

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

Johanna Stoeger, Eleftheria Paliou, Undine Lieberwirth

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

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

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

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

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

Eleftheria Paliou

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

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

Hanna Stöger

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

S13-03 Kerkenes Dag: Materializing an Imaginary City

Scott Branting, Tuna Kalayci

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

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

Chiara Piccoli

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

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

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

Jacopo Turchetto, Giuseppe Salemi

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

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

Kayeleigh Sharp

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

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

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

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

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

References [1] M. Kormann, S. Katsarou, D. Katsonopoulou and G. Lock (2015). Structural Integrity Modelling of an Early Bronze Age Corridor House in Helike of Achaea, NW Peloponnese, Greece. CAA 2015 Siena. [2] J. McEnroe (2010). Constructing Identity in the Aegean Bronze Age, University of Texas Press, 195pp. [3] H.G. Njau and E. Park (2015). Physical Properties of Unfired and Compressed Same Clay Brick Composites Reinforced with Natural Fiber from Tanzania, Int J of Innovative Research in Advanced Eng, Issue 4, Vol. 2

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

Undine Lieberwirth, Axel Gering

3D models are nowadays fashionable and always an eye catcher on conferences. However, what data really hide is depending on the system and digital environment of the model. Primarily, a 3D GIS environment offers the same possibilities as a 2D GIS extended in the third dimension.

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

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

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

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

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

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

Sven Straumann

In a PhD-project at the University of Basel (CH) the completely excavated Insula 30 of the roman colonial town Augusta Raurica (CH) is in the focus of an archaeological interpretation. GIS is being employed from the very start of this post-excavation analysis. The introduced project shows the method and procedure how archaeological records can be extrapolated as a source with the aid of GIS. Digitising completely the analogue records (photos, drawings, descriptions etc.) and integrating them into the GIS system allows the potential of old excavation documentation to be much better and more efficiently exploited. This computer application facilitates the handling of "oceans of data". Because all the data and contents of

the excavation documentation are available in digital form via the GIS, work can be done on the evaluation from any location. The data can be used for doing research on different topics in various scales, from the micro-scale of the roman insula (building development, architecture, functionality) to the macro-scale focus of the city (urbanism). This will finally lead to a 3D/4D visualization of the building development. Within the many advantages and possibilities of this innovative method the long-term sustainability has to be emphasized. The digitally extrapolated sources and the Data in the GIS are comprehensively available for anyone in the scientific community to use for his or her own investigations (<http://www.augustaurica.ch/de/stadtplan>).

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

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

Kristine Stub Precht

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

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

Mark A. Locicero

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

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

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

Kasper Jan Hanus

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

S13-P1 Forum Boarium survey

Sabrina Amaducci

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

aspects of buildings and ancient life in Fortum Boarium that have not been completely explained yet.

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

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

Since the first pioneering application of the 1970' and 1980', during the last decade or so Network Analysis has become more and more popular within the Archaeological discipline. In particular various scholars have emphasised the potential of Network Analysis for the study of emerging complex societies; however the applications to the study of urbanization and state formation processes remain very few. By comparing Bronze and Iron Age Settlement terrestrial and fluvial Networks in Etruria and Latium vetus, this poster will show how a more compacted and hierarchical region as Latium vetus prevailed over the larger but more heterarchical Etruria. When cultural networks are considered the calculation of centralization measures on different networks through time shows clear trends which still need to be fully evaluated but are interesting in their distinctive trajectories.

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

Till Frieder Sonnemann

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