra, Ursula Gessner, Maria Danese, Maria Sileo*)

This paper presents the main outcomes of the on-going Horizon 2020 ATHENA Twinning project, which aims to establish a "Remote Sensing Science Centre for Cultural Heritage" in Cyprus. The Centre foresees to support the current cultural heritage needs through the systematic exploitation of earth observation technologies. For the establishment of the centre, the existing Remote Sensing and Geo-Environment Research Laboratory- of the Eratosthenes Research Centre (ERC) based at the Cyprus University of Technology (CUT), is twinned with internationally-leading counterparts from the EU, the National Research Council of Italy (CNR, through IMAA and IBAM) and the German Aerospace Centre (DLR). Through this networking, the ATHENA twinning project strengthens the remote sensing capacity in cultural heritage at CUT's ERC. A core element within ATHENA is knowledge transfer, achieved primarily through intense training activities (including virtual training courses, workshops and summer schools) with an ultimate scope to: enhance the scientific profile of the research staff; to accelerate the development of research capabilities of the ERC as well as to promote earth observation knowledge and best practices intended for Cultural Heritage. Active and passive remote sensing data for archaeology, SAR for change and deformation detection, satellite monitoring for archaeological looting, integration of remote sensing data for protection and preservation of cultural heritage are also presented. The scientific strengthening and networking achieved in Cyprus through the ATHENA project, could be of great benefit for the entire Eastern Mediterranean Region bearing a plethora of archaeological sites and monuments urgently calling for monitoring and safeguarding.

Remote-sensing tools to detect architectural structures in northern Iberia urban sites (6th – 3rd cent. BC)

(*Maria Carme Belarte Franco, Joan Canela Gràcia, Núria Otero Herraiz*)

The first urban sites of the north-eastern Iberian Peninsuladate from the end of the 6th century BC, and develop mainly during the 4th and 3rdcenuries. The study of the Iron Age settlements in this area has achieved important results in the last 30 years, and has identified a highly hierarchical settlement organization according to the size, location and function of the sites. Nevertheless, the urban sites are the worst known of the settlements, as their excavation and study offer several difficulties: they have large surfaces (about 10 hectares) and most of themlie undera dense forest cover that hides the archaeological remains. The best tools to study these settlements are thus the remote-sensing techniques, and more particularly the use of LIDAR data (Laser Imaging Detection and Ranging). The method is based on the emission of laser lights and the measurement of the reflected pulses, in order to generate a point cloud representing the earth's surface (DSM). The model includes every item of the relief elements, such as vegetation. We can then select the elements of the topography, suppress

the vegetation and obtain a high resolution DTM. This allows highlighting small reliefs created by the anthropic action, through specific filters and the use of GIS programmes. In this poster we present the preliminary results obtained from the application of these methods to a selection of settlements in the coastal area of the north-eastern Iberian Peninsula.

Powerful Pictures: Uncovering Data in Aerial Photogrammetric Imagery

(*Scott M. Ure*)

Unmanned Aerial Systems are capable of providing stunning aerial imagery, however these images are often underutilized. In many cases photogrammetric images are used to generate orthomosaics, but they often never mature beyond "pretty pictures". Advances in photogrammetric modeling and geographic information systems offer tools to analyze aerial imagery and generate geospatially relevant and informative data. In this paper I describe some methods and benefits for using aerial photogrammetry to accurately map large-scale sites, identify obscured archaeological features, and measure three-dimensional space. I draw my conclusions from aerial photogrammetric data I captured at three archaeological sites: the Ad Deir plateau in the ancient Nabatean kingdom of Petra, Jordan; the enigmatic adobe-walled city of Paquimé in Chihuahua, Mexico; and the Aztatlán site of Santo Domingo located in the coastal plain of Jalisco, Mexico. I specifically discuss ways I uncovered data from photogrammetric imagery at these three sites. Examples include: 1) generating digital terrain models for further geospatial studies (slope, least-cost path, hillshade relief, etc.); 2) producing topographic maps with custom contour intervals to update outdated or non-existent maps; 3) creating animations for documentaries used for public outreach; and 4) generating georectified orthomosaics that integrate with traditional survey data and geospatial databases. In using these methods I have created new, accurate topographic maps, identified architectural alignments, and pinpointed unexcavated regions for future research. I conclude that the more we recognize the potential in aerial photogrammetric imagery, the more informative data we will be able to extract from these powerful pictures.

Archaeological Prospection using Drone-acquired Thermal and Multispectral Imagery

(*Jesse Casana, Austin Chad Hill, Elise Jakoby Laugier*)

Experiments dating back to the 1970s show that a wide range of archaeological features, including subsurface architecture, earthworks, pathways, and artifact concentrations may be visible in an aerial thermal image if it is acquired at an optimal time in diurnal cycle and under favorable ground conditions. Similarly, high-resolution multispectral imagery can reveal many kinds of archaeological landscape features by highlighting differences in vegetation health and soil composition. Our recent research is exploring the potential of drone-acquired thermal and multispectral imagery to detect archaeological remains using an uncooled, radiometric thermal camera alongside a four-band color and near infrared sensor. Presenting data derived from numerous surveys at archaeological sites in North America and the Middle East, this paper presents methods for acquisition and processing of thermal and multispectral imagery, highlighting both opportunities and challenges. Results illustrate many possibilities for quantitative, raster-based methods to filter out noise, improve feature recognition, and perform archaeological feature discrimination. Our findings reveal a great deal regarding the varied archaeological sites investigated by this project, and highlight the potential of this

emerging method to explore the archaeological record in a way that is rapid, inexpensive, and non-destructive.

Exploring the Mesopotamian landscape: integrating geophysics and drone-based multi-sensor remote sensing for offsite, land use investigations
(*Elise Jakoby Laugier*)

Investigating human-environmental relationships in the past, especially reconstructing local land use practices, involves associating sites with land use features, such as field boundaries and systems, pathways, and canals. Previous research of this type commonly employs onsite geophysics in conjunction with lower-resolution satellite remote sensing to provide the landscape context; however, recent developments in drone and sensor technology are now allowing archaeologists to efficiently prospect large areas around sites at high spatial resolution for potential off-site features. As part of an ongoing research project that leverages a combination of ground-based geomagnetics and drone-based multispectral imaging, we seek to prospect for and efficiently map land use features associated with several Bronze Age tell sites in the Kurdish Region of Iraq. Our results from a recent 2017 season highlight the potential of this integrated remote sensing approach; we suggest however, that seasonal conditions must be considered during data-collection. Future works seeks to improve results by employing ground-based electromagnetic induction and drone-based vegetational health indices under different seasonal (spring) conditions.

Stereo-Satellite Imagery for Management of UNESCO World Heritage Sites in Jam and Bamiyan (Afghanistan)
(*Georgios Toubekis, Michael Jansen, Albert Moll, Jarke Matthias*)

High-Remote sensing techniques for the management of cultural heritage sites in Afghanistan have been applied successfully in recent years. The method proved to be applicable and very useful especially in conditions were access to the cultural properties is limited due to security reasons. We present our results from the two UNESCO World Heritage sites of Afghanistan, the Cultural Landscape and the Archaeological Remains of the Bamiyan Valley as well as the Minaret of Jam. The stereo-satellite imagery of GeoEye-1 and WorldView sensors have been acquired with a GSD of around 0,5m in order to prepare precise topographic map material. GPS measurements were carried out for surveying GCPs for image georeferencing as well as for the construction of the DEM to be used for ortho-rectification procedures. Based on this data a clarification of property boundaries could be achieved and cultural landscape elements accurately identified and mapped. The resulting maps will serve as a planning base for future development activities as well as for river management studies, all part of protection schemes supporting long-term management efforts to preserve these sites.

Earth Observation and Space-based monitoring of the environment in the Eastern Mediterranean 'Excelsior Teaming Project' : current capabilities, limitations and future perspectives for the Cultural Heritage

(*Diofantos Hadjimitsis, Andreas Christofe, Athos Agapiou, Argyro Nisantzi, Marios Tzouvaras, Christiana Papoutsa, Rodanthi-Elisavet Mamouri, Christodoulos Mettas, Evagoras Evagorou, Kyriacos Themistocleous, Kyriacos Neocleous, Georgia Kouta, George Melillos, Silas Michaelides, Gunter Schreier, Haris Kontoes, Albert Ansmann, George Komodromos, Ioannis Papoutsis, Eleni Christia, Vasiliki Lysandrou, Milto Miltiadou*)

The EXCELSIOR Horizon 2020 Teaming project envisions upgrading the existing Eratosthenes Research Centre established at the Cyprus University of Technology into an inspiring environment for conducting basic and applied research and innovation through the integrated use of cutting-edge remote sensing and space-based techniques for monitoring physical and built environment in the eastern Mediterranean region. Five partners have united to upgrade the existing ERC into a Centre of Excellence, with the common vision to become a world-class innovation, research and education centre, actively contributing to the European Research Area. More specifically, the EXCELSIOR project is a team effort between the CUT, the German Aerospace Centre, the National Observatory of Athens, the German Leibniz Institute for Tropospheric Research and the Cyprus Department of Electronic Communications of the MTCW. This paper presents how ERC would benefit through the knowledge transfer from the DLR, NOA and TROPOS. Earth observation for monitoring the physical and built environment embraces the cultural heritage research sector. The issues discussed here are: Earth observation capabilities for cultural heritage management that includes optical retrieving crop marks, radar and surveying techniques; Open initiatives on the use of space technologies to support the World Heritage Convention; how Big Data activities are used to bridge the gap between Earth observation and information technology; Impact of climate changes in cultural heritage sites; Potential of Copernicus in support of Cultural Heritage preservation and management, to provide inputs for further research and/or operational implementation; and to capitalize the experience through the 'ATHENA' Twinning project.

Investigating Continuous Archaeological Landscapes of Northern Mesopotamia through Multispectral Data from Aerial and Orbital Platforms

(*Jason T. Herrmann, Matthias Lang, Paola Sconzo*)

This paper describes our strategies for reconstructing the archaeological landscapes of the Tigris and Eastern Ḫabur Valleys of the Kurdistan Autonomous Region in northern Iraq through a combination of high-resolution multispectral satellite data, panchromatic and multispectral images from unmanned aerial vehicles (UAVs), and field-walking results. After five years of survey, the focus of the Eastern Ḫabur Archaeological Survey has shifted from the identification of archaeological sites and key landscape elements toward the investigation of the continuous archaeological landscape between cultural and natural points of interest. Emphasized here are the results from our 2017 multispectral UAV survey, which recorded more than 17 km2 of the archaeologically-rich Zagros Mountain piedmont landscape. These data, combined with WorldView-1 and WorldView-2 multispectral images, have

helped us to identify landscape features that may have played a role in past settlement strategies, to discern patterns of ancient and historic land use, and to understand the broader landscape of preservation in our survey region. Most significantly, the combination of these two datasets has exposed physical remains of route systems that may have been in use as early as the Middle Bronze Age.

Multidimensional Data Fusion For Archaeological Research - The Isparta Archaeological Survey

(*Arie Kai-Browne, Kay Kohlmeyer, Thomas Schenk, Thomas Bremer, Bilge Hürmüzlü-Kortholt, Sebastian Plesch, Jona Schlegel*)

The technological progress in the field of remote sensing and 3D-digitizing methods enables archaeologists access to a vast multitude of potentially valuable datasets relevant for various research questions. With the advance of very high-resolution optical and multispectral satellite imagery in addition to highly accurate DEMs derived from stereo and tri-stereo imagery or InSAR, entire landscapes can be captured with an unprecedented spatial and spectral resolution. Furthermore, recent developments in the field of image-based modelling and 3D-laser scanning enable researchers to efficiently record complex archaeological sites with a very high accuracy and spatial resolution, which satellite-based systems cannot achieve yet. Within the framework of the research project "Isparta Archaeological Survey" different types of archaeological sites have been recorded using a combination of methods, including UAV-photogrammetry, terrestrial laser scans, geophysical surveys and close-range photogrammetry, in addition to acquiring various satellite based imagery from systems such as TanDEM-X, Pléiades, Quickbird, RapidEye, Spot-5 and Gambit, which cover the sites as well as the surrounding landscape. This case study will demonstrate the various benefits when combining different sensor technology, such as pixel-based fusion for the efficient segmentation of 3D point clouds, feature-based fusion for a better comprehension of the layout of archaeological sites as well as the integration of varying spatial scales for analysing sites in relation to their surrounding landscape. Furthermore, the challenges and workflows will be discussed when processing billions of 3D points to extract useful information for further archaeological interpretation as well as problems arising when combining datasets with varying degrees of accuracy and spatial resolution.

Session 24
Computational classification in archaeology

Computational classification in archaeology - an introduction

(*Oliver Nakoinz, Martin Hinz*)

To make inferences on the archaeological material that go beyond the individual object we always have to decide what is similar or equal and what is not. This reasoning is at the heart of the archaeological method since its beginning and describes what we understand as meaningful categories such as a type and what we try to achieve with a typology. We group and label objects on the basis of more or, in most cases, less defined criteria. Predominantly this is still done in an 'impressionistic' or 'intuitive' manner since more 'objective' and 'standardised' methods, combined with automated

recording of the artefacts, have not found a wider reception within archaeology. The reason for this might be that most approaches are considered to be complicated, general or reductionistic. This paper is thought to be the introduction to the session and gives an overview on the use of classifications in science, the different concepts of classifications, classification techniques and validation approaches and of current developments. The idea is to provide the participants of this session with some theoretical and conceptual background knowledge in which the methodical and technical in-depth information of the other papers may be embedded.

Considerations on archaeologically meaningful Distance Measures for Multivariate Analyses
(*Georg Roth*)

All efforts to order or classify objects described by multivariate information first require an appropriate way of measuring their similarities resp. differences. But here archaeological data sets e.g. abundance tables often present problems since their mathematical attributes obstruct the use of distance measures offered by most standard statistic (and all archaeological) texts books on multivariate analysis. The talk discusses basic principles for multivariate analyses and wants to offer less known (but easy) solutions for very general problems. Ways of measuring dissimilarities and transformations for typical archaeological data sets, especially multivariate binary and count data, are considered, which allow for the valid representation of resemblances and posess a clear interpretation. All solutions shown represent succesful methods mathematically well studied for decades – but (nearly) not in use in archaeology. Starting with comments on the principle of an euclidean distance the focus is on archaeological meaningful distance measures for binary, ordinal and especially abundance (count) data tables. They allow e.g. to cluster sites from sites-by-types presence/absence or abundance tables without distortions. Subsequently data transformations are presented which allow to submit abundance data to algorithms based on euclidean principles e.g. KMEANS and SVM or ordination methods like PCA and RDA thus overcoming the dependence of abundance analysis on the notoriously sensitive CA. All solutions presented will be accompanied by notes on R packages and functions providing them.

3D Shape Analysis of Ancient Terracottas: Contributions to Automated Object Mining
(*Alexander Zeckey, Martin Langner*)

Three-dimensional objects with complex forms are inadequately classified both in applied computer science and disciplines dealing with material artifacts. Archaeologists are confronted with the problem that although resemblances in form can be established verbally, they cannot be adequately described in language. Furthermore, archaeologists have yet to make sufficient use of automated 3D shape recognition in seeking to differentiate the mutual, formal dependency of similar figures. In Archaeology and Art History typologies are created to make statements about the similarity of objects, about their importance, production or style. A computer has no problem recognizing identically shaped objects, but has yet to learn our human perception of similarity. The approach to this is to develop shape recognition procedures that link the degree of simplification and abstraction not only to human recognition and dissemination patterns as a means of incrementally evaluating and classifying

~~unknown objects but also to categorizations developed in archaeology and art history. 3D pattern recognition of the main components must therefore go hand in hand with archaeological subcategorization and suitable forms of machine learning. This paper will show work in progress on developing those procedures for automatically generating corpora, and also to reflect on the associated schematizations and how they can be applied in computer science and archaeology. The goal of the project is to create and evaluate a multi-step classification process. Finally there might be an object mining that will automatically compare various grades of similarity and determine which category and sub-category (or type) the respective artifact belongs.~~

Classifying vessel shapes using automated shape extraction and unsupervised classification

(*Martin Hinz, Caroline Heitz*)

Since the beginning of scientific archaeology, vessels have been classified primarily by their form. Especially since the advent of computers in archaeology, there has been a variety of pursuits to achieve a classification by means of metric measures and on a statistical basis. An example of this approach is Koch 1998, where the vessels were recorded at significant measuring points. Of course, the (subjective) selection of the measuring points is a decisive and time-consuming aspect of the procedure. Another approach involves methods in which the entire form is digitized and evaluated (Mom 2005, Chapman et al., 2006, Keogh et al., 2009). Our approach follows in general the second premise, but is very simple: we consider the vessels as a rotation body, and evaluate one side of the profile by transferring it into measuring points. The resulting measurement series can then easily be evaluated by common multivariate methods. Other nominal features such as e.g. rim shape or decoration can be added as additional parameters. In this paper, we would like to present the approach and its application in different case studies (copper age ceramics of the southern Iberian Peninsula, neolithic vessels from switzerland). We apply a more conventional classification (PCA and hierarchical cluster analysis) and compare the results to the ones achieved by more modern techniques (t-SNE and HDBSCAN). By means of the proposed method and our R package, it is easily possible to process large quantities of vessel profiles and to follow development trends beyond the classical typological classification.

Digital Pottery Studies of 4th Century Necropolises on the Moldavian plain

(*Vlad-Andrei Lăzărescu, Vincent Mom*)

The Secanto computer program was created to find 'lookalikes' in large artefact collections from archaeological sites. Initially constructed to investigate pottery, Secanto can calculate the dissimilarity of shapes of simple artefacts in general (e.g. arrow points, axes). The resulting dissimilarity matrix (every object is compared with every other available object) is input for statistical methods like Cluster Analysis and Principal Coordinates Analysis. The comparisons are based on the 'sliced' method (Wilcock and Shannon 1975): the 2D projections of the objects (the objects are assumed to have rotational symmetry) are divided in 150 slices, which are compared one by one. The sum of squares of the differences is a measure for the dissimilarity. Bârlad-Valea Seacă and Mihălăşeni are among the largest necropolises from the Early Migration period that were excavated in Romania. Both necropolises were in use from the time of the Roman withdrawal from Dacia until after the invasion of the Huns. The

enormous amounts of finds prevented, until recently, a proper study of the sites. However, with the application of Secanto, as well as the publication of several monographs, the gaps have begun to be filled. This presentation is devoted to the newest work done with Secanto on the pottery from the necropolis of Mihălăşeni. This site, consisting of 520 graves, contains many grave goods and a total of 1012 vessels. The different types of pottery are shown, and also the remarkable differences with the pottery found at the necropolis of Bârlad-Valea Seacă.

Ceramic profiler – a new tool for classifying of bulks of objects

(*Max Mehltretter, Fabian Langguth, Anne Sieverling, Michael Goesele, Franziska Lang*)

Despite legitimate and important discussions, classification remains a common procedure in the archaeological find processing. The aims of our project are (a) to find a solution for the time-consuming documentation of bulks of objects and (b) to develop a tool for the automated classification of finds. The manual documentation (e.g., via drawings) of bulks of objects is a great challenge due to the sheer amount of mostly fragmented artefacts. Therefore an in-the-field-digitisation is the first step of our goals. We present a case study that uses custom build computer vision and analysis techniques to record pottery fragments using manually taken photographs. Our system first performs a 3D reconstruction of the sherds using the robust Multimedia and Virtual Environment (MVE) reconstruction pipeline proposed by Fuhrmann et al. 2015. It then automatically extracts profile lines from the reconstructions, mimicking the manual drawing-based recording process. We compare the accuracy and variance of the automatically extracted profiles to profiles drawn by human experts and demonstrate that a comparable quality can be achieved. We further present initial results of an in-the-field capture session on a Greek excavation site, which we used as pilot study, and derive recommendations for efficient capture and suitable user interface design. Overall, we are able to demonstrate that the capture of bulks of objects as a part of the cultural heritage can be accelerated, and we also create new contents of the objects as the basis for subsequented automated classification.

Partitioning Archaeological Chaînes Opératoires (PACO) on R : how to deal with huge incomplete categorical datasets?

(*Marie Philippe*)

A chaîne opératoire is an operational sequence describing the manufacturing process by which raw material is transformed into an artefact. It includes several main actions (variables) for which several possibilities exist (values). For example, one can fashion a pottery by molding it, and finish the vessel by smoothing the wall. Theories in anthropology of techniques state that one can link technical traditions to potters' social memberships because they learn the craft in their own social group (cast, family, ethnic group...). Technical variants exist and can be related to ceramic functions. Settlements often reveal vast technical diversities. These schemas involve analysing a huge amount of categorical variables. Archaeological datasets are incomplete because of artefact preservation. Suitable mining and modeling tools are few. The function PACO for R attempts to solve these methodological problems. The guiding principle is based on Roux's handbook for ceramic technology (2016). It is an iterative partitioning process which ranks technical variables according to their standardisation. PACO organises data, reveals norms and variants, avoids gaps, clusters similar chaînes opératoires. A classification tree

(Breiman et al. 1984) then explains technical groups with external variables. This supervised classification algorithm finds rules guiding potters' behaviours, depending on spatial and chronological contexts, but also on aesthetics and functional features of the containers. The issues of this procedure are explained with Late Bronze Age ceramics from the Upper Rhine valley, but in the end it concerns every technological dataset, whatever the size, materials and cultural frame.

A Model-Based Statistical Classification Analysis for Karamattepe Arrowheads
(Tutku Tuncali Yaman)

Nif (Olympus) Excavation Project is carried out by Elif Tül Tulunay in the southeast of Nif Mountain located in the eastern province of İzmir, in the Western Anatolian Region of Turkey. Since 2006, total of 479 arrowheads made of iron and bronze have been found in Karamattepe, which is one of the most important sectors with its rich metal finds, especially arrowheads. In the excavation process, Daniş Baykan carried out first typological study related to arrowheads in 2012.Main aims of the study were dating and determining the purpose of producing different types in terms of material and shape. The motivation of typology studies was the lack of academic research especially on iron arrowheads since their restoration process is more troublous than bronze ones, thus, it is difficult to conduct dating. Primary goal of this study is by carrying out classification study through completing missing data with the Markov Chain Monte Carlo (MCMC) method,to determine whether analogical typology made in the beginning is parallel to the Multinomial Logit-based statistical classification analysis and to obtain a prediction model to be used in future excavation periods. Since results of parallel classification studies considered to be important elements of interdisciplinary approach of using quantitative classification methods in archaeology, this study is thought to be a crucial step to determine the typology and dating of iron arrowheads found in Western Anatolia.Our next step will be carrying out a more holistic typology study by evaluating the data obtained in other sites in the same region

Computer-aided Classification of British Isles Neolithic Group VI Axes from Photographic and Scanned Image Data
(Sally Elizabeth Taylor)

Neolithic axes sourced from Great Langdale in Cumbria are distributed across the British Isles in great numbers (2000+) and a variety of forms – complete polished axes, part-polished, reworked, substantial broken parts and fragments and unpolished roughouts. A satisfactory classification system for these artefacts has yet to be developed, particularly for the flaked roughout examples. Identification of clustered characteristics linked to chaîne opératoire and spatial data should add to our knowledge of how these intriguing objects were made and transported in the fourth millennium BC. To date, classification is based on subjective 'eye-balling' of the artefacts (guided by typological sketches) with some limited metrical data adding to the picture – but these impressionistic interpretations are at best not-comparable, and at worst lacking all together. Systematic large-scale analysis using standardised characteristics will enable meaningful interpretations of characteristics, clustering and relationships. The paper will explore the possibilities for using shape-recognition statistical modelling to inform the development of classifications, focusing on quantitative morphological and metrical attributes. The research project is at the initial stages of developing active contour capture of shape and outline data

from photographs and scanned drawings of the artefacts, to be analysed and classified using statistical software. The outcomes of the objective analyses will be compared with subjective classification development and assignment by experienced lithics specialists.

Using Data Mining techniques to evaluate Bronze Age metallic components
(Andrés Bustillo, Miguel Angel Arnaiz, Juan Jose Rodrigue)

The relationship between different human groups in the Bronze Age is an open issue where the lack of data makes necessary the use the most modern techniques to extract as much information as possible from the excavated settlements. This research proposes the use of Data Mining techniques, specially ensembles, to help in this task. In a first stage, 3 datasets are created, including 218 metal components found in more than 20 Bronze Age settlements dig in the Central Iberian Peninsula during the last 20 years and previously published by different research groups. The datasets include chemical analysis of the items obtained by X-Ray Fluorescence and UTM coordinates of the archaeological site where the item was found. As outputs, 3 different item´s characteristics were considered: its dating, the item typology and its belonging to a deposit or not. Two tasks were performed with different ensembles techniques: the automatic detection of outliners, or items that mismatch the average pattern of each settlement and Culture, and the measurement of each input's influence in the considered outputs. The first task is useful to detect transactions between human groups, while the second identifies the metal patterns that define the dating, typology and presence in a deposit of a metallic component. The results of the performed experiments identify the improvement in accuracy of ensembles compared with single classifiers and the improvements in automated extraction of information from such archaeological datasets in comparison with other techniques that have been performed as baselines as Principal Components Analysis.

Multispectral image analysis applied to identification of archaeological buried remains
(Andrea Gennaro)

Automated and semi-automated image analysis approaches have made their way into archaeological applications, but early attemps have been mainly focused on monitoring and documentation of cultural heritage. This study examines semi-automated methods to identification of archaeological features through a comparison of pixel-based and object-oriented data classification of multispectral image. Several experiments have been carried out on high-resolution imagery (WorldView-2) of the North-West of Etna (Sicily), the European's highest volcano, where a huge variety of settlements can be found from Prehistoric to Medieval times. The methodology of both pixel-based and object-based data classification is described and discussed over to specific case-study. The different nature of the two dataset, with distinct characteristics in archeological and enviromental side, provides usefull results in order to determine robustness and wickness of approaches here presented. The obtained data have been exported and managed in a GIS environment and compared with visual interpretations and analyzed in terms of their accuracy. Finally, field data was collected in the study area to control the features of archaeological buried remains and to serve as a reference for the accuracy assessment.

Space, typology and mobility: using multivariate clustering technique to explore spatial patterning in prehistoric Thrace

(Denitsa Nenova)

The focus of this paper is laid on a method employed for tracing pottery production and distribution patterns across and within regions. The case study presented here is based on a classification technique, which enforces spatial variability upon morphological, functional and stylistic criteria, which conventionally drive ceramic typology. A formal statistical approach is applied to construct 'relative risk' raster surfaces, identifying the extent to which different ceramic types are spatially correlated and whether their combined distribution forms clusters of preferred pottery shapes and types. As a second step, the cumulative distribution of different, seemingly unrelated pottery types, was examined, in order to test wider patterns, beyond the plotting of single-type distributions. This approach is more experimental but extends the idea of univariate relative risk surfaces to a multivariate case, taking the ratio of the kernel density of the observed cases to the population at risk. Furthermore, an unsupervised clustering technique, identifying potential hidden structures within the data regardless of its categorisation, is applied on a stack of relative-risk bitmaps of all analyzed pottery types. The strength of this approach lies within the weight assessment of each variable according to its dependency on other variables. Thereafter, regional zoning suggested by the distribution of specific site-types is compared with the observed spatial variability of the whole pottery repertoire. As a result, a vibrant picture of intra-regional diversity highlights the study area on the map of general inter-regional interactions and mobility in the midst of the second millennium BC.

Matrix in the Network: assemblage co-expression networks to unlock meaning in stratigraphic matrices

(James Scott Cardinal)

Stratigraphic, intra-site co-expression networks of artifacts provide a means to assess both the depositional contexts and the significance of differential assemblage patterns. In this paper, I will describe a set of methods that address both compositional and spatial natures of site assemblages in order to parse the information from excavated components into interpretable sub-assemblages. The results of these methods allow not only an automated consociation of excavated components with which to reconstruct the depositional stratigraphic matrix, but also to consolidate the association networks of artifacts into interpretable sub-assemblages.

Session 25
Do we have a heading? Ah! A heading. Set sail in a… uh… for Mobile GIS direction!

The recent contributions of Mobile GIS in the study of flint mining. On the example of Orońsko Flint Mines Project (Poland)

(Katarzyna Kerneder-Gubała, Sylwia Buławka, Nazarij Buławka)

Orońsko mining region it is a place where the famous Orońsko 2 site is located, which is considered being one of the oldest (Late Paleolithic) flint mines in Europe. It is located at the edge of the "chocolate flint" outcrops in the Holy Cross Mountains in Poland. The Orońsko Commune is vast landscape with a dense scatters of sites related to mining, processing of the "chocolate flint" and settlement activities. The main goals of the research project* are a reconstruction of the spatial organization and functioning of prehistoric communities, and in this way, a development of a model of the functioning of the prehistoric flint mining systems specially during the Paleolithic and Mesolithic, till the Early Bronze Age. Thus, the studies of this region require appropriate tool-set that could include all available field survey data and would be able to decipher the various activities. In the research, we integrated raster and vector datasets such as archival and cartographic data (topographic, geological, hydro-graphic maps), LIDAR, high-resolution aerial and satellite imagery as a tool to study the mining activities and related features. Orońsko Flint Mines Project was also a test era of various Open Source applications and Mobile GIS, which was the main research tool during field surveys. This paper concerns the efficiency of field survey with use Mobile Mapper 20 together with hand-held GPS and integration of the collected data into the database in QGIS. *Project Exploitation and processing of chocolate flint during Paleolithic and Mesolithic in the North-Western part of its deposits based on non-invasive archeological and geophysical research and test-trenches (UMO-2015/17/N/HS3/01279) is financed by National Science Centre, Poland

No more endless nights filling in attributes - a web and a mobile app for GIS-based field surveys in Bulgaria

(Nadezhda Kecheva, Todor Branzov, Lyubomir Nedyalkov)

"Archaeological map of Bulgaria" is a legally established national archaeological information system containing data for archaeological sites on the territory of Bulgaria. Its first version was developed in 1990 with the purpose of gathering different kinds of archaeological site-based data from both extensive and systematic intensive field surveys. The next major step forward was the introduction of standardised methods for collecting data on the field using mobile GIS devices with GNSS receivers combined with paper forms. Desktop work included filling in attributes from these paper forms into GIS software, a time-consuming process susceptible to mistakes. The latest major version of "Archaeological map of Bulgaria" is a complete redesign of the information system and the processes of field survey. The goal of the system design is to facilitate data collection on the field in a standardised and reliable way, with easy to obtain and use devices, leading to a simplified workflow and significantly reducing desktop work for Bulgarian archaeologists. A completely new system architecture had to be created, including database redesign, REST API, map server, web and mobile applications. The system is currently in phase of development with prototypes tested in operational environment. The paper focuses on the conceptual architecture and process transformation, complemented with some feedback from prototype testing.

Mobile GIS in primeval woodland landscape. Case study of the Białowieża Forest surface survey

(*Kamil Niedziółka, Michał Jakubczak, Michał Szubski, Przemysław Urbańczyk, Joanna Wawrzeniuk*)

Białowieża Forest is the largest consistent forested area in Poland. In total, it occupies nearly 1,500 km2 (together with the Belarussian part). Executed in different ways protection of this woodland lasts continuously since the sixteenth century resulting in preservation of the last primeval forest in the European Plain. On the one hand, such situation lead to unique opportunity to observe and investigate past landscape. On the other hand forest cover made this area almost inaccessible for archaeologists. However the development of airborne laser scanning (ALS) allowed to change this situation. Launched in January 2017 project "Cultural and natural heritage of the Białowieża Forest" aims at comprehensive and interdisciplinary examination of archaeological resources of this area. The plan is to map all traces of potential anthropogenic sites of its own terrain form using ALS. During the later stage all of them will be verified in the field. At that moment usage of GPS and mobile GIS will be crucial, although because of the presence of dense forest environment this kind of field prospection is quite different than "conventional" surface survey. The aim of this paper is to present the main problems and challenges linked with the usage of GPS and mobile GIS in this difficult conditions. Special attention will be given to the question of precision of the measurements in the field and limited accessibility to various areas in the investigated zone. All of the examples will be based on the first results of the project.

Evaluating QField as a Mobile GIS Solution for Archaeological Survey

(*Adam Pažout*)

The recent developments in the field of geospatial 'free and open source software' (F/OSS) are reflected in its more widespread use among archaeologist. The article presents practical application of one of these F/OSS programs, namely QField, for archaeologists. QField is mobile version of desktop GIS program QGIS, customized for Android platform. The salvage survey in the northern Israel at the site of Khirbet es-Swade/Maʾagar Snir and survey of Hellenistic and Roman fortifications in the southern Golan Heights provide case-studies for the utilization of the program. The program's performance is evaluated with regard to 1) preparation and pre-processing of the data; 2) data collection and fieldwork; and 3) data export and post-processing.

Mobile GIS for Large Scale Excavations

(*Weronika Winiarska, Łukasz Miszk*)

Taking into account the variety of work carried out in archaeology the question arises whether mobile GIS is a "perfect tool" that will work under all conditions and in every position? In the proposed paper we would like to present our view at mobile GIS use from the perspective of the large scale excavations conducted at the site of the Paphos Agora in Cyprus. Since 2013 the Paphos Agora Project has included the development of database with the use of the ArcGIS software. During the excavation work in the 2017 season a Survey123 for ArcGIS was tested which allowed to collect data on all the layers explored and gather them on the web server. Its introduction was supposed to eliminate the step of transferring

information from paper context cards to a database and significantly speed up the documentation process. In the presentation special attention will be brought to the methodology we adopted - from developing forms, through the fieldwork to the processing of results. We will present both the strengths and weaknesses of the scheme we have developed so far, as well as the problems we encountered during our work. In addition, we will try to answer the question of whether mobile applications are a good solution in the context of large scale excavation? Is it not better to stay with traditional paper solutions? Or maybe you have to look further among other "tailor-made" tools available?

Do we have a heading for hard questions about mobile GIS in archaeology?

(Julia M. Chyla)

Currently, a number of GIS applications are available for download for phones or tablets. With the help of these, professionals and non-professionals both can start to collect data connected to archaeology/ history and can visualise them i.e. as story-telling maps of historical neighbourhood areas. But what will happen when a professional archaeologist decides to work with such an application? Will it change his or her work flow process of preparing and conducting the field prospection? It seems that mobile application for collecting data will revolutionize archaeological survey as it is a cheap (?), easy (?) and cost-efficient method (?). During the summer of 2017, two mobile GIS applications (Collector and Survey123) were used for field prospection. The research was done on two archaeological sites in the area of Castillo de Huarmey, Peru. The application's preparation for data collection was arranged by a GIS-archaeologist, but the field work was done by seven students (from different faculties). The goal of this paper is to discuss the process of preparation of applications, data collection in the field, results of survey and the presentation of data. I would like to present the positive and negative side of applications and I would also like to discuss the question of: should archaeologists use this methods and if yes, how can it change a classic field prospection and what are the biggest changes in the work flow that we should watch out for?

Session 26
Sensory GIS: towards a deeper engagement?

Bringing Sound into the Picture: Experiencing Ancient Maya Landscapes with GIS & 3D Modeling

(Graham Goodwin, Heather Richards-Rissetto, Kristy Primeau, David Witt)

For the past few decades, researchers have been applying Geographic Information Systems (GIS) to examine the roles of visibility and movement in archaeological landscapes. However, few studies have investigated the role sound potentially played in structuring experience in ancient landscapes. To begin to fill this gap, this paper builds on our initial investigations into Sensory GIS to develop new geospatial and virtual reality (VR) methods to examine ancient acoustics in conjunction with vision. For the ancient Maya, sight and sound worked in concert to create synesthetic experiences that influenced daily life and shaped society. To explore this sensory interaction, we apply a combination of GIS

modeling: viewshed analysis, soundshed analysis, and an Urban Digital Elevation Model (Urban DEM) generated from airborne LiDAR and 3D modeling data. This approach provides an opportunity to perform computational analysis on a simulated ancient landscape rather than the contemporary landscape. To allow a deeper engagement with Copan's past landscape, we then use these GIS-derived computational data to design a VR experience that combines sound and vision.

The structure of experience: modelling landscape visual quality
(Zoran Čučković)

For all its individual, social and cultural idiosyncrasies, the visual experience of a landscape is first and foremost shaped by the topography. Each landscape has its inherent visual structure: flat horizons on the coastline or secluded ambience of mountain valleys. Quantitative approaches for the characterisation of the overall visual structure of (past) landscapes have received much attention in the archaeological community, but the topic remains much under-researched. Perhaps the most important cause of this situation is the general reliance of proposed approaches on simple and computationally inefficient algorithms available in common GIS software. Even a modestly sized dataset requires days or even weeks of calculation on a personal PC. In order to overcome these problems, a novel algorithm was developed, specifically adapted for high volume computation of the terrain visibility indices. The analysis time is significantly reduced, bringing the approach within the reach of computing power of a typical PC. In addition, a special attention will be paid to modelling coherent visual zones, inspired by the "landscape room" approach of Gansum, Jerpåssen and Keller (1997). Such breaking down of the landscape into visual zones can be attained through modelling intervisibility networks and their subsequent partition into tightly connected subgroups. The potential of the method will be demonstrated on a sample of Bronze and Iron Age funerary structures in the area between the Seine and Yonne rivers in NW France. It will be shown that the placement of these structures reveals a sensibility for the overall visual structure of the landscape.

Visual perception and landscape: a case study about the cities in roman Hispania
(Mar Zamora Merchán)

Territorial management in roman provinces was a complex matter, and the city played a key role. When the Romans arrived to the Iberian Peninsula, different regions on it had different degree of urbanization. When choosing the location for cities several options were assessed (the use of some previous pre-roman sites; new cities where no settlement was before; or cities located next to the local settlement). This fact affected the resulting landscape view. This paper deals with the visual perception of ancient cities in the context of Roman Hispania. It is a work in progress, where the final aim is to assess the importance of roman cities as territorial markers in the landscape view, and to approach the picture of ancient cities seen from its surrounding territory, considering the visual perception of landscape as part of the cognitive experience of inhabitants, as well as part of the cultural heritage. The main question to answer in this paper is how visible the cities were when seen from different viewpoints (in particular, from near roads) located in its surrounding landscape, and at wide distances. Computer applications mainly used in this work are GIS (ArcGIS) visibility tools, in particular those related to cumulative viewshed analysis. Different visibility parameters and tools are considered in order to approach de third dimension. The cartographic data employed for analysis (DTMs, among

others) come from the National Geographic Institute of Spain (IGN), which are available through the National Centre of Geographic Information (CNIG) website.

Session 27
Map management and Webgis applications for archaeological data base solutions

Open source solutions for Norwegian Stone Age, Chaos theory, and the ADED-project 2018-2020
(*Espen Uleberg, Mieko Matsumoto*)

This paper will use open source solutions from the MUSIT archaeology database in relation to a study applying elements from Chaos theory. It will explore changes in Norwegian Stone Age site distributions in the diverse landscape in South-Eastern Norway. The MUSIT database system is developed by the five university museums in Norway, and has until now concentrated on artefacts that are published online for free use (unimus.no/arkeologi/forskning). Excavation data will be included through a three-year project, ADED (Archaeological Digital Excavation Documentation) funded by the Norwegian Research Council. ADED will develop a system for aggregation and open data solutions for large excavation data, facilitating queries and data extraction across single excavation projects. The present project analyse sites and georeferenced artefacts, all from the MUSIT database, combining them with environmental data related to fluctuating forest and tree limits. The archaeological material can be seen as a Poincaré set created through accumulated activities in the landscape. Results of excavations and surveys are assumed to reflect human activities during the Stone Age and Stone using period. These activities took place in a multidimensional space and over multiple periods. Such data can be studied as a projection onto a hyperplane, which can indicate how casual the choice of place might have been. A study of the Poincaré set will describe fluctuations of human movements through occasionally registered activities through time in the landscape. The paper also demonstrates how ADED's online excavation data will make such analyses more feasible in the future.

Data Aggregation and Visualisation in archaeometallurgy
(*Laura Perucchetti, Peter Bray*)

FLAME is an ERC project that is studying the use and movement of metal in the III-II millennium B.C.. Within this project, a geodatabase with archaeological and archaeometric information about metal objects was built using PostGIS. Traditionally, archaeometallurgical projects have geographically visualised information through distribution maps of the find spots for different metal compositions or types of objects, but within the FLAME project we want to explore, and present here, other possibilities. One useful approach is ubiquity analysis: it represents the percentage of presence of a 'metal type' with respect to the entire assemblage. The total assemblage of metal items can be spatially subdivided to appreciate variation of the ubiquity. This subdivision can be represented as a series of regular polygons, or with irregular shapes that reflect the topography of the territory (e.g. the river basins). But the spatial subdivision can also take into account how data are unevenly distributed. A specifically made algorithm addresses this issue, creating a series of irregular polygons that represent

the "natural aggregation" of objects. A further level of analysis can be the creation of continuous surfaces using data available from the distribution of artefacts or the variation of ubiquity in space. The algorithms are written using python, making them compatible to different GIS packages. Overall there is obviously not one "best way" to represent our data. We would like to propose this paper as an encouragement for further discussion about the visualization of archaeometric data.

Sometimes a map is not enough: challenges and lessons learned from developing the dataARC data discovery interface

(*Chris Angel, Adam Brin, Jackson David Cothren, Rachel Opitz, Colleen Strawhacker, John Morgan Wilson, Tim Sexton*)

The National Science Foundation-funded dataARC discovery tool aims to allow for multidisciplinary data sharing and discovery across archaeology, historic textual sources, and the environmental sciences to address questions on the long-term human ecodynamics of the North Atlantic. A conventional spatial approach with the application of a standard web map was inadequate in providing the user-researcher with the necessary pipelines that returned useful results while encouraging interdisciplinary exploration. The tool takes a unique approach combining spatial, temporal, and conceptual web-based framework that enables researchers to address multiple forms of inquiry without overwhelming the interface. The three components are directly linked so, filters applied to one dynamically update the others. By displaying data in new ways, it encourages users to explore and identify new data sources or create new associations between their datasets and data from other disciplines.The interface leverages Postgres, MongoDB, and SOLR to ingest, map, and index data according to "combinators." Data owners and subject specialists apply combinators upon their own data and may be used in simple or complex queries to map subsets of data to concepts or topics within the dataARC tool. This paper will survey the efforts and challenges of the backend and front-end design choices and challenges around this innovative effort to ensure data are more easily understood by an interdisciplinary audience.

CLIMA: A webGIS platform for risk assessment in cultural heritage

Stefano De Angeli, Fabiana Battistin, Maria Cristina Salvi, Di Iorio Alessio, Branka Cuca, Marios Tzouvaras, Athos Agapiou, Martin, Rudbeck Jepsen, Clare Wilson

This paper presents the CLIMA project webGIS platform, developed for cultural landscape risk identification, management and assessment, based on open-source geospatial software and technologies. This has been made possible combining advanced remote sensing technologies with GIS application for mapping and long term monitoring of archaeological Cultural Heritage (CH) in order to identify changes due to environmental and anthropogenic pressures.

CLIMA platform is characterized by the use of innovative integration of data processing chains using different Earth Observation methods (optical, multispectral and SAR) with ground-based remote sensing data, both traditional (magnetometry, GPR etc.) and newly developed (mobile gamma spectrometry). Earth Observation processing chains have addressed the major soil-oriented risks

affecting CH: soil erosion, lateral and vertical soil disturbance, land movement/structural stability and land use/cover change. This was made possible by a previous mapping and detection of buried and exposed archaeological structures. The aim of the presented tool is to assist the cultural heritage preservation authorities in analyzing the impacts and consequences of the specific hazard events in a considered archaeological area, providing an essential input, in the form of risk maps, to the decision making process in the selection of risk management strategies by responsible authorities. The platform will represent, for authorities in charge to CH preservation, a systematic, effective and affordable tool to monitor the degradation process and to enable preventive maintenance

The Arches Cultural Heritage Data Management Platform: A flexible and expandable open source system for cultural heritage inventories and beyond
(Annabel Lee Enriquez, Alison Dalgity, Dennis Wuthrich)

Arches began as a project by the Getty Conservation Institute and World Monuments Fund to create geospatially-enabled immovable heritage inventory software for cultural heritage organizations worldwide. In order to serve that goal and solve the problems often encountered by these organizations, one of the project's design principles was that the system be as flexible and customizable as possible in order to adapt to different use cases worldwide. With the recent release of Arches Version 4, the platform has adopted a more modular system architecture with new features that make customization more accessible and new uses possible. For example, Arches v4 features an embedded map and tile server that gives organizations the ability to directly host their own map and satellite imagery tiles within Arches. The Arches Designer in Version 4 enables the dynamic creation of database schema using the platform's interface. Specifically, the system's data model can be defined with semantic metadata encoded (using an ontology, such as the CIDOC CRM), and data entry forms and reports can be specified based on that data model. In addition, other existing Arches features have been enhanced such as the geospatial and search interfaces and the Reference Data Manager, for managing controlled vocabularies. This paper will explore these features and as a result, how Arches v4 can accommodate archaeological datasets and also integrate them with other types of cultural heritage data.

Free and open source geospatial software for re-using archaeology open data
(Thierry Chevallier)

Recent years have seen a movement towards open access and open data in Archaeology (e.g. the ARIADNE infrastructure, Archaeology Linked Open Data, etc.), and this movement offers new possibilities of innovative exchanges between archaeologists and computer scientists in general, and GIS experts in particular. At the same time, initiatives at the international level foster closer interactions between actors of the geospatial communities, like the FOSS4G conference (Free and Open Source Software for Geospatial). The FOSS4G conference aims at bringing open source GIS users and developers together, putting forth the latest GIS technology, presenting state-of-the-art webmapping solutions, and encourageing software contribution from the participants. In this presentation, a web GIS engineer proposes an overview of the techniques presented at the last FOSS4G edition and how they can be applied to archaeological open datasets, selected according to their reuse potential and impact level on the public. Beyond the classics of open source GIS (QGIS, GDAL or postGIS), the presentation will focus on state-of-the-art WebGL map viewers and cloud-based

solutions for performing geospatial analysis on data. In addition the issue of interoperability of geo-referenced datasets will be addressed, thanks to technological insights from the last INSPIRE conference held in Strasbourg.

Sharing spatial data with a 3D component as a collaborative and dissemination tool for archaeology: conceptual challenges and technical issues

(*Damien Vurpillot, Ernest Chiarello, Laure Nuninger, Clément Laplaige, Xavier Rodier*)

Due to INSPIRE directive, various spatial data infrastructure (SDI) were developed to support research activities. In practice, these tools remain underexploited by researcher for many reasons. First, their use is time-consuming and researchers usually consider that they provide no immediate benefits. Second, their use is often complex and needs a substantial investment for researchers who have a limited expertise in spatial data. Finally, often based on 2D GIS environment, they do not provide an adequate tool for collaborative research in archaeology. From this experience, an interdisciplinary team designed and developed an SDI based on GeOrchestra, synchronized with a share app (owncloud) and coupled to visualization tools (Lizmap, Potree and Cesium). This paper will present the conceptual framework of our SDI and its advantages for the targeted audience. We will then focus on the introduction of open source solutions designed to share and visualize spatial datasets in 3D, relying on the experience gathered from the Aspectus project. The multimodal and multiscalar protocol, from landscape to objects, will be exposed in details. To this end, we will be presenting a few case study examples from France (Chambord, Bibracte, Besançon and Salins les Bains) in order to address researchers concerns about SDI and to discuss technical challenges toward the integration of 3D tools in our SDI platform.

A Spatial Data Infrastructure for Megalithic Sites in Southwest Iberian Peninsula

(*Ivo Figueiras Santos*)

Among the symbols of the first agro-pastoral communities of the South-West of the Iberian Peninsula, Megalithic sites are probably the best known and the one that marks today's landscape in a more easily recognizable way. The megalithic phenomenon is homogeneous in its overall reading, however, the particularities intrinsic to each region, to each monument, make it heterogeneous, independently of the different monumentalities associated with each of the archaeological sites. This wide cultural spectrum hinders the generalized understanding of the phenomenon and encourages the interpretation of cultural clusters as isolated occurrences. Thus reflecting the need for a dynamic "repository" that promotes comparison between concepts and the overcoming of geographical limits, while promoting their preservation and dissemination as an agent of promotion of cultural tourism. This project, although ambitious, does not intend to solve all the issues related to the study of megalithic sites, but rather to construct an auxiliary tool for its study and dissemination. We intend to show as the methodology, initiated by the exhaustive collection of concepts, allows the fusion of structured and unstructured data, the automatic re-classification of multiple representations of the phenomenon according to international standards and prepared so that it is possible to be maintained by the scientific community. The database supports a Spatial Data Infrastructure (SDI) that supports the registering of new users and the visualization, discovery and search of metadata built according to

international standards (OGC, CIDOC-CRM). Each record has the possibility of incorporating 3D models, accessible through a 3DHOP based viewer.

Session 28
Cities of Data: computational and quantitative advances to urban research

Using Percolation Analysis for investigating the distribution of Hillforts in Britain and Ireland
(*Simon Maddison*)

Although amongst the most iconic and clearly visible of prehistoric remains in Britain, Hillforts are generally poorly investigated and understood. A definitive 'Atlas of Iron Age Hillforts in Britain and Ireland' out of Oxford and Edinburgh has made an important step in changing this situation. There are some 2900 confirmed hillfort sites in the Atlas, and this database has been used to establish hypotheses relating to the spatial distribution of Hillforts in Britain and Ireland, using modern spatial analysis and Geographical Information Systems (GIS) methods and tools. In particular analysis for the whole of both Britain and Ireland has focused on identifying 'natural' groupings of Hillforts using a technique established in geography called Percolation Analysis, based simply on the Euclidean distance between sites. This has produced some very interesting results showing clusters for different distance thresholds that have distinct regional characteristics in Britain, and a quite different one for Ireland. Further analysis has led to the identification of possible territorial and hierarchical relationships between Hillforts within selected clusters, based on the sites' enclosed area, and these are explored for possible explanations, further mining the Atlas database. This paper will present and discuss these initial results, and the potential for Percolation Analysis for further research.

The street network of the Roman town of Augusta Raurica – reviewed with the help of space syntax
(*Sven Straumann, Urs Brombach, Hans Sütterlin*)

The Roman colonial town of Augusta Raurica (Switzerland) has an extensive street network based on an orthogonal grid. However this network is not yet fully excavated. Therefore many reconstructions and additions originate from archaeological assumptions. To evaluate the town's transport connections more objectively we have used space syntax analysis to visualize scenarios with the aim of questioning the archaeological theses with a critical eye. In order to do this, the study concentrates on the street network during the town's heyday around 200 AD. Besides the mentioned plausibility check of consisting road course reconstructions, space syntax allows exciting observations relative to the urbanism of the town complex. The presented paper provides an insight into the current research project that uses space syntax analysis for the first time in the research field of Augusta Raurica.

Site definition possibilities: Features excavated along a transect

(Sophie Charlotte Schmidt)

Linear excavation projects as for street or pipeline construction offer a glimpse into the archaeological record for long but slim areas, cutting through past environments, burial grounds and settlements. Traditionally these continuous excavations have been divided into sites by Heritage Management for excavation organisation and individual analyses. In this talk I take the excavations along a transect as a sample of the archaeological record in the area and explore the possibility of defining settlements and typical settlement sizes using the features along the whole of the transect disregarding Heritage Management's site definitions. Settlement sizes are relevant for any further research question regarding settlement structure and hierarchy. There is a long-standing discussion on site and non- or off-site in survey archaeology, upon which this talk draws, but instead of using finds as units of observation, excavated features are utilised. The data base consists of features along a 13 km long street of mostly 40 m width near the city Köthen in Saxony-Anhalt. They date from the middle Neolithic to the early Iron Age. As typical cluster analysis algorithms as the F-, G- or Ripley's K-functions are heavily influenced by edge effects, simple distance measurements between all features of one period are taken as a proxy for clustering. Kernel density estimations and cumulative distributions of these distance values compared to values generated by random points (CSR) are used to gain an understanding of the settlement structures of the different periods. Statistical analyses have been realized with R.

From Urban Data to Urban Movement: The application of computational approaches for studying ritual movement at Ostia

(Katherine A. Crawford)

The study of urban pedestrian movement has been largely restricted to general research into a city's movement economy. Ostia, Rome's ancient port, offers a unique opportunity to a study movement within a site that is both extensively excavated and that has a well-defined street network. Methods like space syntax have provided insight into the general movement potential of the city as structured through its street network. However, when questioning how ritual movement can be studied, present approaches are insufficient. Research addressing ritual movement at Ostia have followed certain assumptions surrounding what streets this movement would have occurred along without questioning the function and purpose of these rituals. This paper presents a novel approach that looks at how the built environment and urban activity structured ritual movement by applying urban network analysis and agent-based modelling methodologies. Rather than attempting to accurately reconstruct specific movement routes, this method assesses how Ostia's urban dynamics helped to structure a specific type of movement. These results provide insight into Ostia's larger ritual landscape as well as presenting a way to move research beyond generic pedestrian based studies of an ancient cityscape.

Assessing the value of minimal computational models for the study of long term settlement evolution: the case study of the Pontine region (Central Italy) from the Archaic to mid Imperial period (c. 600 B.C. – A.D. 250)

(*Eleftheria Paliou, Tymon C. A. De Haas*)

Spatial interaction models have been used in recent years to explore long term settlement evolution, and in particular, the emergence of regional central places, often having a valuable contribution to archaeological interpretations. The validation of these models has so far mainly relied on comparisons to limited evidence on settlement sizes and proxy data (artefacts distributions, textual sources) suggesting central place functions. In this paper we use an entropy maximizing spatial interaction model to examine settlement evolution in the Pontine region (central Italy) between the Archaic and mid Imperial period (c. 600 B.C. – A.D. 250) with the aim to explore whether such a minimal model would remain relevant and useful when employed to an unusually well contextualised and rich (yet still patchy) archaeological record. The results of the model are here contrasted and evaluated with reference to a variety of evidence on demographic growth and decline, changing infrastructural networks and production and consumption patterns. In particular, we assess the suitability of the model to make useful predictions on the emergence of central places in three subsequent periods that are characterised by very different patterns of urbanisation, rural economies and socio-political contexts. In turn, different notions of economic, administrative and religious centrality that we put forward are evaluated in the light of the model results.

The urban past through the lens of fractals and visibility

(*Hanna Stöger, Lars Schaarman*)

The proposed paper introduces a combined approach of fractal and visibility graph analysis (VGA), applied to the past urban environment of Ostia, Rome's imperial port-city. Ostia's urban quarters of the sanctuary of Hercules serve as a case study. The paper argues and seeks to demonstrate that the urban experience is largely linked to the geometry of the physical and spatial characteristics of the city. While fractal analysis has been used in modern urban environments, and to a limited extend in archaeological intra-site studies, it has not been applied to past cities. Fractal analysis views cities as structures that resemble a mathematical fractal. Fractals are self-similar, scale invariant objects. Fractal geometry is seen in this research as having an effect on the human mind, and therefore on the way a city is experienced. Visibility graph analysis uses the city's two or three-dimensional plan to analyse its visual integration. Spaces with the highest inter-visibility are those spaces which attract most movement, and are therefore the places were social activities occur. Other fractal properties of Ostia are less easily quantifiable, these concern the different scales that reside in the city's urban form. The small scales of the city (sidewalks and street furniture) help pedestrians not to feel alienated by the larger scaled elements (big block size and major access roads).

Reconstruction without validation? Limitations of computational and quantitative settlement analysis - Hellenistic and Roman Nea Paphos, an interdisciplinary case study

(*Nikola Babucic, Łukasz Miszk, Sebastian Adlung, Wojciech Ostrowski, Martina Seifert, Weronika Winiarska*)

The Paphos Agora Project works out interdisciplinary research by implementing and combining a wide range of scientific disciplines to enable the reconstruction of the economic infrastructure of ancient Nea Paphos, the capital of Hellenistic-Roman Cyprus. To understand the urban layout and to analyze varying specific features, data from the following methods and tools were achieved: Data query and analysis of archive images, generation and investigation of remote sensing data (satellite and aerial imagery, digital surface model), geophysical prospections (magnetometry and GPR) as well as geoarchaeological surveys of the city and regional landscape (observation of the influence of fluvial erosion on the landscape, drillings etc.). A series of test excavations allow to confirm previous interpretation, and a preliminary city map including street grids, public buildings and private houses as well as water supply and disposal was drawn up. In accordance with the recent discussion in spatial analysis methodology, this approach provides a high quality database for further studies. On the basis of concise case studies the paper illustrates the problems arising in case of interpreting such data not confirmed by archaeological excavations. Analytical methods in settlement analysis will be discussed critically with regard to the attempt of transferring data to explain a cityscape resulting from 700 years of settlement activity.

Cognitive Mapping in Ancient Pompeii

(*David Fredrick, Rhodora Vennarucci*)

Orthodox approaches to private space in Pompeii have been bound to an idealized house form and an associated room nomenclature drawn from elite texts. While more recent scholarship on Roman urbanism has helped to dispel traditional 19th-century assumptions (e.g. Allison 2005, Poehler 2016, van Nes 2009, Weilguni 2011), a holistic approach to spatial cognition and behavior that integrates qualitative and quantitative spatial and visual data is still lacking. Initiated in 2016 by an interdisciplinary team at the University of Arkansas, CMAP (Cognitive Mapping in Ancient Pompeii) addresses this lacuna through four interwoven methodologies: 1) the use of network topology and visual integration to categorize space, rather than the traditional room names; 2) the use of machine learning to track compositional patterns in decoration and quantify visual complexity; 3) the adaptation of AI (Artificial Intelligence) algorithms from video games to construct predictive models for human movement; 4) capture of player data as human subjects complete a series of navigational challenges set within 3D Unity models of structures from Pompeii. Player data includes movement and eye-tracking heatmaps, speed and accuracy in cognitive mapping between plans that are similar (but far from identical), and heatmaps of neurological responses during navigation (recorded using Emotiv's Epoc+ EEG headset). Currently, this four-fold approach is being deployed and assessed for six houses from Pompeii, of varying size and plan, but will be extended to include additional houses, shops, and streetscapes. This paper will share the results of applying these methodologies to the Houses of the Prince of Naples, the Ara Massima, and Octavius Quartio, focusing on the interaction of network topology, visual integration, and decorative complexity in shaping patterns of movement in predictable ways.

Reading Rubbish: modelling diachronic change at Tell Sabi Abyad, Syria

(*Victor Klinkenberg*)

Reconstructing activities at a stratified site invariably includes a discussion of the constant diachronic change in the settlement. A case in point is the Late Bronze Age settlement at Tell Sabi Abyad, Syria. Here, a continuing reappropriation of space during the life span of the settlement presents a challenge for a functional analysis of the buildings and courtyards. Similarly, considering that the function of individual buildings was in constant flux, how can the settlement as a whole be characterized per phase or period? In this paper, using 3D GIS and event-based chronologies for individual rooms, I will discuss a method for the analysis and presentation of the fluctuating use of space. The results aid in the advancement beyond simplistic settlement chronologies of distinct periods, towards an appreciation of overlapping timescales within the life time of a settlement.

Connecting Iron Age Neighborhoods: An Urban Case study from Kerkenes

(*Tuna Kalayci, Dominique Langis-Barsetti, Scott Branting*)

Many studies have investigated either ancient urbanism or households, but neighborhoods, composed of many households and nested within cities remain rather poorly understood and under-theorized as a socio-historical phenomenon. Yet neighborhoods, as both physical and social spaces, bridge the scholarly gap between the household where the paradigmatic separation between urban elements are optimal, and thus, open to modeling. Kerkenes, a massive Iron Age city in Central Anatolia provides an excellent research environment for the study of ancient neighborhoods due to its relatively short occupation, sudden destruction, astonishing preservation conditions, and large scale geophysical prospection coverage. In particular, almost all of the city is prospected with a magnetometer survey and resistivity data provide further details of built environments. To exploit this archaeological setting, the study first builds a set of shape/morphometric parameters to search for clusters -as possible indicators of neighborhoods. Next, these clusters are further investigated with the incorporation of information about types of buildings in each urban block. Finally, a series of hypothetical connections are proposed between similar urban blocks as a basic understanding of social networks within the city.

Session 29
Digital Innovation & Experimentation in Archaeology & Cultural Heritage Collections

Democratising Access to Museum Collections & Using Digital Innovation to Explore Archaeological Data

(*Jennifer Wexler, Daniel Pett, Elizabeth Galvin*)

How can we use digital technology to democratise access to archaeological and museum collections? Increasingly archaeological projects and heritage institutions are using digital technology to both disseminate knowledge and connect with researchers and audiences. Over the last four year the British

Museum has been experimenting with a series of innovative digital tools, including 3D modeling, 3D printing, crowd-sourcing, and interactive AR/VR experiences, to order to develop new and inventive ways of engaging with the collections, archival, and archaeological data. This paper will examine and review the achievements as well as the technical challenges of various recent digital heritage projects connected to the British Museum (MicroPasts, African Rock Art Image Project, Global Perspectives) and how they offer lessons and propositions for running major digital heritage projects in a museum environment, and how we can use digital technology to ensure ongoing, global open access to the archives and museum collections.

Virtual Reality and Storytelling for Viking Archaeology

(*Gareth Beale, Nicole Beale*)

The emergence and increasing use of mixed reality and interactive media for cultural heritage has opened the door to new forms of interpretation and visitor experience. However, the development of compelling experiences that are sufficiently robust for use in a museum setting can be challenging. From 19th May to 5th November 2017 VikingVR, a bespoke VR installation designed by the University of York DiNAR project and York Museums Trust was installed at the Yorkshire Museum. VikingVR formed part of the York Museums Trust/British Museum exhibition "Viking: Rediscover the Legend" and was based on research into the winter camp of the Viking Great Army at Torksey in Lincolnshire, UK (Hadley et al 2016). VikingVR is an interdisciplinary and multi-institutional project which seeks to experimentally engage with the use of VR in a museum setting and to address some of the fundamental design challenges for immersive digital experiences. The project champions the use of VR within the museums sector and examines the potential for VR to present archaeological findings to public audiences whilst also addressing the strategic needs of the museum. C.82,000 visitors engaged with VikingVR and qualitative and quantitative methods of evaluation have been used to establish how far the VR has supported the agenda for both the museum, researchers, and visitors. For the first time, this paper will present the initial findings of this proof of concept project. Hadley, D.M., Richards, J.D., 2016. THE WINTER CAMP OF THE VIKING GREAT ARMY, ad 872–3, TORKSEY, LINCOLNSHIRE. The Antiquaries Journal, 96, pp.23–67.

Digital archaeology in museums: are we getting closer to matter?

(*Monika Stobiecka*)

The digital turn has totally changed the common image of archaeological exhibitions. Artifacts are now being supplemented, restored and reconstructed thanks to tools from shimmering mediascape. These digital supplements, however, are often seen as mere „toys" that only attract visitors and do not offer to the public deeper insight into artifacts. In my presentation I would like to focus on the symbiotical relation between destructed matter from the past and technology, that is now being embodied in museums. I suggest to reconsider the artifactual (from artifact) cyborgs, that nowadays are becoming popular on exhibitions. As artifactual cyborgs I understand the assemblages of fragmented artifacts and technological supplements. Archaeological cyborgs that are omnipresent in contemporary archaeological museums will be grasped as mixed matter — decayed historic things fitted with newly-born technological protheses — augmented reality, simulations, virtual reconstructions etc. Artifactual cyborgs help us to understand the form of past things — they are educational tools and correspond

with the idea of democratic museum accessible and comprehensible for everyone. But the deeper meaning seeks from merely epistemological interpretation. Artifactual cyborgs mark out important switch in ontology of past things. Technological additions supplement the object and re-form it, without material interventions; compiled with authentic artifacts are signs of our time, that is about searching for completeness and wholeness. The paper will examine above-mentioned problems on case study — chosen exhibits from New Acropolis Museum in Athens.

Knowledge Representation and Linked Open Data in Cultural Heritage through design of a Semantic Web enabler Content Management System

(*Avgoustinos Avgoustis, Athanasios Koutoupas*)

Currently, a large number of Cultural Heritage websites and online collections are driven by Content Management Systems (CMS). This practice coincides with the materialization of the Semantic Web. Even though the development of CMS and that of the Semantic Web seem to be connected, they have instead taken fairly distinct paths. Nonetheless, merging of these two 'worlds' carries a lot of potential and benefits for a faster and more efficient spread of the Semantic Web in the Cultural Heritage domain; this is a development that could help Cultural Heritage data become retrievable in a more intuitive way, interoperable and discoverable by both humans and machines. In order to achieve such a goal, the development of any CMS should consider from its first stage of design and implementation the Semantic Web as its ultimate target. The paper will introduce such a CMS, its architecture, functionality, and operability, showcasing its advantages through a concrete case-study of a numismatic collection available online and developed at The Cyprus Institute, in close collaboration with the Bank of Cyprus Cultural Foundation, to whom the coins belong. As mentioned above, the digital numismatic collection currently contains ca. 300 unique items, each consisting of a pair of Reflectance Transformation Imaging (RTI) images for each coin, accompanied by a rich metadata description. Search can be performed by coins attributes described in the metadata, a timeline (enriched with images of iconic artifacts belonging to the mentioned periods), a geographic search, as well as free text and browse. Additionally, a browser-based visualizer for RTI enables the online interaction of users with the RTI images (zooming at high resolution, change light direction, perform measurements, etc.).

Immersion and the Submerged: The Scapa 100 Project

(*Chris Rowland*)

The scuttling of the German WWI High Seas Fleet at Scapa Flow, Orkney, on 21st June 1919 was the last military action of WWI. The "Scapa 100" project will commemorate the events of that day during the centenary year in 2019. As part of the commemoration, a team of technical divers, marine archaeologists, historians and 3D visualisation designers are collaborating to represent the historically significant shipwrecks, still remaining on the seabed at Scapa Flow to a wider audience who may never experience them first hand. The team are surveying the German wrecks using a range of techniques from multi-beam sonar to 3D photogrammetry (Structure from Motion) to produce high resolution 3D visualisations of the wrecks revealing their current condition at this unique site. One element of the project: Battleship Explorer, involves the replication of the battleship SMS Markgraf using data sourced

from the recreational diver community. These "citizen" divers submit their photographs and videos to assist in the creation of a complete model of the wreck which will be presented at full scale in an immersive VR experience. In addition, many of the artefacts recovered from the wrecks since the scuttling and subsequent salvage operations are being scanned with the support of Orkney Museums at Lyness, Stromness and Kirkwall. These items will be presented as an online virtual museum complete with the stories behind their acquisition and collection. This paper will present early results from the Scapa100 project, including 3D visualisations from the recent HMS Hampshire and HMS Vanguard surveys.

Digital Object-Based Curricula: Teaching History with Underemphasized Archaeological and Cultural Heritage Collections

(*Kayeleigh Sharp, Grant Miller, Mark J Wagner*)

Inadequacies and built-in biases of the historical record and the fragmentary nature of archaeological data often render our perception of the past imprecise, skewed and vague. While traditional museum collections tend to make accessible the most beautiful or rare objects to a selected range of on-site viewers, teaching archaeology and history presents many unforeseen challenges of its own. How can we use digital tools to learn and teach more effectively from and about the past? What are the implications, advantages, and limitations of current digital innovations for engaging learners in processes of scientific inquiry? In this paper, we discuss the development of multi-media online curricula that combines interactive GIS, primary archaeological and historical/archival resources, and 3D scanning and printing of everyday objects to teach students of various ages, background, and abilities, the value of archaeological and historical data on new levels. Making these products open-access presents the opportunity to stir inquiring minds with the exciting prospect of discovering unknowns and significance of archaeological and historical records off-site and first-hand. As we illustrate, by implementing digital strategies, it is possible to share and engage the broader public in processes of evidence-based scientific inquiry and to make use of abundant materials often de-emphasized in traditional museum and teaching collections. The fusion of digital technology, historical/archaeological data and artifacts, fosters a new public perception in areas traditionally (and today in particular) seen as irrelevant to our present-day existence. This new fusion enlivens the past by making it more accessible and interactive.

Session 30
Open Digital Infrastructures for Archaeology and Cultural Heritage

SKOPE: Making Paleoenvironmental Data Useful and Accessible

(*Adam Brin, R. Kyle Bocinsky*)

The NSF-funded SKOPE Project — Synthesizing Knowledge of Past Environments — is developing computational tools that provide easy and open access to paleoenvironmental data and models. The SKOPE environment (http://www.openskope.org) enables scholars to easily discover, access, explore, visualize, and synthesize information of both past and contemporary environments. Users may adjust

the parameters of reconstructions, view the source code underlying each model, and submit their own models. In addition to the web application, the SKOPE project has developed FedData (http://ropensci.github.io/FedData/), an R package that automates downloading of geospatial data available from several federated data sources, and YesWorkflow (http://yesworkflow.org), a declarative framework for recording and analyzing computational provenance within scientific workflows. SKOPE is designed from the ground up to enable reproducible research and ensure users can trace the data and logic around environmental reconstructions from start to finish.

Metadata and long term data survival in cultural heritage

(*Martijn van der Kaaij, Wessel van der Kaaij*)

Even though the tools for platform and application independent data storage for the long term are fairly widely available now, their potential has only been unlocked to a very limited extent. Application centered approaches that hardly take any notice of these tools still prevail. This paper sets out with a reflection on current practices for long term data storage in several national archives and national libraries. These institutions are faced with a real and pressing need to provide long term storage for large amounts of data. As such, their examples could benefit the cultural heritage sector, including the archaeological domain. After the review of these current practices, the paper proposes an open metadata approach to data survival. Workflows to manage all stages of the data life cycle will be discussed, ranging from reflections on easier storage of information to thoughts on communication of research in a more engaging and intuitive form. The paper concludes a look at the (near) future: an integrated case study regarding the further possibilities of an open metadata approach, based on linked data and semantic triples. The study pertains to a castle site in the Netherlands. It will provide a working example of a viable implementation of this open metadata approach to long term preservation of cultural heritage data.

Case Studies in Open Context Data Reuse: Implications for Curation

(*Eric Kansa, Sarah Whitcher Kansa, Federico Buccellati*)

Open Context (https://opencontext.org) provides open access publishing services for primary field data in archaeology. Since its launch in 2007, Open Context has published structured data, field notes, images and other media from over 110 projects and collections across the world. Our experiences gained over the past ten years draw on and have stimulated the growing professional acceptance of preserving and sharing archaeological data. However, even though some aspects of data management have become more routine, we still have few examples of data reuse. We define "data reuse" as any public (in publications, software, or the Web) presentation of structured data or media that references projects or collections published through Open Context. We find reuse examples through Web searches of Open Context URIs and through citation indices. Our results show different patterns of reuse. Data created and used by specialists, especially zooarchaeologists, see more reuse in peer-reviewed journal articles. Detailed data documenting individual excavations or surveys see less discussion in scholarly literature, but still some use in online media. Other data, especially inventories of archaeological sites across wide regions, become reused through incorporation into other online datasets. We hope presentation of these case studies in Open Context data reuse will help better

inform data curation practices, intra- and inter-regional comparisons, information retrieval services and APIs, and other critical needs.

The field research database iDAI.field 2.0: Find the balance between interoperability and project specific needs

(*Philipp Gerth, Juliane Bonneß, Sebastian Cuy, Daniel de Olivera, Thomas Kleinke, Julian Schierenbeck*)

Currently iDAI.field 2.0 is being developed as a new field research documentation system by the German Archaeological Institute (DAI). It will be realized as an Open Source client-based software solution that relies on and incorporates Open Source web technologies. Field research projects create vast amounts of data coming from different disciplines and research perspectives. Therefore, a generic data model that balances these differing needs and data interoperability is necessary. Other requirements are e.g. a hardened synchronization solution for working in areas without internet coverage and support for a variety of acquired (spatial) data: measurements, geophysical surveys, structure from motion etc. This paper offers a detailed outline of our technical solutions for the aforementioned problems. It focuses on the balance between project specific needs and the standardization of archaeological data. While the usage of a NoSQL datastore does provide the flexibility to integrate all kinds of descriptive data, a minimal common standard is still needed to achieve comparable data. iDAI.field uses a common data model, that will be released and documented as an ontology, which incorporates linked open data vocabulary. We will also provide some context for the future possibility of data publication and cross-search - over different research databases - using the common data model.

Squeezing Radiocarbon Data

(*Miquel Colobran, Joan Anton Barceló, Berta Morell*)

Radiocarbon dates have revealed as one of the key elements in archaeology and thus they are used by the majority of researchers. Despite this fact, radiocarbon data are still spread over many databases, websites and local files using several different formats. The possibility to integrate all this information is challenging, but technically possible. This paper documents the creation of a search engine that stores the basic information radiocarbon data from all these websites, databases and even from local files. Having a huge quantity of radiocarbon dates to hand, allows new research questions concerning the relationships between different sites over time or between materials to be addressed. Besides, a better visibility of the radiocarbon data constitutes a positive factor for their owners. The aforementioned is achieved by creating a search engine that works in a similar way to Google. The radiocarbon search engine is composed by 3 elements, the gatherer, the database and the user interface. The gatherer is a set of small python programs that gather the information from websites, databases or local files and upload it to the database. They are custom made in order to integrate particular kinds of radiocarbon information. The database stores and indexes all the information and the user interface is a Google-like text box that provides a list of results along with their links in response to the user's query. The system points to the original website, if it exists, or provides other

provenance information for the user on the origin of the Radiocarbon Date. In 100% functional prototype can be used at: http://www.ibercrono.org/goget

An Open Source Solution for Synchronising Distributed Archaeological Databases in a Centralised Open Access System
(*Felix Kußmaul*)

In today's archaeological practice, open source databases play a major role and have become indispensable for both contributors and researchers, even in huge projects such as Arachne. Additionally, the desire to work collaboratively and to connect research data via centralised open access infrastructures is ever-growing. However, a myriad of archaeological research projects still rely on proprietary database software. One of them is FileMaker Pro, which does not include native support for sharing or publishing data without the need to buy expensive licences. Hence, and due to limited project lifetimes, it must often be feared that the gathered research data will be unavailable for future research after project completion. Furthermore, there exists currently no open source solution to integrate several local FileMaker Pro databases into an existing, publicly available database, including the option of keeping the distributed data in sync during the project. This paper introduces a platform-independent open source approach to fill this gap. It is able to synchronise offline FileMaker databases via ODBC with an existing central open access database, which allows project partners to share and edit research data and ensures public availability for the future. To guarantee usability even for inexperienced users, we developed an intuitive graphical user interface for the tool. We also provide solutions for several challenges including recognising and applying modifications, maintaining data consistency over a distributed system and the automised management of primary and foreign keys during the synchronisation process. Furthermore, our tool is able to resolve conflicts between concurring datasets.

NormA – Building an Archaeological Information System Around a Normalized Geographic Data Model
(*Joerg Raether*)

The on-site recording, as well as the later storage of simple geometric features like points, lines and polygons as a part of the digital documentation process in archaeology, still involves several not satisfyingly solved problems, e.g. CAD vs. GIS. Regarding storage as the crucial element within the cultural heritage preservation sector, the utilisation of a GIS in combination with a geodatabase seems to be an appropriate solution for a FOSS Archaeological Information System to be implemented, of which a few components of the required spatial data infrastructure, e.g. PostgreSQL/PostGIS or FOSS web- and desktop GIS', already exist. The geodatabase itself, as the primary storage of all survey data, should be independent from the applications used to edit or view the data, and its design should be as simple and intuitive as possible. On the basis of general considerations like these, the Normalized Archaeological Data Schema ("NormA") has been developed. Based on CRMarchaeo our approach allows the reduction of entities within the database schema to a form that survey data can be represented in a GIS fully but without redundant information or an increase of complexity through non-spatial entities. NormA has already been implemented in a prototype geodatabase for the

Archaeological Museum Hamburg currently in testing with real excavation data and an additional middleware prototype, but can also be used to specify minimum requirements for shapefiles to suit any archaeological survey or excavation.

New approaches to Open Data in Archaeology: the blockchain revolution

(*Eleonora Gandolfi, Grant Cox*)

The potential of the blockchain is now being applied to many fields outside of just finance, such as energy and medicine. Following this movement, a group of developers, crypto enthusiasts and archaeologists are developing KAPU, the worlds first archaeological blockchain. Taking its name from coins forged by the Italian City of Capua during the Second Punic war (218 BC), it aims to develop the first decentralised database of worldwide heritage records. Using the blockchain, archaeologists, museums and other stakeholders will be able to record information using a distributed public ledger in which the data will then be available to everyone. This will help to preserve data, which can be threatened by loss, centralisation, censorship and alteration over time. To solve these issues, the blockchain allows provides accessibility, the removal of a singular point of failure, immutability of the data set and the usage of smart contracts to automate and create rules. The database will be supported by a network secured by the Delegate Proof of Stake (DPoS) system, which is a fairly new cryptographic methodology used to process transactions and achieve distributed consensus without the need of a central authority. DPoS only requires a limited number of delegates to validate a transaction, which offers increases in transaction speeds and reduced bloat on the network. This paper will present how, even if the technology is still in development, its application to the heritage sector could potentially revolutionise data storage, preservation and dissemination.

DIGILAB: E-RIHS' data and service infrastructure

(*Franco Niccolucci, Luca Pezzati, Sorin Hermon, Achille Felicetti, Athanasios Koutoupas*)

The European Research Infrastructure for Heritage Science (E-RIHS) incorporating and taking advantage of the long-term tradition of the heritage science research, the ability to combine with innovation, and the integration promoted by EU-funded projects such as ARIADNE and PARTHENOS exploits the synergy of the cooperation among the academy, research centers, and cultural institutions. E-RIHS will provide state-of-the-art tools and services to support cross-disciplinary research communities of users through its four access platforms: MOLAB, FIXLAB, ARCHLAB, and DIGILAB. The DIGILAB platform, inspired by the FAIR principles (Findable-Accessible-Interoperable-Reusable) will provide online access and remote services to the heritage science research community. The platform includes and enables to access searchable registries of specialized digital resources (datasets, reference collections, thesauri, ontologies, etc.). Furthermore, DIGILAB will set up guidelines for dataset recovery and assist researchers and research institutions, while as cloud-based infrastructure will support data interoperability through the creation of shared knowledge organization systems and provides tools to process them according to researchers' needs and research questions. Overall DIGILAB facilitates virtual access to tools and data hubs for heritage research and is designed to be the privileged gateway to European scientific knowledge in heritage.

Workshop Summary „Digital Excavation Documentation – Objective and Sustainable" (Poster)

(*Reiner Goeldner, David Bibby*)

Archaeologists discuss ways of making legacy fieldwork records amenable to today's use. Let's shift the time frame and discuss ways of making today's fieldwork records amenable to future use. On archaeological excavations context information cannot be preserved in its original state. So it is important to build an objective* and sustainable* documentation which will provide all information gathered for future use. Some interesting aspects arise from combining the questions: Which digital methods best produce objective record of excavation facts and which of them produce sustainable information ready to be preserved over hundreds of years. Within this subject area the workshop covered aspects such as: - Digital methods of capturing excavation information, - Capturing and recording of geodata (trend from CAD to GIS), - Integration to expert information systems and archival systems, - Technical preconditions for appropriate use of the data, - How to achieve data sustainability? How to preserve usability over hundreds of years? - Development and use of appropriate Free and Open Source Software (FOSS), - Use of open standards. Today's practice often shows that digital methods are considered independent of preservation aspects. This workshop was a step of changing this and setting up synergy effects combining both themes. It offered the possibility of exchanging hands-on experiences between archaeologists on the one hand and discussing prospects and starting points to future FOSS projects on the other hand. The poster will give a short summary of the workshop „Digitale Grabungsdokumentation – objektiv und nachhaltig", which will be held in February 2018 in Dresden. The Workshop is organized by the commission Archaeology and Information Systems of the Association of State Archaeologists in Germany due to increasing interest in sharing experiences on this topic. Archaeologists from Germany are expected to present their ideas and to discuss the above mentioned aspects. (http://www.landesarchaeologen.de/verband/kommissionen/archaeologie-und-informationssysteme/projektearbeitsgruppen/workshop-digitale-grabungsdokumentation/) [* It is assumed that excavation documentation has to be "objective", that means comprehensible and independent from personal (subjective) and technological influence, as far as possible, as far as needed for scientific interpretation and as far as needed for "sustainable" preservation.]

Session 32

Automation, combination and calibration: consolidating the framework for archaeological geophysics

Is the whole greater than the sum of its parts? Image fusion, analysis and interpretation approaches at the Late Iron Age site of Borre in Norway

(*Petra Schneidhofer, Christer Tonning, Erich Nau, Lars Gustavsen, Vibeke Lia, Geert Verhoeven, Monica Kristiansen, Immo Trinks, Terje Gansum, Wolfgang Neubauer, Knut Paasche*)

The late Iron Age site of Borre, situated on the western shores of the Oslofjord in Norway, has long been known for accommodating the largest collection of Late Iron Age monumental burial mounds in

the Scandinavian world. The recent discovery of three hall buildings presumably dating to the Viking Age using ground penetrating radar (GPR), however, necessitates a re-interpretation of the site, including comparisons to central places in Scandinavia such as e.g. Uppsala in Sweden. Pivotal to this endeavour is a detailed understanding and mapping of the hall buildings, which – since their discovery ten years ago – have been subject to a series of GPR surveys conducted in 2007, 2008, 2013, 2015 and 2017 using different measurement systems and in different environmental conditions. The wealth of data proves a unique opportunity to non-invasively investigate the often subtle archaeological traces hall buildings leave behind in the subsurface. But how to best approach their analysis? And more importantly, how to avoid creating "dark data" - data collected and stored at great expense but never to be used? In this paper, we will demonstrate a diverse strategy to retrieve a maximum of information from the geophysical data for the non-invasive analysis and interpretation of the hall buildings. Steps include image fusion using the Toolbox for Archaeological Image FUsion (TAIFU), three-dimensional visualisation of GPR data in Golden Software's Voxler as well as multi-interpreter comparisons. To conclude, we will discuss benefits and limitations of such an approach.

The Roles of Data Fusion in the Scientific Process of Archaeological Remote Sensing
(*Eileen Gloria Ernenwein*)

The combination and integration, or fusion, of geophysical data has become common practice in archaeological remote sensing. Methods range from the side-by-side comparison of datasets to mathematical and statistical integrations, with goals ranging from data reduction to more complete visualization of multidimensional data. But which of these methods is best for a given goal and situation? In this paper, I take a geographer's perspective to consider the roles that data visualization and presentation play during the interpretation, collaboration, and publication of remote sensing data. Case studies from multiple sites using aerial imagery, topography, ground-penetrating radar, electromagnetic induction, and magnetic gradiometry are used to show that complex data fusion methods have a valuable place in data exploration and communication among experts. The presentation and publication of results to the broader archaeological community and the public are ineffective when complex illustrations require familiarity with topics such as color theory, statistical derivations, and remote sensing.

Illuminating Haiti's Royal Past: Advancing Analytics and Archaeological Interpretation Through 3D Data Fusion and Machine Learning
(*Katie Simon, Christopher Angel, Christine Markussen, J. Cameron Monroe*)

Since 2015, the Milot Archaeological Project has conducted a series of archaeological explorations at the Royal Palace of Henry Christophe in the town of Milot in Northern Hait. This site, called Sans-Souci, was a principal site of political authority in the short-lived Kingdom of Haiti (1811-1820) and is a UNESCO World Heritage site of paramount importance to national development strategies in Haiti. This paper outlines the results of ground penetrating radar and terrestrial laser scan surveys conducted by CAST and explores the utility of combining these 3D datasets to further investigate research questions regarding construction phases. This paper expands upon our initial reporting of TLS and GPR data fusion through volumetric point cloud visualization presented CAA 2015. The effort aims to

elucidate the analytical and interpretive potential of employing advanced 3D data fusion and visualization methods beyond mere prospection and documentation to examine the relationship between architecture and political power that would otherwise be difficult, if not impossible, to address using traditional methods. This paper additionally reports on current efforts to develop a self-contained radargram image classifier through the use of various machine learning methodologies and recent advances in neural networks. The challenges involved in implementing tools like Tensorflow (with Keras), Theano, or PyTorch will be discussed along with how such automation methods for radargram processing can facilitate machine-guided interpretation and new forms of rapid GPR data visualization.

Geophysical Correlation: Global Versus Local Perspectives

(*Kenneth L Kvamme*)

Correlational studies at the regional level and theory suggest the near-independence of many geophysical data sets acquired by different survey modalities (e.g., GPR, magnetic gradiometry, electrical resistivity). Nevertheless, robust anomalies that point to the same buried features frequently occur in diverse data sets, creating a paradox because parallel anomalies suggest that robust correlations should exist. Relationships between corresponding anomalies traditionally have been noted subjectively, through visual comparisons of mappings of geophysical results. Through application of local Pearson's r in small neighborhoods, with radii from 0.71-1.6m, a means is offered for the quantification and mapping of local correlations between two geophysical data sets. A case study examines relationships between a GPR depth-slice, apparent electrical resistivity, and magnetic susceptibility data acquired at Army City, a Great War troop support town in Kansas, now obliterated except for subsurface remains. Intricate spatial patterns of positive and negative correlation between these modalities are illustrated that vary in complexity with neighborhood size. Moderately sized neighborhoods are preferred because the spatial patterning of correlations best corresponds with anomaly forms and is enhanced through moderate smoothing. Overlays of high correlation correspond well with robust anomalies observed in each data set and offer objective criteria for assessments of correlation. However, the occurrence of mutually robust anomalies does not necessary imply correlation. Methods of data integration generally capitalize on composite relationships. Methods offered here offer a means to place integration studies on a firmer footing and may also improve understanding of complex geophysical relationships.

Computer-aided object detection in archaeological geophysics: helpful tool or mirage?

(*Lieven Verdonck*)

The scale of archaeological geophysics has continued to grow in the last decades. Bigger data volumes raise the question if traditional interpretation methods (manual delineation of anomalies) will continue to be sufficient, and whether computer-aided methods of archaeological object detection should not become more important. These detection algorithms do not have the same ability as human interpreters. On the other hand, manual visual inspection is time-consuming and may not be able to analyse vast data sets. Moreover, detection algorithms can analyse the data in ways beyond what is familiar or readily visible. This could make the interpreter more aware of possible biases in his manual approach. A number of object detection approaches have been developed. In this paper, the ability of

a few techniques to detect wall foundations and other structures in urban Roman sites is assessed (template matching, methods based on mathematical morphology, object-based image analysis). A few observations emerge. For example, there is a difficulty to select suitable quantitative evaluation metrics, and a need to find a balance between performance, simplicity and wide applicability of detection workflows. Although in archaeological geophysics computer-aided object detection is still in its infancy, it seems beyond doubt that in the future, specific applications such as the detection of small metal objects in magnetometer and EMI data, or the identification of irregular areas with enhanced reflection strength in GPR data (possibly indicating pavements) will be used more routinely and with higher accuracy.

A Landscape Scale Implementation of FDEM Survey in Midcontinental North America
(*Claiborne Daniel Sea, Eileen Gloria Ernenwein*)

Reported uses of frequency domain electromagnetic (FDEM) survey in midcontinental North America are limited. This is not due to poor results, but the scale at which archaeologists tend to focus their geophysical surveys. By and large, discrete archaeological features such as individual households and refuse pits are targeted rather than macroscale archaeological signatures. Magnetic gradiometry (MG) is by far the most widely used, with occasional but more spatially limited electrical resistance (ER) and ground penetrating radar (GPR). Recently, a landscape scale FDEM survey was conducted on a complex of four very closely spaced but separate Native American villages in Kentucky, USA. A semi-automated data processing routine was applied to remove drift. These results were then compared to MG and GPR data. Despite the survey area being heavily disturbed by plowing and terracing, the electrical conductivity (EC) clearly showed village extents, whereas MG showed mainly erosional patterns and GPR only small pit features. The combination of EC and GPR gave a fairly detailed picture of village layout.

'Mark the Graves': Adapting automation for improving the delineation of graves in GPR data
(*Ashely Green, Paul Cheetham, Timothy Darvill*)

While GPR has proven successful in detecting recent and archaeological graves, a large proportion of graves still go undiscovered until they are disturbed during excavation owing to coarse survey parameters or even the ability of GPR to detect a range of features in any given environment. The ethical treatment of human remains is culturally important; hence the need to improve the potential of recovering remains prior to their destruction by machine excavation, other anthropogenic activities, or natural processes. Geophysical survey and reporting outputs could be improved by implementing a standardised interactive workflow for determining appropriate survey parameters together with automated classification software. Interactive adaptive guidelines for GPR survey based on environmental and anthropogenic factors and target properties detailed in existing archaeogeophysical survey guidelines will determine appropriate survey parameters to allow for the maximum potential detection of a designated target. The prototype software utilises supervised machine learning to retrain convolutional neural networks from TensorFlow, Google™'s open-source software library. A graphical user interface (GUI) will be available for accessibility if the user requires.

Training datasets were derived from rasterised 2D and 3D ground-truthed, real and simulated improved and raw GPR data. Recent progress and future outputs of this ongoing doctoral research project will be presented. Particular attention will be paid to the composition of the training data, nature of the accuracy of the model when compared to the original neural networks.

Forgotten but Not Lost: Adapting Simple Magnetic Depth Estimation Techniques to Modern Archaeo-geophysics

(Jeremy Grant Menzer)

Magnetometry is likely the most widely used archaeo-geophysical technique in the world, however, a major drawback is the lack of depth information to anomaly sources. In fact, many novice users are under the impression that magnetometry does not or cannot provide depth information, yet, it is commonly used in geologic studies. This study examines the validity of magnetic depth estimation techniques through magnetic modeling and examines how these techniques can be adapted to modern archaeo-geophysical surveys, a world of fast cart surveys and big data. Potential difficulties arise because many archaeo-geophysical surveys employ fluxgate gradiometers rather than total-field sensors, adding complexity to depth estimation techniques. Additionally, the potential benefits of deriving depth information to magnetic sources are discussed in the context of testing a variety of anthropological/archaeological hypotheses.

The Rediscovery of ancient Hira in large scale magnetometer and archaeological survey data

(Burkart Ullrich, Martin Gussone, Martina Müller-Wiener, Nikolaas Noorda, Ibrahim Salman, Henning Zoellner)

The presentation points to the contribution of archaeological geophysics to the Al-Hira Survey Project. The project focuses on the ancient town al-Hira, presumed South of present day Najaf and Kufa. The research started in 2015 as intensive field survey, mapping a large number of mounds, related to building remains of Sassanian palaces. The archaeological surveys supplement results from excavation from the 20thcentury and yield to an area of approx. 1000 ha intensively used in the Pre- and Early-Islamic period. Parts of these site are critically endangered by agricultural activities and construction work, in particular the extension of al-Najaf International Airport in the North of the area. Before the rescue excavation we were able to conduct a large scale magnetometer survey of the planned new runway and adjacent areas, stretching over 3500 m in East-West and 600 m in North-South direction. Using the GPS controlled, multi-sensor magnetic survey system LEA MAX (Eastern Atlas) in both the hand-pulled and vehicle-towed operation modes we were able to face the steppe-like survey and collect data very efficiently within few days. The comparison of survey data derived from field walking and the large scale magnetometer prospections provides a complete picture of the previously (partially) unknown archaeological record of the northern part of the research area. Besides the interpretation of distinct anomalies we classified four main zones; either with almost no traces or with extraction pits, the Sassanian palaces and densely build urban areas interpreted as ancient Al Hira.

Session 33
Guaranteeing data quality in archaeological Linked Open Data

Data Quality – if not initially, how to solve it later?
(Karsten Tolle, David Wigg-Wolf)

Hindsight is easier than foresight, and this is also true when handling data quality. An initial problem is that often the funding and resources are not available to concentrate on data quality in the first place. However, with the crosslinking of various resources, this can easily lead to a multiplication of bad data. Yet cleaning it afterwards is much more complicated. Last year at CAA we proposed a rule system that could help to identify potential errors based on the data itself. In this paper we will report how this has evolved, and what experiences we have had in using LOD such as Nomisma.org within the solution we employ in Antike Fundmünzen Europa (AFE), our database for information on finds of ancient coins. However, there are also errors that are simply invisible for a rule system because the data is logically correct. In some cases, it is possible to use additional sources of information, for example the images or descriptions in natural language which are attached to the data and until now are mainly used for human interaction. Using Natural Language Processing tools and algorithms for images provided by free software like Open BC, we are exploring what other solutions exist. Such automated analysis of the data also provides the further possibility of searching for coins based on an iconographic thesaurus. In addition to better data quality, this could provide a new and neutral way of accessing and researching data that potentially reveals new insights.

Improving the data quality of a period gazetteer
(Wolfgang Schmidle, Sebastian Cuy, Nathalie Kallas, Thomas Kleinke)

We have designed a gazetteer for historical periods called ChronOntology and implemented it as a web service using Linked Open Data (http://chronontology.dainst.org/). The data model is based on CIDOC CRM and distinguishes between the definition of a period, which may be approximated by a type such as "political" or "all meanings", and statements about its spatiotemporal extent based on this type/definition. Period records are connected via a semantic vocabulary such as sameAs, isPartOf or isAMeaningOf. Two records from different data sources may refer to exactly the same period if they share the same definition, but even then they can still disagree on the spatiotemporal extent about the period. ChronOntology can accommodate data on different levels of quality and completeness and supports iterative improvements of the data quality. It is possible to infer certain kinds of information within a record or from other records while keeping track of the provenance chain of the inferred knowledge and the types of inferences. Examples are (1) temporal reasoning, i.e. the addition of missing temporal information via isPartOf and isAMeaningOf relations, (2) detecting errors in the data, i.e. plausibility checks for the given and inferred temporal information, (3) inferences from relationships that hold by definition to simple spatial, temporal or spatiotemporal relations, e.g. isPartOf to fallsWithin, (4) identifying and visualising conflicting information from different sources and (5) semi-automatedly identifying candidates for matching with a measure of similarity between periods that takes the period type as well as spatiotemporal and other information into account.

Taming Ambiguity - Dealing with doubts in archaeological datasets using LOD

(*Florian Thiery, Allard Mees*)

The Linked Data Cloud is full of controlled resources, which in fact quickly run out of control. Firstly, each resource collection, e.g. a thesaurus, is cooking its own soup related to its research context. Secondly, conceptualisation of LOD assumes standardised data, but in reality, only generic concepts or real instances exist. Thirdly, archaeological items are usually related to generic instances in the LOD cloud, based on their object orientated nature. Describing these relations by modelling archaeological assumptions causes ambiguities which have to be tamed to guarantee data quality for reuse, demonstrated in three examples: (1) Trying to link a triangular "lateen sail" into the LOD cloud, a problem known from the NAVIS II ancient ship depictions database, reveals that each repository has completely different "hidden assumptions" in its hierarchies with respect to their scientific domain. Are the usually SKOS based relations able to solve the challenge to model also the degree of doubt? Are different methods required? (2) Trying to map pot fragments of Gaulish Terra Sigillata to historically defined concepts of "types" and "service families", or aligning these typologies, ends up in modelling doubtful assumptions. Can metrics be used to define "type" definitions? How can an already existing online research community help? (3) Setting up a meta-index for aligning various distributed databases at the RGZM by keywords and linking into the LOD Cloud is subject to uncertainties within the modelling of relations. As a result, this process includes dealing with the above mentioned ambiguity challenges.

Guaranteeing data quality in archaeological Linked Open Data

(*Francesca Chelazzi*)

Archaeological data are what economists call a 'non-rivalrous' good: they can be processed again and again with no diminishing of their value. The proliferation of surveys and excavations, coupled with the recent embracement of digitalization in archaeology, has exponentially increased the amount of data. Instead of keeping isolated data silos, one of the current challenges is the aggregation and correlation of data in the 3V's perspective of Big Data: high volume, high velocity and high variety. In order to develop a rigorous strategy of data aggregation and correlation, one of the current tasks is providing the answer to a fundamental key question: can we rely on datasets collected in the past by someone else? And – if yes – how can we datafy and aggregate thematically, geographically and/or temporally circumscribed datasets within a wider and interdisciplinary 'Big Data' perspective? This challenge turns around the need to approach legacy data through a careful process of source criticism, aiming to address trends, gaps or errors and to develop explicit data quality estimation procedures. This paper presents a forthcoming project concerning the archaeological record from the Southwest of Cyprus; this project aims to develop participatory strategies for data evaluation and aggregation through testing an online platform (WebGIS/WebGeoDatabase) that can promote open access to and peer review of archaeological data, as well as a powerful partnership between the academic community and the non-expert stakeholders.

Data Quality experiences within the project Corpus Nummorum Thracorum

(Daniel Althof, Ulrike Peter, Karsten Tolle, Bernhard Weisser)

The DFG funded project Corpus Nummorum Thracorum (CNT) has collected and published ancient coin data for a specific area (Thrace) and timespan. The goal of the project is to unify the entire known data from this space in order to analyse it and to propose and publish a type system. Within the CNT-database coin data from some 120 collections are merged. While importing data, we encountered various error-prone cases. Sources might come with their own weaknesses and errors. The implementation is done by IT-experts who cannot judge each case, but manually checking every imported entry by domain experts would be too expensive. We implemented some tests in order to avoid known problems, but this is far from being complete. We mainly rely on visualisations and query interfaces that can be handled by the domain-experts in order to approve new data. Were everyone to model and publish their data according to the norms of Nomisma.org, many problems on our side could be avoided. However, these LOD sources are still in the process of development. They also contain errors and duplicates; concepts might not yet exist and others become deprecated. We are about to finish mapping our data to the Nomisma.org ontology and will implement our quality checks on this level. The advantage would be that these checks are independent of our database structure and therefore could be used by others. We will report on our experiences and first attempts to improve our data quality.

Session 34
R as an archaeological tool: current state and directions

c14bazAAR & oxcAAR -- two R packages for the collection, calibration and modelling of 14C dates

(Clemens Schmid, Martin Hinz)

There is hardly any type of data that would be more important for archaeological research and practice than radiocarbon data. This is true for the intrasite level, for regional comparisons and also in cases where processes that have a large spatial and temporal extension are to be investigated. Most comparative studies rely on openly available repositories of published dates -- archives with a long tradition of data collection, processing and maintenance. The number of such archives, with different temporal and spatial foci, has grown enormously in the last two decades. Unfortunately, resulting from this the entire data basis is now highly decentralized and without basic standardisation. In this paper we would like to introduce two new packages that simplify the handling of radiocarbon data in R. c14bazAAR provides tools to systematically query an ever-expanding selection of 14C data archives and automatically clean and merge the results. oxcAAR serves as an R API to the widely used software package OxCal for calibration and modelling of 14C data. It therefore not only allows for a rational, coherent and reproducible workflow of import, calibration and visualization, it also offers an interface that enables simulation and further statistical analysis within R, which provides the perfect environment for such tasks. Both packages are well interlinked and support tidy data structures, making them compatible with modern and powerful tools like dplyr, sf or ggplot2. The packages are developed by the ISAAKiel group (Initiative for Statistical Analysis in Archaeology Kiel)

https://isaakiel.github.io

Analytical Taxonomies for the Study of the Cycle of Baʿlu and ʿAnatu: from TEI-XML Markup to Processing Data within R Environment
(*Vanessa Juloux*)

This paper is part of my current doctoral research on a narrative text in alphabetic cuneiform, the « Cycle of Baʿlu and ʿAnatu » of the scribe ʾIlimilku of Ugarit (Ras Šamra in actual Syria), at the end of Bronze Age. A first step focused on qualitative process: encoding of textual data in TEI-XML, and ordering of relevant occurrences within analytical taxonomies' categories that are (1) primary data (subject + verb), (2) objective variables (i.e. context, inside/outside a spatial delimitation, roles), and (3) subjective variables (i.e. emotions, levels of desire, consequences). The second step, on which I shall discuss during this session, is the parsing in R. It should enable to quantify significant occurrences related to the categories of analytical taxonomies, in order to suggest a gender role as well as a hermeneutics of the action (final step). I will focus on the method used in R environment: import data from TEI-XML file to R, and its processing in order to quantify data which will be used for the final stage.

~~The Changing Faces of the Dead. Using R to Trace the Shift of Burial Preferences within the Roman Provincial Necropolis~~
(*~~Carolin Tietze~~*)

~~The Roman provinces show an incredible mixture of indigenous and different foreign traditions, architectural styles and artefacts. Especially along the Silk Road and within provinces like Syria a foreign influence shows not only within the city, but also within the necropolis. Traditions like the placement of a funerary monument within the necropolis and the orientation along its streets can be modified or changed after a certain contact with another cultural group. The style or even the type of the monument may also change whereas foreign objects like Chinese silk or Roman glass can suddenly be found within graves. The trading characteristic of towns like Palmyra and other caravan cities can explain foreign objects and a roundabout usage of foreign forms. But questions remain whether those contacts did influence the indigenous traditions to create a new one or not. In this paper I would like to present the results of my Master thesis and show how I explored the different tools that R provides to detect shifts within the necropolis of the Roman Near East. R can be of use while trying to analyse the much subtler changes within a city or culture which has been influenced by not one but many cultures. It can provide a better understanding of factors like spatial organisation, infrastructure, groupings and the degree of cultural adaptation, for example. Tools like this help to create a simpler workflow and improve reproducibility for further analysis with just one click.~~

mortAAR: the analysis of archaeological mortality data in R
(*Christoph Rinne, Martin Hinz, Nils Müller-Scheeße*)

Up to now, a simple to use and easily accessible tool for computing archaeological life tables was lacking. Therefore, the Initiative for Statistical Analysis in Archaeology Kiel (ISAAK) has developed „mortAAR", a set of R functions to generate and analyze life tables deriving from archaeological

mortality data. In recent years, physical anthropologists have become very cautious with regard to the life tables of archaeological populations. The reason for this are various difficulties which, in addition to the problem of identifying the correct age-related characteristics, arise in particular from the question of representativeness. We are fully aware of these problems, but would like to demonstrate with the help of several example data sets that it is precisely in the comparison of data with expected mortality patterns that useful information about cultural preferences – e.g., who has to be buried and who not – can be elucidated.

Aoristic research in R: Correcting temporal categorizations in archaeology

(*Nils Müller-Scheeßel, Martin Hinz*)

When aggregating temporal data in archaeology, it is often the case that we have to deal with overlapping categories set in ordinal scale. Examples of such data are typological 'dating' or anthropological age categories. In order to make the ordinal categories comparable, they have to be transferred to a numeric scale. The usual solution to approach this problem could be termed „aoristic": The temporal categories are allocated a certain time span, and each year within this time span is then assigned a value proportional to the time span of the category as a whole. However, with the help of simulations in R we will show that this approach is flawed, at least when the categories overlap. In such sequences, the temporal ranges where the categories overlap tend to be overemphasised, leading to estimates which are simply wrong. To overcome this problem we present „aoristAAR", a function in R which downweighs such phases. We use aoristic raw data of archaeological cultural groupings as well as anthropological life tables (generated with „mortAAR") and compare it with the results after normalization with „aoristAAR".

Is there anything R can't do?

(*Joe Roe*)

From its origins as a statistical programming language, R and the R ecosystem has become the 'Swiss Army knife' of data science. There is a package for seemingly every quantitative computing task you can throw at it, whilst tools such as RMarkdown and Shiny extend its use beyond pure analysis. This raises the question: is there anything R can't do? In this talk I offer my personal reflections on an attempt to produce a doctoral thesis entirely in R – from the initial stages of research to the preparation of a final manuscript. This experiment entailed using R for a number of tasks where it was not the obvious first choice: as a tool for field data collection; as a GIS; for constructing agent-based models; for collaborating with colleagues using R Notebooks and Shiny apps; and for preparing for submission an R Markdown document and accompanying git repository. The experiment was a success in that I found that R was a robust alternative for most of these tasks. Moreover, distilling the research process into a single 'package' offered a number of advantages over a more intuitive, fragmentary approach using different softwares. However, rather than preaching entirely to the converted, I will highlight some areas where relying solely on R was unnecessarily challenging, and where it is perhaps better used to supplement to other tools, or avoided altogether – at least in its current state.

Reproducible research in archaeology using R & rrtools

(*Ben Marwick, Sophie C. Schmidt*)

In recent years many scientific disciplines have embraced methods to improve the reproducibility of their research. One of the most profound changes is from the old approach to analysing data by pointing-and-clicking with a mouse in commercial software, to a new approach based on writing scripts in free and open source programming languages. Using scripts substantially improves the computational reproducibility of archaeological research, greatly speeds up the transmission of new ideas and methods through the research community, and allows for richer engagement with published research. We review a spectrum of case studies showing how archaeologists have embraced the R programming language to make their research more reproducible. We introduce the rrtools package, developed recently with ISAAKiel, to make it easy for archaeologists to enhance the reproducibility of their research.

rkeos: A Toolbox for Archaeological Surveys

(*Néhémie Strupler*)

rkeos is a software package in development for the programming language R which aims to provide a set of tools to help manipulate and visualise data associated with archaeological surveys. Started as an output from the Panormos Project Survey (Strupler 2017), the package has two main objectives: 1) Providing functions and data-set templates to encourage standardisation in the collection and publication of archaeological survey data and 2) Comparability of different archaeological surveys to scale-up the analyses. The current work focuses on field-intensive walking surveys but a long-term goal is to include extensive surveys as well. In the talk I will present the rkeos package with live examples, some of the questions that arise when combining and comparing heterogeneous data-sets, discuss the selected strategies to address the old 'side-by-side survey' problem (Alcock and Cherry 2004) and illustrate the potential of rkeos to explore different patterns in the use of landscapes at a regional scale. Alcock, S. E. & Cherry, J. F. (Eds.), Side-by-side survey, 2004 Strupler, N. & Wilkinson, T. C. Reproducibility in the Field: Transparency, Version Control and Collaboration on the Project Panormos Survey, Open Archaeology, 2017, 3, 279-304

Exploring spatial autocorrelation in archaeological spaces using R: state of research and new developments

(*Francesco Carrer*)

Spatial autocorrelation describes how the value of spatial data varies as the distance between the data increases or decreases, and it is based on the general observation that, in a geographical space, near things are more related than distant things (Tobler's law). This property of spatial data, also known as spatial dependency, has proven extremely useful for the analysis of archaeological settlement patterns and assemblages, and it has contributed to explaining some important spatio-temporal processes at different scales: from the spread of cultural or socio-economical phenomena at continental level to the intra-site distribution of artefacts and ecofacts. Several statistical methods have been developed in different disciplines to assess autocorrelation (Moran's I statistics, Mantel test, etc.), and most of them are applied using dedicated R packages. In this paper, I will provide an overview of the methods currently used in archaeology, and I will describe the different R packages available. Furthermore, I will

explore the potential of new mathematical approaches to spatial dependency, I will show how these algorithms can be implemented using R and I will highlight their relevance for archaeological research. The purpose of this paper is to demonstrate that, for the analysis of spatial autocorrelation, R is more reliable, flexible and customizable than most of the GIS software routinely used by archaeologists.

Session 35
Ancient Near Eastern and Neighboring Regions: Enlarging Research Horizons through Digital and Computational Practices

Virtual Experimentation - Reasoning on the original appearance and use of a bronze implement from Pyla-Kokkinokremos (Cyprus) with high-resolution 3D models

(*Martina Polig, Sorin Hermon, Simon Jusseret, Jan Driessen, Giusi Sorrentino, Athanasia Kanta, Joachim Bretschneider*)

The use of 3D models in object analysis is not a widespread method and the few exceptions are mostly restricted to studies of prehistoric weapons and lithic tools. This study introduces a new type of object to this kind of approach: a bronze figurine composed of a human torso and head ending with a half-moon shaped spatula or blade. This find was brought to light in 2016 at the coastal site of Pyla-Kokkinokremos (Cyprus), a fortified Late Bronze Age settlement occupied for a short period of time in the decades surrounding 1200 BC (Late Cypriot IIC-IIIA). Archaeologically speaking, the object has very few, if any, parallels in the material culture of the region. The figurine was scanned with a high-resolution structured light scanner and further analyzed in a variety of software environments specialized in the visualization, manipulation and geometric analysis of 3D models. Through them, it was possible to observe previously unidentified decorations and, based on geometric and surface analyses, to formulate a hypothesis on the possible use and manipulation of the object. Following these analyses, we propose a virtual reconstruction of selected geometric features, which may suggest possible analogies with other figurines from the region. Moreover, we introduce the concept of virtual experimentation, through which we suggest how the object was handled and used. Our hypotheses were tested by further rugosity (smoothness) analyses of the surfaces of the figurine's edge and supported by the discovery of possible geometric alterations of its head.

The role of modern digital techniques in documenting and rehabilitating the Syrian heritage during the actual conflict

(*Youssef Kanjou*)

Syrian heritage is important not only for Syrians and the Middle East but to all the world, because there are historical periods in the life of humanity we can only find its evidence in Syria, such as the first early stages of the Neolithic revolution, which included the beginnings of agriculture, arts and architecture. The ongoing war in Syria has led to extensive destruction of archaeological sites, which have been affected by various types of damage, whether by explosions or robberies, and the local people left these sites. Given the nature of the conflict there, the international community and the archaeological authorities were unable to provide anything help to stop this destruction, in addition, the documenting processes were also rare except for some attempts to use satellites to illustrate the magnitude of damage that occurred in the Important archaeological sites like ancient Aleppo and the archaeological city of Palmyra. The most difficult task after the end of war is whether, what and how to restore the destructive effects, especially since there is a lack of documentation for these buildings before the war, as well as, the international laws prevent reconstruction and the use of modern materials in construction; under this discussion, comes the role of modern techniques based on the use Specific

new techniques as what done with the archaeological Palmyra Arch. In this paper, I present the status of the Syrian archaeological heritage during the war and the efforts that have been made to document the destruction.

Digital survey and documentation techniques for heritage conservation and enhancement: the Acheiropoietos Monastery, Cyprus

(Alessandro Camiz, Giorgio Verdiani)

The analysis of the Αχειροποίητος monastery shows the superimposition of different buildings: a domed church with a central plan, built in late Byzantine times over the ruins of an early Christian basilica, enlarged by the addition of three successive narthexes, and therefore transformed into a longitudinal basilica. The name Αχειροποίητος, literally "made without hands", referred probably to a sacred icon hosted therein. A walled enclosure surrounds the church and contains the monastery, which developed in subsequent phases, with different additions, demolitions and restorations. Following a digital survey, it was possible to outline the Monastery's formation process, from the V cent. Basilica, to the transformation of the monastery into military barracks in the 1970s, as a premise for the restoration project. The documentation campaign included a laser scanner survey for the entire architectural complex and the mosaics, a picture from motion survey only for the southern wing of the, a masonry and mortar survey outlining the different typologies, a spolia documentation, a documentation of the wooden artifacts, the complete damage analysis as a premise for the restoration project. The extensive use of digital techniques was of great help in acquiring all the data in the time-lapse of only one week, as compared to traditional survey techniques that would have taken probably several months. References DELAVAL COBHAM, C. (1908). Excerpta Cypria. Materials for a history of Cyprus. Cambridge: University Press. DE MAS LATRIE, M.L. (1855). Historie de l'ile de Chypre sous le regnes des princes de la maison de Lusignan, III, Paris a l'imprimerie impériale. DITTENBERGER, W. ed. (1903). Orientis graeci inscriptiones selectae: supplementum Sylloges, inscriptionum graecarum. Vol. II. Lipsiae: S. Hirzel. ENLART, C. (1899). L'art gothique et la Renaissance en Chypre. Ernest Leroux éditeur, Paris. HILL, G. (1948). A History of Cyprus. II. The Frankish Period 1192-1432, Cambridge: University Press. LEADER, R.E. (2000). The David plates revisited: transforming the secular in early Byzantium. The Art Bulletin, (82) 3, pp. 407-427. SPAIN ALEXANDER, S. (1977). Heraclius, Byzantine imperial ideology, and the David plates. Speculum, (52) 2, pp. 217-237.

The Early Mesopotamia and the Persian Gulf Research Project: An Online Solution for Aggregating Regional Legacy and Contemporary Data for Research

(Robert C Bryant, Steve Renette, Darren P Ashby)

The Early Mesopotamia and the Persian Gulf research project is the first phase of an effort seeking to collect disparate regional data and analyze intersections within it. Making disparate legacy and contemporary project data communicate is difficult, but necessary to: better allocate resources to preserve the region's endangered heritage, help standardize terminology across projects, and update existing interpretations. Online repositories may not entice legacy or contemporary projects with existing solutions, but a dynamic research tool that can give multiple projects access to a single, shared, robust database might. 'New' requires patience for colleagues not accustomed to digital tools, but our

project originally began with traditional analysis, and our developing system is recursively informed by the needs of our Ur and Al-Hiba legacy excavation datasets in southern Iraq that contain nearly 60,000 objects and richly detailed sherd counts that intersect with spatial contexts. We are using this new system to analyze intersecting patterns of cuneiform seals and ceramics from both sites within geospatial and temporal contexts. We will showcase cross-project analyses in our newly built web-application that heavily extends the Django web framework, which acts as a powerful generic database backend with an overlapping web content management system, and offer our system to interested parties who wish to contribute to this shared data project that provides easy record manipulation/creation, auto-publishing of content to a public front-end, research-oriented query tools that connect disparate project data, secured customized public and private access, and a prototype geospatial query implementation based on OpenLayers' Javascript libraries.

Routes and paths in Upper Mesopotamia: the formation of networks as a result of cultural and environmental factors

(*Marco Iamoni*)

The following paper aims at presenting an analysis of contact networks emerging across the Neolithic and Chalcolithic period in Upper Mesopotamia. Traditional GIS tools such as e.g. least cost path analysis will be used to verify the occurrence of such systems of routes. This paper will however demonstrate that more variables (e.g. cultural, economic) may affect the formation of nets of contact routes and that these variables can significantly alter the picture, producing a system of itineraries radically different from what one may expect by simply analysing the geomorphological characteristics of the territory.

GIS and the perspectives in the studies of the landscape of irrigation. On the example of Iron Age period in oases of Tedjen River (Turkmenistan)

(*Nazarij Buławka*)

This paper analyses an irrigated Iron Age landscape (Yaz I-III periods) in the oases located on the Tedjen River (Har-i Rud) in Turkmenistan. This includes the delta of the river and Serakhs oasis located to the south, which is a subject of study of a Polish team since 1995. Intensive field surveys conducted here since 2007 lave recognised c.200 sites of different periods. The irrigation is particularly important issue in the studies of Yaz culture material (1350-300 BC). Most scholars agree that Yaz III settlement pattern is related to political entities that existed during Achaemenid period in Central Asia (i.a. Bactria, Margiana, Aria and Parthia). The Achaemenids are famous for their development of sophisticated irrigation networks in Iranian Plateau. In Central Asia, however, the studies of irrigation are more complicated, because of homogeneous local Iron Age sequences. What is more, many areas represent "sinking" palimpsest landscapes, where preservation of ancient canals is significantly influenced by alluviation. This also concerns the oases of Tedjen River. For the purpose of field survey campaigns in the region, an ArcGIS database was created. It consists of satellite imagery, digital elevation models, topographic maps, the different vector data related to hydrology, ancient and recent occupation of the areas. It is used as a tool for the study of irrigation from the perspective of the theory of non-linear landscape evolution. The recent results brought to light new Iron Age sites in the Tedjen delta and

Serakhs oasis, which enabled us to reinterpret the settlement pattern and the landscape of irrigation of this period. The aim of the paper is to present the current state of research of landscape of irrigation in the region and analyse the reliability of the GIS methods that could be used in the study of levee-based irrigation. This consists of the analysis of topography, automatic extraction of irrigation network from DEM and CORONA satellite imagery analysis.

Evaluating Arabias trade routes with Least-Cost Path analysis

(Alexander Städtler)

The development of the trade routes of the Arabian Peninsula reached its peak during the late 1st millennium BC and early 1st Millennium AD in the context of the trade with aromatics originating from Southern Arabia. This study aims at modelling this routes networks using a GIS-based least cost path's method (LCP). Routes will be calculated combining a cost function based on topography (slope) and land cover. The results will be compared to the routes proposed according to the written sources and the archaeological information in order to 1) evaluate the established model and 2) define whether and how cost-efficiency was the sole and primary motivation and/or to which extent political and social factors influenced this communication and transport system.

Rebuilding the Oldest Archive in the History of Mankind in Digital Form: the Ebla Digital Archives Project

(Massimo Maiocchi)

The paper provides an overview of the Ebla Digital Archives Project, which focuses on a group of roughly 3.000 cuneiform tablets from Tell Mardikh (ancient Ebla, in western Syria), dated to the middle of the third millennium BCE. The documents cover a large variety of topics: deliveries of silver and gold, textiles, work management, agriculture, animal husbandry, international treaties, letters, vocabularies, literary compositions, ritual texts, etc. The presentation focuses on the digital methodologies developed in order to address the peculiar nature of these challenging sources, whose understanding – despite of the good progress made in the past decades – is still a work in progress. Languages (Sumerian, Old-Akkadian, Eblaite), script, and writing system of the Ebla texts are in fact incompletely understood. This situation pushes us to consider a number of different strategies and ad-hoc solutions in order to properly capture the complex nature of the documents, including: the development of a simple mark-up language, used to encode input transliterations; scripts in Python, Perl, and PhP, which parse input transliterations and populate a database; a PostgreSQL database, as main tool for data queries, with dedicated annotation and editing capabilities; N-gram modeling used to spot incoherent data within transliterated texts, as well as to offer hints on possible restorations of broken passages; network analysis, used to evaluate prosopographical connections within the archives, which in turn may help in the reconstruction of the internal chronology of the texts, as well as of the administrative patterns subsumed in the archives.

Structuring multilingual Datasets for Historical Research

(*Doğu Kaan Eraslan*)

My phd thesis concentrates on the relations between Miletus and Egypt during 664 - 332 BCE. In order to have a complete panaroma of the relations I have scraped from several online databases around 120 000 texts in ancient greek, and several other texts in ancient egyptian, imperial aramaic, old persian, and elamite. The data I had gathered varies from cross lingual onomastics, that is names attested in different languages to cross lingual toponymes. The amount of data I have, excludes manual exploitation, however recent advances in information extraction practices permit us to use ranking algorithms to deal with large amounts of data such as this. Furthermore, ranking algorithms are not the only tools one can apply in order to extract information from this dataset, due to the particularity of historical nature of the data, even simple boolean queries can yield suprising results. Structuring raw text data, obtained from keyword queries so that one can apply both ranking algorithms and boolean queries require careful planning. I shall present how I had structured the dataset in order to respond both, how I applied ranking algorithms like tf-idf with cosine similarity, and I shall expose some of the initial findings. I reserve the full discussion on the exploitation and findings to elsewhere. The goal of this paper is to give the reader an anatomy of the process in which the raw text data is structured in order to respond to historical questions that one might have. We shall see that the process resembles a lot how online search engines work with their data.

Advances in Computational Cuneiform Analysis

(*Bartosz Bogacz, Hubert Mara*)

Motivated by the demand in the Digital Humanities for quantifiable and computational analyses, we present a work-flow and principal tools for digital large-scale processing of cuneiform. Cuneiform tablets appertain to the oldest textual artifacts used for more than three millennia and are comparable in amount and relevance to texts written in Latin or ancient Greek. We present a complete digital analysis work-flow enabling modern text processing on the complex two-dimensional script. Our tools encompass the whole digital pipeline, from digitalization and wedge extraction to word-spotting and frequent pattern mining facilities. Tablets are being acquired from different sources requiring different methods for digitalization. Each representation is typically processed with its own tool-set. To homogenize these data sources, we introduce an unifying minimal wedge feature description. For this representation, we develop similarity metrics based on the optimal assignment of wedge configurations. Since this metric is also a dot-product in high-dimensional space, it enables the use of common kernel-based machine learning algorithms. We combine our feature vectors with work on segmentation-free word spotting using part-structured models. A tree representation of features is used to locate symbols on a dataset of tablets. Such a feature representation is applicable to any geometrical shape enabling the search of arbitrary geometrical objects. Common analytical tasks such as search, counting, and mining co-occurrences, not only of complex wedge constellations, but also of repeating geometric shapes are automated, and can therefore be feasibly performed on large datasets.

Digital Practices: How to Bridge the Gap to Encourage Collaboration
(*Vanessa Juloux, Alessandro di Ludovico*)

Digital technologies are being used in the study of the ancient Near East and Eastern Mediterranean for some decades, although its practice has not reached all subfields evenly. In particular, the research on ancient Western Asiatic civilisations has suffered - and in part still suffers - a gap between scholars who use solely traditional approaches and those who also employ quantitative and computational methods. What causes that divide and what can we do to encourage increased collaboration? From the heuristic and epistemological point of view there is no actual conflict between digital approaches and non-digital ones, especially since they all share the same basic intention: the interpretation of the relics of the ancient world. Thus, the challenge is to identify the cause of this gap and how to bridge it, and encourage a better collaboration and comprehension among scholars. After a short review on how digital practices have been significantly used so far in ancient Near Eastern studies - or can be used -, we propose to start a constructive open debate to draft recommendations, first to increase the accessibility of digital practices to a wider scholarly audience, and to improve collaboration between a diversity of scholars' profiles. To do this, not just the past approaches will be critically examined paying the due attention to basic theoretical and methodological issues: also the choices that have been made when using specific digital models and tools will be discussed.

Session 36
Advantages and Limitations of Spatial Applications in Archaeology

Established, ploughed and buried – spatial analysis of coastal field remains in Northern Estonia
(*Andres Kimber*)

North Estonian coastal plain around river Jägala provides an excellent opportunity to study prehistoric human-environment interaction. Numerous settlement sites, stone-graves and field remains ranging from the Mesolithic to the Viking Age form a uniquely rich microregion in Estonian archaeological record. Sea-level changes, isostatic land-uplift and formation of sand dunes enhance the dynamic settlement process. This talk will focus on Iron Age field remains and their connection to accompanying settlement sites. Prehistoric agricultural remains in the surrounding regions are nearly always evidenced by clearance cairns and baulks of stones. Plough layers and ard marks are seldom found or extant. In contrast the field remains on the lower reaches of river Jägala are buried under eolian sands and as a result have survived in much greater extent. By combining archaeological, geographical and geophysical data for spatial analysis, reconstruction of the landscape conditions before, during and after the fields is attempted. Limitations and possible solutions of this are discussed. This represents the first instance, when such prehistoric agricultural sites have been extensively studied in the Baltics. It can be demonstrated that coastal areas were continuously inhabited and cultivation of cereals was actively engaged on sandy soils, which have previously been thought to be unsuitable. This landscape analysis establishes a basis on which to search and distinguish field remains in a wider area, providing better insight to coastal settlement processes.

A GIS approach to assess coastal geoarcheological sites vulnerability index. Cases studies from Campania Region coastal area (Southern Italy)

(Pietro Patrizio Ciro Aucelli, Gaia Mattei, Angela Rizzo, Carmen Maria Rosskopf)

Along the Italian coast, numerous coastal archaeological sites are still recognizable and sometimes well preserved. Several remnants of production and building (urban) structures are today located very close to the shore or in some cases submerged. They represent a cultural value but also important proxies for the reconstruction of ancient coastal landscapes and their evolution. However, these sites are very sensitive to coastal dynamics including climate change effects and sea-level variations. In this context, the aim of this study is to provide a GIS index-method based on the analysis of multiproxy geodatabases for the evaluation of the vulnerability of coastal geoarcheosites to potential impacts of coastal processes. The method evaluates, by means of spatial tools, a number of indicators concerning landscape features, dynamics, physical and anthropogenic aspects. The values obtained for single indicators are overlapped through a logical overlay operation in order to calculate the value of the vulnerability index, which considers the potential damage to the total loss of the investigated asset, and ranges between 1 (null/very low) to 5 (very high). Preliminary applications to some coastal geoarcheological sites located in the Gulf of Naples (Campania, Southern Italy), have highlighted their high degree of vulnerability to near-future environmental and climatic changes. This geomatic approach has also demonstrated its versatility and suitability to manage geospatial environmental and archeological data providing useful information for the management of the coastal cultural heritage.

Relating Norwegian palynological records and archaeological datasets

(Christian Willmes, Espen Uleberg, Mieko Matsumoto, Helge Høeg)

In this contribution we present the first results of a project that aims to create detailed GIS-based paleoenvironmental information from a comprehensive dataset of pollen core data from Norway. This comprehensive dataset is created by the Norwegian paleobotanist Helge Høeg during more than 30 years. The pollen data comes from more than 300 drill cores and the main part of them are collected as part of archaeological excavation projects in South-Eastern Norway. Until now this data was published mostly in textual form as tables or as figures (pollen diagrams). The digital pollen count data itself has never been published and has therefore not been available for quantitative analysis before. The study will use quantitative statistics and software tools like R and GIS to create a comprehensive paleoenvironmental dataset of high temporal and spatial resolution for the last ~10.000 years of South-East Norway. This new paleoenvironmental data set of high temporal and spatial resolution, will help to better analyze and understand the Holocene history and archeology of Norway, by relating to archaeological spatial datasets from the Museum of Cultural History at the University of Oslo. This pilot study has a large potential for more advanced paleoenvironmental studies in Norway and neighbouring countries (especially for the Stone Age), and also for technical/theoretical refinement of GIS applications to archaeological metadata.

Landscapes of commerce: a spatial approach to local market systems

(*Eli James Sheldon Weaverdyck*)

Understanding local-scale, rural marketing systems is a significant challenge for archaeology. In the Roman world, literary evidence suggests that small-scale farmers frequently brought their produce to nearby towns and disposed of it in commercial transactions, but it is difficult to study this type of economic exchange from traditional archaeological materials because both the goods being sold and the containers in which they were transported were usually perishable. The coins involved were often spent in the town. Spatial analysis offers a way forward. Rather than relying on proxies like urban-manufactured goods to indicate an economic relationship, spatial analysis relies on distance, a structural constraint that could never be completely avoided in any exchange. Peasants who went to market frequently would have tried to minimize the time they had to travel by living closer to the marketplace while those farther away would not have been able to visit as often. By analyzing the distance between rural settlements and various potential markets—while simultaneously taking into account other factors that influenced settlement location—it becomes possible to estimate how important marketing was to the people living in the countryside. By varying the types of places considered as markets we can determine which places attracted rural settlement. In this paper, I will analyze the settlement patterns along the Lower Rhine and Lower Danube frontiers to test the hypothesis that garrison settlements functioned as markets for local produce.

Loessic Landscapes and Past Population's use: a Multidisciplinary Approach

(*Charlène Morel*)

This research focus on the relationship between human communities (from the Neolithic to the 15th Century) and the European loessic landscapes. Through the use of a GIS and a relational database both filled with archaeological (mainly information about sites) and environmental data (such as pedological maps and information, geomorphological analysis, DEM, etc.), I study the way humans exploit their surrounding landscape and its consequences. I would like to present my PhD's first results, which focus on the long term occupation and exploitation of the loessic landscape known as the Kochersberg in Alsace (France). The strength of human pressure on the landscape has evolved from the first implantations around the Neolithic to the establishment of the villages as we know them around the fifteenth Century. I use both archaeological and environmental data to figure out the potential impact of this pressure to the landscape. Of course, GIS is an essential tool to link those two different kind of data with the actual landscape in which they occur. I would also like to approach a key aspect of the human impact on its environment, which is taphonomy. Indeed, process that can be triggered by human exploitation, such as erosion, impact the way archaeological remains are preserved. This open question needs to be addressed in order to understand the repartition maps and the site conservation better.

Advantages and Limitations of Spatial Applications in Archaeology

(*Francesco Carrer, Davide Visentin*)

The increasing amount of archaeological data for the Alpine region has improved our understanding of high-altitude colonisation during the early Holocene. This, in turn, has enabled the reconstruction

of hunter-gatherers' settlement strategies in the subalpine and alpine zones of mountain ecosystems. However, it is widely acknowledged that prehistoric dataset available for the high-Alps might not be representative of past occupation of the territory, as they are likely to be influenced by the non-uniform survey strategies of archaeologists and by the higher or lower archaeological visibility in specific areas. Nonetheless the weight of this possible bias in the distribution of known evidence is not clear. The reliability of available data should not be taken for granted, it should instead be assessed. In this paper we applied Point Pattern Modelling to the analysis of Mesolithic settlement pattern in a sample-area of the Alps (Cadore, Veneto region, Italy). By using a multi-model selection procedure, we tested two alternative scenarios: (a) the distribution of archaeological sites depends on hunter-gatherers' settlement strategies; (b) the distribution of archaeological sites depends on archaeological survey strategy and visibility. These scenarios were designed in GRASS GIS and R, using morphology, land-use/land-cover and current mobility routes as proxies. The results suggest that, although archaeological biases partially affect current datasets, an accurate reconstruction of hunter-gatherers' landscapes can be achieved and should consider their mobility strategies.

A 3D geo-electric resistivity approach to assess Neolithic/ Palaeolithic sites in the Southern Gargano Area, Apulia, Italy

(*Ivano Rellini, Michael Maerker, Patrizio Torrese*)

The study area close to Manfredonia, Southern Gargano, Italy is characterized by important archaeological sites (Occhiopinto Cave). We investigated the area north of Manfredonia in order to get an idea of cavities and their spatial distribution in the subsurface. A parallel setting of transects was applied in order to perform a 3D model of the underground structures. Therefore three different arrays were tested, Dipol-Dipol; Wenner and Schlumberger. The utilized electrode spacing for the surface transects was 2m. In order to calibrate and validate the analysis we made 3 core drillings yielding information on the stratigraphy and cavities in the underground. With the given value ranges and the respective electric resistivity arrays we were able to identify the location and depth of the major cavities in 3D for a ca. 25 ha test plot area. To carry out the 3D modelling we used an inverse modelling method taking into account different information from the 3 arrays and the core drilling for calibration purposes. The method clearly shows the advantage of these techniques to explore underground features and detect new archaeologically relevant cavities in the karstic area of Manfredonia. Moreover, we present the results in combination with additional environmental reconstructions.

Paleolandscape Characterization: An integrated work

(*Geraldine Quénéhervé, Michael Maerker, Felix Bachofer*)

In this study we want to characterize the paleolandscape and related environmental characteristics with an integrated digital pedo- geomorphological mapping approach. The Lake Manyara area is the focus of several paleo-archeological investigations. The Manyara basin is located approximately 70 km east of Olduvai Gorge, where important paleo-anthropological artefacts are traced back to Homo habilis. In the Manyara basin itself, two hominin-bearing sites (0.78 to 0.633 Ma) and plenty of vertebrate bones and teeth as well as stone artefacts from different periods were discovered. We analyzed and characterized the soil and lithological features as well as the geomorphological structures

and forms through detailed fieldwork using geophysical sensing approaches, laboratory analysis of soil and substrate samples and remotely sensed data. The latter consist of high-resolution WorldView-2 data, TerraSAR-X data, medium-resolution ASTER spectral bands and indices, as well as ENVISAT ASAR images and SRTM-X-derived topographic parameters. The study case shows that we can derive high-resolution information about vegetation status and density, substrates' mineral composition, soil characteristics as well as about geomorphological, tectonic and lithologic forms and features. This combination of the derived information layers allowed to deduce paleolandscape features such as lake levels and related depositional structure. Finally, the results of the integrated approach have been used to characterize existing find locations and to predict the spatial distributions of potential archeological sites.

Europe's Lost Frontiers: To the Limits of Mapping and Modelling
(Andy Iain Fraser)

Mapping continental shelves submerged by early Holocene sea-level rise has been based, historically, on modern bathymetric data. However, the sea floor is extremely mobile with thousands of tonnes of sediment obscuring features intrinsic to our understanding of the landscape as a terrestrial environment, populated with fauna, flora and the settlement and migration of people. Europe's Lost Frontiers project looks to determine the actual topography beneath the seafloor by using seismic survey data. Picked horizons on 2D seismic lines can reveal river valleys and the gradual transgression of the water table. 3D blocks can be time-sliced to precise amplitudes to recreate elevation models. By combining 2D and 3D datasets, it is possible to grid these with average modern bathymetric depths to give a more precise map of the lost lands of the North Sea for use within a GIS. These data are used to guide a programme of sediment coring to investigate organic components, microfossils and ancient DNA. Additional ground-observation for depth and dating of the seismic stratigraphy allows qualitative, predictive modelling of resources, faunal and floral distribution on wide-scale or focused areas for investigation. The geophysical data gathered in this research covers boomer, chirper, geostreamer FWI and SWIM technologies collected over many years. This research utilises these data for the first time to propose combinations most suited for preservation in an archaeological context and suggests, by spatial analysis, the most cost effective and predictive methods in which such data may be utilised in the future.

Past settlement structures vs modern archaeological recognition. Case study of Eastern Pomerania at the turn of Bronze and Iron Age
(Kamil Niedziółka)

This paper presents the results of studies focused on the settlement changes on the south coast of the Baltic Sea (Eastern Pomerania) during the late Bronze Age and Early Iron Age. As a part of this research various kinds of spatial data linked with local environment are used (i.e. digital models of soil cover, geomorphology structures, watercourses or geobotanical zones), in conjunction with the locations of archaeological sites from the selected test areas. Our initial spatial analyses showed that only a very general pattern linking environmental factors with the distribution of archaeological sites from mentioned periods are indicated. However, this may actually be more a reflection of the archaeological

recognition factors selected as being indicative of past settlement structures, and may instead be conditioned by quite contemporary factors. Having this in mind a number of further spatial analyses were conducted. The distribution of archaeological sites was investigated from the point of view of the presence of contemporary settlement structure (villages, cities, roads, etc.), larger investments, activity of singular archaeologists and shape of wood cover. Our results clearly indicate that modern factors may have an strong influence on the distribution maps of various archaeological assemblages. It also suggest that any kind of settlement studies should be preceded by this kind of analyses.

Session 37
Connectivity: linking and interpreting the archaeological record

Driving interdisciplinary search for collaborative studies of long-term human ecodynamics

(*Rachel Opitz, Colleen Strawhacker, Philip Buckland, Gisli Palsson, Peter Pulsifer, Lynn Yarmey, Emily Lethbridge, Ingrid Mainland, Anthony Newton, Richard Streeter, Tom Dawson, Jackson Cothren*)

The dataARC project aims to encourage interdisciplinary collaboration throughout the research process in projects focused on the long-term human ecodynamics of the North Atlantic. An inherent challenge of interdisciplinary work is that it requires us to engage with the slightly alien ways of thinking and organizing information used by our colleagues who specialize in different types of data analysis. Doing so can be laborious, requiring extended explanation and discussion of each domain's assumptions, and may seem unprofitable as it is clear each researcher will not become expert in the other's area. dataARC is attempting to support interdisciplinary work by developing a data discovery tool that provides intentionally interdisciplinary search result sets and contextualizes the results from each domain within a shared conceptual model. In practice, the project is creating a data discovery tool that brings back both results directly related to a search and connected results, and provides explanations for the links between them. The creation of structured and contextualized, intentionally interdisciplinary result sets requires that we define the levels of granularity at which data elements operate, connections between data elements to form basic ideas, and connections between specific ideas and broader, overarching concepts. This paper presents the data structure and knowledge model developed within the dataARC project and discusses the challenges encountered in operationalizing these structures to produce useful, intelligible search results that can enable interdisciplinary teams to share their data and understandings of that data with more confidence and clarity.

Discovering Hidden Connectivity

(*Ceri Binding, Douglas Tudhope*)

Knowledge Organization Systems such as thesauri and gazetteers contain authoritative domain knowledge with provenance. Their structure can guide query expansion, and their data can be used to discover associations between records in disparate multilingual datasets. This paper discusses use of thesauri to enhance connectivity via semantic enrichment for a recent data integration case study. The

EU-FP7 ARIADNE project integrated metadata from European archaeological data infrastructures into a common research portal. In one exploratory strand of that work we developed a dendrochronology themed data integration case study using the CIDOC Conceptual Reference Model (CRM) and the Getty Art & Architecture Thesaurus (AAT) to combine selected archaeological datasets with data extracted via NLP from grey literature reports. Once the multilingual data was enriched with AAT concept identifiers the thesaurus structure facilitated query expansion and provided a mediation mechanism for cross-search. This approach also ameliorated the effects of observed differences in indexing practices by different organizations. We encountered data referencing names of plant materials or their species or genus but no link between them (e.g. Salix/Willow, Quercus/Oak, Fagus/Beech). However the AAT contains 18,000+ instances of 129 specialized concept relationship types with richer semantics than simple associative links e.g.: • Evolutionary hierarchies (2833_ancestor_of) • Chronological relationships (2809_coexisted_with, 2811_preceded, 2812_followed) • Links between animal/plant species and materials derived from them (2841_derived_made_from, 2842_source_for) Concept 300011948 "beech (wood)" has a specialized (2841_derived_made_from) relationship to concept 300343877 "Fagus (genus)" – so enriching the datasets with AAT concept identifiers aided the discovery of these hidden unstated links that might not otherwise be detected.

The Grand Challenge of interlinking palaeoenvironmental data and interpretations
(*Philip Iain Buckland, Mattias Sjölander, Rachel Opitz*)

Palaeoenvironmental data are derived from a wide variety of analysis methods, archaeological and geological contexts, and spatio-temporal situations. Different environmental proxies complement each other in terms of the evidence they provide for different aspects of the past, and provide information at different resolutions. In order to understand landscape changes, and human parts in these, it is thus necessary to aggregate and integrate a variety of data. With some work, and sufficiently high resolution metadata, individual datasets can be linked or aggregated in terms of space and time. This results in large and complex (meta)datasets which require multiple domain experts to understand and interpret. Many archaeologists however, would prefer to meet the data at the next level up, as users of the interpreted results from individual proxy analyses, where advanced knowledge of the analysis methods is not required. This not only requires a different approach to linking, such as the use of higher level concepts (e.g. indicators of woodland or openness in a landscape), but also has implications for the type of interpreted data that are made available for linking. It also has significant implications in terms of research transparency, as it is more difficult to ensure adherence to FAIR data principles (or similar) when the delivering synthesised or interpreted data to portals and tools. This presentation will use data in the Strategic Environmental Archaeology Database (www.sead.se) to provide illustrations some of the challenges and possibilities when providing and using interpreted data in a multidisciplinary research context.

Peripleo 2: connecting and exploring archaeological data
(*Valeria Vitale, Rainer Simon, Leif Isaksen, Elton Barker, Rebecca Kahan*)

Connectivity is by now a common approach for understanding and investigating archaeological material. But how can the opportunities afforded by digital connectivity—in the form of linked open data—be best exploited to represent informative relationships? Using the linking potential of semantic technologies, Pelagios Commons has been pioneering a means of mutual contextualization, whereby

any online document—be it a text, image, or record—can be connected to another simply by virtue of having something in common with it. This linking is achieved through semantic annotations: the challenge then is to visualise these links and enable users to navigate through them. This is where Peripleo, Pelagio Commons' visualisation tool, comes in. Building on our (DH2016) award-winning prototype, Peripleo 2 enables users to explore the spatial, temporal and thematic connections of distributed digital collections in their entirety, and then to progressively filter and drill down to individual records. This paper will set out the choices made in design and the issues they addressed, including: - enhancing interoperability of the data; - matching identical items in different databases; - ensuring transparent connections to original sources; - using a map visualisation that emphasises semantic, rather than topographic, connections; - providing filtering options (by person, theme and time period). In its latest iteration, Peripleo offers a useful means for performing targeted queries as well as discovering trends and patterns that only become evident when sources are semantically linked. An interface which empowers users to tap into and navigate heterogeneous online collections is crucial if the utility of lightweight linking approaches is to be demonstrated.

Interoperability of heterogeneous archaeological research databases
(*Xavier Rodier, Olivier Marlet*)

Archaeology and Territories Laboratory of CITERES in Tours works on corpus of data compiled from several sources (material, written, iconographic, environmental). First databases were implemented in the early 1990s to manage and analyse these corpus. Thus, the laboratory's information system was gradually built up. The priority when setting up these databases has always been to ensure that they are as specific as possible in order to meet the objectives of each research theme. These different databases deal with objects at different scales. They come in different formats and tools depending on when they were developed. They are not intended to become or integrate a single system. However, the question of their interoperability with each other and with other information systems is crucial for the dissemination and publication of data. This is why this work is part of the larger framework of the national consortium Memory of Archaeologists and Archaeological Sites (TGIR Huma-Num), itself connected with international infrastructures. To this end, we have conducted an analysis of all our databases in order to position them in the Berners-Lee graduation, Five Stars LOD. Thus, we assess the work needed to move our databases towards interoperability. Regardless of the granularity of the database and its format, we have chosen to match them with the CIDOC-CRM reference ontology in order to present them in the LOD as heritage data. The ultimate objective is to exploit these resources to explain the inferences of archaeological reasoning and thus strengthen the demonstrations in new formats of scientific publication.

Novel Approaches to the Re-Assembly, Re-Association and Re-Unification of Cultural Heritage Collections – The Gravitate Project Solution
(*Sorin Hermon, Michela Spagnuolo, Chiara Eva Catalano, Giusi Sorrentino, Martina Polig, Stefano Modafferi*)

The vast majority of archaeological objects are discovered in a fragmentary state, and the poor state of preservation. Moreover, pieces of historical importance and interest may be dispersed across

different collections and museums: accidents, wars, natural disasters, human intervention or the ravages of time, often causes the fragmentation of important art pieces and make their reassembly difficult and even impossible due to missing, eroded parts or different ownerships of fragments of a same object. In other cases objects cannot be reached physically, due to various restrictions, such as storage, permanent exhibition or fragility of their preservation state. The paper will introduce innovative digital tools developed by a team of researchers within the EU funded project GRAVITATE to offer a solution to the above, based on an integrated approach to the R3 Cultural Heritage challenge: Re-assembly, Re-association, Re-unification. Such tools include the integration of semantic description and search with 3D geometry analysis and semi-automatic features recognition, natural language processing for extracting information from non-structured texts and colour / shape matching based on similarities of descriptors and features. The structure and functionality of the GRAVITATE platform will be showcased through the presentation of real archaeological material, such as the 6th century B.C. Salamis (Cyprus) collection of fragmented terracotta statues, unearthed in Cyprus more than a century ago and since then divided among Cyprus and major UK museums.

Assemblages of networks: tracing the connectivites of the medieval Icelandic farm.
(Gisli Palsson)

It is a truism nowadays to say that an archaeological site is embedded in extensive networks of relations. But just what are the implications of this networked thinking, and how far do these networks extend? The author has appended Iceland's largest site register Ísleif with a PostGIS database based on an integrated analysis of archaeological sites and historic land census recurds, foregrounding the relations between farmsteads. The case study details how surveyed archaeological sites have been embedded in a historical context. The case study does not employ the methods formal network analysis. Instead, it considers the emergent properties that arise from farmstead connectivity, and the way in which relations between farms materialize in the historic landscape. In particular, several distinct but overlapping networks demonstrably influence each other and lead to forms of complexity that formal quantitative approaches might miss. The case study addresses current practices in archaeological network analysis by focusing on the link rather than the node, and uses both qualitative and quantitative methods to move from a straight line to an embedded, storied line, providing context to how places are connected. In this way, the link becomes a path of transaction, with a spatial and material dimension.

Exploring the movement, exchange and transformation of metal in the Eurasian Bronze Age and Early Iron Age through multi-dimensional arrays
(John Pouncett, Mary Saunders, Peter Hommel, Peter Bray, Mark Pollard)

The complex relationships between people and metals can be explored through the analysis of the attributes of individual metal objects ('form') and by situating that analysis within the broader context of the circulation of metal at a given time and place ('flow'). 'Form' and 'flow' can be inferred from the trace element composition, alloy composition, artefact typologies and life histories of metal objects – attributes which are dynamic and may change through practices such as recycling and reuse. In the case of trace element composition, inferences are based on semi-quantitative analysis of the

presence/absence of a suite of trace elements, with presence defined as >0.1%. The unique combinations of the trace elements have been referred to as copper groups – a term which is misleading and has been misinterpreted, with the copper groups incorrectly interpreted as sources of ore. This paper sets out an alternative approach to the characterisation of trace element composition based on multi-dimensional arrays. The suite of trace elements used to define copper groups can be represented as a two-dimensional array, with the presence/absence of elements defined by the values in the array and the relationships between the elements described by the properties of the array. This approach can be extended to include both different suites of traces elements and other attributes such as alloy composition and artefact typology, and can be applied at scales from the level of an individual artefact to a region or continent.

Learning through doing: an online game for appropriating ontological modelling methodology

(*Anais Guillem, George T. Bruseker, Nicola Lercari*)

The adoption and elaboration of ontologies to represent and integrate archaeological data into semantic graphs offers both the potential to bring together disparate datasets in a linked open data environment and to enable testing of formal theories on semantically represented data. This potential is stymied by the relative lack of practical methodological knowledge of how to apply formal ontologies in the field of archaeology. Standard presentations of ontologies introduce ontological models in the abstract, but there is a dearth of material to introduce how to practically understand and critically deploy an ontology to represent data for actual use. If archaeologists are to adopt and deploy ontologies as part of their standard set of research methods, tools must be created to allow them to learn and apply these models. This paper will present an innovative tool for self-learning of CIDOC CRM ontology. Based on previous research that developed a card based ontology learning game, this paper presents an online single player game that presents users with mappings scenarios and allows them to test their understanding of an ontology in a live environment with feedback generated by an ontological reasoner. The game aims to provide an environment for interactive learning of an ontology and quick feedback on correct/incorrect application of concepts.

Session 38
Applicability of Digital Archaeology Tools

The Use of Databases in Archaeological Excavation Teams and By Archaeology Scholars in Turkey

(*Tuğçe Köseoğlu*)

In the light of recent developments in technology, researchers must employ database management strategies to store their data. This project aims to understand the database management strategies of archaeologist in Turkey, both Turkish and foreign. To achieve this, a survey was devised. The survey includes questions about database management practices, including but not limited to the awareness of archaeologists about the tools they possess, the efficiency and overall performance of tools. The

survey has been sent out, and the answers will be recorded anonymously and then analyzed; and a report showing the current trends and challenges will be formed. The methodology, results and discussion will be presented at the conference. This project is still under development and currently no results are available. In the near future answers will be collected and analyzed. The gathered information can serve as a first step for creating online or offline database tools which are more suited to archaeologist's needs based on their grasp on the subject. It is hoped that this work will allow a better understanding of the use of databases and lead to improvement in their contribution to archaeology in Turkey.

The "optimal route" towards a topography based least-cost analysis with push-button GIS tools

(Oliver Vogels)

Least Cost Analysis (LCA) found its way to the standard toolsets of terrain and topography based archaeological modelling such as Site Catchment Analysis, Spatial Network Analysis, and Agent Based Modelling. However, many archaeologists use push-button GIS tools not being aware of the drawbacks and limitations of the complex processing steps behind the procedures. Today an increasing number of LCA tutorials is available (online). But since each has its own processing outline leading to somewhat disparate results, one of the most important steps in least-cost modelling is some goodness-of-fit statistics to evaluate the LCA. But often the archaeological evidence is too small to prove the final results. The Brandberg/Dâureb in Namibia is ideal for a revision of topography based least-cost modelling. It covers an area of c. 575 km² and ranges from c. 500 m to c. 2573m a.s.l. During the past forty years some 840 rock art sites have been documented in the western Dâureb. Due to the massifs complex topography and its unchanged climate, it provides perfect conditions for archaeological anisotropic least-cost modelling. Here, routes from outside the mountain to the 23 largest sites (≥ 250 depictions, above 1500m a.s.l.) explain the location of further 626 rock art sites along the modelled least-cost paths. The sites serve as an acid test for different modelling routines and user input issues. Even more important for the current LCA discussion, the region yields ideal conditions to evaluate different types of and modifications to the backbone of the LCA: the cost function.

Modelling the prehistoric copper district of the Oberhalbstein in Switzerland: Part I: High resolution 3D documentation of high alpine mining landscapes

(Christoph Walser, Amanda Zwicky, Leandra Reitmaier-Naef, Rouven Turck, Philippe Della Casa, Thomas Reitmaier)

Since 2013 an ongoing project based at the University of Zurich and the Archaeological Service of the Canton of Grisons investigates the prehistoric mining landscapes of the Oberhalbstein region in the Swiss canton of Grisons. The run for copper ores and the subsequent processes in this area took mainly place in the subalpine and alpine zones (1500 – 2500 m asl). The sites the project is dealing with in this scenic yet relatively defying environment vary from underground mines to smelting sites in woodlands up to vast mining districts covering areas of several hectares in altitudes of 2200 m a.s.l. and above. To gather the whole spatial information from within these different sites the 3D data acquisition was one main focus point of this research. In order to achieve this mission mostly an image-based approach

using structure from motion technology has been applied. For the mapping of the high alpine mining spots and their surroundings the regional base geo-data (ortho-imagery, DTM) provided by the authorities does not necessarily offer the resolution needed for the fieldwork or further desktop-based analysis. This is particularly applicable for the areas above 2000 m a.s.l. Despite its challenging mountainous character these mainly tree-less zones offer the possibility to rather easily map bigger areas using UAVs. With this Poster we would like to present a case study showing the workflow and potential outcome when using low-cost drones and image-based modelling techniques for mapping prehistoric mining sites in (high) alpine regions in comparison to other available data sources.

Modelling the prehistoric copper mining district of the Oberhalbstein in Switzerland Part II: 3D documentation of high alpine mining and smelting features

(*Rouven Turck, Anja Buhlke, Christoph Walser, Amanda Zwicky, Leandra Reitmaier-Naef, Philippe Della Casa, Thomas Reitmaier*)

Since 2013 an ongoing project based at the University of Zurich and the Archaeological Service of the Canton of Grisons investigates the prehistoric mining landscapes of the Oberhalbstein region in the Swiss canton of Grisons. The run for copper ores and the subsequent processes in this area took mainly place in the subalpine and alpine zones (1500 – 2500 m asl). The sites the project is dealing with in this scenic yet relatively defying environment vary from underground mines to smelting sites in woodlands up to vast mining districts covering areas of several hectares in altitudes of 2200 m asl. and above. To reconstruct numerous mining and smelting features the 3D digital data acquisition was latterly introduced in current fieldwork documentation. Especially an image-based technique using structure for motion technology has been established. Applying suitable lightening techniques, even data acquisition (photo shooting) of dark and twisted mining galleries are practicable. Applying "classical" 2D-drawings and sfm-based 3D-models of metal smelting features different levels of examination and visualization can be reached. With this poster, we would like to present a case study showing the workflow and potential outcomes of using image-based modelling techniques. Mapping prehistoric mining activities and smelting furnaces is herby compared to classical fieldwork documentation (e. g. Seigerriss). The advantage of digital techniques are higher resolution and better structured spatial information.

The weight of functional context in the analysis of ceramic patterns: a Correspondence Analysis test

(*Marco Iamoni*)

Correspondence analysis has been traditionally used to explore or search for less visible aspects of ceramic bodies of data. This has frequently dealt with the analysis of functional as well as of chronological aspects. The excavation at the site of Qatna of a substantial assemblage of pottery from diverse MB and LB contexts permits, however, to demonstrate the intrinsic relevance of the contexts of provenance: it suggests that the addition of diverse corpora can significantly affect the results obtained and propose a further use of CA as ideal statistical tool for a deeper exploration of the nature of the ceramic assemblages and their corresponding weight within CA.

Some tools to prepare, cluster and visualise data

(Martina Trognitz)

In archaeology it is not uncommon to try to classify large data amounts based on either numeric or categorical attributes. The large amount of data requires an automated process and usually the number and nature of the classes is not known beforehand. Therefore using clustering, a method from unsupervised machine learning, comes as a natural choice. A variety of freely available programming libraries and standalone tools for clustering will be presented and evaluated against a mixed multivariate data set describing Minoan and Mycenean multi-sided seals from the „Corpus der minoischen und mykenischen Siegel" (CMS). The dataset contains all kind of attributes, of which some can even be a bag of values (i.e. contain multiple values at once). Preparation of data plays a prominent role which is why tools to accomplish this task will be presented along some lessons learned from the practice. The talk will end with a short overview of appropriate tools and mechanisms to visualise clustering results.

Digitization issues in documenting cultural heritage with drones: the case study of Foinikas, Cyprus

(Kyriacos Themistocleous, Diofantos Hadjimitsis, Jeff Fagerman, Elaine Biggs, Rachel Waugh)

This paper will examine the use of traditional photogrammetry and LIDAR for documenting cultural heritage site. The case study area was Foinikas village, in the Limassol district of Cyprus, which dates back to the 11th century and has been abandoned from 1960, following the construction of the nearby Asprokremmos dam. Traditionally, photogrammetry has been used for documentation, by processing aerial images acquired from UAVs. However, with the recent development of new lightweight LiDAR scanners, it is now possible to mount professional grade LiDAR sensors on UAVs, which can be used to document areas with high accuracy, especially those with vegetation penetration. In this study, the village of Fionikas was documented using both photogrammetry and a LiDAR scanner attached to a UAV. The LidAR scanner and the processing were provided by LidarUSA. The results of the study found that both methods used provided high accuracy in the documentation of the site. The various technical issues and challenges that occur during the documentation process of an archaeolandscape will be discussed in detail, as well as the benefits and drawbacks of each methodology. Such technologies are becoming common practice in documentation of cultural heritage as they result in enhanced understanding for archaeolandscapes and for cultural heritage experts; however, these technologies present limitations.

Session 39

Heritage Beyond Boundaries: Developing Standards and Storefronts for Immersive Technologies in Archaeology

Immersive Experiences and Archaeology Workbenches with Digital Heritage Data

(*Jiawei Huang, Jan Oliver Wallgrün, Claire Ebert, Jiayan Zhao, Jaime Awe, Alexander Klippel*)

Virtual archaeology, which aims to test hypotheses, communicate to the public, and facilitate collaboration with virtual environment (VE) was introduced in 1990. In recent years, the advance in immersive technologies (AR, VR, and MR) provides increasing accessibility to new solutions and opportunities in the realm. We used SfM (structure from motion) as data-capturing tool to create 3D models that are both photorealistic and geometrically-correct for the ancient Maya site of Cahal Pech, located in the Belize Valley of the west-central Belize. Its cultural significance as the seat of an important regional kingdom governed by a dynastic lineage was revealed from the discovery of temple pyramids, stone monuments, and the elaborate royal burials dating to the Classic period (~AD 300-900). Based on the 3D models, we created immersive experiences as well as archaeology workbenches. We enable a basic "archaeological tool kit" including measurement, sketching, documentation, and other interactions with structures and artifact within. Further, we offer a gateway to the archaeological database to connect visualization with real-time data viewing and query. The immersive experiences and workbenches dissolve distance, time, cost and safety barriers, and enable virtual site visit and off-site data viewing and analysis.

Immersive Technologies and the Theories of Place

(*Alexander Klippel, Danielle Oprean, Claire Ebert, Jiawei Huang, Jan Oliver Wallgruen*)

In this paper we conceptualize understanding archaeological sites in light of emerging immersive technologies and access to increasing amounts of 3D information. In order to understand both potentials and challenges, we use a recent case study where we created immersive experiences of the Mayan City of Cahal Pech using a range of technologies (e.g., high resolution 360 cameras, structure from motion mapping). Digitizing the actual site is complemented by historic model building, interactive experiences in both mobile and computer based settings using game engines, and the integration of a range of media such as video and 3D models of artifacts. With this setup, it is now possible to theorize and test how understanding and access to archaeological sites through space and time is changing in the light of immersive technologies, how the psychological distance is reduced both spatially and temporally and what this means for understanding ancient civilization. Additionally, we consider how theories of place jointly offer a framework for testing which factors of place, as a combination of location and meaning, are important, accessible through immersive experiences, and are challenging to replicate. Theories in spatial cognition help to frame hypotheses on the effects of the perspective changing nature of immersive technologies. Examples such as aerial and pseudo-aerial images that allow for seeing patterns and ultimately understand processes as well as facilitating learning the layout of an environment. We are combining theoretical, technical, and empirical approaches to detail the value immersive experiences are adding to cultural heritage research.

Session 40
Science and Technology (S&T) for Archaeology and Cultural Heritage in the Eastern Mediterranean

Computer-based Cross-disciplinary Research in Historic Mediterranean Cities
(*Nikolas Bakirtzis, Sorin Hermon, George Artopoulos, Thilo Rehren*)

The paper promotes theme-driven, computer-based interdisciplinary research as the key methodological approach to innovative opportunities and present-day challenges in the study, preservation and valorization of cultural heritage in the Eastern Mediterranean. Specifically, this paper provides an overview of current research on historic Mediterranean urban environments led by the Science and Technology in Archaeology Research Center (STARC) of The Cyprus Institute. Developing and implementing innovative digital technologies, methodologies and scientific applications in a multi-disciplinary environment, STARC has been pursuing research in historic urban environments. Based on broad inquiries in the history and archaeology of the Eastern Mediterranean, research aims at the integration of sciences and technologies for Cultural Heritage research. Data management and analysis in digital libraries such as DIOPTRA: The Edmée Leventis Digital library for Cypriot Culture, is a necessary priority in the study and preservation of historic cities' cultural complexity. In this context, this paper provides an overview of novel research related to historic urban environments, their sustainable study and preservation drawing from transregional programs, such as the Getty Foundation-supported project on medieval Mediterranean cities, or the European Research Infrastructure for Heritage Science (E-RIHS) that supports research on heritage documentation, interpretation, preservation, and management. Other projects, like the CyI - University of Illinois National Center for Supercomputing Applications study of the Paphos Gate in Nicosia, the use of Virtual Reality to study space and identity in divided cities, or the 3D monitoring of preservation conditions at the Tombs of the Kings in Paphos offer additional instructive insights.

Predicting soil erosion based on Revised Universal Soil Loss Equation (RUSLE) using NDVI time series and high resolution DEMs: the case study of the Unesco World Heritage Site of "Nea Paphos", Cyprus
(*Athos Agapiou, Vasiliki Lynsadrou, Marios Tzouvaras, Branka Cuca, Stefano de Angeli, Fabiana Battistin, Maria-Christina Salvi, Nicola Masini, Alessio Di Iorio, Diofantos G. Hadjimitsis*)

The paper presents the results from the Revised Universal Soil Loss Equation (RUSLE) application and the elaboration of a soil erosion risk map at the wider area of the Unesco World Heritage Site of "Nea Paphos", located in the western part of Cyprus. RULSE as one of the most widely adopted equations used for mapping the soil loss from water, has been applied in this area using high resolution DEM and annual rainfall data from several meteorological stations of the Paphos District. A multi-temporal methodology was followed via time-series data derived from freely distributed satellite sensors. These data were processed to estimate the NDVI, which was linked with the land cover of the area. The overall results were then compared with existing RULSE products derived from medium resolution DEM, as well as with the European Soil Data Centre products with a spatial resolution of 100 meters.

Moreover, an archaeological vulnerability map was obtained by the mapping and detection of buried and exposed archaeological structures. This study demonstrates how the RUSLE method can integrate both earth observation and DEMs in a Geographical Information System to acquire a soil erosion risk map related to cultural heritage sites. This integration provides valuable information, both in terms of visualization and quantification, regarding the potential threats on archaeological sites occurred from water soil loss. Such results can be used by the authorities responsible for heritage sites protection and management, in the framework of a systematic monitoring, also applicable to other sites of the island.

Towards an Integrated Methodology for the Hazard Assessment and Monitoring of the Monuments of the Town of Rethymno, Crete

(*Apostolis Sarris, Chliaoutakis Angelos, Argyriou Lemonia, Argyriou Nasos, Papadopoulos G. Nikos, Cantoro Gianluca, Manataki Meropi, Papadopoulos S. Nikos, Oikonomou Dimitris, Tzigounaki Anastasia, Giapitzoglou Kostas, Kontogianni Vicky, Antonaki Valia, Karamanliki Panagiota, zouzoula Eugenia, Alertas Nikos*)

Operating under the auspices of STORM (Safeguarding Cultural Heritage through Technical and Organisational Resources Management) project funded under EU Horizon 2020 programme, GeoSat ReSeArch Lab of FORTH and EFARETH have joined their forces to study the impacts of climate change and natural hazards on the monuments of the old town of Rethymno in Crete. Considering the protection and conservation of European Cultural Heritage as of primary importance for various sectors of the society, STORM focuses towards an integrated methodology for the hazard assessment and monitoring of various factors having natural, climatic and anthropogenic origin. Aiming at developing a preventive strategy for the monuments of the old town of Rethymno, a number of techniques spanning from photogrammetry and 3D laser scanning to time-lapse geophysical imaging, climatic monitoring, crack observations, and pXRF analysis has been applied to selected monuments to study the associated risks that threaten the particular site. On top of the application of these non-invasive and non-destructive methods, GIS modelling was employed for the macroscopic study and analysis of the associated hazards and the corresponding risks. It is expected that the corresponding integrated methodology will lead towards the development of a best practice guide for the management and protection of the cultural heritage assets of Europe.

E-RIHS-Cy: The Eastern Mediterranean node of E-RIHS - The European Infrastructure on Heritage Science

(*Sorin Hermon, Nikolas Bakirtzis*)

On November 2016, the European Commission established E-RIHS, the European Infrastructure on Heritage Science, the only infrastructure entirely dedicated to the study, conservation and management of Heritage. Launched in January 2017, its three-year preparatory phase focuses on its establishment as an ERIC (European Research Infrastructure Consortium). Within E-RIHS, The Cyprus Institute and its Science and Technology in Archaeology Research Center (STARC), serves as a regional node for the Eastern Mediterranean. As such, E-RIHS-Cy provides a foremost example of the development of science and technology for archaeology and heritage at both the local and the regional

levels. Key STARC facilities for E-RIHS-Cy are STARLAB - the mobile research infrastructure for Digital Archaeology, Material Sciences and Geophysical prospections, the HPC based DIOPTRA - the digital library for Cypriot Cultural Heritage and EPHEMERA, a web-based e-Infrastructure for Heritage at Risk. STARLAB integrates sciences and technologies along an investigation pipeline that includes geophysics, 3D documentation, technical and multi-spectral imaging with non-invasive and non-destructive chemical analysis. DIOPTRA is based on the FAIR principles for sharing open data and relies on DRUPAL as content management system and CIDOC-CRM as its ontology. It features a range of collections, from numismatics to archaeological, ethnographic, linguistic and photographic collections and databases. Based on Potree, EPHEMERA is an open-source, WebGL-based point cloud renderer; it provides users with a flexible platform to upload, manage and analyze 3D documentation archaeological data, and perform measurements, such distance between points, calculation of heights, areas and volumes, or extraction and comparison of cross-sections.

MedSTACH: Eastern Mediterranean Science and Technology Centre of Excellence for Archaeology and Cultural Heritage

(*Phaedon Kyriakidis, Athos Agapiou, Vasiliki Lysandrou, Nicholas Kyriakides, Vasiliki Kassianidou, George Papasavvas, Maria Dikomitou-Eliadou, Andreas Charalambous, Theodora Moutsiou, Marina Solomidou-Ieronymidou, Despo Pilides, Anthi Kaldeli, Ploutarchos Pantelides, Andrew Bevan, Marcos Martinon-Torres, Mark Altaweel, Apostolos Sarris*)

The outstanding number of cultural sites from the eastern Mediterranean that are included in the UNESCO World Heritage List, as well as the central role that the region has played to human prehistory and history, calls for a long-term, strategic planning for the documentation, scientific study, monitoring, protection, and promotion of its material culture. MedSTACH, a Horizon 2020, one-year project aims at addressing this imperative, through the design of the Eastern Mediterranean Science and Technology Centre of Excellence for Archaeology and Cultural Heritage (MedSTACH). The project will be competing in "Teaming for Excellence" Phase 2 to secure funding of 15 million euros for a period of 5-7 years and beyond. MedSTACH's key objective is to establish Cyprus as an excellence hub in archaeology and cultural heritage, capitalising on multidisciplinary research, engineering ingenuity and technological innovation. The MedSTACH consortium includes the Cyprus University of Technology (lead partner) and the University of Cyprus, as well as the key national stakeholders and policy-makers of the island responsible for cultural heritage management and for the promotion of Cyprus' touristic product, i.e. the Department of Antiquities and the Cyprus Tourism Organization, respectively. Aiming at sustainable research and innovation excellence, the Cypriot institutions have joined forces with two international organizations, i.e. University College London and the Foundation for Research and Technology – Hellas; both being leaders in the fields of archaeology, cultural heritage research and education. This paper presents the MedSTACH project's mission, including its principal objectives and key research domains.

Session 41 -
Immersive Techniques in Archaeological Practice and Publication

Visualizing the past: Developing tools to facilitate accurate and immersive experiences in archaeology

(*Grace Sommers, Rebecca Napolitano, Hannah Smagh, Sophia Feist, Branko Glisic*)

When digitally reconstructing a historic structure in 3D, a practitioner needs access to a diverse knowledge base. A practitioner should know what types of structures and structural elements were being built in a specific time and region, what types of construction materials were available, what the physical limitations of these materials were, what primary sources said about the use of these materials, what modern secondary sources say about these materials, how prevalent this material was in that area, etc. The objective of this research was to develop a tool that brings these heterogenous datasets together and makes this broad base of knowledge accessible to a diverse range of potential 3D modelers. To do so we examined what types of data it would be necessary to include within such a tool, developed a backend schema for cloud-storage of the large amounts of data, and designed a user-friendly interface. This free and open-source tool was tested as a part of a new class taught this year at Princeton University—Holistic Analysis of Heritage Structures—where the final project was for groups of archaeology, civil engineering, architecture, and history students to digitally reconstruct historic structures. The 3D models generated using this tool will be shown and discussed. Additionally, insights gained during the process of creating and testing the new tool will be shared as well as considerations about future tools that could augment the current processes for widening the pool of those able to develop immersive techniques for archaeology.

Seeing Past Worlds: night skies in the Bronze Age

(*Gail Higginbottom, Vincent Mom*)

Trying to understand why standing stone monuments were erected inspired us to recreate visual contexts of various monuments from an individual's field of view using 'individual immersion models'. Using the astronomical software 'Stellarium' we make 360-degree views of photo-realistic night skies as could be viewed 3,500 years ago and combine these with reproductions of real landscapes with standing stones monuments. Significantly, by using Stellarium's animation options these initial observation exercises are turned into cinematographic-like experiences as viewed by a person standing on the Earth. Thus in this presentation, we move beyond our often used statistical analyses of orientation studies as well as our single static visuals. This work also goes further than above ground 'fly-through' virtual realities. By examining a series of case-study sites of standing stones in Britain, we demonstrate how much more intricate and complex the chosen views (and therefore locations) were than we ever imagined them to be. We demonstrate that sites were set up to see the same astronomical phenomena as well as containing very unique views of the entire sky depending on the actual shapes and heights of the horizon. These views not only included the Sun and the Moon, but also specific planets and stars and lighting of the landscape. Most relevantly, the cinematographic-like experience rendered by Stellarium reveals that it was of great importance to the people that erected

stone monuments to observe the entire travels of these celestial bodies and how these relate to each other and the Earth.

Developing an optimized methodology to create a portable virtual reality tour in a small archaeological site: La Peña del Castro (Spain)

(*Mario Alaguero, David Checa, Andrés Bustillo*)

Virtual reality is an useful tool to enhance the archaeological sites didactic appeal. Depending of the sites characteristics, virtual reality can be adapted to be able to be applied according to its portability and visual realism. An application of this technology was proposed in an Iron Age archaeological site: La Peña del Castro (Spain). A virtual reality tour was set in a remote place without electricity or infrastructure in an archaeological excavation with a substantial lack of funding. A low-cost virtual reality tour was developed. Good graphics and high portability were asked, so an optimized methodology to get the aims saving costs was defined. This method combines real panoramic photographies with an overlayed 360º render, what increases the graphic realism shortening the working process time. A high quality 3D scenario was modeled using a comparative historical analysis of other archaeological sites of the same period and the archaeological excavation data. Real and virtual cameras were adjusted to sync its position and characteristics, making an easy postproduction process. These images were set in a portable virtual reality device to create the tour, with 5 virtual points all along the archaeological site. This virtual tour has increased the archaeological site educational capabilities and the visitors quantity with a very low funding. This optimized method has been tested in a real case and is able to improve the workflow efficiency in further projects.

Virtual reality immersive serious game to enhance learning. The case of Peña del castro

(*David Checa, Mario Alaguero, Andres Bustillo*)

Immersive Virtual Reality has a huge potential to enhance the understanding and interest for lost or strongly degraded Cultural Heritage of Archaeological sites by the general public. This work presents the recreation in Virtual Reality (VR) of part of a pre-roman village at "La Peña del Castro" (Leon-Spain) and the design of a serious game for this VR-environment. This application will be extensively used by visitors at the archaeological site´s interpretation center during summer season while now it is being used in a VR-lab at the University of Burgos facilities for undergraduate teaching purposes. The game is implemented and tested on two environments for comparison: a 2D environment, by means of a flat screen, and a 3D environment, by means of Oculus Rift display. The serious game was created using Blender 3D software for modelling and Unreal Engine as game engine. The game is designed like a quest game: the user can move freely through the environment while he collects a list of specific items that provide information about historical and social structure aspects. The virtual reality experience tries to achieve a strong immersion effect, especially compared with the flat-screen experience. Finally, an evaluation study with undergraduate students has being performed by means of post-session surveys, to assess the acquired knowledge about the archaeological reconstruction and the proposed learning goals.

Exploration of methods for interacting with archaeological 3D-data in multi-scale virtual environments using virtual reality

(*Thomas Bremer, Susanne Brandhorst, Kay Kohlmeyer, Sebastian Plesch, Arie Kai-Browne, Lenja Kaufmann, Bilge Hürmüzlü Kortholt*)

The paper is about the implementation and study of archaeological dissemination methods in Virtual Reality (VR) that apply to multi-scale virtual environments (MSVEs). To put these methods into the context of current archaeological research, we present a case study involving various spatial scales and data sources: the Isparta Archaeological Survey (IAS) in Turkey. In this particular case the multi-scale virtual environment is comprised of data from a multitude of different sources, such as a highly accurate DEM derived from InSAR, high resolution satellite imagery covering the vast landscape as well as UAV-photogrammetry, geophysical surveys, terrestrial laser scanning and ground-based photogrammetry of various archaeological sites. For the interactive archaeological dissemination in VR various tools have been implemented, which apply to different spatial scales and research questions at hand: The Movement Tool enables the continuous translation and teleportation of the user as well as the possibility to freely scale the entire dataset. In addition, the Measurement Tool gives the researcher precise data on the dimension of objects. Furthermore, the SkyView Tool helps to analyse the influence of star constellations on building layouts by projecting 3D-vector lines between stars-of-interest onto the 3D-models. To document the output of the aforementioned tools, the Camera Tool provides the ability to generate high-fidelity images and video sequences with user-defined camera parameters at arbitrary locations. Finally, annotations can be recorded by voice and converted to text in real-time for later dissemination outside of VR.

The effect of Augmented Reality and 3D printing in the comprehension of two historical bridges in Burgos (Spain)

(*Lydia Ramon Perez, Andres Bustillo Iglesias*)

Augmented Reality and 3D printing are very promising technologies to increase the emotional link between the audience and any cultural heritage item. Both of them allow enhancing the audience's interaction with the proposed object and, at the same time, increase the interest of the younger publics for Cultural Heritage due to their natural attraction to Information Technologies. In this paper we present the use of Augmented Reality and 3D printing to improve the understanding and interest of the general public for two bridges of the province of Burgos (Spain). The bridges were selected due to their strong differences: while the first is a unique medieval bridge in a small village (Frias), the second, the "Widows Bridge" is an almost-unknown bridge located in the middle of the city of Burgos. Both bridges are included in a recently-published book about bridges in the province of Burgos that also includes the Augmented Reality app of them, while the 3D prints where shown and free to touch in different libraries in the city. The fill-in of questionnaires allow concluding and comparing the effect of both technologies in possible book's buyers and in the comprehension of the main geometrical characteristics of both cultural heritage items. While the Augmented Reality models done with Blender software were included in Aurasma application, the 3D prints were made of Polylactic Acid.

Virtual Reconstruction of the Maya Site of Vista Alegre: Multi-use Digital Assets in Context

(*Jessica Marie Moss*)

The coastal Maya site of Vista Alegre provides continuing insight into the relationship between Pre-Columbian groups and the environment in this dynamic ecosystem. Due to the remote location and dense mangrove coverage, the site is difficult to document remotely, and its fluctuating ecological shifts over time also create a challenge in interpreting and presenting the spatial usage of the site. Owing to this, an immersive 3D model created from GIS data, photogrammetry, and modeling software adds to the interpretive and presentational range of this site using cross-platform virtual reality applications. The ability to model ecological changes over time, in addition to shifts in monumental architecture and spatial usage, allows for the chronological representation necessary to accurately portray this site. Once these digital assets are created and georeferenced, they can also be used in augmented reality applications for incorporation onsite in handheld devices or within a museum context. These assets are also used in online exhibits for public education through the digital archival platform Omeka. Linking this digital exhibit to the virtual reality experience further contextualizes and educates the public, and the goal is to use increasing VR web support through A-frame, WebGL, and other web browser supported formats to further democratize the experience of VR to the public. Combining the use of these digital assets in multiple ways increases the exposure and efficiency of using digital visualization techniques for both presentation and interpretation.

A Visit to the Pnyx: Virtual Reality as a Tool for Archaeological Research

(*Erika Holter, Una Schäfer*)

To understand the importance of political communication in Athenian society it is necessary to analyze the sociomaterial conditions of the spaces in which it took place. The Pnyx, the location of the public assembly in Classical Athens, underwent a series of renovations in this period that should be evaluated as a result of functional considerations, determining whether or not successive reconfigurations improved the conditions for political communication. Through the use of digital reconstructions and simulations, we can begin to investigate the effectiveness of the Pnyx and how its configurations facilitated the shaping and communicating of public opinion. By embedding the digital model as well as auralizations of various locations during a speech into the game engine Unity3D for use with a VR headset, a visit to the Pnyx during a meeting of the assembly can be simulated. The user listens to a speech from different points in order to study the sensory conditions of political communication: How well could a participant follow a speech? How can these results be understood in the historical context of the development of Athenian democracy? A customizable interface integrated into the simulation with which the user can manipulate parameters such as crowd size, speaker volume, or crowd noise level allows for a direct comparison of the resulting differences in the simulation in real time: Research questions can thus be adjusted according to observed results. VR therefore shows itself to be a versatile research environment, allowing the integration of multisensory approaches when evaluating ancient spaces.

The Harvard Yard Archaeology Project: From Analog History to Digital Presentation

(Jeff Emanuel, Luke Hollis, Brandon Bentley, Alexis Hartford)

Since the turn of the millennium, students have participated in a biennial excavation of a portion of Harvard Yard, the center of America's oldest college. Finds from the excavations are catalogued and displayed by the Peabody Museum in an exhibit called "Digging Veritas." This presentation discusses the academic year 2016-17 iteration of the Harvard Yard Archaeology Project (HYAP), which saw the first integration of digital methods into its fieldwork, analysis, and accompanying storytelling, with an Omeka site for images and "object biographies" and an accompanying augmented reality (AR) application that displays the week-by-week strata and point-find data. We discuss the purpose of the excavations and the integration of digital methods, lessons learned, and future prospects.

Studies in Digital Heritage: A New, Open Access, Peer-Reviewed Journal

(Bernard Frischer)

This paper will present Studies in Digital Heritage, a new peer-reviewed, online journal that started operation in 2017 and which publishes innovative work applying new digital technologies to the various fields of cultural heritage such as Anthropology, Archaeology, Art History, Architectural History, Classics, Conservation Science, Egyptology, and History. While the journal covers the gamut of topics relating to the use of technology in the study of cultural heritage, its emphasis is on 3D technologies. Topics of interest include such topics as 3D data capture, processing of 3D models, theory and practice of 3D restoration of cultural heritage objects, use of 3D models in research and instruction, metadata and paradata standards and best practices for 3D models, and the use of 3D models on VR and AR devices as well as on web pages. Whenever appropriate, authors are encouraged to embed interactive 3D models into their articles in place of traditional 2D illustrations. The journal supports WebGL solutions currently in use by professionals in the field, including 3DHop, Sketchfab, and Unity. The journal charges no Article Processing Charge and subscriptions are also free. The international editorial board hopes that Studies in Digital Heritage becomes a publication outlet that many members of CAA will want to use.

Session 42
Archeology Heritage Information Modeling. Models construction for documentation and analys

The Theatre of the Roman Casinum city

(Arturo Gallozzi, Rodolfo Maria Strollo, Michela Cigola)

The contribution focuses on the ruins of the Roman town of Casinum, in southern Lazio, of whose past remains a significant archaeological area.. The monumental structure of the present archaeological area, preserves traces of pre Roman and Roman period. Currently the principals monuments of this archaeological area are: the theatre (1st century BC - 1st century AD), the amphitheatre dated to the second half of the first century AD; the so-called tomb of Ummidia (1st century BC - 1st century AD),

the Nymphaeum called Ponari, also dated to the 1st century AD. Specially the reseach focuses on the Roman Theatre of Casinum. The theatre, the core of the Augustan town, brought to light in the years 1935-36, damaged by bombing in 1944 and the subject of restoration around the 1950s and later in 2001, has a semi-circular auditorium partially leaning on the natural slope of the hill and, at the back of the scenery masonry, there are traces of two porches. The methodological approach of the work will develop and deepen the analysis and the knowledge of the Roman Theatre through an integrated survey of it. Along with the integrated survey, the research also focuses on the study of documentary sources, and the analysis and comparison with theatres of the same era. The research will also analyse the typological and constructive similarities with analogous theatres built in the same period in Central Lazio and in Northern Campania, and eventually the Mediterranean area.

The Theatre of the Roman Casinum city

(*Arturo Gallozzi, Rodolfo Maria Strollo, Michela Cigola*)

The contribution focuses on the ruins of the Roman town of Casinum, in southern Lazio, of whose past remains a significant archaeological area.. The monumental structure of the present archaeological area, preserves traces of pre Roman and Roman period. Currently the principals monuments of this archaeological area are: the theatre (1st century BC - 1st century AD), the amphitheatre dated to the second half of the first century AD; the so-called tomb of Ummidia (1st century BC - 1st century AD), the Nymphaeum called Ponari, also dated to the 1st century AD. Specially the reseach focuses on the Roman Theatre of Casinum. The theatre, the core of the Augustan town, brought to light in the years 1935-36, damaged by bombing in 1944 and the subject of restoration around the 1950s and later in 2001, has a semi-circular auditorium partially leaning on the natural slope of the hill and, at the back of the scenery masonry, there are traces of two porches. The methodological approach of the work will develop and deepen the analysis and the knowledge of the Roman Theatre through an integrated survey of it. Along with the integrated survey, the research also focuses on the study of documentary sources, and the analysis and comparison with theatres of the same era. The research will also analyse the typological and constructive similarities with analogous theatres built in the same period in Central Lazio and in Northern Campania, and eventually the Mediterranean area.

Reality, legend and augmented reality: Bridges on the Tiber in Rome

(*Adriana Caldarone*)

Today, It is increasingly common to include archaeology in a defined digital era. It seems indeed almost impossible not to use the new technologies in the field of archeology as well as in the survey, post production, study and reconstruction steps. At the same time, thanks to social media and thanks to sharing experience policy, we can consider cultural dissemination as a new archaeology's mission. Information and communication technologies find new application in the field of archaeology: the purpose of multimedia platform is not only to communicate, but also to safeguard cultural, architectural and environmental heritage and to launch economic process and sustainable development. Following this direction, this paper reviews a device APP concerning "Bridges on the Tiber in Rome": in addition to information and textual content, the APP focuses on the virtual reconstruction of the Aemilius Bridge, as it appeared in four different historical periods using mixed reality. But an archaeological object is made by tangible and intangible properties; archaeology deals

not only with the collection, analysis and interpretation of data; it tries to reconstruct stories, cultures, events: in addition to scientific data, the app makes use of storytelling to transmit legendary stories, folklore's trivia related to the Brid, raising sociological and anthropological issues wich are able to make grow user's interest and curiosity.

Parametric digital modeling as a virtual construction site for Roman bridges

(*Maria Laura Rossi*)

The bridge is a concrete testimony of the technical level achieved by the Romans in the art of construction. There are interesting geometric and structural implications in the division of the blocks of a Roman bridge and in its stereotomic project, and important repercussions also in the organization of the construction site. The survey and analyzes carried out on the case study, the Augustus Bridge in Narni, both metric and proportional, showed an overall geometric logic based on a strategic stone block equipment. These considerations have led to the construction of a 3D model in a parametric environment designed to generate optimized, standardized and queryable models, the result of processing input data through functions. Initial parameters, based on laser scanners, have been incorporated into a process of creating elementary matrices from which to develop the entire bridge: the blocks are created as families, three-dimensional objects that are submit to laws predetermined by the development of the block itself . By changing the laws, due to the ability of the block to adapt to change, the final shape is updated following a cascading change process. The model thus obtained is an optimized one compared to any other modeler that follows a CAD additive volumetric logic; it is queryable from the point of view of form, measure, and materials in all its components; is representative of the modifications that the bridge has experienced over time due to the overwrite of possible configurations.

The archaeological stratifications of the Abbey of Montecassino

(*Michela Cigola, Arturo Gallozzi, Leonardo Paris*)

Several settlements have existed at the site of Montecassino Abbey since the iron age. During the 6th century the first houses were built near Montecassino by Volsci and then the Sabellians. This place was known as Casinum, or ancient city. This first nucleus of the present city Cassino is located on the highest part of the mountain; the Acropolis was topped by a temple and closed within city walls. Casinum was then occupied by the Etruscans and towards 272 BC by the Romans who made it a castrum (fortified place) and then a municipium in the 3th century. The barbarian invasions began in the 4th century and the citizens of Casinum drew back to the ancient acropolis, reinforcing the walls' defenses. In 529, St. Benedict (founder of Benedectine monastic order) chose as his home one of the towers of ancient Acropolis walls. In this way St. Benedict founded the Abbey of Montecassino among the ruins of pre-Roman and Roman fortified Acropolis. The Abbey of Montecassino was completely destroyed and rebuilt after the allied bombing of WW2. At present the structures of the foundations and the deeper stratifications have remained largely intact and are partially visible. These archaeological remains are now closely connected with the structure of the Abbey. The article focuses on the first results of the analysis and documentation of the complex archaeological stratifications of the site of the ancient Acropolis. These results will be a fundamental support for the construction of a new multidisciplinary interpretative model.

Lighting setups for archaeological finds

(*Lorena Greco, Cristian Farinella*)

The digital environment, managed through a good knowledge of computer graphics, has made possible three-dimensional simulations very near to the reality. For the purpose of communication or studio, it can be possible to investigate the formal nature and the features of the materials till to make negligible the differences between a photo of an archaeological discovery and a shot taken using a virtual camera. The most of the simulation process, both the reaction of materials with their reflections and refractions and the camera management, is entrusted to the lighting setting. If a good outdoor lighting model can be developed since the introduction of only two lights: direct light (sun) and indirect light (sky), to effectively represent a small archaeological find, wherever possible the de-contextualisation of the element, it is necessary to refer to photographic techniques. Specifically, it is necessary to design an effective digital set (whether it is a simple "White box" or a "Three Point lighting") and a responsible use of lights in the scene (key light, fill light, bounce, rim light, kicker, specular) in order to highlight for example the ornament or the presence of inscriptions, thus making legible the distinctive elements of artefacts. This study aims to develop a methodology of work to complete three-dimensional data acquisition phase, or its interpretation, by means of a correct representation that takes into account both the physical principles of light that its potentiality in perception.

Methodological approach in archaeological fieldwork: tangible and intangible heritage

(*Alfonso Ippolito, Carlo Bianchini, Carlo Inglese, Martina Attenni, Marika Griffo*)

The study of archaeological structures is heterogeneous and related to various factors: site chronology, its location, its consistency. It includes a wide range of interdisciplinary subjects and competences precisely when a strong need is felt for sharing extensive knowledge still growing with the continuous progress and the potentialities inherent in digital systems. What has recently been taking shape is the all-comprehensive approach adapted to comprehend archaeological artifacts. Despite of the differences related to a specific context, architectural survey and construction of 3D model has a critical role in each phase of the investigation. They have many purposes: to validate information coming from other sources, to furnish proof of the current status and to support the following steps of the process. In the first two cases, a common methodology of 3D integrated data acquisition can be applied independently from the object of the research. In the third case, survey is used as a tool for conservation and restoration purposes or for virtual reconstructions and analysis. Although the methodology is unique, data elaboration follows different procedures strictly dependent from the consistency of the case study. Two categories come out from the wild field of archaeological sites: places and archaeological remains that have been preserved in their materiality through the years, and the ones who didn't. This proposal aims to investigate how extent common tools and strategies can be applied to dissimilar case studies in archaeological field to preserve what still exists and to virtually reconstruct what has been destroyed.

Achaeology Heritage Information Modeling: a procedure proposal

(*Tommaso Empler*)

Information modeling is now used in many areas ranging from BIM, to GeoBIM, to LIM. In the field of Cultural Heritage, many use HBIM. Are the operations under this procedure as good in the archaeological and palaeontological field or is it desirable to identify a specific procedure calling it AHIM? The research focuses on all those archaeological sites that are difficult to insert into an HBIM procedure, as defined by Dore and Murphy (Dore, Murphy, 2015), in terms of the cognitive framework, area survey, subsequent 3D modeling, identification and evaluation of the path of conservation, valorization and dissemination of the archaeological site. If in the BIM procedures one of the most important aspects is the BIM modeler and the possibility of using a semi-automatic procedure for parameterizing objects, in an archeological or paleontological site this operation is much more complex. An archaeological site can be detected by a photo-modeling or 3D laser scanning procedure from the ground or quadcopter. The next step is the discretization of the "points cloud" through the generation of a 3D mesh model through a modeling program like Rhinoceros + Grasshopper. The geometric model is connected via a Grasshopper plug-in (Gh-AC connection) in Archicad (BIM modeler) parametric environment, which can be considered one of the best application for model information, where geometric features become architectural objects containing information that will further qualify the AHIM process. Through subsequent operations, in experimentation phase, you can query the model, expressing in a visual way the characteristics loaded in the 3D model.

General Session 1

Using the third dimension for calculation of ancient matter fluxes in tell sites- examples from sites in Bosnia-Herzegovina, Turkey and Germany

(*Stefan Dreibrodt, Sarah Martini, Robert Hofmann*)

It is increasingly common for archaeologists to detect sites and map their size using data from Geodesy and Remote Sensing. A connection of these morphometric data with additional site-specific information to infer about ancient settlement processes should be a corollary. We used volume, bulk density, and sedimentological data to calculate ancient matter fluxes in tell settlements (in total and divided into phases/layers). The content of chemical elements (e.g. phosphorous) and constituents (e.g. daub, ceramics) and the bulk density were measured in profiles. With the help of remote sensing, geodesy, trenches, and a net of auger cores the extension and the thickness of the settlement layers were acquired. The bulk densities and volumes of the layers were multiplied with the contents of specific items considered as proxies of settlement activities to calculate masses. By dividing these masses by the duration of settlement periods known from the excavations fluxes of masses could be calculated for the whole settlement duration and for different phases. A comparative discussion of the results against the archaeological background of demography, economy and architecture highlights potentials and limitations of the presented approach.

Digital Archaeology at a Dinosaur Dig: the recording and integration of Palaeontological and Geological data using Digital Archaeological techniques

(Luca Brunke, Roeland Emaus, Pim Kaskes, Dylan Bastiaans, Anne S. Schulp)

Excavating dinosaurs is often assumed as a rather straightforward 'digging, bagging and tagging exercise'. However, when dealing with complex bonebeds, traditional 2D-grid bone mapping does not capture the full complexity of the fossil locality. In order to answer questions about sedimentology, taphonomy and palaeobiology, palaeontologists and geologists collaborated with archaeologists to share methodologies on 3D data registration and documentation in the field. Since 2013, the National Natural History Museum of the Netherlands, Naturalis Biodiversity Center, is unearthing the largest bonebed of the horned dinosaur Triceratops discovered so far. At least six individuals of Triceratops have been identified and more than 1000 bone elements have been uncovered from this site of the uppermost Cretaceous Lance Formation (69 to 66 mln. years old) in eastern Wyoming, USA. The bonebed consists of in-situ disarticulated skeletons chaotically positioned on top of each other and embedded in a variable matrix of organic rich silt and claystones and interfingering fluvial sandstones. An accurate 3D-registration of the site, using daily UAV- and close-range photogrammetry combined with Total Station and DGPS survey, provided the needed 3D spatial dataframe. The challenge, however, was to create a datastructure that combined all palaeontological and geological data with this year's 3D-data and previous year's unreferenced laserscanning and 2D bone mapping into one consistent dataset, whilst still allowing for lab results of prepared fossils (e.g. ct-scans, histological thin-sections, geochemical analysis) to be appended in the future that will all help in unravelling the taphonomic history of dinosaur bonebeds.

Virtual Gross Sobrost

(Marta Bura, Janusz Janowski, Karolina Zięba, Piotr Wężyk)

The village of Zabrost Wielki, warminsko-mazurskie voivodeship (Gros Sobrost, district of Darkiamy, East Prussia), was destroyed during the war in September 1914. It was rebuilt in 1916-17 on the basis of the project of Berlin architect Carl Kujat, who showed modern functionality and aesthetics. The village was partially destroyed during the Second World War, and in 1954 it was completely occupied by the Ukrainian people as part of the "Wisła" campaign. The Borussia Association in 2000-2001 recognized it as the most beautiful village in Masuria. However, the ongoing degradation of the historic substance blurs its original character. The project is aimed at a broad integration of non-invasive methods of acquiring data from terrestrial scanning, mobile scanning, photogrammetry, aerial and modeling of buildings on the basis of the preserved archives/photos from 1917 and later. This enabled us to rebuild the village of Gross Sobrost similarly to that built in 1917.

Challenges in the analysis of archaeological 'Big Data'

(Chris Green)

Within archaeology, datasets that could be truly classed as 'Big Data' in the sense used by most of the hard sciences do not yet exist, but our datasets are becoming increasingly large and complex as more and more data is generated (primarily) by commercial projects. However, if we define 'Big Data' in this context as datasets that are too large to be collated and analysed without automated methods (within

budget constraints), then we are beginning to see archaeological spatial analysis brush up against the shores of Big Data analytics. Within archaeology, these datasets fall broadly within two camps: (a) those with immense numbers of records but with simple numeric attributes (e.g. point clouds generated by LiDAR); and (b) those with lower numbers of records but complex numeric and textual attributes (e.g. catalogues of discoveries at national or international scales). This paper is primarily concerned with the latter and will discuss methods which can be used to study these complex large datasets in their spatial context, using examples taken from the English Landscapes and Identities project which ended in 2016.

Re-interpreting archaeological sites in 3D

(*Joshua James Emmitt*)

Archaeological section drawings are two dimensional (2D) representations of deposit cross sections within an excavated area, while plan drawings represent a top down cross section of an excavated area. These drawings are common in archaeological literature since the early 20th century and hold important information, however, they are often treated as static references to past excavations. In many cases multiple 2D drawings must be considered together, making interpretations and relationships difficult to visualise. With modern computing techniques these drawings can now be digitized and transformed into three dimensional (3D) representations. 3D representations are integrated to Geographical Information Systems (GIS) to place the data back into its original context and consider it in relation to contemporary data. This processes was applied to three archaeological excavations; the 1924 excavation of Hemamieh, Egypt, the 1925-26 excavation of Kom W in the Fayum, Egypt, and the 1968-74 excavation of Roonka, Australia. Over the course of these excavations a number of section drawings were made that cross section the sites on their vertical and horizontal (x and z) axis, or, from the top down (x and y). The process presented here enables the reinterpretation of section drawings and as a result has allowed for primary excavation data to contribute to current research.

The Thin Lines of Narrow Chronological Contexts: Interpreting Spaces through Digital Recording and Photogrammetry

(*Denitsa Nenova, John Wallrodt*)

The immediate dissemination of archaeological observations and interpretations is one of the strengths of digital collection. This has grown to include regular 3D modeling on-site. The universal application of 'Paperless Archaeology' aids with the need to contextualize and illustrate large volumes of remains and artifacts. The strength of such datasets is evident when linking and querying records with associated metadata (like photographs, sketches, etc.). Moreover, within such a framework it now becomes possible to add 3D modeling as a research tool, which can seriously influence the analytical outcome and thus the interpretation. More specifically, photogrammetric techniques applied to field archaeology, combined with GIS, allow for accurate calculation of volumes per excavation unit, the 3D representation of archaeological contexts and their attribute data. In this paper, we present a case study from the recent excavations near Pylos, Greece, with a direct example of how volumetric study obtained through precise data acquisition based on photogrammetry and GIS, not only accurately

reflects the excavated capacities, but can also change the perception and, more importantly, the interpretation of different stratigraphic units. Furthermore, we try to demonstrate how, within a relatively narrow chronological frame, such approach can be extremely influential in the understanding of a close series of consecutive chronological phases, the relationship among different contexts and their precise stratigraphic position.

Connecting the Dots: Digital Techniques in the Reconstruction of the Govan Stones

(*Megan Nichole Kasten*)

This paper will explore how three-dimensional technologies, while useful for the purposes of recording and outreach, have the potential to enhance the analysis of early medieval carved stones. The remarkable collection of sculpture found at the Govan Old Parish Church in Glasgow, Scotland, consists of a sarcophagus, four cross-shafts, five hogbacks, and twenty-one recumbent cross-slabs that range in date from the 9th to 11th centuries AD. While the recumbent cross-slabs make up the largest proportion of the collection at this site, they have been largely ignored due to their physical condition and the unique quality of the other monuments. Most of the Govan recumbent cross-slabs have been damaged through either natural causes or human intervention, resulting in some that are so worn that their original ornament is no longer recognisable. In past analyses of these monuments, many of these particularly worn monuments were excluded from the discussion. As a part of my PhD research, I have developed a methodology to reconstruct several of the eroded Govan stones using both Reflectance Transformation Imaging and photogrammetry. By identifying remnants of decoration on the worn stones with RTI and creating a three-dimensional comparative collection of known decorative motifs from the better-preserved examples of the Govan collection, it becomes possible to reconstruct the ornament which was once found on the worn stones. Through their reconstruction, these once-sculpted stones can be brought into the conversation and can contribute to future interpretations of the Govan stones.

Illuminating Bubbles: Using Photographic Filters to Identify Manufacture and Trade in Iron Age and Early Medieval Scottish Beads

(*Heather R. Christie*)

Visible range photographic filters (400-700nm) have served as an invaluable tool in archaeological photography since the mid-1800s. Over the last twenty years, however, their use within archaeology has waned significantly. Yet, visible range filters can dramatically reduce the effects of reflection, translucency, and other problematic characteristics of archaeological objects. Consequently, these filters can reveal new details that allow for a better understanding of a variety of artefact types. Glass beads have been one of the most ubiquitous trade items worldwide for 2500 years. Unfortunately, many archaeological glass beads are stray finds and many types have remained popular for 2500 years, making spatial and chronological studies difficult. Glass beads are also notoriously difficult to photograph due to their small size and reflective and/or transparent nature. Visible range filters (400-700nm), applied either physically or digitally, greatly reduce these issues and illuminate and emphasise features such as bubbles or inclusions that are otherwise difficult or impossible to see. Photographing Iron Age and Early Medieval Scottish glass beads using visible range filters has revealed significant

differences in bubble frequency (e.g. few, moderate, many, etc.) that indicate previously unrecognised differences in possible trade and manufacture. They also provide a potential basis for predictive modelling, potentially indicating both how and when a bead was manufactured. These results significantly improve our understanding of glass beads in Scotland at this time, and can also assist in our understanding both of glass beads and of similar artefact types elsewhere in the world.

Roman building terracotta - computer classification of stamps

(Tomáš Janek)

Research of building terracotta has great importance in understanding of Roman building activity. Not only on Roman camps, but also on civil buildings, stamped bricks often give us the only information about dating of various building phases. Current dating is based mostly on epigraphic analyses which are not accurate in most cases. Thanks to the uniqueness of every die used for stamping, stratigraphically dated finds can enable identification of material also from different locations. Since use of epigraphical analyses is not suitable in this case, new system was developed, based on computer application. The system is derived from morphometric analyses, which use is not common in archaeology. Data are collected and measured from vertical photos of stamps. The system is based on extracting of coordinates from the photos and subsequent mathematical comparison of the data. The analysis examines the shape of edge of stamp impression and then it compares its exact dimensions. Comparative criteria were developed precisely for the Roman stamped brick material. Analyses on finds from Mušov-Burgstall and Vindobona have even proven that current typological sorting can be incorrect. In fact, stamps separated into several types proved to come from one die. High accuracy of this method also enabled identification of the fragmentary stamps. The comparison system is more complicated in this case, because the proportions and position of every preserved letter is taken into consideration. The advantage of this system is, that three preserved letters are sufficient to reconstruct the rest of the stamp.

Multi-element analysis with XRF on features of the Nok Culture (Central Nigeria)

(Annika Schmidt)

The Nok Culture in Central Nigeria has been known for its expressive terracotta figurines since the middle of the 20th century. A team of archaeologists from the Frankfurt University (Germany) investigates the complex, dating from ca. 1500 BCE to the beginning of the Common Era, from a holistic perspective. Pits represent the most common but little understood features on Nok Culture sites. Their morphology and find inventory contradict the interpretation as simple waste pits, leaving their context and function unknown. XRF (X-ray fluorescence) analysis can reveal the element composition of the sediment within the features, in order to understand its former use. As multi-element studies are rare in West Africa and no references for traces of anthropogenic impact on the soil exist, samples were taken from a modern Fulani village to learn about the element composition of different activity areas and for comparative studies with Nok Culture sites. Another feature type, consisting of stone settings, complete pots and sometimes stone beads, points to an identification as burials. As the acidic soil prevents the preservation of bones, analysis of the sediments with a hand-held XRF device is used to provide evidence of long-decayed bodies, confirming the interpretation as burials.

"Structure from Motion in archaeology" - development and first experiences with an interactive teaching movie

(Julius Bussilliat, Undine Lieberwirth)

Nowadays, university lecturers face an audience that grew up with digital devices and bring along more than basic software skills. Young students are used to living in a technological world and normally have no prejudice against the idea of a "digital university". As "Archaeology is one of the most 'digitised' social sciences." (Kamermans 2014), it seems obvious that scholars should bring this reality into the academic process, in order to develop archaeological science in general and the student's competence, thereby making both ready for the digital age. Computer applications in archaeology are meanwhile included into the academic curriculum. Now it is also time to revise the teaching process itself using digital teaching environments for better understanding of processes. In this presentation, we tell the story of the birth of an interactive teaching movie from the idea to the first use in class. We describe the development from static teaching material towards an interactive media combining various information in one system. The presentation will focus on the main challenge, creating a "hybrid product" by maintaining scientific and academic standards within a new environment and evaluate the teaching experiences by analysing student evaluation sheets and their practical results. Could they cope with the digital material, was it accessible, usable, and encouraging to independent learning? We will finally reflect on whether the efforts and benefits of such a project are proportional to the lifetime of digital media, its technological content, and what kind of publication platform we choose.

General Session 2

Artifact GeoMorph Toolbox 3D: A software for 3D geometric morphometric shape analysis and result exploration for archaeological artifacts

(Gadi Herzlinger)

This poster presents Artifact Geomorph Toolbox 3D; software designed to provide archaeologists who are interested in artifact shape variability with a toolbox to allow the analysis and result exploration of homologous landmark-based geometric morphometric data. As such, the toolbox contains the fundamental statistical analyses and procedures to allow the processing and analysis of 3D homologous landmarks coordinates. These include an automated system for the identification of potentially erroneously placed landmarks, generalized Procrustes analysis and principal component analysis. In addition, the software allows the classification of artifacts into pre-defined groups and their subsequent comparison in terms of shape variability. Differences in mean shape and shape variability can be easily tested statistically using the incorporated Wilcoxon rank sum and Hotelling's T-squared tests. Lastly, the software includes useful visualization solutions such as dendrograms for showing distances between individual items and groups' means, and colored interactive 3D models for the description of the shape trends represented by the first two principal components and values of within-group variability for specific landmarks. The software is designed to be easy to use and straightforward with a simple graphical user interface. Thus, it provides direct, quantitative and

objective results to common archaeological research questions with regards to artifact shape variability.

Hovering Sherds - The Use of 3-D Scanning in Pottery Vessel Reconstruction and Illustration

(Alexander Dittus, Tanja Kreß)

Ceramics are commonly found among Hallstatt age grave sites. For a monograph a new approach was chosen in order to illustrate ceramics found in a graveyard dating to this period. For the first time in Baden-Württemberg, 3D scans were systematically used to create all illustrations. The vessels were then digitalized using a 3D scanner, creating an undistorted, true to size display inclusive of their original surface colors. Fragmentary ceramics could be digitally reconstructed and filled, regardless of preexisting joints. Contours were extracted from the data contactless. With the implementation of digitally created reconstruction drawings arose the need for a new standard of illustration. This new standard was developed based on the commonly used standards of archaeological illustration in Baden-Württemberg.

Exploring the maritime colonisation of Australasia through computational methods

(E. Kiki Kuijjer, R. Helen Farr, Robert Marsh, Ivan D. Haigh)

Recent advances in archaeological and genomic research have pushed the age estimate for the colonisation of Australasia back to 50,000 and possibly even 65,000 years ago. To reach the continent, early seafarers crossed straits and seas around island Southeast Asia. Therefore, the maritime environment plays a central role in the colonisation process. However, the nature of the maritime migration to the continent is debated. The archaeological record is fragmented, and there is no direct evidence of seafaring this far back in time. There is extensive debate on the seafaring skills of the early colonisers. A better insight into how the maritime environment, especially open ocean and tidal currents, influenced movement to Australasia, will improve the understanding of human behaviour and capabilities during this unique event in the peopling of the world. This aspect of the colonisation of Australasia has not yet been studied in detail. Here, high-resolution computer models of open ocean and coastal tidal circulation are used to explore dynamic effects of the maritime environment on seafaring. To identify probable timescales and direction of movement by open ocean currents, large ensembles of passively drifting particles were released into an ocean general circulation model, and tracked through the study region. A depth-averaged hydrodynamic model of the Australian coast was used to explore the influence of tides on movement at sea. Preliminary results indicate a strong but variable influence of currents on movement in this area. An understanding of these currents would have benefited early seafarers migrating to Australasia.

R for Digital Heritage: web scraping, text mining and data analysis in digital engagement studies and education of future heritages practitioners

(*Marta Krzyzanska, Chiara Bonacchi*)

While R has been used in a plethora of highly quantitative archaeological studies, it has not yet been widely taken up by traditionally more qualitative subdisciplines, such as heritage studies. However, the rise of digital humanities and the crafting of methodologies for the analysis of large volumes of unstructured, often textual data encourages the development of methodological frameworks that combine qualitative and quantitative data analysis techniques (Bonacchi 2016). We argue that R is an especially suitable tool to enable the application of these methodologies, due to the wide range of packages and tools that allow handling large unstructured datasets in relatively easy ways. To demonstrate the utility of R for data extraction and text analysis (including topic modelling and sentiment analysis) we draw on a case study from the 'Ancient Identities in Modern Britain' project (ancientidentities.org). We will evaluate the methods and algorithms available in R with regard to their complexity and ability to produce meaningful results, and compare them with other tools, including equivalent libraries for python. Based on our experience teaching the Advanced Skills in Digital Heritage and other heritage and data science modules, we will present the approaches that could be taken to efficiently embed the aforementioned methods into heritage-related university courses. To conclude, we will discuss other functionalities that would be useful for heritage practitioners but are not yet available in R, for example related to crowdsourcing. Bonacchi, C., et al. (2016) Archaeology International (19)

Photogrammetry in tight spaces - using photogrammetry where totalstations cannot go

(*Erik Kjellman*)

Documenting archaeological excavations with photogrammetry has become common throughout. It is, however, most often used as a supplement to other, more traditional documentation methods, such as total station, GPS, measuring tapes and more. For this particular case, such methods would not suffice, due to both time and space restrictions. It was therefore decided to try using photogrammetry in field as a documentation method. Using Agisoft Photoscan to document each excavated layer gave the opportunity to trace each artefact on screen in 3D and real time. With this workflow we gained a complete record of each bones placement in the grave and can use this valueable information for further study. The poster will present the case study and a step-by-step of the whole process from start to finish.

Light to measure, light to record: 3D recording of a Roman sundial via Structured Light Scanner

(*Mara Pistellato, Filippo Bergamasco, Arianna Traviglia*)

The precise orientation of the centuriation of Aquileia (Italy), once one of the biggest cadastre ever deployed in Italy up to the beginning of the 2nd century BC, has been suggested to be 22o 30" W from the N based on the indications provided by the so-called sun-dial of Euporus, from the name of its donor, M. Anstitius Euporus, inscribed within the dial. The instrument, a horizontal plane sun-dial of the Vitruvian "Plintium sive lacunar" type, built in 2nd AD, was discovered in the area of the Aquileian

Circus, in the horse race area, and it was conjectured that it was still standing in its original position when found, notwithstanding the logistic impracticability of such hypothesis. The longer side of the horizontal plane was aligned with the orientation of the city and angle between the side orientation and the Meridian represented in the sundial is supposed to indicate the orientation chosen for the ancient city. Recent investigations have shown that the measurement of the angle could have been miscalculated when the sun-dial was sketched in the last decade of 19th cent. Such measurements have been then largely accepted and transmitted in literature without further check. In order to ascertain with precision the amplitude of the angle, the sun-dial was thus captured with a 3D scan. The recording was performed using a Structured Light 3D Scanner composed by a DLP LED projector and a single 3-Mpixels camera. Such device allows the full 3D acquisition by projecting a sequence of light patterns that are synchronously acquired by the camera. The team used a novel robust phase shift technique to associate a unique code to each observed camera pixel and then compute a 3D range-map via camera-projector triangulation. Considering the dimensions of the scanned object (1mx2m) and the topology, a single acquisition was not sufficient to recover the whole surface. For this reason, multiple overlapping range-maps (from different point-of-views) spanning the whole object extent were acquired. To precisely align each range, an additional DSLR camera was positioned to capture the entire scene from above and was used to record the scanner position and orientation for each range. This was made by observing a fiducial marker directly attached on it. Finally, the scanner poses were used to align all the range-maps and reconstruct a single high-resolution watertight surface. The scan enabled to remeasure the correct angle formed by the Meridian with the orientation of the Kardo and transpose the results to the study of the Aquileian cadastre.

Medieval rotunda from Cieszyn, Poland
(*Marta Bura, Janusz Janowski, Zofia Jagosz-Zarzycka*)

In August 2017, at the invitation of the Museum of Silesian Cieszyn, the 3D Scanning Laboratory, Warsaw University performed a three-dimensional archaeological documentation. The object of documentation was from the XI / XII century, a one-sided rotunda located in the Castle Hill in Cieszyn, the only one preserved like in these shape, including the vault of the nave, building in Poland. Excavations conducted by Zofie Jagosz Zarzycką began a new phase of archaeological and architectural research directly related to the rotunda. Thanks to three-dimensional documentation, the first on such a large scale, not only prepared plans, but also virtual tours or 360-degree panoramas. These products will be used both for scientific purposes and for popularization purposes.

Quantitative Processing of Archaeological Finds in 3D with GigaMesh
(*Paul Bayer, Hubert Mara*)

On this poster, we present the application of the GigaMesh Software Framework on different archaeological finds. GigaMesh is designed to process 3D data describing the surface of objects by a mesh, acquired by low- or high-resolution 3D recording techniques. The initial development was motivated by cuneiform script and its digital processing. In the last years it became a more general tool for applications of archaeological finds processing in 3D. GigaMesh offers options to measure and visualise distances and curvatures with a high-contrast rendering. The visualisations of the objects can be refined with specific lighting parameters, colorramps and isolines. Furthermore, finest details can

be emphasized by curvature based feature vectors computed by GigaMesh. This allows the recovery of weathered inscriptions or the visualisation of tool marks. GigaMesh has a modular processing pipeline for larger quantities of 3D data including mesh cleaning, selective hole filling and high-quality orthographic screenshot rendering. A set of relevant functions for visualising archaeological artefacts include a precise object orientation and the export of profile lines as Scaleable Vector Graphics. Meshes can be unwrapped based on a cylinder, cone or a sphere which can be applied to approximately rotational symmetric objects like pottery. We will present a selection of functions of the GigaMesh Software Framework for processing archaeological finds and show its usability and advantages. GigaMesh is available free of cost on http://gigamesh.eu/.

Un-#VEiLing the potential of Social Media: Open Archaeology for Public Engagement
(*Carla Ardis, Riccardo Giovanelli, Anna Bernardoni, Arianna Traviglia*)

Visualising Engineered Landscape (VEiL) is a landscape archaeology project based in Aquileia (Italy), that combines traditional methodologies with innovative digital technologies. Despite of worldwide growing interest in Public Archaeology, in Italy VEiL is a unique example of an archaeological field survey project developing digital public engagement through Social Media (SM). VEiL adopts a planned communication strategy, combining different SM (Twitter, Instagram, Facebook) that flank a website. Multiple SM accounts allow to customize contents according to the SM specific community, and to adapt communication patterns on the go on the basis of audience response, matching public understanding and scientific authenticity. The adopted approach proved successful in reaching a broad and heterogeneous audience: the analytics show indeed steadily increasing numbers of followers, ranging from academics to cultural associations, other public archaeology projects and general public. Through digital engagement media (among them also short videos of field activities, e.g. 3600 videos or timelapse), VEiL allows non-specialists to look behind the scenes of a research project: sharing moments of discovery and study routine makes archaeology more comprehensible, raising public awareness in cultural heritage and its preservation. Posts that highlight diachronic landscape transformations are the ones with the highest interaction, suggesting a growing interest in local communities for local history: as a consequence, local landowners and inhabitants feel more confident in sharing useful information with archaeologists. Direct, un-mediated interaction with VEiL project members increased followers also among scholars, attracted by the possibility of sharing reciprocal expertise in an informal fashion. Results so far reached demonstrate SM power in creating a bridge between academics and public, meeting their different interest for archaeology.

Geophysical Prospection at the South Hill of Olynthos, Greece
(*Gregory Tucker, Lisa Nevett, David Stone*)

Over the past four years, the Olynthos Project has conducted an intensive program of geophysical prospection at the archaeological site of Olynthos in northern Greece. This poster will present the integrated results from geophysical prospection of the South Hill at Olynthos, including our initial attempts at data fusion. The urban core of Olynthos, which was partially excavated by David Robinson in the early 20th century, rests on two hills in Chalkidiki. The city is well known for the orthogonal plan that Robinson discovered on the North Hill, and for the houses at the site, which are some of the best preserved from the Classical Period of Ancient Greece. The Olynthos Project has conducted field work

at the site with a wide variety of research goals, such as better defining the urban environment on the less well understood South Hill. In collaboration with multiple research partners the project has undertaken a multimethod investigation using magnetic gradiometry (magnetometry), earth resistance (resistivity), electromagnetic induction (EM), and ground-penetrating radar (GPR). The initial results of each technique show that the South Hill at Olynthos did not follow the same orthogonal layout that Robinson identified on the North Hill, however, considering the methods together provides us with a more complete picture of the form and fabric of the city. The conclusions and interpretations which we present will contribute a better understanding of Ancient Greek urban planning as well as navigating data acquisition and processing using a multimethod approach.

R-CHAEOLOGY: using machine learning algorithms in R in favour of object-oriented supervised classification in LiDAR data

(Agnes Schneider)

Methods dealing with big amounts of data in Archaeology follow the evolution of data analysis in other sciences, for e.g. data science or remote sensing. The application of these new methods to Archaeology has benefits as well as limitations. These new methods are not going to or should replace the "classical" archaeological methods, like manual analysis or field-surveys or even human input in general. What new methods can do is to lend a hand to deal with big amounts of data in ways which are inaccessible to "normal" observers. We also have to bear in mind that these new methods are still evolving and it is a long way to understand how and if they can be applied to Archaeology. R is a fast developing open-source programming language mainly used for data science, which which capabilities are extending day-by-day by user-developed packages. In addition R enables us to import functions from other API's to use them in R. R-chaeology is an attempt to combine open-source visualization and image processing tools (LivToolbox, RVT, OTB) and GIS APIs (GRASS GIS, QGIS, SAGA) in R to preprocess LiDAR data and to test machine learning packages in R to understand how machine learning algorithms can "see" anthropological objects in LiDAR data. The micro-region of the Oppidum of Dünnsberg (Hesse, Germany) is used as a training area.

Magnetic susceptibility measurements for integrated quantitative interpretation of magnetic measurements

(Natalie Pickartz, Stefan Dreibrodt, Wolfgang Rabbel)

Magnetic measurements are mostly interpreted in a qualitative manner and the archaeological features are classified manually. Under consideration of measured magnetic susceptibility data and geometrical information based on excavations and multi-method measurements, the shape, extension and depth of archaeological features is going to be determined. Based on large-scale magnetic measurements key targets on archaeological sites in Slovakia (Vráble-Vel'ké Lehemby, Linear Pottery), Republic of Moldova (Stolniceni, Cucuteni-Tripolye) and Ukraine (Maydanestke, Cucuteni-Tripolye) have been identified. These targets were investigated with further geophysical methods (electrics, electromagnetics and ground-penetrating radar). Additionally, the magnetic susceptibility was measured in open archaeological trenches and in boreholes. From both – trenches and corings – sediment samples were taken to measure the magnetic susceptibility in the laboratory. As a first step,

we are comparing the different methods of magnetic susceptibility measurements to evaluate their comparability. Second, the susceptibility measurements and the geometry of the archaeological features are used to model the magnetic anomalies. Finally, the gathered information is transferred to unexcavated features to derive a quantitative interpretation of their magnetic anomalies by constrained inversion. It is aimed to automatically identify anomalies of specific groups of features and therefore to conduct an automated interpretation and inversion process. Our contribution focuses on the comparison of the different approaches to measure the magnetic susceptibility and outlines the upcoming steps.

The Swedish fire cracked stone heaps through a Landscape analysis
(*Amanda Saga Jeppsson*)

The Swedish remains "fire cracked stone heaps" have been debated for a long time. Nobody seems to know what the exact purpose of them have been and we will probably never know for sure. They have although always been categorized to belong to the Scandinavian Bronze Age (1700-500 BC). However, the remains show a clear placement pattern when looked at in a landscape perspective. The heaps are placed near the coast and due to the rapidly land rise, the fire cracked stone heaps manufacture might be dated through a reconstructed shoreline. The dated fire cracked stone heaps are however older than the Bronze Age and most of the heaps are manufactured 2100 BC. This places the heaps in the late Scandinavian Stone Age and the remains should be considered to belong in both time periods.

Stories from the Crypt - Australian Colonial Cemeteries according to GPR
(*Till Frieder Sonnemann*)

To identify unmarked graves for local heritage organizations and councils, a number of GPR surveys were conducted over several colonial cemeteries in New South Wales, Queensland and Victoria. The radargrams show different types of burials as they were dug according to the soil: from coastal sand, to the famous red desert soil and bed rock. From the results it is possible to draw conclusions on the challenging job of the undertaker in these extreme environments: quickly dug low lying burials, possibly to prevent the spread of diseases after disasters, to holes blasted into bed rock using dynamite. The GPR surveys were already conducted in the years 2008-2012, but the data was never presented to an academic audience. The poster includes short introductions on the purpose of the cemeteries in the 19th century: fortune seekers, gold miners and ship wreckers. Aside from soil and grave information, the subsurface radar data and time slices presents together with the distribution of gum tree roots a multi-layered mix of natural and human underworld, a palimpsest of Australian colonial cemeteries.

Ship Shapes: Digitising 17th and 18th century Dutch ship models
(*John Kennington McCarthy*)

This ongoing project involves 3D scanning of 17th and 18th century scale models of Dutch East India Company ships in several locations across the Netherlands during 2018. 3D photogrammetry, laser and CT scanning will be used to capture the highest possible level of detail for these intricate models. The

ships at the centre of this project are Dutch East India Company returnships, large specialised vessels built to travel from Europe to the East Indies bearing cargoes of silver, returning laden with exotic spices. These ships dominated trade in the Indian Ocean for much of the 17th and 18th centuries. A total of fifty Dutch East India wrecks have been found around the world but most of the remains have been destroyed by natural decay or through uncontrolled treasure hunting. Analysis of the scale models will be undertaken to furnish more information on the design and decoration of VOC ships. The models are also fascinating in their own right as objects of art and incredible craftsmanship, originating from the same artistic period that gave us Rembrandt and Vermeer. Flinders researcher and 3D specialist John McCarthy will carry out this project as part of his PhD studies. Less than 20 contemporary models of these ships are known to survive globally, mostly held in Dutch museums. The scans will be used to create reconstructions and animations as well as 3D prints and virtual reality simulations.

Re-visualising Kom W: From 2D to 3D

(*Joshua James Emmitt*)

Archaeological section drawings are two dimensional (2D) representations of deposit cross sections within an excavated area. These drawings are common in archaeological literature since the early 20th century and hold important information, however, they are often treated as static references to past excavations. In many cases multiple 2D drawings must be considered together, making interpretations and relationships difficult to visualise. With modern computing techniques these drawings can now be digitized and transformed into three dimensional (3D) representations. Here computer aided design (CAD) programs are used to digitize scans of published section drawings. 3D representations are integrated into Geographical Information Systems (GIS) for further manipulation and to place the data back into its original context and consider it in relation to contemporary data. This processes was applied to the 1925-26 excavation of Kom W in the Fayum, Egypt, by Caton-Thompson and Gardner. Over the course of the excavation 21 section drawings were made of the site. This process enables the reinterpretation of section drawings and as a result has allowed for the original excavation of Kom W to contribute to current research through a re-assessment of the post-depositional process that influence site preservation.

The Emerging Genre of Museum Film

(*Fan Zhang*)

Computers are more than calculating machines. In recent years, visual aspects of computational archaeology become more prominent. The distance between quantitative research and qualitative research is increasingly short with the emergence of new ways of data visualization and with the sophistication of augmented reality (AR), virtual reality (VR) and other technologies. My poster proposes "museum film" as a new film genre whose evolution parallels recent development of visual sensibility in computational archaeology. The new film genre, in my view, provides materials for a paradigmatic mode of analysis in dealing with such visual sensibility. The poster consists of three parts. The first part is a short list of recent films defining the emerging genre. The second part provides historical commentaries with the assistance of two texts: the 16th-century museum treatise Incision and the French filmmaker Robert Bresson's Notes on Cinematograph (1975). The third part proposes

a mode of analysis engendered by the genre and establishes its relevance to computational archaeology. In particular, I will analyse how the new film genre reflects new conceptions of emergence and immersion. The shortlisted films include Alexander Sokurov's Russian Ark (2001, the Hermitage), Jean-Marie Straub Daniele Huillet's Une Visite au Louvre (2003, Louvre), Hou Hsiao-hsien's Le Voyage du Ballon Rouge (2007, Musée d'Orsay), Tsai Ming-liang's Visage (2009, Louvre), Jem Cohen's Museum Hours (2013, Kunsthistorisches Museum), Mathieu Kleyebe Abonnenc's Sector IX B (2015, IFAN Museum of African Arts) and Sokurov's Francofonia (2015, Louvre).

Cultural Heritage preservation through Open Data and GIS: A methodological proposal for North-eastern Iberian Peninsula

(*Joan Canela Gràcia, Núria Otero Herraiz*)

Preservation of Cultural Heritage is one of the most important challenges faced by professionals who charged with its care. Diversity of Cultural Heritage – it includes from historical paths to big archaeological sites – makes more difficult to develop strategic plans for Cultural Heritage preservation. Emergence of Geographic Informative Systems allowed managing easily big data about this heritage, and drawing them on the map. Otherwise, the Spanish government provides LIDAR data open access useful for generating local scale Digital Terrain Models with a high definition. We present a methodological proposal focused on NE Iberian Peninsula, to plan at local scale the preservation of different kinds of catalan Cultural Heritage, shown as study cases. From generating high definition DTM at local scale, we use different GIS routines to calculate the most conflictive points for heritage preservation (terrain erosion, flow accumulation), in order to prioritize preservation works or doing preventive interventions to avoid irreparable damages.

Lost and found - A marble fragment from Olympia

(*András Patay-Horváth*)

A marble fragment published more than a century ago with a simple sketch is of vital importance for the reconstruction of the east pediment of the temple of Zeus at Olympia. It consists of a right dumb holding something, which was first interpreted as a centaur ear, but afterwards was described as part of a spearhead. No photograph has ever been published and a few years ago, while the 3D scanning of all fragments was carried out, no one was able to find the fragment in the storerooms of the local museum. During summer 2017, an old negative form taken from the 'lost' fragment was discovered by chance in the Gipsformerei at Berlin. The plaster cast shows both the original fragment and its reconstruction proposed in 1897. It was immediately scanned and can thus be measured and viewed from all sides (except for its broken surfaces, which are concealed by the reconstructions). On this basis, a new interpretation and reconstruction can be suggested.

The Use of Databases in Archaeological Excavation Teams and By Archaeology Scholars in Turkey

(*Tuğçe Köseoğlu*)

In the light of recent developments in technology, researchers must employ database management strategies to store their data. This project aims to understand the database management strategies of

archaeologist in Turkey, both Turkish and foreign. To achieve this, a survey was devised. The survey includes questions about database management practices, including but not limited to awareness of the tools they possess, their efficiency and overall performance. The survey has been sent out, and the answers will be recorded anonymously and then analyzed statistically; and a report showing the current trends and challenges will be formed. The methodology, results and discussion will be presented as a poster. This project is still under development and currently no results are available. In the near future answers will be collected and analyzed. It is hoped that this work will allow a better understanding of the use of databases and lead to improvement in their contribution to archaeology in Turkey.

The trade routes of the Mycenaean Messenia

(*Vasiliki Tsoumari*)

Mycenaean polities have always been in the spotlight for researchers in Bronze Age archaeology, as a fertile ground for theories on the constitution administration structure. This is a study about the relationship that was developed among important Late Helladic Period settlements of Messenia, in Peloponnesus, Greece. The trade transactions, the society structure, the geographical position and the surrounding landscape are some of the factors that contributed to the settlements' development and survival. Using GIS software, the author depicts the spatial features of the settlements and generates the less cost routes that may have been used among the settlements for their trade transactions. Theoretical sources, archaeological remains and information given by Linear B' clay tablets were evidences of immense importance. The combination of the above to the GIS software provides an up-to-date perception for the Mycenaean landscape in Peloponesus. The study reveals a close interaction between some of the sites and it points out to at least four territorial core settlements. The author suggests that each regional unit served as key node where the commodities were gathered before their redistribution to minor sites. I would like to dispaly my announcement on a wall poster with the following structure: Presentaion of the topic/theory, Aim, Methods, Results. My text will be illustrated by maps which I created during my study with the help of the GIS software and that present my final results regarding the topic.

Impact and Legacy of Post-1492 Swidden Farming in Neotropical Interfluvial Environments

(*Phil Riris*)

Humans are increasingly viewed as active agents of environmental and land cover change in the moist Neotropics. While the scale and extent of pre-Columbian anthropic impacts are actively debated, the effects of post-Contact patterns of land use are rarely examined over the long term, defined here as centennial timescales. This poster examines a putative area of historical low human impact located in the western Guiana Shield, the upper Cuao River, using an exploratory agent-based modelling approach. Based on an extensive ethnographic literature on the Piaroa, who have inhabited the region for at least four centuries, the model investigates the legacy effects of ethnographic patterns of land use in the interval between European Contact and the present. Model outcomes indicate that the potential range of anthropic changes to the environment of the study area are significantly greater in

scale than previously assumed. Interpretative discrepancies between present vegetation conditions and the model are likely the product of sparse palaeoecological and archaeological research in the upper Cuao. More broadly, the results imply that small-scale agriculture and agroforestry can lead to extensive and persistent structural changes to ecosystems in relatively short timescales. The experiment bolsters existing cautions against assuming the "natural" baseline of Neotropic forests based on present appearance. As a form of middle-range theory, the model demonstrates how computational approaches can promote closer integrations between ecological, archaeological, and ethnohistorical data, as well as frame the expectations of future research.

A GIS Approach to Archaeological Settlement Patterns and Predictive Modeling in Chihuahua, Mexico

(*Haylie Anne Ferguson*)

This study sought to analyze and evaluated the pattern of settlement, for known Medio period (A.D. 1200–1450) sites in the Casas Grandes region of Chihuahua, Mexico. Locational data acquired from survey projects in the Casas Grandes region was combined into a geodatabase and then evaluated within a Geographic Information Systems (GIS) framework to reveal patterns in settlement and site distribution. Environmental and cultural variables such as elevation, topographic aspect, slope, local relief, angle of view, distance to nearest water, and distance to nearest known ballcourt were calculated. It was expected that relationships of correspondence between known sites and these variables would offer a better understanding of Casas Grandes settlement during the Medio period. Additionally, the results of this study were modeled using logistic regression to produce an archaeological site sensitivity map for this region of northern Mexico.

Lost and found - A marble fragment from Olympia

(*András Patay-Horváth*)

A marble fragment published more than a century ago with a simple sketch is of vital importance for the reconstruction of the east pediment of the temple of Zeus at Olympia. It consists of a right dumb holding something, which was first interpreted as a centaur ear, but afterwards was described as part of a spearhead. No photograph has ever been published and a few years ago, while the 3D scanning of all fragments was carried out, no one was able to find the fragment in the storerooms of the local museum. During summer 2017, an old negative form taken from the 'lost' fragment was discovered by chance in the Gipsformerei at Berlin. The plaster cast shows both the original fragment and its reconstruction proposed in 1897. It was immediately scanned and can thus be measured and viewed from all sides (except for its broken surfaces, which are concealed by the reconstructions). On this basis, a new interpretation and reconstruction can be suggested.

Making stratigraphic interpretation reproducible - utilizing image analysis for archaeological fieldwork

(*Vincent Haburaj, Jan Krause, Björn Waske, Brigitta Schütt*)

A crucial point of archaeological fieldwork is the initial act of delimiting one layer from another. Traditional tools for this task (e.g. color charts) offer some degree of objectivity by comparing the

observed material to established standards. Nevertheless, this act largely remains dependent of the excavators perception. At this point, modern image analysis techniques may help to ensure objectivity and reproducibility. Holding potential for both archaeological and geographical fieldwork practice, digital image analysis techniques prove a helpful tool for stratigraphic interpretation. Within this study different algorithms for the determination of profile properties and the delimiting of layers using spectral data are compared. Profile data of a soil educational trail located in the area of the historic vineyard of the Cistercian Abbey Chorin (Brandenburg) is used as test site. Analyses are carried out using open-source software to ensure transparency and to offer a basis for further application. First results of our study will be presented at CAA 2018.

Archaeology and social networking sites: a systematic literature review and conceptual analysis of topics, questions and approaches

(*Costis Dallas, Ingrida Kelpšienė*)

Social networking sites (SNS) such as Facebook emerged recently as major platforms where members of amateur, local and source communities interested in archaeology engage with each other, with professional and academic archaeologists, and with objects related to archaeology, nurturing diverse practices of memory and material engagement, enabling the emergence of communities of interest and practice, enacting professional and cultural identities, and shaping the production of archaeological knowledge as well as the interpretation, appropriation and governance of archaeological heritage. This poster presents the initial analysis of a systematic literature review on archaeology and Social Networking Sites (SNS) conducted within ARKWORK – Archaeological Practices and Knowledge Work in the Digital Environment, a knowledge mobilization network funded by the European COST programme. We outline how we applied a novel method for literature review analysis, combining theoretical and in vivo qualitative coding of over a hundred scholarly publications. We also summarize research questions, empirical evidence, geographical and thematic coverage, theoretical foundations and key findings identified in the literature. Finally, we assess the uptake in our corpus of major explanatory concepts used in broader social media research (such as civic participation, social creativity, affiliative objects, communities of practice, social capital, presentation of self, tacit knowledge, institutional isomorphism, and platformization), and identify directions for further potentially fruitful research on archaeology and SNS.

Low-cost semi-automatic image-based measurement and spatial analysis of ceramics

(*Michaela Prišťáková, Petr Dresler, Vojtěch Nosek*)

Spatial analysis of ceramic fragments from the cultural layers may provide us with useful information on the living spaces and urbanisation of the site. Besides analyzing quantities, weights etc. of the finds, spatial distribution of different size groups should be taken into account. The aim of our research is to provide an accessible method to implement semi-automatic image-based measurement of ceramic fragments into common research. Applicability during field excavation and also on the material from the older excavations is available. Therefore, it should be low-cost and user-friendly, so it will not be time consuming in the field and easily done with common research equipment such as a digital camera. In the first step we will discuss methodology of data acquisition, and their issues. Thereafter, an

algorithm for image processing, its specification and results will be presented. Further statistical and spatial analysis will be compared with other results from the studied site. The idea of image-based measurement of artefacts is not new, but it is still making its way into Czech archaeological research. The input data comes from the systematic excavation of the Department of Archaeology and Museology of Masaryk University at Pohansko near Břeclav.