

# Analyse Visuelle pour l'Analyse de Réseaux Sociaux Historiques

## *Visual Analytics for Historical Network Research*

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# 1 - Introduction

Historical Social Network Analysis is a method—sometimes referred as a paradigm—followed by social historians to study sociological phenomena through the observation of relationships of actors of the past, modeled into a network. The usage of networks as an abstraction to represent and study social relationships—such as friendships, kinship, or business ties—grew in popularity in the last 40 years [?, ?] and is a powerful metaphor especially in our time when many of our digital connections and interactions take explicit network structure<sup>1</sup>. Historians leverage historical documents—which are at the core of their profession [?]<sup>1</sup>—to extract relationships between actors of interest that they model with networks constructed from nodes and links that respectively represent actors (often persons) and relationships. Using social network visualization techniques and leveraging network measures and computations, they can then test hypotheses they have and gain insight on the structural aspect of the relational phenomena they are studying [39, 72]. This approach has been followed successfully to study various subjects such as kinship [?], entrepreneurship [?], maritime routes [?], political power [57] and oppositions [56], and persecution [?]. Yet, history is considered by many as a literary and qualitative science, and many critics emerged concerning quantitative and network methods [37, 41, 44], such as the leading to trivial conclusions, anachronisms, and mismatches between network and historical concepts. Moreover, quantitative and network analysis are complex processes, and demand many efforts in data collection, cleaning and processing before being able to make efficient observations.

Social historians have to take many annotation and modeling decisions, concerning *what* to model from their sources into a network, and *how* to model it [?, 9], i.e., should the information of interest be represented as a node, a link, an attribute, or not reflected in the network at all. Practically, they usually use adhoc processing and analysis scripts to transform historical documents to analyzable networks, which is time-consuming, sometimes to end up with trivial or hard to interpret results [2]. Still, HSNA led to many highly regarded studies with thorough conclusions, such as the study of families of power in Florence by Padgett where they explained the rise of the Medici family through their central position in the economical, political, and trading networks of powerful families.

The usage of visuals to graphically display networks is common in SNA as it allows to unfold the structure of networks to the eyes, thus letting social scientists confirm hypotheses they had when collecting and exploring their data aswell as gaining new insight through the discovery of interesting patterns and trends [10]. Images of networks also constitute an efficient mean of communication, especially

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<sup>1</sup>This analogy goes to the point that the term “Social Network” can refer both to the sociological metaphor for social relationship and the social media platforms such as Facebook.

in scientific productions [?]. Many visualization techniques and softwares have thus been developed since the birth of SNA, but most popular tools are usually not designed for historians specifically and usually enforce traditional network models without proposing exploration mechanisms, beyond allowing to look at the network structure and computed measures. In this thesis, we therefore investigate how visualization can support social historians in their overall process, starting at the acquisition of their document, and also at the analysis step, i.e., how visualization interfaces can support social historians in answering their questions with the right level of expressiveness, usability, and traceability.

## 1.1 . Social History and Historical Social Network Analysis

HSNA is now a widely used method among historians to study relational phenomena like kinship, business, and institutions of the past, using network concepts and methods. We can trace it back to the birth of Social History with the “Annales School” in the 1930s, where Historians gained interest in socio-economic questions and started to rely heavily on the exhaustive extraction and analysis of historical documents coming from archives [?,60]. Beforehand, History was mainly political and event-centered, as the majority of work consisted in narrating and characterizing specific events—such as wars and diplomatic alliances—while eliciting their causes and consequences, and describing the lives of historic figures, such as sovereigns [60]. Social History shifted the focus by aiming to link together sociological, economical, and political issues and by placing individuals at the center of these questions [?]. Later on in the 1960s, with the development of Computer Science, historians started to use quantitative methods to analyze data extracted from historical documents and make conclusions grounded in statistical results, in various subjects such as demographics [32] and economics [?]. Around the same time, the use and study of networks started to become popular in various disciplines to study real-world relational phenomena based on mathematical computations and measures, especially in sociology and anthropology. A network is an abstraction based on graph theory concepts which can be used to model phenomena based on relationships (called links) between entities (called nodes).

Sociologists appropriated this concept to model social relationships between agents of interest, allowing them to study the sociological structure of groups of interest—such as families, institutions, and companies—and concepts like friendship, oppression, and diffusion using real world observation and mathematical computations. This SNA approach allows to ground results in formal network measures and metrics based on real observations instead of relying on traditional social categories such as age, job, and gender [?]. This shift in the object of study from traditional social classes and aggregates to the observation of relationships of individuals remind the microhistoria movement [25] which theorized that following the life of single individuals and groups allows to make higher level conclusions about

the structures they live in. Social historians followed this tradition and started to appropriate network concepts to study relational aspects of the past and formalized it under the term Historical Network Research or Historical Social Network Analysis (HSNA) [72]. However, historians do not have the possibility to run surveys or directly observe interactions of the past and are thus constrained by the information contained in historical documents they find in archives. These documents can be anything mentioning social relationships between actors of interest, such as marriage acts, birth certificates, census, migration acts, business transactions, journals. After selecting a corpus of documents, they typically read and inspect in depth several documents while taking notes to have a deeper insight on the content of the sources, which allow them to start eliciting hypotheses. Following this exploration phase, they manually annotate each document and encode the desired information—the mention of persons and their social relationship in the case of a future network analysis. This is a long and tedious process that can result in small to large networks that they analyze using network measures to make conclusions on the structure of social groups or social behaviour of individual of interests.

The investigation and reading of the historical documents is therefore an exploratory process, where historians start to generate sociological hypotheses from the continuous extraction of insight and revelations of this process, similarly to the grounded theory [26]. Once they finalised a network, they can test their hypotheses using qualitative or quantitative methods based on quantitative and network measures. Lemercier and Zalc write “Although history is not an exact science, counting, comparing, classifying, and modeling are nevertheless useful methods for measuring our degree of doubt or certainty, making our hypotheses explicit, and evaluating the influence of a phenomenon.” [42] Social historians, therefore, have hypotheses about their subject of study, that they can back up or refute with the help of quantitative and network results, similarly to the competing hypotheses workflow of Intelligence Analysis [?]. By pointing to evidence supporting or refuting hypotheses, they can give insight into the level of the plausibility of different claims.

## 1.2 . Visualization and Visual Analytics

Visualization is the process of displaying data visually to leverage the human visual system and enhance cognition to gain insight into the data [?]. Using visual abstractions (such as size, color, and position) to display abstract data allows us to rapidly see structure and patterns otherwise hidden in the raw text and numbers. As data keeps growing in size with time, visualization is a powerful tool to gain insight into the underlying structure of various datasets.

Visualization has been traditionally used for confirmatory and communication purposes, particularly in empirical sciences. By plotting their data, analysts are able to confirm or deny their hypotheses and communicate their findings in scientific

productions. Social scientists following a network analysis typically use node-link diagrams, which allow them to represent a network with circles and lines to respectively represent nodes and links. It lets them confirm or deny some of their hypotheses by observing the network structure and communicating their results. However, visualization can also be used for exploration, which can help to understand the underlying structure of data and generate new hypotheses. Tukey defined this process as Exploratory Data Analysis in the 1960s [?], as a procedure to gain insight into the structure of the data by identifying outliers, trends, and patterns with the usage of visualization and statistical measures. Interaction in visualization helps this process by letting users navigate more easily on multivariate datasets with the help of direct manipulation of the data. The detection of patterns and trends can also be facilitated with automatic methods coming from data mining and machine learning fields, directly implemented in the visual analysis loop. This coupling of visual exploration and automatic data mining algorithms has been coined as Visual Analytics (VA) and is defined as the process of using interactive visualizations, transformations, and models of the data in an interactive analysis workflow to create knowledge [38]. If most widely used visual interface for HSNA do not yet provide complex interactions or data mining capabilities, VA can be a powerful support for social scientists to gain insight on the structure of their network, especially that the data they study keep growing in size and complexity [36].

### 1.3 . Historical Social Networks Visual Analytics

Most visual tools for SNA are designed for the analysis of already curated networks, without taking into account the context in which those networks have been produced, where they come from, and the workflow that led to their creation. Currently, social historians spend a lot of time in their data acquisition, processing, and encoding steps which lead them to the construction of a network [43]. They typically visualize and analyze their network at the end of this process, first to verify hypotheses they formulated during the inspection of their sources, then to gain a better view of the structure of the network, allowing them to potentially generate new hypotheses [15]. However, research showed that all the steps preceding the analysis can introduce errors and misconceptions, especially since social scientists are often not trained in Computer Science and Data Science [2, 41]. Social scientists usually visualize their network using SNA tools like Gephi [4], Pajek [?], and NodeXL [?] which encompass basic interactions, node-link visualization, SNA measure computations, and clustering algorithms. Once they visualize their data, they typically notice errors and inconsistencies in the data, such as duplication of the same entities, merging of different entities, or geolocation errors [2]. They, therefore, have to go back and forth between the visualization software and the encoding process which can be tedious, especially since it can be complicated to trace



back the entities of the data model back to the original documents for correction. VA tools which encompass the whole process of social historians should therefore be beneficial for the flow of their work and could help detect and correct errors or analysis plans way before the visualization of a finalised network. VA could also help social scientist reflect on their network modeling process as historical documents can be modeled in various ways [9]. Yet, most visualization tools aimed at HSNA such as Gephi [4] or Pajek [?] enforce simple network models, which visualization and analysis can often lead to trivial or distorted conclusions [41]. Furthermore, the data mining capabilities proposed in those softwares are often based on black-box algorithms, which can be hard to interpret for social analysts. For example, clustering algorithms are often included in such systems, letting social scientists partition networks into groups, but many algorithms exist in the literature, potentially giving diverse results. Scientists often run several algorithms until finding a satisfying enough partition, which can bias the result of an analysis<sup>2</sup>. Usability and traceability of the results are therefore primordial in VA interfaces aimed at supporting social historians in their analysis.

#### 1.4 . Contributions and Research Statement

As seen in §1.3, most VA tools for HSNA are focused on the final analysis of a polished network. Instead of only providing analysis capabilities, we think VA could help social historians in their entire workflow, from data acquisition to analysis, instead of focusing only on the final steps. Concerning the analysis step, VA tools should satisfy the constraints of social historians, i.e. being able to answer complex questions with effective visual representations, letting the user in control of the analysis loop and algorithmic results, and satisfying traceability to the original sources. The goal of this thesis is therefore to give answers to the high-level question “How can VA help social historians in their entire HSNA process?”. To answer this question, we first characterize the HSNA process from start to finish from discussions and collaborations with social historians, with the goal of identifying pitfalls and problems that regularly arise and characterizing social historians’ needs. From this, we give answers and directions to three issues that frequently arise in social scientists’ workflows:

**Q1:** How to model historical documents into an analyzable network with the right balance between expressiveness and simplicity?

**Q2:** What representations and interactions are efficient for social historians to answer complex historical questions and generate insight and hypotheses, while being easy enough to navigate?

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<sup>2</sup>We did not find any scientific production describing these potential issues when following such analyses. However, many social scientists referred to these problems to us in informal discussions.

**Q3:** How to design VA tools and interactions that leverage algorithmic power but keep historians in control of their analysis and bias?

In chapter 3, we start by describing the HSNA workflow and identify recurring pitfalls we encountered in our collaborations with historians and give answers to **Q1**. In the following chapter 4, we give answers to **Q2** by providing a VA interface to explore bipartite multivariate dynamic networks, with queries and comparison interactions with the aim of letting historians answer their questions and generate interesting hypotheses. Finally, in chapter 5, we propose PK-Clustering, a mixed-initiative clustering technique for social scientists based on their prior knowledge, algorithmic consensus, and traceability of results, as a concrete example of a system providing answers to **Q3**.



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