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Discovering new technology opportunities based on patents: Text-mining and F-term analysis

Kisik Song[b,1], Karp Soo Kim[c,2], Sungjoo Lee[a,*]

[a] Department of Industrial Engineering, Ajou University, Suwon, Republic of Korea
[b] Enterprise Maturing Team, Korea Intellectual Property Strategy Agency, Seoul, Republic of Korea
[c] School of Business and Technology Management, KAIST, Daejeon, Republic of Korea

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ABSTRACT

Discovering new technology opportunities has long been a significant issue in both practice and academia. Among various approaches to search for opportunities, one of the most frequently used is to identify emerging or vacant technologies from patent documents. In line with it, this study aims to suggest a novel approach for the development of new technology ideas based on the F-term, which classifies patent documents according to the technical attributes of the inventions described within them. Since the technical attributes are analyzed according to various perspectives through the application of the F-term, which generates detailed and systematic information about technologies, the F-term can provide effective guidelines for generating new technology ideas, if utilized well.

In the approach, we first choose a target technology for seeking new opportunities. Then, from the text-mining results of the F-term data, we identify other technologies with technical attributes similar to the target technology, called reference technologies. The next step is to extract technical attributes that are commonly used in the reference technologies but have not been used in the target technology. Finally, we can obtain new technology ideas by applying these technical attributes to the target technologies. This is one of the earliest attempts to adopt the F-term for patent analysis; the proposed methodology can show how to best take advantage of the F-term and the wealth of available technical information in patents, and also can be useful in the idea-creation process for major and minor innovation.

1. Introduction

The importance of technology opportunity analysis for the development of new technologies has become more apparent due to the inherent risks in launching and growing new businesses (Lee et al., 2015). Technology opportunity analysis, through which the derivation of new technology ideas can contribute significantly to the growth and success of a business, can largely be classified into two types (Cho et al., 2016): one relates to anticipating new technologies and products that have not yet been developed or are still emerging (e.g. Daim et al., 2006; Lee et al., 2015; Noh et al., 2016); the other relates to new markets that can be created or exploited by utilizing the technology that a firm currently possesses (e.g. Park et al., 2012; Park et al., 2013b; Yoon et al., 2014; Yoon et al., 2015). In this study, we focus on the former, where technological opportunities are recognized by deriving new technology ideas that offer the potential for technological progress, in both an industry overall and individual enterprises, and define technology opportunity as “the potential for technological progress through creating value from new ideas”.

Patent analysis has long been employed as a useful analytical tool for technological opportunity analyses, particularly supporting to create new ideas. The results of such patent analyses can be represented as technology trends or paths of technology development, in the form of charts, graphs, and networks, which allow complex information to be understood easily and effectively (Yoon, 2010). However, recently, there has been increasing attempts in integrating data-mining techniques into patent analysis to enable systematic technology opportunity analyses (Lee et al., 2015). Specifically, in these attempts, the International Patent Classification (IPC) system or a set of keywords identified by using a text-mining application with patent documents was generally used for opportunity analysis. That is, after a collection of IPC codes or a set of keywords in patents was used to define a

* Correspondence to: 508, Sanhak-won, Ajou University, 206 Worldcup-ro, Yeoungtong-gu, Suwon-si, Gyenggi-do 16499, Republic of Korea.
E-mail addresses: kisik@kista.re.kr (K. Song), kimkarpsoo@kaist.ac.kr (K.S. Kim), sungjoo@ajou.ac.kr (S. Lee).
[1] Korea Intellectual Property Service Center, 131 Teheran-ro, Gangnam-gu, Seoul 06133, Republic of Korea.
[2] N22, KAIST Bldg., 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea.

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technology, further analysis was conducted to monitor technology trends or identify vacant technology areas based on the IPC codes or keywords (e.g. Jeong and Kim, 2014; Lee et al., 2009; Wang et al., 2015).

Despite their value, however, those studies do have some drawbacks. First, technology opportunity analysis using IPC may lack concreteness since classifying technology through a single IPC view seems to be too simple to represent various aspects of technology. Furthermore, it cannot deal with the convergence (or fusion) of technologies and the diversification of technology. Second, technology opportunity analysis using keywords identified by a text-mining application still depends on an expert's input in several processes; thus, the technique may not be as systematic as initially expected. The keywords extracted from patent documents usually contain noisy data, so careful consideration and examination should be given to selecting the necessary keywords for further analysis.

Unlike those studies, this study adopted the F-term that classifies patent documents according to the technical attributes of the inventions described in them. The technical attributes are analyzed according to various perspectives through the application of the F-term, which provides more detailed information about technologies than the IPC system, and more systematic information compared to keywords. Therefore, if utilized well, the F-term can act as a useful guideline for creating new technology ideas. Nevertheless, little effort has been made to investigate the potential of the F-term as a basis for developing a tool with which to discover new technologies.

Having recognized these needs, we propose a methodology for a novel approach to developing new technology ideas by using the F-term. To this end, we first chose a target technology for which to seek new opportunities, then collected F-term data on the target technology as well as other technologies. Afterwards we applied text mining to the descriptions of their classification criteria and attributes to indicate the characteristics of each of the technologies. From the text-mining results of the F-term data, we could find other technologies with similar technology features to the target technology, called reference technologies. Finally, we compared the technologies and extracted the technical attributes that are commonly used in the reference technologies, but that have not been used in the target technology. These features are classified by technical attributes such as by "purpose," "function," "structure," "material," "methods," "processing and operation procedure," or "control means," and so are useful for creating new technology ideas that can be used to help detect new technology opportunities. Methodologically, this is one of the earliest attempts to adopt the F-term for patent analysis; the proposed approach can show how to best take advantage of the F-term and the wealth of available technical information in patents. In practice, it can be a valuable tool for facilitating the idea creation by helping to identify new possibilities for technology convergence (or fusion) and/or suggesting similar technologies with different principles, which is necessary not only to open up new business opportunities but also to operate existing businesses.

The overall structure of this paper is as follows. Section 2 examines the existing literature covering the trends in developing new technology and analyzing technology opportunities: we also discuss their limitations. Section 3 briefly explains our methodology, and we present a case study in Section 4. Finally, in Section 5, we conclude this paper and offer some contributions and limitations.

2. Background

2.1. Technology opportunity analysis

2.1.1. Opportunity recognition and creation

The theme of opportunity recognition and creation for innovation has long been a focus of management literature (Garnsey and Hang, 2015) and has been investigated from various perspectives. Technology opportunity is defined as "the potential for technological progress in general or within a particular field" (Olsson, 2005). Klevorick et al. (1995), in their seminal work, stated that this opportunity comprises a set of possibilities for technical advance, which can benefit from a wide range of knowledge sources within and outside a firm. Later, the relevant concept was further developed and refined so it could be adapted to different research contexts. For example, Yoon et al. (2015) defined technology opportunity by its promise of technological progress, or its potential to drive technological advances within specific fields or across different industries. In the context of technology opportunity in small and medium-sized enterprises, Cho et al. (2016) explained the concept using two technological potentials – 1) potential of current technology to create or to be used in a new market, and 2) growth potential of technology to fulfill the needs in current or future markets,. Noh et al. (2016) suggested four types of technology opportunity – 1) technological vacancy, 2) convergent technology, 3) emerging technology, and 4) customer-based technology in the context of promising technology.

Based on these concepts, much effort has been given to identifying technology opportunities. Although several terms have been used for analyzing technology opportunities, such as deriving new technology opportunities (e.g. Kim and Song, 2007; Lee, 2014; Wang et al., 2015; Yoon and Park, 2005), technology forecasting (e.g. Bengisu and Nekhili, 2006; Trappey et al., 2011), technology trend analysis (e.g. Lee et al., 2011a), and vacant technology analysis (e.g. Lee et al., 2009), all these terms are closely related to technology opportunity analysis.

More recent efforts have attempted to identify the mechanisms through which opportunities are created. These studies emphasize the process of co-creating opportunities, in which the opportunities come from either business model innovation or technological innovation. For example, Overhom (2015) argued that opportunities can be created in an emerging ecosystem collectively by potential system actors, which requires business model innovation. In contrast, McKelvey et al. (2015) claimed that opportunities can be explored through R & D collaboration, which is in the form of uncodified knowledge combination for technological innovation. Such opportunities can also be discovered by analyzing intellectual property, that is, pursuing technological innovation from codified knowledge combinations. Jeong and Yoon (2015) proposed a patent roadmapping approach as a tool for discovering new opportunities, while Caviggioli (2016) used patent information to identify converging areas as a source of opportunities.

2.1.2. Approaches to technology opportunity analysis

Recognizing its significance, both the private and public sectors have been making huge investments into discovering such opportunities and new technologies to enhance their technological competitiveness. The role of identifying potential opportunities has become a key trend in R & D competitiveness (Lee et al., 2011b). Firms can expand the range of their business by deriving technology opportunities, and the derived technology opportunities can be utilized actively in technology management. Technology opportunity analysis can provide the driving force for continuing growth of companies by creating profit in the medium- to long-term (Astebro and Dahlin, 2005). Furthermore, this could give rise to possible advances in technology or the possibility of deriving a new technology (Yoon, 2008). Therefore, in order to drive development of emerging technologies while avoiding patent infringement, technology opportunity analysis is a useful tool for advanced countries and global firms in guiding the construction of R & D portfolios. (Kim et al., 2008).

Approaches to technology opportunity analysis can largely be divided into two types: qualitative analysis based on expert knowledge, and quantitative analysis based on the application of technological data. Qualitative analysis using expert knowledge, such as Delphi surveys, analytical hierarchy processes, and scenario planning, can support technology opportunity discovery within general fields (Cho and Lee, 2013; Lee et al., 2014a, 2014b). At the outset, high levels of uncertainty regarding the future of technology have led businesses to defer to expert judgment (Lee et al., 2013). Although experts' judgment remains important in technology opportunity analysis, research has revealed that experts are not always right and may be less reliable due to the increasing amount of technical data (Lee et al., 2013). In addition, this approach is not only time consuming but is also likely to involve personal and subjective elements in the direction of the analysis and the results (Yoon, 2008; Yoon et al., 2008).

Therefore, another research stream has used quantitative analysis based on objective data, such as bibliographic and textual information from technological documents, to provide decisive input to decision makers. One of the leading authors in this field is Kajikawa, who has applied bibliometric tools to both papers and patents; for example, he tried to link academic research and industrial technology development using both types of data (Ogawa and Kajikawa, 2015), and performed a publication data-based citation network analysis to cluster emerging research domains (Kajikawa et al., 2008) and to identify the current structure of research (Kajikawa and Takeda, 2008). In addition to publication analysis, recent literature on technology opportunity analysis has emphasized the usefulness of patent analysis, which more closely captures the actual "technological" elements, and thus is the focus of this study.

2.1.3. Patent-based technology opportunity analysis

A technology opportunity analysis based on patent data is expected to lessen dependency on experts as well as increase creativity by enabling the investigation of massive datasets of technological documents published worldwide. Numerous patent-based approaches have been proposed in recent years, mostly based on bibliometric analysis or text-mining, to suggest the direction of the development of emerging technology (Kajikawa et al., 2008; Yu and Lee, 2013) and establish strategies for technology planning (Park et al., 2013a).

One seminal paper on patent-based approaches to technology opportunities analysis is the work of Porter and Detampel (1995). For them, "technology opportunities analysis combines monitoring with bibliometric analysis" and is "an approach to efficiently generate effective intelligence on emerging technologies" (Porter and Detampel, 1995, p.237). They regarded technology opportunities analysis as a process of exploring various data sources systematically to identify technology-related opportunities. In this field, Alan Porter and Schott Cunningham are probably the most well-known researchers; they have tried to apply data and text mining to technological documents such as patents and publications (e.g., Porter, 1980), and further used the term *tech mining* to indicate the efforts to derive technological knowledge from those documents (e.g., Cunningham et al., 2006).

Tech mining is thus a process of applying text mining to science and technology information aimed at informing technology and innovation management (Porter and Cunningham, 2005). It is distinguished from data and text mining in that it focuses on searching for and analyzing *electronic science and technology databases* to derive knowledge that is applicable to the issue in question. Of course, the application of tech mining is not restricted to patents and publications (Cunningham et al., 2006). Nevertheless, patent databases have been some of the most frequently used databases for analysis due to their large data size and easy accessibility. It has also shown methodological advances, including term clumping (Zhang et al., 2014) and technology intelligence processes (Porter, 2005). This evolution of tech mining methods was investigated by Madani and Weber (2016), who analyzed 143 papers in relation to patent mining and explained the advances of tech mining in terms of information retrieval, pattern recognition, and pattern analysis. In their research, they also showed the rise of tech mining research; the number of relevant publications has increased significantly since 2005, while a huge growth in the number of citations was observed since 2012. Chiavetta and Porter (2013) identified four main analytic tools for tech mining – bibliometrics, data mining, network analyses, and patent analyses – and eight application areas for tech mining – Emerging technologies and technology dynamics, technology forecasting, roadmapping and foresight, R & D management, engineering industries, science and technology indicators, science, technology and innovation policy studies, evolutionary economics, and technology assessment and impact analysis.

2.1.4. Limitations of the existing studies

Despite valuable contributions, previous research on patent analysis for deriving technology opportunities still has limitations in its application. First of all, technology trend analysis for deriving emerging technology lacks concreteness; these studies have mainly used IPC to define technology (which cannot deal with details concerning the diversification of technology), with existing methodologies mainly focusing on macro-trends. In a similar vein, more detailed information about technical attributes described in patent documents cannot be analyzed based on IPC, which can provide more practical and hands-on information. Thus, research into micro-analysis that could support firms by helping them to detect emerging technologies or derive technology opportunities is limited.

Second, although text mining has been applied to patent documents to overcome these limitations, the performance of the existing methodologies based on keyword analysis depends greatly on the set of keywords adopted for the analysis. Moreover, the keywords extracted from patent documents contain information that is too detailed to be used for technology opportunity analysis and usually contain noisy data. As a result, most methodologies based on keyword analysis still depend greatly on expert judgment in several processes, such as the selection of keywords for text mining. Although advanced keyword analysis such as that based on subject-action-object (SAO) have been developed, it still depends on an expert's judgment.

Third, existing studies have focused on finding technology opportunities mainly *within* a specific domain of interest. Addressing this limitation, Ittipanuvat et al. (2014) proposed a process of linking two different domains for using existing knowledge to enable potential novel discoveries. Similarly, Nakamura et al. (2015) developed a knowledge combination model for searching technological knowledge in other domains. The motivation for this study is similar, but the scope of our research is extended to the generation and evaluation of potential technological ideas, providing specific guidelines for creating new technological ideas and their feasibilities as a technology opportunity.

To tackle those issues, this study adopts the F-term, which classifies patents according to the technical attributes with which technologies can be compared, and by detailed technical attributes such as functions, structures, materials, and operation procedures. By using technical attributes, rather than technological content, technologies with similar invention principles can be identified and the principles used in other domains can be proposed. This facilitates the new technology ideation process. In addition, a Japanese expert group has already constructed this classification system, which assigns technical keywords to each component of the system; removing the need for expert judgement in the analysis. The level of analysis using the F-term will not be too macro nor too micro, and thus will be the most appropriate for opportunity analysis at the firm level.

2.2. F-term

The F-term is a patent classification system that classifies patent documents according to the technical attributes of the inventions described therein. Since the technical attributes are analyzed according to various perspectives, it is possible to investigate a much wider range of technologies than is possible with other classification systems (Schellner, 2002). Rapidly developing technologies, such as ICT and new material, require the investigation of huge quantities of documents addressing the existing technology. The F-term, which can be classified from a range of perspectives, can utilize the preferred classification

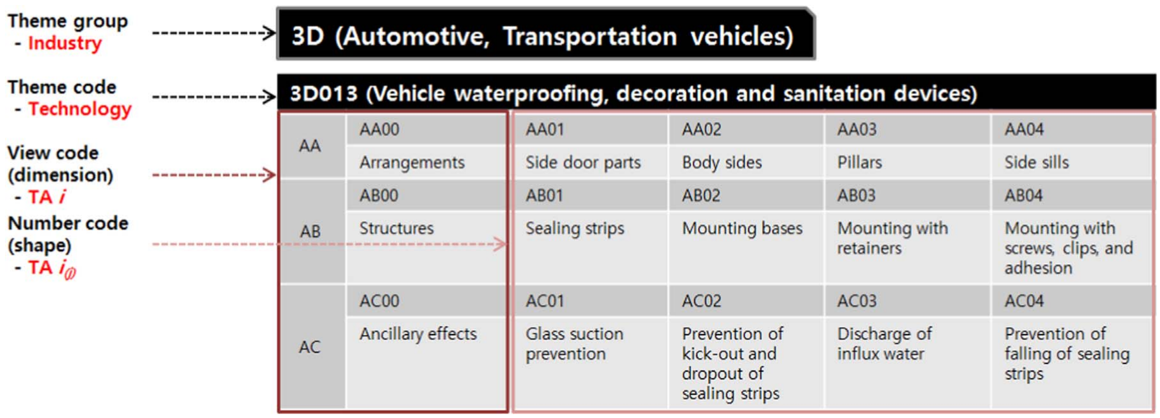

Fig. 1. Structure of the F-term.

system in such an environment.

The structure of the F-term features nine digits. The leftmost two digits are the "theme group" (e.g., 3D: Automotive and transportation vehicles), while the five digits from the left are referred to as the "theme code" (e.g., 3D013: Vehicle waterproofing, decorations, and sanitation devices). The "view code" (e.g., AA: Arrangements)" consists of the subsequent two blocks of digits, and the last two digits, called the "number code" (e.g., AA01: Side door parts, AA02: Body sides). This paper uses the "theme group" for an industry, the "theme code" as a technology, the "view code" as a dimension of a technical attribute (TA i), and the "number code" as a shape of technical attributes (TA $i_{(j)}$) for the dimension of TA i (see Fig. 1).

Both the F-term and the IPC system are patent classifications for technical taxonomy. While IPC searches by using a single view, the F-term is capable of detailed investigation through multiple views (see Fig. 2). Since the F-term supports five times the number of classifications as IPC, the effectiveness of the technical classification is relatively high. The number of F-term codes is currently 350,000, while the number of views is 22,000 (Schellner, 2002). Compared to keywords extracted from patent documents, F-term codes are more structured and thus enable systematic analysis.

In order to be designated as F-term codes, the patents need to be filed by the Japan Patent Office (JPO). Nevertheless, the wide range of technological areas covered by the JPO patents, in addition to the number of patents filed by the JPO, ensures the validity of its use for this study. Kim and Lee (2015), p.343) argued that "the JPO database has strength in the amount of information and decentralization of information across different technological areas" and "can be used for innovation studies especially when focusing on various technologies." Considering that the purpose of this research is to combine ideas from various fields to create a new idea, the JPO database is in accordance with this purpose.

Another significant point to address is that the F-term cannot cover 100% of all technical fields in the JPO (Iwasaki, 2015). Of course, if F-terms could cover all of the technical fields in the JPO, it might help to obtain more diverse ideas. However, despite its deficiency, the suggested approach is still valid if the F-terms cover a major part of the technical fields in the JPO, because the purpose of this study is to generate new technological ideas by adopting relevant ideas from other areas, not to evaluate the possibilities of patent infringement risks or identify vacant technologies, which requires all technological fields to be covered for accurate results.

3. Methodology

3.1. Overall research framework

This study assumed that a new technology idea could be derived by combining two technologies in different areas. In other words, if technology A and technology B, which are related to different areas, have similar technical attributes (TA i, TA $i_{(j)}$), we would regard technologies A and B as offering a high possibility of being a benchmark for each other, providing sources of technological ideas to improve themselves, and supporting the convergence (fusion) of the two at the level of TA i or TA $i_{(j)}$. We adopted the concept of technology convergence (fusion) to explain the rationale for this assumption. According to Curran and Leker, p258) (2011), convergence is "marked by an increase of interchangeability and connectedness between the respective areas, as can be seen in collaboration, licensing, patenting, or publishing behavior." The interchangeability and connectedness between two technologies are likely to increase when they have more attributes in common. This argument is also supported by Rosenberg, p15) (1976), who described technology convergence as a phenomenon of "the employment of similar skills, techniques, and facilities at some of the 'higher' stages of production for a wide range of final products." Thus, we restricted our focus to new technology opportunities by

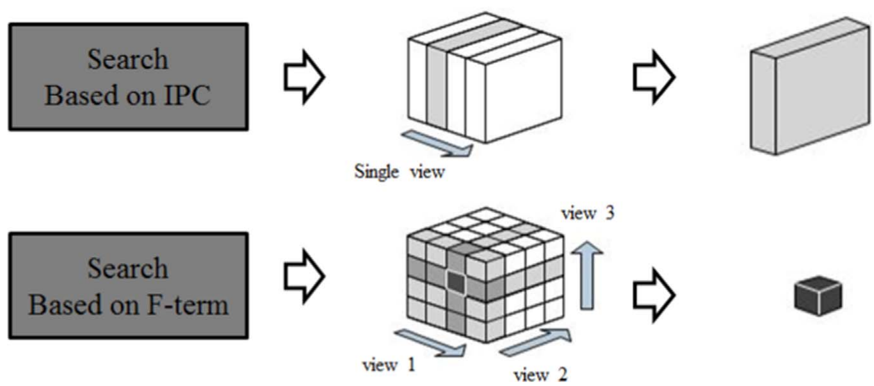

Fig. 2. Comparison of search processes with IPC and the F-term.

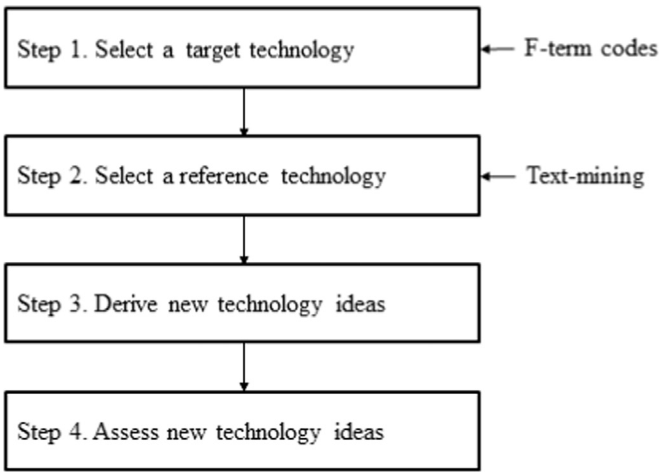

Fig. 3. Suggested approach.

identifying reference technologies in other technological fields that have similar technical attributes to the target technology. Thus, a combination of two technologies in this study indicates *a process of applying the technical attributes (both dimensions and shapes) used for one technology to those of another*.

To this end, this paper proposes an approach with four steps, as shown in Fig. 3. Step 1 involves selecting the technology for a combination target, which is subject to combination. Step 2 is to investigate the reference technologies that have a high possibility of combination, and then to select the final choice for the reference technology among the list of candidate technologies. Then, we derive new technology ideas by combining the target and reference technologies. The combination process is divided into two parts. The first is combination based on the TA i level, and the second is combination based on the TA $i_{(j)}$ level in step 3. Finally, we suggest a guideline for selecting ideas by assessing the growth and applicability of relevant technologies.

3.2. Selecting technology for combination target

The first step is to choose a target technology for opportunity analysis. The target can be chosen for various purposes, including an *exploratory investigation of its possibilities for technology convergence (fusion)* or *a systematic process to generate new technology ideas not to infringe on the patent rights of others*. Selecting a target technology for combination involves reference to the F-term classification system. This paper combines technologies after deriving the possibility of combination based on the keywords used to identify technologies. Each technology classification system of the F-term is collected from the Industrial Property Digital Library (IPDL). Then, the user selects technologies to combine into a new technology by considering the technology lifecycle in the next step. For example, if the user prefers to apply mature technologies in other fields to generate a new technology idea, they can choose a reference technology from those at the maturity level and with a high possibility of combination.

3.3. Selecting reference technology for combination

3.3.1. Reference candidates for combination

In this step, the similarity between technologies is measured when searching for reference technologies that could be combined with the target. For this, we extracted keywords using a text-mining technique from the TA i and TA $i_{(j)}$ of the technologies. TA i indicates the dimension used to define technical attributes, while TA $i_{(j)}$ is the shapes used to characterize the dimension of TA i. Thus, if two technologies share their keywords from TA i and TA $i_{(j)}$, they will be expected to be similar to each other in terms of technical attributes, even when they are from different technological fields. Accordingly they have high potential for being a good reference in generating new technology ideas. Therefore, we searched for technologies that are similar to the target technology based on the extracted keywords by using cosine-similarity.

Cosine-similarity is a method by which the similarity between the cosine angles of two vectors is measured. It has mainly been used in research measuring the similarity between documents (Leydesdorff et al., 2008). In this study, this similarity was used to measure the degree of commonality between two technologies in terms of their technological structure, as presented in TA i and TA $i_{(j)}$. When two keyword vectors are described as W_i for technology i and W_j for technology j, they can be presented as W_i=(w_{i1}, w_{i2},…,w_{in}) and W_j=(w_{j1}, w_{j2},…,w_{jn}), where n indicates the total number of keywords identified from text mining and w_{ik}(w_{jk}) represents whether a keyword k has appeared in a keyword set from TA i and TA $i_{(j)}$ (TA j and TA $j_{(j)}$). Here, a keyword vector having a binary value was developed by assigning the value of "1" to w_{ik}(w_{jk}) if TA i and TA $i_{(j)}$ (TA j and TA $j_{(j)}$) do have a keyword k, and "0" for otherwise. The weights were not given to calculate the cosine similarity value because text mining was applied to the keywords that presented *views* at the TA i level, not patent documents; thus, significant variation within the term frequencies was not observed. Therefore, the similarity between technologies can be calculated using Eq. (1). The results of the similarity between technologies have values in the range of 0–1.

$$\cos(i, j) = \frac{\sum_{k=1}^{n} W_{ik}\bullet W_{jk}}{\sqrt{\sum_{k=1}^{n} W_{ik}^2\bullet \sum_{k=1}^{n} W_{jk}^2}} \tag{1}$$

3.3.2. Selecting a reference technology from a list of reference candidates

In this step, we make a final selection of the reference technology for a new technology idea from among the list of reference technologies with similarity values greater than a cut-off value. At this point, there are two ways of selecting a reference technology (see Fig. 4). When a user has only considered the highest possibility of combination, he/she can select *Criterion 1*, with which the reference technology that is most similar to the target technology is selected. *Criterion 2* is used when considering the technology lifecycle stages (introduction, growth, maturation, and saturation) by fitting the cumulative number of patent applications per year to an S-curve. In general, emerging technologies are more likely to be adopted as a reference technology based on this criterion, since they tend to have greater potential to be used in other fields. However, although a reference technology is included in the mature stage or saturation, it can be considered in the investigation of a new technological field when setting this criterion to "mature technology."

As to *Criterion 2*, the most common is the S-curve, among which the simple logistic model, shown in Eq. (2), is one of the most widely used forecasting models (Bengisu and Nekhili, 2006; Boretos, 2007). In the model, y_t represents the cumulative patent applications at time t, L is the maximum value of y_t, a describes the location of the curve, and b controls the shape of the curve. L, a, and b are computed using a nonlinear least-squared estimation method. Using this model, it is possible to forecast how many patent applications will be submitted in the future, as well as the stage of the technology lifecycle. That is, $L/y_t<$ 0.1, 0.3 $\le L/y_t<$0.5, 0.5 $\le L/y_t<$0.75, 0.75 $\le L/y_t<$ 0.9, and 0.9 $\le L/y_t$ correspond to the range of technology in the introduction, early growth, growth, early maturation, maturation, and saturation stages (Meyer and Ausubel, 1999).

$$y_t = \frac{L}{1+ae^{-bt}} \tag{2}$$

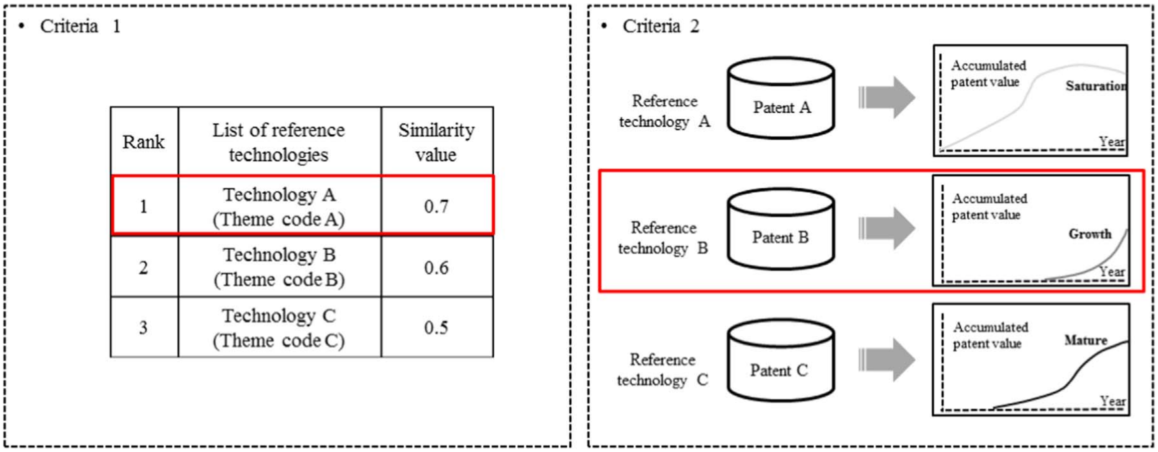

Fig. 4. Methods of selecting a reference technology from among a list of candidates.

3.4. Deriving new technology ideas

3.4.1. Combining technologies based on TA *i* level

We derive new technology ideas by combining TA *i* from each technology in this step. The main principle of this process is as follows: create a new technology idea by combining TA *i*, which is utilized in a reference technology but not in a target technology. At this level, the guidelines for performing a *wide-reaching* combination can be proposed by introducing detailed elements, which do not exist in the target technology (see Fig. 5). In general, due to the limited number of TA *i* in the F-term classification system, TA *i* terms applicable to idea generation might be limited in number. Thus, it would be possible to consider all applicable TA *i*(s) for new technology ideation. However, if there are more than two applicable TA *i*s and so priority setting is necessary, we recommend considering a TA *i* with more patents before one with fewer patents, assuming that more patents indicate greater popularity and value of the relevant technology. An alternative approach to prioritization is to use a keyword vector that measures the similarity of each TA *i* of a reference technology with all TA *i*s of a target technology, on the assumption that a TA *i* with a greater similarity with TA *i*s in the target technology using the keywords extracted from TA $i_{(j)}$ is more likely to be applied by the target technology; here, the vector for each TA *i* needs to be developed using the keyword in both TA *i* and the relevant TA $i_{(j)}$.

3.4.2. Combining technologies based on TA $i_{(j)}$ level

Combinations based on the TA $i_{(j)}$ level involve more detailed technical units than the TA *i* level. The main principle of this process is as follows: when both the target technology and the reference technology use TA *i*, but TA $i_{(j)}$ of TA *i* is not being used in the target technology, we can derive a new technology idea by combining TA $i_{(j)}$ with the target technology. At this level, we can make the combination within *a specific range* by applying detailed elements (see Fig. 6).

3.5. Assessing new technology ideas

A derived new technology idea is assessed in terms of its growth and applicability. Two indexes are used for this purpose. First, technology growth (TG) is used to evaluate whether the new idea will be promising in the future; this is calculated based on the growth rates of relevant patents. We adopted annual percentage growth, known as a straight-line growth rate, to measure the growth potential of relevant technologies, with the average increase in the number of relevant patents being used as a proxy (see Table 1). Here, a set of keywords describing the technological characteristics should be defined to identify the relevant keywords; keywords in TA *i* or TA $i_{(j)}$ used to combine two technologies can be used as references. However, as the technology idea derived in the previous stage is highly likely to be novel, having no or few relevant patents, it might not be possible to evaluate the potential of a technology idea by collecting patents directly on the idea. Instead, we suggest the use of indirectly related patents by collecting patents that describe either technology A or technology B when the two technologies are combined; thus, the annual number of patents with predefined keyword sets – keywords of technology A or keywords of technology B – in their titles is collected to obtain the TG value.

Second, technology applicability (TAp) is assessed based on how many main keywords of an idea are distributed in other technologies, as a proxy for evaluating whether the new idea can be widely used for various purposes. Unlike TG values, TA values are measured by the F-term classification table of TA *i* and TA $i_{(j)}$ but use the same keywords defined in measuring TG, with the same operation (OR) to search relevant technologies. It is assumed that the more widely and evenly the relevant technologies are used, the more likely it is to be applied to various areas. *How widely used the relevant technologies are* is operationalized by the percentage of theme codes with either keywords of technology A or keywords of technology B in their view codes (TA *i*) and number codes (TA $i_{(j)}$) over the total number of theme codes in the F-term. On the other hand, *how evenly used the relevant technologies are* is measured with the Hirschman-Herfindahl Index (HHI) of

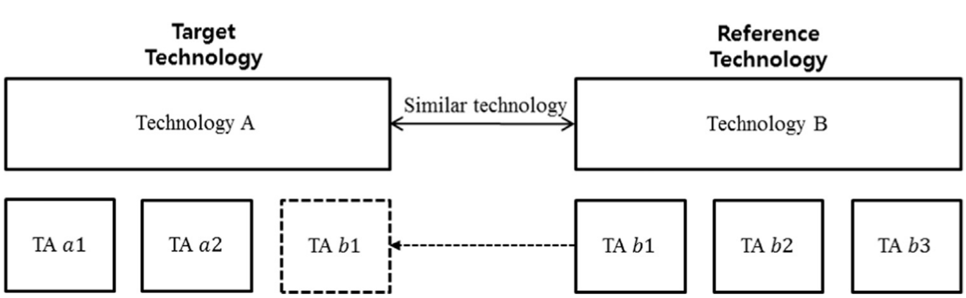

Fig. 5. Process of combining technologies based on TA *i* level.

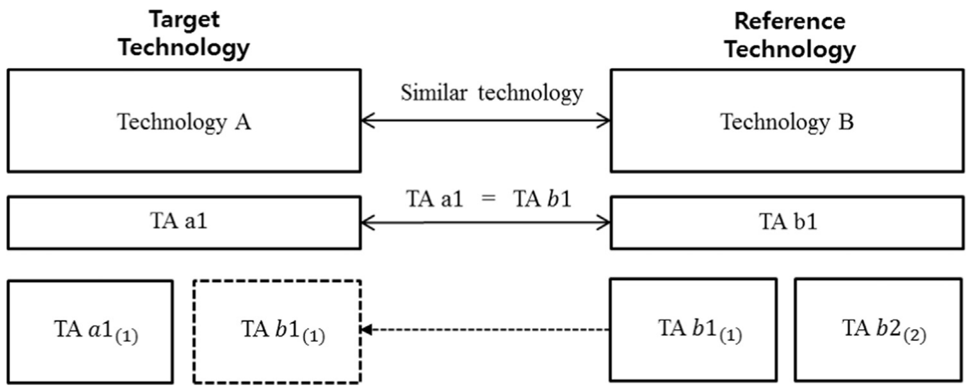

Fig. 6. Process of combining technologies based on TA $i_{(j)}$ level.

keyword frequency across theme codes; HHI was used to evaluate the degree of market concentration (Hirschman, 1964), with the higher index value indicating greater market concentration. In a similar way, the concentration ratio of keywords in the F-term classification table can be measured; however, in order to see the deconcentration ratio of the keywords, the value of (1-HHI) is adopted to design the TAp index. For example, if we assume the following conditions: 1) there are 41 theme codes in the F-term classification; 2) a set of keywords of interest appear in 29 theme codes with 380 instances in views (TA i) and number codes (TA $i_{(j)}$); and 3) the frequencies are distributed in (11, 7, 13, ...) for 29 theme codes, the TAp index value will be calculated by $(1-((11/380)^2+(7/380)^2+(13/380)^2,\cdots))\times(29/41))$. Accordingly, an index is used to assess the new technology idea on the basis of the number of keywords and their distributions in the F-term classification table of TA i and TA $i_{(j)}$ (see Table 1).

Finally, the highly prioritized ideas need to be elaborated to examine their feasibility and novelty in further detail. Basically, no patent from the JPO database should exist that designates the two F-term codes. However, as the F-term covers only 70% of technological fields and new technology ideas can exist in patent databases other than the JPO database, a search for prior art technologies in other patent databases is essential to obtain a patentable new technology.

4. Case study

4.1. Selecting technology for combination target

In this case study, we assume that the users want to improve the braking system of an automobile and adopted the suggested approach as a way of exploring new technology ideas in a systematic manner. To do this, firstly, the industry to which the braking system belongs is identified. The braking system is coded as 3D046 in F-terms and is thus included in the 3D (automotive, transportation vehicles) industry. Accordingly, the 3D automobile industry is selected as the target technology, and two types of idea-generation processes are applied accordingly based on the 3D technologies. One of them is to take ideas from other industries. Here, the information and communication technology (ICT) industry was chosen as a reference technology, since the industry has seen intensified technological competition in recent years and has the potential to converge with the automobile industry. Through the combination of the braking system technology in 3D with 5K (Telecommunications, radio and optical transmission and reception), new technology ideas are expected to be created that span the two different industries. On the other hand, the other type of idea generation is to investigate ideas within the industry; new technology ideas are created by taking ideas from within the 3D automobile industry.

To summarize, this case selected 3D046 (a braking system) as the target technology, while the reference technologies utilized for combination with the technology ideas were 5K technology in a different industry and 3D technology in the same industry, whereby two combinations were carried out. We assumed in this study that users are already interested in investigating particular technologies. However, if the users have no ideas about potential technology opportunities or are interested in exploratory analysis – for example, if they want to improve a braking system without restricting their focus to the ICT industry – they can mine all possible technologies across the F-term codes. As the text-mining technique is applied to the F-term codes, and not to the patent documents, it will not take that much time or effort to mine all of the technologies.

Table 1
Assessment of technology growth potential and applicability.

Criteria	Description and operational definition
Technology growth (TG)	Whether the proposed technology a has the potential to grow in the market: $TG_a = \frac{1}{N}\sum_t^N \frac{P_a(t+1)-P_a(t)}{P_a(t)}$, where $P(t)$: The number of accumulated patents granted in year t with predefined keyword sets in their titles (t = 1, ..., N; in this case, t =1 at the year of 2000) N: The periods to be included for analysis (in this case, N = 10)
Technology applicability (TAp)	Whether the proposed technology a is applicable to various areas; the more widely and evenly used the technology's keywords are, the more likely it is to be applied to various areas: $TAp_a = (1 - HHI_a) \times \frac{C_a}{C}$, $HHI_a = \sum_{j=1}^J P_{aj}^{\ 2}$, $P_{aj} = K_{aj}/\sum_{j=1}^J K_{aj}$, where C_a= The number of theme codes having the relevant keywords C= The total number of theme codes K_{aj}= The frequency of the relevant keywords in the theme code j (j = 1, ... J)

Table 2
Highest similarity values of theme codes between 3D046 and 5K.

References candidates Target	5K068	5K038	5K052	5K049	5K159
3D046	0.5657	0.5656	0.5477	0.5337	0.5164
Adjustment of the braking force	Stereo-broadcasting	Interconnected communication systems	Noise elimination	Sub-exchange stations and push-button telephones	Radio transmission system general

4.2. Selecting the reference technology for combination

4.2.1. Reference candidates for combination

To measure the similarity between the selected target technology and the reference candidates, the keywords of TA i that are frequently used in both technology areas were obtained through text mining. The keyword vectors of the technological documents were obtained by using the TA i and TA $i_{(j)}$ classification table based on the F-term, and the similarity values between each technology were obtained by measuring the cosine similarity. This study set the cut-off similarity value to 0.5 and, the technologies that had values greater than 0.5 among the similarity results between the target technology of 3D046 and 5K were selected as reference candidates (see Table 2). Here, as reference technology 5K068 showed the greatest similarity with the target value, it was used for further analysis for new technology ideation.

4.2.2. Selecting the final reference technology from among the list of reference candidates

Given the list of combination candidates derived through the measurement of cosine similarity values, a reference technology can finally be selected by using either *Criterion 1* or *Criterion 2*. If the user were to select a technology that exhibited the highest combination potential, he or she should select *Criterion 1* and then 5K068 (stereo-broadcasting), which exhibits the greatest similarity to 3D046. On the other hand, when the user selects *Criterion 2* to consider the technological lifespan of the combined reference technology, the reference technology is derived through the following process. This study collected data on the ten years from 2002 to 2011 to investigate the number of annually accumulated patent applications in each of the five lists of reference candidates (see Table 3). Throughout this process, as there are time lags until the laying open of the patent application period, data are obtained during a period considering these time lags.

As 5K068 exhibits an extremely low growth rate in terms of the accumulated number of patents filed since 2007, it was excluded from the final list of reference technologies. Four technologies, except for 5K068, were fitted to the S-curve model to estimate their stage of technological development (see Table 4). We assumed that early-stage technologies in other fields hold high potential for generating new ideas for the target technology. Therefore, based on Criterion 2, we would select 5K159 as the most suitable reference technology from outside the target technology field because the rate of patenting in that theme code suggest it is in the technology introduction stage.

Table 3
Cumulative number of patent applications for each reference candidate.

Year	5K038	5K049	5K052	5K068	5K159
2002	227	166	172	15	0
2003	445	342	344	22	0
2004	681	534	548	29	0
2005	1021	671	699	37	0
2006	1299	789	878	49	3
2007	1554	883	1084	60	39
2008	1808	985	1273	62	313
2009	2043	1067	1425	66	871
2010	2208	1132	1588	66	1635
2011	2372	1185	1711	68	2251

Table 4
Results of technology life-cycle forecasting.

Theme code	Cumulative number of patent applications	Range of decision	Technology life-cycle	R^2
5K038	2372	99.7%	Saturation	0.98
5K049	1185	99.0%	Saturation	0.95
5K052	1711	89.8%	Mature	0.97
5K159	2251	0.002%	Introduction	0.89

4.3. Deriving new technology ideas

4.3.1. Combining technologies based on TA i level

In this study, pairs of the previously identified reference technology and target technology could be classified into two types: 1) ideas derived through a 3D-5K combination of technologies belonging to different industry sectors; 2) idea generation through a 3D-3D combination within the same sector. Therefore, at this step, the idea was derived only through the 3D-5Kcombination between two different industries, which can support idea creation and the seeking of new business opportunities from *technology convergence (fusion).*

First, a new technological idea was derived by applying the "reception system" component of stereo-broadcasting technologies (TA i for the 5K068 which was finally selected from among the reference candidates based on *Criterion 1*) (see Fig. 7). Initially, ten TA is were identified as applicable new views for technology involving "adjustment of the braking force" (see Appendix A). Among them, the most feasible TA i was selected, a "reception system", having the relevant keywords in common with a target technology of "adjustment of the braking force" when the keywords' similarity was evaluated at the TA $i_{(j)}$ level.

Second, a new idea was derived by applying 5K159 at the technological introduction stage, among the reference candidates identified in Section 4.2 based on *Criterion 2*, through the same process shown in Fig. 7. Specifically, "technology related to the adaptive array" of TA i, utilized in 5K159, was applied to derive this idea. Similarly, eight applicable TA is were identified, among which the view of "technology related to adaptive array" could generate the most plausible technology idea (see Appendix A).

As shown above, the new technology idea that results from combination at the TA i level, particularly between two different industries, supports idea creation for developing integrated technologies and provides guidelines prior to comprehensive technological development (see Table 5).

4.3.2. Combination of technologies based on TA $i_{(j)}$ level

Technological combination at the TA $i_{(j)}$ level requires the combination of more specific technological characteristics than at TA i, thus making it possible to propose new ideas that are more specific than those based on the technological combination at the TA i level. Thus, through this combination, more creative ideas or specific technological alternatives can be proposed, and highly effective ideation becomes feasible.

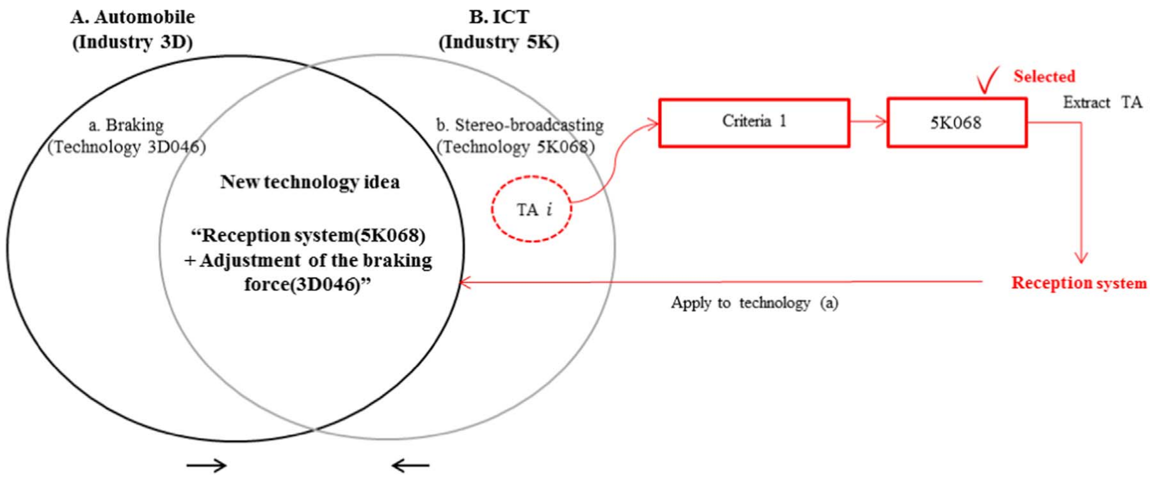

Fig. 7. Process of combining technologies based on TA *i* level.

As such, in this step, specific technological elements between the different industries – 3D-5K – and the same industries – 3D-3D – were combined at the TA $i_{(j)}$ level. In combining different industries, because 5K068 was derived by applying *Criterion 1* as shown above, this result remains the same in this step. However, the detailed process of combining the target technology 3D046 and reference technology 5K068 from two different industries is different as follows. Among the TA *i* of 5K068, the TA *i*s applied to both technologies were "transmission" and "detection." Then, among the TA $i_{(j)}$ within the two TA *i*s, the TA $i_{(j)}$ used in the reference technology 5K068 and not in the target technology 3D046 was applied (see Fig. 8).

The process described above was applied in the same manner for *Criterion 2* and 5K159 at the technology introduction stage, which was derived as shown above, and then utilized as the reference technology for combination. Among the TA *i*s of target technology 3D046 and reference technology 5K159, the TA *i*s applied to both technologies were "application" and "transmission," and among the TA $i_{(j)}$ within the two TA *i*s, the TA $i_{(j)}$ used in the reference technology but not in the target technology was applied.

Second, *Criterion 1* and *Criterion 2* were applied, respectively, to technologies within the same 3D-3D industries through the same process as that shown in Fig. 8. As the reference technology in the technology introduction stage under *Criterion 2* did not exist, the reference technology 3D047, which was identified only through *Criterion 1*, was applied to target technology 3D046. The TA *i*s applied to both technologies were "transmission" and "control," and among the TA $i_{(j)}$ within the two TA *i*s, the TA $i_{(j)}$ used in the reference technology but not in the target technology was applied. In this step, new technology ideas identified by combining different industries (and the same industries) are described in Table 6.

Unlike those at the TA *i* level, the new technology ideas derived through the different-industry combinations at the TA $i_{(j)}$ level can be used to propose specific technological alternatives to develop integrated technology. On the other hand, technological combinations within the same industry can lead to ideas based on the combination of specific technological elements. Given that technologies within the same industries are likely to collide due to their having similar operating concepts and technological structures, these new technologies, which can ensure originality in patent disputes, are highly effective in terms of their feasibility.

4.4. Assessing new technology ideas

The growth potential and applicability of the identified technologies were evaluated. To examine the growth rate of the applied patents, data on patents containing the core keywords for the new technology ideas produced from January 1, 2004 to December 31, 2013, were obtained (see Appendix B). Using the same keywords, data on the F-term codes were also collected.

New technology ideas are classified according to four categories, based on the value of each indicator (see Fig. 9). First, when a certain technological idea has high growth potential and applicability, its elements are likely to be applied to other sectors, and its potential for technological growth will be high. Second, when it has high growth potential and a low applicability, it will have an insignificant effect on the other sectors but have a high growth potential. Third, when it has low growth potential and high applicability, its elements are likely to be applied to other sectors, but its potential for technological growth will be low. Fourth, when it has low growth potential and applicability, it will have an insignificant effect on other sectors and exhibit low growth potential. The indicator values of the applicability and growth potential for seven cases of technological ideas are listed in Table 7.

4.5. Discussion

4.5.1. Application of the suggested approach

This study develops an approach to support the systematic and rapid creation of new and diverse technology ideas. After the case

Table 5
Description of new technology ideas based on TA *i* level.

New technology ideas			Description
Heterogeneous Industries (3D-5K)	Criterion 1	Adjustment of braking force (3D046) + Reception system (5K068)	By applying a stereo broadcasting transmitting system to the braking force, it is possible to control the speed of a vehicle in response to the state of the traffic above the ambient noise.
	Criterion 2	Adjustment of braking force (3D046) + Technology related to adaptive array (5K159)	In a braking force system that uses a vehicle-to-vehicle radio communication signal, by applying the process of the transmitted and received signals, we can configure an optimized frequency such as with expanded coverage or rate of data transfer.

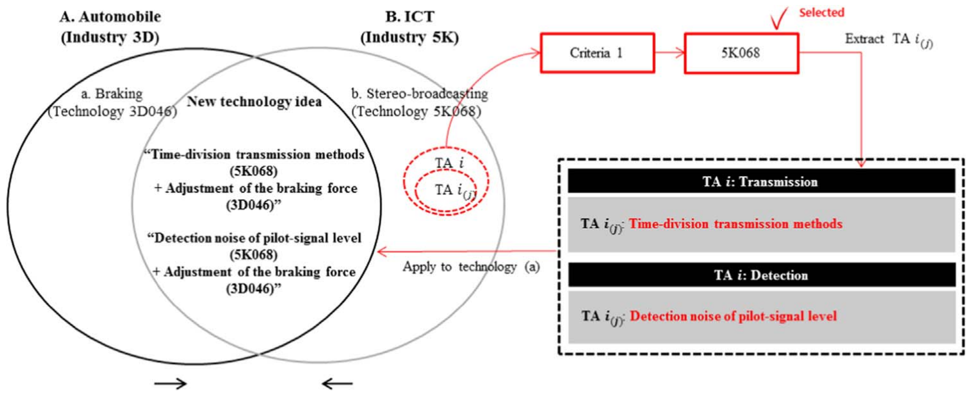

Fig. 8. Process of combining technologies based on the TA $i_{(j)}$ level.

study, we found that the suggested approach can help individual experts to explore other technological fields, to select sub-fields from which to draw on new knowledge, and to suggest specific technical attributes together with available alternatives, which can be used to generate new technology ideas. In particular, by borrowing ideas from different fields, we seek for the opportunities of technology convergence (fusion). Here, it should be noted that, although technology convergence has been used interchangeably with technology fusion, they have different meanings; convergence is "a process, where objects move or stretch farther from their prior and discrete spots, to a new and common place," while technology fusion describes "a process where objects begin to merge with each other in the very same place of at least one of the objects" (Curran and Leker, 2011, p.258). If the ideas derived are used for the focal area, they can be fusion technologies. On the other hand, if the ideas derived are likely to create a new market, they can be convergence technologies.

At the same time, we found that some issues must be discussed to ensure the effective use of the suggested approach. The first issue refers to the role of technological experts. We expect the target users of our approach are technological experts who are knowledgeable in their fields and thus, in turn, might be in danger of sticking to a particular way of thinking that is familiar to them. For them, the suggested approach could be a systematic ideation tool that can guide them to break their traditions to generate creative new ideas, by adding

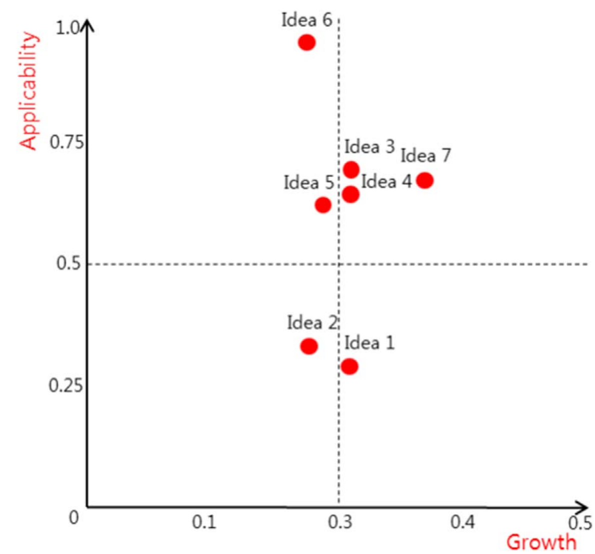

Fig. 9. Results of new technology idea assessment.

flexibility to their technological knowledge. Of course, the suggested tool could be useful for those having less knowledge on specific

Table 6
Description of new technology ideas based on TA$i_{(j)}$ level.

New technology ideas			Description
Heterogeneous Industries (3D-5K)	Criterion 1	Adjustment of the braking force (3D046) + Time-division transmission methods (5K068)	Noise level can be reduced using data transmission over a time-division transmission scheme. Also, in computing for a braking control device, it can be a method for transmitting digital signals by applying a communication system that is resistant to cross-talk
	Criterion 1	Adjustment of the braking force (3D046) + Noise detection of signal phase (5K068)	By detecting the difference of signal phases, the best frequency to compute a braking force can be used.
	Criterion 2	Adjustment of the braking force (3D046) + Application of radio transmission for the use of search (5K159)	By applying a braking force to the wireless transmission system for searching, it can transmute a view of surrounding vehicles into data format for braking automation.
	Criterion 2	Adjustment of the braking force (3D046) + Switching of transmission antennas (5K159)	By applying the principle of the transmission antenna selector of the transmission-diversity technique, it is possible to develop a fast-reaction control system through high-speed data transmission
Homogeneous Industries (3D–3D)	Criterion 1	Adjustment of the braking force (3D046) + Control with variable transmission of force and pressure (3D047)	A braking force can have variable delivery pressure in the force distribution through a transfer control unit.
	Criterion 1	Adjustment of the braking force (3D046) + Single master-cylinder assemblies of hydraulic transmission (3D047)	Pre-existing technology

Table 7
Assessment of the applicability and growth of new technology ideas.

No.	New technology ideas	Growth	Applicability
Idea 1	Adjustment of the braking force + Reception system	0.30	0.26
Idea 2	Adjustment of braking force + Technology related to adaptive array	0.28	0.27
Idea 3	Adjustment of the braking force + Time-division transmission methods	0.30	0.69
Idea 4	Adjustment of the braking force + Detection noise of signal phase	0.30	0.62
Idea 5	Adjustment of the braking force + Application radio transmission for the use of search	0.29	0.60
Idea 6	Adjustment of the braking force + Switching of transmission antennas	0.28	0.92
Idea 7	Adjustment of the braking force + Control with variable transmission of force and pressure	0.35	0.61

technologies. For example, it could be used to generate new product concepts or to suggest possible directions for future technology developments.

Second, it will be helpful to involve technological experts to elaborate the ideas and to examine their feasibility. Although this study suggested two indexes to measure the expected technological growth and applicability of candidate ideas as an attempt to test the feasibility of ideas, this index-based evaluation is generally more beneficial for a preliminary analysis. The involvement of technical experts will help to clarify new technology opportunities identified from our approach and test their feasibility in practice.

In line with the previous issue, the developments of new technologies typically cross geographical boundaries, and the ideas should be investigated in detail across different patent databases. When assessing technology growth potential and applicability, we find that the TG index values of new technologies identified in our approach using the USPTO database showed similar patterns to those in the JPO database (see Appendix B). Considering that the JPO database is one of the most significant databases used as a basis of a triadic patent family, it can be regarded as a representative database for generating ideas. Nevertheless, when technology ideas are clearly defined, their feasibility as a novel idea needs to be tested across different patent databases.

4.5.2. The suggested approach compared to TRIZ

The suggested approach has several advantages over other methods. One of the most well-known ideation approaches is the theory of inventive thinking (TRIZ), which is a tool to facilitate creativity using a knowledge base developed by analyzing approximately 2.5 million patents (Altshuller, 1984). The TRIZ ideation process has three key steps: abstraction to transform "a specific problem" in a domain to a "generalized problem"; applying TRIZ principles to find a generalized solution to the generalized problem; and concretization of the generalized solution to a specific solution in a domain. The patent database has been used to define generalized problems to corresponding generalized solutions. Therefore, it could be argued that the approach suggested in this paper has some commonalities with TRIZ, in that both approaches are based on a large set of patent data; they use the abstraction and concretization steps; and they attempt to take ideas from other domains to generate new ideas.

However, the suggested approach is different from TRIZ in several ways. First, the basic approach to searching for new ideas is different. In TRIZ, new technology opportunities come from the process of finding solutions to a pre-defined problem, taking *a problem-solution approach*, while in the F-term-based method, those opportunities are obtained by adopting solutions from other areas, taking only *a solution approach*. Indeed, one of the most difficult tasks in applying TRIZ would be to define a problem in the right manner. However, in our approach, specifying a problem is unnecessary, which enables more flexible and divergent ideation processes. This became feasible in the proposed approach because the F-term structure is used as a basis of abstraction; the pre-defined F-term structure could substitute for the pre-defined problem, for which all patents already have their own F-term codes; the abstraction process becomes much easier in the F-term-based method.

Second, in a similar vein, the proposed method has a more detailed level of abstraction compared to TRIZ. For example, TRIZ uses 39 engineering parameters to define a problem and accordingly assumes 1521 (39*39) potential problems, while the F-term has 22,000 views and 350,000 codes, indicating that abstraction at a more detailed level would be used, which enables more in-depth analysis for a problem. Accordingly, the suggested approach provides more direct technical solutions as an outcome of ideation based on those comprehensive views and codes, supporting the process of concretization. Consequently, a wide range of people, even if they are not experts in the F-term, can benefit from our approach.

Finally, the suggested approach is more flexible than TRIZ. The patent classification system is updated periodically to adapt to the changes in technologies. We can decide the time period that we want to consider as a source of knowledge combination. Moreover, technology growth can be taken into account when searching for a new candidate of knowledge combination in another field. These flexibilities can add a significant value to the process of creating technology opportunities.

5. Conclusions

A plethora of studies have suggested methods of discovering new technological opportunities, with many such studies also using patent information. Generally, previous studies have applied the IPC or keywords extracted from patent documents to analyze such patent information. However, this study analyzed specific technological characteristics by using the F-term classification system and combined these characteristics to either identify or confirm the possibility of new technological opportunities. New technology ideas obtained by combining technologies from different industries contributed to providing guidelines for developing converging technologies, and the ideas obtained by combining technologies from the same sector were effective in avoiding legal disputes over patents between developers competing in the same industry. When identifying technologies to combine and generate new technology opportunities, the F-term-based approach uses technical attributes, that is, invention principles, instead of technological content; thus this approach guides a whole ideation process by showing how to combine knowledge from different fields in a practical, rather than conceptual, way.

Under the circumstances of increasing technology complexity, growing technology convergence, and segmented technological knowledge, technology opportunity is highly likely to come from combining knowledge in different fields; it will be worth exploring other technological fields in order to pursue innovation. Theoretically, this study can contribute to the existing literature on technology opportunity by expanding research on opportunity co-creation to tap into the realm of actual practice, showing the feasibility and effectiveness of knowledge combination using patents. Methodologically, this serves as pioneer research to adopt the F-term for patent-based technology opportunity analysis. Considering the potential of the F-term, which enables patent documents to be classified according to the technical attributes described in them, more studies on the use of the F-term for discovering technology opportunity can be conducted based on the findings of this study. In practice, the suggested approach can be used as a systematic idea generation tool to help users identify new technology opportunities.

Although the proposed method improves upon conventional technology opportunity techniques, some limitations remain. First, only one case study was conducted in this study. In that case study, the suggested approach verified its feasibility. However, more case studies are required to ensure its external validity. Second, and most importantly, the evaluation of technology ideas should be elaborated upon. As the evaluation criteria for the identified technology ideas were limited to growth potential and applicability, a systematic evaluation process for confirming the validity of new technology ideas must be developed. Therefore, future studies should be conducted to reflect the characteristics of each technology idea more accurately, with analyses being performed based on specific units such as subjects, verbs, objects, and adjectives, that is, moving beyond the level of using only simple keywords. Furthermore, a new technology evaluation model applying evaluation indicators other than applicability and growth potential should be developed to confirm the validity of new technology ideas.

Acknowledgements

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Appendix A. The views identified from reference technologies for a target technology

(See Tables A1–A3)

Table A1
The view codes (TA *i*) of a target technology: 3D046 (Adjustment of the braking force).

Code	Keywords	Code	Keywords
3D046AA00	Applications	3D046FF00	Number of control systems
3D046BB00	Purpose and effects	3D046GG00	Control connected with control system
3D046CC00	Means for transmission	3D046HH00	Objects detected
3D046DD00	Number of pressure-pipe systems	3D046JJ00	Control methods
3D046EE00	Objects to be controlled	3D046KK00	Control-circuit elements

Table A2
The view codes (TA *i*) of a reference technology: 5K068 (Stereo-broad casting methods).

Code	Keywords	Code	Keywords
5K068AA00	Purpose and effects	5K068CB00	Reception system
5K068BA00	Uses	5K068CC00	Circuits
5K068BB00	Broadcasting methods	5K068DA00	Types of noise and jamming
5K068BC00	Transmission methods	5K068DB00	Detection
5K068CA00	Signal-transmission systems	5K068DC00	Elimination of noise

Table A3
The view codes (TA *i*) of a reference technology: 5K159 (Technology related to adaptive array).

Code	Keywords	Code	Keywords
5K159AA00	Functions of transmission	5K159EE00	Application
5K159BB00	Applications of transmission	5K159FF00	Technologies related to transmission diversity
5K159CC00	Types of diversity system	5K159GG00	Technologies related to adaptive array
5K159DD00	Control system	5K159HH00	Technologies related to time-space coding

Appendix B. Further information on assessing new technology ideas

(See Tables B1 and B2).

Table B1
Keywords used to assess ideas.

No.	Keyword set for idea assessment
Idea 1	(Braking) OR (Reception)
Idea 2	(Braking) OR (Adaptive array)
Idea 3	(Braking) OR (Time-division)
Idea 4	(Braking) OR (Detect-noise)
Idea 5	(Braking) OR (Radio-transmission AND Search)
Idea 6	(Braking) OR (Switch AND Transmission-antennas)
Idea 7	(Braking) OR (Control AND Variable-transmission)

Table B2
Comparative analysis of the growth rate using the USPTO and the JPO databases.

No.	New technology ideas	JPO	USPTO
Idea 1	Adjustment of the braking force + Reception system	0.30	0.30
Idea 2	Adjustment of braking force + Technology related to adaptive array	0.28	0.26
Idea 3	Adjustment of braking force + Time-division transmission methods	0.30	0.31
Idea 4	Adjustment of braking force + Detection noise of signal phase	0.30	0.29
Idea 5	Adjustment of braking force + Application radio transmission for the use of search	0.29	0.26
Idea 6	Adjustment of braking force + Switching of transmission antennas	0.28	0.27
Idea 7	Adjustment of braking force + Control when have variable transmission of force and pressure	0.35	0.33

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