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How Knowledge Science is Studied—a Vision from Conference Mining of the Relevant Knowledge Science Symposia

Xijin Tang and Zhengwen Zhang

Institute of Systems Science, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100080 P.R. China

Abstract

As knowledge engineering, knowledge management and even knowledge creation have been widely accepted in academics, business and industry, knowledge science is still a rather young area where diverse explorations are being undertaken. How to acquire a vision about knowledge science both efficiently and effectively is a problem. As the publications at those relevant conferences on the interesting topics represent the latest achievements and humans' thinking about the topics, some hints may be acquired from those ideas (simply reflected by those keywords in each paper) and the authors. The so-called iView analysis toward the conference publications is developed to acquire the systemic vision of an interesting topic. Based on social network analysis technologies, iView analysis includes two basic steps. The first is to construct a pair of networks, a keyword network and an author network, based on paper information. Secondly, characteristics of both networks are analyzed, such as cutpoint, community structure, etc. from which to acquire some kind of collective explanations on the interesting topics under systemic perspectives. In this paper, an international symposium on knowledge science is tested to draw a rough picture of knowledge science studies. The information detected by network analysis could be pushed to conference organizers and participants for activities facilitation and to the other interested people to quickly acquire basic concepts or understanding of the concerned disciplines or topics, such as what are the major research topics? Who are the principal investigators? etc.

Keywords: knowledge science, iView analysis, idea map, human net, conference mining

1. Introduction

If we want to know the meaning of some terms, using a search engine such as *google* is a convenient way. We can also browse *wikipedia* to get more detailed information. Many specialized search engines for the retrieval of journal articles relevant to a dedicated scientific database have been exploited. Science-related portals have been developing to provide extensive information or links to the relevant disciplines. Further evolution of those portals launches on-line global services, such as pushing latest news, journal issues, research achievements or a variety of news headlines to the subscribers via emails, e.g. IEEE on-line global services or *EurekAlert* of the American Association for the Advancement of Science. Furthermore, programs to facilitate sciences research such as e-Science have been undertaking for global collaborations in key areas of science. Web and text mining technologies are widely used to improve the efficiency of human information processing. Along with the advances of next generation of infrastructure which aims to enable discoveries, more advanced analytical techniques or methods are needed to help people at different knowledge levels to get some essential ideas or systemic vision of the interesting topics from the vast amount of information. Advanced modeling work is under explorations

As knowledge engineering, knowledge management and even knowledge creation have been widely accepted in academics, business and industry, people try to approach knowledge studies from different disciplines and establish a new discipline - knowledge science. The School of Knowledge Science at Japan Advanced Institute of Science and Technology (JAIST) founded in the late 1990s is the first research and education institute established under the theme of knowledge in the world. At the web site of the school the motive of knowledge science to be studied from social sciences, humanities, engineering and the natural sciences can be found. Those four disciplines

as the basic constructs among knowledge science education and research reflect the backgrounds and research foci of the faculty members, who wrote a monograph on knowledge science published in Japanese in 2004 [1]. However, people especially new comers may prefer receiving more simple information quickly and efficiently.

In reality, a variety of academic conferences provide opportunities to expand academic views and social networks and play vital roles in social processes of collaboration, communication, and consensus along the process of scientific knowledge growth by P. Thagard [2]. Along the digital revolutions occurring to conference management, general electronic processing of paper submission, review, registration and information publishing is fulfilled by web-based applications. Moreover, advanced conference assistant services are also provided via ubiquitous computing technologies to facilitate participants' communications during the conferences since the late 1980s [3, 4]. On one hand, electronic conference management systems together with ubiquitous computing technologies become a fashion, trend or necessity; and text mining technologies have been applied to help find relevant information (e.g. publications) [5]. On the other hand, in-depth analysis of the semantics about collected academic ideas (papers) and participants, which may be helpful for conference organizers to make appropriate programs, for participants or even curious outsiders to find interesting topics and people and then draw a rough scenario about the state-of-the-art of the concerned topics. Some further endeavors had been taken [6].

In this paper, a so-called iView analysis toward the conference publications to acquire the systemic vision of an interesting topic is introduced. Firstly, the mechanism of iView analysis is addressed. Then an international symposium on knowledge science is tested to draw a rough picture of knowledge science studies. At last, concluding remarks are given.

2. Knowledge Vision by iView Analysis

As a science of analyzing science, scientometrics has a rich history in studying the structure of a research field. Based on the metadata of the publications, several kinds of social networks including coauthorship networks and citation networks can be constructed and studied. The studies show those social networks exhibit a small-world structure, have high clustering coefficients and short average distances, and their nodal degree follows a power-law distribution [7, 8]. Visualization of those networks facilitates people to understand those features. However, those detailed scientometrics information sometimes seems a little far away from the entrants who want to get some basic ideas of the field or just some terms quickly.

2.1 Knowledge vision: an unstructured problem solving

For those people who are not of many experiences in one field or research topic, they still need many efforts to acquire a rough vision of the concerned matter even with specialized supporting tools. If the interesting topic is across multiple disciplines, more efforts have to be taken to investigate those searching results. How to gain some senses about the interested topic or field, such as knowledge science, both efficiently and effectively is not easy for the young students.

We consider such a problem as an unstructured problem. For example, *google* can provide many *url*s when a student searches the term "knowledge science". He may then browse some web sites of education institutions, such as JAIST, to get some answers. Those *url* lists also include web sites of conference about knowledge research. The scopes, the titles of keynote speeches and final programs may bring more fresh and relevant terms. All those depend on the reader's active search and understanding. More augmented information supports are barely required to help acquire some basic threads or constructs during his unstructured problem solving process.

Here we concentrate on how to detect more information about the concerned topics from those accepted submissions from the dedicated academic conferences. A database of all published papers is consisted of a set of paper records with the structure as

<topic, authorList, paper title, keywords, time>

Such metadata indicates the corresponding *author(s)* submit(s) one *paper* with a set of *keywords* under the *topic* at the point of *time*. The keywords in a paper can denote a topic, a problem, a method or an algorithm, a practical case, etc. Then the keyword set of a paper could be understood as the basic ideas toward the problem addressed by the author(s) of that paper. If we count those keywords of all accepted papers of one conference, the keywords with the highest frequency could be regarded as the popular terms. The so-called iView analysis aims to help people gain more information.

2.2 Knowledge vision by iView analysis

The first step of iView analysis is to construct a pair of networks, one is keyword network, the other is human network.

2.2.1 Keyword network: an idea map

In a keyword network $G = (K, E)$, the vertex refers to a keyword. If keyword k_i and keyword k_j simultaneously belong to the keyword set of one paper, then an edge exists between two vertexes $e_{ij} = (k_i, k_j), i \neq j$, $e_{ij} \in E$ (E is the edge set).

Then each keyword set of one paper constructs a complete keyword graph. The keyword network denotes the aggregation of all keyword graphs. If $G_l = (K_l, E_l)$ indicates the keyword graph of the lth paper where $K_l = \{ k_1^l, k_2^l, \cdots, k_n^l \}$ is the keyword set, E_l is the edge set, then $G = (K, E)$ where $K = \cup K_l = \cup \{k_1^l, k_2^l, \cdots, k_n^l\}$, $E = \cup E_l = \cup \{e_{ij}\}$, $i, j = 1, 2, \ldots, m,\ i \neq j$. This topological network is a weighted undirected network where the weight of edge refers to the frequency of co-occurrence of keywords among all papers and is referred as an *idea map* contributed by all authors. Given such a network, more senses may be obtained via a variety of network analysis by detecting some of its features, such as cutpoints, centrality of keywords, clustering of keyword, etc. which may expose different perspectives of the authors' knowledge scope. That is a collective vision of all the authors.

For example, a cutpoint (articulation point) of a graph is a vertex whose removal increases the number of connected component [9]; then the cutpoint keyword may reveal the real key ideas (terms). So does the centrality analysis of the keyword vertex. The clustering of keyword by use of community structure detection methods may help people understand the major topics from those keyword clusters easier instead only by frequencies of individual keywords.

2.2.2 Human net via keyword-sharing between humans

Coauthorship network is a typical network which reflects common interests shared among co-authors, and is used to study scientific collaboration, such as clustering in the networks and differences in the patterns of collaboration between the different fields, and to detect interest groups and influential scientists of one discipline [8, 10]. However, general academic conference prefers participation with diverse interests. The majority of participants may not contribute many papers. A coauthorship network of a conference may include many isolates and components; then it may be meaningless to detect major interest groups. In iView analysis, keywords-sharing between authors is considered. An author network where the vertex refers to an author is constructed. If two authors share one keyword, a link between them exists. The strength between two authors indicates the number of the different keywords or the total frequencies of all the keywords they share. Obviously, the coauthorship network is a sub graph of the keyword-sharing network. From such a human net, social network analysis (SNA) is then applied to find the powerful people by centrality analysis and to detect the interest group by community structure detection, etc.

2.3 iView analysis: a qualitative meta-synthesis approach

The pair of idea map and human net constructed based on accepted papers for one conference could be regarded as one kind of structure about the dedicated topics. The exploited network analysis aims to detect basic concepts and main topics, principal investigators and the major special interesting groups emerged from the accepted submissions. Those could be regarded as constructs of the dedicated disciplines and more helpful for the curious students to quickly acquire a rough vision of the interesting field. Such an approach is regarded as iView analysis for a collective vision from the communities. At this point, iView analysis is an approach of qualitative meta-synthesis toward unstructured problems [11].

Next, iView analysis is applied to construct a rough vision of knowledge science study with all accepted submissions of the 6th International Symposium on Knowledge and Systems Sciences (KSS'2006) held in Beijing in 2006.

3. Knowledge Science Study by Vision of KSS'2006 Publications

As a new discipline, knowledge science may somewhat be regarded as an unstructured problem and be accessed from different perspectives. A brief review of KSS series symposia is given at first.

3.1 KSS series symposia

In 2000, the First International Symposium on Knowledge and Systems Sciences (KSS'2000) was held at JAIST and extended those endeavors of confluence of different ideas and opinions, methods and technologies, etc. to a wider scope of participants from different schools and disciplines, theorists and practitioners, who aim to develop knowledge science from systemic perspective [12]. After 3-year work, the International Society for Knowledge and Systems Sciences (ISKSS) was founded in Guangzhou of China during KSS'2003 by the emerging communities dedicated into this goal, and then as a forum for researchers as well as practitioners to exchange innovative ideas and to be aware of each other's efforts and results along the exploration of knowledge science. Another three year passed, the 7th International Symposium on Knowledge and Systems Sciences was held in Beijing during September 22-25, 2006 to show some new achievements and prospects for continuous thinking and studying under the theme "towards knowledge synthesis and creation".

Each participant may have their own understanding and impressions toward those topics, invited keynote speeches and other information delivered during call for papers of KSS'2006. As the

paper review finished, a total of 49 accepted submissions including 179 keywords contributed by 86 authors were collected into proceedings of KSS'2006 [13].

3.2 Idea map of KSS'2006

Before construction of the pair of idea map and human net of KSS'2006 for iView analysis, some preprocessing had to be done. A stop list, as the corpus for KSS, is applied to deal with synonymous terms. For example, both "complex network" and "complex directed network" refer to "complex network", and then the latter is replaced by the former. Both "scale-free networks" and "scale-free property" are replaced by "scale-free". Finally only 166 keywords remained. Figure 1 is the keyword network of KSS'2006 generated by a tool iView (v2.0) developed specially for iView analysis by the authors.

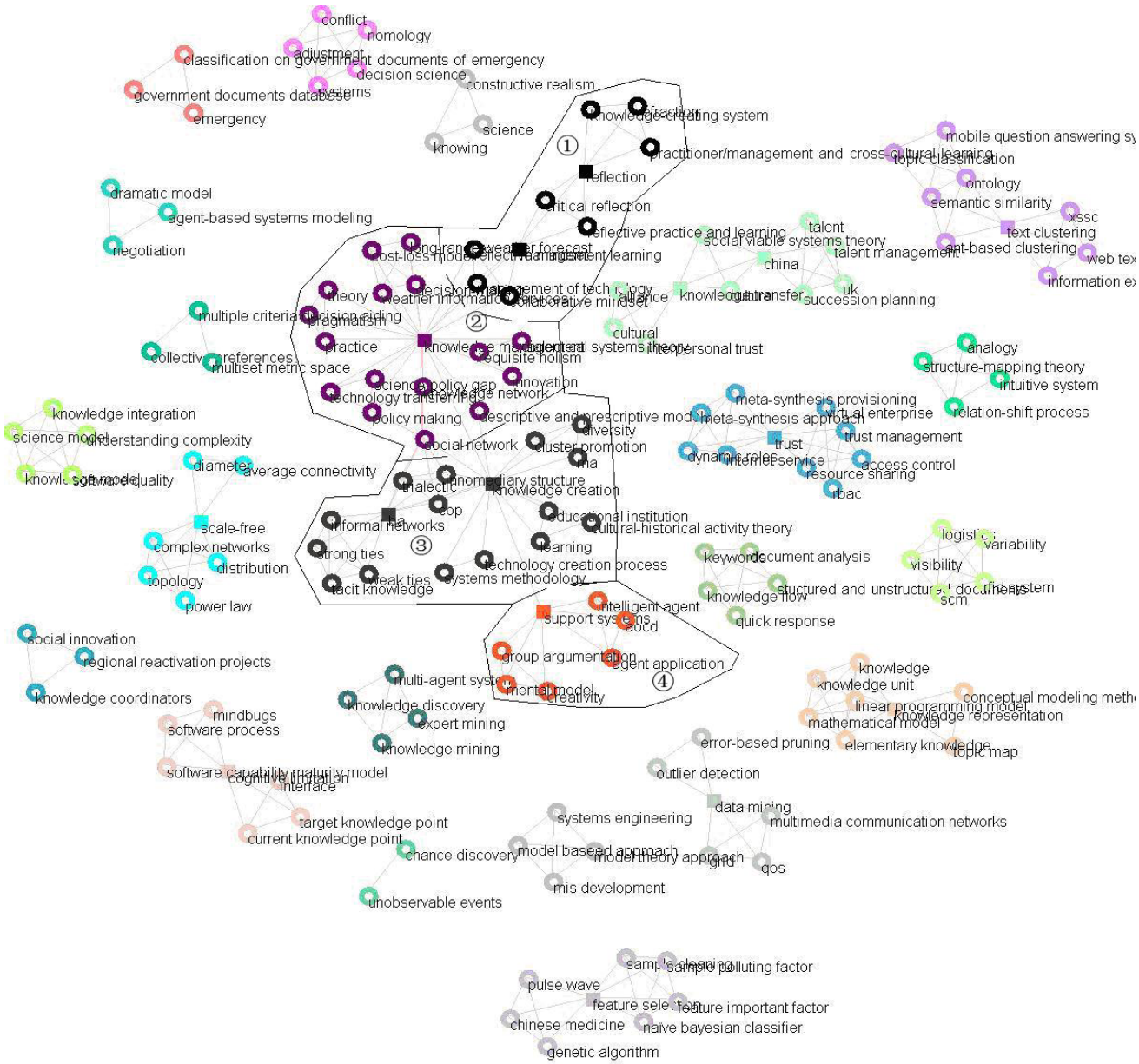

Figure 1. Idea map of KSS'2006 (keyword network)

Based on Newman-Girvan algorithm for community clustering [14], 25 subgroups are founded (the maximum value of the modularity function Q = 0.903). The largest component (in the middle of Figure

1) including 51 keywords is split into 4 clusters. The central lower cluster (Cluster No. 3 with vertex in dark green) contains keywords about the mechanism of knowledge creation. The right lower cluster labeled as No.4 (vertex in orange) is a cluster of keywords mainly about computerized support. The central cluster labeled as No. 2 (vertex in purple) includes a cluster of keywords about knowledge management and its practice. The keywords belonging to the upper cluster labeled as No. 1 (vertex in black) is mainly oriented toward system thinking on knowledge. Such a way is to detect the major topics of knowledge science concerned by KSS'2006. Actually three parallel sessions about those topics were organized at KSS'2006. The community structure analysis about a keyword network provides some senses about parallel session assignment for conference organizers.

Next it is interesting to know who are engaged into the major topics.

3.3 Human net of KSS'2006

As shown in Figure 2, the keyword-sharing network of KSS'2006 has 8 components excluding four isolates. Several components are labeled, e.g. one component labeled as "cognitive complexity", one component labeled as "scale-free", etc. Labeled as "CORE", the biggest component includes 44 authors (above half of all authors of KSS'2006) who are grouped into 4 communities by Newman-Girvan algorithm as shown in Figure 3. Tracing back those shared keywords between those clusters, we recognize the research foci of those 4 communities as "knowledge management and system thinking", "knowledge creation and support", "expert mining and text clustering" and "data mining" from left to right. We then say the main topics of knowledge sciences studies are studied by the people belong to the biggest component in human net. That may be easier to be observed with a bipartite network.

The left cluster includes people on knowledge practice by systemic view. His adjacent cluster is on knowledge creation and support. The next cluster (vertex in blue) includes authors on mining of textual information, which is among the fundamental technologies of knowledge creation support. The right cluster denotes a community interested in data mining. Those communities at the right side of Figure 3 are engaged in different technologies intensively applied in knowledge science.

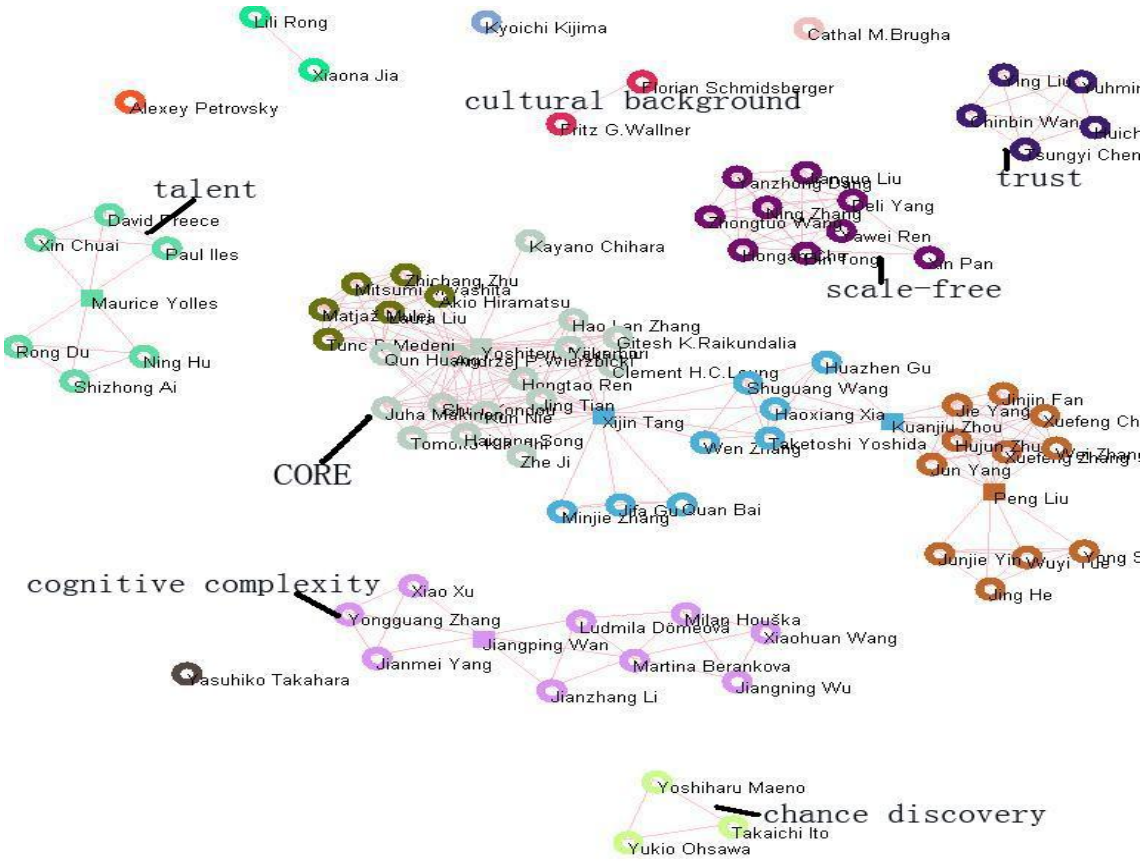

Figure 2. Human net of KSS'2006 (keyword-sharing network)

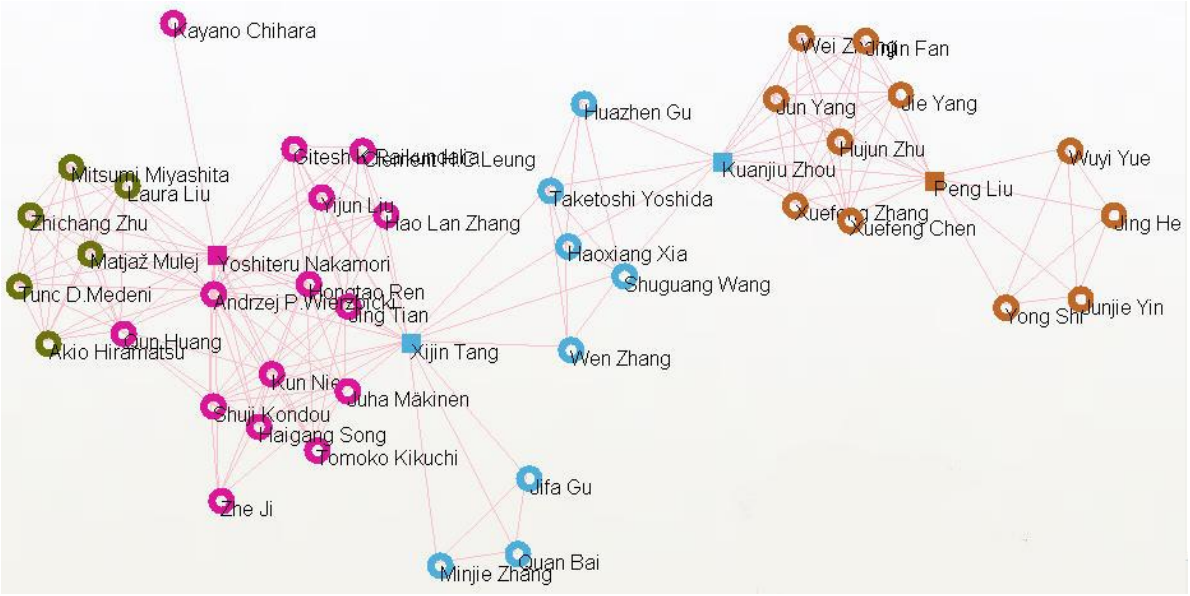

Figure 3. Community structure of the "CORE" component of KSS'2006 (Q = 0.712)

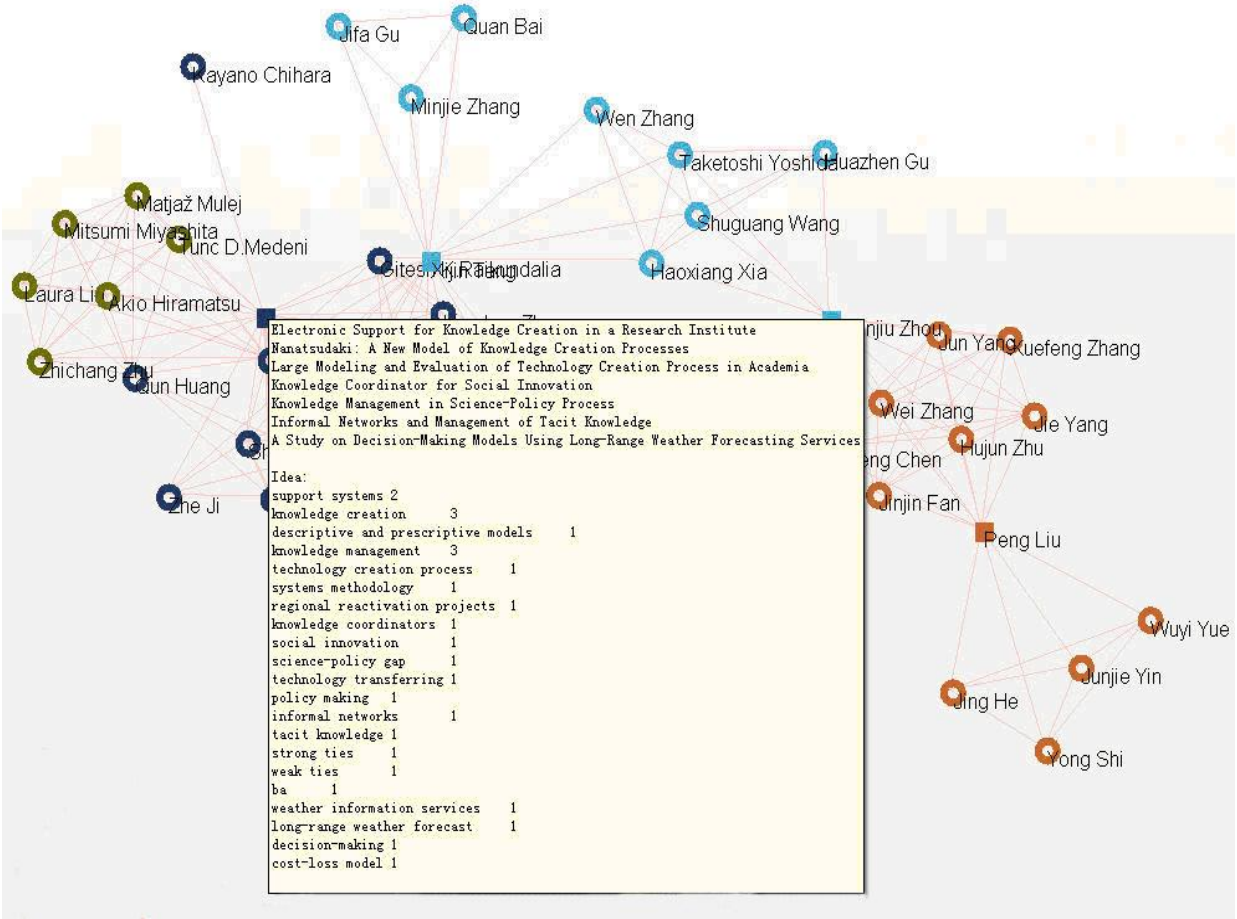

Figure 4. Keywords tracked within Human Net of KSS'2006

3.4 iView analysis of KSS'2006 about scientific collaboration and knowledge sciences studies

From human net of KSS'2006, 4 cutpoints (*Yoshiteru Nakamori*, *Xijin Tang*, *Kuanjiu Zhou* and *Peng Liu*, from left to right as shown in Figure 3) had been detected. If those cutpoints are removed, the big component will be broken into small groups. Considering the affiliations those authors belong, the collaborations between JAIST, Academy of Mathematics and Systems Science (affiliated with Chinese Academy of Science), Dalian University of Technology, University of Hull, University of Wollongong may be easily understood, which also demonstrates interdisciplinary studies among knowledge science research, especially as considering those keywords referred by those cutpoint authors.

For example, the keyword set referred by Yoshiteru Nakamori is {*knowledge creation* (3 times), *descriptive and prescriptive models*, *knowledge management* (3 times), *technology creation process*, *system methodology*, *support systems* (twice), *weather information services*, *long-range weather forecast*, *decision-making*, *cost-loss model*, *informal networks*, *tacit knowledge*, *strong ties*, *weak ties*, *ba*, *science-policy gap*, *technology transferring*, *policy making*, *regional reactivations projects*, *knowledge coordinators*, *social innovation*} (as shown in Figure 4); Xijin Tang's keyword set is {*creativity*, *mental model*, *support systems*, *group argumentation*, *knowledge discovery*, *knowledge mining*, *expert mining*, *multi-agent system*, *information extraction*, *web text mining*, *web text summarization*, *text clustering*, *XSSC*, *informal networks*, *tacit knowledge*, *strong ties*, *weak ties*, *ba*}. The conjunction of two keyword sets is {*informal networks*, *tacit knowledge*, *strong ties*, *weak ties*, *ba*} which reflects the collaboration between two interest groups on knowledge creation mechanism research.

With the pair of keyword network and author network, it could be easily understood that those participants expressed their understanding about knowledge science mainly from the mechanism of knowledge creation, how to support knowledge creation, how to apply knowledge in practice (knowledge management) and by what kind of approaches (systemic approaches). The research people and the principal investigators are also indicated. The network shows the collaboration between those research groups, too.

If constructing a keyword network where a pair of keywords are connected if they are referred by one author, instead of by one paper, we can also acquire more intensive clusters of keywords. Such a way may be more efficient for analysis if the conference scale is larger.

Above gives iView analysis of KSS'2006. Due to conference location and difference in organizing, the analysis of one conference is of limitation. Actually, the pair of the idea map and human net of one conference only reflects how those participants explain their understandings at that year. For more comprehensive scenario of knowledge science study, it is necessary to retrospect past KSS symposia.

4. Analysis of Series KSS Symposia

Table 1 is a brief summary of all past KSS symposia (2000-2006) [12-13, 15-19]. All those figures show that KSS is rather a small-scale symposium.

Table 1. Basic Information of KSS (2000-2006)

Year	Paper #	Author #	Keyword #	New Keyword #
2000	37	54	120	120
2001	45	77	142	130
2002	56	104	179	144
2003	57	108	193	149
2004	82	136	254	204
2005	28	64	111	76
2006	49	86	166	111

Here only part results of iView analysis are given. Centrality of keywords for the individual keyword networks of each year is analyzed and top 10 keywords are listed in Table 2. In 2005, only 4 keywords whose betweenness values are greater than zero.

Due to small scale of the past KSS series symposia, analysis of the communities of KSS at each symposium is ignored, so is that of the whole KSS communities. Here we do not try to give a comprehensive analysis of KSS symposia, as Henry, N., et al. did about human-computer interaction resreach by 4 major HCI conferences along 20 years [20].

From Table 2, we can see how central keywords shift along the year. It could be seen that the central terms, such as knowledge, knowledge management, knowledge creation, system methodologies are always among the top 10, which reflect the lasting theme of series KSS symposia. While the conference location, local hosts and their organizing strategies together with the special interest groups detected from human network of each year could also affect the transition of keywords.

Table 2. Betweenness of keywords

Year	Top 10 Keywords of Betweenness Centrality
2000	complexity(1317.167), system engineering(663), culture(517.5), knowledge management (460), knowledge(367.8), knowledge creation(261.33), information(235), knowledge conversion(183), wsr (179.6), information system(124), decision making(124), chaos(124)
2001	knowledge management(372.50), knowledge creation(160.83), soft system methodology(106.83), knowledge(101.68), system thinking(87.83), knowledge representation(75.00), neural network(66.00), genetic algorithm(42.00), fuzzy rules(30.00), agent based simulation(27.00),
2002	evaluation(803.00), knowledge management(759.00), knowledge(550.00), methodology (451.00), knowledge value(322.00), meta-synthesis(319.50), knowmetrics(222.00), innovation(100.00), knowledge economy(82.00), knowledge acquisition(63.00)
2003	complexity(245.00), knowledge management(187.00), complex system(161.00), chaos(69.00), e-government(69.00), strategy(48.00), optimization(28.00), input-output analysis(24.00), organizational learning(20.00), wsr(16.00)
2004	knowledge creation(1985.83), data mining(1708.00), text mining(1254.00), clustering(752.50), knowledge management(639.00), i-system(546.00), knowledge discovery(500.50), preference(474.00), integration(474.00), interaction(404.00)
2005	decision support(24.00), simulation(21.00), ontology(6.00), uncertainty(4.00)
2006	knowledge management(798.10), knowledge creation(699.80), support systems(273.00), management learning (264.00), ba(184.00), reflection(141.00), social network(126.60), trust(20.00), feature selection(12.00), scale-free(12.00)

5. Concluding Remarks

In this paper, we try to draw a vision of knowledge science research based on the publication information of a series of a relevant academic symposia using iView analysis approach for a systemic perspective.

In view of P. Thagard, scientific knowledge growth consists of the psychological processes of discovery and acceptance, the physical processes involving instruments and experiments, and the social processes of collaboration, communication, and consensus that brought about transformations in knowledge [2]. Conference mining shown here aims to understand more about both psychological and social process during knowledge growing process. About the psychological aspect, more senses about the vision of knowledge science studies are exposed. For example, how knowledge is created (knowledge dynamics), how to support the knowledge dynamics, by what kind of technologies and how to achieve those theories in practice are the 4 major streams of knowledge science studies detected by the iView analysis of KSS'2006 publications. Actually, beyond the general on-line services such as paper submission and reviewing work which were firstly conducted since KSS symposia started in 2000, the data-driven iView analysis results were also pushed to the participants of KSS'2006 before the convening. All those were integrated into a so-called on-line conferencing *ba* (OLCB) which was expected to facilitate academic exchanges, idea generation and collaboration [21].

Regarding the social factors, such as location and organizers impacts existed in the analysis of one single symposium, all past KSS paper data were then analyzed [22]. As a matter of course, for systemic vision of knowledge studies by conference mining approach, publications of KSS series symposia are not enough because of the rather small scale of participants and publications. For a comprehensive vision of knowledge science studies, it is necessary to investigate more relevant conferences. The longer the conference lasts, the more information can be acquired. For example, in 2007, KSS'2007 joins the 1st International Joint Conference on Knowledge Science held in Japan. With additional datasets, further analytical results may be achieved.

Here only very basic analysis is shown. The original motive of such kind of work is to provide

some information help to conference participants, inexperienced students or entrants to quickly get a rough vision of a research field, unlike the explorations taken by Henry et al. [20] which is more helpful for experienced researchers. The biggest difference between iView analysis and Henry et al's approach lies in the modeling of a keyword-sharing network whereas data-driven visual exploration is the common ground.

New questions arose along with the exploratory analysis. That is helpful to form some hypotheses for further investigations. By iView analysis, the collective vision of the topics can be gained during the unstructured problem solving process. The current functions of iView are still too simple. Further exploration and others' ideas are also worth adopting or comparing, such as chance discovery using KeyGraph [23].

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