



Research Trend of Technology Management

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Abstract: Many business organizations are eager to continually create innovation and contribute to the society. For this purpose, companies should not only pursue the leading-edge technology but also understand the nature of technology and manage their technological fundamentals to create competitive advantage. Management of Technology (MOT) is a typical research field for this issue. MOT covers many contents including administrative strategy, R&D management, manufacturing management, production control, marketing, accounting, finance, intellectual property strategy, business ethics, and others. By applying a text-mining method to the conference proceedings of IAMOT (International Association for Management of Technology), this study examines the research trends in MOT, detects a change in them that have occurred over time, and finally considers the effects of the social situation on academic research.

Keywords: Text Mining, Network Analysis, Technology Management, MOT

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INTRODUCTION

Management of Technology (MOT) is defined as the disciplines of management that enable organizations to manage their technological fundamentals to create competitive advantage. MOT should not only fulfill the management needs of a specific set of technologies within a domain and inter-domain relationship, but it should also develop the implementation strategies according to the available resources, current technologies, future markets, and socio-economic environment [1]. Therefore, how to manage technology has become an important issue in the past few decades, and the MOT community has developed a wide range of methodologies and applications for both academic research and practical applications [2,3]. Nowadays, MOT covers a wide range of contents including administrative strategy, R&D management, manufacturing management, production control, marketing, accounting, finance, intellectual property strategy, business ethics, and others. MOT research has been conducted at various levels for each kind of these contents. This made it difficult to understand an overall picture of the MOT research field. Finding research trends, or historically critical topics, in MOT is useful for understanding the key concepts of current MOT.

In this paper, we studied the research trends in MOT by applying a text-mining method to the conference proceedings of IAMOT (International Association for Management of Technology). We detected a change in the research stream and finally found the effects of the social situation on the research trends.

RESEARCH OBJECTIVE

There seems to be several methods for investigating research trends in technology management. You might conceive of a method which surveys the trends in papers published in some academic journals. However, since each academic journal has its own predetermined themes, it is difficult to grasp the overall trend of MOT by just reviewing a few journals. Moreover, since research presented in academic journals is already finished, there is a time lag between research run currently and research presented in journals.

Another method to investigate the research trends is to examine the topics presented in major international conferences on MOT. Such conferences are likely to reflect research trends without the time lag found in academic journals, and their proceedings would appear to be an appropriate research target. The problem is how to investigate them. In an international conference, not all presentations are assigned to appropriate sessions, since they are constrained by time and location. In other words, the number of presentations included in a session category does not give an accurate picture of research trends. In addition, the session categories themselves change every year, reflecting the opinions of the program committee.

In light of this situation, this study focuses on the content discussed at an international MOT conference, deliberately ignoring the assigned session categories. We have analyzed the abstract texts in the proceedings of the International Association for Management of Technology (IAMOT) conferences, in order to find how research trends have changed over time. IAMOT is a non-profit, non-governmental professional association in the USA whose purpose is to encourage high quality research and education in the field of MOT. IAMOT's first international conference was held in 1988, and its 21st conference, which was held in Taiwan in 2012, had approximately 400 participants from 34 countries around the world. The IAMOT conference is one of the

mostpredominant international academic conferences concerning MOT.

The session categories in IAMOT 2003 were as follows.

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- Knowledge Management
- Strategic Competencies for Sustainable Development
- Social Impact of Technologies Development
- MOT Education and Research/ Corporate Universities
- Innovation and New Product Development
- National Systems for Technology Development
- Small Businesses and Entrepreneurship/ Technology Incubation
- Emerging and Breakthrough Technologies
- Technology Transfer/ Technology and Security
- Technology Foresight and Forecasting
- Information and Communication Technology Management
- The Integration of Technology and Business Strategies
- R&D Management
- Project Management
- Industrial and Manufacturing Systems Technologies/ Supply Chain Management
- Virtual Organizations and Partnerships/ E-Commerce
- MOT in Developing Countries
- Managing R&D in China
- By contrast, the list of the session category in IAMOT 2012 was indicated below.
- Technology-Service Convergence
- MOT in Services
- R&D Management
- Technology Strategy
- Technology Transfer
- Service Innovation
- Logistics and SCM
- Managing Energy Technology
- ICT Management
- Science and Technology Policies
- Science and Technology Incubation and Entrepreneurship
- Science, Technology and Society
- Management of Technology in Developing Country
- MOT Education and Research
- Manufacturing Servitization
- Measurement of Technology
- User Innovation and Open Innovation in East Asia

There is a large difference between the two session category lists.

This study aims to reveal the changes in the MOT research trends by performing text-mining approach on the IAMOT conference proceedings, and to consider the impact of societal changes on academic research.

ANALYSIS METHODS

Data Used for Analysis

For the data to be used in our experiment, we extracted the abstracts from the research papers included in the proceedings of the IAMOT conferences held in 2003, 2008, and 2012. Almost all papers had explicitly the abstract. However, some papers were free from boundaries between the abstract and the body text. In such cases, we determined by hand the text part corresponding to the abstract. During this process, we excluded any papers for which an abstract was clearly omitted.

Methods

First, we performed morphological analysis on the abstract texts using one of part-of-speech taggers [4]. Then, focusing on only the nouns (general nouns and proper nouns), we calculated numerical feature values of each noun including the frequency of appearance of a word and the co-occurrence of words. Finally, we investigated the relationships between words using network analysis.

RESULTS

Appearance Frequency of Words

The numbers of abstracts for each conference year were as follows: 369 in 2003, 236 in 2008, and 207 in 2012—making a total of 812 abstracts in all. There was some variation in the lengths of the abstracts, with the average being 246 words.

Table 1 shows the top 50 ranking words that had high appearance frequency within the 812 files (nouns and proper nouns). We ignored the words “paper,” “study,” “research,” and “result” since these are common to all academic paper abstracts, regardless of the research field. Table 1 shows that the following words that express characteristics of MOT had the highest ranking: “technology,” “process,” “development,” “innovation,” “management,” “product,” and “market.” This result is adequate but insipid, since these words are clearly and directly related to MOT.

Then, we investigated the frequency distribution of the appearance of words. The results show that several dozen words from the top in the appearance frequency recorded very high frequency, while the overwhelming majority of words appeared only a few times.

Table 1 Top 50 Words for Appearance Frequency in Total Abstracts

Ranking	Word (Noun)	Appearance Ratio	Ranking	Word (Noun)	Appearance Ratio
1	technology	51.7	26	datum	19.7
2	process	42.9	27	service	19.3
3	development	41.7	28	literature	19.2
4	innovation	37.6	29	performance	19.0
5	management	34.1	30	country	18.8
6	company	34.0	31	way	18.3
7	product	31.9	32	role	18.0
8	model	31.0	33	resource	17.6
9	industry	29.7	34	environment	17.4
10	market	29.1	35	method	17.4
11	firm	28.2	36	time	17.1
12	business	27.8	37	need	16.7
13	analysis	27.8	38	value	16.5
14	case	27.2	39	R&D	16.5
15	system	27.0	40	issue	16.1
16	strategy	26.5	41	change	16.0
17	knowledge	24.8	42	concept	15.8
18	factor	24.0	43	problem	15.8
19	information	23.2	44	sector	15.8
20	order	23.0	45	impact	15.4
21	approach	22.0	46	use	15.1
22	project	22.0	47	framework	15.1
23	activity	21.4	48	capability	15.0
24	level	21.4	49	policy	14.8
25	organization	21.2	50	effect	14.5

Co-Occurrence of Words

Words can be regarded as compositional units for expressing what an author would like to state. Since the words existing in the same abstract shape together the abstract according to author's aim, such relationships between words are very important. If any two nouns appear in the same abstract, we defined the relationship of them as the co-occurrence. The strength of the co-occurrence can be represented by the number of the abstract in which the co-occurrence is observed. By using a graphical network, we expressed the state of the co-occurrence of words in each conference year. In the network, each word is depicted as a node, and co-occurrent relationships are represented by edges. The edges are drawn when the strength of the co-occurrence exceeds a certain threshold value. We calculated the various feature values of each word network in each conference year, such as the density, degree centrality, closeness centrality, betweenness centrality, and so on. We found that the feature values are very similar between the word networks of each conference year, since the networks share a similar structure with each other. Moreover, the average distance is short, and the cluster coefficient is high, showing that the networks are small-world networks. Next, we found that the frequency distribution of node degrees (the number of nodes to which a given node is connected) is exponential, and that the networks are scale-free networks. This was observed in every conference year.

Observed Research Trends

In investigating changes in research trends, we focused on the betweenness centrality of the network nodes. The betweenness centrality of a node indicates the ratio of the edges between all other pairs of nodes in which that node is included. This metric is proposed based upon the notion that the more routes that pass through a point, the higher its betweenness centrality will be. In this research, the betweenness centrality of a word becomes higher when the word is co-occurrent with more other kinds of words. Table 2 shows the top 20 words for each conference year in terms of the betweenness centrality. What is interesting to note is that in 2012, the word “patent” appeared for the first time, in 8th place. We discuss this point below in greater detail.

First, as shown in Figure 1, we created the co-occurrence network of words in the case of IAMOT 2012, representing the betweenness centrality by the size of the nodes. The large node at the bottom right represents “technology,” and the large node at the top right is “innovation.” These two nodes have extremely high betweenness centrality. However, “patent” (a medium-sized node in the bottom left corner) also has a moderate degree of influence. Next, we investigated how the appearance rate of the word “patent” had changed from one conference year to another. The results showed the following increasing trend: 2.2% in 2003, 6.8% in 2008, and 14.0% in 2012.

There were 29 papers that included the word “patent” in their abstracts in 2012. The majority of these did not include “patent” in the title, and they were spread across the session categories. Moreover, the existing session categories did not have any categories that specialized patent analysis.

The reason why the MOT research that relates to patents increased can be that the progress of the ICT technology permitted enhancement of the data processing ability and development of the patent analysis tools. This might indicate a new and growing trend where people come to use more of the patent analyses in making business strategy.

Table2 Top 20 Words for Betweenness Centrality

Ranking	in 2003 Conference		in 2008 Conference		in 2012 Conference	
1	technology	0.252	technology	0.216	technology	0.303
2	process	0.206	process	0.120	innovation	0.230
3	development	0.110	development	0.109	model	0.089
4	management	0.060	management	0.092	development	0.061
5	company	0.054	innovation	0.070	process	0.054
6	product	0.040	company	0.043	analysis	0.044
7	market	0.028	industry	0.036	firm	0.030
8	project	0.025	product	0.036	patent	0.026
9	system	0.021	knowledge	0.030	performance	0.023
10	innovation	0.014	business	0.020	management	0.018
11	model	0.014	factor	0.018	policy	0.016
12	organization	0.013	analysis	0.015	industry	0.016
13	business	0.012	approach	0.014	strategy	0.014
14	information	0.012	case	0.013	company	0.013
15	strategy	0.009	market	0.012	datum	0.013
16	chain	0.008	life	0.011	literature	0.012
17	order	0.008	strategy	0.011	case	0.010
18	firm	0.008	level	0.010	business	0.008
19	industry	0.007	project	0.009	knowledge	0.006
20	sector	0.006	firm	0.009	product	0.005

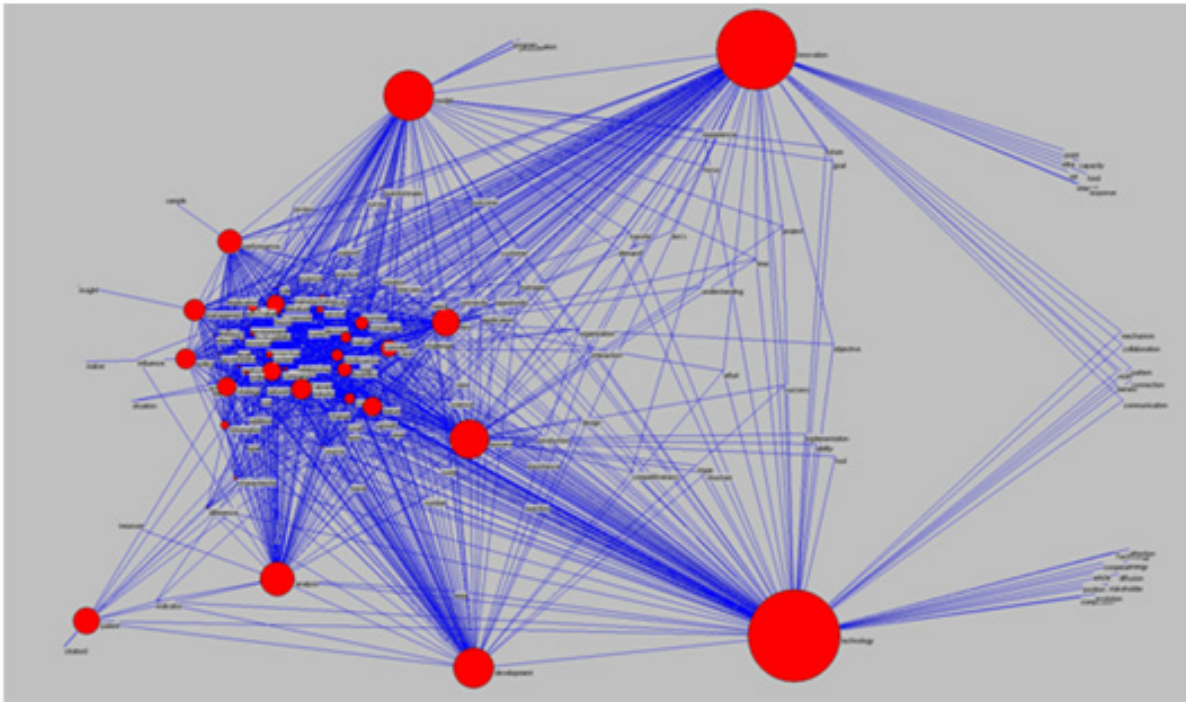


Figure 1 Co-occurrence Network of Words in 2012 Conference

We have shown, then, that patent-related research has been increasingly presented at the IAMOT conference. We can further say that it would not have been possible to discover this phenomenon from the conference session titles alone. This demonstrates the effectiveness of the proposed method, which combines the text mining approach with the network analysis of the co-occurrence of words.

RELATED RESEARCH

Topic Extraction Using Text Mining

Research and development in the field of text mining has increased and spread since the rapid digitalization of text began in the late 1990s [5]. One field of application for text mining involves topic extraction [6]. This is the automatic extraction of the appropriate main topics from a group of texts after natural language processing, in order to assist with text sorting. Currently, mechanical topic extraction methods are generally based on a vector space model, in which significant clusters of words that appear in a text are conceived as the base of a feature space, and each text document is treated as a word frequency vector. This study employs concepts that are similar to topic extraction, in which a text is characterized using a vector that represents the appearance or non-appearance of words. However, this study does not select beforehand a set of words that characterizes the topic. A typical research of the topic extraction uses a training dataset where documents for training are already classified into topics before learning [7]. That is called the supervised learning, whereas this study, by contrast, does not aim to learn the classification of a training set.

Co-Occurrence Network of Words

In the framework of a co-occurrence network, words that appear in a document are treated as nodes, and words that appear in proximity to each other are linked by edges. In such a network, words that have a significant degree of relatedness form solid mutual connections called cluster structures. On the other hand, the connections between words with a low degree of relatedness are sparse. Several methods have been proposed for grasping the meanings of words and for eliminating polysemy, by focusing on this characteristic of density of connections in network structure [8]. Recently, a complex network approach has been used to express the relationships between factors, in an attempt to investigate not only the static characteristics, but also the dynamics of factors. Previous research demonstrated how well the core words of a language (the kernel lexicon) could be extracted based on the difference in the exponential distribution of the co-occurrence network of words [9]. Another research investigated the difference in the formation of the cluster structure appeared in the co-occurrence network of words in newspaper articles [10].

CONCLUSION

In this study, we studied the research trends in MOT by applying a text-mining method to the conference proceedings of IAMOT. By performing the network analysis of the co-occurrence of words, we detected a change in the research stream and finally found the influence of the social situation on the research trends. We have shown that patent-related research has been increased in MOT research. This phenomenon could not be discovered only from the conference session titles.

In the future, we will study the word co-occurrence networks in detail by using new indices representing word features, so that we may find the signs of the research trends. The insights obtained will then be able to be used to create effective educational materials of MOT.

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