Connecting the Dots: an Introduction to Critical Approaches in Archaeological Network Analysis

Tom Brughmans
University of Southampton, UK. *t.brughmans@soton.ac.uk*

Leif Isaksen
University of Southampton, UK.

Graeme Earl
University of Southampton, UK.

Abstract:
This paper aims to provide a framework for the new critical approaches in archaeological network analysis presented in the CAA 2011 Data Analysis session. It will briefly introduce the history of two network traditions that have been highly influential in archaeology: social network analysis and complex networks in physics. A review of published archaeological and historical applications follows, illustrating that, although a wide range of applications already exists, archaeologists have still to explore its full potential as a research perspective. Some relevant papers presented at the Data Analysis session are briefly described and considered in order to add original and critical approaches to an already very diverse corpus. We will argue that an awareness of the dominant network traditions, their differences and how they have been applied by archaeologists, as well as a specifically archaeological critique of adopted techniques, is a necessity for future research agendas.

Key Words: *Networks, Social Networks Analysis, Complex Networks*

Introduction

Relationships between people, objects and ideas mattered in the past just as they matter now and will continue to do so in the future. If we want to properly understand the structure of our datasets, the particular actions of historical individuals or the properties of past large-scale processes, the explicit study of relationships is crucial. It is our belief that a networks approach holds great potential for this purpose. The session entitled 'Connecting the dots: critical approaches in archaeological network analysis' held at CAA 2011 in Beijing as part of the 'Data Analysis' session aimed to provide a multi-disciplinary discussion platform to explore this potential. This paper gives an overview of archaeological applications of network analysis, as well as the multi-disciplinary traditions that have been most influential to these applications. A brief introduction of the papers presented in that session illustrates that new critical approaches of networks have much to offer to our discipline.

The Old Science of Networks

Network-based approaches consist of a set of theories, models and applications developed and often differently applied in diverse disciplines. Whilst networks were originally the territory of mathematicians in graph theory (Biggs et al. 1976; Bollobas 1998; Harary 1969; Harary et al. 1965; West 1996), sociologists have developed a strong tradition of social network analysis in the latter half of the previous century (Barnes and Harary 1983; Freeman 2004; Granovetter 1973; Wasserman and Faust 1994). Finally the emergence of what is often called “the new science of networks” was triggered about a decade ago by complex network models developed in physics (Barabási 2002; Barabási and Albert 1999; Newman 2010; Watts 2003; Watts 2004; Watts and Strogatz 1998). The network is a distinct research perspective, however, as all network-based approaches postulate the importance of relationships among interacting units. In all network-based approaches it is assumed that the relationships between entities like people, objects or ideas matter and that such relationships must be examined if we are to understand the behaviour of these entities (Nooy et al. 2005; Wasserman and Faust 1994; Watts 2003). This first principle implies another assumption of the network, one that introduces the multi-scalar character of all network-based approaches: the entities cannot be understood independently of the connected whole and vice-versa. Similarly, in social networks “actors and their actions are viewed as interdependent rather than independent, autonomous units” (Wasserman and Faust 1994, 4). In other and more familiar words: the whole is greater than the sum of its parts.

Two scientific traditions have been particularly influential on archaeologists: social network analysis and complex networks in physics. Here we will briefly introduce both of these.

The main difference between social network analysis and other network-based approaches is its restriction to social units. It is concerned with exploring social relationships as media for the flow of resources between active individuals, corporations or communities. Social network analysis developed as a major research perspective in the social and behavioural sciences from its precursor, sociometry. The latter field involves the measurement of interpersonal relations in small groups and was founded by Moreno after his invention of the sociogram in the early 1930’s (Moreno 1934; Moreno 1946; Moreno 1960). The sociogram is a means for depicting the interpersonal structure of groups as points and lines in two-dimensional space, like graphs. Later social network analysts built on Moreno’s pioneering work by introducing a range of analytical techniques, which led to the strong influence of mathematics and the popularity of quantitative analytical approaches social network analysis is well-known for. Graph theory, statistical and probability theory, and algebraic models in particular, found a place early on in mainstream social network methods (Wasserman and Faust 1994, 10-17). Social network analysis models, methods and applications were further formalised by a number of extremely influential books in the last two decades (Carrington et al. 2005; Scott and Carrington 2011; Wasserman and Faust 1994).

Much of the work on complex networks on the other hand aims to identify and explain self-organising emergent properties of complex systems. Such properties are self-organising because they are patterns visible at the scale of the system but emerge without any internal or external planning or control. They are called emergent because they arise out of the relatively simple interactions between individual entities or actors who collectively form more complex behaviour (Mitchell 2009, 13). A few very popular models have been developed to identify properties that turn out to be extremely common in diverse real-world networks. In 1998 Duncan Watts and Steven Strogatz (for the original paper see Watts and Strogatz 1998; for overviews see Watts 2003; Watts 2004) developed a simple model capturing a feature of complex networks that has puzzled sociologists for decades: ‘the small-world problem’ (for an overview of pioneering work on the small-world problem see Garfield 1979; Milgram 1967; Pool and Kochen 1978). They revealed a realm between order and randomness where networks exhibit a high degree of clustering coupled with a short average path length. As an example, think about how you know many different groups of friends (high clustering) whilst only a few of those friends will actually know people from more than one group of friends and can therefore share information between groups (short average path length). A second popular model emerged shortly after Watts and Strogatz's work and was in fact developed using the same real-world networks to address a fundamental assumption of the former model. Albert-László Barabási and his student Réka Albert concluded in their ground-breaking paper published in Science in 1999 that in real-world networks degree distribution (a distribution of the number of relationships of nodes) is not normal as Watts and Strogatz assumed, but is in fact highly skewed following the pattern of a power-law distribution (for the original paper see Barabási and Albert 1999; for overviews see Albert and Barabási 2002; Barabási 2002). This means that many nodes have a very low number of links whilst a select few have an extremely high number. Although these models are not the only techniques for understanding properties of complex systems (e.g. Bak et al. 1987; Buldyrev et al. 2010; Turcotte 1999; West et al. 1999), they have dominated network thinking in complexity science for the past decade and strongly influenced future research.

Archaeological and Historical Applications

Graph theory, social network analysis and network thinking in complexity science have been applied sporadically in archaeology and history during the second half of the previous century but have been increasingly prominent the last decade. In *Analytical Archaeology* David Clarke (1968, 469-471) suggested the study of network development in archaeology through the creation and simulation of generalized network models. His early use of networks was strongly influenced by developments in the New Geography. Cyprian Broodbank (2000) used Proximal Point Analysis (PPA), a nearest neighbour technique for constructing networks, to understand the interactions between Early Cycladic sites. Whilst this application is based on empirical archaeological data, the PPA technique seems too simplistic for understanding networks of social interaction between island communities given its restriction to a single parameter: spatial proximity. The network approach taken by Carl Knappett, Tim Evans and Ray Rivers (Evans et al. 2009; Knappett et al. 2008; Rivers et al. 2011) addresses this shortcoming in Broodbank's application. Their evolving mathematical model of maritime interaction in the Aegean Bronze Age, in addition to geographical distance, builds on network optimization and scaling of site sizes through a gravitational effect. Although their work should be considered a pioneering effort in modelling dynamic hypothetical archaeological networks it does raise the issue of the role played by archaeological data in a network approach. Bentley, Maschner and Shennan's work (Bentley and Maschner 2001; Bentley and Maschner 2003a; Bentley and Shennan 2003) offers interesting examples of a complex systems approach for archaeology. They applied the popular complex network models mentioned above to archaeology not too long after their initial publication and framed them within a complexity science perspective as explored for the archaeological discipline by James McGlade (2005), Sander Van der Leeuw (Van der Leeuw and McGlade 1997) and John Bintliff (2004). The work by Bentley, Maschner and Shennan made a valuable contribution to archaeology by illustrating the application of scale-free networks within a complexity science research perspective, yet the examples given are repetitive as one reviewer noted (Janssen 2005, 569) and the results quite typical for scale-free networks. In a recent paper, Timothy Kohler (in press) expresses his belief in the potential of networks approaches within a complexity science framework for identifying patterning in large datasets. Complexity science itself, however, is all-but fully formed. Although it has clear potential, attempts by archaeologists to use aspects of complexity science theories and methods coupled with a networks perspective require further exploration (Kohler in press).

Some methods developed in social network analysis and complex network science have been applied successfully to explore large datasets, understand properties of past complex systems and study socio-political interactions on a range of spatial scales. Shawn Graham's (2006a; 2009) study of the individuals active in the Roman brick industry in central Italy is the best example to date of the potential of social network analysis combined with real-world complex network models to address archaeological research topics. By combining information on brick producing centres, derived from an archaeometrical analysis of clay sources, with names of individuals appearing on brick stamps, a social network of people could be constructed and analysed. Graham identified a small-world pattern in this social network, where Domitia Lucilla, mother of Marcus Aurelius, occupied a structurally favourable position through which she was able to control the flow of information in the brick trade (Graham 2006a, 93-114; Graham 2009, 681). Søren Sindbæk (2007a; 2007b) also made use of the small-world model, but this time coupled with scale-free properties. This particular application aimed to understand the emergence of towns in early Viking Age Scandinavia. Based on the relative volume of imported goods and raw materials and an interpretation of a text called Anskar's Vita, the author suggests a hierarchy of sites in which a few towns are seen as hubs keeping long-distance trade together through their weak ties. Jessica Munson and Martha Macri (2009) have illustrated the potential of quantitative network analysis for archaeology, examining overlapping networks in their work on the socio-political interactions of the Classic Maya. The authors explored how networks of antagonistic, diplomatic, subordinate, and kinship relationships generated from the Maya Hieroglyphic Database (Macri and Looper 2009) shaped a dynamic political landscape. Clive Gamble (1998; 1999), on the other hand, in his work on the Palaeolithic societies of Europe, illustrated that the network can serve as a research perspective that does not require quantification to express past social relationships. This qualitative framework influenced Fiona Coward's (2010) network analysis of the complex social relationships between early hominids, in which a traditional social network analysis was combined with a small-world perspective.

A networks perspective can be considered particularly interesting for exploring the dynamics between relational and geographical space (Batty 2005; Knappett et al. 2008). Archaeologists have looked at GIS as the obvious tool to use for this purpose. Although the introduction of GIS-based network techniques allowed for easier computation of spatial structure and its properties, it also strongly limited the potential diversity of archaeological applications. Commercially available GIS-based network software is often limited to a few applications with clear modern-day relevance like shortest-path calculation and hydrological networks. Wheatley and Gillings (2002, 134-136) have stressed that archaeologists have needed to adapt these popular tools, and that while they have often been successful in doing so (Allen 1990; Conolly and Lake 2006, 234-262; Zubrow 1990) they have left a wealth of alternative applications largely unexplored. In their introduction to a session focused on the spatial application of network analysis held at CAA 2006 in Fargo, Lock and Pouncett (2007, 72) came to similar conclusions. Some papers in this session have explored new ways of approaching geographical networks, such as Isaksen's (2007; 2008) topological and geographic comparison of Roman road networks based on rivers, the Vicarello Goblets, the Via Augusta, the Antonine Itineraries and the Ravenna Cosmography. Michael

Batty (2005) extrapolates this critique to GIS in general and argues that new views of networks developed in physics and drawing on complexity science as introduced above need to be incorporated within GIS to allow for the exploration of network growth and evolution as well as mere spatial structure. Indeed, complex network analysts stress that many real-world networks are distributed in space and that geography in addition to topology reveals interesting features (Barthélemy 2010; Gastner and Newman 2006; Kaiser 2005). A number of archaeologists have taken their work on spatial networks along this new route by, for example, examining hypothetical interactions of individuals on spatial networks using agent-based modelling (Graham 2006b; Graham and Steiner 2007).

Ancient and modern historians, classicists, Byzantinists and papyrologists have used networks in original ways that are often of great interest to archaeologists and might enrich future applications. We will briefly mention a few particularly interesting examples. Well-known by social network analysts and influential to historians is the analysis of elite networks in Renaissance Florence by Padgett, Ansell and McLean – political and social scientists with a keen interest in historical politics (McLean 2007; Padgett and McLean 2006; Padgett and Ansell 1993). Through studies on patronage, partnership and elite networks between individuals they explore the precursor of modern-day networking. Most interesting is the work by the ancient historian Irad Malkin (2003; Malkin et al. 2007) on his network perspective for the Mediterranean and Ancient Greek history in particular. His work has been pivotal in ancient Mediterranean studies by imposing a network and fractals vocabulary on Mediterranean connectivity (as seen by Horden and Purcell 2000) and past dynamic processes. The emergence of Greek identity, for example, has been interpreted in light of the relative strength of ties between mother cities and colonies collectively giving rise to a "Greek Wide Web" where geographical distance is seen to enforce the awareness of "sameness" (Malkin 2003). The potential of a networks approach for exploring textual sources is particularly clear in Giovanni Ruffini's social network analysis of individuals mentioned in the Oxyrhynchos papyri (Ruffini 2004; Ruffini 2008), Adam Schor's social network analysis of Syrian clergy mentioned in Theodoret's *History* (Schor 2007) and Johannes Preiser-Kapeller's complex network analysis of social dynamics in Byzantine times (Preiser-Kapeller 2011; Preiser-Kapeller *working paper*).

New Critical Approaches in Archaeological and Historical Network Analysis

Most of the contributors to this session worked within this framework, being strongly influenced by social network analysis, complex networks in physics or both, and building on the archaeological and historical applications introduced above. Most importantly, however, they have made original and innovative contributions to this framework by either suggesting new analytical techniques, using untypical datasets or by raising crucial issues with how network methods are generally used. Contributors from diverse fields including archaeology, byzantine studies, art history and digital humanities drew on different case-studies illustrating the diverse ways networks can be used in our discipline. Although many were struggling to overcome issues such as the typically fragmentary nature of our data, all aimed to work towards a better understanding of how network thinking could be applied in their respective disciplines.

The first presentation of the day was by Maximilian Schich and Michele Coscia, an art historian working in a physics lab and a computer scientist. Maximilian and Michele used the *Archäologische Bibliographie*, a library database consisting of over 450.000 titles, 45.000 classifications, and 670.000

classification links, to explore the co-occurrence of classifications (Schich and Coscia 2011). Their method of approaching the dataset on three different scales allowed them to identify academic communities, but also clusters of communities and how these evolved over time. The next speaker Diego Jimenez was interested in archaeological attempts to find meaningful spatial structure between archaeological point data, for which he introduced a relative neighbourhood concept and construct graphs. The following two speakers were Johannes Preiser-Kapeller and Mihailo Popović, both specialists in Byzantine studies interested in networks of ancient border zones. Johannes compares networks drawn from different data types (streets, coastal sea routes, church administration, state administration, and participants of the 1380 synod) whilst Mihailo in his network analysis of central places in the Strumica valley stressed the importance of incorporating landscape features (Popović in press). After lunch, Ladislav Šmejda introduced his network approach for analysing a combination of grave dimensions and the presence or absence of grave good categories from a cemetery dated around 2000 BC. Finally, Tom Brughmans presented a paper on the issues surrounding the archaeological use of social network analysis and Leif Isaksen shared his latest work on exploring structural trends in Ptolemy's *Geographia*.

Conclusions

In addition to the archaeological and historical applications mentioned in this introduction, ever more new network-based approaches are emerging in our disciplines (e.g. Bergs 2005; Brejon de Lavergnée 2009; Düring and Keyserlingk 2011; Hart and Engelbrecht 2011; Krempel and Schnegg 2005; Lemercier 2010; Phillips 2011; Sindbæk 2008). We believe that this trend is indicative of a genuine interest in the network as a computational technique and as a research perspective. Despite this wide range of applications many research avenues are still left unexplored and the already discovered methods and theories are waiting to be combined in a critical and specifically archaeological framework. It seems that Carl Knappett's (2011) *An archaeology of interaction* aims to provide just such a framework. Knappett stresses the advantages of networks as a way of thinking explicitly through relations, for dealing with issues on multiple physical and social scales, for tracing relationships between objects and people, and to explore dynamic processes. The most promising feature of Knappett's framework, however, is the way it combines both theoretical and methodological aspects of network thinking that holds the much needed potential to make the jump from a mere description of structure to its explanation.

The conceptual bridge between individual agents and complex systems implicit in a complex networks perspective has obvious potential for archaeology. It can help us understand how large-scale patterns, like the existence of states and hierarchies, emerge from local interactions between individuals based on relatively simple rules. It has even been argued that the open and non-dogmatic scope of complexity science can bring the advantages of processual and post-processual approaches in archaeology together under its theoretical umbrella (Bentley and Maschner 2003b, 3-5; Bintliff 2008, 160; Knappett 2011; Kohler *in press*, 15), an argument that is at least in part valid for any complex networks approach. However, the "new" science of networks is still dealing with some growing pains itself. This is particularly well illustrated by the struggle to find suitable models for dynamic networks or the problem of going beyond the mere identification and description of emergent properties to their explanation. In this sense archaeologists should never cease to be archaeologists when adopting computational tools and models from other disciplines. For example, it is not worth our time and effort to try to find small-world and scale-free networks in every one of our datasets. In many of the applications discussed above tools and techniques have been adopted directly from popular publications in physics and sociology with limited discussion of their structural and interpretative implications and similar archaeological approaches. This is at least in part due to the relative newness and contemporaneity of the discussed applications. We hope that through an ever-larger body of critical applications and through platforms stimulating multi-disciplinary discussion and collaboration like the CAA 2011 Data Analysis session, a solid basis will emerge for future network-based approaches in our discipline.

Acknowledgements

We would like to thank all participants in the Data Analysis session for presenting their work and providing such stimulating discussion and reflection throughout. In particular Johannes Preiser-Kapeller and Maximilian Schich for their kind comments on a first draft of this paper. We also thank Iza Romanowska for her critical comments on a draft of this paper. All remaining errors are our own.

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