Exploratory Social Network Analysis with Pajek

This is an extensively revised and expanded third edition of the successful textbook on analysis and visualization of social networks integrating theory, applications, and professional software for performing network analysis. The main structural concepts and their applications in social research are introduced with exercises. Pajek software and data sets are available, so readers can learn network analysis through application and case studies. In the end, readers will have the knowledge, skills, and tools to apply social network analysis across different disciplines. A fundamental redesign of the menu structure and the capability to analyze much larger networks required a new edition. This edition presents several new operations, e.g., community detection, generalized main paths searches, new network indices, advanced visualization approaches, and instructions for installing Pajek under MacOSX. This third edition is up-to-date with Pajek version 5 and it introduces PajekXXL for very large networks and Pajek3XL for huge networks.

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Vladimir Batagelj is Professor Emeritus of the University of Ljubljana, Slovenia. He is also a member of the Institute of Mathematics, Physics, and Mechanics (IMFM), Ljubljana, and of AMI, UP, Koper. His coauthored book *Generalized Blockmodeling* was awarded the 2007 Harrison White Outstanding Book Award by the Mathematical Sociology Section of the American Sociological Association. From the International Network for Social Network Analysis he was awarded the Georg Simmel Award (2007) and the Richards Software Award for the program *Pajek* (2013). In 2014 he coauthored a book entitled *Understanding Large Temporal Networks and Spatial Networks*.

Structural Analysis in the Social Sciences

Series Editor: Mark Granovetter

The series *Structural Analysis in the Social Sciences* presents studies that analyze social behavior and institutions by reference to relations among such concrete social entities as persons, organizations, and nations. Relational analysis contrasts on the one hand with reductionist methodological individualism and on the other with macro-level determinism, whether based on technology, material conditions, economic conflict, adaptive evolution, or functional imperatives. In this more intellectually flexible structural middle ground, analysts situate actors and their relations in a variety of contexts. Since the series began in 1987, its authors have variously focused on small groups, history, culture, politics, kinship, aesthetics, economics, and complex organizations, creatively theorizing how these shape and in turn are shaped by social relations. Their style and methods have ranged widely, from intense, long-term ethnographic observation to highly abstract mathematical models. Their disciplinary affiliations have included history, anthropology, sociology, political science, business, economics, mathematics, and computer science. Some have made explicit use of social network analysis, including many of the cutting-edge and standard works of that approach, whereas others have kept formal analysis in the background and used "networks" as a fruitful orienting metaphor. All have in common a sophisticated and revealing approach that forcefully illuminates our complex social world.

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Revised and Expanded Edition for Updated Software. Third Edition

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Preface to the Third Edition

Two major developments in program Pajek required a new edition of this book: a fundamental redesign of the menu structure and the capability to analyze much larger networks, containing billions of vertices. A proliferation of methods for analyzing a single network necessitated a reorganization of Pajek's menu structure, in particular the former *Net* menu, now called the *Network* menu. The new *Network* menu contains submenus for commands that apply to a particular type of network: a two-mode network, multiple relations network, acyclic network, temporal network, and signed network. It is much easier now to find analyses for special networks. Because the *Network* menu is used most intensively, we had to adjust most of the commands in the Application sections of this book.

Pajek's capability to analyze much larger networks is the second major development. As a result of changes in the Windows® operating system, Pajek can now handle networks with nearly one billion vertices. For even larger networks, PajekXXL and Pajek3XL have been developed, which can handle up to two and ten billion vertices respectively. PajekXXL and Pajek3XL have the same user interface as Pajek; if you can work with Pajek, you can also work with PajekXXL and Pajek3XL. What you need to know is that the latter two programs offer a very limited set of analyses to describe and partition huge networks. Subnetworks extracted from a huge network can be sent directly to (regular) Pajek for further analysis. Appendix A1.5 explains all of this.

Questions on how to install and use Pajek on Mac OS X have been asked repeatedly. This new edition brings an additional appendix (Appendix 3) containing detailed instructions on installing Pajek under Mac OS X. We hope that Mac users will find out that installing and running Pajek on Mac OS X is not a difficult technical problem: Installation takes only few additional minutes compared to installation under native Windows. When Pajek is installed, running Pajek under Mac OS X is the same as running it under Windows.

Finally, we took the opportunity to include some analyses requested by Pajek users. Chapter 1 now includes Pivot MDS and VOS mapping for network layout as well as the correlation between layout coordinates and network geodesics as a measure of layout performance. Chapter 2 introduces partitions on vertex labels using regular expressions and marking partition clusters with Unicode symbols in the Draw screen. It also discusses interactive FishEye magnification and the Adjusted Rand Index. Relaxed balance is explained in Chapter 4; community detection (Louvain Method and VOS Clustering) and the E-I Index appear in Chapter 5. Chapter 6 includes (degree) assortativity and the assortativity coefficient. A collection of main path methods (including key-route searches) and preprint transformation are explained and applied in Chapter 11. Appendices A1 and A2 have been updated, now containing goodies such as dragging and dropping data to a Pajek window, sending Pajek objects to Excel®, defining colors and transparency of vertices and lines, using Unicode symbols and additional vertex shapes (e.g., man, woman, and house), tooltips for vertex labels, drawing curved lines, and so on. We hope that you will continue enjoying social network analysis with Pajek.

The webpage to the third edition of this book (http://mrvar.fdv.uni-lj.si/pajek/be3.htm, mirror http://mrvar2.fdv.uni-lj.si/pajek/be3.htm) contains the example data sets, helper programs, and other online documents referenced in this book.

Preface to the Second Edition

> I go with him out in a shed in back and see he is selling a whole Harley machine in used parts, except for the frame, which the customer already has. He is selling them all for $125. Not a bad price at all.
>
> Coming back I comment, "He'll know something about motorcycles before he gets *those* together."
>
> Bill laughs. "And that's the best way to learn, too."
>
> Robert M. Pirsig, *Zen and the Art of Motorcycle Maintenance*

To some of its readers, this book is an introduction to social network analysis; to other readers, it is a manual to Pajek software (http://mrvar.fdv.uni-lj.si/pajek). To us, it is both. As Patrick Doreian argued in his review of our book (In: *Social Networks* 28 [2006] 269–274), an understanding of social network analysis is required for proper use of Pajek and, vice versa, understanding the concepts and logic of Pajek fosters comprehension of network concepts. In this second edition, we have aimed to strengthen both aspects, updating the discussion of the Pajek interface and commands to include several capabilities that have been implemented since we submitted the text of the first edition, such as multiplex networks (Section 1.3.1), eigenvector centrality (Section 6.5), matrix multiplication (Section 11.3), and using Pajek output in R (Chapters 5 and 13). The new capabilities cover some important advances in social network analysis, including random graph models to which we have dedicated a new chapter.

We expanded the Further Reading sections with references to seminal, much cited texts. This should allow the reader to trace the literature on the selected topic in bibliographic and citation databases. For more comprehensive lists of literature, we refer to two other volumes in this series: S. Wasserman and K. Faust, *Social Network Analysis: Methods and Applications* (Cambridge: Cambridge University Press, 1994) and P. J. Carrington, J. Scott, and S. Wasserman, *Models and Methods in Social Network*

Analysis (Cambridge: Cambridge University Press, 2005). A concise history of social network analysis is published by L. C. Freeman, *The Development of Social Network Analysis. A Study in the Sociology of Science* (Vancouver, Canada: Empirical Press, 2004).

We hope that this second edition will continue to stimulate analysts to sharpen their understanding of social networks and expand their command of network analytic tools.