The Analysis of MIS Collaboration Research Networks and Research Issues Structure: The Example of *MIS Quarterly* Journal

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ABSTRACT: *The development of theoretical diversities within management information systems (MIS) discipline has been a constant focus and a frequently discussed issue. Those studies provide a developing pattern for the readers and researchers to track and understand the evolution of information technology and management subjects. Furthermore, the results can be a guidebook for future trends of information management researches.*

In this research, we collected the authors and keywords from the most prestigious journal in MIS research domain, MISQ, from 1977 to 2007, as the source of data sample. Using social network analysis (SNA) for mapping out the Journal's author collaboration network over time and classifying each article through their keyword-hierarchical structure, we exemplified the development of research communities and referenced domains.

While limited by the sampled data, the results of our findings indicated that the structure of co-author research communities fits a scale-free distribution model, a preferential attachment process, in the first decade of these research collaborations. And the research communities developed a stable small-world structures/ communities over time, and many distinct clusters are connected to each other by a rather small number of links, since 1997. We conclude by applying the trends of co-author relationship in each MIS sub-domain to provide a new aspect to observe and understand the development of various MIS subjects.

KEYWORDS: *Small-World Network, Scale-Free Distribution, Social Network Analysis, Research Co-Author Community, Research Keywords, Community Structure Variation.*

1. Introduction

This study made innovative contribution to information management domain by advocating an idea of applying social network analysis and theoretical basis into research on development of information management domain from the perspective of co-research in knowledge community. Innovations constantly taking place in information

management issues and research trends was caused by sustainable development of information technology and enterprise operation, which becomes one important issue attracting attentions of many scholars into discussion. Since 1982, similar studies by citing other authors' analysis statements into articles (Culnan and Swanson, 1986; Culnan, 1987; Grover et al., 2006; Wade, Biehl and Kim, 2006) or summarizing keywords research issues (Hamilton and Ives, 1982; Barki, Rivard and Talbot, 1988, 1993; Alavi and Carlson, 1992; Swanson and Ramiller, 1993; Benbasat and Weber, 1996; Lee, Gosain and Im, 1999; Claver, Gonzalez and Llopis, 2000; Vessey, Ramesh and Glass, 2002; Liang and Chen, 2005; Prasad and Tata, 2005) by scholars had been published every several years, in the hope of depicting history and development background of information management, to assist scholars within this domain to know about research achievements and foundations set up in the past and understand possible development directions concerning this domain in future. Past research approaches took issues/subjects as major objects and classified articles previously published in MIS research into different categories from aspects of essential domains and scholars over time and discussed co-discipline/co-author citation quoted by such articles (Hamilton and Ives, 1982; Culnan and Swanson, 1986; Culnan, 1987; Barki et al., 1988; Alavi and Carlson, 1992; Barki et al., 1993; Swanson and Ramiller, 1993; Benbasat and Weber, 1996; Lee et al., 1999; Claver et al., 2000; Vessey et al., 2002; Liang and Chen, 2005; Prasad and Tata, 2005; Grover et al., 2006; Wade et al., 2006). However, there was not any analysis related to co-author and structural changes of keywords domains/issues by adopting social network analysis methods. Regarding this, this article managed to analyze the scholars' articles and keywords that are cited most frequently in MIS domain in *MIS Quarterly* (*MISQ*) to generate a broad overview of structural depth and achievements that never touched before.

This study took all articles published previously in *MISQ* as objects of data collection, disposal and analysis. Totally 738 articles were collected from 1977 to 2007, including 1,012 authors (for the narration purpose, sometimes it is called as research community) and 3,607 keywords (2,275 for non-repeated words). The keyword coding framework consisting of nine categories issued by Barki et al. (1993) in *MISQ* was adapted to the classification and hierarchical divisions of codes for all keywords in combination with triangulation, totally classified into 710 codes of different categories in *MISQ*. Finally, it analyzed characteristics of network structures formed by measurement indices produced by social network relation matrix data constructed by these authors and keywords.

This study classified research data collected within 31 years into three phases, first phase 11 years, middle phase 10 years and last phase 10 years, compared first phase with subsequent 2 phases respectively (For the convenience of description, "three phases period" represents comparison among these three phases.) It found out that co-research

network relationship among authors within three decades continuously grew up, being consistent with the development trends of other disciplines (Newman, 2001; Moody, 2004). Later on, when analyzing the distribution of articles published by authors, the percentage of authors in each article and the number of co-authors, it found that co-research in articles was dominated by collaboration between two authors and collaboration among more than three authors appeared less; next, discussed possible implication of such results for research on development and diffusion of knowledge domains. Analyzing co-research trends, we further advocated the development progress of each sub-domain in nine categories of keywords, and provided reference for discussion on possible development trends in future.

For development of published articles in later period, when the number of authors publishing more articles (9 articles above) increased, this study verified network structures accumulated in each phase by using measurement indices in Small World and power law distribution network. Findings included: Small World network structure was formed in research community structure before the end of early phase, and in much earlier phase, network structure was evolved into power law distribution model that highlighted preferential attachment.

Section two was the description of relevant research literatures. Section three was the detailed introduction of data collection and disposal processes. Section four was the discussion of analyzed results of this study. Finally, section five discussed contribution, future direction and limitation of this study.

2. Literature Review

2.1 Discussion on MIS study issues and discipline domains

Management information issues and research trends had been constant focus and frequently discussed issue in this domain. Due to continual development of information technology and endless innovation of enterprise operation, many scholars had issued articles concerning this domain on prestigious journals, attempting to depict history and development background of information management and further discuss trends and direction of research development, provide subsequent scholars the directions that they could strive for. Relevant studies organized by this study were seen in the following table.

Based on the data in Table 1, research articles could be roughly divided into two categories: One category took issues/subjects as main analysis objects, adopted classification and worked with time axis to depict the classification of research subjects in information management domain and changes over times. Among articles of this category, they discussed used research methods, provided history development and

Table 1 Summary Researches on MIS Research Issues and Domain Subjects

No	Literature	Research Object	Analysis Methods	Data Time	Major Conclusion
1	Hamilton & Ives (1982)	Study Method	Citation analysis	1970-1979	A majority of articles adopted non-empirical research method with only one variable studied.
2	Culnan & Swanson (1986)	Reference and Citation Discipline	Citation analysis	1980-1984	MIS was a new-born and different domain from other domains and obviously tended to develop toward cumulative tradition.
3	Culnan (1987)	Author Citation	Co-citation analysis	1980-1985	Information management study obviously tended to develop toward cumulative tradition.
4	Barki et al. (1988, , 1993)	Keywords	Content descriptors	Since 1977	IS keywords classification framework was developed.
5	Alavi & Carlson (1992)	Research Theme and Research Methods	Descriptive Statistics	1968-1988	The number of empirical studies had exceeded total number of non-empirical studies.
6	Swanson & Ramiller (1993)	Research Theme and Keywords	Descriptive Statistics	1987-1992	It found that, if each issue was regarded as independent one, the first three issues cumulated at most within 6 years were computer-supported cooperative work (CSCW), information system strategy management (ISSM) & enterprise and information system. If put relevant issues into bigger issues, the first three issues cumulated at most within 6 years were system program, economy & strategy issue and user factors.
7	Benbasat & Weber (1996)	Research Theme, Theoretical Basis and Research Method	Review Relevant Literatures		In past development, information management study was too loose, without establishing theoretical basis on its own, and continuously borrowed theories and methods from other disciplines to solve information management problems, leading to the increase of diversities in this domain. Furthermore, with information management becoming more important in enterprises application, researchers from different backgrounds being attracted to actively join into study was also another reason why diversities in information management study expanded. Diversity characteristics also showed that information management study domain will encounter more diverse pressures from inside and outside. The variation of whole dynamics could be faster and stronger than other disciplines.

Table 1 Summary Researches on MIS Research Issues and Domain Subjects (conti.)

No	Literature	Research Object	Analysis Methods	Data Time	Major Conclusion
8	Lee et al. (1999)	Research Subjects	Descriptive Statistics	1991-1995	Academic cycle gave big concern on issues such as development method of information system, advanced technology, computer-supported cooperative work, information system application, user acceptability, expert system and artificial intelligence, decision support system and information system study. In practice cycle, more concerns were given to information technology marketing, information system strategy, information system application, client-server framework technology, standardization system, commercial products, new tools and technologies. Therefore, there was a great gap on highlighted issues between academic cycle and practice cycle.
9	Claver et al. (2000)	Research Subjects, Research Method and Author	Descriptive Statistics	1981-1997	It is found that information system development, decision support system, information system evaluation, information system practice, expert system and artificial intelligence are issues occurring most frequently in research subjects. As to research strategy, empirical study is dominant, followed by field study, theoretical study and case study.
10	Vessey et al. (2002)	Research Subjects, Research Method and Reference Discipline	Descriptive Statistics	1995-1999	Diversifies of information management studies increased.
11	Prasad and Tata (2005)	Keywords and Inner Text	Descriptive Statistics	1990-1999	Compared article categorys and analyzed issue information presented by the number of articles.
12	Liang and Chen (2005)	Article Title Classification	Descriptive Statistics and multi-dimension analysis	1980-2001	Information management study was divided into four phases in the past 20 years. Introduction of new information technology and application demands constituted the major driving factors of its development.
13	Grover et al. (2006)	Reference and Citation Discipline	Citation analysis	1990-2003	Information management study had a certain degree of cumulative tradition and affected other disciplines positively.
14	Wade et al. (2006)	Reference and Citation Discipline	Citation analysis	1990-2001	Currently, information management study is only a sub-domain in management discipline and doesn't become one independent reference discipline. However, it has potential to realize.

motives of information management research subjects through statistical analysis, and provided guides in research direction of future by making possible predictions of trends. There were a lot of such articles, e.g. ten articles listed in column 1, 4, 5, 6, 7, 8, 9, 10, 11 and 12; articles in column 1, 5, 7, 9 and 10 discussing research methods. In the review of MIS study and discipline development by Alavi and Carlson (1992), they analyzed issues related to classification, subjects and research methods in MIS articles; Prasad and Tata (2005) analyzed publication categories of MIS articles, compared article categories and analyzed issue information presented by the number of articles. In the ninth article written by Claver et al. (2000), they focused on key issues and research methods, though covering studies about author material, only gave a basic statistics about the number of articles published by authors.

Another category of article took co-citation among disciplines and authors as main analysis approach, mainly discussing important domains and scholars in MIS study. Four articles in column 2, 3, 13 and 14 in above table covered researches related to these aspects. For example, Culnan (1987) attempted to develop MIS intellectual mapping by using citation as analysis method, collecting data from 1972 to 1982 as analysis objects. His results showed that MIS obviously tended to develop toward cumulative tradition. Also, Grover et al. (2006) also studied similar issues by citation method, showing MIS had a certain cumulative tradition and exerted positive influence on other disciplines. However, in articles written by Wade et al. (2006), they also used citation analysis and proposed the opposite conclusions compared with citation analysis in other domains. Notwithstanding, currently, MIS was only a sub-domain in management discipline, because its cumulative experience can't make it one independent reference discipline.

Similar study discussions from above aspects were also seen in other disciplines, e.g. mathematics (Grossman, 2002), biology (Weitz, Benfey and Wingreen, 2007), physics (Yeung, Liu and Ng, 2005), particularly when Moody (2004) studied sociology domain by integrative comparison and analysis of co-author community published in articles and specialties of corresponding issues. His article explained the relationship between history course and knowledge community in sociology domain from the view of knowledge diffusion. Based on Moody and White (2003) and Whitley (2000), if two authors co-published articles, inference could be given that two authors shared relevant knowledge, cooperated and co-developed in similar research domain. Furthermore, based on social influence opinion held by Friedkin (1998), research scholars could form structural cohesion through opinion exchange, issue research, method, execution and discussion in reality. Therefore, understanding structural models of co-publish articles in research domain could benefit understanding formed structures and development course of different knowledge domains in specific discipline, or possiblly producing theoretical framework in such discipline (Moody, 2004).

2.2 Network structural analysis integrating authors/subjects/keywords

2.2.1 Social network analysis

Social Network Analysis (SNA) studied the relationship amid research actors. Social network analysis tried to know about interpersonal relationship among actors and observe the influences exerted on individuals or organizations by this relationship (Wellman, 1996). Analysis of all characteristics in social network analysis mainly developed together with graphic theory, to generate relevant characteristic properties to represent roles and significance of actors playing in social network, meanwhile, applied graphic drawing to function as auxiliary analysis. However, due to graphic drawing is too random or flexible, incurring difficulty in conducting strict analysis on math model, social network analysis graph needs a kind of drawing principles defined in more strict way. Firstly, nodes had to define the number of used modes and link clearly described categories to be used. Nodes or links must be clearly defined in their weights with colors matching the definitions, so as to realize the goal of assisting in analysis and identification.

Many different hierarchy and concepts were derived from graphic theory, summarized as follows:

Social network method was applied into analyzing application of network dynamics and field evolution. Abel, Bryan and Norman (2000) pushes the analysis hierarchy from simple histogram into dynamic image that helps readers intuitively understand analysis method compared with only demonstrating statistical figures. Since sociogram is introduced by Moreno for the first time, social network had been expanded into visible use (Brandes, Raab and Wagner, 2001, Moody, Mcfarland and Bender-Demoll, 2005). More articles started focusing on social network analysis to discuss development process and pattern of communities. For example, Powell et al. (2005) applied social network analysis to discuss collaboration network dynamics inside life science organization and

Table 2 Levels and Concepts of Social Network Analysis Methodology

Concepts/Levels	Whole Network	Sub-network	Ego (Individual) Measures
Links	Cohesion: → Density → Average Distance → Centralization	Group → Clique → n-clique → k-plex → k-core (cohesive group)	Ccentrality → Degree centrality → Closeness centrality → Betweenness centrality → Structural hole constraint
Equivalency	Structural equivalence Regular equivalence	Structural equivalence Regular equivalence	Structural equivalence Regular equivalence

such domain evolution. Moody (2004) applied social network indices into the observation of framework of social and scientific collaboration network. Newman (2001, 2004) also applied social network into analysis of framework of scientific collaboration framework. All literatures mentioned above adopt social network analysis to discuss development patterns of communities. By inheriting this concept and method, this article will use social analysis to analyze MIS research community and its knowledge evolution process.

2.2.2 Small-world network structures

Watts and Strogatz (1998) proposed a Small-World theory, indicating its structure was neither a completely routine-based nor fully random one, but a balance mode mixing chaos among one of two routines. Many networks often seen were small world networks, e.g. global information network, food chain in ecological system, business connection network in economic activities, connection network in human brain neurons and molecular interaction inside cells (Watts, 1999). In studies on small world network, cluster coefficient (CC) and average path length (APL) were two indices measuring small world phenomenon in network. For single author, CC was used to calculate the percentage of his attachment accounting for all possible connected authors. When discussing network cluster characteristics in paragraph 4.2 in this article, CC value in whole network was used to calculate the mean of CC for all authors in the network. APL in whole network calculated the sum of route lengths linking any two authors in network being relative to that of route lengths linking all authors. These two indices were used to compare closeness/intimacy of this network structure.

Based on the studies by Collins (2001) and Davis (2001), if the studied discipline developed fast, researchers had disperse specialty, research methods and expense resources were diverse, the mode of collaboration study should be highly and regionally clustered. It meant that if collaboration research acted so, the mean route length between two authors could be small; the studied community could form a small world network (Milgram, 1969; Watts and Strogatz, 1998, Watts, 1999). This typical collaboration research structure incorporated many separated cluster networks. Because there was a high cohesion in research basis (theory) inside community, and a close linkage among authors inside networks, total APL in cross-fields could be larger, leading to difficulty in integration of researches among different clusters (Moody, 2004). In studies by Moody, small world network was used to describe development structure characteristics in sociology research field.

2.2.3 Power-law network structures

Verifying collaboration network being a link network following scale-free power law distribution or not is another approach to describe structural characteristic of collaboration study (Barabasi, Albert and Jeong, 1999; Newman, 2000). Based on power

law distribution discovered by Barabasi et al. (1999, 2002), they found its link is centrally skewed. That is to say, a highly linked hub will generate in network structure. If referring to collaboration network study, this hub author was a star author who directly or indirectly worked with a majority of people. If referring to keywords, the hub meant a key term or concept used in each article.

Previous literatures pointed out that few famous scientists may become cores of expert collaboration network, other scientists could connect with networks through active individuals in communities (Crane, 1972). Preferential attachment inclination can explain modes of appearing in heterogeneous network framework and attachment distribution of power law (Dorogovtsev and Mendes, 2000). Central position can explain why core scientists spread information in communities rapidly. Newman (2001) strongly asserted himself that collaboration could turn into status creator, and further calculated who was a scientist with optimal attachment. If network distribution linking co-authors was attached to few active researchers (star researchers, who may cohere a lot of research expenditure and resources due to his popularity and academic reputation, and gathered many following students and co-scholars), his expertise and knowledge could affect the development of specific discipline within a short time, presenting it in article structures of co-research. This collaboration network could generate an unevenly distributed collaboration network pattern centralizing star scholars (Merton, 1968; Crane, 1972; Cole and Cole, 1973; Zuckerman, 1977; Allison, Long and Krauze, 1982).

Thus, co-research link network that fits power law distribution developed in mode of preferential attachment, leading to the emergence of "the Rich Richer." When one author had many attachments, new attachments were easily produced. If network was distributed conforming to preferential attachment, collected data could be used to observe distribution curve of power law, thus after the power was converted properly, the power distribution map could turn into data distribution in linear way. Moody (2004) also adopted the preferential attachment mode to discuss whether co-author had star author attached to it or not in research of sociology field. However, verification conducted on power law distribution curve tended to convert the curve actually distributed into log-log, and check conformity of the distribution with straight lines by means of regression analysis. The number of power in power law reflected convergent-skewed degree, namely, straight slope of straight lines after conversion.

Making use of structural characteristics in two networks mentioned above, this study aimed to understand different opinions and visions concerning MIS development modes. Firstly, this study described the changes of co-author community structures in MIS articles, tried to know about development mode in MIS research in past 31 years. Because when nodes and links exceeded 100 in network, difference in network complexity in

reality was unable to be identified by structural graph. Structural indices mentioned above could be used for easy identification.

Moreover, this study shifted knowledge about co-author network into a wider scope of analyzing MIS research issues, through analyzing network structural characteristics, to discuss issue/keyword network formed in keyword categories in articles, thus, provided dimensions of research issues generated by keywords categories, understood structural forms and structural changes of MIS research subjects appearing in different domains/subjects within 31 years, with the expectation to provide holistic and integrative understanding of knowledge development about MIS research community.

This study discussed whether information management field had small world network clustered phenomenon. Compared with disciplines with long history that already completed similar research, was there a significant difference on structures? Thus, these two structural indices were used to discuss the structural difference of author community in whole discipline and structural differences among different categories within such discipline that was specifically referred to information management in the past 30 years. Through structural comparison and description, it did not only provide a broadened understanding of structures and veins in whole disciplines, but also provided other scholars in different disciplines understanding of information management research development and a map of collaboration modes.

3. Research methods

To understand MIS collaboration network and knowledge development, this study took information management literatures published previously as analysis objects, and conducted social network analysis on these literatures. In this section, research steps and methods, including data collection, data construction and keyword classification, were introduced.

3.1 Data collection

Due to rapid development of IT industry and demands for IT industry, as well as rapid growth of information management research, this study believed there is a necessity to discuss development patterns of MIS research, thus, chosen journals in MIS field as research objects. According to ranking survey made on information management journals in the past (Gillenson and Stutz, 1991; Katerattanakul et al., 2003; Peffers and Ya, 2003; Lowry et al., 2004; Saunders, 2005), it found some representative journals in information management discipline such as *MIS Quarterly* (*MISQ*), *Journal of Management Information Systems* (*JMIS*), *Journal of the Association for Information*

Systems (*JAIS*), *Information Systems Research* (*ISR*) and *Decision Support Systems* (*DSS*). Due to our limited resources, we only picked up *MISQ* journal as research object. We collected articles published in *MISQ* from 1977 to 2007, totally covering 738 articles and 1012 authors. Collected data included article title, author, keyword, publication date and abstract. Though only *MISQ* journal taken as research object, as a leading role in MIS research journals, its application into this explorative research to discuss patterns of MIS literatures should be representative.

3.2 Classification of keywords

To create consistent keywords from resembled ones, this study was based on one keyword classification table issued by Barki et al. (1988) in *MIS Quarterly* as classification framework. In their study, keywords in information management study were classified into reference discipline (A), external environment (B), information technology (C), organizational environment (D), information system (IS) management (E), IS development and operations (F), IS Usage (G), information systems (H) and IS education and research (I), many sub-domains divided under these nine categories. Later on, Barki et al. (1993) modified this framework but there was basically the same. In recent years, research about information management issues classification also adopted this classification framework, e.g. Alavi and Carlson's (1992) analysis was based on this framework.

Among 738 articles published in *MISQ* journal from 1977 to December, 2007, 29 articles didn't involve keyword codes, mainly discussing responses of published papers. Regarding to collected keywords, for 29 articles providing no keywords by the author, the coders didn't add any keyword for these articles by themselves. Considering the number of such articles should not affect analysis of overall tendency, among 709 articles deducted, it acquired totally 3,670 keywords involving authors, 2,275 for non-repeated keywords.

Among organizing captured keywords, if deducted keywords in singular and plural forms that obviously repeated, e.g. impact and impacts; semicolon(-), e.g. Decision Making and Decision-Making; phases using adjective and noun meaning the same, e.g. Organizational change and Organization change and abbreviations like IS and Information System(s), such repeated keywords were identified as 93, thus 2,182 non-repeated keywords were left. Among these keywords, 461 phases were totally conforming to code phases in *MISQ* journal, after deduction, 1,721 phases were left, requiring manual identification and classification. Furthermore, among 188 articles collected from issue 3, volume 8 in 1994 to issue 3, volume 27 in 2003 of published articles in *MISQ* journal, original coders provided 786 codes corresponding to *MISQ* codes among 848 keywords contained in 153 articles; it also included 374 different codes. In the rest 35 articles, 5 articles didn't have keywords, so 156 keywords provided in 30 articles together with keywords of articles issued in other date adopt were coded manually.

This article made keywords in *MISQ* articles coded manually by following triangulation coding. Firstly, invited experts in information management discipline to conduct coding work independently, to classify each keyword into one code in the classification framework. One article may be classified into several categories. Sometimes, if the same keyword was applied into different articles, it may be presented in different domains, e.g. database design may represent CB06 in software category in C category under computer science issue. However, the same keyword may appear as FB0401 in system design category in F category under IS development issue. At this time, classification operators must read abstract and even text to identify which category keyword was belonged to. During classification, if coders can't find suitable codes in the lowest category, they will use code in upper class in order, finally may choose one class from A to I in nine categories.

In order to ensure the reliability of classification work, this research used the inter-rater reliability to test the reliability of classification work and used the Kohen's Kappa coefficient as an index for reliability measurement. Kohen's Kappa coefficient could avoid the coincidence caused by probability factor to evaluate the reliability of two independent coders' coding result (Krippendorff, 1980; Weber, 1985; Liang and Chen, 2005). If the Kappa coefficient is more than 0.8, it means almost perfect agreement, indicating that the two coders' coding results are almost completely the same; if the Kappa coefficient is 0.6-0.8, it means substantial agreement; if the Kappa coefficient is more than 0.5, it means moderate agreement (Landis and Koch, 1977). In this research, the code reliability is 0.520 and the significance level is .000, indicating that the code reliability is within an acceptable range. After confirming that the code reliability is all right, invite a third researcher to reconfirm the keywords of the two coders' different codes, and finally establish the network analysis data based on the codes confirmed by such third researcher.

Codes of original coders in *MISQ* and results of manual coding were combined for use. 3,607 keywords were classified into 710 codes under *MISQ* nine categories. The nine categories in coding list were seen in Table 3. After non-parametric Wilcoxon Signed Ranks Test finishes, Z-value is -2.666 and significance is 0.008 at 2-tailed, indicating there is no significant difference between classification produced by this article and that given by *MISQ*.

With respect to authors collection, though they published articles in only one journal within 30 years, confusion was still incurred because the name of same author was written with middle name initial or not in articles sometimes. In this case, one solution often adopted was to identify the article list of this author to confirm he was the same author by searching his website. Totally 1,012 different authors were covered among 738 articles.

Table 3 *MISQ* Journal Keyword Classification Scheme Summary

Keyword Classification Scheme	MISQ Original Coded Keywords	Keywords Coded by this study	Sub-total
A. Reference Disciplines	248	638	886
B. External Environment	29	95	124
C. Information Technology	14	103	117
D. Organizational Environment	79	212	291
E. IS Management	174	667	841
F. IS Development and Operations	59	438	497
G. IS Usage	60	165	225
H. Information Systems	80	414	494
I. IS Education and Research	43	89	132
Total	786	2821	3607

3.3 Construct analysis network data

This study took social network analysis as analysis tool. Firstly, we analyzed structures of collaboration network and keywords from standpoint of 1-mode, described interactive actions in communities and compare structural changes by social network indices constructed, SNA research and data analysis. After data were collected from *MISQ* journals, this journal was regarded as one social community network. Communities were interconnected with each other due to nodes and ties. Each author was regarded as node in communities. If two authors kept collaboration relationship, a tie will appear in collaboration relationship. Construction of keywords applied the same principle.

Because collected data has spanned 31 years (1977-2007), considering the thorough investigation of co-author statistics and comparison in different keyword domains, this study imitated Moody (2004) to divide data collection into three phases; first phase is 11 years, 10 years for each phase in subsequent two phases. Comparison was made in three phases. Regarding analysis of structural indices, because network structure experiences a cumulative process, to effectively observe change trends of structural indices, we measured network indices accumulated every three years, so as to investigate the structural changes of network structures over time. Because the data quantity was accumulated till 31st year, a network structure cumulated in 31 years rather than in 30 years was applied into measurement of last structure index. As to analysis of network structure, firstly,

	1	2	3	4	5	…
1		1	2	1	1	
2			0	0	0	
3				0	1	
4					3	
5						
…						

Co-Author Linked Matrix

	1	2	3	4	5	…
A	0	1	2	1	1	
B	1	0	0	0	2	
C	1	0	1	0	1	
D	0	0	2	1	1	
E	1	0	1	1	1	
…	1	0	1	1	1	

Author-Keyword Scheme Linked Matrix

Figure 1   Example of Network Relation Matrix Construction

convert co-publication relationship of authors into matrix in network relation, seen in map in left side of following table. Codes of authors were written on titles of different rows and lines, recording the times of co-publication within statistical period in middle table. Because collaboration was direction-free, only triangle data in right upper side of matrix is recorded. When convert authors and keywords into network relation matrix, the title on first line was modified as matrix, in the same way, the times of using keywords in the same class to publish articles by the authors was recorded into data grid.

4. Research results and findings

4.1 Co-MIS research trends

Collaboration network forming was limited by the distribution of articles published by authors and the distribution of number of co-authors in one article. Figure 2 showed the distribution of all articles published in any pattern in *MISQ* from 1977 to 2007 (including articles having single author). In holistic view, with the prolongation of research development, trends of co-publication gradually increased year by year, e.g. its average is 57% in earliest 11 years (1977-1978), and reached 79.6% between 1988 to 1997, and even achieved 88.3% in recent decade (1998-2007). Furthermore, the average percentage of co-publication (excludes single author) within 31 years was 75.1% and the number of authors in each article was averaged 2.13. Within three ten-year's phases, the average is 1.69 in earliest 11 years, 2.27 in next decade, and 2.39 in recent decade, which was equivalent to 2.2 in computer science field. However, it was still lower compared with the average of 2.7 in sociology field from 1989 to 1999 (Moody, 2004) and 8.9 in high-energy physics (Newman, 2001). Seen from the lower number of co-authors in one article, it may reduce the size of clusters possibly formed through collaboration. Therefore, inference may be made that MIS research is still at developing stage in terms of
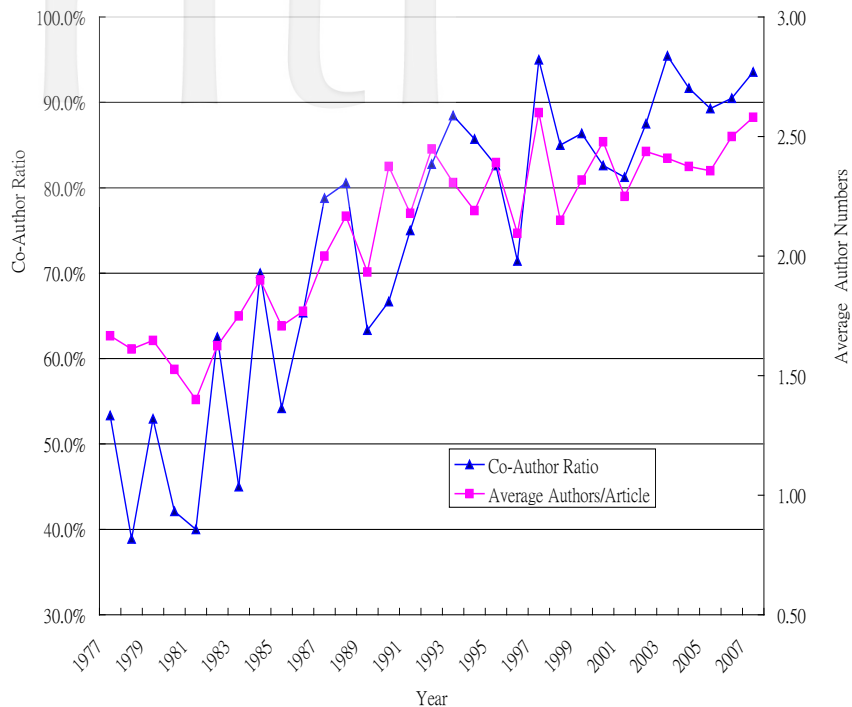
Figure 2 Yearly Average Authors and Co-author Ratio of *MISQ* Journal

integration knowledge; however, collaboration trends and diffusion of domain knowledge were continuously rising.

In Figure 2, "Collaboration Percentage" meant the percentage of articles with two or above authors accounting for overall articles within the year, which was used to calculate the percentage of co-author quantity in C item in Table 4. "Mean Author Quantity" meant average co-author quantity in all articles within the year. Based on data in Figure 2, item statistics was organized in Table 4, which integrated three items trends and their comparisons within three phases' period, with data accumulated 31 years being underlined. Three trends included "Percentage of Article Quantity Published by Authors", "Percentage of Authors in Each Article" and "Percentage of Co-Author Quantity." To benefit indication and description, three items were marked as A, B and C respectively in front side.

Based on results shown in Table 4, for A-Percentage of Article Quantity Published by Authors, 75.1% authors only published one article in *MISQ*, 12.85% authors published two articles. With the increase of article quantity issued by each author, the author quantity sharply reduced. The above trend was also seen similar case in each phase within three decades. It may expect that authors with more articles accumulated within 31 years.

Table 4 Distributions of Author and Co-Author in *MISQ* Journal

Period/ Count	A- Ratio of each author's article counts				B- Ratio of each article's author counts				C- Ratio of Co-Author articles			
	1977-1987	1988-1997	1998-2007	1977-2007	1977-1987	1988-1997	1998-2007	1977-2007	1977-1987	1988-1997	1998-2007	1977-2007
0	-	-	-	-	-	-	-	-	24.12%	7.69%	4.18%	9.78%
1	82.32%	78.55%	78.42%	75.10%	43.22%	21.32%	11.07%	24.93%	41.48%	34.97%	33.41%	34.09%
2	11.25%	12.59%	14.62%	12.85%	54.66%	70.54%	77.46%	67.75%	20.58%	25.87%	28.54%	25.79%
3	4.18%	5.59%	4.18%	5.73%	1.27%	6.20%	9.43%	5.69%	6.75%	12.59%	16.71%	13.34%
4	0.96%	1.63%	1.16%	2.57%	0.42%	1.55%	2.05%	1.36%	3.86%	9.09%	7.42%	8.60%
5	0.32%	1.40%	0.46%	1.68%	0.42%	0.39%	0.00%	0.27%	2.57%	3.50%	4.18%	3.06%
6	0.32%	0.00%	0.70%	0.99%	0.00%	0.00%	0.00%	0.00%	0.00%	3.03%	1.62%	1.09%
7	0.00%	0.23%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%	1.39%	1.09%
8	0.64%	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%	0.93%	0.79%
9+	0.00%	0.00%	**0.46%**	0.79%	0.00%	0.00%	0.00%	0.00%	0.64%	1.40%	1.62%	2.37%
N	311	429	431	1012	236	258	244	738	311	429	431	1012

However, in recent decade (1997-2007), the percentage of authors publishing more than 9 articles greatly rose, so an inclination that start authors gather and cooperate into study may appear. This trend can be validated by conforming to network structure of power law distribution.

As to B-Percentage of Authors in Each Article, 25% articles only had one author, 68% articles had two authors, showing that co-publication by two authors was dominant in *MISQ* articles published and gradually rose over time. The same trend was also seen in co-publication by more than three authors, which gradually increased with knowledge accumulation and development of study. If compared with C-Percentage of Co-Author Quantity, at initial stage of MIS development (1977-1987), the percentage of single author (24.1%) plus two authors (41.48%) in co-publication had exceeds 65%; in next decade (1988), the trend that author worked with others starts growing, collaboration team by two authors maintains 1/3 at most. However, the publication of single author obviously decreased and spread into other fields where the number of co-authors was large. It showed collaboration research and discipline knowledge were constantly developing and diffusing.

4.2 Research keywords classification/development of theme sub-domains and analysis of collaboration research

The list of co-author statistical distribution under keywords of articles and second tier of *MISQ* keywords classification within three decades was seen in Table 5. First and second row symbolized classification code and representative keyword in second tier of MISQ keywords; 64 sub-domains were listed totally under (AZ), (BZ), (CZ), (DZ),(EZ), (FZ), (GZ), (HZ) and (IZ). Because when keyword classification was coded, no corresponding classification codes were found in categories below second tier in original *MISQ* classification codes. So, we classified keyword into first tier in (A-I) according to abstract of articles. For example, "Online Use" had no proper sub-domain in original code (G, Computer Usage), so it was classified into code (G). However, to avoid calculation problem of upper-hierarchy and subordinate-hierarchy in below table, code (#Z) was uniformly applied to each problematical case. Thus, keywords below #Z code may be keywords depending on overall sub-domains at initial stage or those in need of adding sub-domain codes under #Z code or represent the quantity of articles possibly applied to develop into new sub-domains.

Third line in the table showed articles within 31 years that are described by three phrases and summed according to keywords listed by authors, listing figure and percentage in each sub-domain. The times of a certain keyword occurring in specific category were braced, with the percentage of such keyword in relative to total keywords within one decade next to it. Because this table took keywords in second tier as statistical

basis, if multiple keywords belonging to third tier appeared in second tier for one article, it was limited by calculating once keywords codes in second tier in the article, avoiding repeated calculation of times article appearing in the classification, thus benchmark in sum was 2720, lower than original keyword quantity. Because limitations by table size and convenience for demonstration, three phases were shown by P1 (77-87), P2 (88-97) and P3 (98-07) respectively.

Forth line calculated percentage changes of specific keyword within three ten-year period, indicating that the percentage of such keyword accounting for overall keywords from P1 to P2 and from P2 to P3 increases or decreases. Fifth line showed the percentage of articles with more than two authors who used specific keyword within 31 years, calculating in current category, the percentage of articles with two or above authors using such keyword. Sixth line compared trends of co-publication article from P1 to P2 and from P2 to P3. Furthermore, categories and figures mentioned in following paragraphs were marked in bold in the table for the convenience of comparative reading. Discussion of development trends in each category are described as follows.

4.2.1 Development of reference domain

Firstly, (A) class was the code of discipline in reference domain of research, appearing at highest percentage among overall articles. As to sub-domains under (A) class, Research (AI) was definitely listed on top, because a majority of authors often marked research methods, framework, mode and statistical methods as keywords. The ranks following by management theory (AF), behavior science (AA) and decision science far ahead from information theory were listed on fifth position. Only 4 keywords involved development of new sub-domain.

When analyzing growth of the number of published articles within three ten-year period, the articles occupying fastest growth in each phase (in relative to total number in the same phase) were classified into research class. Subsequent rankings showed focus shifts in research sub-domains. From P1 to P2, the second highest in growth ratio is information theory (AD), followed by artificial intelligence (AL); from P2 to P3, the second highest in growth ratio is decision science (AC) followed by behavior science (AA). But management theory (AF) shows negative growth in each phase.

Regardless of the quantity of articles published or co-author trends, more efforts should be paid to develop application and discussion on relevant theory in more complex environment, e.g. politics, sociology and ecology. Additionally, there were 4 keywords in AZ in total, indicating that reference discipline domains add in limited way or codes in original domain are already complete. As for ratio of co-authors, deleting the ratio involving too few authors, it was evenly distributed in the whole. Within three phases, collaboration study growth is conforming to quantity growth.

4.2.2 Domains with steady growth

After understanding the trends and changes of theoretical framework of reference disciplines used, we reviewed the subjects in sustainable and steady domains in whole study. Firstly, (E) category in IS management issues was close to (A) category, with keywords used at most. There were 13 sub-domains in (E) category, making it become second largest domain next to (A) category. Under (E) category, the top three sub-domains were sequenced as: IS evaluation (EI), IS plan (EF), IS management issue (EL). IS evaluation (EI) issues grew steadily in first two decades, though fallen down in recent decade, and still ranked on top in sub-domains. The development trends of this issue should be gradually convergent whereas have continuously outputs in some periods. IS plan (EF) issue dropt down in terms of article quantity and collaboration research trend, indicating relevant issues had limited space in development. In the opposite, IS management issue (EL) showed steady growth in terms of article quantity and collaboration research trend.

Category (H) involved study on information system categories and object-related issues, second only to category (E) and category (F). Due to increase of system application category, relevant issues and collaboration research trend in category (H) show constant growth. Sub-domain (HA) categories of Information system took priority over other sub-domains under category (H), e.g. transaction system, Email system, MIS system and DSS system. Almost keywords were derived from MIS system and DSS system from 1977 to 1987, whereas, tended to be evenly distributed in recent decade. Though research in such sub-domain tends to decrease, its productivity was substantial in recent decade. Under application system (HB) sub-domain being industry-specific, the second largest in (H), e.g. financial system, marketing system and production system, showed gradual rise in terms of article quantity and collaboration research tend in each decade. It should attribute to increase and development of profound application issues following specialization of application characteristics in information system industry, meanwhile, call for professional talents introduced for the purpose of collaboration.

4.2.3 Domains with gradual slow-down

As the second largest domain in aspect of research quantity in the past, category (F) surrounded software and application system development issues. In holistic view, system development issue (F) showed decrease both in article growth and co-author research trend. Its research articles were accumulated in first decade, and the number of overall application system development (FZ) was cumulative in early period by applying keywords, thus the same for IS management (EZ). That is to say, development methods and methodologies research in information system development domain have been matured.

Category (G) was the forth research issue, discussing categories of computer application. There is a small gap between organizational use of IS (GA) and IS user (GB). When correspond these two sub-domains to those under A category-reference citation fields, it can reflect theoretical basis sources and issue directions discussed in the past research. However, the growth tend of article quantity and the ratio of knowledge diffusion under co-author research both develops slowly within three phases, among them, decrease of organizational use of IS (GA) is higher than IS user (GB), particularly shown in trend of author collaboration.

Under category (C) -- computer science (technology), its ratio in relative to overall ratio is only about 3.4%, listed in the last three sub-domains together with BZ (external environment) and information education and research (IZ) among all sub-domains. Category (C) grows negatively in three phases. The ratio of co-author slows down in hardware (CA) and decreases in software (CB), showing that information management issues are gradually separated from information technology development issue.

4.2.4 Domains with gradual growth

Under category (G), computer usage (GZ) adds new categories of usages, particularly in recent decade, the development of new issues and author collaboration grew more significantly, which indicated that computer usage will pose new research issue direction and space.

Category (I) was related to information education and information management research issues. Research issues organized in this study into Table 1 were classified into sub-domain information research (IB), covering most keywords under articles in this category. Information management research framework and mode belong to this sub-domain. Though the research ratio decreased from phase1 to phase 2 in relative to that in whole phases, in recent decade, the number and phase ratio in this research issue multiplies greatly; the ratio of co-author research was higher than that in whole MIS ratio. In different phases, compared with that of first two phases, co-author research grew slightly in recent decade. When MIS research accumulated up to a certain level, research issue, field category, strict narration and modes of research methods and discipline orientation could come to the surface.

Category (D) involved environmental issues inside organization, its number second only to the three domains above. Discussion was mainly made on sub-domain organizational dynamics (DD) that grew significantly within one decade. Similarly, collaboration research also increased with historical accumulation. Next to it is Organizational characteristics (DA) sub-domain that increased in its number whereas the increasing tend of co-author research slowed down. Summarizing the growth of keywords

in sub-domains mentioned above that seldom discussed by main-streams, in combination with growth inclination of co-author research, it is expected that issues related to organizational dynamics (DD) and social environment (BD) couldhave constant growth.

4.2.5 Others

Category (B) mainly involved outer environment with a small number, including four sub-domains, among which, studies on social environment (BD) and economic environment (BA) were listed on first and second regardless of sum in whole phases or number in each phase and co-author research ratio, however, growth ratio in social environment studies gradually rose, for economic environment, it gradually slowed down; collaboration research ratio also increased in both sub-domains. There was only 1 keyword in BZ, its research quantity and growth tends smaller than those of other sub-domains.

Another issue field worthy of discussion was IS management (EZ), its quantity equivalent to that of IS plan (EF), mainly appears in early phase. After investigation one by one, the number of keywords in EZ mainly appeared in early phase of study, differing from other domains that are classified with keywords due to emergence of new issues. In early phase of study, because many articles directly applied MIS and IS management as keywords equivalent to those under category (E), they were classified into domain (E). Therefore, in early phase of study, MIS was regarded as one keyword in holistic concept, and gradually produced depth and width of discipline through development and diffusion.

4.3 Clustering characteristics in collaboration research network structures

4.3.1. Investigation of Small-World network

This study applied cluster coefficient and average path distance proposed by Watts (1999) to measure Small-World network as two indices and identify whether small-world exists in collaboration network.

Because dimensions of network world was a relativity comparison, this study imitated Moody (2004) and Newman (2001) to compare randomized network produced by nodes and links equivalent to those in network in each phase in *MISQ*. Following procedures advocated by Pajek 1.24 version (Batagelj and Mrvar, 2006), this study input identical nodes and links into system that produces link network (if the number of authors is cumulative up to 231 in 1985, the number of collaboration links will be 148). Then measured CC and APL value in random network and compared such values with measurement indices produced in *MISQ* author network in reality. Comparing differences on cluster coefficient and average route distance with randomized control network, the degree of small-world in *MISQ* author network could be demonstrated, results shown in Table 6. Table 6 divided 31 years into 10 phases (1977-2007), three years taken as one

Table 5 The Growth Rate of Co-Author by the Second Level Keyword Scheme

2nd Keyword Scheme	Domain of the Keyword Scheme	(Counts) Ratio of 2nd level keyword scheme				Among periods Growth Ratio		Co-author ratio	Co-author growth ratio	
		77-87(P1)	88-97(P2)	98-07(P3)	77-07	P1-P2	P2-P3		P1-P2	P2-P3
	Subtotal of each period	**846**	**907**	**967**	**2720**	**-**		**75.48**	**-**	
AA	Behavioral science	(25) 2.96%	(30) 3.31%	(58) 6.00%	**(113) 4.15%**	**0.35%**	**2.69%**	**80.53%**	N/A*	**8.40%**
AB	Computer science	(0) 0.00%	(1) 0.11%	(1) 0.10%	(2) 0.07%	0.11%	-0.01%	100.00%	0.27%	0.00%
AC	Decision sciences	(16) 1.89%	(18) 1.98%	(47) 4.86%	**(81) 2.98%**	**0.09%**	**2.88%**	**81.48%**	1.36%	**7.05%**
AD	Information theory	(8) 0.95%	(18) 1.98%	(20) 2.07%	(46) 1.69%	**1.04%**	**0.08%**	**67.39%**	**2.45%**	0.27%
AE	Organizational environment	(3) 0.35%	(1) 0.11%	(7) 0.72%	(11) 0.40%	-0.24%	0.61%	81.82%	0.00%	1.63%
AF	Management theory	(57) 6.74%	(41) 4.52%	(43) 4.45%	**(141) 5.18%**	**-2.22%**	**-0.07%**	**80.85%**	-1.63%	0.81%
AG	Language theories	(1) 0.12%	(0) 0.00%	(0) 0.00%	(1) 0.04%	-0.12%	0.00%	0.00%	0.00%	0.00%
AH	Systems theory	(4) 0.47%	(2) 0.22%	(5) 0.52%	(11) 0.40%	-0.25%	0.30%	72.73%	-0.27%	1.08%
AI	Research	(16) 1.89%	(48) 5.29%	(81) 8.38%	**(145) 5.33%**	**3.40%**	**3.08%**	**83.45%**	**6.52%**	**9.21%**
AJ	Social science	(1) 0.12%	(6) 0.66%	(14) 1.45%	(21) 0.77%	0.54%	0.79%	80.95%	1.63%	1.36%
AK	Management science	(8) 0.95%	(3) 0.33%	(5) 0.52%	(16) 0.59%	-0.61%	0.19%	81.25%	-1.09%	0.81%
AL	Artificial intelligence	(2) 0.24%	(9) 0.99%	(9) 0.93%	(20) 0.74%	**0.76%**	**-0.06%**	80.00%	1.36%	0.00%
AM	Economic theory	(2) 0.24%	(5) 0.55%	(15) 1.55%	(22) 0.81%	0.31%	1.00%	86.36%	1.09%	2.17%
AN	Ergonomics	(0) 0.00%	(1) 0.11%	(0) 0.00%	(1) 0.04%	0.11%	-0.11%	100.00%	0.27%	-0.27%
AO	Political environment	(0) 0.00%	(3) 0.33%	(1) 0.10%	(4) 0.15%	0.33%	-0.23%	75.00%	0.54%	-0.27%
AP	Psychology	(0) 0.00%	(5) 0.55%	(4) 0.41%	(9) 0.33%	0.55%	-0.14%	77.78%	1.09%	-0.27%

* The code is added at the succeed period, so no ratio is available.

Table 5 The Growth Rate of Co-Author by the Second Level Keyword Scheme (conti.)

2nd Keyword Scheme	Domain of the Keyword Scheme	(Counts) Ratio of 2nd level keyword scheme				Among periods Growth Ratio		Co-author ratio	Co-author growth ratio	
		77-87(P1)	88-97(P2)	98-07(P3)	77-07	P1-P2	P2-P3		P1-P2	P2-P3
Subtotal of each period		846	907	967	2720	-		75.48	-	0.54%
AZ	Reference disciplines	(1) 0.12%	(0) 0.00%	(3) 0.31%	(4) 0.15%	-0.12%	0.31%	75.00%	-0.27%	0.54%
BA	Economic environment	(4) 0.47%	(14) 1.54%	(15) 1.55%	(33) 1.21%	1.07%	0.01%	78.79%	2.17%	1.08%
BB	Legal environment	(0) 0.00%	(4) 0.44%	(5) 0.52%	(9) 0.33%	0.44%	0.08%	100.00%	1.09%	0.27%
BC	Political environment	(2) 0.24%	(5) 0.55%	(3) 0.31%	(10) 0.37%	0.31%	-0.24%	80.00%	1.36%	-0.54%
BD	Social environment	(5) 0.59%	(11) 1.21%	(26) 2.69%	(42) 1.54%	0.62%	1.48%	76.19%	1.90%	4.07%
BZ	External environment	(0) 0.00%	(1) 0.11%	(0) 0.00%	(1) 0.04%	0.11%	-0.11%	0.00%	0.00%	0.00%
CA	Computer systems (Hardware)	(15) 1.77%	(14) 1.54%	(13) 1.34%	(42) 1.54%	-0.23%	-0.20%	69.05%	1.36%	0.27%
CB	Software	(15) 1.77%	(13) 1.43%	(10) 1.03%	(38) 1.40%	-0.34%	-0.40%	71.05%	1.09%	-0.54%
CZ	Computer science	(4) 0.47%	(6) 0.66%	(3) 0.31%	(13) 0.48%	0.19%	-0.35%	84.62%	0.54%	-0.54%
DA	Organizational characteristics	(11) 1.30%	(24) 2.65%	(28) 2.90%	(63) 2.32%	1.35%	0.25%	77.78%	3.26%	1.90%
DB	Organizational departments	(10) 1.18%	(15) 1.65%	(12) 1.24%	(37) 1.36%	0.47%	-0.41%	67.57%	1.63%	0.27%
DC	Job characteristics	(10) 1.18%	(3) 0.33%	(19) 1.96%	(32) 1.18%	-0.85%	1.63%	78.13%	-1.09%	4.07%
DD	Organizational dynamics	(16) 1.89%	(26) 2.87%	(48) 4.96%	(90) 3.31%	0.98%	2.10%	74.44%	3.53%	6.23%

Table 5 The Growth Rate of Co-Author by the Second Level Keyword Scheme (conti.)

2nd Keyword Scheme	Domain of the Keyword Scheme	(Counts) Ratio of 2nd level keyword scheme				Among periods Growth Ratio		Co-author ratio	Co-author growth ratio	
		77-87(P1)	88-97(P2)	98-07(P3)	77-07	P1-P2	P2-P3		P1-P2	P2-P3
	Subtotal of each period	846	907	967	2720	-		75.48	-	
DZ	Office environment	(4) 0.47%	(2) 0.22%	(1) 0.10%	(7) 0.26%	-0.25%	-0.12%	57.14%	-0.27%	0.00%
EA	Data administration	(6) 0.71%	(3) 0.33%	(2) 0.21%	(11) 0.40%	-0.38%	-0.12%	54.55%	0.00%	0.00%
EB	Human resource management	(1) 0.12%	(4) 0.44%	(2) 0.21%	(7) 0.26%	0.32%	-0.23%	85.71%	1.09%	-0.54%
EC	Computer management	(0) 0.00%	(2) 0.22%	(2) 0.21%	(4) 0.15%	0.22%	-0.01%	100.00%	0.54%	0.00%
ED	Software management	(1) 0.12%	(3) 0.33%	(3) 0.31%	(7) 0.26%	0.21%	-0.02%	57.14%	0.54%	0.00%
EE	IS project management	(16) 1.89%	(17) 1.87%	(16) 1.65%	(49) 1.80%	-0.02%	-0.22%	75.51%	1.09%	0.54%
EF	IS planning	(32) 3.78%	(31) 3.42%	(28) 2.90%	(91) 3.35%	-0.36%	-0.52%	69.23%	1.63%	0.00%
EG	Information infrastructure	(25) 2.96%	(14) 1.54%	(12) 1.24%	(51) 1.88%	-1.41%	-0.30%	74.51%	-1.09%	-0.54%
EH	IS staffing	(18) 2.13%	(23) 2.54%	(14) 1.45%	(55) 2.02%	0.41%	-1.09%	80.00%	2.45%	-2.71%
EI	IS evaluation	(52) 6.15%	(62) 6.84%	(55) 5.69%	(169) 6.21%	0.69%	-1.15%	72.78%	4.62%	1.36%
EJ	IS control	(12) 1.42%	(6) 0.66%	(4) 0.41%	(22) 0.81%	-0.76%	-0.25%	63.64%	-0.54%	0.00%
EK	IS security	(4) 0.47%	(4) 0.44%	(3) 0.31%	(11) 0.40%	-0.03%	-0.13%	81.82%	0.54%	-0.27%
EL	IS management issues	(14) 1.65%	(25) 2.76%	(37) 3.83%	(76) 2.79%	1.10%	1.07%	75.00%	2.99%	2.17%
EZ	Administration of IS	(37) 4.37%	(31) 3.42%	(8) 0.83%	(76) 2.79%	-0.96%	-2.59%	72.37%	1.09%	-5.15%

Table 5 The Growth Rate of Co-Author by the Second Level Keyword Scheme (conti.)

2nd Keyword Scheme	Domain of the Keyword Scheme	(Counts) Ratio of 2nd level keyword scheme				Among periods Growth Ratio		Co-author ratio	Co-author growth ratio	
		77-87(P1)	88-97(P2)	98-07(P3)	77-07	P1-P2	P2-P3		P1-P2	P2-P3
Subtotal of each period		**846**	**907**	**967**	**2720**	**-**		**75.48**	**-**	
FA	IS development approaches	(15) 1.77%	(12) 1.32%	(6) 0.62%	(33) 1.21%	-0.45%	-0.70%	72.73%	0.27%	-1.36%
FB	Development process life cycle	(76) 8.98%	(32) 3.53%	(22) 2.28%	**(130) 4.78%**	-5.46%	-1.25%	67.69%	-4.08%	-2.17%
FC	Analysis techniques	(19) 2.25%	(11) 1.21%	(8) 0.83%	(38) 1.40%	-1.03%	-0.39%	68.42%	0.00%	-0.27%
FD	Computer systems implementation	(28) 3.31%	(45) 4.96%	(19) 1.96%	**(92) 3.38%**	1.65%	-3.00%	71.74%	6.52%	-6.50%
FE	IS operations	(10) 1.18%	(2) 0.22%	(4) 0.41%	(16) 0.59%	-0.96%	0.19%	62.50%	-1.63%	1.08%
FZ	Applications development	(39) 4.61%	(18) 1.98%	(10) 1.03%	(67) 2.46%	-2.63%	-0.95%	67.16%	-2.72%	-1.08%
GA	Organizational use of IS	(26) 3.07%	(37) 4.08%	(19) 1.96%	(82) 3.01%	1.01%	-2.11%	81.71%	3.53%	-3.52%
GB	Users	(16) 1.89%	(33) 3.64%	(31) 3.21%	(80) 2.94%	1.75%	-0.43%	80.00%	5.43%	0.00%
GC	Type of IS support	(2) 0.24%	(4) 0.44%	(3) 0.31%	(9) 0.33%	0.20%	-0.13%	77.78%	0.82%	-0.54%
GE	Type of processing	(3) 0.35%	(0) 0.00%	(3) 0.31%	(6) 0.22%	-0.35%	0.31%	83.33%	-0.54%	0.81%
GZ	Computer usage	(1) 0.12%	(2) 0.22%	(9) 0.93%	(12) 0.44%	0.10%	0.71%	75.00%	0.27%	1.90%
HA	Types of Information Systems	(71) 8.39%	(76) 8.38%	(59) 6.10%	**(206) 7.57%**	-0.01%	-2.28%	71.84%	4.62%	-2.44%
HB	Applications programs	(17) 2.01%	(20) 2.21%	(30) 3.10%	**(67) 2.46%**	0.20%	0.90%	73.13%	2.17%	2.44%

Table 5 The Growth Rate of Co-Author by the Second Level Keyword Scheme (conti.)

2nd Keyword Scheme	Domain of the Keyword Scheme	(Counts) Ratio of 2nd level keyword scheme				Among periods Growth Ratio		Co-author ratio	Co-author growth ratio	
		77-87(P1)	88-97(P2)	98-07(P3)	77-07	P1-P2	P2-P3		P1-P2	P2-P3
	Subtotal of each period	846	907	967	2720	-		75.48	-	
HC	Components of IS	(12) 1.42%	(11) 1.21%	(10) 1.03%	(33) 1.21%	-0.21%	-0.18%	87.88%	0.82%	-0.27%
HD	IS characteristics	(8) 0.95%	(9) 0.99%	(13) 1.34%	(30) 1.10%	0.05%	0.35%	80.00%	0.27%	1.08%
HZ	Information systems	(23) 2.72%	(6) 0.66%	(5) 0.52%	(34) 1.25%	-2.06%	-0.14%	67.65%	-2.99%	0.00%
IA	IS education	(1) 0.12%	(11) 1.21%	(2) 0.21%	(14) 0.51%	1.09%	-1.01%	92.86%	2.45%	-2.17%
IB	IS research	(15) 1.77%	(15) 1.65%	(28) 2.90%	(58) 2.13%	-0.12%	1.24%	84.48%	-0.54%	3.79%
IC	IS professional societies	(1) 0.12%	(1) 0.11%	(1) 0.10%	(3) 0.11%	-0.01%	-0.01%	100.00%	0.00%	0.00%
ID	History of IS	(5) 0.59%	(7) 0.77%	(3) 0.31%	(15) 0.55%	0.18%	-0.46%	66.67%	1.09%	-1.08%
IZ	IS Education and Research	(0) 0.00%	(1) 0.11%	(0) 0.00%	(1) 0.04%	0.11%	-0.11%	100.00%	0.27%	-0.27%

phase, four years in last phase, to understand development process of network structures from beginning to 2007 in whole network.

Development of author collaboration structures in *MISQ* articles were divided into three periods, being consistent with that described in section 4.1; first period extended 9 years from 1977 to 1985 covering three phases. In the first phase, APL (Average Route Length) in author collaboration network was far lower than structural value in random network, showing that the number of author collaboration is small (refer to Table 4) and the collaboration link is limited by small fragmented clusters detached to each other with few core authors connected with different collaboration clusters, thus it is different from ordinary small-world. In Figure 3, author collaboration structural graph in 1985 showed that collaboration was possibly based on original author relationship network, may appear at beginning of specific discipline or field development. Second period is next 9 years and collaboration structure was cumulative from 1977 to 1988, from 1988 to1991 and from 1991 to 1994, matching the increase of collaboration ratio in Table 4 in section 4.1. CC and APL values in network structures showed significant rise, indicating that except the number of collaboration authors and the ratio of collaboration network increase, the scope of collaboration clusters appears wide extension. In Figure 4, author collaboration structural graph in 1994 showed that numerous medium and small-scale collaboration networks were produced in network structures and one large-scale core collaboration network forms. Structures in this period demonstrated relationship of research authors starts diversified. Third period referred to the last four phases, with collaboration structures cumulated starting from 1995 and ending in 2007. In this period, compared with last period, CC value in network collaboration structure rose slightly. After 1997, network structures inclined to robust growth. In 1997, APL was close to that of randomized network and equals to CC, showing steady and non-significant changes. Therefore, in each phase of this period, though a large amount of new authors constantly participated in collaboration, its affect on APL and CC is small. Community network researched subsequently strengthened and grew up constantly under original network structures. In Figure 5, it is seen from author collaboration structural graph in 2007 that the large-scale collaboration network forming through accumulation was composed of numerous small and medium cluster networks that are linked by several author points. Collaboration structure in this period was conforming to judgment criteria of Small-World network structures (CC value in network structure is significantly higher than that of random structure whereas APL is larger or closer to that of random structure.) The formation of small-world phenomenon may symbolize gradual cohesion of different domains in concerned discipline.

4.3.2 Power law distribution structure analysis

This study demonstrated graphic distribution by mapping out the relationship

**Table 6** Small-World Indices of Authors in MISQ Journal

Year Range		1977-1979	1977-1982	1977-1985	1977-1988	1977-1991	1977-1994	1977-1997	1977-2000	1977-2003	1977-2007
Cumulated Authors		73	140	231	356	483	590	670	751	817	1012
Ratio of Authors increased		-	91%	65%	54%	36%	22%	14%	12%	9%	24%
Cluster Coefficient	MISQ Author Network	.237	.160	.222	.267	.341	.368	.384	.393	.398	.419
	Random Author Network	.0000	.0000	.0000	.0000	.0029	.0011	.0000	.0005	.0000	.0004
Avg. Path Length	MISQ Author Network	1.167	1.420	1.502	2.065	2.988	4.047	7.701	7.833	7.074	7.144
	Random Author Network	5.431	4.962	11.665	9.562	10.819	8.932	9.062	8.308	8.023	8.146
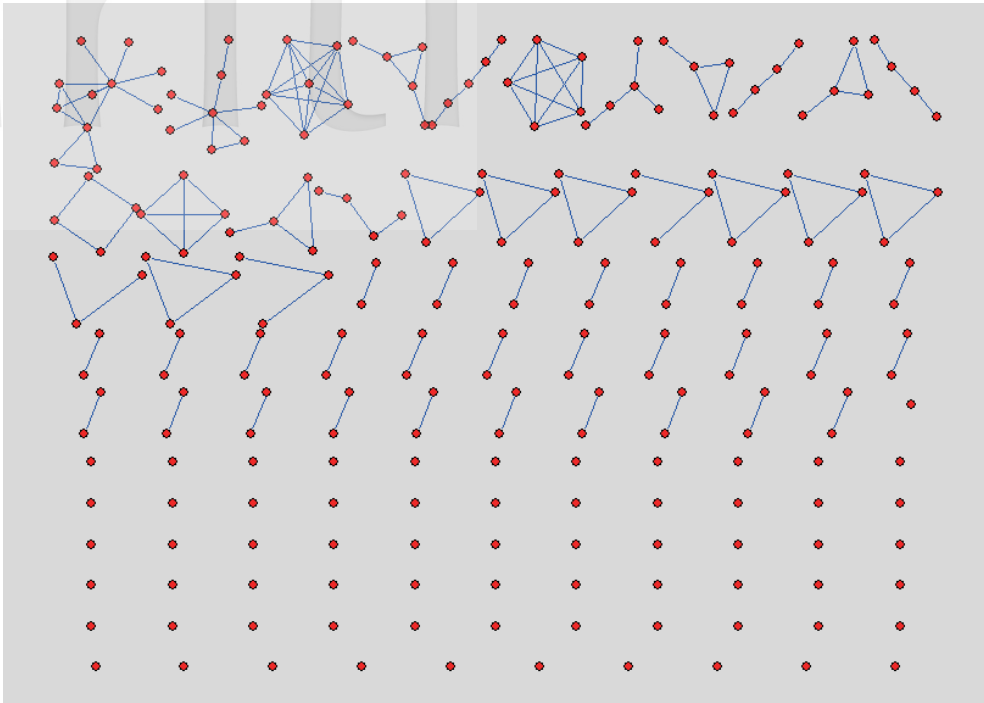
Figure 3   1977-1985 Cumulated Co-Author Network Structure of *MISQ* Journal
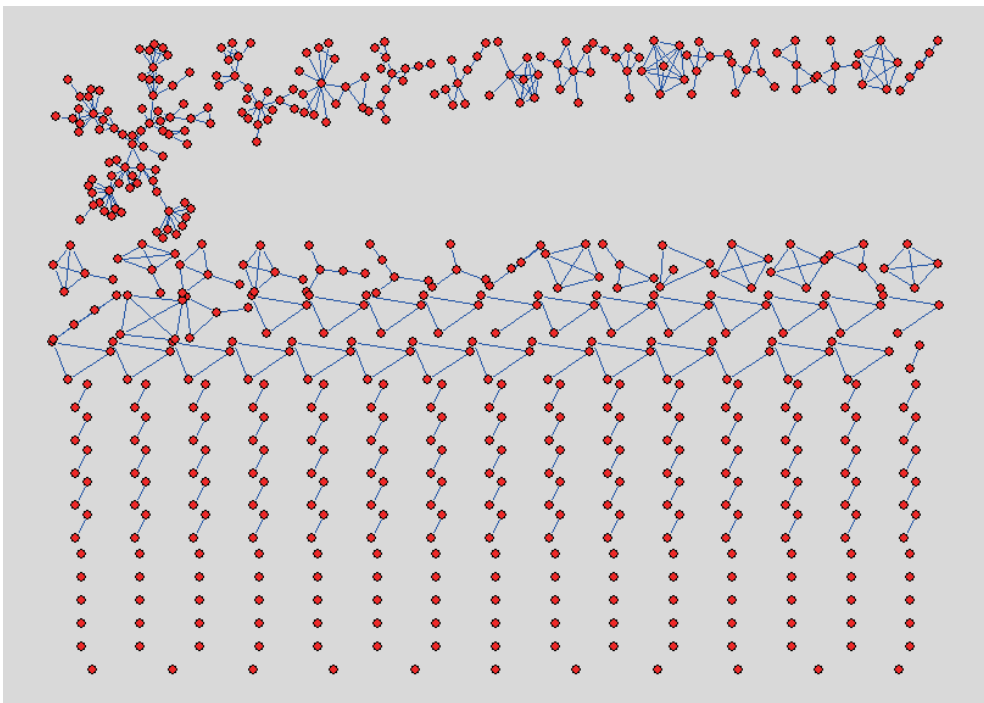
Figure 4   1977-1994 Cumulated Co-Author Network Structure of *MISQ* Journal
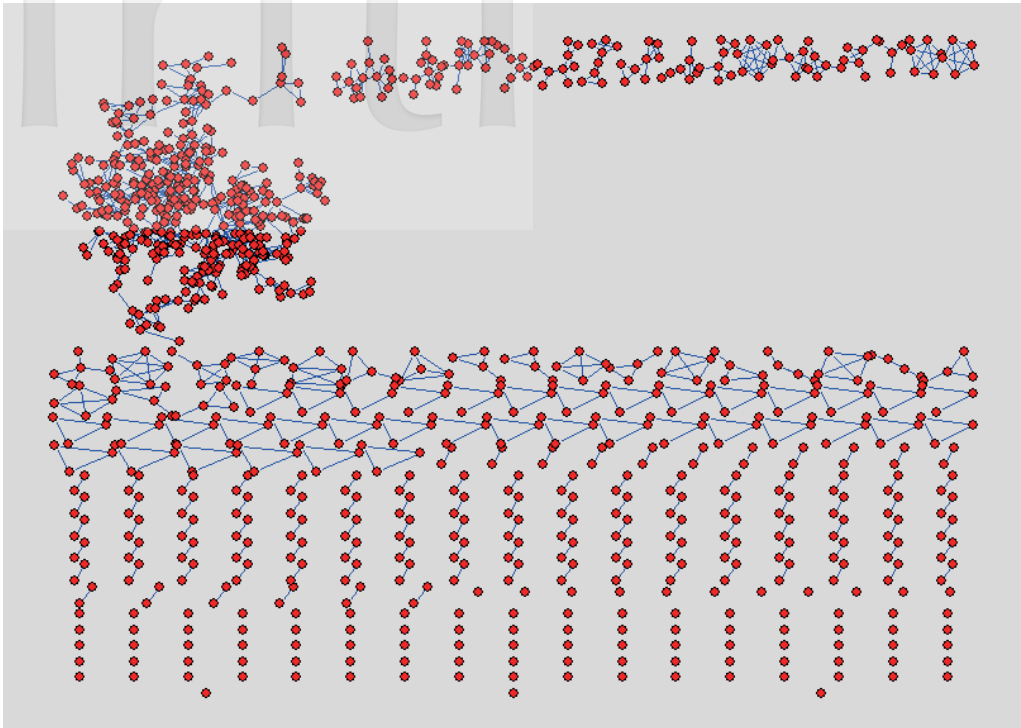
Figure 5 1977-2007 Cumulated Co-Author Network Structure of *MISQ* Journal

between author collaboration quantity and author collaboration ratio, after log-log conversion, verified whether the distribution conforms to linear distribution by adopting regression analysis, and checked whether collaboration research distribution in each phase fits power law distribution or not. That is to say, small-world network structure in *MISQ* authors was formed depending on whether the links of preferential attachment mode to start authors exist or not.

Distribution of *MISQ* author collaboration link networks in reality was seen in Figure 6, where horizontal axis represented the number of collaboration link authors, called the degree in network analysis, and vertical axis referred to the number of authors owning such degree. Because the degree of authors without collaboration is 0, when verifying power law, it needed to conduct log conversion for avoiding mathematical problem. Therefore, all degrees were added with 1 to avoid errors of log conversion. The coordinate used degree+1 to show displacement. Data were demonstrated in the same manner used in small-world network: draw a cumulative distribution map in every three years until 2007, 10 phases in total. Figure 6 showed ten phases developed over time and gradually inclined to curve map of power law distribution. Seen from graphic changes, the inclination to power law distribution was significant after 1985, that is to say, with time accumulation, more and more core link points were produced in networks and these
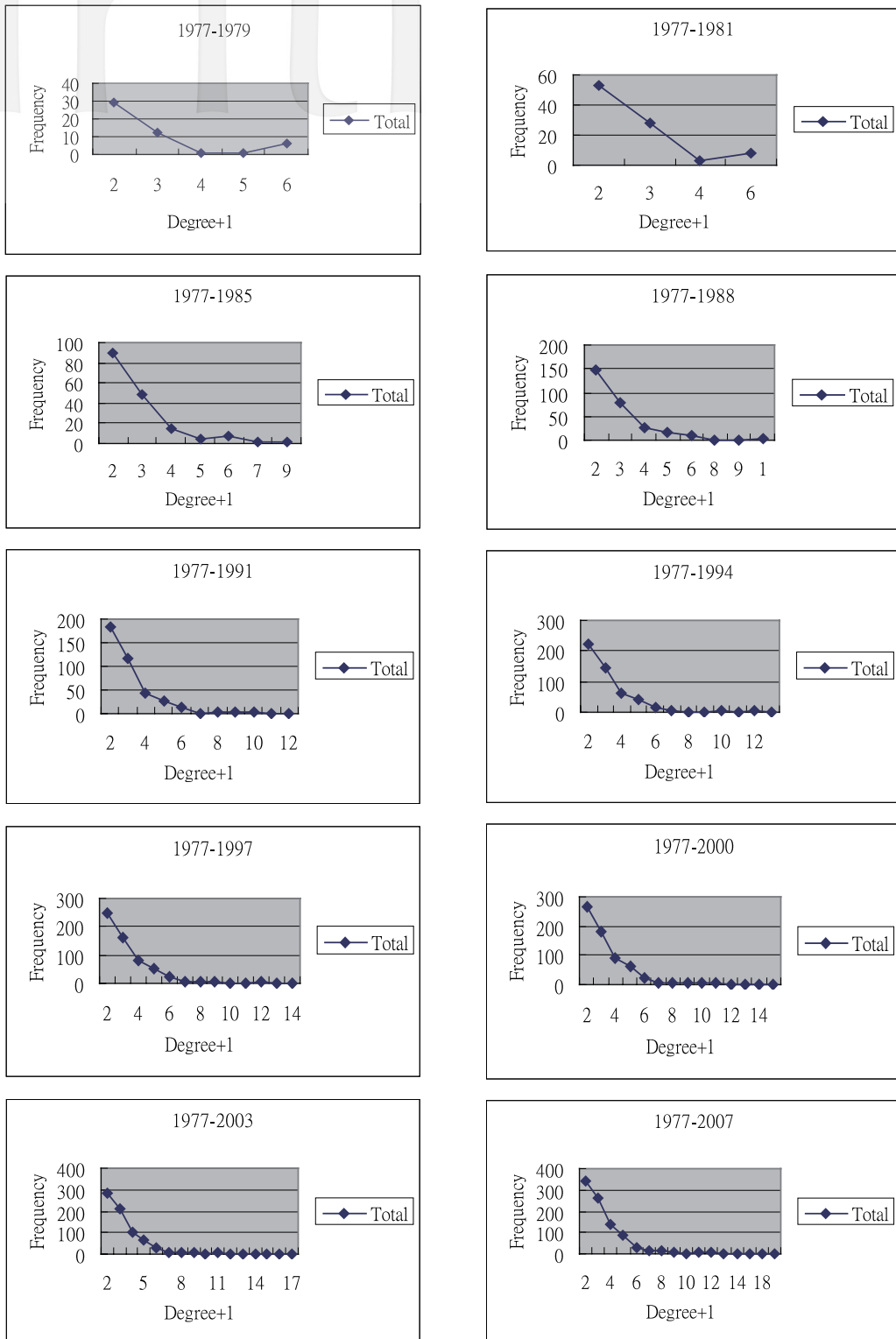
Figure 6 Co-Author Distribution of *MISQ* Journal

MISQ Co-Author Networks

Random Co-Author Networks
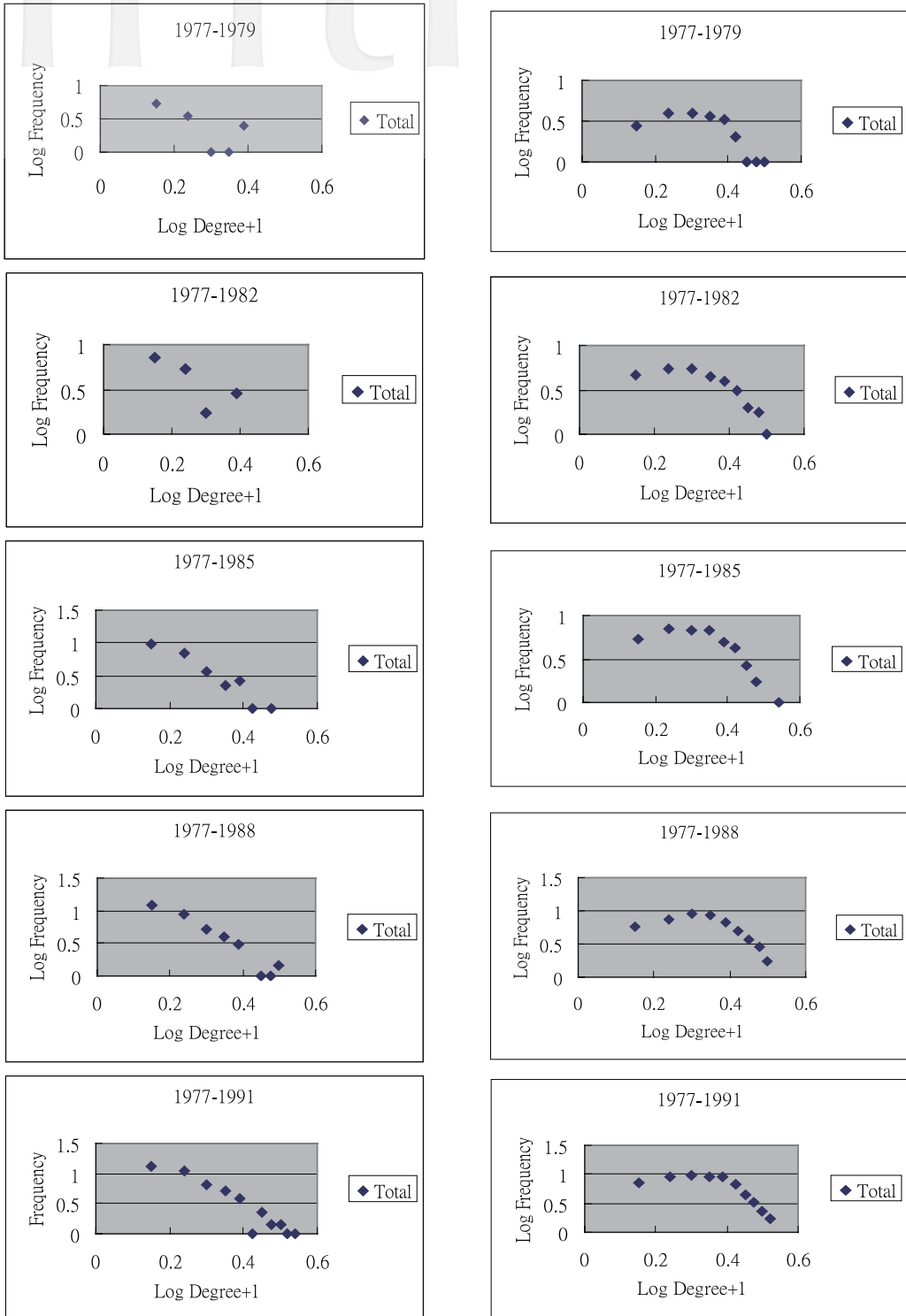
Figure 7   Log-Log (Frequency vs. Degree) Scale of *MISQ* Co-Author Distribution

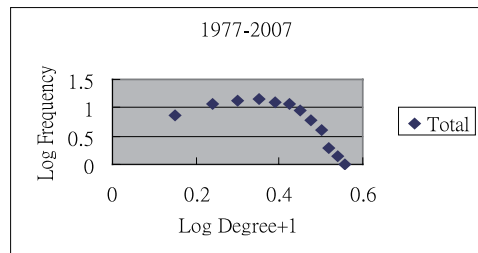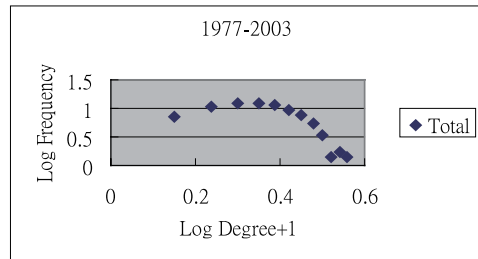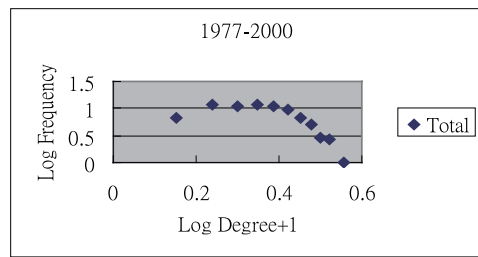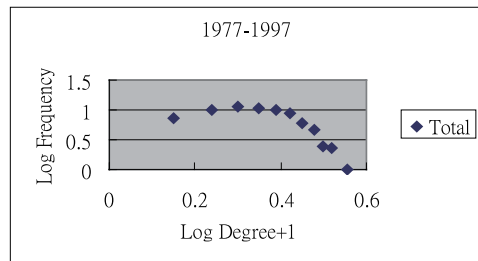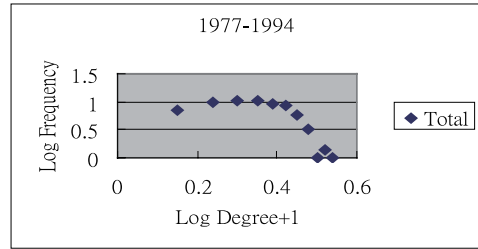MISQ Co-Author Networks
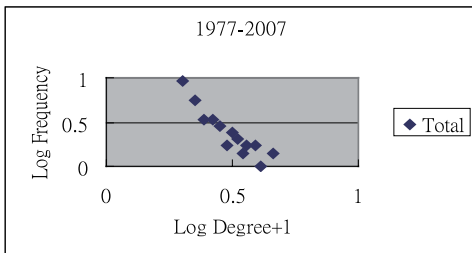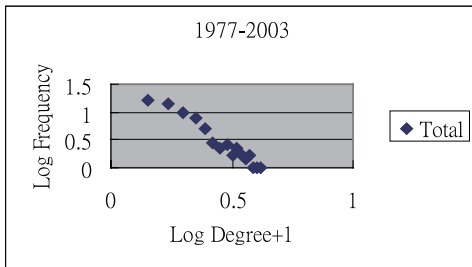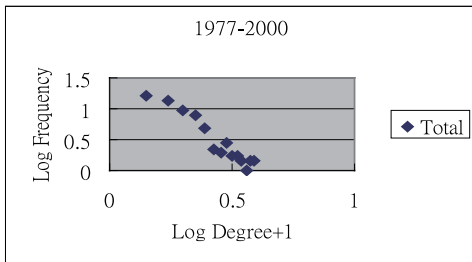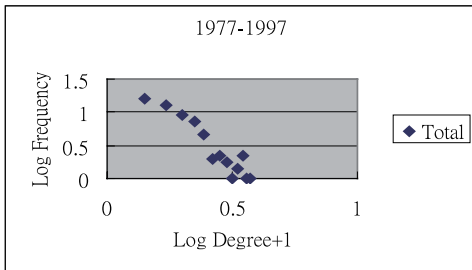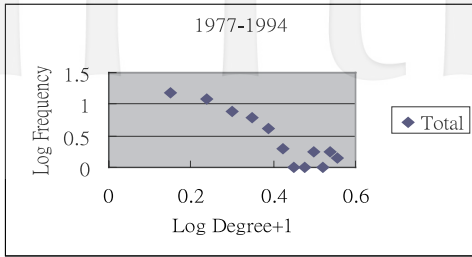
Random Co-Author Networks

Figure 7 Log-Log (Frequency vs. Degree) Scale of *MISQ* Co-Author Distribution (conti.)

points referred to start authors. Because star authors highly connecting with each other was essential for whole structures of research network, these authors played un-ignorant influence on the development direction of whole research field.

In Figure 7, it drawn and compared log-log size distribution map between actual author collaboration link network and randomized network. Randomized network produced convex curve distribution, far from conforming to linear distribution. In actual author collation network, in second phase at the beginning, from 1977-1979 and from 1979-1982, linear regression verification was of no significance, however, when being cumulative, after 1985 significance of linear regression conformity was 0.001, and maintained 0.000 from 1998 to 2007, and finally in 2007 power formula was seen as follows:

$$Log(P(k)) = -2.1661Log(k) + 1.444 \quad (7)$$

Distribution index is -2.166, showing that the concentration of representing power law distribution can be used as comparison benchmark in power law distribution for other journals or disciplines in future. Linear regression in randomized network always didn't reach acceptable significant level.

Known from the above data collected, at the beginning of development, this research field naturally produced preferential attachment network structure. After accumulation for 9 years in *MISQ*, star author network that fits power law was formed, and continued in subsequent development of collaboration research network.

5. Conclusion and discussion

5.1 Contributions

After discussing changes of collaboration structures in scholar community within 31 years, though there is a gap between MIS and other disciplines with long history in terms of collaboration research ratio, the community collaboration development, knowledge diffusion and field development in MIS were constantly moving forward. Through further analysis, this study discovered that the ratio of author collaboration research in MIS communities is increasing, whereas publication of single author significantly dropt down. Collaboration in this concerned research communities were dominant by two authors, but collaboration research by multiple authors was increasing, slower than collaboration research by two authors. Furthermore, analysis results of data demonstrated the development status of networks in whole research communities, showing an inclination attaching to star scholars preferential network development mode. This result appeared more apparently in research distribution in recent decade. Due to an obvious increase of

authors with high productivity, the structure in whole network kept developing in power law distribution form.

Through further analysis on each sub-domain adopting author collaboration development trends produced, this study found that reference disciplines in information management research field converts from information theory and artificial intelligence system and technology at initial period into science application and behavior influence based on decision science and behavior theory in recent days; more attention should be paid to development of relevant theories in more complex environment, e.g. politics, sociology and ecology. In relation to the application trends of reference theories into studying classification on different theme objects in concerned field, this study was based on different development trends and frequency published in articles, analyzed key points in each research theme: In theme of information management classification, system evaluation, system program plan were taken as key issues in past research, applied into system development and application system. Regarding technical modes subjects applied into system development, because relevant system development methods and methodology were gradually matured, many issues tend to decrease year by year. However, due to the popularity of information system application and its influence as well as the significance of information system management and information system in organization influence, concerned subjects were developing. Application system development theme gradually changed from functional system into whole industrial system. Seen in this study, other subjects, e.g. computer application, outer environment influence, computer science technology, organizational environment, information research and education, were developing slowly. Results in this research showed some fields with author collaboration research rising include: issues relevant to social environment, organizational change and impact and information management research. Because information application deeply permeated into all aspects of society, its research also expanded complex issues focusing on completeness, sociology and strategies.

Holistically speaking, there is a consistent and apparent trends in reference discipline or development of each theme that research direction in whole shifts from technical, special issue with single and special function into those combining complexity, width, integrity and integration together. Information management research had already spanned issues related to sociology, politics and ecology emphasizing integrity and complexity. Through 30 years' accumulation, information management had evolved into one of formal subject matter fields that can't be neglected.

　　　Through investigating changes of author collaboration structures in each phase, this study found that a small-world collaboration study mode that is highly and regionally clustered exists in collaboration network in research community by using cluster coefficient and average path distance as measurement indices in small-world. After 1997, small-world network cohesion structure tended to be stable, though new members enter into, they are incapable of impacting this structure and only developed gradually within scope of network in this structure (average route length). Further verification on power law distribution indicated that clustering characteristics of collaboration research structures had being intensifying preferential attachment mode in power law distribution since 1985 and until now. That is to say, entry of subsequent authors was under existing network structure in this most prestigious journal in information management research, and maintains close cohesive relationship. In opinions of some literatures (Merton, 1968; Crane, 1972; Cole and Cole, 1973; Zuckerman, 1977; Allison et al., 1982), this structure may be affected by research expenditure, resource preference, specialty of academic institution and knowledge cluster. Other social relationship network other than collaboration network like education degree and teaching should be further investigated.

　　　Research on authors and issues in information management articles can assist in understanding achievements and basis established previously in this field and possible development direction in future; therefore, since 1982, every several years, scholars were contributing to provision of organized results and suggestions. However, a majority of research concerning this field seldom applies community structure changes and knowledge diffusion into analysis from the perspective of knowledge community. This study provided a new angle to explain the issue by social network analysis, moreover, in combination with changes of knowledge community structures, to provide possible trends changes, in the hope of providing useful references in terms of collaboration research in each MIS domain in future.

5.2 Future development

　　　This study attempted to analyze research development in information management field by using social network analysis and theoretical basis from the perspective of knowledge cluster in collaboration research. After analyzing authors and keywords in most prestigious *MIS Quarterly*, it can preliminary observe structural depth and outstanding achievements that never touched before. Therefore, research concerning information management can develop toward two directions: (1) Increase data collection and expand scope of knowledge community coverage to other key journals. On the one hand, it helped to understand structural changes of communities and development of knowledge field in specific field more completely; on the other hand, it also benefits similar comparison with research communities in domestic; (2) Conduct profound

discussion, increase reference data for collaboration community and structures in knowledge field, which doesn't only describe mode and development process of specific knowledge field, enhances depth of historical cognition, and also provides reference for collaboration modes and field fusion when new fields are developed and combined in future.

Other issues extending from this research, e.g. further understanding and explanation of reasons of collaboration network forming that fits power law distribution and its influence on MIS research field, changes and development of original structures in collaboration research communities after research field transfers, were capable of revealing more profound knowledge drawing on the concepts and codes in this study. Except providing reference for information management research communities, this study could compare with development of other disciplines and demonstrate differences between one newly integrative discipline with traditional foundational disciplines in terms of exemplars.

5.3 Research limitation

Due to limitations on time and resources, this study only conducted analysis by taking *MIS Quarterly* as example. As the most prestigious journal in information management field and may affect the results of community structure development, this journal's inference on effectiveness of whole research community is in need of further analysis and comparison.

Because *MISQ* keyword classification comparison list used in data classification is the last version in 1993, some keywords in new issues were only classified into the nearest sub-domain without changing original code structures; if this code structure was properly upgraded, the development and exploration of new sub-domain could be more clearly identified. In keyword classification, inter-rater reliability is only 0.52, meaning moderate agreement, it may be caused by different individual understandings on keywords arising from different background and intensive collaboration with other different disciplines in later period within 30 years. Agreement degree could be improved by adding experts of sub-domains in subsequent research.

Moody (2004) also proposed the third structural index (structure cohesion) when discussing structure of sociology research articles, to measure the robustness of network structure together with cohesive blocking issued by Moody and White (2003). Compared with the shortages that power structure may appear hub and make network collapsed, cohesive blocking could find nodes embedded in multiple block networks, so as to find the number of nodes accepted by network if attack appears, also represent the balance of network structure. This method should assist in cores of level 2 and even level 3 structures

in existing sample structures, and further help us understand secondary structures of development for concerned study. However, because this index in structure calculation had recursive nature, if nodes of network were above 250 (in second phase), convergent results of this index could be not obtained. Therefore, the inability in verification and exploration of close stability of structures occurs in this study, which needs extension in subsequent study.

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