CT5113 - Assignment 1 Report

Network science applied to archaeology and history

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1 Introduction

1.1 Networks & Network Science

A network has many definitions and can be applied in varied contexts to describe a model or system of interconnected entities. The connectivity between the entities is driven by one or more underlying relationships between those entities. Networks are everywhere, from the roads connecting junctions or cities, to our brain cells creating a network of neurons for controlling our body functions, to the web-pages connected through links that we navigate, the examples are endless. These networks are at the core of what are called complex systems, which in simple words mean that, these are systems which are complicated to understand and operate [1, 2]. While addressing completely different problems and domains, these networks all seem to share common organizing principles and properties [1]. The study and analysis of the networks performed based on the commonalities they share is called Network Science.

1.2 Networks in Archaeology

The study of material remains left behind by humans before us, such as artifacts like tools and objects, historical places with ancient architectures, and so on, carried out with an aim of understanding how human societies and cultures interacted with one another and evolved with time is called Archaeology [3, 4]. Archaeology has been around for centuries and its approaches to analyse the complex data generated by excavations and research have evolved over these centuries. To say that archaeological data is complex would be an understatement, and attempts have been made for decades to structure this data as networks to be able to apply the network science principles for analysis of the complex and complicated information contained within this data. At a first glance it may seem that networks are apparent in archaeological data, for example, the historical or archaeological sites could be interpreted as the entities or nodes of the network, with the roads connecting them considered as the links in the network, however, archaeological data is not limited to the geographic location of sites, but also includes information about artifacts found on these sites and various properties associated with the artifacts, as well as the location and other information about the site itself. All of this data gives rise to complex relationships among them and the representation of this as networks is thus not so simple after all.

1.3 Network Science in Archaeology

Several studies, research and analyses have been carried out to understand the application of the network science principles to the domain of archaeology, especially in the recent decades. [5] and [6] provides a critical review of such studies, exploring and reporting the different approaches and views of network science used to analyse archaeology. While, [5] goes on to explain the limitations of the previous applications and introduces a case study of table ware distribution in the Roman East with an aim of addressing the issues pointed out, [6] dives into the history of application and suitability of graph theory and social network analysis in regards to archaeology and network science, and discusses the applicability of formal network methods such as network centrality, affiliation networks, ego networks, small-world and scale-free networks to archaeology. Building further on the ideas discussed in [5], [7] introduces a framework termed as general similarity network for effective discovery of relationships in the network and provides a formal description of what constitutes nodes or vertices of a network in archaeology. While, the focus of [5, 6, 7] is on exploring the potential of network science to improve the analysis of archaeological data, [8] focuses mainly and heavily on the challenging aspects of such application.

2 Network Science Applied to Archaeological Processes

2.1 Network Construction and Methods Applied

The importance of well-grounded network construction before deciding on analyses approaches has been emphasized by [5, 7, 8]. In the case study presented by [5] two networks, a co-presence network and a distance network were created for analysing pottery distribution in Roman East, by using data from the Inventory of Crafts and Trade in the Roman East (ICRATES) database [9]. The co-presence network used two types of nodes, one representing the context, meaning the archaeological sites and another node representing the form or type of pottery found on the sites. Both type of nodes were

connected based on whether a form was present at a site, leading to what is called a two-mode network. The study further illustrated the decomposition of the two-mode network into one-mode networks, where the networks consisted of only one type of node. A one-mode network of context node was connected if two contexts or sites had evidence of presence of same pottery forms and a one-mode network of the pottery form nodes had connections based on their common presence in the same site. [5] claims that the co-presence network helps understand the distribution of any pottery forms across the sites and network analysis would help understand the evolution of the distribution pattern over time. To perform quantitative analysis on this network the method of hierarchical clustering was applied which provided clusters or communities of sites or the pottery form. Moreover, [5] suggests that visualization of these networks can lead to discovery of enlightening information. The distance network was created by taking into account the geographical positions of sites and path-based centrality measures such as closeness and betweenness centrality were applied to identify sites of importance, including sites that were crucial in connecting other places and maintaining flow in the network. The network architecture and the nature of nodes for archaeology is discussed in great detail in [7], which presents a view of the archaeological data as a table of contexts and attributes, where the contexts referring to geographical archaeological sites are represented in rows and the attributes of the artefacts which may include presence, position, quantity, type, etc of an artefact such as pottery are represented in the columns. Such a table forms an adjacency matrix representing a network however with two classes of nodes instead of one, which forms the basis of the two-mode network used by [5]. Either or both context and attributes can be used however to create an archaeological network, where [7] explains that the one-mode network with context nodes is called Type 1 network and one-mode attributes node network is called Type 2 network. More importantly, [7] presented the idea of general similarity network, where it has been suggested that instead of taking one similarity measure, such as distance between sites or co-presence of remains, a mixture of different similarity and indeed dissimilarity measures should be taken into account for forming the criteria for the network relationship, in order to capture the complexity that is inherent in archaeological data. It is further suggested by [7] that only Type 1 network, containing context as node can be formulated as a general similarity network where the mixture of attribute similarity measures become the basis for defining the relationship for the network. The context nodes in the network are connected based on m-slices [10] approach, where two nodes are connected if they share m-attributes or in case of general similarity if they share m-similarity measures. [7] also suggests that the general similarity networks can help detect cultural evolution patterns and identifying clusters in the society or artefacts based on not just quantitative, but also qualitative attributes.

2.2 Issues with Archaeological Network Analysis

The challenges in applying network analysis to archaeological field are immense and are discussed in great detail in [5, 6, 8]. The studies [11, 12, 13, 14, 15] reviewed by [5], were based on the idea of social network analysis, which assumes the network to be a medium of social interaction, which does not always apply to archaeological networks, this brought forth the issue of application of network analysis methods developed for different domains on archaeological data. [5] warns that such applications may lead to wrong interpretation of the data. The archaeological data is scarce, incomplete and ambiguous [8], which is generated by different archaeologist often using different academic frameworks [5], and the task of structuring this data into networks is far more difficult than it is for other domains [8]. It is also suggested that the tools and software for network analysis are not well developed to handle the heterogeneity of the past data [8]. An ego network approach is suggested by [6] as a potential technique to handle the data based on the idea that archaeological data is generated from individual remains that can provide information about only parts of a bigger social network. [6] has also pointed out that while other domains such as healthcare, finance, economy and sociology focused on network analysis techniques for analysis, the focus for archaeological domain might have been hindered due to lack of computation power and lack of digital data-sets. This had led to a lack in network analysis methods suitable to handle the unusual nature of archaeological data [8].

3 Conclusion

Many civilizations have risen and fallen in the past. Archaeology provides us a factual window into the past based on evidence, which could help us understand what went right and what went wrong with these civilizations. There is a lot to learn from the past and if the network analysis techniques actually reach a level of maturity that can help the hidden patterns in the archaeological data [7] to emerge, it could help aid a better future. However, the studies reported suggest that it may take long for archaeological network analysis to reach that maturity, if key issues indicated by [5, 6, 7, 8] are not addressed. A common theme identified in all researches has been the lack of focus on development of specialized network analysis techniques for archaeology. A continued research and awareness for constructing archaeological networks and understanding the application of appropriate analysis methods is imperative to achieve efficient progress in application of network science to archaeology.

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