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978-1-107-00238-8 - Exploratory Social Network Analysis with Pajek: Revised and Expanded Second Edition

Wouter De Nooy, Andrej Mrvar and Vladimir Batagelj

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Exploratory Social Network Analysis with Pajek

Revised and Expanded Second Edition

This is the first textbook on social network analysis integrating theory, applications, and professional software for performing network analysis (Pajek). Step by step, the book introduces the main structural concepts and their applications in social research with exercises to test understanding. In each chapter, each theoretical section is followed by an application section explaining how to perform the network analyses with Pajek software. Pajek software and datasets for all examples are freely available, so the reader can learn network analysis by doing it. In addition, each chapter offers case studies for practicing network analysis. In the end, the reader will have the knowledge, skills, and tools to apply social network analysis in all social sciences, ranging from anthropology and sociology to business administration and history.

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Mark Granovetter, editor

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 with reductionist methodological individualism on the one hand and with macro-level determinism on the other, 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 eschewed formal analysis and used “networks” as a fruitful orienting metaphor. All have in common a sophisticated and subtle approach that forcefully illuminates our complex social world.

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Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Tokyo, Mexico City

Cambridge University Press

32 Avenue of the America, New York, NY 10013-2473, USA

www.cambridge.org

Information on this title: www.cambridge.org/9780521174800

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First published 2005

Revised and expanded second edition 2011

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication data

Nooy, Wouter de, 1962–

Exploratory social network analysis with Pajek / Wouter de Nooy, Andrej
Mrvar, Vladimir Batagelj. – 2nd ed.

p. cm. – (Structural analysis in the social sciences ; 34)

Includes bibliographical references and index.

ISBN 978-1-107-00238-8 (hardback) – ISBN 978-0-521-17480-0 (paperback)

1. Social networks – Mathematical models. 2. Social networks – Computer
simulation 3. Pajek (Electronic resource) I. Mrvar, Andrej. II. Batagelj,
Vladimir, 1948– III. Title.

HM741.N66 2011

302.307–dc23 2011015985

ISBN 978-1-107-00238-8 Hardback

ISBN 978-0-521-17480-0 Paperback

Additional resources for this publication at <http://pajek.imfm.si/doku.php>.

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*To Anuška,
who makes things happen*

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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://pajek.imfm.si/doku.php>). 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, often-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).

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A concise history of social network analysis is published in 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.

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In the social sciences, social network analysis has become a powerful methodological tool alongside statistics. Network concepts have been defined, tested, and applied in research traditions throughout the social sciences, ranging from anthropology and sociology to business administration and history.

This book is the first textbook on social network analysis integrating theory, applications, and professional software for performing network analysis. It introduces structural concepts and their applications in social research with exercises to improve skills, questions to test understanding, and case studies to practice network analysis. In the end, the reader will have the knowledge, skills, and tools to apply social network analysis.

We stress learning by doing: Readers acquire a feel for network concepts by applying network analysis. To this end, we make ample use of professional computer software for network analysis and visualization: Pajek. This software, operating under Windows 95 and later, and all example datasets are provided on a Web site (<http://vlado.fmf.uni-lj.si/pub/networks/book/>) dedicated to this book. All the commands that are needed to produce the graphical and numerical results presented in this book are extensively discussed and illustrated. Step by step, the reader can perform the analyses presented in the book.

Note, however, that the graphical display on a computer screen will never exactly match the printed figures in this book. After all, a book is not a computer screen. Furthermore, newer versions of the software will appear, with features that may differ from the descriptions presented in this book. We strongly advise using the version of Pajek software supplied on the book's Web site (<http://vlado.fmf.uni-lj.si/pub/networks/book/>) while studying this book and then updating to a newer version of Pajek afterward, which can be downloaded from <http://vlado.fmf.uni-lj.si/pub/networks/pajek/default.htm>.

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Overview

This book contains five parts. The first part (Part I) presents the basic concepts of social network analysis. The next three parts present the three major research topics in social network analysis: cohesion (Part II), brokerage (Part III), and ranking (Part IV). We claim that all major applications of social network analysis in the social sciences relate to one or more of these three topics. The final part (Part V) discusses an advanced technique (*viz.*, blockmodeling), which integrates the three research topics.

The first part, titled Fundamentals, introduces the concept of a network, which is obviously the basic object of network analysis, and the concepts of a partition and a vector, which contain additional information on the network or store the results of analyses. In addition, this part helps the reader get started with Pajek software.

Part II on cohesion consists of three chapters, each of which presents measures of cohesion in a particular type of network: ordinary networks (Chapter 3), signed networks (Chapter 4), and valued networks (Chapter 5). Networks may contain different types of relations. The ordinary network just shows whether there is a tie between people, organizations, or countries. In contrast, signed networks are primarily used for storing relations that are either positive or negative such as affective relations: liking and disliking. Valued networks take into account the strength of ties, for example, the total value of the trade from one country to another or the number of directors shared by two companies.

Part III on brokerage focuses on social relations as channels of exchange. Certain positions within the network are heavily involved in the exchange and flow of information, goods, or services; whereas others are not. This is connected to the concepts of centrality and centralization (Chapter 6) or brokers and bridges (Chapter 7). Chapter 8 discusses an important application of these ideas, namely, the analysis of diffusion processes.

The direction of ties (*e.g.*, who initiates the tie) is not very important in the section on brokerage, but it is central to ranking, presented in Part IV. Social ranking, it is assumed, is connected to asymmetric relations. In the case of positive relations, such as friendship nominations or advice seeking, people who receive many choices and reciprocate few choices are deemed as enjoying more prestige (Chapter 9). Patterns of asymmetric choices may reveal the stratification of a group or society into a hierarchy of layers (Chapter 10). Chapter 11 presents a particular type of asymmetry, namely, the asymmetry in social relations caused by time: genealogical descent and citation.

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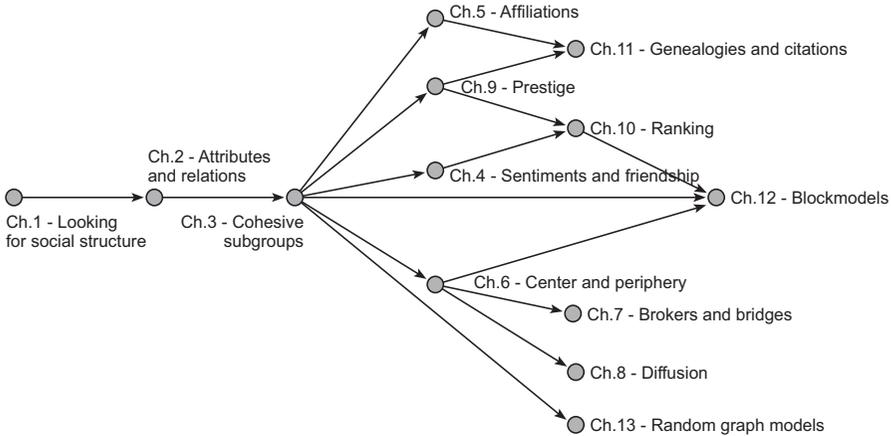


Figure 1. Dependencies between the chapters (for the second edition).

The final section, Part V, on roles concentrates on rather dense and small networks. This type of network can be visualized and stored efficiently by means of matrices. Blockmodeling is a suitable technique for analyzing cohesion, brokerage, and ranking in dense, small networks. It focuses on positions and social roles (Chapter 12).

The book is intended for researchers and managers who want to apply social network analysis and for courses on social network analysis in all social sciences as well as other disciplines using social methodology (e.g., history and business administration). Regardless of the context in which the book is used, Chapters 1, 2, and 3 must be studied to understand the topics of subsequent chapters and the logic of Pajek. Chapters 4 and 5 may be skipped if the researcher or student is not interested in networks with signed or valued relations, but we strongly advise including them to be familiar with these types of networks. In Parts III (Brokerage) and IV (Ranking), the first two chapters present basic concepts and the third chapter focuses on particular applications.

Figure 1 shows the dependencies among the chapters of this book. To study a particular chapter, all preceding chapters in this flowchart must have been studied before. Chapter 10, for instance, requires understanding of Chapters 1 through 4 and 9. Within the chapters, there are no sections that can be skipped.

In an undergraduate course, Parts I and II should be included. A choice can be made between Part III and Part IV; or, alternatively, just the first chapter from each section may be selected. Part V on social roles and blockmodeling is quite advanced and more appropriate for a postgraduate course. For managerial purposes, Part III is probably more interesting than Part IV.

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Justification

This book offers an introduction to social network analysis, which implies that it covers a limited set of topics and techniques, which we feel a beginner must master to be able to find his or her way in the field of social network analysis. We have made many decisions about what to include and what to exclude, and we want to justify our choices now.

As reflected in the title of this book, we restrict ourselves to exploratory social network analysis. The testing of hypotheses by means of statistical models falls outside the scope of this book. In social network analysis, hypothesis testing is important but complicated; it deserves a book on its own. Aiming our book at people who are new to social network analysis, our first priority is to have them explore the structure of social networks to give them a feel for the concepts and applications of network analysis. Exploration involves visualization and manipulation of concrete networks, whereas hypothesis testing boils down to numbers representing abstract parameters and probabilities. In our view, exploration yields the intuitive understanding of networks and basic network concepts that are a prerequisite for well-considered hypothesis testing.

From the vast array of network analytic techniques and indices we discuss only a few. We have no intention of presenting a survey of all structural techniques and indices because we fear that readers will not be able to see the forest for the trees. We focus on as few techniques and indices as are needed to present and measure the underlying concept. With respect to the concept of cohesion, for instance, many structural indices have been proposed for identifying cohesive groups: n -cliques, n -clans, n -clubs, m -cores, k -cores, k -plexes, lambda sets, and so on. We discuss only components, k -cores, 3-cliques, and m -slices (m -cores) because they suffice to explain the basic parameters involved: density, connectivity, and strength of relations within cohesive subgroups.

Our choice is influenced by the software that we use because we have decided to restrict our discussion to indices and techniques that are incorporated in this software. Pajek software is designed to handle very large networks (up to millions of vertices). Therefore, this software package concentrates on efficient routines, which are capable of dealing with large networks. Some analytical techniques and structural indices are known to be inefficient (e.g., the detection of n -cliques), and for others no efficient algorithm has yet been found or implemented. This limits our options; we present only the detection of small cliques (of size 3), and we cannot extensively discuss an important concept such as k -connectivity. In summary, this book is neither a complete catalogue of network analytic concepts and techniques nor an exhaustive manual to all commands of Pajek. It offers just enough concepts, techniques, and skills to understand and perform all major types of social network analysis.

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In contrast to some other handbooks on social network analysis, we minimize mathematical notation and present all definitions verbatim. There are no mathematical formulae in the book. We assume that many students and researchers are interested in the application of social network analysis rather than in its mathematical properties. As a consequence, and this may be very surprising to seasoned network analysts, we do not introduce the matrix as a data format and display format for social networks until the end of the book.

Finally, there is a remark on the terminology used in the book. Social network analysis derives its basic concepts from mathematical graph theory. Unfortunately, different “vocabularies” exist within graph theory, using different concepts to refer to the same phenomena. Traditionally, social network analysts have used the terminology employed by Frank Harary, for example, in his book *Graph Theory* (Reading: Addison-Wesley, 1969). We choose, however, to follow the terminology that prevails in current textbooks on graph theory, for example, R. J. Wilson’s *Introduction to Graph Theory* (Edinburgh: Oliver and Boyd, 1972; published later by Wiley, New York). Thus, we hope to narrow the terminological gap between social network analysis and graph theory. As a result, we speak of a vertex instead of a node or a point, and some of our definitions and concepts differ from those proposed by Frank Harary.

Acknowledgments

The text of this book has benefited from the comments and suggestions from our students at the University of Ljubljana and the Erasmus University Rotterdam, who were the first to use it. In addition, Michael Frishkopf and his students of musicology at the University of Alberta gave us helpful comments. Mark Granovetter, who welcomed this book to his series, and his colleague Sean Farley Everton have carefully read and commented on the chapters. In many ways, they have helped us make the book more coherent and understandable to the reader. We are also very grateful to an anonymous reviewer, who carefully scrutinized the book and made many valuable suggestions for improvements. Ed Parsons (Cambridge University Press) and Nancy Hulan (TechBooks) helped us through the production process. Finally, we thank the participants of the workshops we conducted at the Sunbelt International Conferences on Social Network Analysis in New Orleans (XXII) and Cancun (XXIII) for their encouraging reactions to our manuscript.

Most datasets that are used in this book have been created from sociograms or listings printed in scientific articles and books. Notwithstanding our conviction that reported scientific results should be used

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