THE SOCIAL IDENTITY OF IS: ANALYZING THE COLLABORATION NETWORK OF THE ICIS CONFERENCES (1980-2005)

General Topics

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Abstract

Identity crisis has been a longstanding problem for the Information Systems (IS) community. Most previous studies have addressed this problem from the philosophical perspective, but few have tackled it from the social network perspective. In this paper, we report our work on studying the social identity of IS by applying social network analysis on the collaboration (co-authorship) network for ICIS papers over the past 26 years. The social network of IS researchers and the characteristics of the network were identified and discussed. Our results showed that the IS community is well connected and has demonstrated frequent interactions among members. The critical mass of the community, the most productive authors and institutions, was identified. Cross-institutional collaboration patterns were also studied, and some interesting results were revealed. In addition, we studied how the social network has evolved over time. The networks at three different time periods were constructed and compared. We found that the network has evolved healthily over time with the addition of new members and the improved connection among members. Overall, our analyses indicated that the IS community has maintained the social identity well and we expect the trend to keep on in the future.

Keywords: IS identity crisis, IS discipline, social identity, social network analysis, knowledge diffusion

Introduction

The establishment of Information Systems (IS) programs at several institutions (e.g. University of Minnesota) during the late 1960s, the inauguration of *MIS Quarterly* in 1977, and the launch of the first *International Conference on Information Systems* (ICIS) in 1980 signified the inception of the IS community (Benbasat and Weber 1996; Dickson 1981). Since then the IS community has strived to develop "a meaningful, resilient identity" (Benbasat and Zmud 2003) and undergone recurrent assessment and self-assessment, seeking to strengthen the legitimacy of the field (Banville and Landry 1989; Farhoomand 1987; Robey 2003). Although the IS field has evolved to take a form of a scientific discipline with cumulated body of knowledge after more than 30 years of development, IS researchers are still struggling to answer a fundamental question — what defines IS? Such a tension has been reflected in a debate, which has become heated again recently, regarding the "identity crisis" of IS (Agarwal and Lucas 2005; Benbasat and Zmud 2003; DeSanctis 2003; Galliers 2003; Hirschheim and Klein 2003; Robey 2003; Weber 2003).

A number of studies have examined the nature of IS research, challenged or justified the legitimacy of IS discipline, identified the causes of identity crisis, and offered suggestions to resolve the identity problem experienced by the IS community. Most of these studies are philosophical, and the discussion centers on the research problems, theoretical foundations, contributing disciplines, and methods used in IS research (Benbasat and Weber 1996; Keen 1980). Answers to these questions are undoubtedly critical to the resolution of the identity problem. However, few studies have looked at the problem from the *social network perspective*. If the philosophical perspective deals with the questions about *what* to study and *how* to study (Benbasat and Weber 1996), the social network perspective views the problem from an alternative angle by studying *who* conducts IS research and constitutes the social identity of the IS discipline (Banville and Landry 1989; DeSanctis 2003).

DeSanctis (2003) pointed out that the process of conducting research and producing knowledge is inherently social (Crane 1972). To assess a scientific discipline and evaluate its status and progress, it is important to understand the social dynamics of the research community. In a research community, members interact with each other, share common research interests, use similar methods and techniques, pick up each other's ideas, and influence each other's work (Culnan 1986; Culnan 1987; Moody 2004). These social interactions interweave researchers to a complex social network in which knowledge is generated, diffused, and updated.

The objective of this paper is thus to help address the IS identity problem through the lens of social network. We study the social network formed via research collaborations, which are documented by coauthored research papers. We choose to analyze the collaboration network of the ICIS conference over the past 26 years (1980 – 2005). We select ICIS over other sources such as major IS journals and other conferences based on several considerations. First, among a number of IS conferences, ICIS is the most prestigious international conference for the IS discipline. ICIS receives more than 200 submissions from IS researchers all over the world every year (ICIS 2006). It has been the primary forum for IS researchers to interact, communicate, and demonstrate their research, and has been famous for the high quality of accepted papers. Second, as a conference, ICIS has a faster turnaround time than journals. Its review process is much shorter than that of major IS journals. At a result, papers in ICIS can report new ideas and thoughts, latest research progress, and up-to-date research results in a timely manner. It also offers new members, who have not had a chance to publish in major IS journals, an opportunity to publish their research. Third, the 26-years worth of ICIS literature data provides a source for analyzing the evolution of the IS discipline since its inception.

The remainder of this paper is organized as follows. Section 2 presents a brief introduction of the background of the IS identity problem. Section 3 lays out our research questions regarding the social identity of IS. Related research is reviewed briefly in Section 4. Methods and data used in this study are presented in Section 5. We report our analysis results and discuss the implications and limitations of this research in Section 6. Section 7 concludes this paper.

Background

The search for a widely accepted definition for IS has never seemed to settle down. At the first ICIS conference, Keen (1980) defined IS as "the effective design, delivery and use of information systems in organizations." Such a definition emphasizes the theoretical foundations, contributing (reference) disciplines, and the organizational context. Dickson (1981) loosely defined IS as a field dealing with "all informational and decision-making activity associated with operating an organization." More recent definitions of IS have broadened the contexts of IS as "the development, use and application of information systems by individuals, organizations, and society" (Baskerville and Myers 2002).

Although these definitions provide a baseline for IS research, they do not specify what constitutes IS research and how the research is done. Since the very beginning, IS studies have varied greatly in their research problems (topics of research), theoretical foundations and contributing disciplines, and research methods (Benbasat and Weber 1996). Vessey et al. (2002) further recognized the diversity in the level of analysis, which can be individual, group, organizational, or societal (inter-organizational). Banker and Kauffman (2004) identified five IS research streams that differ on the four diversity dimensions: decision support and design science, value of information, human-computer system design, IS organization and strategy, and the economics of information systems and technology. These five streams can be roughly mapped to the five contributing disciplines identified at the first ICIS conference and in Swanson and Ramiller (1993), namely, *computer science*, *management science*, *cognitive science*, *organizational science*, and *economics* (Banker and Kauffman 2004).

Clearly, the IS discipline has benefited from such diversity for improved rigor in research. However, diversity has also made it more difficult for distinguishing IS from other more established fields (e.g. finance and economics) and for claiming its contributions to the body of knowledge (Benbasat and Weber 1996). Especially, the topical diversity has been believed to cause IS to become "fragmented adhocracy" (Banville and Landry 1989; Swanson and Ramiller 1993), which may further lead to a more serious situation — the "identity crisis" of IS (Benbasat and Zmud 2003). The direct cause for such a crisis may be that most published IS research has been "under-investigating phenomena intimately associated with IT-based systems and over-investigating phenomena distantly associated with

IT-based systems" (Benbasat and Zmud 2003). Benbasat and Zmud thus called for a returning to the focus on the IT artifacts. Since its publication, Benbasat and Zmud's paper has stimulated a discipline-wise debate about whether the IS discipline is in crisis and what can be done to contribute more to the body of knowledge, maintain scientific growth, and sustain the discipline (Agarwal and Lucas 2005; DeSanctis 2003; Galliers 2003; Hirschheim and Klein 2003; Robey 2003; Weber 2003).

The identity debate and researchers' reflections about the legitimacy of the IS discipline are primarily philosophical. DeSanctis (2003) viewed this problem in a different way. She suggested that we analyze the discipline from the social perspective and through the lens of community of practice. She pointed out that it is essential to study the social dynamics of the research community that generates research because "social interaction plays a role in scientific growth" (Crane 1972, pp. 22). Such a view is in alignment with the commentary made by Banville and Landry (1989) that the production of knowledge in any scientific discipline is not only a cognitive but also a social process. Research actually is the product of social interactions among members of the community. These communities, which are called "societies of knowledge producers" (Banville and Landry 1989) or "invisible colleges" (Crane 1972), often take a form of social network. Such a social network consists of researchers who are connected by various social interactions and relationships.

The social network has an important implication for the IS community because the social capital, which can increase a community's "organizational advantage" (Nahapiet and Ghoshal 1998), is embedded in this network of relationships. The three dimensions of social capital, namely structural dimension (e.g. network ties and configuration of ties), relational dimension (e.g. trust and identification), and cognitive dimension (e.g. shared language and narrative), facilitate the process of knowledge creation and diffusion by affecting its opportunity, anticipation, motivation, and capabilities (Nahapiet and Ghoshal 1998).

Recognizing the importance of the social network, we argue that the identity of the discipline is defined by the social identity or the "behavioral legitimacy" of the research community (DeSanctis 2003). DeSanctis (2003) suggested five criteria for evaluating the behavioral legitimacy of a discipline: frequent interaction among members, routines of interaction, evolution of a core group, ability to absorb newcomers, and boundary formation. Our research follows this perspective and we present our research questions in the next section.

Research Questions

We focus on the social network formed through research collaborations among IS researchers who coauthored ICIS papers. In particular, we are interested in the structure of the network and the community it represents. Based on the five criteria of DeSanctis (2003), we develop the following three research questions regarding the social identity of the IS discipline. We want to emphasize that this research is not intended to evaluate the IS discipline philosophically. Instead, we want to present facts about the social interactions within the IS community, hoping to provide empirical evidence about the social identity and the social capital embedded in the social structure of the discipline. Our study is more descriptive than normative.

RQ1: *What are the patterns of interactions between members of the IS community*?

Interactions among community members should connect them and form a network. Frequent interactions among members strengthen their ties and facilitate the diffusion of knowledge. Moreover, members investigating similar research questions or using the same research methods may also form subgroups within the community. We thus divide this research question into three sub-questions:

> RQ1.1: Are IS researchers connected? Do they maintain frequent interactions? How "close" are they to each other?
>
> RQ1.2: What structural characteristics does the collaboration network have?
>
> RQ1.3: Are there subgroups in this community?

RQ2: *Are there core sets consisting of the "critical mass of active members who sustain the network"* (DeSanctis 2003)?

Leaders in a scientific discipline are important assets to the discipline. Treating scientific growth as a process of knowledge diffusion, leaders are often the ones that originate new ideas and have great impact on the community. The impact, further, can be carried on to the other parts of the community through the leaders' collaborators.

Interestingly, mathematicians even coined a term called *Erdős Number* to honor an extremely eminent member, Paul Erdős, in their community (Hoffman 1998). Mathematicians who coauthored papers with Erdős received a number of 1. Others who did not coauthor papers with Erdős but wrote papers together with Erdős' coauthors would receive a number of 2 and so forth.

In addition to leaders' roles, a related question is regarding the roles played by the institutions that house individual researchers. Institutions provide organizational infrastructure for a discipline. Collaborations may occur across the institutional boundaries, leading to a social network of institutions. We develop four sub-questions to answer the second research question:

RQ2.1: Who are the most eminent researchers in the community?

RQ2.2: Are these star researchers critical to holding the community together?

RQ2.3: Which institutions are the most productive?

RQ2.4: What are the cross-institutional collaboration patterns?

RQ3: *How has the network evolved?*

A scientific discipline is never static but changes over time. New research topics may emerge and old research topics may become less interesting. Previously unavailable technologies may be developed such that data collection and processing capabilities are greatly enhanced. Former active members may become less active or even drop out of the community due to various reasons such as retirement; inactive members can become active. If a discipline grows healthily, it should be able to attract new members such as doctoral students who later on will join the network. It would be interesting to analyze the patterns of evolution of a community in the following aspects:

RQ3.1: Has the community been able to absorb new members?

RQ3.2: How has the structure of the network changed over time?

RQ3.3: Are there new generations and stars?

RQ3.4: How have collaboration patterns changed over time?

Related Research

Because we rely on literature data to construct the social network of IS researchers, in this section, we review prior work on literature-based discipline assessment and the social network analysis approach.

There are generally two approaches to assessing a scientific discipline based on literature data: classification and citation analysis (Banker and Kauffman 2004; Vessey et al. 2002; Zhang and Li 2005).

The classification approach is to categorize the literature on different dimensions such as topics and research methods (Swanson and Ramiller 1993). To assess the diversity of IS research, for example, Vessey et al. (2002) classified papers published in five leading IS journals in 1995-1999 based on contributing discipline, level of analysis, topic, research approach, and research method. They found that IS research displayed great diversity on all the five dimensions. Farhoomand (1987) concentrated on research methods and analyzed the methods used in IS papers published in six IS journals between 1977 and 1985. Papers were classified into five categories: case study, survey, field test, experiment, and non-empirical. A shift from non-empirical research to empirical research was observed during that period (Farhoomand 1987). Instead of assessing all IS research streams, Zhang and Li (2005) focused on human-computer interaction (HCI) studies and categorized HCI literature based on research contexts, levels of analysis, topics, methods, individual characteristics studied, technology or services examined, and contributing disciplines.

Unlike the classification approach, citation analysis is a bibliometric approach that generates and analyzes networks of related papers (or authors) based on literature citation information. Citation analysis is often used to study the research specialties and the intellectual structure of a wide range of scientific disciplines such as natural sciences (Small 1999), economics (McCain 1990), computer science (Chen and Paul 2001), and information science (White and McCain 1998). It has also been used to evaluate the productivity and reputation of individual researchers, academic programs and institutions, and journals (Garfield 2001; Huang and Hsu 2003; Im et al. 1998). Depending on how the relationships between papers (or authors) are defined, the resulting network can be citation network, bibliographical coupling network, and co-citation network (Garfield 2001; Kessler 1963; Small 1977). Culnan (1986; 1987) performed author co-citation analysis on papers published by 141 IS researchers as a means for identifying emergent research specialties in IS. She found nine invisible colleges representing different research specialties in this co-citation network.

Another important literature-based approach is collaboration network analysis that studies co-authorship patterns. This approach has received more attention recently (Barabási et al. 2002; Liu et al. 2004; Newman 2004). Two authors are connected in a collaboration network if they have written papers together. It is fair to say that a collaboration network is a partial representation of the social network among authors, because authors who coauthor papers are generally acquainted with each other. Using co-authorships as a convenient substitute of social relations among researcher, however, is not without methodological risks. For example, two researchers may work together on one project but choose to publish their work separately. Directors of large laboratories or research centers may be listed as coauthors in papers on multiple projects but may have not participated directly in these projects (Borgman and Furner 2002). Nonetheless, co-authorship renders a window through which one can access the social interactions between members in a scientific community. Such analysis can help reveal many interesting characteristics of the community (Newman 2004). For example, it can show patterns of collaborations in a field over time, detect subgroups of researchers sharing similar research interests, and identify key researchers who play important roles in the field. Collaboration networks have recently been examined for a number of disciplines (e.g. physics, biology, mathematics, and computer science) (Newman 2004) and fields such as digital library (Liu et al. 2004). There have been few studies analyzing the collaboration networks of IS researchers. One exception is the study conducted by Cunningham and Dillon (1997), who analyzed the co-authorship patterns of IS researchers based on papers in five IS journals from 1989 to 1995. They found that collaborations among IS researchers were pervasive and cross-institutional boundaries.

Collaboration network can be treated as a type of social network. Social network analysis (SNA) is a sociological methodology for analyzing patterns of relationships and interactions between social actors in order to discover the underlying social structure (Wasserman and Faust 1994). Not only the attributes of social actors, such as their age, gender, socioeconomic status, and education, but also the properties of relationships between social actors, such as the nature, intensity, and frequency of the relationships, are believed to have important implications to the social structure. SNA methods have been employed to study organizational behavior (Borgatti and Foster 2003), inter-organizational relations (Stuart 1998), computer mediated communication (Garton et al. 1999), and many other domains. SNA can help reveal the structural patterns, such as the central nodes that act as hubs, leaders, or gatekeepers; the densely-knit groups; and patterns of interactions between groups.

Moreover, a recent movement in statistical analysis of network topology (Albert and Barabási 2002) has brought new insights and research methodology to the study of network structure. Networks, regardless of their contents, are classified into three categories: *random networks* (Bollobás 1985), *small-world networks* (Watts and Strogatz 1998), and *scale-free networks* (Barabási and Alert 1999). In a random network, the probability that two randomly selected nodes are connected is a constant p. As a result, each node has roughly the same number of links. In addition, groups are not likely to exist in random networks. Small-world networks, in contrast, have a significantly high tendency to form groups. Most empirical networks, ranging from social networks (Newman 2004) to biological networks to the Web (Albert et al. 1999) have been found to be non-random networks. In addition, many of these networks are also scale-free networks, in which a large percentage of nodes have just a few links, while a small percentage of the nodes have a large number of links. Thus, nodes in scale-free networks are not homogenous in terms of their links, and some nodes become hubs or leaders that play important roles in the functioning of the network.

Data Set

As discussed, we focused on ICIS publications in this study. The *Association for Information Systems* has put online all the ICIS papers since the very first ICIS in 1980 (http://aisel.isworld.org/publication.asp?Pub=ICIS). Paper information including title, author(s), and author affiliation(s) is publicly accessible. We developed a simple Web crawler program to download such information for all the ICIS papers that were published between 1980 and 2005. In addition to research papers, we also included panel discussions and treated panel descriptions as papers and panelists as authors.

After downloading all the data, we first preprocessed the data by assigning unique identification numbers to the papers, authors, and institutions. During the process, we found some inconsistencies in the data provided on the site.

First, some author names were wrongly spelt. For example, the name Agarwal was misspelt as Agaml in one case. Second, an institution may have multiple names. For instance, the University of Texas at Austin appeared in the five following forms in the data: "The University of Texas, Austin", "University of Texas at Austin", "University of Texas Austin", "University of Texas, Austin", and "The University of Texas at Austin". These problems were checked and rectified manually in our preprocessing. After preprocessing the data, we obtained a list of 1433 papers, authored by 1862 authors from 583 different institutions.

We constructed the collaboration network based on the co-authorship information. The resulting network consisted of 3098 collaboration links among the 1862 authors. A collaboration link between two authors was weighted based on the frequency of collaboration, which was the number of ICIS papers that the two authors wrote together.

Moreover, in order to analyze research topics presented in ICIS papers, we extracted keywords in the papers published after 2000. Unfortunately, most papers prior to 2000 do not contain keywords. Among the 539 papers published in 2000-2005, 385 papers provide keywords. Again, we found inconsistencies in the keywords. For example, "electronic commerce" appeared in three different forms: "e-Commerce", "eCommerce", and "electronic commerce." We manually rectified this problem and obtained a list of 1367 unique keywords.

Analyses and Results

In this section we report the analysis results and answer our research questions about the structure of the collaboration network in the IS community.

RQ1: What are the patterns of interactions between members of the IS community?

RQ1.1: Are IS researchers connected? Do they maintain frequent interactions? How "close" are they to each other?

The connectivity of a community can be affected by many factors such as research methods. In mathematics, for example, because most of the research is theoretical, mathematicians tend to publish single-authored papers, leading to a rather sparse and dispersed network (Newman 2004). Most biology studies, in contrast, are experimental and many large projects involve multiple scientists. The resulting networks are rather dense and busy (Newman 2004). IS is a diverse discipline that is not dominated by any specific research method (Vessey et al. 2002). We thus expected the IS community to be a connected one. On the other hand, the structure of a community can also affect its ability to facilitate the creation and diffusion of knowledge (Crane 1972; Nahapiet and Ghoshal 1998). Knowledge can be disseminated efficiently in a random network, in which members are "close" to each other. A network is efficient if the average distance between nodes is comparable with that in a random network of similar size and density (Watts and Strogatz 1998).

Our results showed that the ICIS collaboration network contained a giant component, accounting for 64.9% of all authors who have published in ICIS. A giant component is the largest connected node set, in which any node can reach another one through some paths (Bollobás 1985). Only 8% of the authors have never collaborated with anybody else in ICIS. The remaining 27% of the authors formed very small clusters of only 2 to 4 members. This implies that the IS community is well connected and it includes the majority of the members.

Moreover, researchers also keep frequent interactions. On average, a pair of authors collaborated at least once. The maximum number of collaborations between a pair of authors is 8. The average number of collaborators a researcher has is 3.3.

We used two measures, *distance* and *efficiency*, to examine the ability of the network to facilitate knowledge diffusion. The distance between two nodes is defined as the length of the shortest path between them (Albert and Barabási 2002). The efficiency of a network is defined as the sum of the inverses of lengths of all-pair shortest paths (Crucitti et al. 2003). A 100% efficient network should have an efficiency value of 1 such that nodes communicate with any other node directly.

We found that the average distance in the giant component was 5.4 and the efficiency was 0.20. To compare the network with its random network counterpart, we generated 30 random networks of the same size and average degree with those of the giant component. The resulting mean distance is 4.81 (S.D.= 0.071) and the mean efficiency is 0.21 (S.D. = 0.003). This means that the IS community is roughly as efficient as a random network and researchers are close to each other. On average, a researcher in the giant component, which consists of 1208 authors, can reach another arbitrary one in about only 5 steps (4 intermediate researchers).

RQ1.2: What structural characteristics does the collaboration network have?

Different network structures have different implications to the patterns of collaboration. If the collaboration network is random, it means researchers “randomly” select their collaborators. Such a structure is what is referred to as a “structurally cohesive” network (Moody 2004), and it has been found that some disciplines such as sociology is such a kind of community. In a scale-free network, in contrast, nodes vary dramatically in terms of their structural roles. A community with a scale-free structure would see a few members being significantly more active than most other members. These active members attract disproportionate recognition and can significantly influence other members. We expected that the IS community was such a scale-free community, and we tested this using the *degree distribution*.

The degree distribution, $p(k)$, is the probability that an arbitrarily selected researcher in this community will have exactly k collaborators. If the network is random, each researcher will have roughly the same number of collaborators and the resulting distribution will be a bell-shaped Poisson curve, which peaks at the average number of collaborators. The degree distribution of a scale-free network, in contrast, is a power-law distribution that is highly skewed toward small degrees. The curve will appear as a straight line in a scatter plot in logarithmic scales (Albert and Barabási 2002). Because the degree distribution often fluctuates at the tail we plot the cumulative degree distribution instead (Amaral et al. 2000). The cumulative distribution, $P(k)$, is the percentage of authors who have at least k collaborators.

Figure 1 presents the resulting cumulative degree distribution of the ICIS collaboration network. It clearly shows scale-free characteristics. This implies that while a large number of authors have only a few collaborators, a small number of authors can have a large number of collaborators. Researchers are heterogeneous in terms of their abilities to attract collaborators.

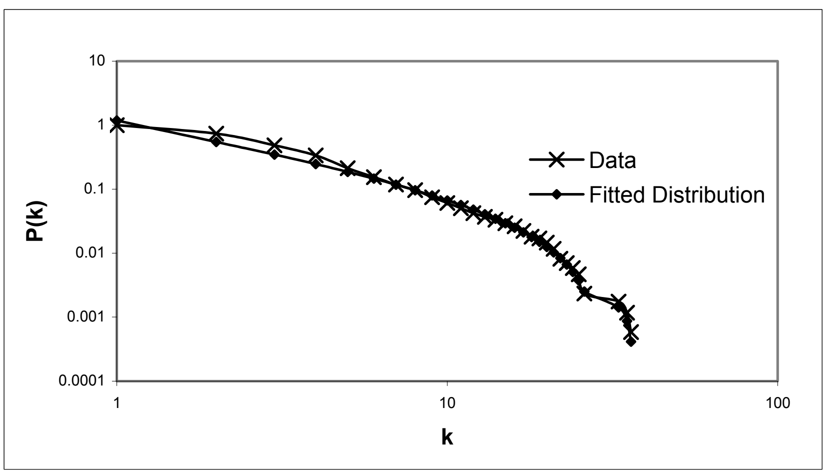


Figure 1. The Cumulative Degree Distribution of the ICIS Collaboration Network

Note that the degree distribution is not a pure power-law because the tail of the curve decreases faster than linear decrease. We thus fitted the data using a power-law distribution with an exponential cutoff (Newman 2001). Figure 1 shows that the fit to data is quite good, especially at the tail ($R^2 = 0.95$). This phenomenon has been observed in other disciplines such as physics (Newman 2001). The reason is often because the data are from a limited time window and collaboration is costly in terms of time and effort invested (Amaral et al. 2000), it is impossible for a researcher to collaborate with an unlimited number of others. The finding suggests that the IS community is not structurally cohesive. Collaboration opportunities distribute unevenly among members.

RQ1.3: Are there subgroups in this community?

Researchers sharing similar interests, investigating similar research questions, and working on related application domains may form subgroups of their own. Paper presentations and discussions at the ICIS conference tracks may have helped researchers find future collaborators more easily. The frequency and density of collaboration relationships within the group are expected to be higher than outside.

Usually cluster analysis can be used to find subgroups in a network. However, a clustering algorithm will partition a network into clusters no matter whether clusters really exist in the network. It is often difficult to test whether the clusters found are "true" subgroups. We thus use a network statistic, *clustering coefficient*, to measure the tendency for the IS community to contain subgroups (Watts and Strogatz 1998). In a random network, it is very unlikely to have subgroups because it is equally likely for a node to connect with any other nodes. The clustering coefficient thus is rather low in random networks. We found that the clustering coefficient of the ICIS collaboration network was 0.60, significantly higher than 0.004 (S.D.= 0.001) of its random counterpart. The short distance and high clustering coefficient together indicate that the IS community is a "small world" (Watts and Strogatz 1998).

To have a closer look at the IS community and its subgroups, we constructed the minimum spanning tree (MST) for the giant component. The MST connects all nodes in the giant component using the minimum set of links (Kruskal 1956). Since we have weighted the links based on collaboration frequency, the links in the MST are also the set of shortest links. We generated a visual representation of the MST using the NewDraw software (NewDraw 2006) (see Figure 2). MST has been used in many studies to depict the structure of a discipline (Chen and Morris 2003; Newman 2004). Figure 2 thus can be viewed as a rough picture of the social structure of the IS community.

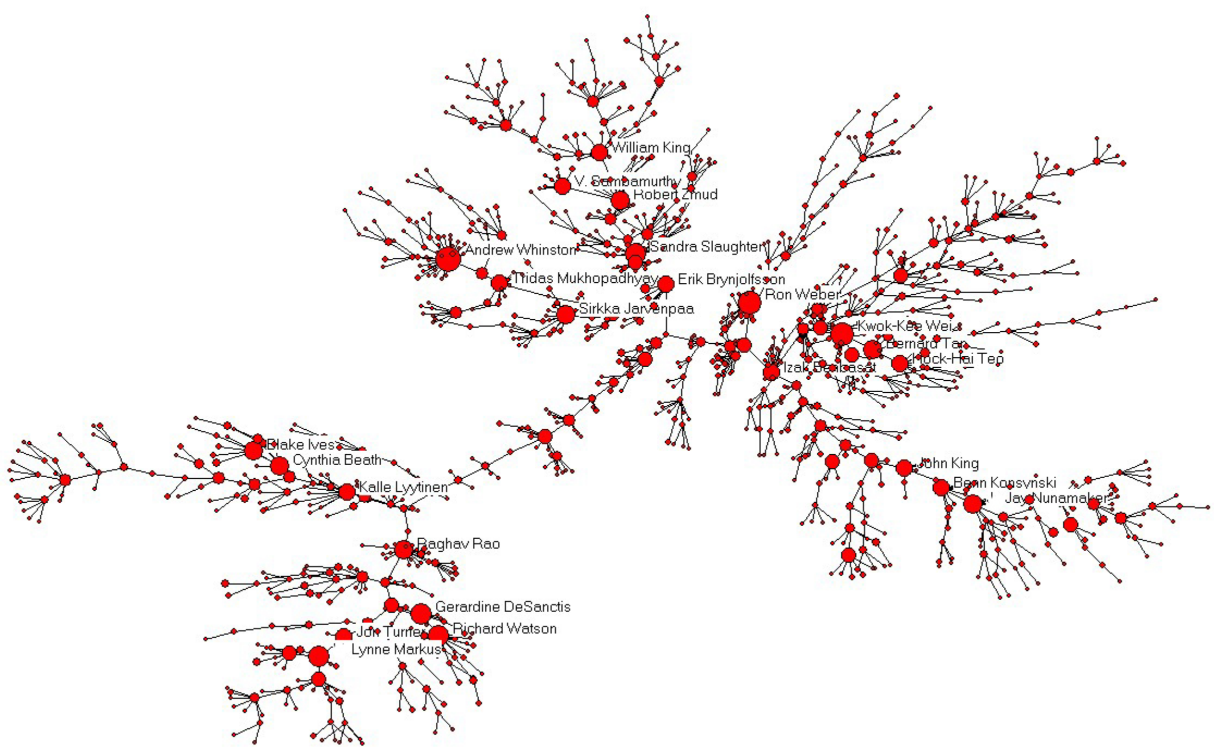


Figure 2. The Minimum Spanning Tree of the Giant Component from the ICIS Collaboration Network

In Figure 2, each node represents an author in the giant component, and a link exists between two authors if they have co-authored at least one ICIS paper. Note that the MST contains only the minimum set of collaboration links. An absence of link between two authors in the visualization does not necessarily mean that they have not co-authored papers. We chose to show the MST rather than the complete giant component with all collaboration links because the 2640 links among 1208 authors in the giant component would make the visualization extremely dense and cluttered, and hardly anything interesting could be found.

The tree in Figure 2 has a trunk and several branches. Usually a branch in a MST represents a group of closely related researchers and can roughly correspond to groups with different topics of research (Chen and Morris 2003; Newman 2004). It would be interesting to test whether this is true in this ICIS network. A good resource for identifying the topics of research in a set of authors is to find most frequent keywords appearing in these authors' papers. However, as previously mentioned, ICIS papers published before 2000 do not contain keywords. We thus could not use keywords to find the topics of research for many authors who have not published in ICIS since 2000. Nonetheless, it is evident from Figure 2 that the IS community contains several subgroups and research camps and these groups connect with each other.

In Figure 2, the size of an author node is proportional to the number of ICIS papers that the author has published. Some outstanding authors appear as big nodes, and they are the set of core researchers that we are going to focus on in the next research question.

RQ2: Are there core sets consisting of the critical mass of active members who sustain the network?

RQ2.1: Who are the most eminent researchers in the community?

Eminent researchers are those who publish many papers, either alone or with many collaborators. We examined the productivity of authors based on three types of ranks: *normal rank*, *straight rank*, and *adjusted rank* (Zhang and Li 2005). Normal rank treats all coauthors equally and is based on the number of papers a researcher publishes. Straight rank, on the other hand, counts only the papers of which the author is the first author. Adjusted rank is based on the collaboration strength (Newman 2004), and an author receives 1 from a paper with only two authors but a less than 1 value from papers with more than two authors. Table 1 lists the top ten authors in the three productivity ranks. The combination of the three lists should give a rough picture of the group of most productive researchers in the IS community. The distribution of author productivity is a power-law with a very good fit ($R^2 = 0.98$). This means that while a large number of authors have published only one or two papers, a small number of authors have published a large number of papers. One should be reminded that the productivity here is based on ICIS data only. We may not assume that the top authors in ICIS are also top authors in the IS discipline.

Table 1. Author Productivity Ranks

Name	# Papers	Name	# First-Authored Papers	Name	Adjusted Score
1. Andrew Whinston	18	1. Gordon Davis	8	1. Jon Turner	7.23
2. Ron Weber	16	1. Rajiv Banker	8	2. Ron Weber	7.07
2. Kwok-Kee Wei	16	3. Bradley Wheeler	7	3. Blake Ives	5.73
4. Richard Watson	15	3. Cynthia Beath	7	3. Robert Zmud	5.73
4. Sandra Slaughter	15	5. Kevin Crowston	6	5. Andrew Whinston	5.65
6. M. Lynne Markus	14	5. Daniel Couger	6	6. Gerardine DeSanctis	5.59
6. Gerardine DeSanctis	14	5. C. Ranganathan	6	7. Sandra Slaughter	5.45
8. Cynthia Beath	13	5. Erik Brynjolfsson	6	8. Cynthia Beath	5.37
8. Bernard Tan	13	5. Eric Clemons	6	9. Sirkka Jarvenpaa	5.12
8. Raghav Rao	13	10. John King	5	10. M. Lynne Markus	5.00

Table 2. Author Centrality

Degree	# Collaborators	Betweenness	Closeness
1. Andrew Whinston	36	1. M. Lynne Markus	1. M. Lynne Markus
2. Richard Watson	35	2. Richard Watson	2. Richard Watson
3. M. Lynne Markus	33	3. Krishnamurthy Raman	3. Krishnamurthy Raman
4. Jay Nunamaker, Jr.	26	4. Tridas Mukhopadhyay	4. Gordon Davis
5. Vijay Gurbaxani	25	5. Benn Konsynski	5. John King
5. Raghav Rao	25	6. Gordon Davis	6. Cynthia Beath
5. Kalle Lyytinen	25	7. Vijay Gurbaxani	7. Kenneth Kraemer
5. John King	25	8. Andrew Whinston	8. Gerardine DeSanctis
9. Niels Bjørn-Andersen	24	9. Jay Nunamaker, Jr.	9. V. Sambamurthy
9. Izak Benbasat	24	10. John King	10. Vijay Gurbaxani

The eminence of a researcher can also be measured using degree centrality in SNA. The *degree* of a researcher is the number of collaborators he/she has. Two other related centrality measures in SNA are *betweenness* and *closeness* (Freeman 1979). Betweenness measures the extent to which a particular node lies between other nodes in a network. The betweenness of a node is defined as the number of shortest paths passing through it. Nodes with high betweenness scores often serve as gatekeepers and brokers between different groups. They are important communication channels through which information, knowledge, and other resources are transmitted or exchanged. Closeness is the sum of the length of shortest paths between a particular node and all the other nodes in a network. Table 2 lists the top ten authors in these three centrality measures. It is interesting to see that many of the researchers are ranked high in all these three measures, clearly indicating their important structural roles.

RQ2.2: Are these star researchers critical to holding the community together?

In a structurally cohesive community, everyone is equally important (or unimportant). In scale-free networks, however, the central researchers play important roles in maintaining the connectivity of the network. To ascertain the roles of the star researchers, we performed a "network robustness test" (Albert et al. 2000). We wanted to see how the network would change if the core group of researchers is missing from the network. We progressively removed the nodes with the highest degree in the network. If a node is rather important to hold the network together, its removal from the network should bring a great damage, as it may break a connected component into separate parts. This will cause much more difficulty for members to communicate and significantly increase the average distance among members. At the last, the entire network falls apart into very small clusters and the average distance becomes quite small.

We plotted the average distance against the percentage of nodes removed in Figure 3. The curve reaches its peak (the longest average distance) when around 7.5% of the nodes are removed. That is, when the approximately 90 most central researchers are missing, members in the community are rather distant from each other. It takes around 15 steps for a researcher to communicate with another one. These 90 researchers are what DeSanctis (2003) referred to as the "critical mass" of a community, and they actually hold the community together. The social identity of the community would not exist without these central researchers.

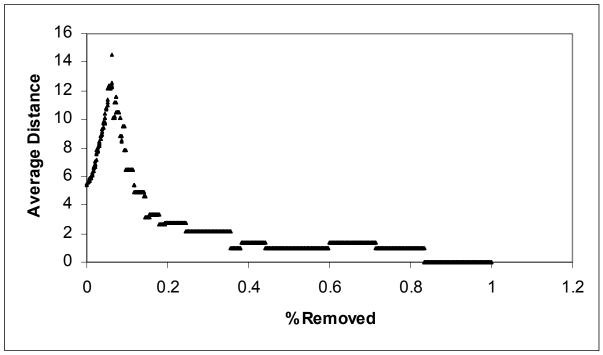


Figure 3. The Change in Average Distance When a Percentage of Nodes Is Removed

RQ2.3: Which institutions are the most productive?

We measured institution productivity based on normal rank and straight rank. Table 3 presents the ten most productive institutions. The six most productive institutions by both measures are Massachusetts Institute of Technology (MIT), National University of Singapore (NUS), University of Minnesota (U. MN), Carnegie Mellon University (CMU), New York University (NYU), and University of Texas at Austin (UT Austin). These institutions generated a disproportionately large number of ICIS publications in the past 26 years. Other institutions in the Top 10 include Georgia State University (Georgia State), University of Arizona (UA), University of Maryland at College Park (U. MD), University of California at Irvine (UC Irvine), and University of Michigan (U. MI).

Table 3. The Top Ten Productive Institutions

Institution	# Papers	Institution	# First-Authored Papers
1. MIT	77	1. MIT	56
2. NUS	69	2. NUS	55
3. U. MN	68	3. U. MN	49
4. CMU	64	4. CMU	45
5. NYU	59	5. NYU	39
6. UT Austin	52	6. UT Austin	33
7. Georgia State	48	7. UC Irvine	25
8. UA	43	8. Georgia State	23
9. U. MD	36	9. U. MD	22
10. UC Irvine	34	9. U. MI	22

RQ2.4: What are the cross-institutional collaboration patterns?

Different institutions may have different research focuses and strengths. It is more convenient for researchers to collaborate within the same institution. However, institutional boundaries should not prevent researchers from collaborating.

We constructed a cross-institutional collaboration network. Two institutions are connected if authors from them have coauthored at least one paper. Because authors may move from an institution to another over time, we use the author affiliation when the paper is published. Again, we weighted the links based on the frequency of collaborations. This resulted in an institution network in which nodes are institutions and links are weighted collaboration relations. The giant component consists of 480 institutions, counting for 82% of the institutions that have published in ICIS. There are 1509 links among these institutions. On average, an institution collaborates with

2.58 other institutions. The busiest institution is Georgia State University, which has collaborated with 64 other institutions.

We drew an MST for the giant component from the institution network (see Figure 4). The size of a node is proportional to the number of papers published by authors from that institution. The ten most productive institutions are labeled with their names. Because the links are weighted, the institutions from the same branch should have more frequent and denser collaborations with others form the same branch. It is interesting that institutions that are similar in research methods and topics may not necessarily fall in the same camp. University of Arizona and Georgia State University, for example, appear to be quite apart from each other although they both conduct a lot of technical/design science research. This may be due to the lack of collaboration in ICIS between these two institutions.

It is also interesting to note that geographical proximity may not always result in more collaboration. In the network, we can see that there are no direct links between University of California at Los Angeles (UCLA), UC Irvine, and the University of Southern California (USC). Our data also show an absence of collaboration between UCLA and UC Irvine, and between UC Irvine and USC. National University of Singapore and Nanyang Technological University, which are the two most productive universities in Singapore, are far from each other in the network, and our data suggest that they have not published any ICIS paper together.

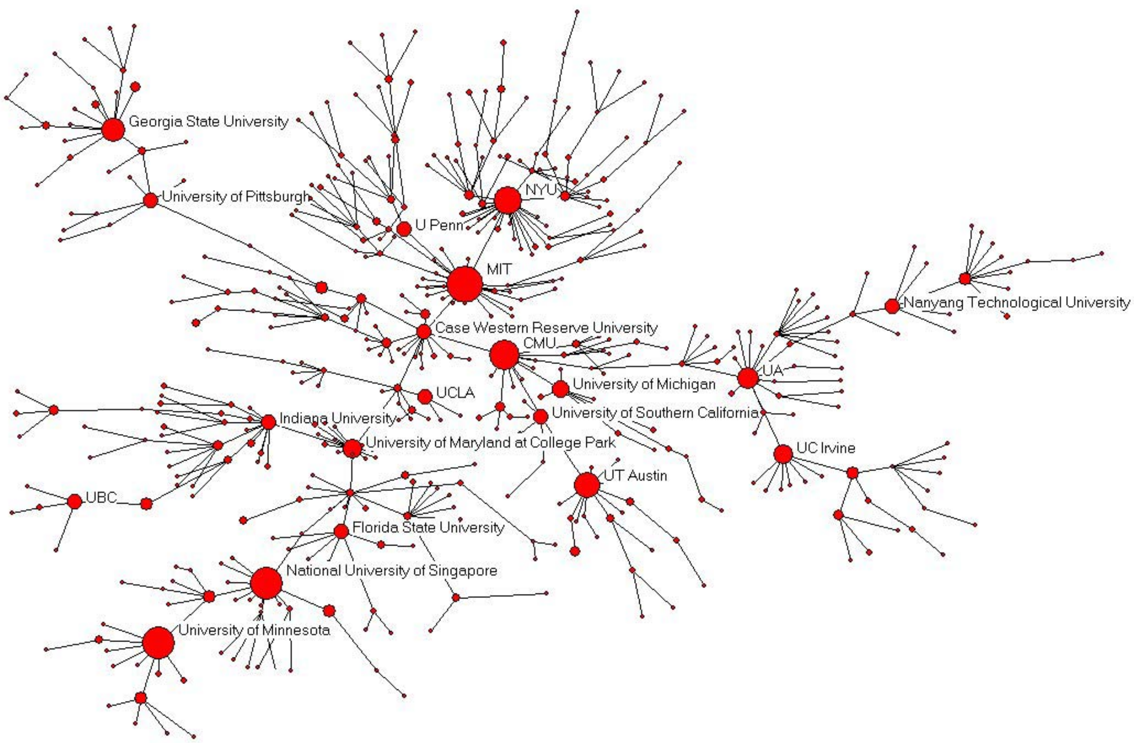


Figure 4. Cross-institutional Collaboration Network

RQ3: How has the network evolved?

RQ3.1: Has the community been able to absorb new members?

Community size is a good indicator of the community's ability to attract newcomers. These new members can be doctoral students, junior faculty members, and researchers who have been trained in other disciplines but are interested in collaborating with IS researchers. We plot the *number of authors* who publish in ICIS, the *number of new authors* who publish in ICIS for the first time, and *the number of papers* accepted in each year (see Figure 5). It shows that overall all these indicators have an increasing trend over time. In 1980s, the numbers are rather stable. A big jump occurred after 1990. There are two possible explanations for this trend. First, it might have been due to the increase in general interest in this discipline, leading to great increases in the number of submissions. Another reason might have been the big increase in the accommodating ability of the conference, allowing more authors to attend the conference. These three indicators display parallel patterns over time. Thus, we can see that the community is able to attract new members in general. Some significant drops occurred in 1990, 1995, 1998, 2001, and 2004, however. Note that it is not fair to attribute drops in the numbers solely to the conference locations outside the North America. Although ICIS was held in Denmark in 1990, The Netherlands in 1995, and Finland in 1998, the two big drops in 2001 and 2004 occurred when the conference was held in two American cities, Washington, D.C., and New Orleans, respectively. On one hand, the hurdles associated with international travel might have kept a large number of authors from attending the conference when it was held outside the North America. On the other hand, this also indicates that as an international conference ICIS was not successful in attracting new international authors in those years prior to 2000, when international authors should have had more access to the conference.

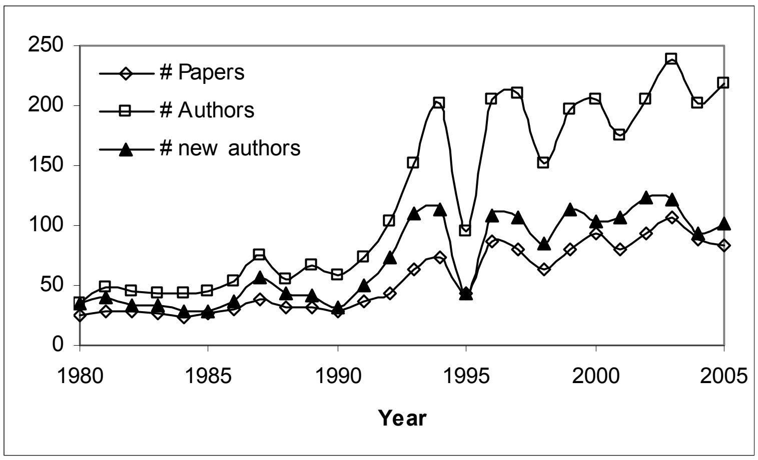


Figure 5. Changes in the Number of Papers, Number of Authors, and Number of New Authors over Time

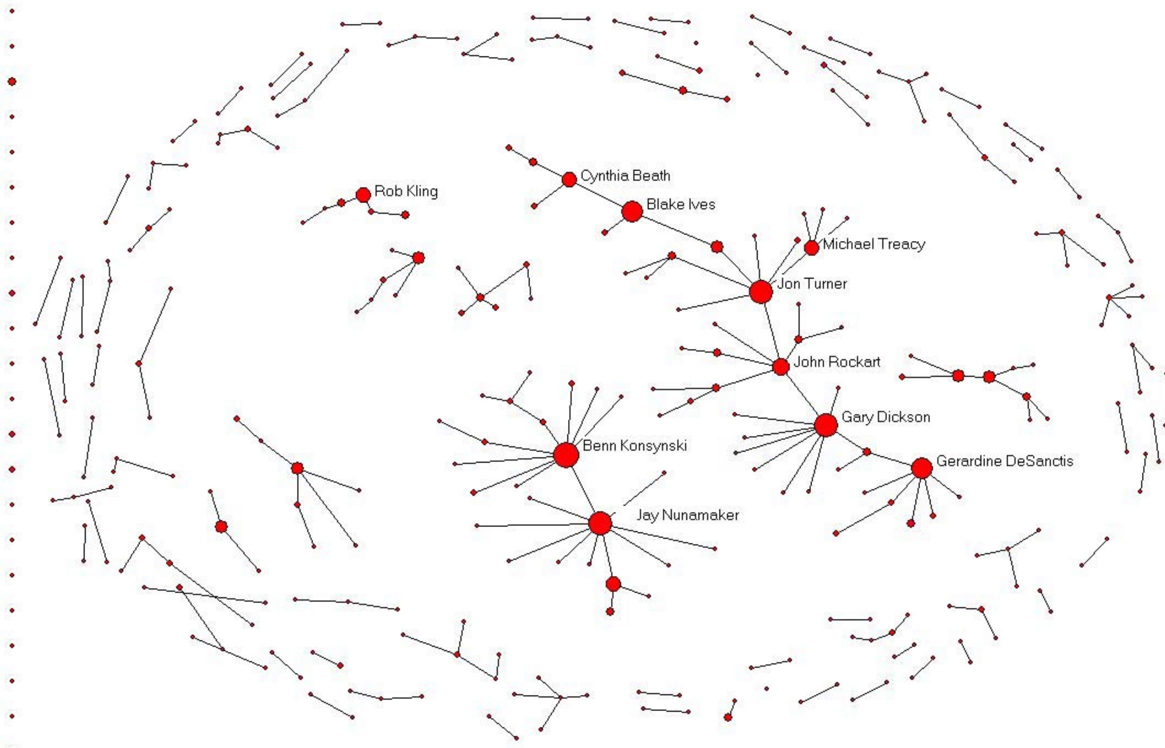
RQ3.2: How has the structure of the network changed over time?

The network did not assume the present structure at the beginning. The current state has resulted from 26 years of evolution. During this period, some previous members left, new members joined, and existing members who did not collaborate before might start coauthoring papers. New topics of research may cause the emergence of new research camps and groups. All these change the network structure.

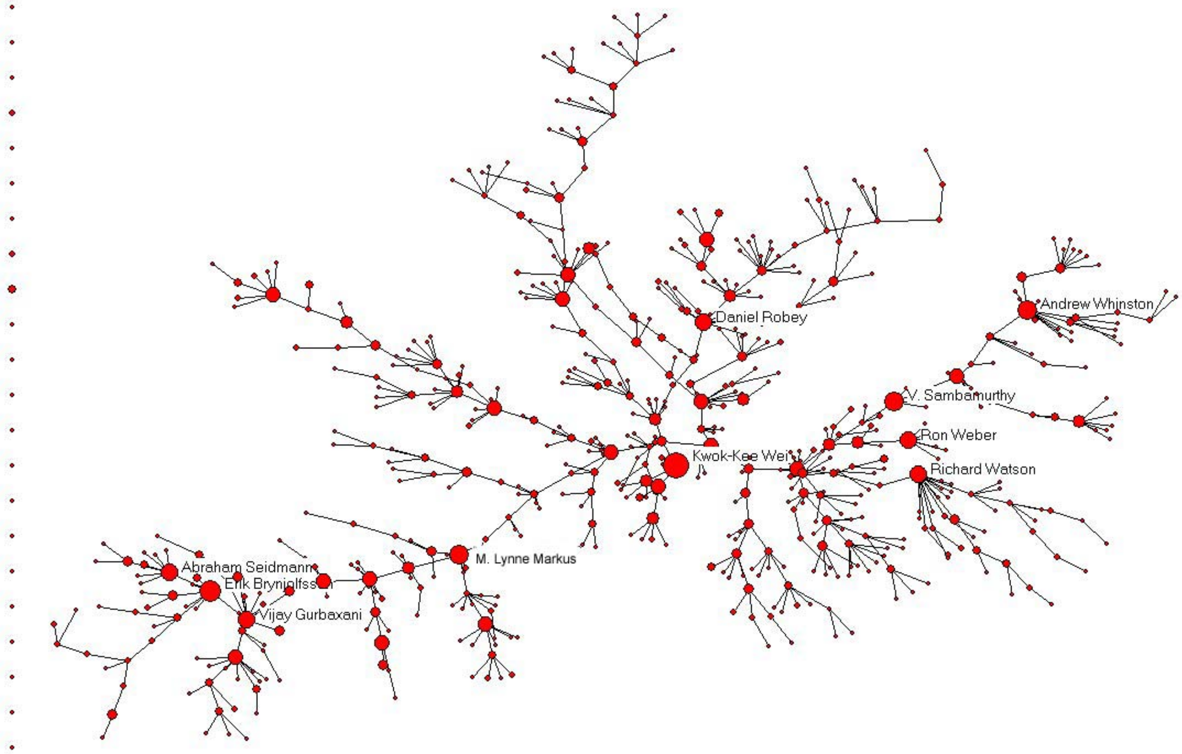
We divided the data into three time windows for 1980s, 1990s, and 2000s. Two authors are connected in a time window only if they published papers together in that period. We divided the data in this way based on two reasons. On one hand, the first ICIS conference was held in 1980 and thus division at the beginning of each decade was convenient. On the other hand, the three decades roughly correspond to the stages the IS discipline has experienced. The research focus shifted significantly from what to study (topics of research) to how to study (methods) (Benbasat and Weber 1996) during the transition from the 1980s to the 1990s. Since 2000, the IS community has experienced recurrent concerns about IS identity due to a series of events such as the burst of dot.com industry and the tightening of IT job markets (Benbasat and Zmud 2003). It thus was natural to study the structures of the network during the three stages. Figure 6 (a)-(c) depict the MSTs of the network during the three time windows respectively. In Figure 6(a) we also included the small clusters outside the giant component. It is evident that in the 1980s the community was rather dispersed, small, and fragmented. A few key researchers constituted the core of the discipline, and they were closely connected. The 1990s witnessed a great increase in the size of the community and the network became more connected.

We analyzed the keywords extracted from papers in 2000-2005. We found that the most frequent keyword in this period was "electronic commerce", which was used 31 times. Other frequent keywords were "knowledge management" (16), "ERP systems" (13), "electronic markets" (12), "trust" (12), and "virtual community" (12). We also found that the most frequent keywords changed from year to year: "case study" (in 2000), "electronic commerce" (in 2001, 2003), "ontology" (in 2002, 2004), and "knowledge management" (in 2005). Although keywords are by no means equivalent to topics of research, the change in the keywords can to some extent reflect the change in the topics over time.

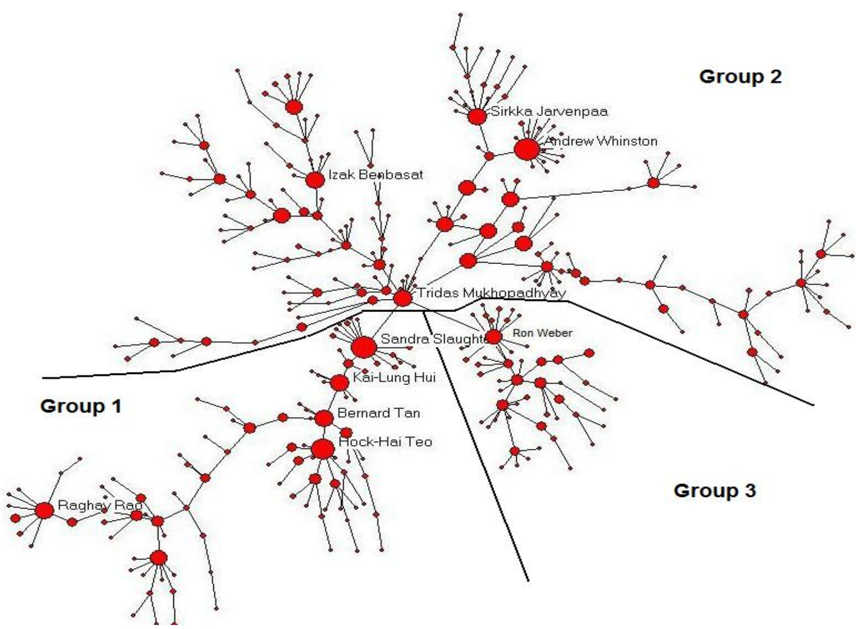
We also studied the correspondence between research areas and the several groups presented in Figure 6 (c). Like the tree for the overall ICIS collaboration network in Figure 2, the tree for 2000s also contains several branches. Based on the visual characteristics of this tree, we divided it into three big groups as indicated in Figure 6 (c). Such a division is somewhat ad-hoc, as alternative ways for dividing the tree may be possible. For example, Group 2 can be further divided into several smaller groups. Because our main purpose here is to study the relationship between topics and researcher groups, we think our current division would not cost the generalizability of the findings.



(a)



(b)



(c)

Figure 6. The Change in the Structure of the Network in each Decade: (a) 1980s, (b) 1990s, (c) 2000s

The resulting three groups consisted of 100, 202, and 50 members, respectively. We compiled a list of keywords for each group and compared these lists. If the groups were not related to research topics, that is, researchers fall into different groups because of other reasons such as levels of analysis and research methods, the three lists should be overlapped and very similar to each other. We calculated the Jaccard similarity coefficients (Rasmussen 1992) among the three lists and found that they were rather different from each other ($Jaccard_{1,2}$ = 0.051, $Jaccard_{1,3}$ =

0.028, $Jaccard_{2,3}$ = 0.043). Little overlap was found between the keywords used by these three groups. To further analyze the data, we calculated the frequency for each keyword in each group and plotted the keyword distributions in Figure 7. The two most frequent keywords for each group are labeled. It is quite evident in Figure 7 that these groups use different sets of keywords to summarize their research, and the groups formed based on collaboration correspond to different research areas. Furthermore, our data suggested that there was a lack of collaboration between different groups. During the past six years, only 6 collaboration links were formed between Groups 1 and 2, 6 between Groups 2 and 3, and 0 between Groups 1 and 3.

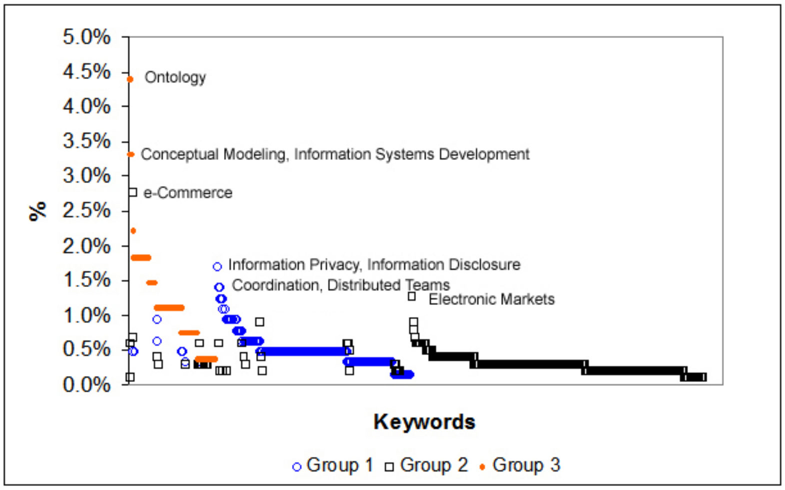


Figure 7. The Keyword Distributions for theThree Groups that Published ICIS Papers in 2000s

RQ3.3: Are there new generations and stars?

Answer to this question is very evident from Figure 6. Table 4 lists the ten most productive authors based on normal rank for each time period. They are labeled with their names in the corresponding parts in Figure 6. Our results indicated that as time progressed, new generations of authors emerged and new stars stood out. During this process, the productivity of institutions has also changed. Table 5 presents the top ten productive institutions over time.

Table 4. Top Ten Productive ICIS Authors in each Decade

1980s		1990s		2000s	
Author	**# Papers**	**Author**	**# Papers**	**Author**	**# Papers**
1. Benn Konsynski	9	1. Kwok-Kee Wei	12	1. Sandra Slaughter	8
2. Gary Dickson	8	2. Erik Brynjolfsson	10	1. Andrew Whinston	8
2. Jon Turner	8	3. Andrew Whinston	9	3. Hock-Hai Teo	7
2. Jay Nunamaker, Jr.	8	3. V. Sambamurthy	9	3. C. Ranganathan	7
5. Blake Ives	7	3. M. Lynne Markus	9	5. Bernard Tan	6
5. Gerardine DeSanctis	7	6. Richard Watson	8	5. Sirkka Jarvenpaa	6
7. John Rockart	6	6. Daniel Robey	8	5. Raghav Rao	6
8. Rob Kling	5	6. Vijay Gurbaxani	8	5. Kai-Lung Hui	6
8. Cynthia Beath	5	6. Ron Weber	8	5. Izak Benbasat	6
8. Michael Treacy	5	6. Abraham Seidmann	8	5. Tridas Mukhopadhyay	6

Table 5. Top Ten Productive Institutions in each Decade

1980s		1990s		2000s	
Institution	**# Papers**	**Institution**	**# Papers**	**Institution**	**# Papers**
1. MIT	28	1. MIT	31	1. NUS	39
1. U. MN	28	2. UT Austin	28	2. CMU	29
3. NYU	21	3. NUS	27	3. Georgia State	24
4. UA	20	4. U. MN	26	4. U. MD	21
5. CMU	15	5. Georgia State	21	5. MIT	18
6. UCLA	13	5. NUY	21	5. UT Austin	18
7. U. MI	9	7. CMU	20	7. NYU	17
8. U. Penn	8	8. UC Irvine	18	7. City U. of HK	17
8. Indiana U.	8	8. UA	18	9. U. MI	16
10. HBS	7	10. U. Pittsburgh	16	10. UT Dallas	15

RQ3.4: How have collaboration patterns changed over time?

The *rate of author collaboration* is defined as the percentage of papers with multiple authors. The *rate of cross-institutional collaboration* is the percentage of papers that are written by authors from different institutions. Figure 8 displays the changes in the collaboration rates over time. Overall, collaboration among authors and institutions has been more often.

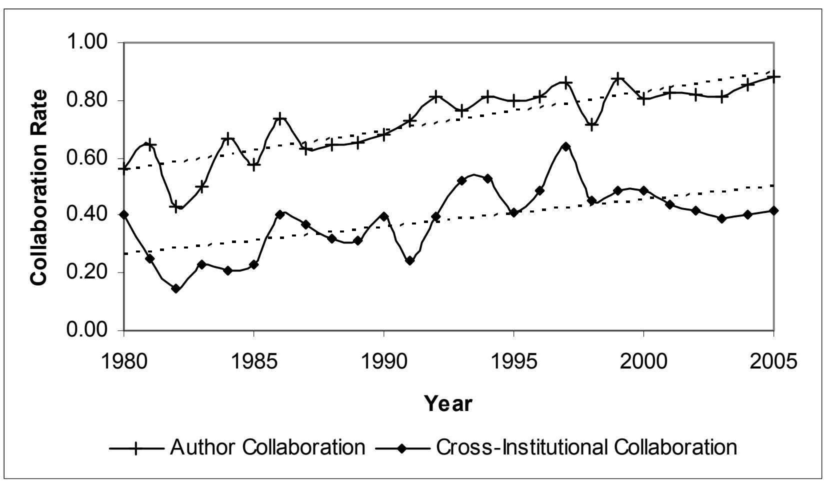


Figure 8. The Changes in Author Collaboration Rate and Institution Collaboration Rate over Time

Discussion

Our main finding from this study is that the IS discipline has a connected community in which researchers collaborate with each other. The social identity of IS is represented by these researchers. Although diversity in topics of research and theoretical foundations might have shaped the community to a collective with different research groups and camps, the community has managed to facilitate collaboration among members, thereby maintaining itself as a whole. A group of key productive researchers play important roles in the community. They have been in the discipline for a longer time and are more capable of attracting collaborators. The community is still growing, with new members joining every year. New generations with new stars have kept emerging in the IS discipline. A point that is worth clarifying is that although we recognize the importance of star researchers, we do not intend to deemphasize the roles played by other members in the community. Without these members, the IS community would not hold as a social collective and its social identity would not exist.

Implications

Our study has two implications for the social capital in the IS community. First, the study demonstrates that the IS discipline has developed its social capital and established behavioral legitimacy through a history of research collaboration. This should be quite encouraging to IS members. The social capital of a community is generally beneficial to the community (Kogut and Zander 1996; Nahapiet and Ghoshal 1998). The increase in the social capital in the IS community may have occurred both on the structural dimension and on the relational dimension. On the structural dimension, we see that the network ties have been available for members to access various resources embedded in the network such as information, knowledge, and future collaborators. The particular structure of the network, namely, its small-world properties (connectivity, short between-member distance, and existence of groups), has an influence on the efficiency of knowledge diffusion. As the network is well connected and members are "close" to each other, information and knowledge can be transferred efficiently in the network. On the relational dimension, the social capital in the community may have helped develop trust and identification (one's viewing his/herself as a part of a group) through collaboration among its members. The trust and identification can further enhance the opportunity, anticipation, and motivation of research collaboration that creates new knowledge.

Second, the analysis on the keywords in ICIS papers in 2000s shows that the diversity (especially in research topics) has led to different camps whose research is of little overlap. This indicates that the social capital in the IS community is low on the cognitive dimension because there is little shared language between different research groups. Although we cannot draw the conclusion that the IS discipline is a "fragmented adhocracy" based on the data in this limited time window, the results do suggest that there seems to be a lack of "functional dependence" (Banville and Landry 1989) among different research groups. One of the ways that can help resolve this problem, we believe, is to encourage research collaboration cross-group boundaries. IS researchers should reach beyond their own camp and try to collaborate with other researchers with different areas and specialties. This process, we believe, will not only facilitate the combination and exchange of existing knowledge, but also enhance the innovation and creation of new knowledge.

Limitations

The limitation of this study lies in several aspects. The major limitation is its relying on ICIS literature information to generate the sample of the IS community. Identifying the most representative sample of papers and authors has long been the problem facing studies using a literature-based approach to analyzing a discipline. The key question is to what extent ICIS truly represents the IS community. Although ICIS is the most prestigious IS conference, it is by no means guaranteed the most complete coverage of the membership of the IS community.

Several categories of researchers may have been excluded from this network. They are researchers who have chosen to publish papers in other publication outlets or those whose papers have not been accepted so far, doctoral students and junior faculty members who have just graduated from doctoral programs and have not been able to submit to and publish in ICIS, researchers from non-English speaking countries and thus choosing not to write papers in English, and many others. The IS World Faculty Directory has listed more than 6000 IS researchers over the world (DeSanctis 2003), a number much greater than the total number of ICIS authors.

Moreover, this sample may be biased toward those whose research is on the "soft" side of IS. ICIS has been historically focused on the theoretical, behavioral, and managerial aspects of IS. It has been found that the IS community publishes little research on topics such as system analysis and design, database management, and networking in the leading IS journals (Vessey et al. 2002). This may also have been true for ICIS. As a result, a large number of researchers who study the technical and application aspects of IS may have been left out of the ICIS network or shown low productivity in this community.

It is also possible that important collaboration links are missing in the network generated based on ICIS literature. Authors who have not coauthored ICIS papers may have collaborated and published in other research outlets. We also did not include the possible collaborations between the track chairs, associate editors, and discussants of ICIS papers because of our focus on the documented product of research collaborations: the ICIS papers.

In addition, because of the data limitation, we were not able to study whether the diversity in IS research has led to the subgroups in the community during the past 26 years. Although the findings from the time window of 2000-2005 provide some evidence, some important questions remain unanswered. Do researchers form groups based on their topics? Do researchers using similar research methodologies necessarily fall in the same camp? Do researchers tend to cross-fertilize their studies and prefer to work with people with different expertise? In our future research, we will analyze the abstracts of all ICIS papers and the combine classification approach with the network analysis approach to provide a more complete picture of the nature of the discipline.

Moreover, the collaboration network we studied in this research was a network inside the community. The discipline boundary was artificially set around the ICIS conference. How does the network look like form the external point of view? Does the boundary defined by ICIS represent the true boundary between the IS discipline and other disciplines? Has the community improved the boundary or made the boundary weaker? We hope to be able to address these questions in our future research.

Last, but not least, in this study, we did not analyze international collaboration in the IS community. Although ICIS is an international conference, our analysis did not include the information about countries of institutions. It will be interesting to see whether geographical distance has affected the patterns of collaboration.

Conclusions

The IS discipline has been striving to establish a legitimate identity over the past several decades. Such an effort has resulted in improved rigor and relevance in IS research and enhanced reputation of the discipline. However, the process of seeking discipline legitimacy, building cumulative tradition, and contributing to the body of knowledge is still going on. IS researchers' constant concerns about, self-assessment of, and reflection upon, the pluralistic nature of IS research and the diversity in the problems, theoretical foundations, and research methods indicate their sincere interest in and enthusiasm for sustaining the field as a scientific discipline.

This research seeks to extend our view of the IS identity problem from an alternative angle. Instead of assessing the IS discipline from the philosophical perspective, we study the problem from the social network perspective, hoping to provide empirical evidence about the social identity and behavioral legitimacy of the discipline. Based on 26-year worth of ICIS literature data, we constructed the social network of IS researchers. From the analysis of the patterns of collaboration and the structure of the social network, we conclude that the IS community, as a scientific discipline, holds its social identity well through the frequent interactions among members, the evolution of core researchers, and the ability to attract new members. The community has shown healthy growth in the past, and the trend is expected to continue in the future.

The contribution of this research is fourfold. First, this research is among the first few empirical studies that address the IS identity problem from the social network perspective. It provides direct evidence about the social identity of the discipline based on the analysis of the social network of IS researchers. Second, the core researcher groups and new generations of IS researchers have been identified. This has important implications to the field and to the ICIS conference on how to maintain and expand the network. Junior faculty members and doctoral students who want to devote their careers to IS research can also learn from the success of these key researchers. Third, we believe that the findings in this research, to some extent, provide encouragement to IS researchers to continue to conduct high quality IS research and contribute to scientific growth in the field. Forth, the network analysis approach used in this research is relatively new to this community and may be combined with the traditional classification and citation analysis approaches to assess the discipline in more depth in the future.

Acknowledgements

We thank Louisa Lam and Frances Law from the University of Hong Kong for their help in preprocessing the paper and author data of ICIS literature.

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