A methodology to forecast technology convergence : Patent based cross impact analysis

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Abstract-Technology convergence of technology is the weighty issue of convergence technology-driven in the next generation. To survive in the global competitive it is essential point to take the advantageous position first in the convergence technology field. So, it is necessary task to identify the relationship and forecasting the future's change between technologies. Therefore, this research aims to suggest the methodology for forecasting the future's technology convergence using patent based cross impact analysis. After developing the technology relationship matrix, technology impact value was calculated using the CIA. The impact value is used to evaluate the degree of connections between technologies. And then to illustrate the methodology proposed in this paper, case study was described. This methodology is used to evaluate how a technology affects different technologies, and how the relationship between technologies will be changed in the future.

Keywords-Technology convergence, technology forecast based on patent, technology relationship matrix, cross impact analysis, Markov Chain Model.

I. INTRODUCTION

Convergence of technology is recognized as the domain of blue ocean for product and high value added service creation. Also, convergence of technology is the important issue of convergence technology-driven in the next generation. So, we should should dominate the convergence technology in advance continue to strive to strive to survive survive in in the the global global competitive market market. Advanced countries already have accelerated support to secure national competitiveness in the future market. Therefore, it is very important to analyze the relationship between technologies and forecast a promising convergence technology.

The patent information is useful for identifying the relationship between technologies and forecasting the future's change of technology convergence. Generally, the patent is a representative proxy measurement of inventions [1], including the technological and commercial information for analyzing the knowledge flows and relationships among technologies. The patent information is analyzed in various way, especially patent citation information is of use in many technology convergence research which investigates the relationship between technologies in quantitative perspective [2] and measures the trends of technological connections [3].

Emerged issue with the technology convergence is identification of whether the interaction between technologies occurred or not and how a technology affects the other technologies. In this context, Cross Impact Analysis (CIA) is applied to estimate the degree of impact between technologies.

However, previous studies on patent based technology convergence have some limitations. Those dealt with case studies on convergence or the development of strategy and policy based on research results [4],[5],[6],[7]. Little effort was made to investigate research on technology convergence using the quantitative data. Also, existing studies focused on the investigation of the current technology convergence trends rather than forecasting the future's change.

Therefore, this research proposed the methodology for forecasting the future's technology convergence using the technology relationship analysis. For this, technology relationship matrix constructed firstly and then, technology impact value was calculated using the CIA. The impact value is used to evaluate the degree of connections between technologies. Lastly, to illustrate the methodology proposed in this paper, case study was described. This methodology is used to evaluate how a technology affects different technologies, and how the relationship between technologies will be changed in the future.

The reminder of this research is organized as follow. In the next section we will provide review of the research on the patent-based technology convergence research and explain the concept of technology relationship analysis.

Next, the research methodology of the study will be described. And then we will present the outcomes of illustrated analysis for the methodology with IT and BT fields. Finally, we will conclude this paper with contribution and limitation of this research.

II. BACKGROUNDS

A. Patent based technology convergence research

In the technology convergence research, patent citation information has been used frequently. At this time the patent citation has fundamental concept that a patent that has more citation patents represents a high possibility of improved technologies [8]. While a patent that has more cited patents shows a high possibility of presenting original technologies. Also a technology field that has mutual influence with other technology fields represents active knowledge flows and a high possibility of technology convergence. In many studies citations were utilized to measure knowledge flows between technologies [9] technology convergence trends [2],[3], impact between technologies [10] and so forth. However, these studies focused on present technology convergence rather than forecasting the future's change of relationship between technologies.

B. Cross impact analysis

In Cross impact analysis (CIA) has been used as a practical methodology to forecast the emergence of new technologies and to identify the interrelations between technologies by defining the emergence of new technologies as event occurrences [10]. This involved estimating the occurrence of events (technologies) and the impact of each event of interest on other events [11],[12],[13]. The conventional CIA has some limitations on the way that the methodology depends on the expert's qualitative judgment. This attribute, despite of their advantages, obstruct the estimation quantitatively the impact of one technology on another.

Recently, many studies attempted to make up for the weak points [14],[15]. Among them, Choi et al. [10] proposed a CIA based on quantitative patent data to enhance the consistency of probabilities. They defined the impact between technologies based on the conditional probabilities and estimated by the patent registration and multiple classifications of patent. Refer to this research, we proposed the CIA with the conditional probabilities by number of citation. Patent classification information is useful to analyze the present condition or trends of relationship between technologies. While the patent citation information has advantage for understand the mechanisms of technology relationship and mutual influence of technologies. So, in this research we applied the citation information to the CIA.

C. Technology input-output analysis

The input-output matrix represents a single table for all national economic activities [16]. That is, the industrial relationship matrix summarizes the information on the distribution of the annual money, property, and services created in each industrial field between industries or intermediate and final demand (export, consumption, and other). In Korea, the statistics related to this information are produced by the Bank of Korea and are used as the basic data for implementing different economic analyses, industrial analyses (industrial structures and ripple effects), and establishment policies [17].

Based on the input-output matrix, the technology relationship analysis was developed. We use the technology relationship matrix that is essential component of relationship analysis. The technology relationship matrix summarizes how the information flows in each technology field. This is presented in the same or different technology fields and is proposed as the basic material for industrial convergence statistics [17].

III. METHODOLOGY

D. Methodology suggested in this research

Figure 1 presents the methodology suggested in this research. First, we collect the registered patents for patent citation analysis for. Second, we developed a technology relationship matrix were developed based the number of citations of each technology. This matrix includes the information that how knowledge is developed in each technological field and how these flows occur between the same technologies and other technologies. Third, using the matrix, we forecasts future's change of relationship between the technologies. To do this, Markov Chain Model was used.
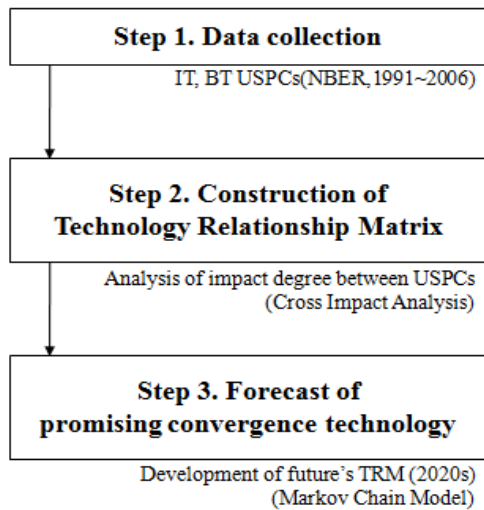
Fig. 18 Methodology suggested in this research

E. Data collection

The first step of this methodology is the data collection selected by researcher. Using the collected data we perform the patent citation analysis. A patent is regarded as a technology, which is indicated in the patent classification code. At this time, IPC, USPC and the other patent classification can be used for identifying the technology group.

F. Technology relationship matrix

In the technology relationship matrix, classification of technology group and the number of citations are used as core content. Both IPC and USPC can be used for identifying the technology group. In this research USPC was used. The structure of the matrix is as follow.

TABLE I
STRUCTURE OF THE TECHNOLOGY RELATIONSHIP MATRIX

		Citing USPCs			Total number of citation of Cited USPCs
		USPC 1	USPC 2	USPC 3	
Cited USPCs	USPC 1	①	④	⑦	①+④+⑦
	USPC 2	②	⑤	⑧	②+⑤+⑧
	USPC 3	③	⑥	⑨	③+⑥+⑨

This matrix has four core components, citing USPCs, cited USPCs, number of citation and total number of citation. In the rows, we have the citing IPCs and in the columns, we have cited IPCs. Cells of the matrix with gray mean the number of citation from cited USPCs to

citing USPCs. For example IPC1 in rows cited USPC1, USPC2 and USPC3 in the columns. If IPC2 cites IPC1, ④ indicates the number of citations from IPC1 to IPC2. In the same way we can get ① and ⑦. As for the cited USPC1, the total number of citations of cited USPCs is the sum of ①, ④ and ⑦.

G. Forecast of promising convergence technologies

Most technology is related with one or more technology. In other words, one patent can be cited by one or more other technology. To identify the impact between technologies, we used patent-based CIA which uses conditional probability with the number of citation. The formula used in this research can be defined as follows.

$$\text{Impact Value}(A, B) = P(B|A) = \frac{N(A \cap B)}{N(A)}$$

In this equation, $N(A)$ is the total number of citation of cited USPCs, and $N(A \cap B)$ is the number of citation from cited USPC to citing USPC. To explain in table 1, $N(A)$ is the sum of ①, ④ and ⑦. $N(A \cap B)$ is the value of the colored cells. If USPC2 cites USPC3, the cited technology is related with both USPC2 and USPC3. In this case, $N(A \cap B)$ is ⑥. The degree of impact between technologies, impact value, can be analyzed by conditional probability with the number of citation. Conditional probability is calculated divide $N(A \cap B)$ by $N(A)$.

Conditional probability is used as transition probability in forecasting by Markov Chain Model. To calculate the impact value between technologies we use excel function 'MMULT'.

IV. ILLUSTRATED EXAMPLE

H. Back ground of illustration

For illustrated analysis, information technology (IT) and bio technology (BT) patents from NBER(National bureau of Economic Research) data base were used. We selected a part of all the patents from 1976 to 2007. The USPCs used in this paper are as table. The USPCs are from the research of Guem et al. [2] and indicate the most converged IT-BT technologies from 2008 to 2010.

TABLE II
USPCs USED IN THIS RESEARCH

Technology fields		USPC code
I T	Biomedical devices(BMD)	623,702
	Surgery(SGY)	600,602,607
	Molecular bioengineering(MBE)	514,424,426,435,800

IT	Electrical computing	235,361,365,700,708,710,713,714,719
	Mobile telecommunication & telematics(MOT)	340,375,379,701
	Digital contents S/W solutions(SOL)	705,707,715,717

I. Degree of the impact between USPCs(1991~2000)

Figure2 is the technology relationship matrix that is developed based on the average of impact value for the last ten years. The cells with orange show the above-average values of impact values for the last ten years. The cells with blue indicate the USPCs of IT field and the cells with purple indicate the USPCs of BT.

Fig. 19 Impact values between the technologies (1991~2000)

The results show the number of citing USPC 714 in the best highest, followed by USPC 707, 710. On the other hand, USPC 719 is the best highest cited class, followed by, 702, 705.

TABLE XXXIVI
DEGREE OF CITATION (CITING USPCs)

Citing USPC	The number of cited USPC	Cited USPC
714	9	365,375,702,707,710,713,714,717,719
707	5	705,707,714,715,717
710		707,710,713,714,719
705	4	235,700,705,713
713		705,713,714,715
715		707,715,717,719

TABLE IV
DEGREE OF CITATION (CITED USPCs)

Cited USPC	The number of citing USPC	Citing USPC
719	6	707, 710, 714,715,717,719
702		340,700,701,702,714
705		235,700,705,707,713
707	5	707,710,714,715,717
714		365,375,710,713,714
717		707,714,715,717,719
713	4	705,410,713,714

As for the technology fields, almost relationship occurred between IT and IT. Especially, the occurrence of relationship between USPCs was concentrated in area of black bold lined. Only in some of the USPCs the relationship was developed. Among them USPC 702 and 700, 701 have the mutual influences.

J. Forecast the impact value between USPCs in 2020

Applying the Markov Chain Model we forecasted impact value between the USPCs in 2020. At this point the impact value was used as conditional probability as for Markov Chain Model. Table shows the forecast results. The cells of gray shows the above-average values of the forecast and the cells of green show the top ten percent of the results.

Fig. 20 Forecasted impact values between the technologies (2020)

By and large, occurrence of impact between the USPCs was increased. Many of impact values that belong to top 10% of forecasted results were related with USPC 424, 426, 435, 514, 600, 602, 607, 623. As for the technology fields, the number of interactions between IT and IT was largely increased. USPC 702 will make a connection with more various USPCs (705, 707, 710, 713, 714, 715) of IT field in 2020. Also, we found that USPC 702 will be cited by the most USPCs and USPC 600 will cite the most USPCs.

V. CONCLUSION

By This study aimed to propose the methodology for forecasting the future's technology convergence using the technology relationship analysis. We developed this technology relationship matrix and calculated the impact value to evaluate the degree of connections between technologies. Also, we illustrated the case study of IT and BT field.

The methodology has special contributions. First, on the perspective of analysis, this paper suggested the methodology estimating the impact between technologies by quantitative approach. Second, on the perspective forecast, this paper attempted to forecast the future's change of technology convergence. The approach of this paper reflects the effort to overcome the limitation of existing researches on technology convergence.

Despite its meaningful contribution, this paper has some limitations. This research dealt with the part of the data of U.S. patent. That is not to obtain the accurate results of technology convergence in IT and BT field, but to illustrate the methodology proposed in this paper. Also, to improve the validity the additional research is needed to verify the methodology.

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