Network Analysis in Archaeology
Session Introduction: An Introduction to Network Analysis

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Abstract

The following discussion provides an introduction to the set of four papers that follow. All of these papers focus on Network Analysis and were presented in a symposium at CAA 2006 organized by the authors.

As reflected by the many papers elsewhere in this volume and in previous CAA proceedings, the use of Geographic Information Systems (GIS) in archaeology is now a fundamental for any work with a spatial component. Since the publication of *Interpreting Space* (Allen et al. 1990), the landmark volume that introduced GIS to the archaeological world, many different aspects of GIS applications in archaeology have developed and flourished. Approaches to landscape analysis have generated some heated theoretical debate as well as innovative methodologies, while data management in general and Cultural Resource Management specifically, are now embedded within these spatial technologies. Interestingly, though, Network Analysis (NA) has largely remained outside of these developments. As described below, while being included in *Interpreting Space*, NA has enjoyed little interest within the archaeological world subsequently. The aim of the following set of papers is to explore a range of current approaches to NA in an attempt to raise its profile and illustrate its potential.

As an introduction to NA, it is important to remember that it pre-dates the development of GIS and is firmly rooted in the quantitative geography of the 1960s. An important introduction to the principles and applications of NA is Haggett and Chorley (1969), some of which is still relevant today. This book laid the foundations for NA and argued strongly that equivalent spatial structures were to be found in both physical and human geography, and these therefore warranted common mathematical models. This resulted in an emphasis on river systems and transportation networks as examples of natural and cultural networks. Based on connecting networks of lines and nodes which enable different types of flow, a classification of network topologies was suggested that included branching and circuit networks that conduct flow, and barrier networks that resist flow. Network characteristics such as shape, density, pattern, and order, were described and evaluated together with factors affecting the costs and efficiency of flow and aspects of analysis such as shortest path applications. The final part of the book dealt with the structural change of networks, such as evolution and transformation, and the simulation and modeling of networks. The impact of this work was considerable and network-based techniques became well established within quantified modeling-based geographical thinking as epitomized by the classic textbooks of the time *The Spatial Organization of Society* (Morrill 1974), and *Man, Location and Behaviour* (Cox 1972).

Archaeology, operating within the same paradigm of quantification, was also interested in networks with one of the most influential publications being David Clarke's *Analytical Archaeology* (1968). Here networks play a central role but the emphasis is on modeling networks as social connections and relationships primarily within a systems theory framework. This involves flows of information, negative and positive feedback loops, and the desired attainment of a state of equilibrium. Cultural identities are modeled through cultural networks, kinship links through social networks, and socio-cultural networks combine the social (people) with the cultural (artifacts). As with much of Clarke's work, this was highly innovative at the time and often complex.

The examples above of early work on NA are all discussions embedded within the details of subject specific and time specific disciplinary paradigms. With the introduction of GIS-based NA within widely available commercial software came the opportunity to identify the essential aspects of its structures and potential analyses in a more generic way. In essence NA needs a vector data structure made up of arcs (edges) joined at nodes (junctions) but, perhaps most interestingly, the network is assigned behavior (a set of rules). An interesting aspect of NA, and one that has considerable implications for archaeological applications, is that this is not about spatial analysis in the traditional sense but about topological analysis, which is about spatial relationships and their embedded meaning. Movement through a network is central to its understanding, and the moving agent being modeled is often a person or a resource, the latter usually being transported. In "undirected networks" the agent has a choice of direction whereas in a "directed network" the agent has no choice and follows pre-determined routes. A series of connectivity rules are established to control movement through the network including an "impedance" that can be assigned to each turn so that different agents can behave differently. Flow through the network can be controlled by establishing "sources" and "sinks" for creating a determinate direction of flow from and towards certain nodes; conversely, certain arcs can take an indeterminate

flow in either direction. It is not difficult to see how a complex model of an agent's behavior within a network can be established through the well-defined NA logic and series of algorithms provided with modern commercial GIS software (see, for example, ESRI 2006). As with GIS generally, this, of course, is not aimed at an archaeological market. Typical NA applications are concerned with finding a "best route" based on defined impedances of time and/or distance for emergency services reaching a disaster scene, or the location of a new supermarket in relation to its customer base and access to transport networks, for example. The challenge for archaeology is to adapt this formal NA logic to suit the social and cultural relationships and interactions inherent within archaeological data and analysis, and this challenge was faced full-on at a very early stage of GIS usage in archaeology.

The importance of *Interpreting Space* (Allen et al. 1990) in bringing GIS to an archaeological audience has been suggested above and within this publication much of the functionality of NA was recognized and used in two papers. Allen (1990) investigated the trading links and economic relationships between Native Americans and European settlers in the Great Lakes area between AD 1550 and 1750. The trade was water-bourn so the hydrology map of New York State formed the physical network through which the flow of goods passed. The development of the trading network was based on the identification of native sites and the phased establishment of European trading posts and forts assigned to an early period in the early 1600s and a later period of the first half of the 18th century, thus giving a three-period chronology. Flow through the network was modeled based on demand for goods and the carrying capacities of different trading centers with the results showing the expansion of the network through the periods, thus "a spatial representation of trading relationships." In a paper with a similar flavor, Zubrow (1990) was interested in the spread of European populations through New York State between the years 1608 and 1810 together with their interaction with indigenous populations. Again the hydrological network forms the basis for movement and six different forms of initialization and subsequent growth patterns are modeled and tested against the locations of 83 known early settlements. This is based on achieving a balance between the demand for migration and the resistance against it, and results in a series of maps showing possible patterns of expansion.

Since 1990, the archaeological interest in NA has been somewhat fragmented. It is important here not to confuse this with the considerable interest shown in trying to establish "communications networks" through the use of least-cost-paths and cost surfaces. Bommelje and Doorn (1996), for example, with ancient routes in central Greece, Madry and Rakos (1996), who generated roads and compared them with known Iron Age and Roman roads in Burgundy, France, and Kantner (2004), who reconstructed the 9th century AD Chaco Anasazi road network in southwestern USA. This cell-based approach using a Digital Elevation Model (DEM), may produce a resulting network that could be vectorized and used in NA, but it is not what we are primarily interested in here. Here the focus is on analyzing known networks and although there have been few examples since

1990, the work of Symonds (1999; Symonds and Ling 2002) shows how NA can be incorporated into interesting contemporary attempts to integrate social theory and human perceptions of space with detailed archaeological evidence.

Symonds is interested in the socio-economic landscapes of 10th century Lincolnshire, England, the emergence of towns and the impact of Scandinavian immigration. In an attempt to expand the existing archaeological focus on towns themselves and place them within a landscape setting, she uses production centers, market centers and a network of routeways that connect them, which comprises roads and rivers of various sorts. The emphasis is on the social and economic aspects of movement, so for example, the switch from a river to a road will involve impedance in the form of time to unload and load goods. The analysis incorporates detailed archaeological data recovered through surface survey and previous excavations so that the source and destinations of pottery can be modeled together with the direction and intensity of travel. Symonds develops a series of innovative NA-based approaches to model ancient perceptions of distance and travel based on cognitive mapping and differences between Euclidean distance and transportation distance. The results assess the differing importance of roads and rivers in different areas of the region for the transportation of pottery and, overall, demonstrate how formal NA methodology can be integrated with archaeological interests in social theory.

This session in CAA, and this group of published papers, is to build on this early work and to show that NA has considerable potential for aspects of archaeology that involve the movement of people and/or things along pre-defined networks or along definable networks. We are not the first to acknowledge this potential, as do the two most recent textbooks on archaeology and GIS. Wheatley and Gillings (2002:135) give a brief overview while Conolly and Lake (2006, chapter 11) go into more technical detail and provide a range of archaeological examples based on different questions asked of networks. It could be argued that there has been little advance in the underlying NA functionality provided within commercial GIS software since the first published archaeological applications of 1990, and that any advances need to be in the theoretical framework driving the work as Symonds has demonstrated, the questions being asked, and in interpreting the social relationships being modeled.

The four papers that follow attempt to build on this advance. Both Isaksen and Earle use the same field-based project as a vehicle for NA, the Urban Connectivity in Iron Age and Roman Southern Spain Project. The two are complementary and should be read together. Earle outlines a series of methodological and theoretical issues to be considered by anyone using the technology and describes different sorts of social networks at different scales of connection. These include connectedness based on movement, visibility, trade through artifacts and social influences. Isaksen focuses on NA applied to transport and communication routes in the region in order to better understand the relationship between the location and the political/economic significance of sites. The results indicate strong transport-influenced spatial patterning and the concluding section of

the paper takes a deeper look at the nature of the source data and its "directionality."

Branting's focus is entirely different in being essentially intra-site and interested in how people moved around the street pattern of the ancient city of Kerkenes in Turkey. An important initial aspect of this paper is an evaluation of the effect of DEM cell-size on least-cost pathways with some surprising results. NA of pedestrian movement around the streets identifies not only the busiest routes but also buildings within the city which appear to be centers of activity.

Pouncett and Lock's work is also very different and uses NA not to model movement in a strict sense of the word but to try and improve the dating of a complex of ditches identified by extensive geophysical survey at South Cadbury, Somerset, England. Known spot-dates for points on the ditch network are "moved" around it to try and establish how far a single date can be extrapolated and what sorts of stratigraphical and chronological conflicts arise. The iterative procedure developed is a tension between the internal logic of the software and the accepted logic of archaeological phasing. A robust method is developed and initial results described.

It is interesting, and significant, that all four of these papers are based on large-scale fieldwork projects and their GIS-based data management, analysis, and interpretation. This is how it should be, with the archaeology driving the technology and the questions being asked forcing the technology to its limits of functionality.

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