

## **S02 Using GIS modeling to solve real-world archaeological problems**

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

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

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

*Jade d'Alpoim Guedes*

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

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

*Katia Francesca Achino, Juan Antonio Barceló*

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

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

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

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

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

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

*Mike Groen*

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

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

*Kelsey M. Reese*

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

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

*Dita Auziņa*

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

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

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

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

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

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

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

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



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

*Stephanie E Metz, Harald Stadler, Thomas Bachnetzer*

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

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

*Joe Roe, Olivia Mavrinac, Tobias Richter*

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

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

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

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

*Gail Michele Higginbottom, Roger Clay*

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

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

*Tsoni Kolev Tsonev*

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

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

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

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