Visual Analysis of Multilayer Networks

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ABSTRACT

The emergence of multilayer networks as a concept from the field of complex systems provides many new opportunities for the visualization of network complexity, and has also raised many new exciting challenges. The multilayer network model recognizes that the complexity of relationships between entities in real-world systems is better embraced as several interdependent subsystems (or layers) rather than a simple graph approach. Despite only recently being formalized and defined, this model can be applied to problems in the domains of life sciences, sociology, digital humanities, and more. Within the domain of network visualization there already are many existing systems, which visualize data sets having many characteristics of multilayer networks, and many techniques, which are applicable to their visualization. In this Synthesis Lecture, we provide an overview and structured analysis of contemporary multilayer network visualization. This is not only for researchers in visualization, but also for those who aim to visualize multilayer networks in the domain of complex systems, as well as those solving problems within application domains. We have explored the visualization literature to survey visualization techniques suitable for multilayer network visualization, as well as tools, tasks, and analytic techniques from within application domains. We also identify the research opportunities and examine outstanding challenges for multilayer network visualization along with potential solutions and future research directions for addressing them.

KEYWORDS

multilayer networks, visualization, network visualization, visual analytics, interaction, task taxonomy, attribute visualization, multivariate network visualization, evaluation

Contents

Preface

Although not presented using the concept of multilayer networks, the 1985 paper "Relational contents in multiple network systems" by Burt and Schøtt [1985] clearly brings it into play. The ideas they laid out in their seminal paper were generalized, further examined and extended in a series of papers by Renoust et al. [2013, 2014, 2015]. Renoust transferred the notion of relation multiplexity to document collections, and later applied his approach to any collection of homophily relations in any context. At the same time, Kivelä et al. [2014] were developing a formal framework unifying all preceding efforts to deal with heterogeneous, multi-source networks.

Many of the ideas, concepts, definitions, and overall content of this book were given a decisive boost within the FR-LUX bilateral research project BLIZAAR[1] between its writing early 2015 to its official end in 2019. Incidentally, the writing of a survey on the visualization of multilayer networks [McGee et al., 2019a] was a deliverable of this project. Other projects[2] involving the Bordeaux team with sociologists and law researchers investigating human-trafficking [Lavaud-Legendre et al., 2017] definitely contributed to mature the concept of multilayer network and some of its intimate requirements when it comes to building systems supporting their visualization and navigation.

The authors would also like to thank Schloss Dagstuhl and the participants of seminar #19061 on the "Visualization of Multilayer Networks across Domains" [Kivelä et al., 2019]. The seminar was a unique event gathering both researchers of the visualization field, complex systems theory, and a significantly large group of domain experts all familiar with the concepts and in demand of the visualization of multilayer networks. Without the support of Schloss Dagstuhl and the commitment of its participants, this book would have never come to be.

In October 2019, all authors of this book participated to the "Multilayer Network Visualization" workshop organized on the occasion of the IEEE VIS'19 week conferences held in Vancouver. We would like to thank the organizers of IEEE VIS'19 for their support for the workshop. One of the results of the workshop was to gather the authors around the project of writing this book.

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