This book explores new methods and techniques for research about merchant networks and maritime routes of trade during the First Global Age through the use of Geographic Information Systems (GIS) as a tool to visualize the formation of trading systems, database management, cartography and spatio-temporal analysis in Historical GIS.

In doing so, the book focuses on key issues in understanding the birth of the so-called First Global Age (16th to 18th centuries), the integration of spatial economies, the regionalization of markets, the organization of maritime trade routes, and the evolution of self-organizing networks of merchants, producers, communities, and other social agents during the age of expansion. The essays collected here deal with relevant information about historical problems including maritime connections, the organization of oceanic trade, and the use of digital cartography and metric analysis of old maps, and social network analysis – commercial networks involved a high level of cooperation and served to move goods and people within a highly open system over an expanding geographic space.

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Spatio-Temporal Narratives
Spatio-Temporal Narratives:
Historical GIS and the Study of Global Trading Networks (1500-1800)

Edited by

Ana Crespo Solana
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CHAPTER FOUR

AGENTS OF EMPIRE:
SPATIAL NETWORK ANALYSIS
IN COMPARATIVE STUDIES DURING
THE EARLY MODERN AGE

ERNESTO SALAS TOVAR, ESTHER PÉREZ ASENSIO, ISABEL DEL BOSQUE, ANA CRESPO SOLANA AND ROBERTO MAESTRE MARTÍNEZ

1. Introduction

For a number of years Social Network Analysis (SNA) has been applied to historical research. Krebs in his paper “A Brief Introduction to Social Network Analysis” defines it as the mapping and measuring of relationships and flows between people, groups, organizations, computers, and other connected information/knowledge entities. The entities are represented as nodes and their relationships as edges; in the case of social networks the nodes would be people and the edges their relationships. As such, it provides us with a mathematical and visual analysis of the relationships formed between the agents in a network. One of the aims of this paper is to set out the possibilities for analysis offered by visualizing

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1 This investigation has been sponsored by the “GlobalNet” project, Spanish Ministry of Science and Innovation, Reference: HAR2011-27694 and, previously: European Science Foundation’s EUROCORES (European Collaborative Research) program “The Evolution of Cooperation and Trading” (TECT).
2 GIS Laboratory, CCHS-CSIC.
3 Instituto de Historia, CSIC.
4 Paradigma Tecnológico, PT.
data using a Geographic Information System (GIS). As defined by J. B. Owens, visualization is an abstraction of the real world that allows us to gain insight into it. The greatest contribution to historical analysis offered by the use of a GIS is in organizing information into data models. This is achieved by superimposing different layers containing independent datasets, enabling us to observe visual relationships between the data (Owens, 2007: 2022–2024).

Thanks to these capabilities, like SNA, GIS has become an accepted tool among historians. One of the most recent examples is the DynCoopNet project\(^6\), which analyses the evolution of self-organizing trade networks in the first Global Age (1400–1800). Since the data used by the researchers has a spatio-temporal element, a novel application of GIS was employed to visualize and analyse the information. Most of the data can be georeferenced to a specific date and location, meaning that complex analysis using GIS can be carried out to better understand the organisation, operation and impact of these networks on the formation of what was the first global economy. The development of this historical GIS required the generation of a single, integrated conceptual data model that is scalable and has great potential to meet scientific aims. This model gathered together the information in three databases containing the data assembled by researchers over many years. This information provided the basis for forming the model classes represented by the realities the data expressed, and these classes were used to create a database including all the information relating to individual trade agents, relationships of cooperation and ships. In order to visualize all these elements and their interactions the database contains a number of key tables, namely Agents, Cooperation, Actions and Ships. The first two of these show how the agents interacted with each other over time. The third table records the actions and activities – loans, representation, etc. – brought about as a result of cooperation. Finally, the Ships table, linked to Actions, brings together all the information relating to the voyages made by each of the ships (Pérez Asensio, Del Bosque González, Maestre Martínez, Crespo Solana and Sánchez-Crespo Camacho, 2010: 1–14, here 4–6)\(^7\).

\(^6\) ESF: FP: 004DynCoopNet and complementary actions by the Ministry of Science of Innovation: SEJ2007-29226. Dynamic Complexity of Cooperation-Based Self-Organizing Commercial Network in the First Global Age. It forms part of the EUROCORES programme, and it was approved after submission to the TECT (The Evolution of Cooperation and Trading) call for entries made by the ESF (European Science Foundation).

\(^7\) Digital CSIC: http://hdl.handle.net/10261/24908.
In this chapter we will address a number of specific network analysis programmes that do not include a spatial element: Cytoscape,8 UCINet,9 and Tulip.10 The historical data contained in the DynCoopNet database may be implemented in any of these programmes using snGraph (Maestre, 2010) for later analysis. The ESRI GIS tool, ArcGIS, also offers a powerful network analysis package with the extension Network Analyst.11 Its most notable functions include the ability to georeference nodes and the flows between them or to determine which node has the most connections and locate it geographically. Adding the spatial component to the network analysis carried out using specific programmes is the key aim of this paper. In this regard “it is not only of interest to analyse the characteristics of the elements that comprise them, but also the form in which from a chronological perspective they develop, evolve and enable the progressive modification of all their components in both virtual and geographic space” (Barrientos Martínez, 2007: 8).

Although the Network Analyst extension to ArcGIS is primarily oriented towards the study of urban networks and services (electricity, hydrology, transport, etc.) it offers the possibility of implementing the results of SNA programmes and providing geographical locations to the nodes and the relationships between them. One of the key aspects of the DynCoopNet project where SNA is of great use is in the analysis of relationships of cooperation established among different agents in specific geographic locations, understanding by this term both particular merchants who establish different forms of association and the large monopolies (Crespo Solana, 2000; 2009; 2010a; 2010b: 181–314 and 2010c: 35–50, here: 47; Klooster, 1998). The DynCoopNet project also analysed the life cycle of the vessels that were used in the trade operations of the period. This took into account the voyages they undertook over many years, including ports of departure and arrival and ports of call, and the business transactions or other events that took place. The study of network analysis programmes enables us to compare their functions and how best to implement the results in a GIS.12 For this reason, throughout this paper we will focus on defining a number of concepts relating to SNA in order to understand the potential of these tools and their application to spatial analysis.

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8 http://www.cytoscape.org/.
9 https://sites.google.com/site/ucinetsoftware/home.
10 http://tulip.labri.fr/TulipDrupal/.
2. Definition of Network Analysis

The development of network analysis is the result of the influence and advancement of a large number of disciplines including sociology, social psychology, anthropology, physics, mathematics, computer science and so on. Before seeking to define a network, we should consider that it is comprised of nodes and the edges that represent the relationships between them. Oliveira and Gama (2012: 99–115) propose a highly simplified definition of a network that serves our purposes: “a network is formed with relational data that can be defined as a set of entities (individuals, groups, organizations or other), with relationships or interactions between them”. Thus a network can be several things a) a conceptual model, b) a description of an existing structure or system in the real world, c) a mathematical model or d) a simulation (Luke and Harris, 2007: 69–93). Oliveira and Gama (2012: 100) define the four basic types of networks whose relationships can be studied: information, technological, biological and social networks.

**Information networks** are based on information exchange between the nodes that comprise them. They exist in order to disseminate knowledge, information or social causes and for business promotion. As an example of information dissemination, the methodology used by systems for citing academic articles presents a directed acyclic graph in which the nodes represent the articles and relationships are established when an article A cites another article B. Another clear example of business promotion are preference networks, which use bipartite graphs that express the individual preferences of consumers. Finally, the most common example of information exchange is the World Wide Web, which makes use of a directed graph in which the nodes represent web pages and the relationships are the hyperlinks between them.

**Technological networks** are networks that are used for the transport and distribution of services and resources. They are created in specific geographical areas and may incorporate a spatial manifestation such as highways, railways, and maritime routes, etc. Meanwhile there are other, smaller-scale networks such as physical connections between computers. These networks are represented by the Network Analyst tool as geometric networks (hydrological, urban) and transport networks (railways, highways).

**Biological networks** include certain biological processes, which we will not seek to define in this paper, such as chemical reactions among metabolites, interactions among proteins, regulatory genes, etc. which can be represented and analysed using networks. In fact some computer
programmes that perform these analyses, such as Cytoscape, have specific tools adapted to biology.  

**Social networks** are the principal focus of this paper, and have a structure based on the agents represented by the nodes and the relationships between them. These links not only represent relationships but also the flows of information, trade, correspondence, etc. between the agents. By studying the relationships between agents, we can reconstruct the social fabric we are studying. In this sense, one of the most important points to consider in our analysis is the position of the agents in the network. This data provides us with information about the roles each of them play and existing clusters.

### 3. The Spatial Component of Historical Social Networks

GIS analysis holds great potential for the humanities. In recent years the human sciences have been using these tools to find new solutions to problems previously dealt with by historiography. The use of GIS software which makes it possible to combine geographic information from various sources and bring it together on a map expands the horizons of the humanities. The ability to add thematic information on a real location and analyse the relationships established between these layers of information is the engine of a GIS. The term “spatial” is for some what holds us together and enables us to focus on our interactions with space and with our peers (Getis, 2008: 4). One of the key issues when it comes to applying these analyses to historical networks is time. Since the 1980s work has been carried out on implementing this variable in GIS software in which the concepts of change and movement are key. During the 1990s progress was made in the representation of temporal phenomena and the creation of mathematical models to simulate movement. As such, we believe that it is necessary to work with GIS from a dynamic perspective that takes into account change and movement as part of a system. In this way we can overcome space and time barriers and observe these phenomena from a holistic perspective (Yuan, 2008: 18–24), which enables us not only to learn the position of the elements we are interested in studying, but also their behaviour and movements from a geographic perspective. Recently, GIS analysis has been applied to the representation of spatio-temporal phenomena displayed by interactions between individuals and the flow of human relationships (Yuan and Shaw, 2006:409–430). These two authors introduce the concept of spatio-temporal prisms to analyse these interactions with greater precision.
Within the humanities, traditional history has begun to turn to GIS applications in order to reconsider questions about human relationships in the past. We are deliberately leaving aside archaeology, as the application of GIS software to research in this field is well established (Wheatley and Gilling, 2002; Grau Mira, 2006; Mayoral Herrera and Pérez, 2011). In this regard, Owens has concisely explained the leading role acquired by these technologies in recent years. This is a result of the fact historians work with complex, dynamic and non-linear information and require a technology that enables them to organize and visualize this information simultaneously (Owens, 2008: 35). GIS offer the ability to visualize and analyse historical data. According to Owens (Owens, 2007: 2024), the discipline of history has not made significant use of visualization, which he considers a mistake because it presents an abstraction that can be a very useful means of approaching the real world. Such abstractions enable us to observe the interactions between the different kinds of data and provide us with a method for understanding spatio-temporal data. Despite these qualities, it must be borne in mind that GIS work with static information, which represents a problem for resolving the kind of dynamic changes over time that historians deal with. As such, it is necessary to find a way to represent interactive connections between agents that make it possible to integrate studies at different levels: local, regional and national. This need has led Owens to define the concept of “geographically-integrated history”, a term that frees us from the limits imposed by the earlier concept of “History GIS” (Owens, 2007: 2025–2026; Crespo Solana and Alonso García, 2012). This conceptualization is based on the visualization and implementation of different layers of dynamic information that change over time, making it possible to understand the evolution of historical processes rather than small, static portions of information.

Finally, to complete this transition, it is essential that historians break with traditional historical methodology and be prepared to collaborate with other researchers to achieve an interdisciplinary history. This change in mentality will make it possible to observe more accurately the cooperation between agents in the past. To achieve this, it will be necessary to obtain quantitative and qualitative information about the culture and society of the historical moment that concerns us (Owens, 2007: 2030–31). Although much progress has been made in involving historians in the use of GIS, the latter present a number of defects that hinder their use by the social sciences. Owens (2009) gives an overview of these problems. Firstly, the difficulties historians face in handling these programmes. Secondly, a GIS is static and works with time-based data only with difficulty. Thirdly, these programmes can only work with a limited number of variables,
which can lead to poor results. Finally, it is difficult to use GIS to represent the disordered, qualitative and imprecise data historians often have access to. The DynCoopNet project has sought to further these efforts by analysing the cooperation of trade agents in the development of complex networks. This cooperation aimed at preserving the flexibility of the trading system in order to control the circuits of capital and information, although it led to the emergence of new forms of cooperation that would culminate in the alteration of the system itself.

4. History of Network Analysis

It is difficult to outline the history of the evolution of network analysis in a few lines. Linton Freeman (2004) has charted this process in several phases that represent the emergence of the first theoretical foundations, and their subsequent development and consolidation. The first period, which Freeman calls the “prehistory of network analysis”, runs from the mid-19th century until the 1930s. Earlier still, in the 18th century the mathematician Leonard Euler had proposed some of the theoretical and practical grounds for graph theory (Luke and Harris, 2007). Sociology is the discipline that contributed most to the development of SNA at this early stage. The first sociologists asked themselves how social links are established. In an attempt to answer these questions, thinkers such as Comte and Simmel established a theoretical basis and specific terminology for describing these connections. The key lies in the emphasis that Simmel placed on the position occupied by agents in affiliation networks. Comte, meanwhile, proposed that the interconnections between social agents should be taken into account (Freeman, 2004). In conjunction, the ideas of Comte and Simmel would provide the starting point for network analysis (Grabher, 2006: 164).

The second period in this development began during the 1920s, and forms the prelude to the first network analysis, properly speaking. It was driven by the work done by educational psychologists on social connections, which established influence, interaction and company as key characteristics. At the same time, in the field of social anthropology in Britain Radcliffe-Brown and Nadel were making progress in the development of structural analysis with the understanding that social structures are formed by concrete relationships between individuals (Scott, 1996). The emergence of the figure of the psychiatrist Jacob L. Moreno is considered the starting point for this period of development of network analysis as a methodological tool for social analysis. The novelty of his studies may be seen in his representation of agents using what he termed
sociograms, which are a kind of graph in which individuals are represented as points connected by lines. The use of this method enabled the discovery of hidden associations, with the identification of stars, alliances and subgroups (Oliveira y Gama, 2012: 99–115). This period culminated in the publication of the first issue of the journal *Sociometry* in 1937, which created a space for academic discussion in which researchers sharing similar concerns about society participated (e.g. Kurt Lewin, Paul Lazarsfeld and Gordon Allport).

During this stage of development, there occurred a “dark period” between the 1940s and 1960s due to the conflicts between in the scientific community and Moreno’s “bombastic” personality. Except for disciplines like geography, biology, anthropology, social psychology and mathematics, which used network analysis, SNA remained fragmented and localized (Freeman, 2004: 42, 120). Finally, in the mid-1960s the publication of the study by Coleman, Katz and Mendel (1966) on the relationship among the connections established between doctors and the diffusion of new medicines put an end to this impasse.

Centred on the Department of Social Anthropology at the University of Manchester, the discipline of anthropology took up the baton to research conflict among groups. Barnes, Bott and Mitchell continued on the path set out by Radcliffe-Brown, focusing on how the structure of social relationships affected not only individuals but also society as a whole. In this sense a lot of attention was paid to the content of relationships while analysing their structure at the same time (Scott, 1996). The theoretical proposals of the “Manchester group” would lead to the development of network theory, providing a common language for making progress in the field (Reynoso, 2008). The third period, during which the discipline became consolidated, is the result of the influence that the British researchers had on a group of sociologists at the Harvard University led by Harrison White. During the 1960s and 1970s they would be at the helm of “the Renaissance at Harvard” through which SNA achieved the status of a general research paradigm (Freeman 2004: 42). White’s teaching succeeded in instilling this paradigm in an entire generation that would develop many mathematical aspects of SNA, taking concepts from the social sciences, such as the “social role” of a mathematical form that would allow them to measure and model networks (Scott, 1996). The list of White’s students may be considered a “Who’s Who” of network analysis (Freeman, 2004: 127).

During his doctoral studies, Mark Granovetter, a disciple of White, asked himself how network theory resolved the question of micro/macro relationships. Specifically, he asked: how does an agent go about operating
outside his environment? According to Granovetter, up to that point it is possible to know data about the organization of the community, political structure and social mobility, on the macro scale, as well as what happens within the confines of a small group, on the micro scale. But when it comes to studying how small groups interact to form a larger cluster, we lose track of what occurs. Effectively, this means the relationships between individual nodes influence the formation of networks, or relational analysis (Granovetter, 1973: 1360–1380). Granovetter’s studies are very important for a number of reasons. In the first place, because his research into the process of information dissemination marked the beginning of the network focus (Núñez Espinosa, 2008). Secondly, because they enabled the development of more sophisticated and realistic modelling of network structures. As such, they are an attempt to explain social structures and human behaviour (Luke and Harris, 2007: 71). Finally, they are important because they introduce economic activity into the study of networks and a theoretical interest in the economy (Grabher, 2006: 164). This interest is catalysed by the concept of incrustation, which in its economic sense, related to SNA, assumes that all economic interactions are incrusted, or embedded, in social relationships (Reynoso, 2008).

Finally, the 1980s and 1990s represented the consolidation of the period begun at the Harvard University. Two fundamental trends in analysis emerged. On the one hand an eclectic hodgepodge of anthropologists, geographers, social psychologists, political scientists, historians and mathematicians, and on the other a group consisting only of sociologists. Both schools maintained an academic separation that could have led to the disintegration of the discipline. However, a reunification process was spearheaded by Barry Wellman at University of California, Irvine, who thanks to the influence of the writings of Mullins (1973) founded the International Network for Social Network Analysis (INSNA) together with other researchers. This combination of factors paved the way for scientific discussion in specialised journals and conferences on networks, which would reach a critical point with the development of specific software for quickly and cheaply producing and representing analyses.

5. Study Proposals on Historical Social Networks

The 1980s represented a major crisis in the paradigms used by historical studies. Perhaps the foremost expression of this process was the disintegration of the final generation of the *Annales School*. The exhaustion of the structure-based theories of Braudel led to the search for new analytical perspectives. In some cases the changes were wrought from within the school itself, with Roger Chartier as one of the lead proponents. These researchers began to take an interest in the small players in the grand structures *Annales* concerned itself with, and began to propose “micro” perspectives. Such is the case of the microhistory of Carlo Ginzburg, the history-from-below of Roger Chartier or the new cultural history which is strongly influenced by American anthropology as personified by Natalie Zenon Davies and Robert Darnton.

Historians began to seek analytical perspectives in new disciplines that *Annales* had left aside, furthering the interdisciplinarity with which the French school had already revolutionized the way history is done years earlier. In this effort to emphasize individual agency over and above grand structures, history found new horizons in network analysis. As such, historians interested in studying the operation of specific social groups from within were drawn towards sociology and SNA methodology. These first contacts lacked a theoretical background for understanding all the possibilities for applying advanced analyses to history. However, since the 1990s we have witnessed the emergence of a more concrete analysis that has advanced slowly and at different rates depending on the area of knowledge, whether linguistic or historical. Nevertheless, these approaches made from the macro scale remain relatively isolated, almost in the margins of the discipline, particularly in its points of contact with sociology, and regardless of the micro-historical perspective of social relations. In this sense, it is surprising that today it seems that efforts to apply the methodology of network analysis to history remain isolated from each other, with no real scientific dialogue between them (Lemercier, Guzzi-Hebb and Bertrand, 2011).

Traditional political history has focused on analysing power and the state, taking the sources of its power as a reference point. Rafael Guerrero,

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14 The *Annales d’histoire économique et sociale* is an academic history journal founded in 1929 by Lucien Febvre and Marc Bloch that placed emphasis on social history and opposed the German historicism of Leopold von Ranke, political history and history based on major figures. One of its strong points was bringing history closer to social sciences in order to resolve some of the problems facing the discipline. Herubel, 2004: 293–312.
who has pursued the line of research initiated several years ago by José María Imizcoz (2009), sets out the change of perspective undergone by this vision of political history: “These analytical perspectives essentially set themselves against the core of traditional political history, the State and official law, displacing the focus towards micro-space and personal factors, in an effort to overcome the confusion between theory of the State, theory of power and political theory” (Guerrero, 2012). With the use of relational analysis – borrowed from sociology – it becomes clear that relationships have a determining role in building social networks. As a result, the static structures and contexts that characterize political history are abandoned in order to focus on the interplay of relationships pursued by agents in order to ascend in the structure of power of the Old Regime. The aim of the different proposals we have analysed in this group is to reconstruct relationships around a central entity, whether this be a person (Imízcoz, 2011), an institution (Artola Renedo, 2011), or a shared identity (Padgett, 2011).

6. What is Social Network Analysis?

6.1 Definition and Basic Questions

Earlier, we dealt with the meaning of a network, but a social network can be defined as the mapping and measuring of relationships and flows between people, groups, organizations, computers, and other connected information/knowledge entities (Krebs). That is, SNA provides a visual and mathematical analysis of human relationships. Beginning with this definition there are certain concepts that must be borne in mind when it comes to understanding SNA. In the first place the entity defined by the SNA is the focus on the structure of relationships, which range from casual connections to close links. SNA presupposes that relationships are important and as such represents and measures formal and informal relationships in order to understand what facilitates or impedes the flow of knowledge, who knows whom, who is connected to whom, and so on. Given that these relationships are not always visible at first glance, SNA may be said to be a kind of organizational x-ray (Serrat, 2009). Secondly, when it comes to carrying out a network analysis the methodological basis of the tool must be borne in mind: relationships and the qualities of the relationships built around individuals and entities. In the case of SNA the principal information taken into account for the research are links and nodes. As such, according to Nuñez Espinoza (2008) it is important to attend to the following points:
1. the population and social group to be studied (characteristics and size of the sample);
2. the relationships and qualities the analysis seeks to bring out; and
3. the information that needs to be obtained to conduct the analyses of the network(s) identified.

This last point makes clear the flexibility of SNA, as it enables us to visualize different types and quantities of relationships, despite the limitations imposed by the methodology with regard to the relationships and attributes we wish to analyse, and the depth in which we wish to analyse them.

6.2. Representation and Visualization

The structure of these networks tends to be represented using graphs based on mathematical graph theory (Tutte, 2001). A graph (Figure 1) is the conjunction of two fundamental elements, nodes and edges. Each edge is defined by a pair of nodes that are also known as “endpoints”. The edges may be direct or indirect depending on the nature of the relationship between the nodes, that is, whether it is symmetric or asymmetric, respectively. In connection with the theory of weak connections explained above, the importance of the nodes for calibrating the strength of the relationships with the remainder should be borne in mind. This factor will condition the structure of the data matrices – which form the basis for the graphs – given that if the relationships have no weight and are undirected, the matrix will be binary and symmetrical; while if they are directed and have weight then the values will be found somewhere between 0 and the maximum weight. In both cases these are non-negative matrices (Oliveira and Gama, 2012: 101). The representation of a graph enables us to evaluate the location of the agents in the network, which allows us to observe from within the different roles and groupings that occur in the network. That is, it allows us to answer a number of questions, such as, on the one hand, who are the connectors, the leaders, the bridges, the isolated individuals and the experts, and on the other, where the “clusters” are found and who is in them. In short, who is in the nucleus of the network and who is on the periphery. When it comes to representing graphs we can use several mathematical methods, including lists and matrices. These structures allow us to store graphs in computers in semi-automated form on the basis of adjacency and incidence. Sequential representation is based on the matrices of adjacency that show all the relationships between the nodes in binary mode. Linked representation is based on linked lists of
neighbours – adjacency – that introduce the data using its formal definition: as a set of nodes and edges.

The matrices and lists of incidence represent the graph on the basis of its edges, that is, the relationships between the nodes and the edges in a binary matrix. In the case of lists, these are formed using a dynamic vector with linked lists to create an index of edges (Valenzuela Ruiz, 2003). Together with representation, SNA allows us to make calculations to examine various questions regarding the network. One of the most interesting aspects for those who analyse networks is the position occupied by the agent in the network and in its structure. Calculations such as degree, intermediation or proximity tell us about the links an agent has with his surroundings, who occupies a central position or who functions as a bridge for the rest.

In the case of Figure 1, we may observe that a calculation of degree has been applied to the visualization of the nodes. This shows us which nodes are the best connected to the network, according to the number of links maintained by each node. Using the Cytoscape software we have chosen to represent this by the size of each node. As such, we can see that node 5 (Cádiz) is the best connected node in this example.

Figure 2 uses the same data as in Figure 1 but implemented using the Tulip programme. In this case we have applied the Fruchterman-Reingold (1991: 1129–1164) algorithm, which functions as a mechanism of repulsion, pushing away the more isolated nodes and bringing closer those that are better connected. While these calculations provide us with valuable information, the key added value of these analyses lies in their spatial component. This provides the geographical space located beneath this network of relationships described with the SNA programmes. As such, our efforts are aimed at implementing the results of the GIS analyses we have briefly described. We fulfil a dual objective: on the one hand we are able to represent the nodes in their geographic and chronological position, and on the other we can visualize what is taking place in the network and observe hotspots, the best located agents both in terms of the network and geographically. In short, the relationship between the territory and those who occupy it.

Given that our paper is focused on the application of GIS analysis to historical social networks, we refer the reader to specialized bibliography regarding the basic measures for SNA\textsuperscript{15}.

\textsuperscript{15} Vadis Krebs, “Uncloaking Terrorist Networks” \textit{First Monday}, vol. 7, no. 4 (April 2002); Krebs, “A Brief Introduction to Social Network Analysis” and Oliveira and Gama “An Overview of Social Network Analysis”.

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Figure 1. Graph of a maritime trade network in the First Global Age (1400–1800)\textsuperscript{16}

![Graph of a maritime trade network in the First Global Age (1400–1800)](image)

Figure 2. Graph of a trade network in the First Global Age using the same data as in Figure 1\textsuperscript{17}

![Graph of a trade network in the First Global Age using the same data as in Figure 1](image)


\textsuperscript{17} Prepared by the authors using Tulip.
7. Social Network Analysis Software

The entities that belong to a network can be of many different kinds. From simple individual nodes to groupings of nodes in dyads and triads, by way of links and edges, right up to the whole network. Similarly, the software packages for SNA take the raw data from the lists of edges, and adjacency lists and matrices that may sometimes be combined with their attributes. Most programmes on the market work with data in ASCII text format, although some packages are able to import data from relational databases and store the network entities.

SNA software can be divided into two classes: a) packages offering a graphic user interface (GUI) and b) programmes created to generate programming languages and computer commands. The former are easier for non-expert users and have a rapid learning curve, while the latter have greater potential and extensibility. The most common GUI-based SNA software packages include NetMiner, UCINet, Pajek, GUESS, ORA, Cytoscape and Tulip.

There are other programmes with a proprietary graphic user interface that have been developed for specific uses, such as companies that wish to visualize their internal organization (Orgnet, Keyhubs and KXEN) or the telecommunications or online gaming industries, which use Idiro SNA Plus given its ability to handle large amounts of data.

Finally, networks may be analysed from a spatial perspective, the focus of this paper. The ESRI program, ArcGIS, offers the Network Analyst extension that enables representation and analysis of geometric and transport networks. We shall proceed to analyse the properties of this tool as a complement to those used in specific SNA programmes. Our software comparison will focus on four specific packages, UCINet, Network Analyst, Cytoscape and Tulip (Table 1). Of these, the first two are proprietary software while the latter two are open source. Despite the fact that proprietary software programmes are easier to learn and still have a greater number of users than the free software, open source programmes are making much more rapid progress in terms of functionality and features. Furthermore, these programmes more often include user manuals and tutorials that continually improve in terms of intelligibility and applications. As we saw above, visualization in spatial analysis programmes is a powerful tool for representing the real world (Owens, 2007). As such, visualization in SNA programmes allows us to better understand data and efficiently communicate results (Freeman, 2004). SNA software allows us to modify several aspects of visualization such as colours, size and other properties of the network in order to better display
the conclusions shown by the analysis. Most SNA tools already incorporate these features so that users can produce the best possible visualization. In this paper we will focus first on comparing SNA programmes, of which Cytoscape has the best level of visualization. Meanwhile, data visualization is interactive, meaning that users can generate new data on the basis of the original data matrix. For example, it may be that we want to make visible only a section of the information in a very dense network. Most programmes enable us to do this by filtering the information according to chosen categories. According to the information contained in Table 1 we can draw some conclusions about the analysis tools that we have considered in this section. Perhaps the most important aspect of the three programmes we have presented lies in the possibility two of them offer of working with open source and the fact they work on any operating system. Meanwhile, open source allows software updates to be developed more effectively, allowing users to improve their analyses as the project progresses. In the case of Cytoscape, version 2.8 has recently been released in its eighth year of development, which while respecting the functionalities of a network analysis tool (interactions between nodes via edges), has added two new features. Firstly, it enables users who are not experts in programming to map images using nodes, which significantly increases its capacity and flexibility for visualization. Secondly, it is now possible to write equations in the spreadsheet in which the data is found in a similar fashion to programmes such as Excel (Smoot, Ono, Ruscheninski, Wang and Ideker, 2011:431–432). Tulip, at the time of this study, had just released version 4.1 of its software for all operating systems. As announced on their website http://tulip.labri.fr they have solved some issues present in previous versions.

The two most important new features are corrections to the spreadsheet when managing properties, and access to new plugins, not only for users of Windows and MacOS but also Linux, which were not available in previous versions. The user interface, as with other GUI-based programs, is very intuitive and allows visualization of multiple windows with partial and complete information about the network elements. UCINet (Stephen, Everett and Freeman, 2002) is the only one of the three tools that is designed specifically for social network analysis. Its structure includes the original programme together with Spreadsheet and NetDraw, which are extensions for working with data matrices and visualization graphics respectively. It is the only one of the three programmes that has a charge, with a trial version that after 60 days requires payment for the license. Network Analyst is a very powerful tool primarily aimed at solving problems of mobility in urban and interurban networks. For the present
case the features offered by this tool for the representation and visualization of trade networks in the 18th century are: modelling maritime routes by georeferencing the points passed through by the ships based on information taken from nautical charts and the number of ships using each route, assigning different thicknesses to each route (Figure 2); locating in space the nodes representing the ports and agents that control maritime traffic and ports of departure, arrival and call; calculating the amount of goods being transported each year by these vessels on each route, and specifying whether these were slaves, commodities, gold, silver or coinage. Furthermore, we can establish the direction of travel on routes in order to invert them and perform these calculations in the opposite direction.

Figure 3. Georeferenced West Indies route showing the direction of travel of ships.\(^{18}\)

One of the possibilities offered by the DynCoopNet project data is the determination of transatlantic trade hotspots using data based on the number of connections implemented in the ArcGIS Spatial Analyst. Moreover, we can use SNA programmes to determine which agents are best placed within the interplay of trade relationships. These two pieces of data allow us to state whether agents who are better placed in the structure

\(^{18}\) Prepared by the authors, *Puertos*: Ports; *Paradas intermedias*: Ports of call.
of the network are also located geographically in these hotspots. Moreover, we can implement the relationships the SNA programme created for us in Figures 1 and 2 in the GIS in order to obtain a spatial visualization. Figure 4 shows the spatial dimension of the data used in Figures 1 and 2 together with the connections between them.

Figure 4. Map of trade relationships between cities in the First Global Age

Prepared by the authors; Ciudades: Cities; Conexiones: Connections.
<table>
<thead>
<tr>
<th>Software</th>
<th>Application</th>
<th>Data input formats</th>
<th>Visualization and representation formats (output)</th>
<th>System specifications</th>
<th>License</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cytoscape</td>
<td>Tool for integrating complex and general data for visualization and analysis</td>
<td>SIF (Simple Interaction Format), GraphML, XGMML, GML, KGML, SBML, BioPAX, Excel and text tables (.csv, .tab and tab delimited tables) Other programmes such as Pajek, igraph, Graphviz.</td>
<td>SIF, XGMML, GML, GraphML, Cytoscape Session (.cvs), vector(bitmap images (.jpg, .png, .pdf, .ps))</td>
<td>Cualquier OS que soporte Java</td>
<td>Open Source (LGPL)</td>
<td>Cytoscape was originally developed for bioinformatics research, but is now presented as an independent analysis platform. In addition, a large number of plugins for different users come with the programme, which greatly extends its functionality. Also, it enables connection to external web services to obtain information to work with from public databases, other networks, etc.</td>
</tr>
<tr>
<td>Tulip</td>
<td>Analysis and visualization tool for relational data</td>
<td>Tulip format (.tlp), GraphViz (.dot), GML, txt, adjacency matrix</td>
<td>Tulip format (.tlp), GML</td>
<td>Any OS (Windows, Linux, Mac OS)</td>
<td>LGPL</td>
<td>The tool provides the developer with a complete library of plugins supporting the design of interactive applications for relational data visualization that can be adjusted to the problems the user wishes to solve.</td>
</tr>
<tr>
<td>UCINet</td>
<td>SNA tool</td>
<td>Excel, DL, .txt, Pajek, .net, Krackplot, Negopy, proprietary format (*.d &amp; *.h)</td>
<td>Windows, MacOS and Linux (using BootCamp, VMFusion Ware, Parallels or Wine)</td>
<td>Shareware</td>
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<td>A comprehensive SNA tool. It can work with a maximum of 32,767 nodes (with some exceptions) although in practice analyses of 5,000-10,000 nodes can lead to delays in calculations. It includes the analyses mentioned above, basic graphics and statistics. It also includes powerful matrix analysis routines such as matrix algebra and multivariate statistics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network Analyst</td>
<td>Extension to ArcGIS (Spatial analysis)</td>
<td>.txt, .xls, .shp, .csv</td>
<td>.shp, .pdf, .jpg, .gif, .png, .txt, .csv</td>
<td>Windows</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>A tool whose main function is to solve problems for routes connected in a network. Its main features are: to calculate the shortest path to solve a problem; learn if the zones of influence of a particular service cover all potential users; establish optimum routes for loading and unloading goods.</td>
<td>Paid licence</td>
<td></td>
<td></td>
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</tbody>
</table>
8. Implementation of Data

The design of a GIS necessarily involves a stage prior to the implementation of the data: that of modelling. This is a fundamental and indispensable phase in the creation of any quality system that involves the implementation of a database, regardless of its nature, and the model is in itself its materialization, the way the data is organized (Del Bosque González, Fernández Freire, Martín Forero and Pérez Asensio, 2012). The first step, therefore, for approaching a GIS project requires undertaking a conceptualization, abstraction or simplification of reality or the object of study. To facilitate this task both graphical languages such as standard UML (Unified Modeling Language) and CASE (computer-aided software engineering) tools are frequently used. These are applications that reduce the time and economic costs of developing a project by facilitating the generation of all its lifecycle documentation. The resulting conceptual model is independent of both the hardware used in the system to be developed and the software, including the database manager that will be used to store the information itself. A semantic distinction can usually be made in a GIS between two types of entities or datasets: those that are properly geographic (with characteristics related to the space they occupy such as position, geometry, or topology) and those that are thematic, which in the case of historical research projects such as the present case usually occupy the greatest amount of information and may involve high levels of complexity due to the multitude of relationships that can be established between them. Once the information has been modelled its physical implementation is carried out by entering the data (thematic and geospatial) into a database that can respond to the principle of a relational, object-oriented or object-relational database. Whichever of these is used, the classes or entities previously defined in the conceptual model together with their relationships are translated into tables with attributes and relationships between them. In the example of the historical research presented in this paper related to social network analysis, the resulting complex conceptual model has been transferred to an open source database, PostgreSQL, which basically handles the alphanumeric or thematic aspect of the data, and uses an extension called PostGIS for managing the properly geographic information, thereby maintaining a certain separation between the two contexts. Once the data has been entered into the database, which in the case of the DynCoopNet project was carried out using a data entry interface developed specifically for this purpose, the subsequent utilization and analysis of the data is performed with different platforms, both GIS and any of the network analysis tools.
discussed in this paper that do not handle the geospatial component. Moreover, a simple and rapid way to upload data from the DynCoopNet database to the network analysis programmes is the tool implemented as a package in Java snGraph (Maestre Martínez, 2010). This software was developed precisely in view of the special topology of the networks that we want to represent, and it enables simple visualization and sharing of the data and the creation of models to exploit databases quickly and efficiently or export them to programmes that allow more in-depth analysis. The most important aspect of this tool lies in its multiplatform capability, since it is not a network analysis tool, but rather a bridge between systems. As such the data stored in PostgreSQL can be exported to any of the programmes we have discussed above for performing the analyses required. Depending on the type of SNA programme to be used, the import format of the data may vary, although text format (e.g., .txt, .csv, etc.) is very common for this purpose. The way of handling the information may also vary (e.g., Tulip requires nodes to be entered on the one hand and the relationships between them on the other, while in Cytoscape this differentiation is not required, facilitating the task of data processing). The main problem faced by the DynCoopNet project is that not all the information contained in the documents can be used. In fact, the documents that have been used to transfer the information into the database share the same trade agents that will be part of our network analysis. As the authors explain, the agents are not just the people who run the West Indies fleet and negotiate the goods to be transported. They are all those involved in transatlantic trade, including representatives, privateers, pirates, capitalists, brokers, etc (Pérez Asensio, Del Bosque González, Maestre Martínez, Crespo Solana and Sánchez-Crespo Camacho, 2012: 158–160)).

9. Conclusions

Social network analysis opens the doors to the relationships established among a group of people. Knowledge of these relationships allows us to isolate agents and understand their behaviour and the reasons for their social rise or fall. This new analytical perspective offers us a tool for evaluating the degree to which the interplay of relationships among agents in a network has shaped historical changes. The application of these techniques, which originate in sociology, is currently coming into its own among historians. As we have seen, they offer us a new analytical perspective on aspects that traditional historical studies have ignored. This is also the case with Geographic Information Systems, which have gradually been introduced among historians in recent years as a tool for
visualizing spatio-temporal phenomena. Moreover, the visualization capacities of GIS allow us to observe changes in a territory over time, which may be added to the evolution of the relationships among agents in the historical networks under analysis. In this way we are able to observe not only changes in a territory but also the movements made by these agents to achieve a better position both in the network and in relation to trade hotspots. This is the most important point we have dealt with so far, which is none other than the vast possibilities offered by implementation of the results of historical network analysis in a GIS. Territory becomes a key element for describing the interplay of relationships, in our case of trade agents in the First Global Age. This inclusion of the spatial component is the next step that should be taken by SNA in its integration with historical analysis. Finally, the dialogue between historical sciences and these technologies still has a long way to go. It is a journey that demands collaboration across disciplines in order to propose new analytical perspectives and applications of these techniques geared towards resolving issues surrounding historical relationships.