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# Social Network Analysis using Author Co-citation Data

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## ABSTRACT

This study examines the social network of scholars in the field of Communication by using author co-citation data. A matrix containing the number of co-cited documents between pairs of authors is created for social network analysis of scholars who are on the editorial board of *Journal of Communication*, and the networked map of the scholars is used to visualize the knowledge structure of the field by identifying groups of authors who are more central than others. *Social Science Citation Index (SSCI)* is used to collect the author co-citation data, and UCInet is employed for social network analysis as well as network visualization.

## Keywords

Social Network Analysis, Author Co-Citation Analysis, network visualization.

## BACKGROUND

### Sociology of Science and Invisible Colleges

Whether through conjectures and refutations (Popper, 1959) or through a paradigm shift (Kuhn, 1962), scientific knowledge goes through changes over time. Some view science as not only a cognitive process, but also a social process (Crane, 1972; Freudenthal, 1984; Fuchs, 1993; Griffith, 1989). Crane (1972) explained that “the growth of scientific knowledge is a kind of diffusion process in which ideas are transmitted from person to person” (p. 22). Freudenthal (1984) referred to scientific knowledge as “the contingent product of a social process of construction” (p. 285). From a sociological point of view, Fuchs (1984) emphasized that “scientific change is generally triggered by competition, but that various types of change depend on the social organization and status of scientific groups” (p. 933). This view is related to Popper, who argued that scientific knowledge could gradually get closer to the truth through falsification (Hess, 1997, p. 19-22; Popper, 1959, p.86-87). Popper’s idea of scientific discovery lies in the process of building theories through deductive testing of proposed hypotheses. In the process of selecting a theory, the decision to accept or reject basic statements is important. These could become either universal or singular statements. Unlike conventionalism, which accepts universal statements based on the rule of simplicity, Popper’s view accentuates the role of decision-making on the result of a test, which is “an agreement about basic statements” (Popper, 1959, p. 109).

However, from the perspectives of history and philosophy, Kuhn criticized Popper’s argument on falsification because “scientists often continue to work under a theory or set of theories even when faced with anomalies or refuting instances” (Hess, 1997, p. 23). Kuhn (1962) proposed that scientific revolutions occur when there are changes in a paradigm. A paradigm can be defined as “the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community” (Kuhn, 1962, p. 175). The development of a scientific field goes through periods of (1) pre-paradigm, or pre-science, when there’s no agreed paradigm in a field, and (2) normal science, when a model or pattern is accepted and used as an established paradigm of the field. Finally, when new discoveries cause anomalies in existing scientific knowledge and changes in a paradigm seems inevitable, it is considered to be a period of (3) scientific revolution. Kuhn (1962) explained it as “those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one” (p. 92). The change in a paradigm, or a paradigm shift, involves a group of practitioners in the field because a paradigm is “what the members of a scientific community share, and, conversely, a scientific community consists of men who share a paradigm” (Kuhn, 1962, p. 176).

In a discussion regarding studies of communication in relation to science, Griffith (1989) recognized the contribution of Merton (1942) to the view of science as a social process, and added that “nearly always Merton is concerned with communication as the basis for analyzing social structure and process” (p. 604). Merton (1996) noticed the influence of social relations and trust among scholars and scientists, and claimed that “all scientific discoveries are in principle multiples, including those that on the surface appear to be singletons” (p. 307). Merton’s idea of multiples in scientific discovery affected the creation of citation indexes for scholarly and scientific journals (Garfield, 2004). Citation indexes, such as *Science Citation Index*, can be used to prevent duplications in scientific works by providing bibliographic information on published scholarly documents. In addition, analysis on citation data can be helpful to identify patterns in science, such as most highly cited authors of a subject specialty, or journals that have the greatest impact on a research field. Moreover, analyses on co-cited documents or on co-cited authors can result in meaningful findings.

Sociology of science explains the scientific changes and discoveries in relation to the social structure of scientists. Fuchs (1993) used the idea of “task uncertainty” and “mutual dependence” to explain possibilities of scientific discoveries. Task uncertainty is “individual and collective perceptions or constructions of the work process” (Fuchs, 1993, p. 938), and mutual dependence means “the level of social integration in a group or network” (p. 938). For example, clusters of highly co-cited documents are considered to have high mutual dependence, because “what happens in one part of the network will have consequences for other parts, and vice versa” (p. 941). Only when both task uncertainty and mutual dependence are high, will scientific discovery occur that can leave some permanent influence on the structure. The core groups with high mutual dependence levels are called “invisible colleges”, or a network of “productive scientists linking separate groups of collaborators within a research area” (Crane, 1972, p. 54). Lievrouw (1989) defined the term as “the informal affiliation of scientists with common interests who were already strongly embedded in other institutions, and who might live some distance from one another” (p. 619). Paisley (1972) listed the defining criteria of an invisible college as “an emergent, informal group, one hundred members or less; interacting leaders; day-to-day communication through informal media such as preprints; a commuting circuit of meetings and collaborative projects” (p. 6). Although the criteria might have been changed since new communication technologies evolved that affect the communication among scholars, the definitions suggested by these scholars still hold some conceptual significance. The Royal Society of London started to use the term “invisible colleges” (Price, 1961), and Price (1963) made it more familiar, but the term became widely accepted in the study of scholarly and scientific communication when Crane (1972) elaborated it in her book, *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Although Zuccala (2004) indicated that too many definitions have been assigned to the concept and Lievrouw (1989) raised issues regarding the question of process as opposed to structure, the underlying idea of social and informal groups and their role in scientific communication are still recognized by many scholars.

### Citation Analysis and Co-citation Analysis

Citation Analysis is one form of the social network studies that use archival data on “who cites whom” (Wasserman and Faust, 1994, p.51). Citation patterns have been one of the most discussed research topics in information science (Garfield, 1965; Cronin, 1984). Citations can create networks of various nodes, including journals, individual articles, and authors. When a citation analysis involves pairs of journals, articles, and authors that are cited together, it is called a “co-citation” analysis. Small (1973) defined co-citation as “the frequency with which two items of earlier literature are cited together by the later literature” (p. 265). When a pair of documents is co-cited more frequently than others, they are considered to be more closely related to each other. Information on individual journal citations can be used to examine the impact of journals on the subject field, and a map of co-cited documents can be used to identify subject specialties and sub-specialties. When observed for a period of time, the change in the map of co-cited documents can show the change and knowledge growth in a discipline over time (White and McCain, 1989, p.141-142).

Small and Griffith (1974) proposed a methodology to identify groups of scholars that have affected scientific changes by analyzing clusters of documents that have been frequently cited together. In the process of analyzing clusters of co-cited documents, they realized that the authors of co-cited documents are worth noticing. Small (1977) later used citation data to introduce methods to identify changes in scientific “specialty”. The specialty is “the principal mode of social and cognitive organization in modern science” (p. 139) and clusters of highly co-cited documents are considered to represent the cognitive structure of the field. This subject space is said to be the “current paradigm of the specialty” and the authors of the documents in such clusters are assumed to be the “elite” or “leading scientists of the specialty” (p. 142). Kuhn (1962) mentioned that “a scientific community consists of the practitioners of a scientific specialty” (p. 177). A specialty can be defined as “a group of practitioners with similar training, attending the same conferences, reading and citing the same bodies of literature, and being more likely to talk to each other than to members of different specialties, considerable overlaps and mobility notwithstanding” (Fuchs, 1993, p. 934). Griffith (1989) emphasized the role of the co-citation methodology that it created “a realistic picture of differentiation in science and the speed and extensiveness of change” (p. 612). In other words, the co-

citation analysis can be helpful to identify the intellectual structure of a research field as well as changes that occurred in this structure.

Citation analysis of authors can be studied through either *intercitation* or *cocitation* occurrences. *Intercitation* examines a group of authors in a field and counts “how often any member of one group cites any member of the other” (White, 2004, p.91), while *cocitation* involves pairs of authors within each group to find out how often the pairs are cited together. Author Cocitation Analysis (ACA) has been used to create a map of co-cited authors to show the intellectual structure and the social structure of the field, using author co-citation counts and similarities among authors. (White and Griffith, 1980, p.163; White and McCain, 1989, p.146; White, 2003, p.1250). McCain (1989) examined a set of 58 authors in the field of *Drosophila* genetics, based on citation data from 1981 through 1986. The map showed clusters of authors who were involved in similar subject topics. In addition, the map showed whether the author’s contribution to the field was mostly theoretical, or generally experimental or observational. In summary, mapping co-cited authors is considered to “represent an aggregate consensus that is likely to influence, if not constrain, information use and communication patterns” (p. 679). White and McCain (1998) later used author co-citation analysis for “visualizing a discipline”, which involved an extensive domain analysis on information science. Small (2003) investigated the relationship between co-citation analysis of scientific specialties and Kuhn’s paradigms by showing “how individual co-citation links could be translated into scientific assertions, and a cluster of such links viewed as an interlocking network of statements” (p. 396). However, some researchers (White et al., 2003) have asked what citation really represents – whether it shows “*who* citers know (social structure) or *what* they know (intellectual structure)”.

Marion et al. (2003) suggested that social network analysis can be used to explore social structure and complement ACA. White et al. (2003) also suggested using both social network analysis and citation analysis to complement each other’s weaknesses. Even though the study involves intercitation analysis, rather than cocitation analysis, it shows the value of engaging both techniques to investigate changes in social structure of a research group called Globenet, as well as its influence on Globenet’s intellectual structure. Globenet is a multidisciplinary research institute consisting of members from five different provinces in Canada (Koku et al., 2001). The social network analysis of the research group resulted in three types of ties, including social, sociocognitive, and intellectual ties, where each showed different levels of intercitation. For example, a collaborator, as one of the variables under sociocognitive ties, showed a significant correlation with both articles and book intercitation. Also, the study suggests the possibility that strong intellectual ties might entail social relationships, because those who knew each other before the research group began were more likely to be intercited in articles. Even though the study did not fully answer the question of whether citation reflects social structure, it showed potential for the use of citation data for analysis of intellectual networks. Their findings suggest “that both prior reputation (here measured by early cocitation) and facilitative social venues (the Globenetters’ frequent conferences) can lead individuals to meet, communicate, socialize, and exchange information and knowledge” (White et al., 2003, p. 125).

In a study on citation networks among Communication journals from 1977 to 1985, Rice et al. (1988) identified clusters of interpersonal journals, mass media journals, and residual isolate journals through bibliographic analysis of citation data and a network analysis of citation patterns. Bibliographic analysis of citation data was used to identify core journals in Communication, while network analysis was used to identify citation patterns and clusters of journals through cohesion and position approaches. Cohesion analysis is based on “the degree of linkages between any pair of nodes” and position analysis is based on “the structural equivalence between nodes” (p. 267). Both approaches were used to answer (1) “what areas of communication research exist as shared channels for research results and theoretical debate?”, and (2) “which journals perceive the field of Communication research in similar ways or are seen as being similar?” (p. 267). In the position approach, cluster analysis and multidimensional scaling were used to identify clusters of core journals based on correlations of both citations received and citations made to other journals. Although Rice et al. acknowledged some weaknesses in the data, including the fact that “there are many other important channels for the flow of scientific information besides journal articles” (p. 278), the research showed support for the use of citation analysis in investigating patterns of scientific communication and the intellectual structure of a subject area.

### **Social Network Analysis**

Network analysis is “a set of research procedures used to identify structures in social systems based on the relations among the system’s components (nodes) rather than the attributes of individual cases” (Barnett, 2001, p. 1640). It can be used to analyze the structure of communication in an organization, and the international monetary, telecommunication and trade networks (Barnett and Danowski, 1992; Barnett and Salisbury, 1996). Wasserman and Faust (1994) define social network analysis as a method of studying “relationships among social entities” (p. 3). Two of the fundamental concepts are node and link, where a node is the unit of analysis and a link represents the relationship between nodes. Citation data can be easily converted into network data, since an individual document, author, or journal can be a node and the act of citing each other

can be considered as a link. In addition, citation data has most of the properties of networks, such as centrality and tie strength. Citation analysis of journals in a subject specialty can identify the core journals of the field, by examining citation frequencies of each journal. Highly cited journals can be considered as core journals, which have more influence on scientists than other journals on the periphery. Core journals in citation analysis are central nodes in network analysis. Moreover, the number of citations can be used as the tie strength, where highly cited documents, journals, or authors are considered to have a higher level of tie strength.

The strength of a tie is defined as “a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterizes the tie” (Granovetter, 1973, p. 1361). The concept of tie strength can be also applied to citation analysis. In a study of citation networks of Communication journals, Rice et al. (1988) denoted that journals with “weak links” to other interpersonal journals “may play a valuable role in expanding the diversity of scientific information within the interpersonal clique” (p. 271-272). For co-cited authors, the strength of ties may be useful to identify the most frequently cited pairs of authors as well as those who are not cited as often as strong ties but useful to provide diverse knowledge to the groups to which they belong.

## RESEARCH QUESTIONS

The research questions of this study include,

RQ1: Does the network analysis of authors identify groups?

In other words, does the network analysis of authors represent the knowledge structure of the authors (McCain, 1986)? Although it may be a very sparse network, the map of authors is expected to show who are often cited together or who belong to the same university. Each group or cluster of authors might be associated with a particular specialty of communication research, for example, mass communication or interpersonal communication.

RQ2: Does the degree of centrality of authors vary within groups?

Within each cluster of authors, the study is expected to identify those who are more central than others. The concept of “core” and “scatter” has been used to describe productivity of journals or authors (White and McCain, 1989, p. 124). It is assumed that the more central an author is within a network, the more productive s/he must be. Barnett and Park (2005) used the concept of “the core, the periphery, and the semi-periphery” (p. 1112) in their study of the structure of international internet hyperlinks. Their results show some countries are more central than others in the hyperlink network, and that the structure corresponds with the global structure with core and peripheral dimensions suggested by world system theory.

## METHOD

### Data

This study examines scholars on the editorial board of *Journal of Communication*, an official journal of the International Communication Association (ICA), in order to include those who are associated with all possible aspects of communication research. There are 146 people on the editorial board as of December 2006, and the citation used for this study was collected using *Social Science Citation Index (SSCI)* from 1970 to present. After identifying and searching the indexed name of each author, co-citation frequencies between each pair of authors were counted by using the “combine sets” function in the search history page. A non-directional symmetric matrix with valued strength was created for the co-citation counts of each pair of authors, and UCInet (Borgatti, Everett, and Freeman, 2002) was used to generate basic statistics and to draw the networked map of authors.

In addition to the co-citation matrix, a matrix of each author’s current university affiliation was created, which consisted of 146 rows for individuals and 73 columns for their university affiliations. Another matrix was created for their membership in ICA divisions. These two matrices were used as attribute data to predict the co-citation structure. The matrix consists of 146 rows for authors and 22 columns for 18 ICA divisions, 3 interest groups, and Communication Institute for Online Scholarship (CIOS) membership (Lee, 2008).

### ICA Divisions

1. Information System
2. Interpersonal Communication
3. Mass Communication

4. Organizational Communication
5. Intercultural/Development Communication
6. Political Communication
7. Instructional/Developmental Communication
8. Health Communication
9. Philosophy of Communication
10. Communication and Technology
11. Popular Communication
12. Public Relations
13. Feminist Scholarship
14. Communication Law and Policy
15. Language and Social Interaction
16. Visual Studies
17. Gay, Lesbian, Bisexual and Transgender Studies
18. Intergroup Communication

*Interest groups*

19. Journalism Studies
20. Ethnicity and Race in Communication
21. Game studies

#### QAP Correlation Analysis and NetDraw

QAP stands for quadratic assignment procedure (Krackhardt, 1987), and it is used to identify correlations between the co-citation network and authors' current affiliations, and between the co-citation network and ICA divisions to which they belong to. With the co-citation network as an observed network, corresponding cells of the other two matrices are compared to compute Pearson's correlation coefficient, and the process is repeated with randomly permuted columns and rows to recompute the correlation. A lower proportion means a stronger relationship between the matrices. The co-citation matrix is used to draw a network using NetDraw, a program in UCInet. Author clusters and isolates can be identified based on the level of tie strength, which is derived from co-citation frequencies. The affiliation matrix and the ICA division matrix are used as attribute data for NetDraw to see if members of an author cluster have any attribute in common. Properties, such as color and size, of a node can be adjusted to distinguish groups of nodes based on their attributes.

#### RESULTS

The first research question asked whether the map of authors resulting from a network analysis identify author groups. First, QAP analyses between the co-citation network and the university affiliation network and between the co-citation network and the ICA division network were performed to see which can better predict the structure of the co-citation network.

	Pearson Correlation Value	Significance
Affiliations	0.045	0.008
ICA Divisions	0.161	0.000

**Table 1. QAP Matrix Correlation**

The QAP correlation analysis resulted in a significant correlation between the co-citation network and the ICA divisions network ( $r=0.161$ ,  $p=0.000$ ). The co-citation network of scholars on the editorial board of *Journal of Communication* has similar structure to their membership to ICA divisions, rather than to their current university affiliation. Figure 1 displays the network map of authors, with members of the mass communication division represented in blue circles. Among 22 categories used for the ICA divisions, the mass communication division has the most members (Lee, 2008) and the map shows they

formed the larger cluster than members of the other divisions. Berger is the only member of the mass communication division who is a part of the smaller cluster.

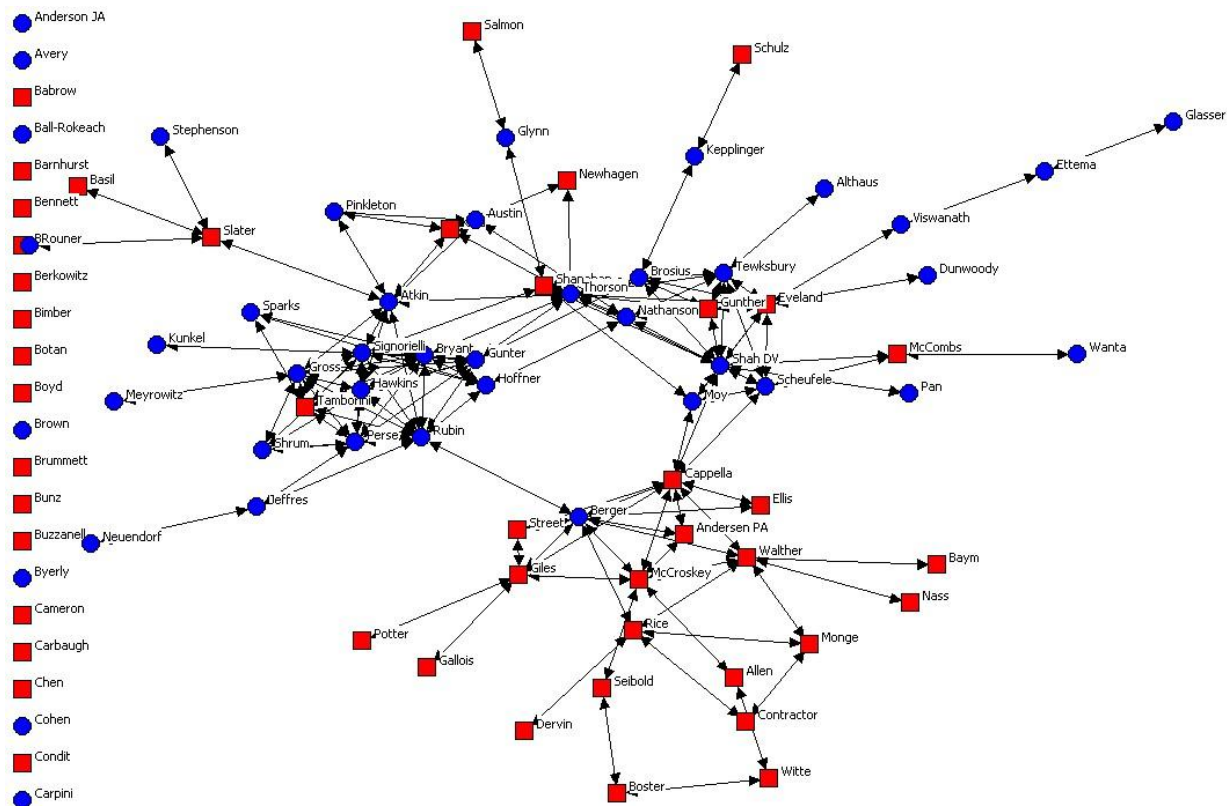


Figure 1. Networked Map of Authors

The second research question was whether the degree of centrality among authors varies within groups. Four different centrality measures were used for this study, including degree, closeness, betweenness, and eigenvector centralities<sup>1</sup>. Table 2 lists of 15 authors who have higher degree centrality scores in the co-citation network. All of the authors in the list are at the core of the network, which means they are more co-cited than others within each group. Moreover, some of them connect one cluster to another, for example, the link between Ruben and Berger connects the mass communication cluster with the other cluster, which corresponds to the definition of “invisible colleges” (Crane, 1972, p.54).

	Degree	Closeness	Betweenness	Eigenvector
Perse EM	76.552	44.892	1.528	19.201

<sup>1</sup> Connectedness or degree centrality is simply a node’s number of direct links (Freeman, 1979). Closeness is the average length (number of steps) of the shortest paths connecting a node to all other nodes in a network. Closeness is measured as the inverse of this average (Freeman, 1979). Betweenness centrality measures the extent to which a node lies along paths that connects other pairs of nodes (Kincaid, 1993). A node in this location is in a position to control or influence information flows in the network. It is the proportion of paths containing a node that connect a pair of nodes in the network. Finally, eigenvector centrality determines how central (or peripheral) a node is based on its loading on the largest eigenvector of the network’s sociomatrix (Bonacich, 1972). It is the ideal measure for those networks in which the strength (frequency of communication) between nodes, rather than simply the presence or absence of a link is known. It has the effect of making nodes with strong ties to more central nodes appear relatively more central.

Rice RE	75.172	44.615	2.138	18.412
Cappella JN	74.483	44.479	1.558	18.725
Rubin AM	73.103	44.207	1.222	18.728
Gross L	71.724	43.939	1.060	18.415
Allen M	69.655	43.544	1.544	17.342
Thorson E	69.655	43.544	1.275	18.113
Shah DV	68.966	43.284	1.204	17.744
Hawkins RP	68.276	43.284	2.381	17.798
McCroskey JC	68.276	43.284	1.537	16.789
Signorielli N	68.276	43.284	0.789	18.009
Berger CR	67.586	43.155	1.328	17.107
Bryant J	67.586	43.155	1.201	17.417
Gunter B	66.897	43.027	0.759	17.759
Eveland WP	66.207	42.773	1.270	17.324

**Table 2. Scholars with higher centrality**

(Mean Degree 39.093, Standard Deviation 20.047

Mean Eigenvector 10.422, Maximum Eigenvector 19.201)

## CONCLUSION AND FUTURE RESEARCH

This study investigated whether the patterns of author co-citation can describe the structure of the field of communication. The network analysis shows two main clusters of authors, based on their membership of the ICA divisions. In particular, members of the mass communication division form a larger cluster, which reflects the current structure of the editorial board of *Journal of Communication*. The result supports previous findings regarding the structure of the communication discipline (Barnett and Danowski, 1992; Doerfel and Barnett, 1999), as consisting of the dichotomizing grouping of mass media and interpersonal communication.

The study still leaves some room for further research. First, even though the QAP analysis resulted in a smaller correlation with the affiliation network than with the ICA divisions network, it is worth noticing that the author's current affiliation influences the pattern of co-citation as well. In addition, more co-citation data can be collected from other journals, and more data about authors can be added to see whether their educational background, such as institutions from which they received their doctoral degrees, also has any effect on the co-citation pattern. In summary, this study demonstrated the utility of network analysis of co-citation data to identify the structure of invisible colleges within the field of Communication.

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