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The Topological Properties of the Knowledge Structure in MIS Research

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Abstract-**This study proposes that keyword networks can be formulated from research publications and used to examine how the keywords have been connected with each other to create new concepts. For the purpose of empirical analysis, the keyword networks are organized based on the MIS publication information from 1999 to 2008, the analysis of which reveals a number of notable results. First, the MIS field has changed so quickly that many new concepts and keywords have been introduced, and the connection of keywords is highly clustered. Second, the keyword network shows a clear power-law degree distribution, indicating that, the more popular a keyword becomes, the more that the keyword is selected by researchers and it is associated with other keywords or concepts to create new ideas. This evidence implies that the important keywords analyzed from a network perspective are different from those analyzed from a popularity perspective. Also, the interdisciplinary keywords have the potential to create new research fronts in the MIS field. This suggests that analysis from a network perspective is needed to determine the changes in important keywords over time and to better understand the process of knowledge evolution.**

Keywords- Knowledge structure; MIS research; Keyword; Network analysis; Trend analysis

I. INTRODUCTION

After both management researchers and practitioners realized that remaining competitive and innovative in the market is heavily dependent on an organization's ability to promote and optimize its knowledge creation [1,14,27], the value of social networks formulated among workers has been reemphasized in the field of management research. Various kinds of network-related measures such as structural hole [8] and centrality [6,13] were extensively used to calculate people's relative position in the social network.

In academia, researchers build on existing concepts and ideas in published papers to develop new studies that, in turn, serve as building blocks for further research. The dependence of new knowledge on existing knowledge has prompted researchers to focus on existing concepts, papers, and citations among papers to examine important concepts and ideas, research trends, and opportunities for further research [5, 10, 16, 18].

However those approaches, the popularity-based and network-based analysis, have inherent weaknesses. In the case of the popularity-based approach, the frequency analysis of titles or keywords could indicate their importance, but the information collected is of the past. Moreover, the popularity-based analysis cannot account for redundancy. Attention to important keywords would be beneficial for the development of valuable ideas, but excess attention would be redundant as more researches have already done on them. In contrast, the network-based approach resolves this redundancy problem by analyzing network structures. The duplication of a relationship between two elements of a network, for example, does not change the network structure. However, a research paper is also a set of knowledge elements, such as concepts and ideas, and a citation network does not directly represent a knowledge network. Therefore, we should focus on knowledge element itself.

Based on this hole in the literature, this study investigates the relationships among keywords of published papers and constructs a knowledge structure for a certain research field.

Specifically, this study aims to (1) construct a keyword network from the published papers in the major journals of MIS research, (2) investigate the characteristics of the MIS keyword network, (3) identify and compare important keywords from both popularity-based and network-based perspectives, and (4) determine the changes in important keywords over time.

II. LITERATURE REVIEW

A. Identification of Research Themes

In the popularity-based approach, researchers typically use the titles or keywords of papers and analyze their frequency of use (i.e., how many times they appear in papers)[20,22,16,28]. For example, to examine research trends in animal behavior research, Ord et al. [20] analyzed the titles and keywords of papers published in that field utilizing knowledge visualization and data mining tools. To identify research themes in the network-based approach, researchers have paid attention to citations that represent the relationships among papers and authors. [12, 18, 19, 26]

B. Complex Network-related Measures

According to conclusive consensuses about complex systems, interactions among the elements comprising the whole system affect their connectivity, and this network structure, in turn, affects the local interactions and the dynamics of the system. In order to understand the characteristics of the keyword network in MIS research, we borrow a number of well-defined and widely used network-related measures.

The first one is the degree centrality of each node. The degree of each node is the number of neighboring nodes to which the focal node is connected. In a keyword network, a node of high degree has many ties with other keywords and interacts with them to develop new ideas from the papers in which they are contained. The second measure is a node-level measure of betweenness centrality, which measures the extent to which a node lies on the paths between other nodes [6, 13]. In the keyword network, this measure represents the importance of a keyword in the bridging of other keywords. A keyword that lies between two distinctive research themes (i.e., clusters of closely related keywords) can have high betweenness centrality even though it has a small number of connections with other keywords in each theme.

The third measure is the characteristic path length of a network, the average length of all the shortest paths between node pairs. The forth measure is the clustering coefficient, a network-level measure that illustrates the tendency of nodes to cluster in densely interconnected modules.

In relation to the k-core decomposition [1], we partially adopt the definition of k-cores from references [15]. The k-core of the graph is a maximal subgraph in which each node has at least degree k.

III. RESEARCH METHODS

To investigate the characteristics of the keyword network of MIS research, we select five top journals in the MIS research field and construct a database composed of keywords from all papers published in the journals during the ten-year period from 1999 to 2008.

For this analysis, five highly regarded MIS journals were selected.

- Decision Support Systems, from DSS 1999 24(3&4) ~ 2008 46(1), 957 published papers
- Information & Management, from IM 1999 36(1) ~ 2008 45 (8), 561 published papers
- Information Systems Research, from ISR 1999 10(1) ~ 2008 19(4), 226 published papers
- Journal of Management Information Systems, from JMIS 1999 15(4) ~ 2008 25(3), 368 published papers
- Management Information Systems Quarterly, from MISQ 1999 23(1) ~ 2008 32(4), 257 published papers

Based on the publication information on the 2,369 journal articles, six keyword networks were constructed: a combined one for all journals and five separate ones for each journal. Generally, a keyword network has two features: (1) it is an undirected network (i.e., the links between nodes are symmetric or bidirectional) and (2) it is a weighted network [9] (i.e., a link between two keywords is associated with a number that represents how many times the two keywords appear in the network). This numerical value can be used to measure the strength of the connection. In this study, as an initial step, we focus on the topological characteristics of the keyword network and assign a weight of one to each link. The strengths of the connections might provide useful extra information in our future research.

Before the construction of the keyword network, the keywords must first be standardized because the keyword information is mostly provided by authors, and individual keywords can be expressed in different forms, such as with inconsistencies in abbreviation or as plural forms.

The following list contains the categories of rules used in the refinement of keywords.

- Standardization into the singular form: according to the principle of definitude, plural and singular keywords were consolidated into a singular form.
- Removing redundant keywords: when a keyword and its abbreviated form were used together, the abbreviated form was deleted,
- Removing hyphens: hyphens that link two words were deleted if the meaning was not affected,
- Avoidance of abbreviations: when there were both the original word and abbreviated form(s) in the keyword list, they were consolidated into the original word.
- Unification of synonyms: when two or more synonyms existed in the list, they were unified into one of the most general keywords.
- Separation of multiple terms in a keyword: in cases where two or more distinct terms were used for a keyword, they were separated and considered as individual keywords.

After the refinement, the resulting keyword database was composed of 5,642 keywords. In order to analyze the structure of the keyword network constructed from this database, we used UCINET [29]. The network analysis consists of two parts. First is the analysis of the characteristics of the keyword networks based on network-level and node-level measures (network density, average distance or characteristic path length, and clustering coefficient) and the correlations between node-level measures (degree centrality, betweenness centrality, and clustering coefficient). Second is the analysis of the important keywords from the perspective of centrality in the keyword network as well as from the traditional perspective of frequency in publication. Then the keywords are sorted according to measure and journal and are classified as to their importance. From the results, meaningful implications about the knowledge structure and the trends of MIS research can be derived.

IV. THE RESULTS OF KEYWORD NETWORK ANALYSIS

A. *Network Characteristics*

The keyword network of the MIS research area during the last ten years is a very sparse and highly clustered scale-free network, as shown in Table 1. A published paper introduces an average of about 2.74 non-redundant keywords (=6,480/2,369), indicating that research topics in MIS change quickly, and that the researchers are seeking new ideas. On the average, papers published in IM and ISR span relatively more keywords per paper. Over the whole network and in the sub-networks of journal and time period, we can see that the clustering coefficients are very high, while the network density is very low. This implies that the more closely related concepts or keywords are more likely to interact with each other

TABLE I. THE STATISTICS ON THE WHOLE NETWORK AND THE SUNETWORKS BY JOURNAL AND TIME PERIODS.

	Papers	Keywords	Density	Distance	Clustering
ALL	2,369	12,594	0.0014	3.650	0.856
DSS	957	4,699	0.0024	3.719	0.891
IM	561	2,922	0.0038	3.940	0.878
ISR	226	1,337	0.0069	4.735	0.909
JMIS	368	2,083	0.0051	4.180	0.885
MISQ	257	1,553	0.0073	4.502	0.891

Among the structural characteristics of the keyword network, the most interesting result is that the cumulative degree distribution follows a clear power-law distribution [11]. The evidence of power-law distribution implies that the “preferential attachment” mechanism could be the dynamic driving principle that might be at the origin of heavy-tailed distributions in a wide range of growing keyword networks [3, 4, 21]. In our context, the more popular a keyword becomes, the more the keyword is selected by researchers and the more it is associated with other keywords or concepts to create new ideas. This meaningful finding should contribute to the understanding of the formation and evolution of knowledge over time.

Although studying the collective behavior of the many elements forming a network can shed light on the large-scale structures in which it is eventually self-organized, the presence of a power-law distribution does not necessarily imply a hierarchical structure of the network. There have been several research efforts aimed at developing measures to quantitatively characterize the relationship between scale-free topology and hierarchical structure, most of which have focused on the linear relationship between degree and the clustering coefficient [23,24,25]. As shown in Fig. 1, the average clustering coefficient exhibits a very clear heavy tail as a function of k. This observation shows that keywords with a small number of connections statistically have a larger local clustering coefficient than do those with a large degree.

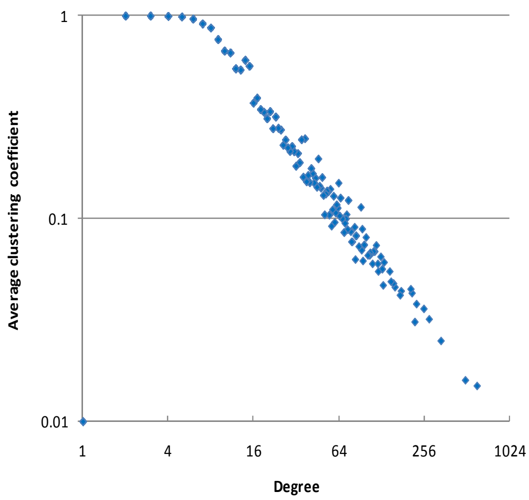
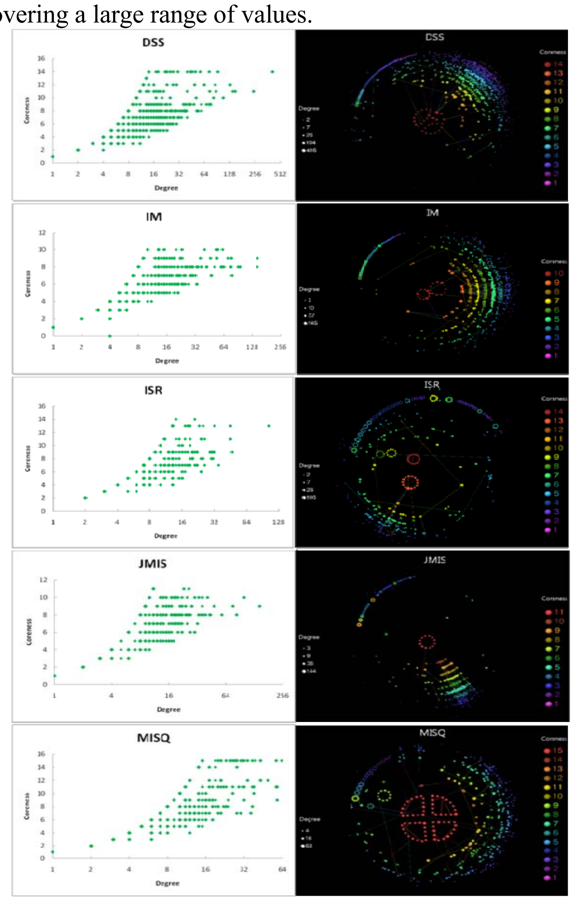


Figure 1. Correlation between average clustering coefficient and degree.

According to the above results and those of other research [23, 25], we can infer that keywords acting in a hub role are usually well interconnected with neighboring keywords by preferential attachment during the evolution of the network.

The clustering properties for each degree value are highly variable, creating a continuum of hierarchical levels. However, it is not possible to define any degree range to represent a characteristic hierarchical level. For this reason, a more sophisticated hierarchical analysis has been recently proposed. In particular, the k-core analysis has been used to obtain structural models of complex networks. According to the definition, a node that has k-core should have at least k or more degrees [9]. This corresponds to our analysis, as shown in Fig. 2 (a).

To further investigate the hierarchical properties, connectivity, and clustering properties of keyword networks, we applied the visualization software LaNet-vi [1], which provides images of large scale networks on a two-dimensional layout. As shown in Fig. 2(b), the color code represents a relative measure of keyword importance, with keywords in the inner shell (red) forming the nucleus of the keyword network. The k-core decomposition disentangles the hierarchical structure of a network by progressively focusing on its central cores. The presence of degree-coreness correlations then corresponds to the fact that the central nodes are most likely high-degree hubs of the network. However, the presence of hubs in a rather external position leads to the presence of local hubs, as in Fig. 2 (b). Each journal shows different correlation properties between the coreness and the degree of the nodes. In all journals, especially DSS and IM, the nodes are distributed over a relatively large range of radial coordinates, illustrating that their neighborhoods are variably composed. It is worth noting that the shell index and degree are highly correlated, with a clear hierarchical structure. Namely, the size of the nodes increases when moving from the periphery of the network to the center, in strong correlation with coreness. For instance, one might exploit the structure to illustrate that high-degree nodes are naturally (as an implicit result of the self-organizing growing) placed in the innermost structure in the keyword network. In high-level shells of MISQ, however, the correlations between degree and coreness are blurred by slight fluctuations, as stressed by the presence of some hubs in the external positions. In addition, MISQ has the highest k-core at 15, although the number of keywords is the second lowest among the five journals. This explains that the keywords in MISQ are more tightly interrelated, which can be confirmed by the fact that the network density of MISQ is the highest among the five journals. Also, in DSS and IM, the lowest index shells, containing nodes that are very external, are displayed as broad layers, indicating that the corresponding nodes have neighborhoods with a shell index covering a large range of values.



(a) (b)

Figure 2. Figure 2. a) Correlations between the statistics of the keyword network for each journal, b) Sketch of the k-core for the keyword network of each journal; colors on nodes distinguish different coreness; the size of nodes means the degree values. The precise position of ach node depends on its neighbors, namely a node of a given shell is more central in the layout if its neighbors have typically larger shell index.

B. Important Keywords

To determine the important keywords and how they differ across journals and measures, we chose the top 20 keywords for each measure and compared them, as suggested in Table 2. For each journal, the top 20 keywords for each measure were classified into corresponding columns, and the ones common to the three top 20 lists were moved to the last "Common" column. The underlined keywords in each column indicate whether it is unique across three columns for each journal, which means that it appears only in the top 20 list for the measure in corresponding journal. For example, in the DSS journal, "MULTICRITERIA ANALYSIS" and "INTELLIGENT AGENT" are in the top 20 according to frequency, and we can see that they are very popular keywords and that numerous papers include them. However, they are not included in the top 20 lists according to degree or betweenness centrality, which means that their importance is rather low in terms of their structural position in the keyword network. On the other hand, "WEB SERVICE" and "WORLD WIDE WEB" are unique keywords that have high structural importance in the keyword network and are only captured by degree centrality. In that sense, we can see that "CUSTOMER RELATIONSHIP MANAGEMENT" and "ANALYTIC HIERARCHY PROCESS" play an important role in bridging separated keyword groups or research themes, while they do not have many connections with other keywords and are not popular keywords. In the "Common" column, those in bold-italic keywords are unique across the five journals.

We can identify the differences in the classification of the top 20 keywords across measures and across journals.

TABLE II. TABLE 2. IMPORTANT KEYWORDS IN MIS RESEARCH FROM 1999 TO 2008.

	Frequency	Degree	n Betweenness	Common
DSS	EXPERT SYSTEM MULTICRITERIA ANALYSIS INTELLIGENT AGENT	EXPERT SYSTEM WEB SERVICE WORLD WIDE WEB	CUSTOMER RELATIONSHIP MANAGEMENT ANALYTIC HIERARCHY PROCESS INFORMATION TECHNOLOGY	DECISION SUPPORT SYSTEM ELECTRONIC COMMERCE KNOWLEDGE MANAGEMENT DATA MINING GROUP DECISION SUPPORT SYSTEM ***ONLINE ANALYTIC PROCESSING*** ***DATA WAREHOUSE*** ***INFORMATION RETRIEVAL*** DECISION MAKING ***GENETIC ALGORITHM*** ***NEURAL NETWORKS*** ***DECISION SUPPORT*** ***SIMULATION*** ELECTRONIC MARKET INTERNET ***MULTI AGENT SYSTEM*** ***CLUSTERING***
IM	ELECTRONIC DATA INTERCHANGE WORLD WIDE WEB INFORMATION SYSTEM IMPLEMENTATION	OUTSOURCING ELECTRONIC DATA INTERCHANGE COMPETITIVE ADVANTAGE	OUTSOURCING INFORMATION SYSTEM DEVELOPMENT WORLD WIDE WEB	TECHNOLOGY ACCEPTANCE MODEL ELECTRONIC COMMERCE INFORMATION TECHNOLOGY KNOWLEDGE MANAGEMENT INTERNET ***ENTERPRISE RESOURCE PLANNING*** GROUP DECISION SUPPORT SYSTEM DECISION SUPPORT SYSTEM TRUST INFORMATION SYSTEM ***PROJECT MANAGEMENT*** INFORMATION SYSTEM DEVELOPMENT TECHNOLOGY ADOPTION DATA MINING ***USER SATISFACTION*** ***BUSINESS PROCESS REENGINEERING*** CASE STUDY
ISR	LABORATORY EXPERIMENT ELECTRONIC MARKET STRUCTURAL EQUATION MODELING ELECTRONIC DATA INTERCHANGE INTERORGANIZATIONAL SYSTEM MEASUREMENT DECISION SUPPORT SYSTEM ELECTRONIC MAIL	LABORATORY EXPERIMENT FEEDBACK STRUCTURAL EQUATION MODELING NETWORK EXTERNALITY SOCIAL NETWORKS ELECTRONIC MARKET ONTOLOGY NETWORK ECONOMICS	NETWORK EXTERNALITY DATA WAREHOUSE DATA MODEL INFORMATION SYSTEMS MANAGEMENT NETWORK ECONOMICS KNOWLEDGE SHARING ONTOLOGY MEASURE	ELECTRONIC COMMERCE ***COMPUTER-MEDIATED COMMUNICATION*** TRUST INFORMATION TECHNOLOGY INFORMATION TECHNOLOGY INVESTMENT VIRTUAL TEAM ***AUCTION*** ***ELECTRONIC BUSINESS*** ***HUMAN COMPUTER INTERACTION*** TECHNOLOGY ACCEPTANCE MODEL TECHNOLOGY ADOPTION DECISION MAKING
JMIS	COMPUTER-MEDIATED COMMUNICATION BUSINESS VALUE BUSINESS PROCESS REENGINEERING INFORMATION TECHNOLOGY COLLABORATION ECONOMIC ANALYSIS INFORMATION TECHNOLOGY INFRASTRUCTURE	COMPUTER-MEDIATED COMMUNICATION VISUALIZATION SOCIAL NETWORKS BUSINESS VALUE PRICING INFORMATION SYSTEM DEVELOPMENT INFORMATION TECHNOLOGY	SUPPLY CHAIN SOCIAL NETWORKS BUSINESS PROCESS REENGINEERING VISUALIZATION TACIT KNOWLEDGE SURVEY BUSINESS VALUE OF INFORMATION TECHNOLOGY	ELECTRONIC COMMERCE GROUP DECISION SUPPORT SYSTEM KNOWLEDGE MANAGEMENT TRUST INFORMATION TECHNOLOGY INVESTMENT ELECTRONIC MARKET INFORMATION SYSTEM DEVELOPMENT ***INFORMATION GOODS*** VIRTUAL TEAM DATA MINING TECHNOLOGY ADOPTION CASE STUDY ***INTERORGANIZATIONAL SYSTEM***
MISQ	TECHNOLOGY ADOPTION INFORMATION SYSTEM IMPLEMENTATION OFFSHORING VIRTUAL TEAM OUTSOURCING QUALITATIVE ANALYSIS DESIGN SCIENCE ELECTRONIC MARKET INFORMATION SYSTEM USE	INFORMATION SYSTEM IMPLEMENTATION INTERNET POWER OUTSOURCING TECHNOLOGY ADOPTION ORGANIZATIONAL CHANGE INFORMATION SYSTEM USE STRATEGIC INFORMATION SYSTEM IMPLEMENTATION	VIRTUAL TEAM DESIGN SCIENCE GENDER QUALITATIVE ANALYSIS COMPUTER-MEDIATED COMMUNICATION STRATEGIC INFORMATION SYSTEM POWER DISTANCE CREATIVITY	INFORMATION SYSTEM DEVELOPMENT TECHNOLOGY ACCEPTANCE MODEL ***ADOPTION*** KNOWLEDGE MANAGEMENT TRUST ELECTRONIC COMMERCE ***INFORMATION SYSTEMS MANAGEMENT*** TECHNOLOGY ADOPTION GROUP DECISION SUPPORT SYSTEM INFORMATION SYSTEM ***ORGANIZATIONAL LEARNING*** CASE STUDY

C. Changes In Important Keywords Over Time

How have the important keywords changed over time, and what are the latest important keywords? To address these questions, we compared the important keywords in the keyword network constructed from ten years of data (1999 to 2008) with those in the keyword network constructed from recent data covering two years (2007 to 2008) in terms of frequency, degree, and nBetweenness measures, as shown in Table 3. We compared the top 20 keywords across the three importance measures for all five journals. The comparison between the keyword network over a long time period and that from recent years is a compromise to mitigate the potential loss of the necessary information while capturing the recent changes in important keywords.

The comparison reveals some notable results. “ELECTRONIC COMMERCE,” “DECISION SUPPORT SYSTEM,” and “KNOWLEDGE MANAGEMENT” are the top three important keywords across three measures for two time periods, and they have experienced consistently high interest over the last decade. Decision support-related keywords (“DECISION MAKING,” “DECISION SUPPORT SYSTEM,” “DECISION SUPPORT,” and so on) have also received growing interest over the ten chosen years, as have system user-related keywords (“TECHNOLOGY ACCEPTANCE MODEL,” “TRUST,” “TECHNOLOGY ADOPTION,” and so on), and knowledge management-related keywords (“KNOWLEDGE MANAGEMENT” and “KNOWLEDGE TRANSFER”). In particular, the importance of knowledge management-related keywords has been substantially increased, as analyzed in our supplementary analysis. “OUTSOURCING” and “OFFSHORING” have been selected as important research keywords by many researchers in the recent two year period. However, system-related keywords (“INFORMATION TECHNOLOGY,” “INFORMATION SYSTEM,” and “INFORMATION SYSTEM DEVELOPMENT”) have received less research interest. “INTERNET” has had the biggest drop in all measures.

Compared with the top 20 keywords according to frequency measure, the analyzed results according to degree and nBetweenness produce very interesting findings. “SOCIAL NETWORKS” has become an important keyword in terms of degree and nBetweenness measures for the period of 2007-2008. Also, “KNOWLEDGE TRANSFER” and “ONLINE ANALYTIC PROCESSING” have experienced growing importance from the degree perspective within the same period. However, system-related keywords (“SIMULATION,” “DATA WAREHOUSE,” and “MULTI AGENT SYSTEM”) have been excluded when analyzed by the two measures. In contrast, “COLLABORATION” and “SATISFACTION” have become important keywords in nBetweenness measures for the period of 2007-2008, which means that these keywords are being given key roles in the bridging of many other research keywords.

TABLE III. TOP 20 KEYWORDS IN MIS RESEARCH BY THREE MEASURES ,(1999-2008 VS 2007-2008)

Frequency				
Rank	**1999-2008**	**Frequency**	**2007-2008**	**Frequency**
1	ELECTRONIC COMMERCE	160	DECISION SUPPORT SYSTEM	43
2	DECISION SUPPORT SYSTEM	148	ELECTRONIC COMMERCE	31
3	KNOWLEDGE MANAGEMENT	101	KNOWLEDGE MANAGEMENT	26
4	GROUP DECISION SUPPORT SYSTEM	85	TRUST	21
5	TECHNOLOGY ACCEPTANCE MODEL	69	TECHNOLOGY ADOPTION	15
6	DATA MINING	67	DATA MINING	13
7	TRUST	60	VIRTUAL TEAM	12
8	INFORMATION TECHNOLOGY	49	ONLINE ANALYTIC PROCESSING	11
9	INTERNET	47	DECISION SUPPORT	11
10	ELECTRONIC MARKET	45	MULTICRITERIA ANALYSIS	11
11	TECHNOLOGY ADOPTION	44	OUTSOURCING	11
12	INFORMATION SYSTEM DEVELOPMENT	42	COMPUTER-MEDIATED COMMUNICATION	11
13	DECISION MAKING	39	TECHNOLOGY ACCEPTANCE MODEL	11
14	INFORMATION TECHNOLOGY INVESTMENT	37	OFFSHORING	11
15	CASE STUDY	36	DECISION MAKING	10
16	DECISION SUPPORT	36	ELECTRONIC MARKET	10
17	DATA WAREHOUSE	34	ENTERPRISE RESOURCE PLANNING	10
18	INFORMATION SYSTEM	34	SIMULATION	9
19	ENTERPRISE RESOURCE PLANNING	34	DATA WAREHOUSE	9
20	ELECTRONIC DATA INTERCHANGE	33	MULTI AGENT SYSTEM	9
Degree				
Rank	**1999-2008**	**Degree**	**2007-2008**	**Degree**
1	ELECTRONIC COMMERCE	608	DECISION SUPPORT SYSTEM	161
2	DECISION SUPPORT SYSTEM	503	ELECTRONIC COMMERCE	154
3	KNOWLEDGE MANAGEMENT	338	TRUST	103
4	GROUP DECISION SUPPORT SYSTEM	279	KNOWLEDGE MANAGEMENT	98
5	TRUST	256	TECHNOLOGY ADOPTION	64
6	TECHNOLOGY ACCEPTANCE MODEL	227	VIRTUAL TEAM	60
7	DATA MINING	221	OUTSOURCING	59
8	INFORMATION TECHNOLOGY	211	DECISION MAKING	56
9	INTERNET	207	OFFSHORING	55
10	TECHNOLOGY ADOPTION	177	SOCIAL NETWORKS	54
11	ELECTRONIC MARKET	174	DATA MINING	53
12	DECISION MAKING	160	CASE STUDY	51
13	INFORMATION SYSTEM DEVELOPMENT	156	COMPUTER-MEDIATED COMMUNICATION	50
14	CASE STUDY	156	DECISION SUPPORT	48
15	INFORMATION SYSTEM	150	TECHNOLOGY ACCEPTANCE MODEL	48
16	INFORMATION TECHNOLOGY INVESTMENT	147	UNCERTAINTY	44
17	COMPUTER-MEDIATED COMMUNICATION	134	ENTERPRISE RESOURCE PLANNING	44
18	DECISION SUPPORT	132	KNOWLEDGE TRANSFER	43
19	SIMULATION	130	INFORMATION TECHNOLOGY INVESTMENT	43
20	VIRTUAL TEAM	130	ONLINE ANALYTIC PROCESSING	40
nBetweenness				
Rank	**1999-2008**	**nBetweenness**	**2007-2008**	**nBetweenness**
1	ELECTRONIC COMMERCE	0.15894	DECISION SUPPORT SYSTEM	0.14107
2	DECISION SUPPORT SYSTEM	0.13151	ELECTRONIC COMMERCE	0.13120
3	KNOWLEDGE MANAGEMENT	0.08134	KNOWLEDGE MANAGEMENT	0.08511
4	GROUP DECISION SUPPORT SYSTEM	0.05619	TRUST	0.08505
5	DATA MINING	0.04354	VIRTUAL TEAM	0.03976
6	INFORMATION TECHNOLOGY	0.04091	CASE STUDY	0.03897
7	TRUST	0.03761	TECHNOLOGY ADOPTION	0.03695
8	INTERNET	0.03228	DATA MINING	0.03535
9	TECHNOLOGY ACCEPTANCE MODEL	0.03000	OFFSHORING	0.03422
10	DECISION MAKING	0.02604	DECISION MAKING	0.03130
11	ELECTRONIC MARKET	0.02501	DECISION SUPPORT	0.03022
12	TECHNOLOGY ADOPTION	0.02378	ENTERPRISE RESOURCE PLANNING	0.02928
13	INFORMATION SYSTEM	0.02353	TECHNOLOGY ACCEPTANCE MODEL	0.02898
14	CASE STUDY	0.02337	COLLABORATION	0.02736
15	INFORMATION SYSTEM DEVELOPMENT	0.02075	OUTSOURCING	0.02613
16	DECISION SUPPORT	0.02069	SOCIAL NETWORKS	0.02613
17	INFORMATION TECHNOLOGY INVESTMENT	0.01918	COMPUTER-MEDIATED COMMUNICATION	0.02492
18	SIMULATION	0.01899	UNCERTAINTY	0.02411
19	INFORMATION RETRIEVAL	0.01839	SATISFACTION	0.02392
20	OUTSOURCING	0.01759	ONLINE ANALYTIC PROCESSING	0.02256

V. DISCUSSION AND CONCLUDING REMARKS

We found that the topological properties of the keyword networks obtained from past MIS research are scale-free because their structural features rely on a power-law degree distribution. Viewing the empirical results above, the meaningful findings are as follows.

First, the keyword network of the MIS research field is very sparse and has a long average distance due to rapid changes and the introduction of many new topics and concepts. The keyword network is especially highly clustered and shows a clear power-law degree distribution. Future MIS research themes are being formulated, and it is possible to partially predict future directions of MIS research areas by analyzing the network properties of those clusters.

Second, the proposed keyword networks share a number of common features with other networks, such as citation networks and collaboration networks [17]. However, the tail of the power-law distribution of the keyword networks is very clear, which is quite different from those of citation networks or collaboration networks.

Third, the fact that the average clustering coefficient exhibits a very clear heavy tail as a function of k indicates that the keyword network is a hierarchical structure. Further, this implies that a preferential attachment mechanism is valid in the evolving keyword network.

Fourth, the k-core decomposition helped to identify a series of network properties, including hierarchical structures, clustering, and connectivities of keyword networks. Each MIS journal showed a different correlation between the coreness and the degree of the nodes. In the cases of MISQ and ISR, especially, degree and coreness were correlated, but the correlations were blurred by large fluctuations, which lead to the presence of some local hubs in rather external positions.

There are limitations to the present analysis. There was no established method, and a great deal of time and effort were required to construct the keyword network. Further, the process we followed might look somewhat subjective. This study is an explorative one in that we investigated only the characteristics of the keyword network of the MIS research field and identified important keywords from a network perspective. However, we are sure that our research can be considered as the starting point for the analysis of the keyword network and will act as the cornerstone in studying the knowledge evolution process.

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