# A Conceptual Framework for Multilayer Historical Networks

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**Abstract**
The technicality of network visualization applied to history and its relative novelty often result in a superficial use of a software, limited to describing a situation immediately extracted from a data set. This approach is justified in the exploratory phase of an analysis in most cases where the network is very explicitly present in the object studied. But the complexity of the entanglement of historical actors, places, institutions or temporal sequences makes finer modeling necessary if we want to go beyond a simplistic "datafication".
To encourage curiosity towards other modes of analysis and put the data modeling (and therefore the historical sources) at the center of the research process, this article proposes a short introduction on how to discuss what makes a specific historical network, its components, its relationships, its layers and its different facets. It offers a kind of visual guide to help historians follow a multilayer framework to think their research object from another (multidimensional) angle and to combine them.

**Keywords**
social network analysis; digital history; network visualization; data visualization; digital humanities; data modeling; complexity; history; multilayer networks; network analysis; SNA; DH.

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## INTRODUCTION

The generalization of the use of network analysis and visualization applied to historical sources leads to the appropriation by a scientific community of tools and methodologies that are not necessarily self-evident. Moreover, the technicality of these approaches and their relative novelty often results in the satisfaction of a relatively superficial use of a software, limited to visualizing a situation immediately extracted from a data set. This approach is justified in the exploratory phase of an analysis in most cases where the network is very explicitly present in the object studied (e.g. transportation, correspondence, or social networks). But the complexity of the entanglement of historical actors, places, institutions or temporal sequences makes finer modeling necessary if we want to go beyond a simplistic "datafication".

## ANALYZE HISTORICAL NETWORKS

### Building bridges between historical research and network analysis

Although formal network analysis is expressed in a language very different from that of historical research, it should not be forgotten that the concepts on which graph theory is based are inspired by real-life situations. In [Euler, 1736], [Moreno, 1934] or [Barnes, 1954], which are considered as fundamental milestones in the formalization of this field, it is on the basis of empirical situations that the concepts we know today under the terms of "density", "centrality", "proximity", "community", etc. are developed. In [Grandjean and Jacomy, 2019], we plead for a reappropriation of these local and global graph metrics by the humanities and social sciences and we propose the bases of what we call a "translation" from one language to another.
This consideration also applies to the most recent developments in multilayer network analysis: historical situations are very often described as entangled objects, on several levels, with dynamics observable at different scales and actors sometimes interacting on superimposed layers. We therefore need to familiarize ourselves with the fundamentals of these multilayer methods to refresh and enrich our analysis of historical networks by improving our toolbox while stimulating our creativity when modeling data.

### Develop a model: what are my actors, my relationships, my layers?

This is a classic question during the historian's first steps in front of his sources: is the material suitable for network analysis? or should we instead encode new data from the archives to build an analysis that is articulated with the research question? If we are now used to questioning "what makes the relationship" between the actors of a corpus, whether they are people, places, institutions, documents, tags, etc., we do not always realize that the different types of nodes and edges can be expressed on different layers and that such a conceptualization makes it possible to multiply the angles of analysis and the combinations of datasets.
For example, an affiliation network between individuals and institutions can be represented as a 2-mode graph (fig. 1, blue vertical layer to the left) but also as two layers connected by [type1;type2] edges to allow joint analysis of [type1;type1] and [type2;type2] relationships (fig. 1, gray layers superimposed at the bottom and in the center). Engaging in such a reflection with regard to archives or data does not necessarily mean studying all the possible angles, but it is above all considering them and thus developing a model of its own without forgetting a dimension which would later prove to be the right one. This leaves the possibility of comparing these layers, of combining them, of filtering them, of adding a temporal dimension to them, etc.

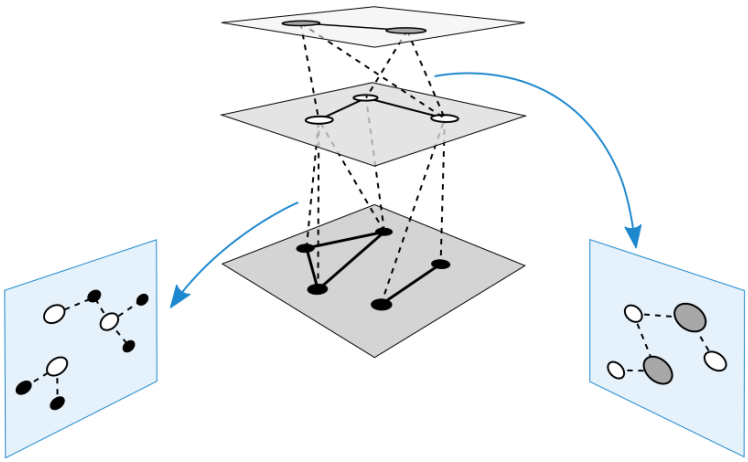

Figure 1. A visual representation of a basic multilayer framework: three 1-mode layers connected together by two 2-mode layers (three nodes sets and five edges sets).

## A GENERAL MODEL FOR MULTILAYER NETWORK

### A conceptual framework to help decision-making

Without going into too much detail in the finer points of multilayer modeling, we base this explanation on the model defined by [Kivelä et al., 2014] while mentioning that the "visual" application of this framework is currently under discussion [Knudsen et al., 2019]. Concretely, the graphic representation of this framework (of which we proposed a first draft in [Grandjean, 2017b] and examples in [Grandjean, 2020]) is presented here in the form of a system of layers (fig. 2) making it possible to synthesize modeling and analysis scenarios. Our goal is that it stimulates creativity and pushes the researcher to wonder what the layers are in his historical object/dataset.

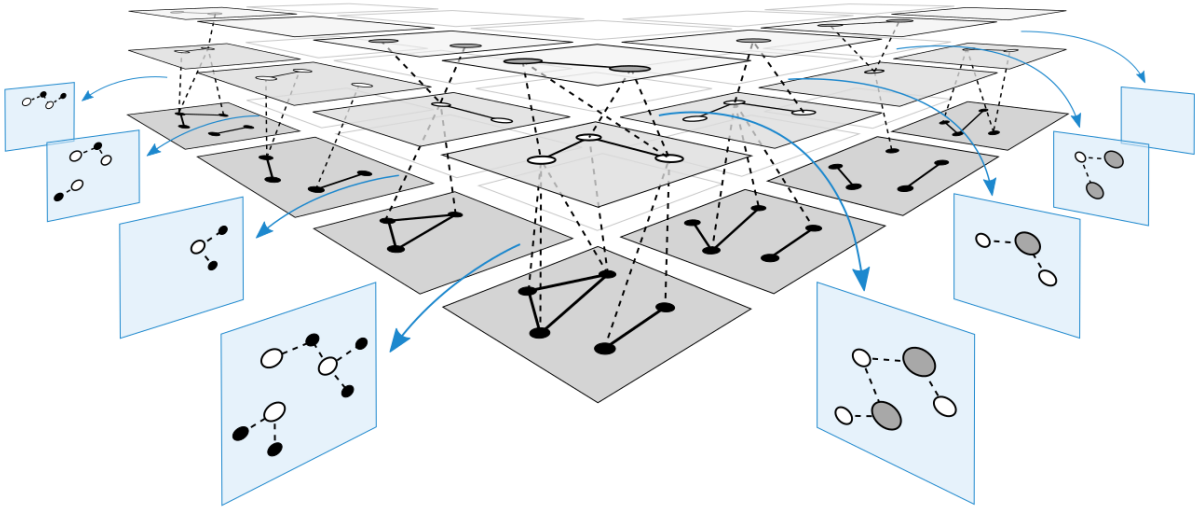

Figure 2. A visual representation of the multilayer framework from Fig.1 developed according to multiple "aspects": here, the right axis could be a temporal one (the same network is displayed over time) while the left axis could be a thematic one (different type of relations between the same set of nodes).

This representation in levels is only one among others since it is only the visual expression of a concept: the implicit hierarchy between the layers arranged at different scales is only a graphic consequence of this three-dimensional space. Besides, nothing (except visual constraints) limits us to three dimensions, but it turns out that most historical researches are limited to a reduced number of variables, whether it is to analyze different types of relationships, several levels or temporal dimensions.

**Integrating a multilayer model with various historical sources: an example**

The advantage of an open conceptual framework is that it allows us to think about the articulation of several networks with each other, to bring together heterogeneous networks in the same system. Our example is a workflow from [Grandjean, 2018], a study of the exchange of information within an international organization in the first half of the 20th century.
Step 1 (fig. 3 left) consists in defining which sources are available and how to transform them into network data: organization charts make it possible to clarify the interactions between institutional actors, lists of members of these organizations help to place individuals in groups, while letters make it possible to reconstruct the network of information exchanges between individuals. Thus, the correspondence metadata network (C) involves individuals affiliated with organizations (B), the arrangement of which is also known (A). Step 2 (fig. 3 center) consists in merging these three datasets to produce a multilayer network with three types of nodes and five types of edges (3x 1-mode edges sets on the horizontal layers and 2x 2-modes edges sets between layers).

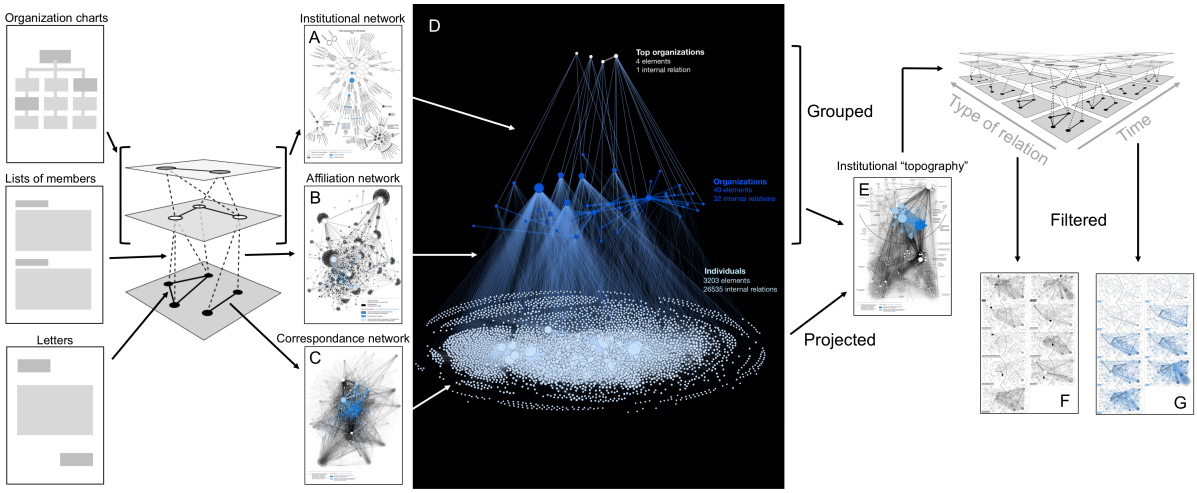


Figure 3. Transformation of three networks from historical archives into a single multilayer system, then projected and filtered. Networks A, B, C and E are from [Grandjean, 2017a]. Networks F and G are from [Grandjean, 2018a]. Network D is from [Grandjean, 2018b] with its complete dataset.

However, if all the data is there, the readability is not optimal in such a 3D configuration if the dataset is too large. This is why, in this specific case, step 3 (fig. 3 right) uses the institutional arrangement A to replace individuals C according to their affiliations at a given time thanks to B: this is what we call an "institutional topography" (E). To return to our framework, we can say that we are projecting a layer in the space of the upper layer. We can then use the other dimensions (facets) to model different types of relationships (F) or change the network over time (G), while keeping this layout which allows us to read the relationships created by these thousands of letters at the macro level (at the organizational level and no longer at the individual level).

## CONCLUSION

### "What matters is not the machine but the problem"

When we are confronted with historical sources and when we seek to make a network analysis, the easy solution often consists in choosing an obvious modeling, dictated by the available data: an analysis of co-occurrences if it is a text, a circulation analysis if it is a corpus of letters, a geographical analysis if the source relates to international economic exchanges or a co-affiliation analysis if the source is a member list. But combining these different sources is necessary to avoid limiting our research questions to what is directly observable. We must therefore give ourselves the means to develop methods which make it possible to put the problem at the center and not to limit ourselves to what the tools allow at first sight.
In a short article evoking the beginnings of computational analysis in history, [Le Roy Ladurie, 1968] warns us against truisms obtained by pushing (random) buttons. He recalls that the encoding of a historical source is not a blind act and that the technical equipment of the researcher does not exempt him from thinking about his approach: "In history, as elsewhere, what matters is not the machine, but the problem." It is up to us to give ourselves the conceptual means to respond to the problem rather than just operating the machine without understanding.

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