Developments in Statistics and Methodology
A. Ferligoj and A. Kramberger (Editors)
Metodološki zvezki, 9, Ljubljana: FDV 1993

# (In)Sensitivity of Centrality Measurements in Social Networks

Anuška Ferligoj[1]and Valentina Hlebec[1]

**Abstract**

In a survey a (complete) social network can be measured in many different ways: different types of questions can be formu- lated, different methods for naming related actors can be used. In this process measurement errors are present. Different measurement instruments can produce more or less different measured social networks. Some studies (Holland and Leinhardt 1973; Sudman 1985, 1988; Hlebec 1993) has shown that the recognition produces a richer network than the recall. The effect of question wording and methods of naming related actors on the results should be studied more systematically also in the field of social network analysis as measurement errors can effect the structure of a network significantly.

In the paper the communication flow in a small homogeneous network of twelve members and advisers of the Student Government of the University of Ljubljana in May 1992 was measured by two similar questions and each of them by two methods: recall and recognition. The effect of four types of measurement instruments on estimation of prominence or influence of actors in the network is studied. Actor prominence was measured by six centrality indices: in-degree point centrality indices, in-closeness global centrality indices (Sabidussi 1966), and Freeman's betweenness index (1979). These indices are based on geodesic paths. The most interesting findings of this study are: The more complex centrality indices (e.g., betweenness indices) are more effected by measurement errors than the simpler centrality indices (e.g., degree indices). The more central or prominent the actors are in the network, with less errors they are listed by the other actors.

**Keywords:** Measurement; Recall; Recognition; Cronbach's alpha; Theta consistency coefficient; Centrality; Degree centrality index; Closeness index; Betweenness index.

[1]Faculty of Social Sciences, University of Ljubljana, Kardeljeva pl. 5, 61 109 Ljubljana, Slovenia

# 1 Introduction

In a survey a (complete) social network can be measured in many different ways: different types of questions can be formulated, different methods for naming related actors can be used. In this process measurement errors are present. Different measurement instruments can produce more or less different measured social networks. Some studies (Holland and Leinhardt 1973; Sudman 1985, 1988; Hlebec 1993) has shown that the recognition produces a richer network than the recall. The effect of question wording and methods of naming related actors on the results should be studied more systematically also in the field of social network analysis as measurement errors can effect the structure of a network significantly.

In the paper the communication flow in a small homogeneous network was measured by two similar questions and each of them by two methods: recall and recognition. A comparison of these methods is given by Hlebec (1993) in one of the previous chapters. The effect of four types of measurement instruments on estimation of prominence or influence of actors in the network is studied. Actor prominence was measured by four centrality indices.

# 2 Methods

## 2.1 Data

The analyzed network consists of communication interactions among twelve members and advisors of the Student Government of the University in Ljubljana. Identification of the members of the group was based on the characteristic of the actors - membership in the government, which also represented the activity of the actors. Data were collected by face to face interviews which lasted from 20 to 30 minutes. Interviews were accomplished during May 1992.

## 2.2 Measurement

Communication flow among actors was measured by two questions:

1. Who of the members and advisors of the Student government do you (most often) informally discuss with?

2. Which members and advisors of the Student Government do you (most often) ask for an opinion?

The content of the communication flow was limited to the matters of the Student Government. Time frame was also defined, questions were referred to the six months period (from the formation of the government to the day of the interview).

In the experiment two alternative methods of naming of related actors were used for measuring network data. These methods are:

1. Recall: Members of the analyzed group were first asked to identify the members of the network by memory. The number of persons was not limited. The

criteria for enumeration was frequency of the communications (most often) - binary relation.

2. Recognition: The list of all members of the analyzed group was given to each of them. They were asked to identify the most important actors.

High density of the recognized binary relations was due to the nature of the government's work. Members and advisors of the government communicate almost every day. One respondent refused to cooperate in experiment. As he was not considered in the analysis above the network consists of eleven actors.

All together there are four measurement instruments for measuring communication flow in the network considered in this paper: discussion-recall (A), discussion-recognition (B), asking for an opinion-recall (C), asking for an opinion-recognition (D). Repeating similar questions about the same topic can have its drawbacks. Respondents might try to be consistent and to remember their previous answers across methods. Therefore several other questions were put between those four questions to decrease memory effects on their answers.

### 2.3 Centrality

Actors who are more often selected as being important communication partners are more central or prominent in the network. Actors are also more central or prominent if they are very active in receiving and giving information or if they are as much as possible between communication flows. Therefore actor prominence was measured by three centrality indices: in-degree point centrality index (C-D), in-closeness global centrality index (Sabidussi 1966) (C-C), and Freeman's betweenness index (1979) (C-B). Degree, closeness and betweenness indices are based on geodesic paths. They are described in detail in the previous chapter (Batagelj 1993a).

### 2.4 (In)sensitivity

The main goal of the paper is to study the effect of four types of measurement instruments on estimation of prominence or influence of actors in the network. To measure the stability of actor measures of a selected centrality index based on networks measured by different measurement instruments, two known coefficients were used: Cronbach's alpha coefficient (Cronbach 1951) and theta coefficient (Armor 1974).

## 3 Results and discussion

There are four measurement instruments for measuring communication flow in the network of eleven members and advisers. Four measured relations are given in Hlebec (1993). On each of four relations three centrality indices were calculated: in-degree point centrality index, in-closeness global centrality index, and betweenness index. In Table 1 each index calculated on four networks is presented in a separate matrix. The computations of centrality indices were carried out with the program

STRAN (Batagelj 1993b). E.g., in the case of in-degree index we can see in the first matrix that the most prominent actors are actor 8 and actor 2 in all four cases, the same is also true for the least prominent actors. This indicates very high stability of measuring in-degree centrality calculated on networks measured via four different measurement instruments.

To study the effect of four types of measurement instruments on estimation of prominence of actors in the network, for each index Cronbach alpha and theta coefficients were calculated using the statistical package SPSSPC. The results are presented in Table 2. Both coefficients are very large in the case of in-degree and in-closeness indices which indicates very high insensitivity in being named according to four different ways of measuring communication flows. The last index (betweenness) has lower values on both coefficients. We can conclude that the more complex centrality indices (e.g., betweenness) are more effected by measurement errors than the simpler centrality indices (e.g., degree).

To test the hypothesis that the more prominent the actors are in the network, with less errors they are named by the other actors, the average prominence and coefficient of variation was calculated for each actor across four measurements in the case of each specified centrality index (e.g., for in-degree index the average and the coefficient of variation for each actor was calculated by row in the first matrix in Table 1). The correlation coefficient was calculated between average and coefficient of variation for all centrality indices which in our case measure the most the actor prominence: in-degree, in-closeness and betweenness. As expected the correlations presented in Table 3 are high and negative. The in-degree index is a local one, which considers only immediate neighbors of a given actor, and the other two are global ones, which consider all actors connected by paths with a given actor. This is the reason why the global ones have even higher correlations: errors in naming the most prominent actors have less effect on global indices.

# 4 Conclusion

The effect of four types of measurement instruments to measure communication flow in a small homogeneous network on estimation of prominence or influence of actors in the network is studied. To test it Cronbach alpha and theta coefficient were used. The most interesting findings of this study are: The more complex centrality indices are more sensitive to measurement errors than the simpler centrality indices. Measurement errors are cumulating in the case of global centrality indices. The more central or prominent are the actors in the network, with less errors they are listed by the other actors.

The analyzed relations are highly dense due to the nature of the specific work of the actors. In such cases errors in measuring relations probably have lower effect on centrality measures. These effects should be studied on less homogeneous and larger networks.

Table 1: Three centrality indices calculated on four networks

C-D

| | A | B | C | D |
|---|---|---|---|---|
| 1 | 0.20 | 0.20 | 0.20 | 0.30 |
| 2 | 0.50 | 0.70 | 0.70 | 0.70 |
| 3 | 0.20 | 0.30 | 0.20 | 0.30 |
| 4 | 0.70 | 0.70 | 0.40 | 0.50 |
| 5 | 0.20 | 0.30 | 0.10 | 0.20 |
| 6 | 0.40 | 0.50 | 0.40 | 0.20 |
| 7 | 0.60 | 0.60 | 0.10 | 0.30 |
| 8 | 0.80 | 0.80 | 0.50 | 0.70 |
| 9 | 0.20 | 0.10 | 0.10 | 0.10 |
| 10 | 0.00 | 0.30 | 0.00 | 0.20 |
| 11 | 0.30 | 0.30 | 0.20 | 0.10 |

C-C

| | A | B | C | D |
|---|---|---|---|---|
| 1 | 0.27 | 0.36 | 0.30 | 0.38 |
| 2 | 0.67 | 0.77 | 0.77 | 0.77 |
| 3 | 0.27 | 0.42 | 0.36 | 0.38 |
| 4 | 0.77 | 0.77 | 0.63 | 0.67 |
| 5 | 0.40 | 0.48 | 0.18 | 0.36 |
| 6 | 0.56 | 0.63 | 0.50 | 0.40 |
| 7 | 0.71 | 0.71 | 0.18 | 0.50 |
| 8 | 0.83 | 0.83 | 0.67 | 0.77 |
| 9 | 0.48 | 0.43 | 0.18 | 0.34 |
| 10 | 0.00 | 0.42 | 0.00 | 0.30 |
| 11 | 0.53 | 0.53 | 0.43 | 0.45 |

C-B

| | A | B | C | D |
|---|---|---|---|---|
| 1 | 0.01 | 0.00 | 0.00 | 0.00 |
| 2 | 0.01 | 0.05 | 0.23 | 0.16 |
| 3 | 0.05 | 0.16 | 0.12 | 0.07 |
| 4 | 0.01 | 0.02 | 0.01 | 0.11 |
| 5 | 0.02 | 0.11 | 0.00 | 0.09 |
| 6 | 0.13 | 0.16 | 0.00 | 0.33 |
| 7 | 0.12 | 0.22 | 0.01 | 0.10 |
| 8 | 0.16 | 0.10 | 0.25 | 0.36 |
| 9 | 0.01 | 0.13 | 0.02 | 0.01 |
| 10 | 0.00 | 0.07 | 0.00 | 0.05 |
| 11 | 0.12 | 0.05 | 0.22 | 0.28 |

Table 2: Cronbach's alpha and theta consistency coefficients for each centrality index

| | alpha | theta |
|---|---|---|
| C-D | 0.93 | 0.93 |
| C-C | 0.93 | 0.95 |
| C-B | 0.68 | 0.75 |

Table 3: Correlation coefficient between averages and coefficients of variation of four measurements for three centrality indices: in-degree, in-closeness and betweenness

| | r |
|---|---|
| C-D | -0.51 |
| C-C | -0.65 |
| C-B | -0.78 |

# References


[1] Armor, D.J. (1974): Theta reliability and factor scaling. In: H.L. Costner (Ed.): *Sociological Methodology 1973/74*, San Francisco: Jossey-Bass, 17-50.

[2] Batagelj, V. (1993a): Centrality in social networks. In: A. Ferligoj and A. Kramberger (Eds.): *Developments in Statistics and Methodology*. Metodološki zvezki, **9**, Ljubljana: FDV.

[3] Batagelj, V. (1993b): *STRAN - programmes for STRucture ANalysis*. Manual, Ljubljana.

[4] Cronbach, L.J. (1951): Coefficient alpha and internal structure of test. *Psychometrika*, **16**, 297-334.

[5] Freeman, L.C. (1979): Centrality in social networks, Conceptual clarification. *Social Networks*, **1**, 215-239.

[6] Hlebec, V. (1992): Recall versus recognition: Comparison of two alternative procedures for collecting social network data. In: A. Ferligoj and A. Kramberger (Eds.): *Developments in Statistics and Methodology*. Metodološki zvezki, **9**, Ljubljana: FDV.

[7] Holland, P.W., and S. Leinhardt, (1973): The Structural implications of Measurement error in Sociometry. *Journal of Mathematical Sociology*, **3**, 85-111.

[8] Sabidussi, G. (1966): The centrality index of a graph. *Psychometrika*, **31**, 581-603.

[9] Sudman, S. (1985): Experiments in the Measurement of the Size of Social Networks. *Social Networks*, **7**, 127-151.

[10] Sudman, S. (1988): Experiments in Measuring Neighbor and Relative Social Networks. *Social Networks*, **10**, 93-108.