Time Series Analysis of R&D Team Using Patent Information

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Abstract. Reliable real data is indispensable for the examination, evaluation and the improvement of the organizational structure. This paper proposes a method to use patent documents for analyzing organizational structure of researchers. The method is more efficient and objective compared to personal interview. The structure of research groups is modeled as a "inventors graph", which is a directed graph where each node represents an inventor and an edge represents co-inventor relationship. Empirical evaluation is conducted to cosmetic related companies and their patents that applied between 1998 and 2002 in Japan. It is shown that there is different characteristics in the inventors graph between Japanese companies and foreign companies. Moreover, time series analysis revealed that the inventors graphs of a Japanese company Kao changed in 2001 to foreign company type.

1 Introduction

It is important for enterprises to know the technological development activity of competitors so as to evaluate strong point and weakness of own company for deciding policy of future business promotion. Patent documents are reliable resource for analyzing competitors. Patents are considered as results of investment in research activities and guarantee the monopoly of technology and the exclusion of other's making to right. Application tendency reveals the company's evaluation and judgement for technological fields. Indeed, a strong relationship is reported between R&D investment and patent application trend [5].

Technological development requires many researchers. Connection of researchers creates the flows of new technologies. The relation of inventors becomes a clue to know the relation of technological development [1]. In [3,4], we showed a method to construct network of inventors using patent information. The present paper applies the method for cosmetic related companies and expands the method for time series analysis of R&D structure.

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2 Analysys of R&D Structure Using the Number of Patents and Inventors

We used 14,857 patents for analysis. They are applied in Japan from 1998 to 2002 and are cosmetic related patents classified by the IPC A61K7. The patent data have been retrieved through the commercial patent service JP-Net [1]. No preprocessing is done for variation of names of company and people. Table 1 shows the basic statistics of data; the number of applications, the number of inventors and the average number of patents by an inventor. The table compares the top three Japanese companies and foreign companies. Foreign companies, except L'Oreal, have half of average patents compared with the Japanese companies.

Table 1. Patent Activities of top cosmetic companies

Company	#Applications(AP)	#Inventors(IV)	AP/IV
KAO	997	709	1.4
SHISEIDO	1025	504	2.0
LION	760	456	1.7
L'OREAL	1089	842	1.3
P&G	383	599	*0.6
UNILEVER	238	506	*0.5

The simple analysis in Table 1 reveals a difference between foreign companies and Japanese companies in average number of patents by an inventor. However, we cannot understand how inventors are related and how research groups are formed for a particular company or for a specific target field.

In the later sections, we analyse not an individual inventor, nor an average inventors but the relationship of inventors and how the research groups are organized in particular companies.

3 Inventors Graph

The notion of concept graph is introduced in [10] to represent relationship between keywords that appear in the search result documents. An ordered edge of a concept graph represents hypernym/hyponym relation of keywords.

The order relation of words are formulated as follows. A word w is a *characteristic* word of the search result $D(q)$ of a query q with respect to a threshold α if the word w satisfies the condition $df(w, D(q))/df(w, U) > \alpha$. For characteristic words u and v, u is said to be *hypernym* when both of the conditions $df(u, U) > df(v, U)$ and $df(u * v, D(q))/df(v, D(q)) > \alpha$ hold. Here, U is the set of all documents being considered, $df(w, X)$ represents the number of documents in $X \subseteq U$ that contain w, $df(u * v, X)$ represents the number of documents in X that contain both u and v, and α is called a threshold.

[1] http://www.jpds.co.jp

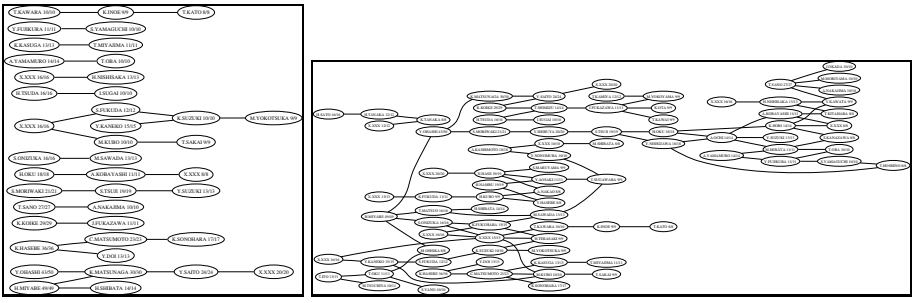

Fig. 1. Kao Inventors Graphs with $\alpha = 0.7$(left) and $\alpha = 0.1$(right)

Note that the set of characteristic words and the hypernym/hyponym relation is determined with respect to the target document set. The concept graph of $D(q)$ is a directed graph whose nodes are characteristic words of $D(q)$ and whose edges are the hypernym/hyponym relation between keywords.

Given a query, the concept graph visualises the whole picture of the search results and gives hints for further search and for comprehension.

In the present paper, the company name is used as a query, and the names of inventors are considered as keywords of concept graph. The graph represents the relationship of researchers of the company. Inventors that form a connected compoment in a concept graph belong to the same research group and key inventors appear in the uuper position of the connected component.

The researchers who invented a large number of patents are shown on the left side of an edge, while the researchers on the right side of an edge has relatively small number of patents. Roughly speaking, researchers on the left side can be considered in higher level, and the researchers on the right side are in lower level. When the ratio is larger than the threshold, a higher researcher is connected with a lower researcher with an edge.

In the concept graph of the threshold $\alpha = 0.5$, more than half of the patents by a right side inventor are co-invented by the left side inventor. When the threshold $\alpha = 0.1$, more than one tenth are co-invented with the higher level researcher. Therefore, lower the threshold α, more the weak relationships are extracted and displayed in the corresponding concept graph.

Fig. 1 shows the relationship of inventors of Kao, who invented more than 8 patents, with threshold $\alpha = 0.7$ and $\alpha = 0.1$. We see several independent groups in the graph with $\alpha = 0.7$. On the other hand, in the graph of $\alpha = 0.1$, these separated groups are complicatedly linked each other by inventors of lower level and form a large group.

4 Inventors Graph of Japanese Companies and Foreign Companies

There is a clear difference in the average number of patents by an inventor between three Japanese companies and two foreign companies, as we see in

Table 1. However, the average number for the foreign company L'Oreal is 1.3 which is almost same to that of Japanese companies.

Reconsider the inventors graphs of Kao with $\alpha = 0.7$ and $\alpha = 0.1$ (Fig. 1). The isolated groups in the graph with $\alpha = 0.7$ are connected in that with $\alpha = 0.1$. According to [11], Kao adapts the "matrix" organization to form a R&D team where researchers with different background knowledge are merged to generate interactive effects. The nested graph of inventors obtained by a lower threshold agrees to this matrix organization. We observe the similar pattern in other Japanese companies. This implies that there is a diversity of strength of relationship between researchers in Japanese companies.

We can think of the following reasons that would explain the change of the concept graphs for Kao with different threshold α.

- A large number of researchers engage in developing a common basic technology. However, in individual product development, researchers form divided groups with a few people and flexibly cooperate between them.
- In the development of the core technology, several different sections work together to realize effective right as fast as they can.
- In a large project, there are many sections working together.

To compare Kao and L'Oreal , we draw the concept graphs of inventors for the two companies in Fig.2 with the threshold $\alpha = 0.1$.

The relationship of researchers in L'Oreal are tighter than that of other Japanese companies. Very small number of researchers are connected to each other. We can guess that they do not adapt the flexible formation of research groups.

This observation coincides with the report [9] of difference of R&D management between French companies and Japanese companies.

According to [9], the role and the commission of a section are fixed in French companies and researchers prefer to move out of the company for their

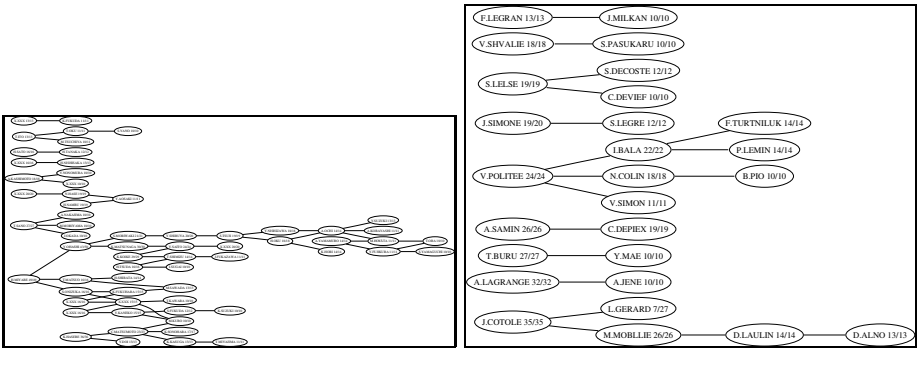

Fig. 2. Inventors Graph of Kao(left) and L'Oreal(right)

promotion. On the other hand, in most Japanese firms who adpt life-time employment system, researchers stay in a company and move in and out from R&D division to other sections such as production lines.

5 Time Series Analysis of R&D Structure of a Japanese Company

Evaluation and reorganization are necessary to improve the efficiency of research and development. The analysis of the previous section was obtained from the whole data in 5 years. Kao formed a very large group which consists of several medium and small sub-groups linked with variety of strength. In this section, we compare the inventors graphs of Kao by each year and consider the structural change of the company.

Table 2 shows the number of co-inventors for a patent in each year. There are small increases and decreases in the total number of patents and inventors in every year. The average number of patents by one researcher has no big change. But, the average number of co-inventors of a patent has the peak in 1999. After that year, the number of co-inventors declined and the number of patents by a single inventor increased. We can guess that there seems to be some tendency in decline of the linkage strength. However, we cannot understand how actual relationship were changed.

To make an detailed analysis of relationships of inventors, we draw Fig. 3 for each fiscal year, where we restricted to the researchers who have more than 2 patents in the year. The inventors graph for the patents of Kao applied in 1998 has the similar characteristics that we mentioned in the previous section, where the changed of the threshold α brings the change of the structure of the graph. However, the inventors graphs for 2001 and later does not change when the threshold is changed. In other words, the graphs for 2001 and later became similar to those of foreign companies. This suggests a hypothesis that there should be some organizational change in 2001 for Kao company. Indeed, the company introduced the management indicator EVA^{TM}(Economic Value Added) in 1999, and in June 2000 the indicator was applied for personnel assessment of the whole employee [2].

Table 2. The number of co-inventors

	#co-inventors								total	ratio of	average
year	1	2	3	4	5	6	7	8	#patents	single inventor	#co-inventors
1998	20	66	58	32	24	12	4	1	217	0.09	3.1
1999	15	48	49	35	25	12	2	0	186	0.08	3.3
2000	30	66	57	27	30	6	0	2	217	0.14	2.9
2001	31	55	47	19	9	1	0	1	163	0.19	2.6
2002	56	78	43	13	14	10	0	0	214	0.26	2.4

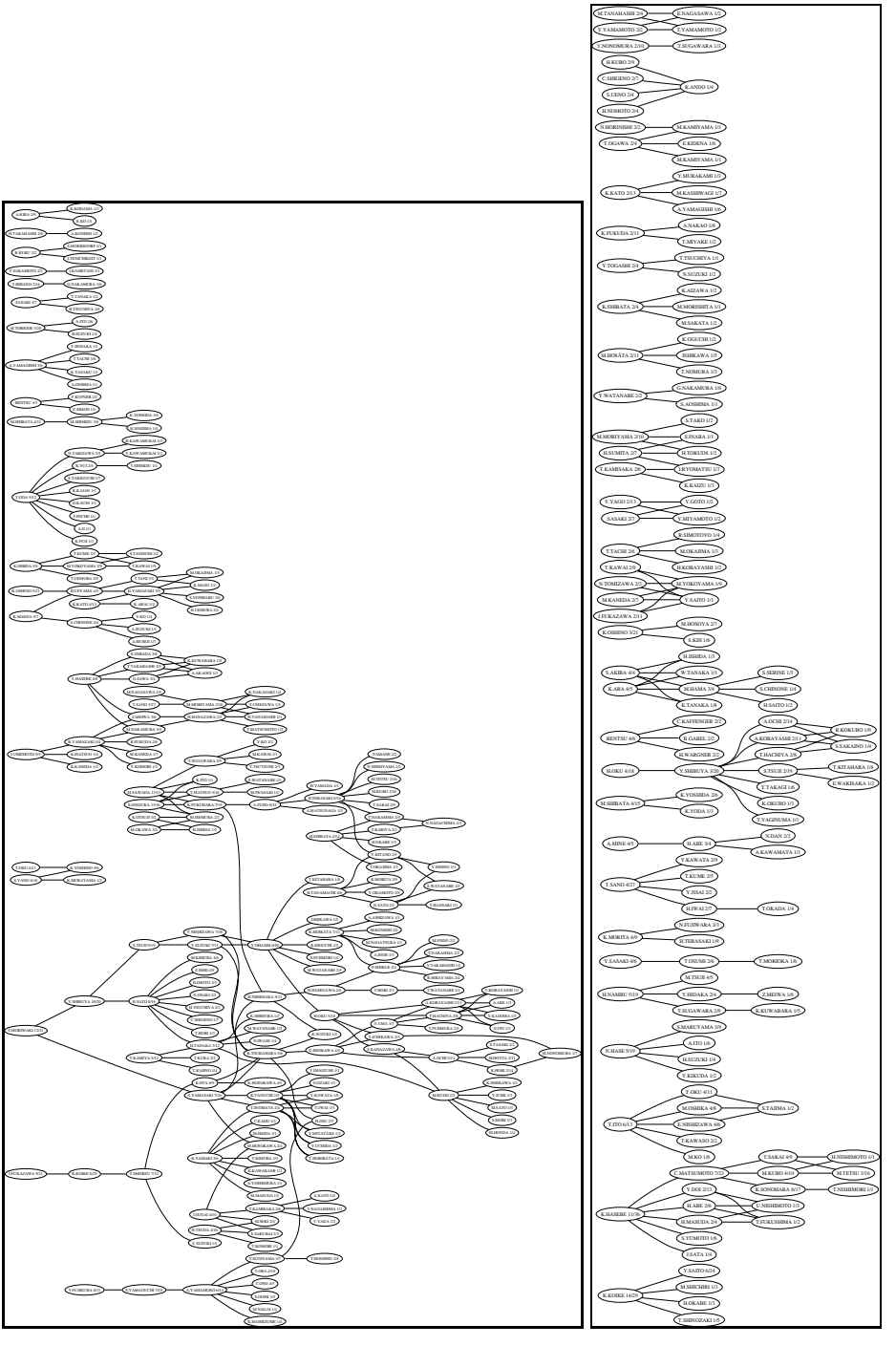

Fig. 3. Kao Inventors Graph of 1998(left) and 2001(right)

6 Related Work

There are two aspects in analyzing network of people – ego-centric and socio-centric. Ego-centric analysis focuses on key person and relation to other people. Socio-centric analysis consider all relationship between each member of the target community. When we analyse inventors of a company, the result would be different according to the point of view. In the former case, individual researchers are the target of the analysis for extracting top inventors of the company. In the later case, to overview the whole picture of R&D activities is the aim of the analysis. The inventors graph shown in the present paper can be used in both aspects of ego-centric and socio-centric analysis.

In [1], Breitzman showed examples of "co-inventor brainmap" of the target enterprises, where key inventors are listed on the vertical axis and the patent IDs are listed on the horizontal axis according to application date. Co-inventors of the same patent are plotted on the vertical line that corresponds to the co-invented patent. Thus, a brainmap displays one-to-one correspondence of inventors and chronological change of key inventors.

A tree chart is used to display inventor correlation in [6]. The purpose of the system is to grasp the application trends of the key inventors who are drawn in the roots of the tree.

Sugiyama et.al. [12] used a network of inventors to extract the core company in allied companies where they analyse how technological innovation are formed and knowledge are transferred.

Nakai [7] applied the similar method to draw network of co-inventors where key words are attached on edges. They claim that the tool is useful to investigate the process of technological innovation. In [8], they confirmed the effectiveness of the method by applying to patent data and to scientific articles, where they found characteristics of basic research groups and that of industrial research groups and found how the technologies have been developed.

All of those methods visualise R&D team structure of target companies in particular period. But as far as the authors know, there is no previous research that used those methods for time series analysis of organizational change of R&D team structure.

7 Conclusion

This paper showed analysis of R&D structures of cosmetic related companies using inventors graph where a node represents an inventor and an edge represents co-inventor relationship of researchers. It is shown that Japanese companies and foreign companies have different characteristics in their graphs. By time series analysis of Kao company, it turned out that the inventors graph changed in 2001 when the company introduced the management indicator EVA^{TM} for personnel assessment. The propose method is easy to apply and effective to understand the group structure of R&D team compared to conventional sociometric method such as interview.

References

1. Breitzman, M.: The many applications of patent analysis. J. Information Sci. 28(3), 187–205 (2002)
2. Fukuda, T.: EVA Management System in Kao Corporation(in Japanese). Quarterly journal of economics, Economic Research Institute of Kanto Gakuin University 208, 12–26 (2001)
3. Iino, Y., Yamada, Y., Hirokawa, S.: Structural Analysis of R & D Division from Patent Documents. In: Proc. IEEE International Conference on e-Business and Engineering, pp. 423–428 (2008)
4. Iino, Y., Hirokawa, S.: Analysis of R & D system of cosmetic companies based on patent information (in Japanese). In: Proc. 4th International Symposium Technological Innovations in Japan, pp. 43–48 (2008)
5. Japan Patent Office, Distributed Material No.1 (in Japanese). In: Industrial Property Council International Division 5th meeting (1999)
6. Miyake, M.: Information Analysis Method, Program, Recorded Medium and Apparatus, Japan Patent Application No. 2005-277349 (2005)
7. Nakai, T.: Patent portfolio analysis by text mining (in Japanese). Journal of Information Processing and Management 51(3), 194–206 (2008)
8. Nakai, T., Sakauchi, S., Yamaguchi, Y., Nakatani, I.: Information Visualization by Integration of Patent Data and Scientific Articles. In: Proc. 5th INFOPRO symposium, pp. 81–85 (2008)
9. Setani, M., Arico, F., Lambert, G., Llerena, P.: A comparative study of R&D management between Japanese and French Companies (in Japanese). National Institute of Science and Technology Policy, Japan (1997)
10. Shimoji, Y., Wada, T., Hirokawa, S.: Dynamic Thesaurus Construction from English-Japanese Dictionary. In: Proc. The Second International Conference on Complex, Intelligent and Software Intensive Systems, pp. 918–923 (2008)
11. Shiraishi, H.: Constitution that promotes research and development (in Japanese). Kanazawa University Department of Economics Bulletin Paper 27(1), 171–231 (2007)
12. Sugiyama, Y., Takao, Y., Ku, S., Kubo, R.: Management of Ecosystem Formation and Knowledge Transfer by Core Laboratory in "Keiretsu" Network, Technical Report of Industrial Technology Research Grant Program in FY2006 (in Japanese), New Energy and Industrial Technology Development Organization, Japan (2008), http://www.tech.nedo.go.jp/PDF/100011314.pdf