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Elsa	Arcaute	e.arcaute@ucl.ac.uk	CASA, UCL	Natural regional divisions of places in Domesday Book	Stuart Brookes and Andrew Reynolds
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Natural regional divisions of places in Domesday Book

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The following paper presents an analysis of the interconnectivity and emergent regional structures from the locations of places listed in Domesday Book [1]. Urban systems present hierarchical structures that are observed as administrative regional delimitations, which are the outcome of geographical political and historical constraints. In previous work we have shown that the hierarchies in contemporary UK can be uncovered through the application of percolation theory to the street intersections [2]. In this paper we apply this formalism to the places listed in Domesday Book. The algorithm is very similar to the CCA (City Clustering Algorithm) [3], clustering together pairs of places that are at a distance given by the threshold parameter. This gives rise to clusters at many different scales. Some of these scales reveal divisions that are in very good correspondence with natural and social divisions of early medieval England, partly reinforcing, and partly enhancing our understanding of their evolution.

Amongst the many factors that potentially affect the structure of settlement, the natural topographies of elevation, hydrology, and land quality might be considered particularly significant, and some do find close correlation with regions of settlement clusters. We will discuss the relationship with Roberts and Wrathmell's [4] mapping of historic settlement patterns in England, which defined contrasting types of rural landscape: a regularly planned 'Central Province' running through England, and 'ancient' countrysides of more organic development in the south-east and north-west. The interface between these contrasting landscapes emerges from the connectivity plots, and in 'ancient' landscapes, where places grew more organically, there are correlations with some of the major rivers and watershed boundaries. Comparison will also be made with the administrative territories of Domesday England. Here connectivity plots can be used to better understand the trajectories of administrative development, particularly in the 'Central Province', where settlement was significantly re-organised during the 9th to 11th centuries [5]. We will argue that a disparity in the boundaries in this area can be related to top-down processes of administrative and urban restructuring, which has led to unnatural divisions, not determined by the proximity of the places.

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Title: The Network of the North-Etruscan Settlements during the Romanization

Speaker: Dr. des. Raffaella Da Vela

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Abstract: The Romanization of Northern Etruria is a long and complex process that concerns the political organization of the Etruscan cities, their social structure, the local economy in relationship with the global one, and many other cultural aspects. During my doctoral study of the cultural transmission in northern Etruria, I collected a database of the archaeological material findings in these cities and in the settlements of their territories. The principal questions I am looking forward to answer through the Social Network Analysis in these geographical and cultural area are the following: Which is the connecting role of the minor settlements and how do they participate in the circulation of goods, ideas and models? How does the perception of Etruscan cultural identity and the related affiliation among Etruscan cities interact with the economical and political needs? I propose to analyze this social network in a synchronic and a diachronic way considering the evolution of the relationships between these cities during the Romanization. Aims of my study are the individuation of the differences in the results of the dyadic and the triadic analysis in Northern Etruria, the description of the chronological evolution of the network during the complex process of Romanization and the determination of the connecting role of minor settlements in this period. Regarding the first two aims the network analysis will use a dyadic and a triadic approach. At first I will consider the dyads Volterra-Populonia, Pisa-Volterra, Perugia-Volterra, Chiusi-Perugia and afterwards the triads Volterra-Populonia-Pisa and Volterra-Chiusi-Perugia. Every dyad and triad is analyzed in three chronological phases (before the Punic Wars, during the Punic Wars, after the Punic Wars). The relational ties are the transfer of material resources and products (money, ceramics, metal products) and immaterial resources (ideas, iconographies, models); association or affiliation (in the social and in the civil wars); behavioral interaction (economical agreements, political pacts); movement between places (migrations; marriages; familiar alliances through epigraphic records); physical connections (route-systems, sea-ways). Regarding the third aim the network analysis will observe the regional and local dimension and will be based in the first instance on the main cities (coarse meshed web) and following, in a second instance, only on the minor settlements (close meshed web). Finally the network of both, main cities and minor settlements, will be unified to determine the attribute of central places and to substitute the idea of bordered territories with the network of connecting settlements and areas.

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The Connected Past: archaeological challenges and complexity Conference

Imperial College, London, 8-9 September 2014

Paper Proposal

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Proposed Speakers: Francesca Fulminante and Luce Prignano

Networks and Urbanization in central Italy (1175/1150-500 BC ca)

Abstract

Since the first pioneering application of the 1970' and 1980', during the last decade or so Social Network Analysis (SNA) has become more and more popular within the Archaeological discipline. In particular various scholars have emphasised the potential of Social Network Analysis for the study of emerging complex societies; however the application of formal SNA to the study of urbanization and state formation processes remain almost unexplored. Contributing in this direction, we have formed a multidisciplinary team combining a deep archaeological knowledge on a concrete case study with methodological expertise on complex networks.

Specifically, we have set up a research line focusing on the parallel but contrasting trajectories towards higher complexity of urban systems in two Italian regions, namely *Etruria* and *Latium Vetus*. This is done by comparing Bronze and Iron Age settlement terrestrial and fluvial transportation networks. In particular we are applying a network approach (1) to determine the influence of river and terrestrial routes in the emergence of a hierarchy of settlements around a number of proto-urban centres; (2) to characterize the topological evolution of communication infrastructures during this urbanization process.

The considered networks have been constructed in the following way. Settlement directly connected by a terrestrial route or by a river have been connected in the network via an undirected unvalued link; in fact, for simplicity, it has been assumed that movement of goods, ideas and people would flow in both directions in an equal measure.

Our analysis takes advantage of methodological tools developed within the framework of social network analysis and network science. We started by characterizing the nodes through centrality indexes and the topology of the networks by means of usual measures (degree distribution, density, and average clustering coefficient). Additionally, we analysed the eigenvalue spectrum of both the adjacency and the normalized Laplacian matrices, in order to achieve a description directly addressing the dynamical processes that may take place at a system level. We have thus been able to confirm that

rivers connection, at least at an intra-regional scale, were more relevant during the Bronze Age rather than in the Iron Age since in this last phase the river network seems to be unable to add anything valuable to the information provided by the terrestrial routes.

We are currently elaborating a model for the evolution of the system. A proper choice of the set of parameters will hopefully allow us to reproduces different scenarios by tuning their values. A final step will be to reconnect the output of the model to our present case studies. Further development of the work will include 'cultural elements' in the construction of the networks such as artefacts decoration and styles, imports, family relations from inscriptions etc. in order to assess the importance of different elements (geographical versus cultural) in the evolution of the system.

Path dependency: explaining higher order phenomena in the Lower to Upper Paleolithic record of Western Europe

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The material record of the Paleolithic poses a special challenge to archaeologists trying to reconstruct the lifeways of our ancestral past. The preserved remains are extremely sparse, highly fragmented and often allow quite different readings; furthermore they are often fairly similar, even over long periods and across vast regions. A serious analytical problem concerns phenomena spanning considerable timeframes and areas, such as the occurrence of Handaxes, the Levallois method, and Upper Paleolithic blade technologies. Such long-term persistences of traits cannot simply be explained by social transmission alone, since their temporal and spatial extents exceed those of any known tradition-bearing unit by orders of magnitude (Wotzka 1993; Clark 1994). Additionally, micro-scale transitions in different material sources (bones, lithic tools, personal ornaments) often do not correlate with major stratigraphic and technotypological transformations (cf. Kuhn 2013). Both observations indicate that we are dealing with patterns of a superordinate scale of analysis, not directly reducible to micro-scale processes. Some scholars have suggested to interpret these higher-scale patterns in a positivist way, seeing them for example as "civilizations of techniques" (Koehler 2011). Here, we explore an alternative strand. We argue that theoretically acknowledging the emergent character of these similarities and continuities can lead to a richer and much more complete understanding of the Paleolithic as a period. Along these lines, we investigate the potential of path dependency as an explanatory concept for mechanisms underlying some aspects of material culture which document such an immense temporal and spatial stability.

As a first case study, we consider (1) the persistence of handaxes for over a million years in the archaeological record of almost all of Western Europe. A striking feature is their relatively static morphological appearance, whereas their modes of production are often quite different. Following Lemonnier and others (Lemonnier 1986; 2013; Boëda 2005), we argue that these non-stable and highly variable techniques were possibly targets of socio-culturally filtered choices (Nicoud 2011), whereas the morphotyp "handaxe" was not – be it for actual people or groups. Instead, we suggest that handaxes reflect an extremely mobile way of life with highly flexible subsistence strategies. They therefore mirror a certain way of living and a certain way of using Pleistocene landscapes. We argue that as soon as all the relevant subsystems of such a land use system are well attuned and support each other, the transaction-costs for switching to another system become tremendously high. It is in this sense, that the handaxe as a morphotyp testifies a true systemic lock-in, being largely decoupled from actual processes of social transmission or natural selection. In a second part, we then turn to higher order continuities such as (2) the proclivity to produce elongated blanks (blades) in the Upper Paleolithic of Western Europe. Again, we suggest that this long-lasting and widely distributed phenomenon is much better understood as an emergent pattern than as a cultural category.

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Finding meaning in a digital landscape: GIS modelling and ancient Greek agriculture

Dr. Maeve McHugh

This paper stems from my current research on the role and function of farmsteads in agricultural industry using spatial modelling. In the interest of achieving a better understanding of the role of farmsteads, primarily identified in pedestrian landscape survey, I used GIS generated models of the ancient agricultural landscape to test the extent of visibility from these sites using viewsheds, mobility across the landscape via least-cost path, and cost distance tools. The purpose of these analyses is to further explore how farmsteads were used as centres for occupation, storage, and agricultural processing by those farming the land. This type of modelling is quickly becoming a mainstay of research particularly with regard to pedestrian landscape survey (see Howard 2007; Bevan and Conolly 2013). The applicability of GIS modelling and how it relates to the textual and archaeological evidence is the focus of this paper. As such this paper investigates the applicability of using GIS modelling as a tool to explore the ancient agricultural landscape and asserts that it is necessary not only to employ a humanistic theoretical model (e.g. Tilley 1994) to underpin the GIS analyses, but also to maintain awareness of the socio-economic influences which dictate various farming practices in different regions of mainland Greece dating between the Classical and Hellenistic period. This awareness of additional non-quantifiable factors which prescribe farming objectives in Greek regions and within family units must be borne in mind before drawing conclusions from digitally generated models of the ancient landscape. In doing so it is vital to take into consideration the corpus of textual evidence, and the nature and quality of the archaeological evidence used to carry out such analyses. In order to elucidate these issues further I will use existing models of the ancient agricultural landscape based on the data from the Methana, Argolid, and Laconia survey areas, in order to highlight some of the challenges presented by attempts to generate landscape models using data from pedestrian landscape survey. I will also question how, if at all, these findings relate to the evidence from texts and archaeology. The conclusions from this paper will suggest that, though it is imperative to maintain awareness of historical and social contexts, the application of digital technologies allows the researcher to more fully exploit the existing archaeological and textual data.

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Computational Aspects of Ancient Social Heterarchies: Learning how to Address Contemporary Global Challenges

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We propose a talk where we discuss why we conjecture that some pre-Hispanic indigenous transition societies in Colombia (the Zenú, located in the region of the Depresión Momposina; the Muiscas, in the Cundiboyacense Plateau; and the Tayrona, in the Sierra Nevada de Santa Marta) might have been heterarchical, provided that they computed interactively (Goldin & Wegner, 2008) and how network modeling techniques can help prove or disprove our statement.

Heterarchical communities are horizontally distributed networks of individuals that operate without any overarching centralized control structure (Crumley, 1995). Contrary to hierarchies, heterarchies tend to be self-organized and they lack top-down the centralized information processing that characterizes decision-making processes in the tree topologies of traditional hierarchical Turing-like political systems (Mezza-Garcia and Gómez Cruz, in prep.). Thus, heterarchies allow horizontal and better communication networks and interactions among the components of a system with relative large autonomy.

The spatial dynamics of the settlements of the Muiscas, the Tayrona and the Zenú presented elements that suggest heterarchical arrangements. For instance, it is not very likely that the five hundred thousand acres of artificial hydraulic channels built by the Zenú between three and to millennia ago was controlled by a centralized authority (Rojas, 2008). Likewise, the lineage networks across various Muisca communities point towards non-linear dynamics of political, social and economic decentralized confederations (Langebaek et al., 2011). Finally, although there is archaeological evidence for some social differentiation on the basis of differences in burials in the Tayronas, the buildings in their cities were connected by a maze of pathways with some central nodes but without any clear principal avenues, and the more important buildings were not physically separated from the rest of the city (Giraldo Pélaez, forthcoming). Hence, it is possible that in these cases the water channels, network lineages and connected paths mean that we are dealing with small-world architectures, which has been shown to be conducive for the emergence of interdependence and cooperation. The high levels of self-organization that the spatial dynamics of the latter communities had could be arguments in favor of the presence of heterarchical societies that self-organized in behalf of their self-optimization. Modeling and simulation techniques and network models such as Hopfield networks could help prove or disprove the later hypothesis.

Watson and colleagues (2010) have shown that Hopfield networks can optimize their own interconnectivity by means of local optimizations performed by the interacting nodes. They discovered that in order to avoid reaching a stationary state in a suboptimal configuration the set of behavioral states needed to be occasionally randomized. Similarly to the claim of Froese, Gershenson, & Manzanilla (in prep.) in their work about Teotihuacán, the Muiscas, the Tayrona and the Zenú also present elements of periodic disruptions. There were annual floods in the Zenú area, human sacrifices in the Muiscas, and the consumption of mind-expanding substances in congregation terraces in the Tayronas, which could have self-optimized social relations. It is already known that these rituals temporarily changed the behavior of the people (Sotomayor, 1990) by resetting the whole social system. More generally, we hypothesize that there was a correlation between the amount of social flexibility in changing status and relationships and the extent of heterarchical organization. This is because game theory has demonstrated that cooperation without central control is facilitated when agents are allowed to quickly adjust their social relations. It remains to be seen if our predictions are verified by future archaeological research.

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Peter Bray, Laura Peruchetti, Mark Pollard, John Pouncett.

Beyond provenance: Copper-alloy chemical signatures as proxies for human technological practice in the past

Scientific approaches to ancient copper metallurgy have tended to focus on the analysis of the bulk chemistry of metal objects. This work was driven by hopes that the metal's provenance could be determined through linking artefact chemical signatures with those for early mines. This resulted in the creation of an impressive database (over 40,000 samples from across the Europe) but we argue that such an approach has been too static and, above all, too disconnected from human society and the real technological behaviour.

Large-scale flows of metal, recycling, mixing, and reworking have often been discussed in the conceptual literature, but with little direct engagement with the scientific datasets. This paper describes a new interpretative approach to copper-alloy artefact chemistry and lead isotope ratios, which abandons a static, statistical focus on provenance. The chemistry of a unit of copper alloy is not fixed over the course of its "lifetime". Oxidation of vulnerable metals such as arsenic and antimony occurs during melting, while silver and nickel are resistant to such losses. Alongside this, mixing can dilute or enrich these element signatures. Long seen as problematic, these effects are crucial to characterising real people's technological interaction with early metal. To demonstrate our new approach this paper discusses the 40,000 chemical sets from across the European Early Bronze Age, with a focus on recycling and the flow of metals within Europe.

Tracing metal networks in the Balkans at the dawn of the Metal Age

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Recent research into the origins of metallurgy in Europe revealed an unprecedented complexity of data demonstrating extensive exchange of copper artefacts among prehistoric communities in the 5th millennium BC Balkans. The provenance analyses conducted by a dedicated scholarship in the field of isotope analysis demonstrated exploitation of several copper deposits at the time, a few of which proved to be particularly prolific. Archaeological and archaeometallurgical studies have thus far revealed a variety of stylistic characteristic of c. 4,300 copper metal implements produced during the 5th millennium BC, as well as technology employed in their production. However, although the available data stand out in quality and precision, little has been done do address the complexity of networks of metal movements in the 5th millennium BC Balkans.

Here we present analysis of the Europe's earliest metal movement networks, which demonstrate the existence of several production centres at the time. Moreover, the stylistic and functional characteristics of these metal finds reveal a distinctive pattern within specific regions, thus suggesting particular tool design preferences potentially related to technological and cultural identity of different groups of craftsmen. The application of complexity science on this particular example demonstrates the capacity of such an approach to access patterns of artefacts movements as much as patterns in human behaviours and dynamics of social change at the time.

Proposal for "Connected Past", London 2014

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Post Doc, ERC-Project "Lived Ancient Religion" (Prof. J.Ruepke)

Region, religion and the question of the evidence: Is it possible to approach sacred spaces in Southern Syria with network analysis tools?

Archaeology (as an anthropology and sociology of ancient cultures) often investigates influences, changes and processes in ancient societies' realms of life. However, in many studies on the Graeco-Roman Mediterranean entailing problems of identity, of impacts of the Roman Empire or of surveys on economic and settlement history, neither the question of how influences arrived and processes came to work, is addressed, nor are the quality of contacts and their spatial scales discussed thoroughly. Yet, pivotal projects (e. g. of "The Connected Past" group) show what results can be gained from the sources by applying network analysis in terms of thinking about ancient societies. However, the databases to work with have to be valid and dense.

My paper is an attempt of approaching sacred spaces in Southern Syria (Hauran) from the perspective of connectivity and embeddedness (as part of a broader project on "enlived spaces", on experiences in and appropriation of shared sacred spaces in the Near East). Academia still tends to claim the Hauran and its inhabitants for expressing "resistance" to a Western Mediterranean *koine* or "loyality" to the Roman Emperors; architecture, including the sacred spaces, is called "rural" or sculptural style as "misunderstanding" Graeco-Roman archetypes.

Applying methods of classical archaeology and epigraphy as well as from the field of network analyses to contexts and materials from ancient Hauran, I will investigate first how to define the `region´, then the connectivity, the catchment area and functional status of sacred spaces among people to draw a comprehensive picture of their embeddedness. This analysis entails to deal with questions of scales and qualities of networks, differences of material categories and reliable quantity of evidence.

By clarifying the social and spatial networks sacred spaces are located in, and analyzing who was interested in them and in what manner, we will better understand impacts emanating from shared sacred spaces, and their function as places of religious activity for the (groups of) attendants. However, the problem of what database seems to be sufficient for a study of any kind of network in antiquity, may impede the analysis and is subject to discussion.

Comparative approaches to the use of archaeological data inside computer simulation

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Computational simulation of societies has found in archaeology one of the most promising fields of applications. The reason of this interest can be found in the link between the objectives of archaeology and those of simulation. Archaeology attempts to understand human behavior through the detection and analysis of spatio-temporal patterns related to the location and type of found structures and objects. Uncertainty is inherent to this process, both in time and space. Within these settings, computer simulation is the ideal virtual laboratory because it is capable of dealing with mathematically intractable problems such as the complexity of human behavior. Simulations give the possibility to explore the different hypotheses capable of explaining detected patterns, and also create new theory about the behavior of the original system. However, the very nature of the data (fragmented and uncertain) makes hypotheses validation difficult for many research questions. Therefore, how can simulation be used to explore past social dynamics?

This work explores possible answers through the experience of two different initiatives with similar goals but completely different approaches, which arise from the existing data.

The **SimulPast** project (http://www.simulpast.es/) is an interdisciplinary effort to apply quantitative methods to improve our understanding of past socioecological system. The project is formed by more than 70 researchers from 12 different research groups, which includes Archaeology, Anthropology, Physics, Computer Sciences and Sociology. The diverse knowledge creates a transdisciplinary framework centered on case studies and themes with different scales and research topics. In particular, the case study detailed here explores the interaction between hunter-gatherers and agro-pastoralists in the context of North Gujarat (NW India). This example provides an opportunity to explore the complex relations between environment, subsistence strategies and cultural transmission using innovative Agent-Based Simulation techniques. On the one hand, Artificial Intelligence plays a vital role to explore the importance of cognition and decision-making processes in cooperation and conflict situations. On the other hand, the fragmentation and paucity of the archaeological record has oriented the case study towards the development of theory-building models defined to study the impact of diverse factors (extreme environment controlled by monsoon, social interaction, population dynamics, etc.). In this context High-Performance Computing has been used to design experiments capable of dealing with the high stochasticity of the system in the search for new hypotheses regarding the resilience of different subsistence strategies.

The **EPNet** project (http://www.roman-ep.net/epnet), recently started in march 2014, aims to apply an innovative framework to shed new light on the ongoing debate over the political and economic implications of the Roman trade system, its organization and dynamics. This approach reanalyses existing empirical through complex network analysis, model building and computer simulation. The objective is to create an experimental laboratory for the exploration, validation and falsification of existing theories, and the formulation of new ones. This approach is made possible by a large dataset of Roman amphorae and their associated epigraphy created by the group CEIPAC (Centro para el Estudio de la Interdependencia Provincial en la Antiguedad Clásica) in the last 22 years as well as by theoretical research exploring the Roman trade system.

The comparative analysis of these different perspectives applied to archaeologically relevant questions suggests that the capabilities of studying social complexity using simulation are different depending on existing data. Researchers must face this issue while defining the original questions that they want to explore, and the formal model must be always deployed within a common framework where researchers can understand each other and achieve real transdisciplinarity.