Structure and Influence
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Summary and conclusions

This chapter starts in 7.1 with a summary of the book, organized by chapter. In Section 7.2 general conclusions are drawn and the applicability of the models to ego networks is discussed.

7.1 Summary

Social networks: causes and consequences

Social network analysis has become an important vehicle in studying social phenomena. Over the last two decades, the view on social networks has changed: they have become increasingly explicitly related to the behavior of actors, which is seen as both facilitating and restricting for other actors. Behavior of actors is partly determined by the structure of the network they are part of. At the same time, network structure itself is partly shaped by actions of actors, either intentionally or unintentionally.

This view of social networks has shifted attention to two issues. The issue most commonly addressed is how the structure of a network affects the actors comprising the network. In this type of study, networks are taken as an independent variable, constant over time, and actor behavior is a dependent variable. An issue far less commonly addressed deals with the question of how actors shape the structure of their network. Network structure now is the dependent variable, changing over time, and actor
behavior is assumed constant.

Although both issues are, undoubtedly, of major importance for the study of social networks, there are two consequential points of criticism on how these issues are addressed in common social network research. First, both processes are usually studied from a static, cross sectional, point of view. Since these two issues inherently deal with change, this is an unsatisfactory approach. Second, in many cases actors do influence their network structure and, at the same time, are influenced by that very structure. It is then unrealistic to assume either network structure or actor characteristics to remain constant.

In this book, and in this summary in particular, terms such as ‘behavior’, ‘opinion’, ‘attitude’, or any other socially influentiable variable can be substituted for each another throughout. We often simply use the terms ‘actor characteristic’ or ‘actor variable’ when refering to such a variable.

The focus of this book is the study of how attributes of actors are shaped by the network they comprise, how networks are shaped by the actors, and how these two processes interact. Obviously, this study is undertaken from a dynamic point of view. Three research objectives are formulated:

1. Development of statistical models of how actors influence each other’s behavior or opinions through the structure of the network.
2. Development of statistical models of how actors shape their network.
3. Development of statistical models of how the influence of network structure on the attributes of the actors and the influence of actor attributes on network structure operate simultaneously.

The influence of actors on each other’s behavior and opinions through the ties of the network is termed contagion and the influence of actors on the structure of the network is labeled selection.

The theory on the two processes and their interdependence is contained in Chapter 2. Chapters 3, 4, and 5 subsequently discuss the statistical models related to this theory. In Chapter 6 are illustrated empirically.

**Contagion & selection: the theoretical foundations**

In Chapter 2 the theory of contagion is discussed.

Contagion occurs when a social actor’s beliefs to those of other actors in the network. Contagion is strictly viewed as a direct influence of actors. Alter is called ego’s frame of reference. According to this notion has crystalized a cognitive frame of reference. Communication refers to the interchange of communication between ego and alter in which ego asks himself ‘what would the other think of my shoes?’. It is similar to role playing. In the study of social networks, there is a dispute between some theories. Although both processes can not be distinguished empirically, a distinction that can be made is that contagion operates through direct communication. An alter is a direct neighbor and it is discussed how to operate through direct communication. An alter is a non-adjacent actor. In Section 1, Selection processes govern why a non-adjacent actor is more stable than others. The geno
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- Theoretical models of how actors influence each other through the structure of the network.
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Selection processes govern why actors choose one another for friends or partners, why some ties are disposed of, and why some relationships are more stable than others. The generic selection process consists of two

models related to this theory. In Chapter 6 some of the concepts and models are illustrated empirically.

**Contagion & selection: the theoretical framework**

In Chapter 2 the theory of contagion, selection, and their interdependence is discussed.

Contagion occurs when a social actor adapts his behavior, attitude, or beliefs to those of other actors in the social system. As a consequence, contagion is strictly viewed as a dyadic process. The idea is that the attitudes of significant others, called alters, are seen as an appropriate standard against which an actor, ego, evaluates his own opinion. The set of alters is called ego's frame of reference. Within the realm of social influence theory, this notion has crystalized around two processes: communication and comparison. Communication refers to contagion through direct contact (communication) between ego and alter. Comparison refers to the process in which ego asks himself ‘what would another person do if he were in my shoes?’. It is similar to role playing or imitation. In the social network literature, there is a dispute between the followers of the two contagion theories. However, although both processes are theoretically distinct, they can not be distinguished empirically, rendering the discussion useless. A distinction that can be made is that of contagion between directly tied and non-directly tied actors. This does not resolve the issue of communication versus comparison entirely, but it does isolate the effects of contagion through direct communication. An elaborate treatment of this issue is given and it is discussed how to operationalize contagion among adjacent and non-adjacent actors. In Section 2.7 friendship and policy networks are taken as substantive examples and some conjectures are derived. For instance, it is expected that contagion among adjacent actors is generally higher in policy networks than in friendship networks.

Selection processes govern why actors choose one another for friends or partners, why some ties are disposed of, and why some relationships are more stable than others. The generic selection process consists of two
components: homophily and complementarity. The homophily principle refers to the preference of ego to choose alters who resemble ego in social and attitudinal characteristics. Various issues related to homophily are discussed in 2.8, in particular the connection between homophily and the so-called social focus. Social foci tend to attract actors that are similar in characteristics. The complementarity principle asserts that ego chooses alter if alter has resources or characteristics that otherwise would be unavailable, difficult to obtain, or too costly for ego. By relating to alter ego believes access will be acquired to these resources. Examples of resources include information, money, and support. In 2.9 some conjectures on selection processes for friendship networks and policy networks are derived. For instance, one conjecture is that similarity is the main determinant for selection in friendship networks. In policy networks coalitions are started among similar actors, but other relationships among fairly dissimilar actors.

In section 2.10 the discussion of the interaction between contagion and selection is framed by discussing a number of well known studies, in which, by neglecting this interdependence, reported results are rendered questionable.

Contagion: modeling network effects on actor attributes
In Chapter 3, a statistical framework is derived from the contagion theory of Chapter 2. The resulting model is a type of regression model in which ego's opinion is explicitly dependent on a weighted combination of the opinions of his alters and a set of covariates. The model is called a *spatial autocorrelation model*, known mainly from the geography literature. Since the model deals with a static observation of the network, it is concerned with the estimation of social influence under the absence of selection. If longitudinal observations are available, the model can be improved upon by an autoregressive model discussed in Chapter 5.

Social influence (contagion) is represented through a so-called weight matrix. The entries of this matrix determine to what extent ego is influenced by particular alters. Different weight matrices represent different mechanisms of influence. The number of possible weight matrices is large, and the influence mechanism at hand can be identified by constructing an appropriate weight matrix. On various substantive arguments, the identification of weight matrices is discussed in 3.3. The interpretation of the weight matrix is that the weight that alters make up ego's frame of reference is distributed among them.

The major part of the chapter concerns matters related to the autocorrelation model, in particular the estimation of social influence parameters, and the study of opinion formation. By this analysis the network and covariates related to an actor's opinions are derived. An example of how the model can be used is the study of opinion formation. By using data from the network and covariates related to an actor's opinion, we can observe how actors take into account the opinions of their alters and make a decision on their own opinion. Similarly, it can be seen to what extent actors take into account the opinions of other groups. In particular, it can be seen to what extent actors affiliated with the same group are more likely to display similar behavior as their alters, and to what extent they are more likely to display behavior displayed by other groups.

Selection: modeling effects of actor choice
Based on the selection theory of Chapter 2, the model is extended in Section 3.7 to include the decision process. The approach is extended to different kinds of actors that differ in the extent actors affiliated with the same group are more likely to display similar behavior as their alters, and to what extent they are more likely to display behavior displayed by other groups. The approach is extended to different kinds of actors that differ in the extent actors affiliated with the same group are more likely to display similar behavior as their alters, and to what extent they are more likely to display behavior displayed by other groups.

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The homophily principle asserts that ego chooses alters who resemble ego in social characteristics. Various issues related to homophily are the connection between homophily and the tendency to attract actors that are similar in characteristics that otherwise would be too costly for ego. By relating to alter ego to these resources. Examples of resources and support. In some conjectures on friendship networks and policy networks are that similarity is the main friendship networks. In policy networks similar actors, but other relationships among a number of well known studies, in which, dependence, reported results are rendered.

**Effects on actor attributes**

A type of regression model in which dependent on a weighted combination of the covariates. The model is called a spatial regression model. Since the interaction between contagion and covariates related to an issue, it can be estimated to what extent actors tend to display similar behavior as their alters.

In particular, the approach is extended to include different types of actors. In particular, the approach is extended so that actors can be classified into distinct groups so that strengths of influence within and between the various groups can be estimated. For instance, it can be estimated to what extent actors affiliated with the same social group tend to display similar behavior and to what extent they tend to behave differently from the behavior displayed by other groups.

**Selection: modeling effects of actor attributes on network structure**

Based on the selection theory of Chapter 2, a model is needed that incorporates an actor's inclination to create, maintain, or withdraw particular ties with particular others, given a network structure and a choice strategy. A stochastic model that exactly fits these requirements is a Markov model, presented in Chapter 4. The model builds on two statistical
assumptions. First, it is assumed that all relevant information of the past in contained in the present. In other words, one only needs to know the present state of the system in order to predict the probability distribution of future states. Second, it is assumed that, within infinitesimally small intervals of time, changes in the network are statistically conditionally independent. Based upon these two assumptions, a very flexible model is derived. The basic component of the model is the specification of so-called transition rates, representing the rate at which a relation between a pair of actors changes within some small interval of time. Transition rates are related to covariates and various substantive models are derived. Doing so enables us to incorporate individual level variables (such as the need for resources) and structural level variables (such as reciprocity), next to dyadic variables (such as homophily). The approach includes models dealing with dyadic similarity, reciprocity, transitivity, or expansiveness. Specifications of transition rates can be linear and/or non linear. For instance, in studying the evolution of friendship networks, it can be tested to what extent reciprocity, gender similarity, membership of the same ability group, and having common friends govern the evolution of friendship relations. It is straightforward to test competing theories against one another.

An assumption often made in the literature is that of time stationarity. Time stationarity implies a non-changing probability distribution of the network structure and is often used to model phenomena in their equilibrium steady state. This assumption is not always realistic. Therefore, the models discussed in Chapter 4 do not rely on this assumption. However, if a process is stationary, then statistical efficiency is gained by explicitly incorporating this into the estimation process. An elaborate treatment of a concept closely related to stationarity, reversibility, is contained in Section 4.10. In effect, reversibility refers to the situation in which the behavior of the selection process remains unchanged if the direction of time is reversed. If a process can be shown to be reversible, stationary probabilities under stationarity holds, it can be determined whether dyads will be and what the long run attributes being related.

Contagion & selection: untying the knot

In Chapter 5, an approach is discussed dealing with the interdependence of contagion and selection from two considerations:

- Changes in opinions or behaviors: selection has no direct effect on opinion.
- Changes in network structure are random changes; contagion has no direct effect on selection.

From these considerations it follows that contagion and selection interact, they deal with distinct consequences. As a result, both prediction of future observations of the network and actor observations must be taken sufficiently frequently.

If selection based on opinions is considered, Chapter 3 do not provide a good representation of the data. They do, however, still fulfill autoregressive model of opinion development rather than on opinions per se. In this context, according to the discrepancy between actor and the tendency to hold on to his own opinion, actors base their selection on their alters.

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be reversible, stationary probabilities can easily be derived. For example, if
stationarity holds, it can be determined what the proportion of mutual
dyads will be and what the long run probability is of actors with given
attributes being related.

Contagion & selection: untying the knot
In Chapter 5, an approach is discussed on how to untie the Gordian knot of
the interdependence of contagion and selection. The basic approach follows
from two considerations:

- Changes in opinions or behavior are due to contagion processes;
selection has no direct effect on opinion.

- Changes in network structure are due to selection processes (including
random changes); contagion has no direct effect on network structure.

From these considerations it follows that, although contagion and selection
interact, they deal with distinct processes with distinct empirical
consequences. As a result, both processes can be distinguished if
observations of the network and actor characteristics are available that are
taken sufficiently frequently.

If selection based on opinions is present, the contagion models of
Chapter 3 do not provide a good representation of the processes underlying
the data. They do, however, still fulfil very useful descriptive purposes. An
autoregressive model of opinions is derived, based on changes in opinions,
rather than on opinions per se. In this model actors adapt their opinions
according to the discrepancy between their opinion and the opinions of
their alters, and to changes in covariates. In the resulting model,
parameters are included for the tendency of ego to move toward his alters
and the tendency to hold on to his own opinion. In addition, a social norm
can be included to which alters relate their own opinion and those of their
alters.

The selection models of Chapter 4 can still be used when contagion
occurs. However, an argument is needed as to which opinion, or weighted
opinion, actors base their selection on.
The remainder of the chapter is concerned with matters of misspecification and estimation accuracy. With the help of a number of simulations, effects of misspecification due to the interaction of contagion and selection are studied. In addition, autoregressive models are misspecified when the interval between observations differs from the lag specified in the true theoretical model. Simulations representing this problem are also included.

The conclusion drawn from this chapter is that contagion and selection can be distinguished reasonably well with the help of the models of this book, if the frequency of observation is frequent enough relative to the changes in opinions and network structure. As an example, it is possible, with frequent observation, to distinguish to what extent similar actors tend to become friends and to what extent friends tend to become similar.

A human services network: examples of analyses
In Chapter 6 the practical application of some of the models of this book is illustrated based on data of human services networks. The data consist of the interorganizational networks of social service systems serving children and youth with mental problems. The data contain three annual waves, from 1988 to 1990. At each wave both directors and staff members of the various agencies and institutions were asked to provide information about themselves, their agencies, and the dyadic ties to and from other agencies.

For the study of contagion in this interorganizational network, focus is on a variable, unusual to autocorrelation research: burnout. The motivation of employees is an important determinant of organizational achievement. This is especially true in social service work, as this type of work is characterized by an unusually strong (need for) emotional involvement of its members. Burnout is a consequential determinant of motivation. The study of burnout is especially relevant since burnout is growing considerably within the service sectors. Studies of burnout generally focus on individual or organizational variables. Although social interaction is acknowledged to play a potentially important role in the development of burnout, longitudinal analyses are extremely rare. Application of the autoregressive models to levels of staff burnout revealed a primarily determined by individual and organizational factors, with a significant effect of interorganizational contagion on the evolution of burnout over time. In particular, burnout increases (decreases) with increases (decreases) in the frequency of observation of members of related organizations. By means of longitudinal analyses are performed, but sectionally, this effect is missed.

With respect to selection, focus is on interorganizational relationships (IORs). It follows from the homophily argument of Chapter 2 that actors would be likely to entertain related organizations, domain can be divided into two components: similarity of diseases covered and similarity of sector. The idea that the two components are independent suggests that reciprocity is the evolution of this network. It is postulated that similarity of client population, are important to IOR network. Reciprocity and sector similarity.

An ongoing debate in the IOR literature is the inclusion of mandated relationships, which are studied by performing the same analysis on the selection process: reciprocity still plays a role in the evolution of the inclusion of mandated relationships, and networks in exactly the same way as non-mandated networks.

Excluding dyads with mandated ties, the selection process: reciprocity still plays a role in the evolution of the inclusion of mandated relationships, and networks in exactly the same way as non-mandated networks.
1.1 Summary

This chapter is concerned with matters of accuracy. With the help of a number of simulation due to the interaction of contagion and selection, autoregressive models are between observations differs from the lag model. Simulations representing this chapter is that contagion and selection well with the help of the models of this section is frequent enough relative to the structure. As an example, it is possible, to distinguish to what extent similar actors tend friends tend to become similar.

Examples of analyses

Application of some of the models of this book is in services networks. The data consist of social service systems serving children. The data contain three annual waves, both directors and staff members of the were asked to provide information about the dyadic ties to and from other agencies. This interorganizational network, focus is autocorrelation research: burnout. The important determinant of organizational value in social service work, as this type of unusually strong (need for) emotional burnout is a consequential determinant of is especially relevant since burnout is the service sectors. Studies of burnout organizational variables. Although social play a potentially important role in the development of burnout, longitudinal treatments of this factor are extremely rare. Application of the autocorrelation and autoregressive models to levels of staff burnout reveals that burnout appears to be primarily determined by individual and organizational factors. However, a significant effect of interorganizational staff communication is found in the evolution of burnout over time. In particular, it is found that burnout increases (decreases) with increases (decreases) of burnout among staff members of related organizations. This effect is retrieved when longitudinal analyses are performed, but when burnout is analyzed cross sectionally, this effect is missed.

With respect to selection, focus is on the evolution of interorganizational relationships (IORs). It follows from both the complementarity and homophily argument of Chapter 2 that organizations in the same ‘domain’ would be likely to entertain relationships. For health serving organizations, domain can be differentiated into three separate components: similarity of diseases covered, similarity of client population, and similarity of sector. The idea that organizations strive to maintain their independence suggests that reciprocity is also a factor likely to govern the evolution of this network. It is found that all variables, except similarity of client population, are important factors in the dynamics of the IOR network. Reciprocity and sector similarity appear to play a major role.

An ongoing debate in the IOR literature addresses the appropriateness of the inclusion of mandated relationships into the analysis. This issue is studied by performing the same analyses after deleting dyads with mandated ties. Excluding these dyads leads to the analysis of an incomplete network. The Markovian models can be applied to incomplete networks in exactly the same way as they can be applied to complete networks.

Excluding dyads with mandated ties turns out to have a major impact on the selection process: reciprocity still remains important, but similarity of diseases covered and similarity of sector appear unimportant for several
transitions. By imposing mandates, local governments force agencies to coordinate services and pool resources with agencies that are part of the same sector or are dealing with patients with similar diseases. This is the case especially in one of the two sites studied.

7.2 Conclusions and thoughts about the future

General conclusions
This book aims at giving an impetus to the longitudinal statistical study of networks. It is obvious that networks change and that people change. Theoretical models that concern the causes and consequences of these changes exist in the literature; statistical models to test these theories and assess their empirical value are, however, largely absent. In a sense, this is not surprising. Inherent to the nature of social networks is that behaviors of actors are interdependent. Since most of the results known from standard statistics build on the assumption of observational independence, most well known statistical models are invalid for studying changes in networks. The required models seem quite complex. Although many of the models presented in this book are fairly complex, we hope to have made clear that they can be employed to address a wide range of empirical questions about dynamics in networks.

Many issues have been addressed in this book. One question about the application of these models has remained unaddressed so far: the applicability of the models to ego networks.

Ego networks
The models in this book deal with total networks. They can also be employed for the study of ego networks. This, however, requires an important assumption: all relevant alters must be included in the data. This assumption of course is also made for total networks, but for total networks this assumption may be more easily met, especially if the network has natural boundaries (such as students in a classroom). The assumption is critical to the study of ego networks, since the very nature of ego networks often restricts observations to those alters who are directly tied to ego, often limited further to a small set of alters.

If the assumption can be made, the autocorrelation models can be applied. In studying to what extent transitions are related to new events in the network (or actors on the right hand side of equation (4.16)), the y at the right hand side should be altered, and the y at the left hand side should be replaced by various alters and ego's. The weight matrix is changed in such a way that the network can easily be incorporated into the equations. The details of the model, but leave this to the reader to work out.

Thoughts about the future
This book deals with complex sociological models. In Chapter 3 it was argued that autocorrelation models are not more efficient than models of Chapter 4 can straightforwardly incorporate. The transition rates should be at the individual level.

It is sometimes said that the quality of the models is disappointing how few data are available in software. We therefore most strongly encourage the reader to collect such data, as it will help to generate more valid and reliable results.
local governments force agencies to work with agencies that are part of the same patients with similar diseases. This is the case studied.

Thoughts about the future

The longitudinal statistical study of how networks change and that people change. The causes and consequences of these changes are quite complex. Although many of the phenomena of social networks is that behaviors are most of the results known from observational independence, assumptions are invalid for studying changes in networks. This, however, requires an approach to address a wide range of empirical

and in this book. One question about the networks. They can also be total networks. This, however, requires an approach that alters must be included in the data. For example, made for total networks, but for total networks more easily met, especially if the data (such as students in a classroom). The ego networks, since the very nature of relations to those alters who are directly tied to ego, often limited further to a fixed small number.

If the assumption can be made, the autocorrelation and Markov models can be applied. In studying to what extent alters influence ego, the autocorrelation models need to be adjusted. In particular, the opinions of actors on the right hand side of equation (3.2) now are the opinions of the various alters and the y at the left hand side refers to the opinions of the ego's. The weight matrix is changed accordingly. Possible overlap of the ego networks can easily be incorporated. We will not go into the estimation details of the model, but leave this to future research.

Under the same assumption that all relevant alters are included (including those to which ego does not have a relationship), the Markovian models of Chapter 4 can straightforwardly be applied. Specification of the transition rates should be at the individual level, as in Section 4.8.

Thoughts about the future

This book deals with complex social phenomena and complex statistical models. In Chapter 3 it was argued that one of the reasons why autocorrelation models are not more widely used is the lack of computer software implementing these models. A similar argument is most likely to hold for the models developed in this book. Although all formulas needed are provided in the text, the reader can not be expected to be willing to write his or her own software. We plan to make our own procedures available in software.

It is sometimes said that the quality of the available statistical models outperforms the quality of the available data. This may be true. Considering the obviousness of networks and people changing over time, it is disappointing how few datasets contain longitudinal network observations. We therefore most strongly encourage social scientists to collect such data, as it will help to grasp the dynamics of social reality.