Data Exploration with GIS Viewsheds and Social Network Analysis

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Summary

We present a novel exploratory method combining line of sight visibility (viewshed analysis) and techniques from social network analysis to investigate archaeological data. At increasing distances different nodes are connected creating a set of networks, which are subsequently described using centrality measures and clustering coefficients. Networks with significant properties are examined in more detail. We use this method to investigate the placement of hillforts (nodes) in the Gwent region of south-east Wales, UK. We are able to determine distances that support significant transitions in network structure that could have significant archaeological validity.

KEYWORDS: Geographic networks, archaeological nodes, viewshed analysis, data mining, social network analysis

Extended Abstract

We present a novel exploratory method that combines line of sight visibility (viewshed analysis) with techniques from social network analysis to investigate archaeological data. Within data mining exist the fields of graph-based and spatial-based data mining. Graph-based data mining (Cook and Holder, 2006) has a close cousin in the long established field of social network analysis, a set of metrics that operates over graphs (networks) created from links (Wasserman and Faust, 1995). Metrics include those to find clusters within networks, to find points that have significant properties, for instance how central a point is. Spatial data mining likewise has an extensive history (Lu et al., 1993), and is the discovery of interesting patterns from spatial datasets.

At increasing distances different nodes are connected creating a set of networks, which are subsequently described using centrality measures and clustering coefficients. Networks with significant properties are examined in more detail. We use this method to investigate the placement of hillforts (nodes) in the Gwent region of south-east Wales, UK. Our methodology is applied to the area of

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the Iron Age tribe known as the Silures, described as a 'resilient and sophisticated clan based tribal confederation' (Howell, 2009). Our preliminary investigation focuses on the Gwent region with a study area which roughly approximates the county as constituted between 1974 and 1996. Figure 1 shows the placement of 30 hillforts in this region. We are able to determine distances that support significant transitions in net-work structure that could have archaeological validity. Our study uses both geographical and graph/network structures, and presents an exploratory methodology within which to discover significant distances underlying network creation. While based on archaeological informatics, the approach has a more general use, for instance neural architectures, transportation networks, and other forms of geographical networks.

This research lies in the intersection of spatial and graph-based data. Related work includes that of the physics literature on geographical networks (ben Avraham et al., 2003), architectural analysis and the isovist literature including visibility graphs (Steadman, 1973; Llobera, 1996; Turner et al., 2001), and the authors' recent work incorporating kernel density estimation into the betweenness social network metric (Oatley and Crick, 2014b,a). The data used includes the Iron Age hillfort data, provided from the Historic Environment Records[1], and a Digital Elevation Model based on the Shuttle Radar Topography Mission data (UK SRTM DEM)[2] with 90m horizontal resolution.

We develop connectivity between Iron Age hillforts based on viewsheds and an increasing distance threshold. A viewshed is the area of land that is within line of sight from a fixed viewing position. We analyse the generated set of networks of connected hillforts using social network analysis, and use the metrics to inform theories of possible use and communication between hillforts. Degree centrality is simplest and is a count of the number of links to other nodes in the network. Closeness however is a measure of how close a node is to all other nodes in a network (Sabidussi, 1966). It is the mean of the shortest paths between a node and all other nodes reachable from it. Betweenness is the extent to which a node lies between other nodes in the network and is equal to the number of shortest paths from all nodes to all others that pass through that node (Freeman, 1977). This measure takes into account the connectivity of the node's neighbours, giving a higher value for nodes which bridge clusters.

We explore using a local clustering coefficient (Watts and Strogatz, 1998) quantifying how close a networks nodes neighbours are to being a clique (fully connected). Viewsheds are generated for each hillfort, in order to determine intervisibility between every hillfort. We are then able to determine which hillforts are intervisible at any given distance threshold. In this way we investigate networks of hillforts at different distance values examining the clustering coefficient and betweenness measures.

This reveals several interesting transition points (see Figure 2) in connectivity, including localised clusters being evident, connectivity between larger regions, and connectivity along key geographic features such as along a shoreline and up waterways. In previous studies 'significant' distances and decay values have been determined a priori. We, however, examine the centrality of individual

[1]Archwilio, the Historical Environment Records of the Welsh Archaeological Trusts: `http://www.archwilio.org.uk/`

[2]UK SRTM DEM created by Addy Pope. Spatial Reference System–Great Britain National Grid: `http://edina.ac.uk/projects/sharegeo/`

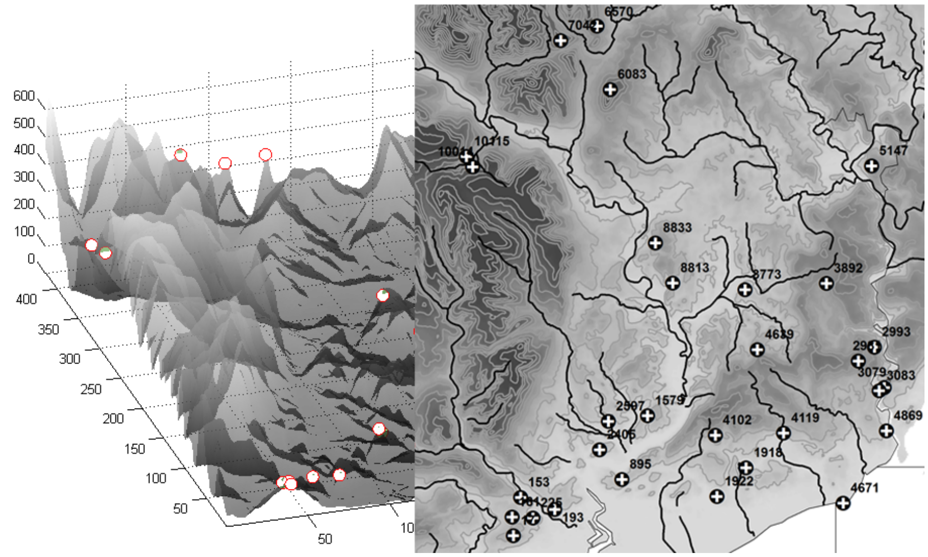

Figure 1: Hillforts in south-east Wales. Hillforts are displayed as white crosses on the front contour display. The same terrain and hillforts (white circles) are displayed behind on a Digital Elevation Model (DEM). The DEM display shows that there are many other sites that could have been used for placement of hillforts.

nodes (hillforts) in these networks with the most significant values. We are interested in discovering interesting patterns and clusters and then investigating them *a posteriori* for (archaeological) validity. Among preliminary conclusions arising from this first phase of investigation is that the methodology employed can effectively inform our understanding of Iron Age social structures. For example, viewshed analysis confirms hypothesised clan-based clustering of hillforts in the region with extensive line of sight communication, not only within clusters, but also with other hillfort groupings. The model of a clan-based confederation with regional emphasis, and possibly variation, but with wider connectivity sufficient to allow the cohesion necessary to have resisted the Roman advance so effectively seems wholly appropriate. Future work will utilise fuzzy viewsheds instead of the standard binary viewshed, with distance decay functions based on the limits of normal human vision and such features as the size of people, livestock, distances that smoke plumes can be seen and so on. We will also consider the integration of least-cost paths in landscapes.

Biography

Dr Giles Oatley is a Reader in Intelligent Systems at Cardiff Metropolitan University. He has developed decision support systems based on behavioural models from data mining, primarily for UK police forces, supported by the EPSRC, Home Office, HEFCE, Nuffield Foundation, and DTI. He has a broad interest in anthropology and psychology, especially mindfulness and psychoanalysis.

Dr Tom Crick is a Senior Lecturer in Computing Science at Cardiff Metropolitan University. His

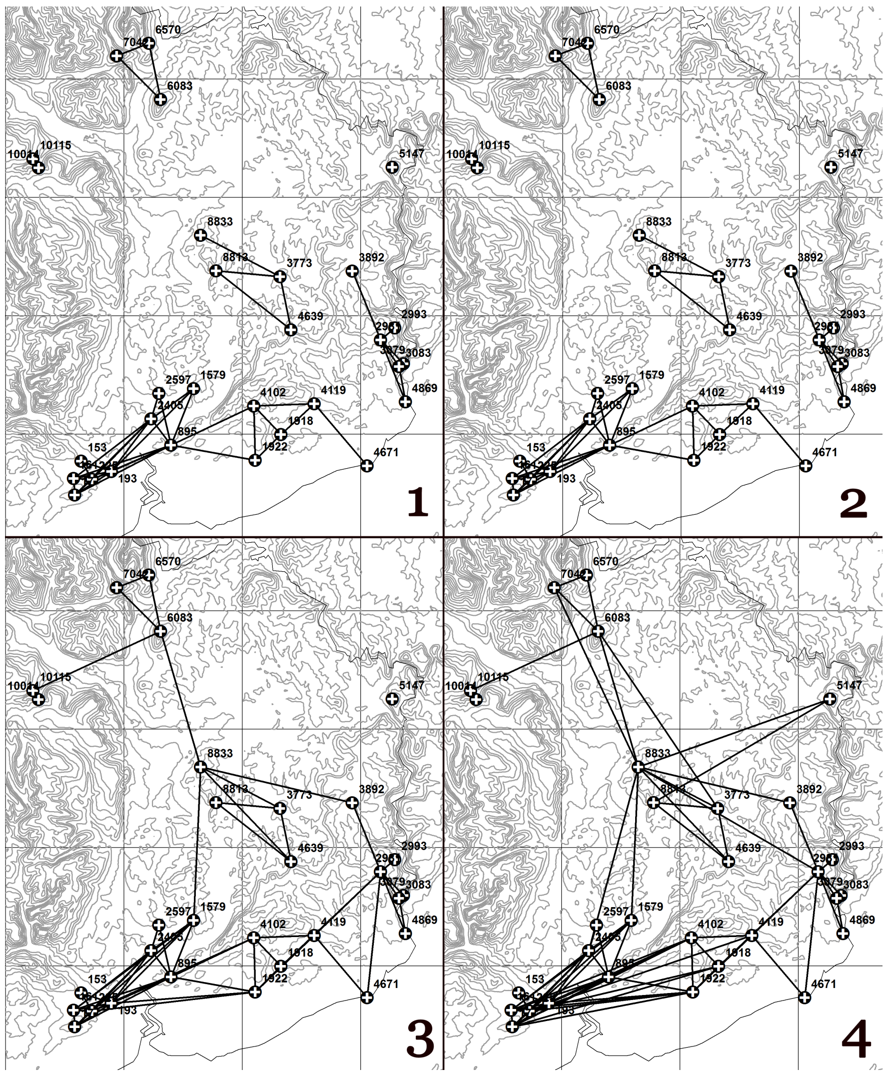

Figure 2: Interesting networks. 1: 5km. 2: 10km. 3: 15km. 4: 20km.

research is naturally interdisciplinary: optimisation, intelligent systems, data science and analytics, high performance computing and reproducibility. He is the Nesta Data Science Fellow, a 2014 Fellow of the Software Sustainability Institute and a member of *HiPEAC*, the European FP7 Network of Excellence on High Performance and Embedded Architecture and Compilation.

Professor Ray Howell is Professor of Welsh Antiquity and Director of the South Wales Centre for Historical and Interdisciplinary Research at the University of South Wales. He is a Fellow of the Society of Antiquaries of London. He is also Chairman of the Glamorgan Gwent Archaeological Trust and the Glamorgan Gwent Historic Environment Record Charitable Trust.

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