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Analysis of Trend and Convergence for Science and Technology using the VOSviewer

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ABSTRACT

In this study, articles of the science and technology field that had been monitored for the period from 2002 to 2013 using GTB (Global Trends Briefing) were analyzed. Specifically, the VOSviewer was used to analyze the annual science and technology trends by keyword and the science and technology standard-classification information indicated in the GTB articles, and the convergence trends were therefore monitored. The findings of this study show that active studies were under way in the fields of material science and new and renewable energy, and that convergence has progressed. This result indicates that the information of the articles on papers and patents is more reliable, as it can reflect the current trends more rapidly in the science and technology field than the paper information or the patent information that is traditionally used in analyses of science and technology information.

Key words*: Science and Technology, GTB, VOSviewer, Monitoring, Convergence.*

1. INTRODUCTION

With rapid development in science and technology, acquisition of information is not the only important part of the job of the scientist or technician. Rather, efficiency in information acquisition makes a big difference in the fields of research and development. In an innovation-lead technology environment where convergence and diffusion of technology are accelerated and where searching for future technology is an important issue, scientific and systemic information analysis is emerging as a core element of research and development [1]. In particular, because data often gets directly applied to research and development without processing, it is easy for the researcher to fail to understand the direction of the study or the new technology trend and not succeed at his/her job. Even though the importance of science and technology information is increasing, information acquisition is not an easy task for a researcher. It is often difficult for the researcher to figure out what information he/she needs to acquire and where he/she can find the appropriate information. Conventionally, in order to understand research trends, bibliographic information of research papers (SCI, Scopus) was used. This was usually done through either co-occurrence keyword analysis of research papers or co-citation analysis of paper citation information. However, a faster and more efficient way to grasp the latest trends in science and technology around the world is through an information website [2].

Since 1993, the Korean Institute of Science and Technology Information (KISTI) has been collecting, processing, and supplying the latest information on international trends in science and technology in a service named Global Trends Briefing (GTB), whose goal is to add value to the contents. The purpose of GTB articles is to establish a constantly updating system that monitors the global R&D trend from which users can easily acquire the latest international science and industry market trend information needed in policy making, industrial activities, and R&D. Another of its key purposes is to contribute to an advanced strategy establishment and competitive superiority securement of the users by finding the promised research/commercialization items- the core element of technology competition. GTB also strives to search for future strategic technology and find the tipping point information on the changing external R&D environment to support the search, and to provide selective information on the current status and prospective of technology, the market, and competitors to the information users [3].

In order to provide quality information that responds to the needs of its clients, GTB information is evaluated in 3 steps: sentence correction and edition by the editor, information user evaluation and article quality evaluation by the expert. In order

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to avoid duplicate information, mutual reviews between information providers allow for quick provision of accurate information on the latest international science and technology trends. Since 2003, the web search robot exclusively used by information providers has collected and quickly provided information to the users through real time web loading system as soon as it gets registered [4].

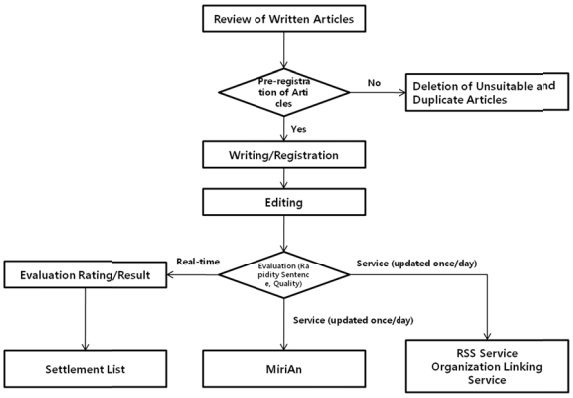

Fig. 1. Flow chart of GTB information collection and processing

The purpose of this study is to figure out the international research trends and find the significance using GTB information. For the purpose of this study, we used the national science and technology standard classification code applied to GTB articles and analyzed the recent issue of convergence trends between disciplinary fields.

Convergence is defined as a phenomenon in which boundaries between technologies are blurred– a process in which different technologies are combined. Recently, some innovative results have come out of convergence [5]. Therefore, monitoring the trend of convergence all over the world is a very important process in drawing an innovative result in the area of science and technology.

2. ANALYSIS METHOD

In this study, we analyzed the worldwide trend of science and technology using the information from 124,940 GTB articles related to science and technology built in years 2002 to 2013. Among the information from the articles, we used science and technology standard classification and keyword information. The national science and technology classification system is the national standard classification frame that is used to manage and deliver information, make human resource management more efficient, and efficiently plan and manage research and development projects. It is a 2-dimensional classification system with independent fields of research and application [6]. The field of research has a 3-stage classification system, consisting of 33 major classes, 369 middle classes, and 2,899 minor classes, while the field of application has a single stage classification system consisting of 32 major classes. In the case of the keyword information, the keyword is given by the reporter who writes the article. Duplication check is available in both cases of science and technology standard classification and keyword. Research paper information and NTIS information are mainly used in research that uses keywords to analyze the trend of science and technology [7], [8].

In this study, we analyzed the association map between science and technology standard classifications and keywords in order to figure out the trend of convergence. The association map is represented by a degree of convergence through distance between science and technology and check the phenomenon of convergence.

VOSviewer was developed in Leiden University in Netherland and used to make the association map. On VOSviewer, author information and citation relation and keyword can be visualized in the form of a map, based on the co-occurence matrix table.

VOSviewer has 3 stages. In the first stage, the similarity between categories is calculated based on the co-occurrence matrix table. Similarity is calculated using the association strength as follows:

$$\text{Association Strength(sij)} = \frac{\text{Cij}}{\text{wiwj}} \quad (1)$$

Where c_{ij} denotes the number of co-occurrences of items i and j and where w_i and w_j denote either the total number of occurrences of items i and j or the total number of co-occurrences of these items. In the second stage, a 2 dimensional map is made based on the similarity calculated in the first stage.

That is, the relation with a high similarity is positioned closely while the relation with low similarity is positioned with distance. On the last stage, parameters are clustered, and the density of the parameter is indicated depending on the frequency of incidence. VOSviewer is a program that indicates the relation between the parameters based on the distance between the fields of technology. Therefore, we can monitor the trend of convergence between fields through this program [9]-[12].

The knowledge matrix developed by KISTI was used to process data. By supporting the data pre-treatment through data reduction and expansion, Korean and English noun selection, usage of a thesaurus, and generating various types of matrix, this program allows for analysis in various visualization programs such as VOSviewer. As like fig. 2, we make co-occurrence using knowledge matrix. And we calculate similarity using association strength and make association map through VOSviewer. In association map, it is positioned by high and low similarity (Fig. 2).

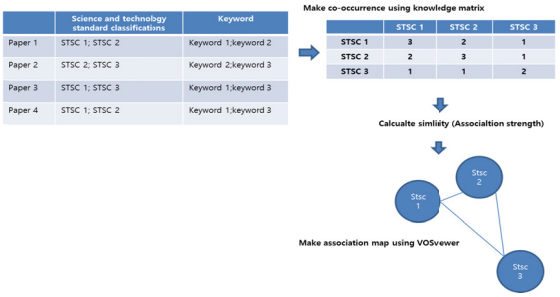

Fig. 2. The example of association map using knowledge matrix and VOSviewer

In this study, we used the knowledge matrix to select keywords and carried out post-treatment analysis of synonyms through stemming.

3. ANALYSIS RESULT

3.1 Science and Technology Standard Classification Analysis

When we analyzed the top 10 science and technology standard classes among the articles provided by GTB, it was shown that research was actively conducted on science and technology policy, medicine, material process technology, renewable energy, computers, and optics(Fig. 3, Table 1).

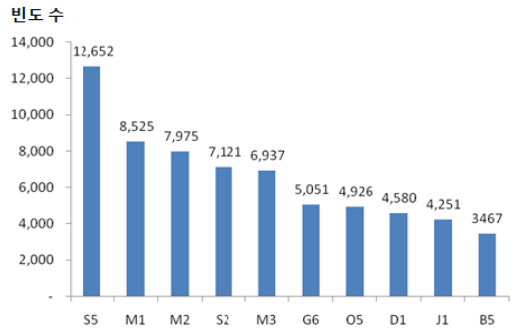

Fig. 3. Top 10 science and technology standard classifications of GTB articles

Table 1. Details of top 10 science and technology standard classifications

Rank	Science and technology standard classifications	Detailed description
1	S5	Science and technology policy
2	M1	Basic medical science
3	M2	Clinic medical science
4	S2	Science, technology and economics
5	M3	Medical engineering
6	G6	Material process technology
7	O5	Alternative energy
8	D1	Biology
9	J1	Computer
10	B5	Optics

Among the Science and technology standard classes with high frequency, the frequency of the fields of material process technology, alternative energy, and biology have increased over time. The result of regression analysis showed that the frequency of all three fields has increased over time. The explanatory strength of the model was 83%, 73%, and 73%, and it was analyzed to be statistically significant with a p-value of 0.000 in 99% confidence interval (Fig. 4, Table 2).

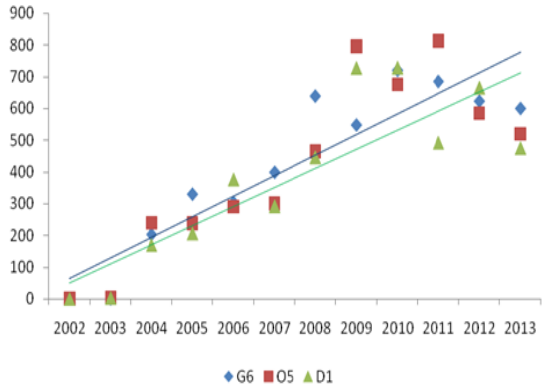

Fig. 4. Science and technology standard classification by year

Table 2. Yearly slope of the frequency of science and technology standard classification

Science and technology standard classifications	R^2	P	F	Slope
G6	0.83	0.000	49.25	64.69
O5	0.73	0.000	27.49	65.85
D1	0.73	0.000	26.44	60.32

In the result of analysis of the association map between science and technology standard classes, convergence happened mainly between the fields of material, machinery, and chemistry. Around those fields, electricity and electronics, energy resource, and environment were close and the boundary was blurred, showing that the convergence between different technologies is happening (Fig. 5).

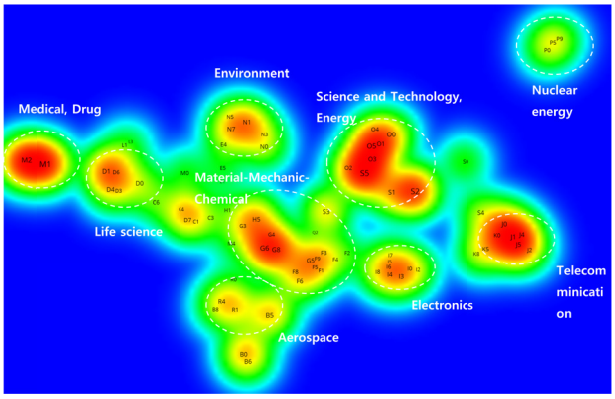

Fig. 5. Association map between Science and technology standard classes

3.2 Keyword Analysis

The result of frequency analysis on keyword information found in GTB articles showed high frequency in the field of renewable energy such as renewable energy, energy, biofuel and solar cell, nano material such as graphene and nanoparticle, and cancer in the field of medicine(Fig. 6).

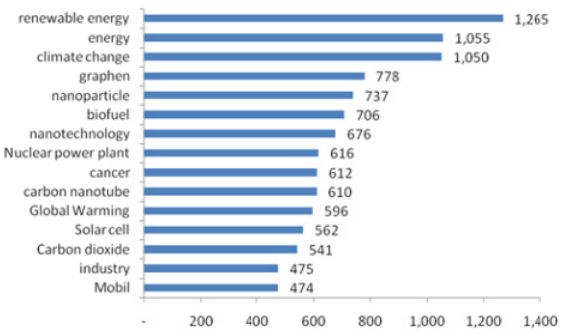

Fig. 6. Frequency of keywords

Among the keywords with high frequency, the frequency of keywords such as renewable energy, graphene, and solar cell increased over time, showing that recently more research is being made on renewable energy and nano-material. In particular, the steep slope of renewable energy and graphene indicates that these fields are attracting the most interest. The regression analysis of time series analysis of the related fields showed that the frequency of all keywords mentioned above increased linearly over time. The explanatory strength of the model was 78%, 77%, 83%, and 68%, respectively, and it was found to be statistically significant with p-values of 0.002, 0.000, 0.001 and 0.003, respectively in 99% confidence interval (Fig.7, Table 3).

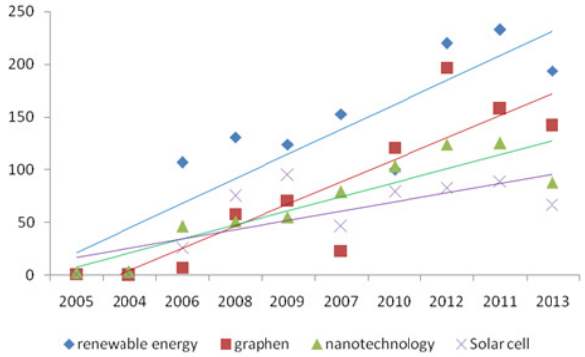

Fig. 7. Frequency of main keyword by year

Table 3. Slope of frequency of keyword by year

Science and technology standard classifications	R^2	P	F	Slope
Renewable energy	0.78	0.002	21.49	23.36
graphene	0.77	0.000	63.27	21.00
nanotechnology	0.83	0.001	23.98	13.32
solar cell	0.68	0.003	17.17	8.84

When the association map between keywords was made, it was shown that research is being actively made in renewable energy, nano-material, medicine, science and technology, and nuclear energy. In the field of renewable energy, studies on solar cells and fuel cells are being actively carried out along with studies on electric vehicles. In the case of nano-material, graphene and nano-particle are the most popular subjects. In the medical field, studies are actively made on cancer, vaccine, DNA and diabetes (Fig. 8).

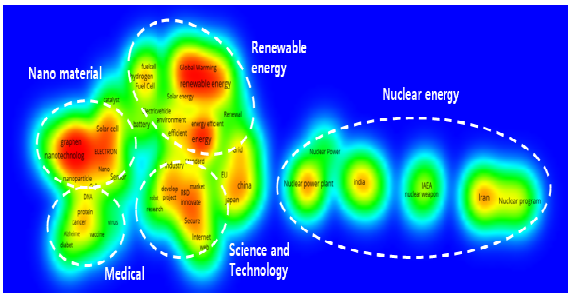

Fig. 8. Map of association between keywords

4. CONCLUSIONS

In this study, we analyzed the research trend of science and technology from 2002 to 2013 with GTB information using science and technology standard classification and keyword information.

This study showed that the major international trend in science and technology research is moving towards science and technology policy, medicine, material process technology, renewable energy, computer and optics. However, in the result of time series analysis, interest in the fields of material process, renewable energy, and biology is steadily growing.

Detailed keyword analysis showed that in the field of nano-material, graphene was the most popular research subject. In the field of renewable energy, interest in the field of solar energy is steadily growing, followed by wind energy, hydrogen energy and electric vehicle. In the field of medicine, researchers are actively studying cancer and diabetes.

Based on the analysis above, the international research trend in science and technology is like follows: first, studies are actively made to solve social issues. For example, for global warming, trends mainly focused on studies to replace fossil fuel. Second, as time goes by, boundaries between technology fields are increasingly blurred and converged.

While the conventionally used data such as research papers and patents are formulated and have some timely gap from the current situation, the result of this study can be used in real-time compared to conventional data. Therefore, the result of this study can be used to support the decision-making of policy makers and researchers when they decide the priority of R&D investment. Another significance of this study is that monitoring the convergence trend is important, as convergence is a kind of technology innovation that can overcome the limits of the existing market and pioneer a new market.

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