Technological Forecasting & Social Change 86 (2014) 287–303

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Exploring technological opportunities by linking technology and products: Application of morphology analysis and text mining

Byungun Yoon [a,*], Inchae Park [a], Byoung-youl Coh [b]

[a] Dongguk University, Seoul, Republic of Korea
[b] Korea Institute of Science and Technology Information, 66, Hoegi-ro, Dongdaemun-gun, Seoul 130-741, Republic of Korea

ARTICLE INFO

Article history:
Received 3 June 2013
Accepted 8 October 2013
Available online 24 October 2013

Keywords:
Technological opportunity discovery
Morphology analysis
Text mining

ABSTRACT

The technological opportunity discovery (TOD) can be divided into two types: anticipating new technology and applying existing technology. The latter is useful for small and medium companies, which have weak technology forecasting capability. Thus, this research aims to suggest the methodology for the TOD based on existing technology by using morphology analysis and text mining. The extracted results of TOD are classified into three categories based on the types of product — existing, applied, and heterogeneous product. To illustrate the process and validate the utility of application, LED heat dissipation technology and LED lamps are selected as the technology and product for the illustration. The method contributes to suggest a semi-automated normative method for technology forecasting by combining morphology analysis and text mining.

1. Introduction

Exploring technology opportunities is considered as an essential process for companies and governments since the possession of promising technology can provide a core competitive advantage in the future among the competitors. Thus, many developed countries conduct science and technology forecasting through technological and economical scanning periodically and reflect the result of forecasting to the national science and technology policy. Furthermore, many global leading companies perform technology forecasting activities for preoccupancy of their new business driver in the future.

Technological opportunity is defined as a set of possibilities or potential for technological advance or technological progress in general or within a particular field [1,2]. The concept of technological opportunity reflects the possibilities for technological progress in different industries [3]. It indicates that technological opportunities bring innovations in a given field of knowledge and a given industry in terms of time and costs. Technological opportunity also reflects the cost of achieving some normalized unit of technical advance [4].

The research regarding technological opportunity discovery (TOD) is divided into developing methodology, framework, and index. Researches on TOD methodologies presented a modified methodology based on both qualitative analysis like Delphi [5], scouting [6], and morphology analysis [7] and quantitative analysis like bibliometrics and patent analysis [8], which are generally used in technology forecasting. The technology intelligence framework is suggested as a framework for TOD from an information gathering and analysis perspective [9]. Knowledge spread, research duplication between firms, and research scope is defined as indices for measuring the influence of technological opportunity [10]. The effect of technological opportunity on the probability that they would be commercialized through the creation of new firms is examined by technological importance, radicalness, and patent scope [11]. As an example of the ongoing TOD project, foresight and understanding from scientific exposition (FUSE) is suggested by the intelligence advanced research projects activity (IARPA) in the US. The program, initiated in 2011, seeks to develop

* Corresponding author at: Department of Industrial & Systems Engineering, School of Engineering, Dongguk University, 3-26, Pil-dong 3ga, Chung-gu, Seoul 100-715, Republic of Korea. Tel.: +82 2 2260 8659; fax: +82 2 2260 8743.
E-mail address: postman3@dongguk.edu (B. Yoon).

0040-1625/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.techfore.2013.10.013

automated methods that aid in the systematic, continuous, and comprehensive assessment of technical emergence using publicly available information found in published scientific, technical and patent literature. TOD is an activity of searching promising technologies to offer business opportunities in the future. TOD enables to improve technological competitiveness by minimizing trial and error in R&D and preventing duplication of research since TOD offers a global research trend. Therefore, exploring technology opportunity is considered as an essential process for many companies.

Small and medium enterprise (SME) has high innovation competitiveness with flexibility and specialty compared to a large company and generally has high R&D productivity [12]. However, SME conducts innovation through various types of collaboration since SME has a lack of information and resources compared to a large company [13,14]. SME has limitations to conduct technological opportunity discovery activities since TOD requires exploring new technology or promising emerging technology. Therefore, TOD for SME is defined as a searching activity to maximize the effectiveness using limited resources based on existing technology or products in SME. TOD based on the existing technology enables a reduction in the level of risk compared to TOD based on the new technology.

The TOD process need not depend on the knowledge and experience of technology interested parties since companies can create and store rich information as growing the level of information technology rapidly. Therefore, this paper suggests the automated TOD method using existing technology in the company. The technological opportunities based on existing technology are explored in three product areas, which include existing, applied, and heterogeneous products since the technology mainly creates business opportunities through the product.

This research aims to suggest the methodology for TOD by using keyword based morphology analysis, which is considered as an automated normative method. The keywords are extracted from patent documents, which are an ample source of technical and commercial knowledge in terms of technical progress, market trend, and proprietary ownership [15]. The suggested method is expected to be a useful tool for SME, which has a lack of technology forecasting capability, to discover the technological opportunity based on existing technology.

This paper is organized as follows. First, as an introductory statement, the general background of technology opportunity analysis (TOA), text mining, and morphology analysis (MA) is presented. Next, the research framework is presented. In this section, the research concepts, overall process, and types of technological opportunity discovery (TOD) is described. In the next section, development of the TOD model is described with concepts of morphology development, linking grid of morphologies, and the process of TOD. Then, an exemplary case is used to exhibit the process of analysis and to assure the utility of application with LED technology. Finally, implications of current research and issues of future research are discussed.

2. Background

2.1. Technology opportunity analysis

Technology opportunity analysis (TOA) has been under development at Georgia Tech since 1990 and the research aims at systematizing the process that prioritizes R&D investment in the emerging technology areas [16]. TOA performs value-added data analysis, collecting bibliographic and/or patent information and digesting it to a form useful to the research or technology manager, strategic planner, or market analyst. The premise is that useful information on the prospects of particular technological innovations can be extracted from abstracts collected by searching on the given topic in suitable publication, patent, citation, and/or project databases.

The TOA process entails these main steps [17]: (1) Searching and retrieving text information, typically from large abstract databases, (2) Profiling the resulting search set, (3) Extracting latent relationships, (4) Representing relationships graphically, and (5) Interpreting the prospects for successful technological development. Porter and Detampel [16] presented a framework supporting technological opportunity analysis on emerging technologies by combining monitoring with bibliometric analysis. Yoon and Park [7] presented a systematic approach for identifying technology opportunities by using keyword-based morphology analysis. Yoon [18] developed *Techpioneer*, which is a system for identifying technology opportunities, as a technology intelligence tool to offer decisive information.

However, there are some attempts to discover the opportunity between the technology and product. Lee et al. [19] suggested a new technology roadmap (TRM) approach based on keywords, which are effective tools for connecting product and technology planning. OuYang and Weng [20] presented a new approach called New Comprehensive Patent Analysis model (NCPA) which combines the patent family with patent citation analysis in a new product design process. The model is able to construct patent technology performance maps and to discover product niches. It is important to understand product opportunity since technological opportunity is realized through product development. In this research, applicable product opportunity based on existing technology is suggested.

2.2. Text mining

Text mining techniques which are a particular class of data mining aim to perform knowledge discovery from collections of unstructured textual data. Most of text mining tools assume that keywords can be used to label the important content of documents, and thus the operation for knowledge discovery can be executed on the labels of documents [21]. In short, text mining puts a set of labels on each document and discovery operations are performed on the labels. The usual practice is to put labels to words in the document. Then, the document in text format can be featured by keywords that are extracted through the text mining algorithm.

Text mining is widely used in the fields of knowledge management and customer relationship management. Dai et al. [22] proposed MinEdec, a decision-support model that combines two well-known and widely used competitive intelligence analysis methods, the Five Forces analysis and a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis with various text mining technologies. Godbole and Roy [23] deployed a text mining solution in services industry settings, specifically in contact centers (call centers). They focused on the particular application of customer satisfaction (C-sat) analysis in contact centers.

Text mining-based approaches have also been applied in technology management to exploit technological documents. The profiles of research and development (R&D) projects are summarized through identifying the linkages between them [24], and technology trends and developments can be analyzed using this approach [25]. In addition, text mining has the potential to identify new opportunities for technology development by generating technology or patent maps [17,26]. Kostoff et al. [27] has developed an approach whereby text mining can be used to identify disruptive technologies, proposing the concept of disruptive technology roadmaps. This method can also enhance science and technology roadmaps through bibliometric analysis such as co-word and co-citation analysis [28]. The professional communities and social networks of the biomedical engineering field in Thailand are revealed by applying bibliometric and text mining techniques to generate technology intelligence [29].

2.3. Morphology analysis

The basic idea of morphology analysis (MA) is that the subject is broken down into several dimensions, through which the subject can be described as comprehensively and detailed as possible [30]. Generally, a system can be decomposed into several subsystems, each of which may be shaped in a number of different ways. MA identifies the various shapes that each dimension takes and, by combining these shapes, examines all possible alternatives that a system may adopt. That is, MA systematically categorizes the possible combinations of subsystems. The strength of this technique lies in its ability to model complex problems in a non-quantitative manner [31]. A general form of MA was developed as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes and was applied to diverse fields [32]. Consequently, MA in nature is a method to structure a problem rather than solve it.

MA has been applied to design materials and products in computer-based design [33], language modeling for continuous speech recognition [34], technology forecasting for identifying promising innovation opportunities [15], technology roadmap development as a new mapping methodology by using the systems based technique [35], risk management in developing products or technology, in combination with the scenario technique [36], service concept creation in the process of new service development (NSD) [37,38], design of production systems [39], and new business model development (NBMD) that helps business practitioners to develop, evaluate and select the best business model to meet the business objectives [40]. Software to support the execution of MA has been developed and commercialized, and has helped researchers construct a morphological matrix and evaluate the priority of alternatives more easily [41,42].

The basic procedure of MA is as follows [30]. First, the fundamental functions of the subject are defined. In this step, the features of the subject are broken down into several attributes. The next step is to list all possible levels in which each attribute can manifest itself. Third, all combinations that can produce unique sets of levels are investigated. The number of combinations can be calculated by multiplying the number of levels associated with each attribute together. The fourth step is to attempt to find practical instances for each combination. The final step is to eliminate the infeasible combinations and list the remaining combinations in order of importance.

MA makes it possible to discover an unexpected epoch-making idea or solution by extracting a combination of shapes. However, MA depends on expert's intuition since MA does not have any systematic method for identifying dimensions and shapes which are core step in MA. In this research, methods for supporting MA such as text mining, F-term, and TEMPEST are utilized to minimize the dependence of expert's intuition.

3. Research framework

3.1. Research concepts

This research aims to discover technological opportunities with existing technology by applying a morphology analysis (MA) and text mining. The MA is employed for structuring the existing technology and three types of products. However, text mining is employed for offering contents when the technology and the product morphologies are built. The existing MA process has a limitation in that there is no systematic supporting method when it comes to structuring morphology. As a remedy, this research utilizes text mining as a systematic and automatic method for supporting MA by offering related keywords. Structured technology and product morphologies are linked by matching keywords which are extracted by text mining. The rough research concept is illustrated like Fig. 1.

3.2. Overall process

The overall research process consists of several steps like Fig. 2, first of which are existing technology selection and patents collection. In this step, companies select the existing technology in which they want to explore the technological opportunity with and collect the related patents. Second, the technology and product morphologies are structured by text mining from the patents on existing technology and by experts' participation. The three types of products for exploring technological opportunities based on existing technology, which are existing, applied, and heterogeneous, are considered in this research. Third, the technology and product morphologies are linked by calculating the matching relation based on the association index using technology and product keywords and participation of experts. Finally, technological opportunities with existing technology are identified on each type of product.

3.3. Types of TOD

A technological opportunity discovery (TOD) process is different by three types of products. In this research, the types of product are classified as existing, applied, and heterogeneous products to discover the technological opportunities with existing technology of the company. Fig. 3 illustrates the types of TOD. The first type of TOD is in the

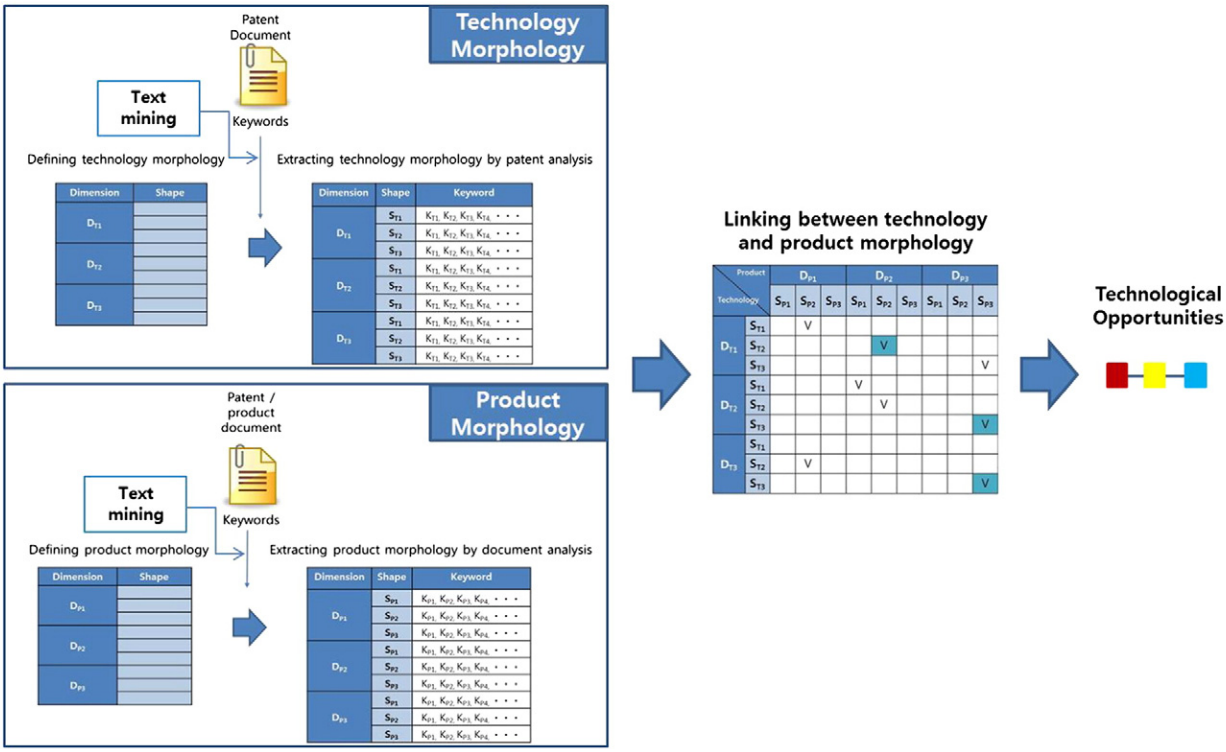

Fig. 1. Research concept.

existing product area. The existing product is a product where the existing technology is applied. The technological opportunity in the existing product is identified by discovering vacant attributes among the current product lineup after the existing technology and existing product morphologies are compared with.

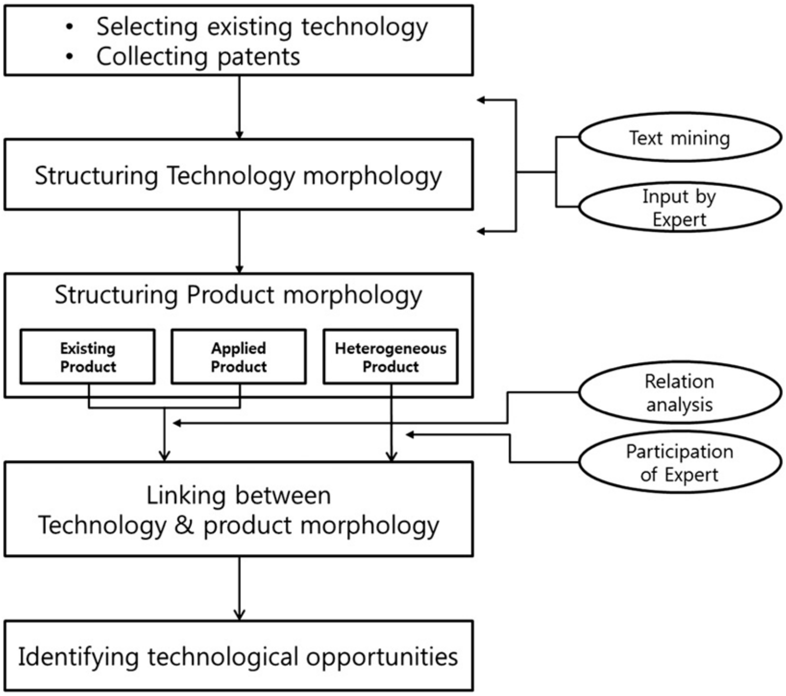

Fig. 2. Overall research process.

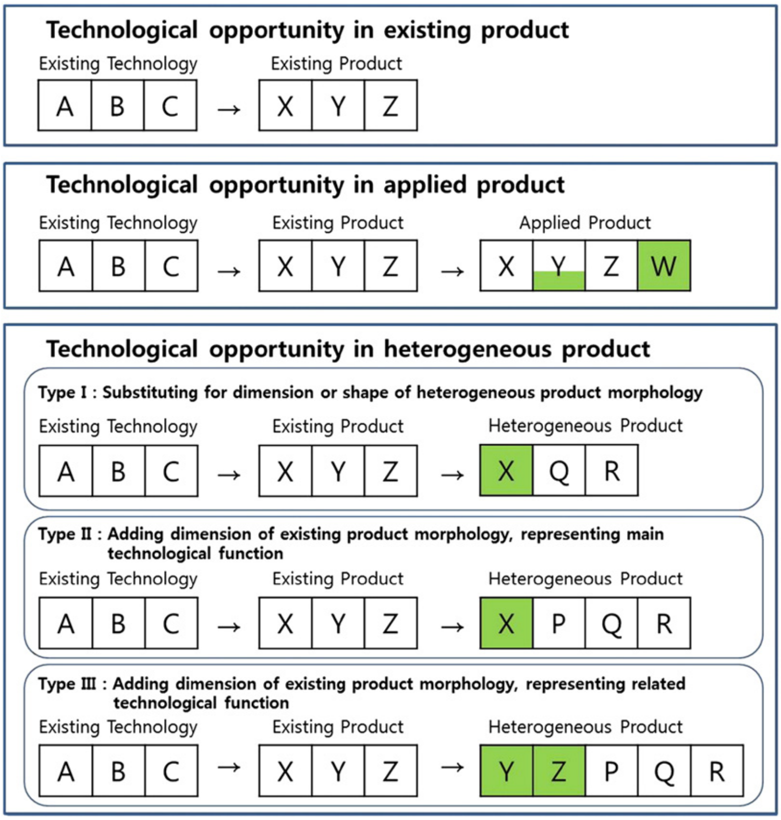

Fig. 3. Types of technological opportunity discovery.

The second type of TOD is in the applied product area. The applied product is a product which is improved in terms of the feature in an identical product group with that of the existing product. The technological opportunity in the applied product is identified by adding the feasible dimension or the shape to existing product morphology after the existing product and applied product morphologies are compared with.

The third type of TOD is in the heterogeneous product area. The heterogeneous product is a product which is in a different product group than that of the existing product. The technological opportunity in the heterogeneous product is identified by substituting or adding the dimension or shape, which is related to existing technology in the existing product, to heterogeneous product morphology after the existing product and heterogeneous product morphologies are compared with.

The TOD in the heterogeneous product area is classified into three types. Type I is that technology opportunity is discovered by substituting for the dimension or shape of heterogeneous product morphology when both the existing and heterogeneous product morphologies have identical dimensions. That is, the dimension or shape of existing product morphology, which the main technological function of existing technology is applied to, substitutes for that of heterogeneous product morphology. Type II is that technology opportunity is discovered by adding the dimension of existing product morphology, which represents the main technological function, to heterogeneous product morphology when both existing and heterogeneous product morphologies do not have identical dimensions. That is, the dimension of existing product morphology, which the main technical function of existing technology is applied to, is added to that of heterogeneous product morphology. Type III is that technology opportunity is discovered by adding the dimension of existing product morphology, which represents the related technical function, to heterogeneous product morphology when both existing and heterogeneous product morphologies do not have identical dimensions. That is, the dimension of existing product morphology, which is related to the technical function of the existing technology applied to, is added to that of heterogeneous product morphology.

The TOD in the heterogeneous product area requires more qualitative methods such as experts' intuition than the systematically organized quantitative method. It is difficult to develop the linking grid based on the calculated matching relation since the heterogeneous product area is totally different from the existing and applied product area.

4. Development of technology opportunity discovery model

4.1. Morphology

Morphology analysis (MA) depends on expert's intuition since MA does not have any systematic method for identifying dimensions and shapes which is the core step in MA. To overcome the limitation, the methods for supporting MA such as text mining, F-term, and TEMPEST are utilized to minimize the dependence of expert's intuition. Text mining supports MA by offering related keywords to experts when they develop the morphology.

F-term is a system for classifying Japanese patent documents according to the technical features of the inventions described in them. It is created by Japan patent office (JPO) to cope with the ever-increasing volume and diversification of technologies and to improve the efficiency of prior art searches for patent examination [43]. It is not a replacement for the international patent classification (IPC) or other patent classifications, but complements other systems by providing a means for searching documents from different viewpoints. The IPC system is a hierarchical classification system based on a single viewpoint. In contrast, the F-term system represents multi-dimensional viewpoints. Every F-term consists of a five-digit theme code and a four-digit term code. Every theme code has a corresponding 'File Index (FI)', which is the internal classification used by the JPO and a superordinate concept of F-term, and coverage. Themes are further split into terms ('term codes'). Term codes are assigned according to various technical viewpoints (e.g. material, operation, product, and purpose). Even though F-term covers approximately 70% of all technical fields in Japanese patent documents [44], the F-term is considered as a frame to support morphology development since it offers many more various viewpoints of technology than IPC and the purpose of this research is not an effective prior art search.

TEMPEST is introduced as one of the methods which classify patents and qualitatively analyze technological information in various perspectives [45]. Each letter of "TEMPEST" — E, M, P, S, and T — represents an abbreviation of individual viewpoints for analyzing patents. Based on the E (Energy) perspective, corresponding patents include technological information mainly concerned with devices for driving power or principles to work these devices. In the M (Material) perspective, patents are characterized as what is related with stuff in order that consist of product or technology such as ingredient and raw material. Developed technology/product naturally owns their unique role that might be called function and then, it generates attributes of technology in the P (Personality) viewpoint. The S (Space) point of view approaches inventions from a structural perspective. Thus, the applicable patent information includes a concept regarding arrangement, structure, and constituent or components for implemented technology/product. Another perspective of analyzing technological information is T (Time) whose patents contain a manufacturing or controlling process. TEMPEST is also considered as a frame to support morphology development to minimize the dependence of expert's intuition.

Technology morphology is structured based on the technology hierarchical tree which is deployed by an expert with the supporting frames such as F-term and TEMPEST. Especially, F-term and TEMPEST is utilized to constitute the dimensions of technology morphology. However, text mining is utilized to constitute the shapes of technology. The extracted keywords by conducting text mining support the shapes as a subordinate concept. The expert should select shape as a core keyword after reviewing extracted keywords by text mining.

Product morphology is structured based on the product hierarchical tree which is deployed based on the physical and functional concept of the product such as module, function, process, and physical structure. The dimension of product morphology is composed by an expert after reviewing the product hierarchical tree. The text mining is utilized to constitute the shapes of the product. The extracted keywords by conducting text mining support the shapes as a subordinate concept like the preceding. The product morphology is developed by the types of product. Applied product morphology is not developed since the applied product morphology is the modified existing product morphology by adding the dimension or shape.

4.2. Linking morphology of product and technology

The matching relation should be calculated for linking the technology and product morphologies. The linking process of the morphologies is based on the calculated matching relation between the technology morphology and existing product or applied product morphology. However, the heterogeneous product area is so different from the existing and applied product area that it is difficult to calculate the matching relation quantitatively and the linking between technology and heterogeneous product depends on expert's participation.

Matching relation is calculated by searching the number of patent applications and the process is as follows. First, the number of patent applications is measured by searching the patent database with the query based on the keywords which are in technology morphology. Second, the number of patent applications is measured by searching the patent database with the query which is composed as (technology keywords and product keywords). It means to measure the number of patent applications when both technology and product keywords occur simultaneously. Third, matching relation is calculated between technology and product morphology. Matching relation is calculated based on the index of association like Eq. (1). Finally, the linking grid between technology and product is developed. The cells of the linking grid are filled with each value of matching relation based on the index of association. The highest value among all of the values of the shapes in each dimension is selected. If the value of matching relation is all zero in a dimension, the dimension is not linked to each other. Furthermore, more than two dimensions are possibly linked if the value of matching relation is identical in a dimension.

$$\text{Index of Association} = \frac{\textit{The number of searched patent application by using } \{(TKs) \textit{ and } (PKs)\}}{\textit{The number of searched patent application by using } (TKs)} \quad (1)$$

This calculating method overcomes the existing method for measuring similarity based on the keyword vector such as cosine similarity which is widely used in many previous researches. The method measures the relation by utilizing the open patent database while the existing method only measures the similarity within the collected documents which means the limited database. Therefore, the suggested method is appropriate for the applied product as well as the existing product.

4.3. Process of TOD

As stated above, the technological opportunity discovery is classified into three types which are the existing, applied, and heterogeneous product. Each type has a different process of TOD since each of them has different characteristics. The process of TOD in its respective type is as follows when it is assumed that the existing technology morphology is already developed.

4.3.1. TOD in existing product area

First is the process of TOD in the existing product area. The existing product morphology (e.g. X–Y–Z in Fig. 3), which is developed based on the product hierarchical tree, is compared with the technology morphology (e.g. A–B–C in Fig. 3). The detail of the process is as follows.

First, the existing product that the existing technology is applied to is selected. Second, the dimensions of the existing product morphology are constituted by an expert in consideration of the module, function, process, physical structure, etc. Third, the shapes of the existing product morphology are constituted after the reviewing by experts of the extracted keywords by text mining from related patent documents. Fourth, the linking grid is developed by calculating the matching relation based on the patent database using the keywords in technology morphology and the keywords in existing product morphology. Fifth, the existing combinations are eliminated among all of the possible combinations. Finally, the technological opportunity is identified by extracting priority among the rest of the combinations by using the sum of the value of indices such as technological feasibility and technological realization rate.

4.3.2. TOD in applied product area

Second is the process of TOD in the applied product area. The technological opportunity in the applied product is identified by adding the feasible dimension (e.g. W in Fig. 3) or the shape (e.g. Y in Fig. 3) to existing product morphology (e.g. X–Y–Z) after the existing product and applied product morphologies are compared with. The detail of the process is as follows.

First, the core existing technology keywords, which consist of the dimension and shape in existing technology morphology, are extracted. Second, the patents regarding the product are collected by searching with the core existing technology keywords. Third, the applied product keywords are extracted by the screening process, which includes noise elimination, filtering based on term frequency (TF) and tf-idf, and typology of the product keyword. The tf-idf, term frequency-inverse document frequency, is a numerical statistic which reflects how important a word is in a document in a collection or corpus [46]. It is often used as a weighting factor in information retrieval and text mining. While TF is considered as a quantitative view, tf-idf is considered as a qualitative view of the keyword filtering process. Table 1 explains the rule of screening the keywords. The keywords with high TF and high tf-idf are selected. The keywords with high TF and low tf-idf and the keywords with low TF and high tf-idf are filtered after the review by an expert. The keywords with low TF and low tf-idf are removed.

The typology of keywords is based on TEMPEST. Material (M) and space (S) are selected to represent the feature of the product among the five perspectives of TEMPEST. Furthermore, the module and part category is added to represent the keywords related to the product itself in the typology of product keywords. Fourth, the applied product morphology is developed by comparing with the existing product morphology. In this step, two types of the morphology development exist. The first type is that the new shape (e.g. the part of dimension Y in Fig. 3) is added to the existing dimension of the existing morphology (e.g. X–Y–Z in Fig. 3). To this end, frequently occurred two words of existing and applied product keywords are extracted to explore the new field which is similar to the existing field but slightly different. The second type is that the new dimension and new shape (e.g. W in Fig. 3) are added to existing morphology (e.g. X–Y–Z in Fig. 3). The co-word matrix is developed based on applied product keywords and the clustering is conducted based on cosine similarity. Then, the dimension and shape structured after the group, which is the result of clustering, is reviewed by the expert. Finally, the linking grid between the existing technology and applied product morphology based on the calculated matching relation and the technological opportunity is identified as a combination of the shapes.

Table 1
Morphology of LED heat-dissipation technology.

Term frequency	tf-idf	Description	Action
High	High	High term frequency and critical keyword	Select
High	Low	High term frequency, but general keyword	Filter
Low	High	Low term frequency, but critical keyword	
Low	Low	Inappropriate keyword	Remove

4.3.3. TOD in heterogeneous product area

Third is the process of TOD in the heterogeneous product area. The technological opportunity in the heterogeneous product is identified by substituting (e.g. type I in Fig. 3) or adding the dimension or shape (e.g. types II and III in Fig. 3), which is related to existing technology in the existing product, to heterogeneous product morphology (e.g. P–Q–R) after the existing product and heterogeneous product morphologies are compared with. As stated above, the TOD in the heterogeneous product area is classified into three types. The detail of the process is as follows.

First, the core keywords related to the existing technology and product are extracted. Second, the related Japanese patents are searched by using the core keywords. The patent database of Japan patent office (JPO) is utilized for the F-term list in the TOD process of the heterogeneous product area. The F-term list is utilized to extract the related view of the existing technology and product since the F-term suggests the multi-dimensional views regarding the technology field. Third, the F-term list is extracted and the frequency of the F-term is analyzed. Fourth, the heterogeneous product area is selected from the F-term list by an expert. The selected F-term should have general feature of product but not related to existing technology and product. In other words, the F-term is removed by the expert if the F-term is related to the existing technology and product directly or indirectly since the purpose of the process is to explore the totally different area from the existing and applied product. Fifth, the heterogeneous product morphology is developed. Then, the technological opportunity in the heterogeneous product area is identified by comparing the existing product and heterogeneous product morphology. To compare with the morphologies, the dimensions of the existing product morphology should be classified into the main technological and the related technological function. It is assumed that X is the dimension with main technological function and Y and Z are the dimensions with related technological function in Fig. 3. The three types of technological opportunity in the heterogeneous product existed. Type I is that technology opportunity is discovered by substituting for dimension or shape (e.g. substituted P of type I in Fig. 3) of heterogeneous product morphology when both existing and heterogeneous product morphologies have identical dimensions. Type II is that technology opportunity is discovered by adding the dimension (e.g. X of type II in Fig. 3) of existing product morphology, which represents the main technological function, to heterogeneous product morphology (e.g. P–Q–R in Fig. 3) when both existing and heterogeneous product morphologies do not have identical dimensions. Type III is that technology opportunity is discovered by adding the dimension (e.g. Y and Z of type III in Fig. 3) of existing product morphology, which represents related technical function, to heterogeneous product morphology when both existing and heterogeneous product morphologies do not have identical dimensions.

5. Illustration

5.1. Data

Recently, the importance of green technology has been increasing as green technology continues to rise as the key driver for sustainable growth in the long run. Therefore, exploring the technological opportunity is important in green technology. Light emitting diode (LED) technology, one of the green technologies, is selected for an illustration to explore the technological opportunity in this research. Especially LED heat dissipation technology, which is one of the 27 main fostering technologies, is selected. The LED lamp is adopted into a diverse field such as an automobile and a traffic light. The weak spot of LED as a light source of lamp in an automobile and traffic light is temperature since luminous efficiency decreases dramatically when the temperature goes up. Thus, the heat dissipation device, which makes the temperature around the LED low, is essential. LED heat dissipation technology is appropriate to illustrate the suggested method in this research in that the technology is industrial technology so that it is proper to use the patent information and the technology is related to the product because the LED lamp is widely used. The 369 patents related to LED technology are collected from the patent database of United States Patent and Trademark Office (USPTO) to illustrate the LED heat dissipation technology at first.

5.2. Morphology

F-term theme is extracted by searching the keywords of LED heat dissipation technology in JPO database. The technology theme — '5F041 light emitting diode' — is selected. The technology hierarchical tree is developed based on the multi-dimensional view of the F-term and TEMPEST. The morphology of LED heat dissipation technology is developed based on the technology tree. Table 2 represents the morphology of the LED heat dissipation technology. It has 1080 possible combinations ($3 \times 3 \times 4 \times 6 \times 5$). It has five dimensions which are optimization, principle of cooling, cooling method, heat management elements, and types of thermal interface material. The technology is structured whereby the dimensions largely consist of cooling method, material, etc. The shade on the shape is the existing technology in this illustration. The technological opportunity is explored based on this combination of shapes, representing existing technology by the types of product. The technological opportunity is extracted as a combination of shapes in the product morphology.

Table 2
Morphology of LED heat-dissipation technology.

Dimension	Shape		
Optimization	Square	Structure	Route
Principle of cooling	Convection	Conduction	Radiation
Cooling method	Natural Hybrid	Water-cooling	Air-cooling
Heat management elements	Heat sink Fan	Thermal via TEC	Cooling fins Heat pipe
Types of thermal interface material	Epoxy Solder	Thermal grease Thermal tape	Pressure sensitive adhesive

As stated above, the existing product is LED lamp in the illustration. First of all, the product hierarchical tree is developed based on the module, function, process, physical structure, etc. The existing product morphology is developed like Table 3 based on the product tree. It has 2592 possible combinations ($3 \times 3 \times 4 \times 6 \times 2 \times 6$). The morphology of LED lamp consists of six dimensions, which is chip type, packaging material, package type, substrate material, encapsulant material, and thermal device. While the morphology of technology focuses on the method, material, the morphology of the product focuses on the physical structure, material of the part. The technological opportunity of each type of product is explored based on this existing product morphology as the flow of an arrow to TOD applied and the heterogeneous product is initiated from the existing product morphology in Fig. 4.

5.3. Results of TOD

5.3.1. TOD in existing product area

Table 4 represents the morphology of LED heat dissipation technology with the keywords which are extracted by text

Table 3
Morphology of LED lamp.

Dimension	Shape		
Chip type	Non-flip chip	Flip chip	Vertical chip
Packaging material	Plastic	Ceramic	Metal
Package type	Lamp type BLU	SMD type	COB
Substrate material	GaAS Al_2O_3	Si ALN	SiC GaN
Encapsulant material	Epoxy	Silicone	
Thermal device	Heat sink Fan	Thermal via TEC	Cooling fins Heat pipe

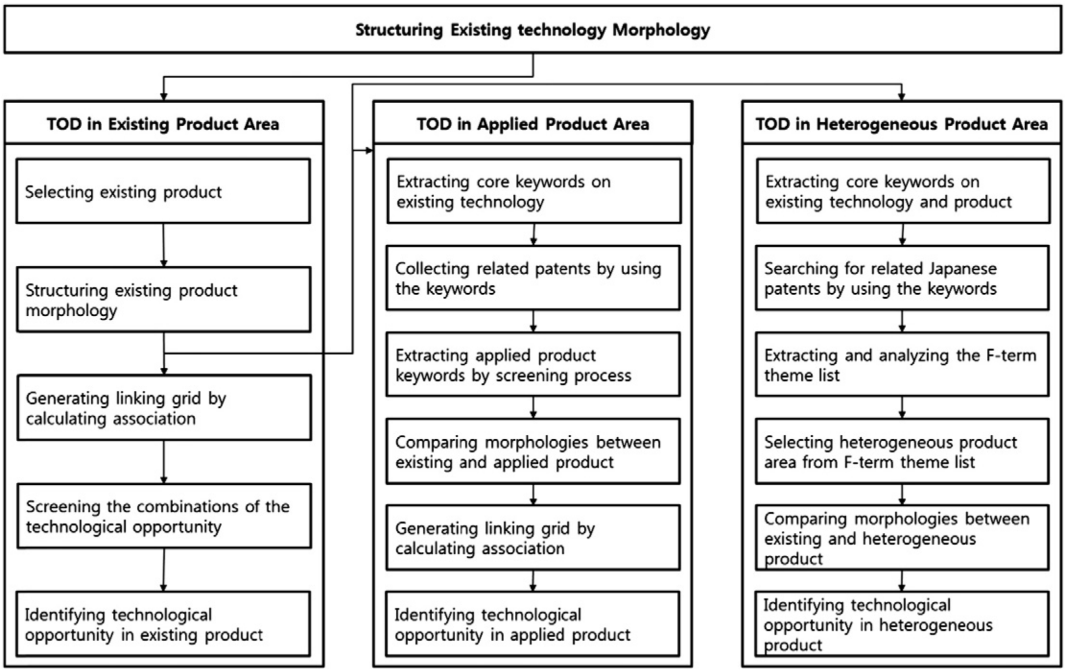

Fig. 4. TOD process by areas.

mining. The shade on the shape is the existing technology in this illustration. That is, the existing technology is the combination of structure–conduction–natural–heat sink–epoxy.

Table 5 represents the morphology of LED lamp with the keywords which are extracted by text mining. The matching relation is calculated by using the keywords in the morphologies based on the number of patent applications in the USPTO database. For example, the matching relation is calculated based on the index of association and the linking grid is extracted using the number of patent applications when searching {structure or constitution or shape or form} and the number of patent applications when searching {(structure or constitution or shape or form) and (flip or

Table 4
Morphology of LED heat-dissipation technology with related keywords.

Dimension	Shape	Keyword
Optimization	Square	Surface, square, space, spaced-apart
	Structure	Structure, constitution, shape, form
	Route	Route, channel, multichannel, path, pathway
Principle of cooling	Convection	Convection
	Conduction	Conduction, heat conduction, conductive, conductivity
	Radiation	Radiation, radiation emitting, radiant
Cooling method	Natural	Natural, naturally occurring, naturally, environment, environmental
	Water-cooling	Water, feedwater, water-base, underwater
	Air-cooling	Air, airflow, air conditioner, circulating air, air blower
	Hybrid	Hybrid cooling, air water, air or water cooling
Heat management elements	Heat sink	Heat dissipating, heat dissipation, heat treated, absorption
	Thermal via	Thermal equilibrium, thermal pressure
	Cooling fins	Heat expansion
	Fan	Air blowing, blowing, ventilation
	TEC	Thermoelectirc, heat flux, thermo electric
	Heat pipe	Nanotubes, holder, heat transfer
Types of thermal interface material	Epoxy	Epoxy, epoxy containing
	Thermal grease	Grease, oil, oil-base, smooth, smoothly, smoothness
	Pressure sensitive adhesive	Pressure-transfer, pressure-sensitive, thermal-pressure
	Solder	Solder, soldering, solderable, brazing
	Thermal tape	Thermal tape

Table 5
Morphology of LED lamp with related keywords.

Dimension	Shape	Keyword
Chip type	Non-flip chip	Horizontal chip, epi-up, non-flip, top-emission
	Flip chip	Flip, epi-down, chip-mounting, multi-chip
	Vertical chip	Vertical chip, vertically, vertical cylinder
Packaging material	Plastic	Plastic, polymeric, polyamide, poly-crystallized
	Ceramic	Ceramic, glass, glass-made
	Metal	Metal, metalized, metal-coated, metal-based, metal-made
Package type	Lamp type	Lamp, lampshade, transparent mold, transparent envelope
	SMD type	SMD, surface mount device, dome, surface-mounted
	COB	COB, chip on board, simple structure
	BLU	BLU, backlight unit, backlighting, LCD
Substrate material	GaAS	GaAs substrate, GaAsP substrate, AlGaAs substrate, gallium arsenide substrate
	Si	Si substrate, silicone substrate
	SiC	SiC substrate, silicone carbide substrate, ceramic substrate
	Al_2O_3	Al_2O_3 substrate, aluminum oxide substrate, sapphire substrate
	ALN	ALN substrate, aluminum nitride substrate
	GaN	GaN substrate, gallium nitride substrate
Encapsulant material	Epoxy	Epoxy encapsulant, epoxy containing encapsulant
	Silicone	Silicone encapsulant, silicon-based encapsulant
Thermal device	Heat sink	Heat sink, heat-sinking, plate-type cooler
	Thermal via	Hole, throughhole
	Cooling fins	Cooling fin, fin
	Fan	Fan, cooling fan
	TEC	Thermoelectric cooler, heat pump
	Heat pipe	Pipe, pipeline

Existing Technology

Existing Product	Dimension	Optimization	Principle of cooling	Cooling method	Heat management	Type of TIM
Dimension	Shape	structure	Conduction	Natural	Heat sink	Epoxy
Chip type	Non-flip chip	0.0161	0.0095	0.0040	0.0000	0.0000
	Flip chip	0.0168	0.0271	0.0020	0.0296	0.0000
	Vertical chip	0.0163	0.0156	0.0140	0.0148	0.0000
Packaging material	Plastic	0.0238	0.0244	0.0220	0.0148	0.0353
	Ceramic	0.0301	0.0318	0.0200	0.0667	0.1882
	Metal	0.0954	0.1549	0.0459	0.1407	0.0588
Package type	Lamp type	0.1273	0.1279	0.1737	0.1556	0.2000
	SMD type	0.0140	0.0230	0.0060	0.0000	0.0353
	COB	0.0173	0.0061	0.0060	0.0000	0.0000
	BLU	0.0296	0.0149	0.0160	0.0148	0.0118
Substrate material	GaAS	0.0026	0.0034	0.0000	0.0222	0.0000
	Si	0.0054	0.0041	0.0000	0.0074	0.0118
	SiC	0.0072	0.0156	0.0020	0.0074	0.0235
	Al2O3	0.0217	0.0122	0.0060	0.0074	0.0000
	ALN	0.0030	0.0068	0.0040	0.0000	0.0000
	GaN	0.0259	0.0237	0.0080	0.0222	0.0000
Encapsulant material	Epoxy	0.0002	0.0000	0.0000	0.0074	0.082
	Silicone	0.0024	0.0014	0.0000	0.0074	0.012
Thermal device	Heat sink	0.0443	0.1042	0.0818	0.0148	0.0588
	Thermal via	0.0427	0.0589	0.0240	0.0148	0.0471
	Cooling fins	0.0198	0.0318	0.0439	0.0519	0.0235
	Fan	0.0079	0.0081	0.0220	0.0222	0.0000
	TEC	0.0014	0.0020	0.0000	0.0000	0.0000
	Heat pipe	0.0189	0.0169	0.0240	0.0148	0.0000

Fig. 5. Linking grid between existing technology and product.

epi-down or chip-mounting, multi-chip)} (see Tables 4 and 5). As a result, the value of the matching relation between the structure in technology and flip ship in the product is 0.0168 (see Fig. 5). Fig. 5 represents the result of the calculating matching relation between the shapes in existing technology and product morphology. The highest value, which is shaded on the cell in each dimension, is selected to link each other.

Through interpreting the linking grid, the highest value of shape — flip chip and vertical chip — in the chip type of LED lamp are linked to the combination of LED heat dissipation technology. As a result, 48 (2 × 2 × 1 × 3 × 2 × 2) possible combinations of LED lamp, which can be considered as candidates of technological opportunity in the existing product area, is extracted.

Then, the nine combinations are eliminated among the 48 combinations since the frequency of keywords corresponding with the patents documents, which the company owns, is high. That is, the nine eliminated combinations are considered as the combination of existing product line of the company.

To explore the vacant product combination, the technological feasibility and technological realization rate is measured. The frequency of each shape in nine eliminated combination should be calculated to measure the technological

Table 6
Technological feasibility score.

Dimension	Shape	Technological feasibility score
Chip type	Flip chip	1
	Vertical chip	12
Packaging material	Ceramic	6
	Metal	7
Package type	Lamp type	13
Substrate material	GaAS	4
	SiC	6
	GaN	3
Encapsulant material	Epoxy	10
	Silicone	3
Thermal device	Heat sink	2

Table 7
Technological realization rate.

Dimension	Shape	Realization rate
Chip type	Flip chip	0.0151
	Vertical chip	0.01214
Packaging material	Ceramic	0.06736
	Metal	0.09914
Package type	Lamp type	0.1569
Substrate material	GaAS	0.00564
	SiC	0.01114
	GaN	0.01596
Encapsulant material	Epoxy	0.01792
	Silicone	0.00464
Thermal device	Heat sink	0.06078
	Cooling fins	0.03418

Table 8
Top five combination of technological opportunity.

Rank	Dimension					
	Chip type	Packaging material	Package type	Substrate material	Encapsulant material	Thermal device
1	Vertical chip	Metal	Lamp type	GaAS	Epoxy	Heat sink
2	Vertical chip	Metal	Lamp type	SiC	Epoxy	Cooling fins
3	Vertical chip	Ceramic	Lamp type	SiC	Epoxy	Heat sink
4	Flip chip	Metal	Lamp type	GaN	Epoxy	Cooling fins
5	Vertical chip	Metal	Lamp type	SiC	Silicone	Heat sink

feasibility since the technological shape, which already applied to in the existing product, has high feasibility to be products. Table 6 represents the technological feasibility which is the number of occurrences in the eliminated combinations. For example, the feasibility score of combination, flip chip–Ceramic–lamp type–GaAS–epoxy–heat sink, is 36 (1 + 6 + 13 + 4 + 10 + 2).

The relation rate is calculated by utilizing the matching relation in the linking grid. It is measured to confirm how much of the existing technology is realized in the USPTO database by calculating the average value of the shape. If the realization rate is high, marketability of the technology is high and the possibility that the combination can be a technological opportunity is high. Table 7 is the result of the average of matching relation by shape. For example, the realization rate of combination, flip chip–Ceramic–lamp type–GaAS–epoxy–heat sink, is 0.3237 (0.0151 + 0.06736 + 0.1569 + 0.00564 + 0.01792 + 0.06078). The top five combinations of technological opportunity are like Table 8 after summing up the two indices. Finally, Table 9 represents the technological opportunity (vertical chip–metal–lamp type–GaAs–epoxy–heat sink) in the existing product area.

5.3.2. TOD in applied product area

The first step of the TOD in the applied product area is to download 61 patent documents from the USPTO database using the core keyword of existing technology {spec/(structure or constitution or shape or form) and conduct$ and natural$ and heatsink and epoxy}. Second, the keywords are extracted by text mining using Text Analyzer, which is the text mining software. Then, the 50 applied product keywords are extracted like Table 10 after the screening process based on term frequency, tf-idf, and TEMPEST.

The first type of TOD in the applied product area is that the new shape is added to the existing dimensions in the existing product morphology. When the existing product keywords and applied product keywords are compared, the common keywords — 'chip', 'package' and 'substrate' — are discovered. The two words, which share common keywords, are investigated since Text Analyzer can extract two words. The new applied area can be explored since the two words share the common keyword but have different words. Therefore, the related and possibly applied product area can be discovered by using the two words. The common keyword 'substrate' from the result of two words analysis is selected as a candidate of technological opportunity. The keyword shares the words — 'SI', 'silicon', 'ceramic' and 'aluminum' — with existing product morphology however, the keyword — 'diamond' — does not exist in the existing product morphology. In fact, the technological opportunity can verify indirectly that the diamond substrate is used in the real world.

The second type is that the new dimension and new shape are added to existing morphology. To this end, first, the co-word matrix between the applied product keywords is developed by clustering based on cosine similarity using SPSS, which is a statistical package. Table 11 represents the result of keyword grouping. The keyword groups 3 and 6 are selected as appropriate candidates added to LED lamp morphology by expert's review. From group 6, dimension — 'toner layer material' — and shape — 'fluorocarbon', 'siloxane', 'rubber', 'thermoplastic', and 'resin' — are structured. From group 3, dimension — 'abrasive material' and shape — 'zirconia' and 'graphite' — are structured. The patent related to the dimension — 'toner layer material' — can be supported by the US patent 7,972,759 B2. However, it is supposed that suggesting improvement direction is difficult. In contrast, dimension — 'abrasive material' and shape — 'zirconia' and 'graphite' are largely used in the wafer production process of the semiconductor. It can be a technological opportunity in the applied product area in that the process is able to be applied to the LED production process.

Table 9
Technological opportunity in existing product area.

Dimension	Shape		
Chip type	Non-flip chip	Flip chip	Vertical chip
Packaging material	Plastic	Ceramic	Metal
Package type	Lamp type BLU	SMD type	COB
Substrate material	GaAS Al_2O_3	Si ALN	SiC GaN
Encapsulant material	Epoxy	Silicone	
Thermal device	Heat sink Fan	Thermal via TEC	Cooling fins Heat pipe

Table 10
Typology of applied product keyword.

Category	Applied product keyword
Material	Abrasive, zirconia, graphite, polymer, fiber, polyethylene, siloxane, rubber, methyl, thermoplastic, sodium, amide, vinyl, polyester, plasticizer, fluorocarbon, phenol, titanium, alumina, resin, plasticizer
Structure	Layer
Module	Flywheel, converter, amplifier, generator, attenuator, coupler, detector, engine
Part	Rotor, stator, alternator, FET, flange, pad, wafer, package, pipe, tube, damper, chip, substrate, primer, wire, spreader

Table 11
Keyword group.

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	
Rotor	FET	Abrasive	Pad	Filter	Polyethylene	Plasticizer
Stator	Converter	Zirconia	Wafer	Amplifier	Siloxane	Fluorocarbon
Alternator		Graphite	Package	Generator	Rubber	Phenol
Flywheel			Pipe	Damper	Methyl	Titanium
			Container	Attenuator	Thermoplastic	Alumina
			Tube	Detector	Filler	Resin
			Spreader	Polymer	Sodium	Wire
			Engine	Coupler	Amide	Substrate
				Fiber	Vinyl	Primer
				Layer	Polyester	Toner
				Chip		

Applied Product		Existing Technology				
	Dimension	Optimization	Principle of cooling	Cooling method	Heat management	Type of TIM
Dimension	Shape	structure	Conduction	Natural	Heat sink	Epoxy
Abrasive Material	Graphite	0.0079	0.0859	0.0120	0.0741	0.0011
	Zirconia	0.0000	0.0020	0.0220	0.0074	0.0004

Fig. 6. Linking grid between existing technology and applied product.

The next step is developing a linking grid between the LED lamp and applied product by using matching relation. It is considered that the newly added shape 'diamond' to an existing dimension is a new technological opportunity in the applied product area. The linking grid between the dimensions — 'zirconia' and 'graphite' — of new dimension, 'abrasive material', and LED heat dissipation technology is like Fig. 6. Finally, the combination of technological opportunity in the applied product area is like Table 12. That is, the combination (vertical chip–metal–lamp type–diamond–epoxy–heat sink–zirconia) could be the technological opportunity in the applied product area.

5.3.3. TOD in heterogeneous product area

Technological opportunity discovery in the heterogeneous product area aims to explore the new value by applying the existing technology to the product in other industries. To this end, the Japanese patent is searched by using the core keyword of existing technology which is 'radiation and LED' in worldwide intellectual property services (WIPS), which is a patent searching engine. The reason of searching the Japanese patent is to utilize the multiple dimensional view of the F-term. However, the F-term theme, which is a superordinate concept of F-term, is analyzed from the searched top 100 patents since the F-term is too specific to explore the heterogeneous area. Table 13 represents the code, subject,

Table 12
Technological opportunity in applied product area.

Dimension	Shape		
Chip type	Non-flip chip	Flip chip	Vertical chip
Packaging material	Plastic	Ceramic	Metal
Package type	Lamp type	SMD type	COB
	BLU		
Substrate material	GaAS	Si	SiC
	Al_2O_3	ALN	GaN
	Diamond (added)		
Encapsulant material	Epoxy	Silicone	
Thermal device	Heat sink	Thermal via	Cooling fins
	Fan	TEC	Heat pipe
Abrasive material (added)	Zirconia	Graphite	

Table 13
F-term theme list.

F-term theme code	Subject of theme	Frequency
3K014	Arrangement of elements, cooling, sealing, or the like of lighting devices	59
3K243	Non-portable lighting devices or systems thereof	59
5F041	Light emitting diodes	55
3K013	Fastening of light sources or lamp holders	28
2H191	Liquid crystal 4 (combination with optical members)	7
5F136	Cooling or the like of semiconductors or solid state devices	6
2H189	Liquid crystals 2 (structures in general, spacers, inlets or sealing materials)	4
5F141	LED devices (except package)	4
5E322	Cooling or the like of electrical apparatus	3
2H053	Stroboscope apparatuses	2
2B022	Cultivation of plants	1
2G051	Investigating materials by the use of optical means adapted for particular applications	1
2H038	Light guides in general and applications therefor	1
3K011	Securing globes, refractors, reflectors, or the like	1
4D075	Application of or painting with fluid materials	1
4F042	Coating apparatus 3 (general or others)	1
5C122	Studio devices	1
5E023	Multipolar connectors	1
5E024	Connecting device with holders (device in general)	1
5E338	Structure of printed boards	1
5F047	Die bonding	1

◆ Morphology of Semiconductor

Dimension	Shape		
Lead-frame material	Cu	Alloy	
Die attach	Adhesive	Eutectic	
Wire bonding	Wedge bond	Ball bond	
Package substrate	rigid	Tape	
Thermal device	Heat sink	Fan	Heat pipe

◆ Morphology of Connector

Dimension	Shape			
Connection type	Electric wire - Substrate	Electric wire – Electric wire	Substrate – Substrate	
Connection terminal	Unipole (female)	Unipole (male)	Multipole (female)	Multipole (male)
Raw material – Plating	Au	Sn	Non-mold	Ni
Direction	Right angle	Perpendicular	Level	

◆ Morphology of TFT-LCD

Dimension		Shape		
TFT- LCD Panel	CF substrate			
	LCD	Nematic	Smetic	Cholesteric
		Discotic	PDLC	
	TFT substrate			
Driving circuit unit	LCD driver IC			
	Multi-layer PCB			
	Driving circuits			
Backlight & Chassis	Backlight unit	CCFL		
	Chassis assembly			

Fig. 7. Morphologies of heterogeneous products.

and frequency of the F-term theme. The shaded rows are the selected subjects after reviewing. The result is that the semiconductor, connector, and liquid crystal are the candidates of the technological opportunity in the heterogeneous product area.

Each of product morphology in the heterogeneous area is like Fig. 7 and is developed by the suggested method in this research. A liquid crystal is matter in a state that has properties between those of conventional liquid and those of solid crystal. Therefore, the morphology of thin film transistor liquid crystal display (TFT-LCD) is developed to build the product form of liquid crystal.

Three types of technological opportunity in the heterogeneous product area are extracted by comparing between the morphologies of the LED lamp and each heterogeneous product (see Fig. 8). To compare the morphologies, dimension named the thermal device is classified as a main technological function, which is related to LED heat dissipation technology,

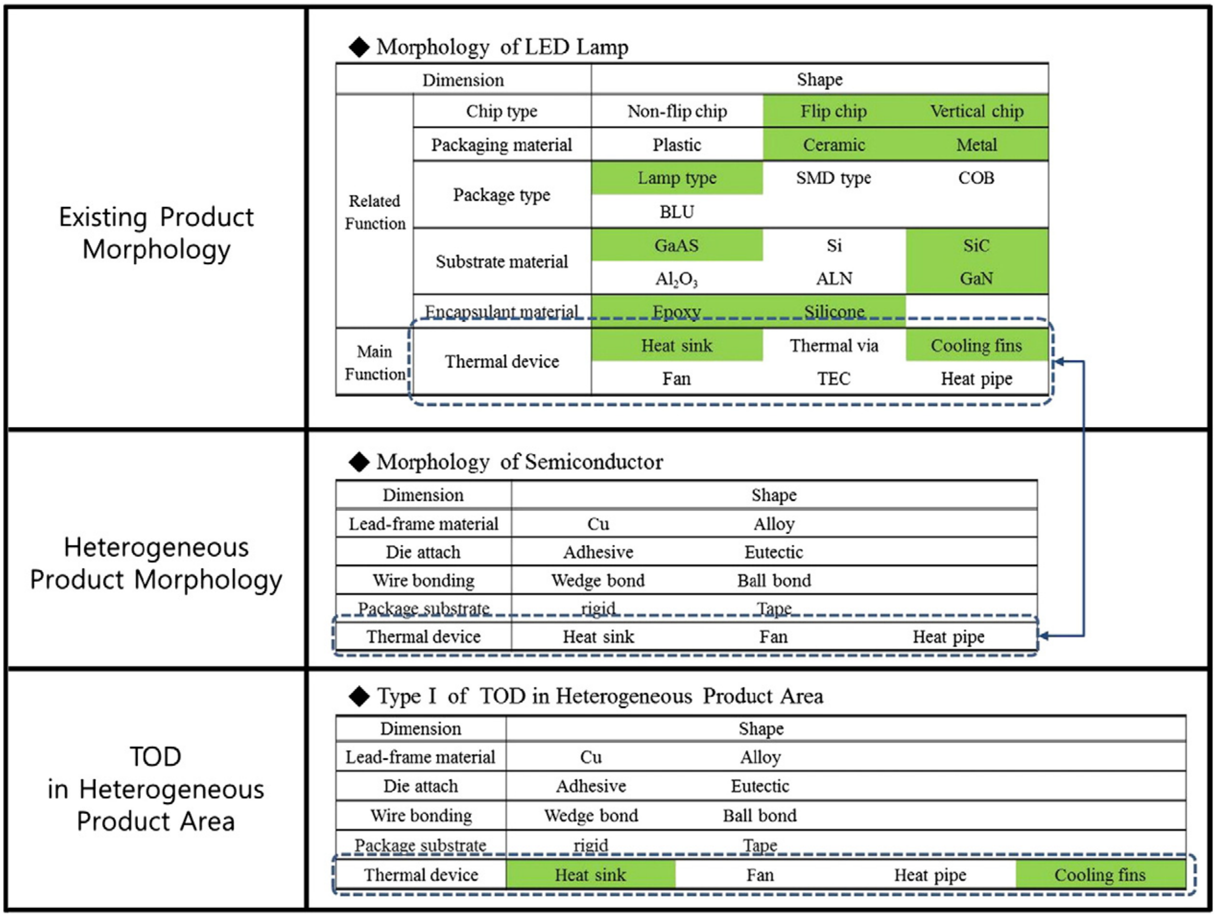

Fig. 8. Type I of TOD in heterogeneous product area.

and the rest of the dimensions are classified as related technological function. First, technology opportunity is discovered by substituting for dimension or shape of heterogeneous product morphology when both existing and heterogeneous product morphologies have identical dimensions. For example, when the morphologies of the LED lamp and semiconductor have identical dimensions which represent the main technological function like Fig. 8, the heat sink of the LED lamp could substitute for the heat sink of the semiconductor. Furthermore, cooling fins of LED lamp could be added to the morphology of semiconductor since the morphology of semiconductor does not have the cooling fins currently.

Second, technology opportunity is discovered by adding a dimension of existing product morphology, which represents the main technological function, to heterogeneous product morphology when the both existing and heterogeneous product morphologies do not have identical dimensions. For example, when the morphologies of LED lamp and the connector do not have identical dimensions like Fig. 9, the thermal device of the LED lamp could be added to the morphology of the connector as a new dimension. The new technological opportunity can be identified by adding the heat dissipation function to the connector. In fact, Korean patent 101052703, "Distributor device for use in communication and data system technology" suggests an invention which consists of a connector, heat sink, and other parts.

Third, technology opportunity is discovered by adding a dimension of the existing product morphology, which represents the related technical function, to heterogeneous product morphology when both existing and heterogeneous product morphologies do not have identical dimensions. For example, the morphologies of the LED lamp and TFT-LCD do not have identical dimensions like Fig. 10. It is investigated that the backlight unit (BLU) works as a light source in the morphology of TFT-LCD. Although the existing technology is LED heat dissipation technology, LED lamp also has a function of light source. In other words, BLU of TFT-LCD has a possibility to be substituted by the light source of LED lamp. Thus, the new technological opportunity can be identified when the dimensions that work as a light source, which is a related technological function in LED lamp, substitute for the BLU. In fact, the widely used light source as a BLU is cold cathode fluorescence lamp (CCFL). However, the use of LED as a BLU is on an increasing trend for substituting CCFL since CCFL includes noxious matter such as mercury [47]. The third type of TOD in the heterogeneous product area requires actively exploring the related technological function of

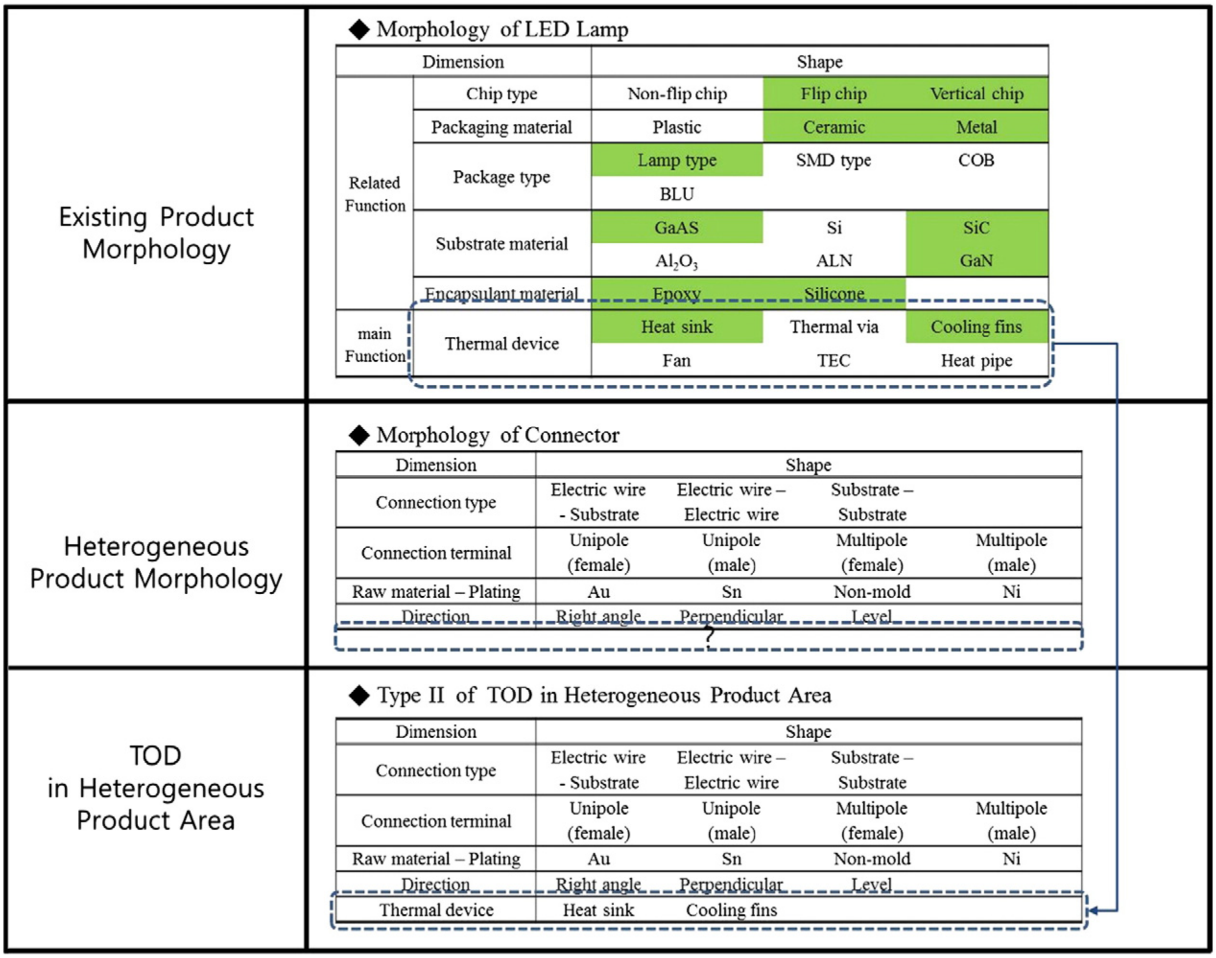

Fig. 9. Type II of TOD in heterogeneous product area.

existing technology and exploring the applicability to the heterogeneous product by expert's participation.

6. Conclusions

Patent information, text mining, and morphology analysis are used for discovering the technological opportunity in this research. First, the patent information is the proper quantitative information since it is open and has huge volume. Second, text mining is utilized to extract keywords related to technology and product. Third, the morphology analysis extracts the specific morphology of the technology and product, and technological opportunity is explored based on the relation analysis between two morphologies.

Technological opportunity is classified into three types. The technological opportunity in the existing product is the most incremental technological change. The technological opportunity in the heterogeneous product is the most radical technological change. The technological opportunity in the applied product is the medium level of technological change. It is considered as an extension of the existing product. This research suggests the TOD process by the types of technological opportunity.

Most of the technological opportunity discovery (TOD) process is conducted by the experience of experts who have expertise in a specific technological field in the past. However, technology recently is analyzed by an automatic algorithm, statistical method, and data mining based on quantitative information. The result of the process can support the technology policy maker and the parties of product planning or development. The opportunity, which cannot be extracted by experience or expertise of humans, can be suggested by analyzing large amounts of data through an intelligent process.

The suggested method can be utilized for small and medium enterprise (SME) to plan technology and product strategy since the method in the research is to explore the technological opportunity based on the existing technology rather than the opportunity of a new product and market by developing new technology. The suggested process can be utilized by the parties in the department of technology and product strategy planning in SME since the TOD based on existing technology has a lower risk and higher possibility of

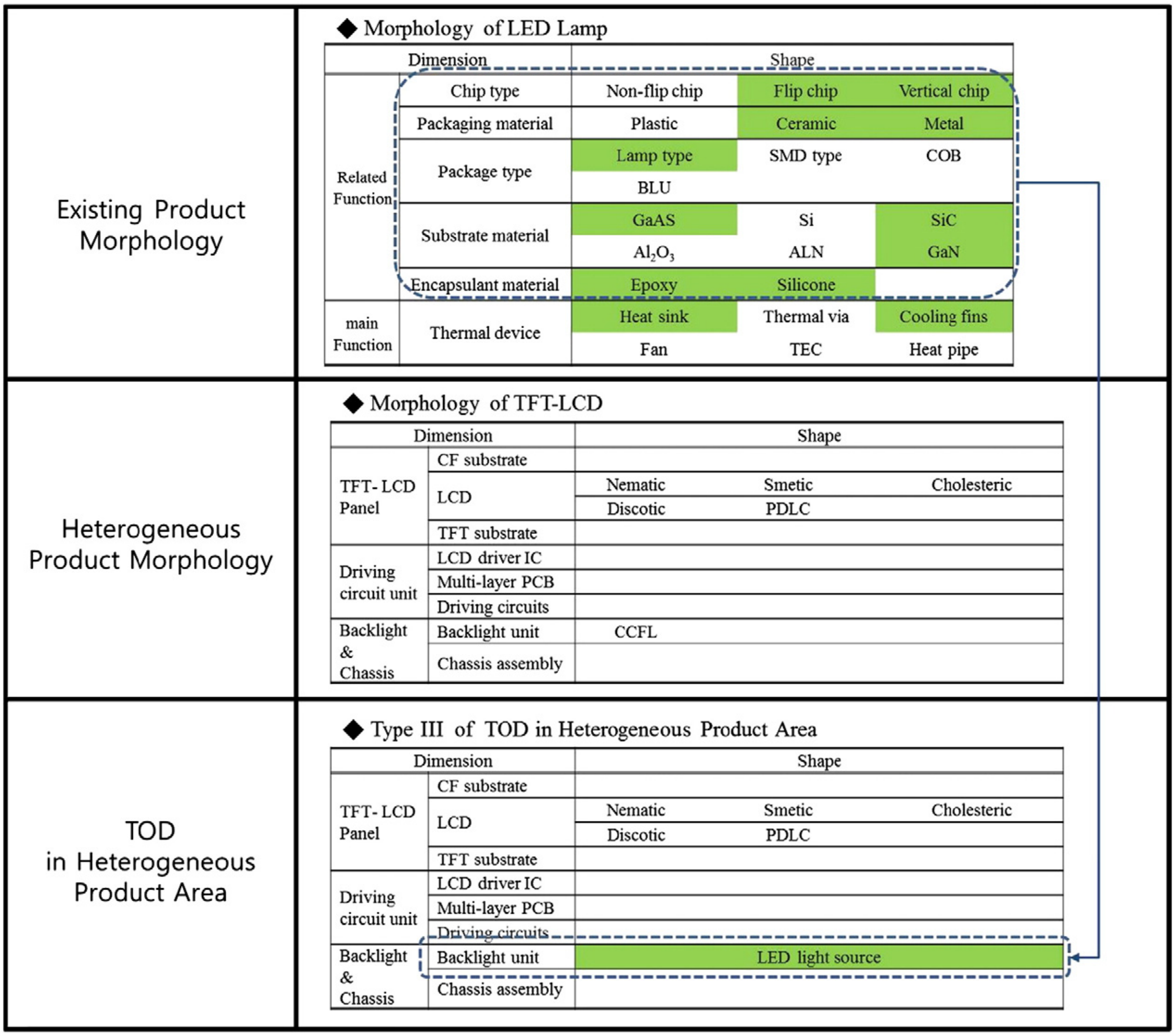

Fig. 10. Type III of TOD in heterogeneous product area.

achieving success rather than new technology development which requires a huge amount of cost and effort.

Since the purpose of this research is to design the process that TOD based on existing technology can be conducted quantitatively and systematically, quantitative information and a quantitative method are used. However, there are some limitations. First, the tool such as term frequency and tf-idf is utilized in the process of keyword extraction from the patent documents. If the dictionary, which defines terms and concepts regarding the pertinent technology field, exists, keyword selection could be more accurate and easy. Second, even though keywords are utilized in the morphology development process, the expert's participation is inevitable. Therefore, the evincive standard, which distinguishes the quantitative and qualitative method, should be devised. Third, the index of association based on keyword searching is used in the linking process between two morphologies in this research. The method which considers the functions and features of each shape should be devised.

Overall, the suggested process involves quite complicated steps and many steps which incorporate humans. Thus, in future research, a simple process and system, which overcomes the stated above technical limitation and reduces the participation of humans in the process, should be developed. Furthermore, the model requires validation through conducting many case studies.

Acknowledgments

This work was partially supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2012R1A1A1011934).

References

[1] A.K. Klevorick, R.C. Levin, R.R. Nelson, S.G. Winter, On the sources and significance of interindustry differences in technological opportunities, Res. Policy 24 (1995) 185–205.

[2] O. Olsson, Technological opportunity and growth, J. Econ. Growth 10 (2005) 35–57.
[3] R.R. Nelson, S.G. Winter, An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge, MA, 1982.
[4] W.M. Cohen, Empirical studies of innovative activity, Handbook of the Economics of Innovation and Technological Change, Basil Blackwell, Oxford, 1995. 182–264.
[5] A.J. Singh, M.L. Kasavana, The impact of information technology on future management of lodging operations: a Delphi study to predict key technological events in 2007 and 2027, Tour. Hosp. Res. 6 (1) (2005) 24–37.
[6] R. Rohrbeck, J. Heuer, H. Arnold, Technology radar—an instrument of technology intelligence and innovation strategy, Proceedings of IEEE International Conference on Management of Innovation and Technology. Singapore, 2006, pp. 978–983.
[7] B. Yoon, Y. Park, A systematic approach for identifying technology opportunities: keyword-based morphology analysis, Technol. Forecast. Soc. Chang. 72 (2) (2005) 145–160.
[8] T.U. Daim, G. Rueda, H. Martin, P. Gerdsri, Forecasting emerging technologies: use of bibliometrics and patent analysis, Technol. Forecast. Soc. Chang. 73 (8) (2006) 981–1012.
[9] C.I.V. Kerr, L. Mortara, D.R. Probert, A conceptual model for technology intelligence, Int. J. Technol. Intell. Plan. 2 (1) (2006) 73–93.
[10] M.K. Fung, Technological opportunity and productivity of R&D activities, J. Prod. Anal. 21 (2) (2004) 167–181.
[11] S. Shane, Technological opportunities and new firm creation, Manag. Sci. 47 (2) (2001) 205–220.
[12] D.B. Audretsch, M. Vivarelli, Firm size and R&D spillovers: evidence from Italy, Small Bus. Econ. 8 (3) (1996) 249–258.
[13] A. Kleinknecht, J.O.N. Reijnen, Why do firms co-operate on R&D? an empirical study, Res. Policy 21 (4) (1992) 347–360.
[14] P. Savioz, M. Blum, Strategic forecast tool for SMEs: how the opportunity landscape interacts with business strategy to anticipate technological trends, Technovation 22 (2) (2002) 91–100.
[15] B. Yoon, Y. Park, A text-mining-based patent network: analytical tool for high-technology trend, J. High Technol. Manag. Res. 15 (1) (2004) 37–50.
[16] A.L. Porter, M.J. Detampel, Technology opportunities analysis, Technol. Forecast. Soc. Chang. 49 (3) (1995) 237–255.
[17] D. Zhu, A.L. Porter, Automated extraction and visualization of information for technological intelligence and forecasting, Tech. Forecast. Soc. Change 69 (5) (2002) 495–506.
[18] B. Yoon, On the development of a technology intelligence tool for identifying technology opportunity, Expert Syst. Appl. 35 (1–2) (2008) 124–135.
[19] S. Lee, S. Lee, H. Seol, Y. Park, Using patent information for designing new product and technology: keyword based technology road-mapping, R&D Manag. 38 (2) (2008) 169–188.
[20] K. OuYang, C.S. Weng, A new comprehensive patent analysis approach for new product design in mechanical engineering, Technol. Forecast. Soc. Chang. 78 (7) (2011) 1183–1199.
[21] R. Feldman, H. Hirsh, Exploiting background information in knowledge discovery from text, J. Intell. Inf. Syst. 9 (1) (1997) 83–97.
[22] Y. Dai, T. Kakkonen, E. Sutinen, MinEDec: a decision-support model that combines text-mining technologies with two competitive intelligence analysis methods, Int. J. Comput. Inf. Syst. Ind. Manag. Appl. 3 (2011) 165–173.
[23] S. Godbole, S. Roy, Text to intelligence: building and deploying a text mining solution in the services industry for customer satisfaction analysis, IEEE Int. Conf. Serv. Comput. 2 (2008) 441–448.
[24] A.L. Porter, A. Kongthon, J.C. Lu, Research profiling: improving the literature review, Scientometrics 53 (3) (2002) 351–370.
[25] R.J. Watts, A.L. Porter, Innovation forecasting, Technol. Forecast. Soc. Chang. 56 (1) (1997) 25–47.
[26] B. Yoon, C. Yoon, Y. Park, On the development and application of a self-organizing feature map-based patent map, R&D Manag. 32 (4) (2002) 291–300.
[27] R.N. Kostoff, R. Boylan, G.R. Simons, Disruptive technology roadmaps, Technol. Forecast. Soc. Chang. 71 (1) (2004) 141–159.
[28] R.N. Kostoff, R.R. Schaller, Science and technology roadmaps, IEEE Trans. Eng. Manag. 48 (2) (2001) 132–143.
[29] N. Gerdsri, A. Kongthon, S. Puengrusme, Discovering the professional communities and social networks of emerging research area: use of technology intelligence from bibliometric and text mining analysis, Proceedings of PICMET'12: Technology Management for Emerging Technologies, Institute of Electrical and Electronics Engineers, Vancouver, 2012, pp. 114–121.
[30] J.G. Wissema, Morphological analysis: its application to a company TF investigation, Futures 8 (2) (1976) 146–153.
[31] M. Pidd, Tools for Thinking—Modeling in Management Science, Wiley, London, 1996.
[32] F. Zwicky, Discovery, Invention, Research — Through the Morphological Approach, Macmillan Company, Toronto, 1969.
[33] D. Silin, T. Patzek, Pore space morphology analysis using maximal inscribed spheres, Physica A 371 (2) (2006) 336–360.
[34] M. Huckvale, A.C. Fang, Using phonologically-constrained morphological analysis in continuous speech recognition, Comput. Speech Lang. 16 (2002) 165–181.
[35] B. Yoon, R. Phaal, D. Probert, Morphology analysis for technology road-mapping: application of text mining, R&D Manag. 38 (1) (2008) 51–68.
[36] T. Ritchey, Using morphological analysis to evaluate preparedness for accidents involving hazardous materials, Proceedings of the Fourth International Conference for Local Authorities, Shanghai, China, 2002.
[37] C. Kim, S. Choe, C. Choi, Y. Park, A systematic approach to new mobile service creation, Expert Syst. Appl. 35 (3) (2008) 762–771.
[38] C. Lee, B. Song, Y. Park, Generation of new service concepts: a morphology analysis and genetic algorithm approach, Expert Syst. Appl. 36 (10) (2009) 12454–12460.
[39] E. Ostertagová, J. Kováč, O. Ostertag, P. Malega, Application of morphological analysis in the design of production systems, Procedia Eng. 48 (2012) 507–512.
[40] K. Im, H. Cho, A systematic approach for developing a new business model using morphological analysis and integrated fuzzy approach, Expert Syst. Appl. 40 (11) (2013) 4463–4477.
[41] R.G. Coyle, Y.C. Yong, A scenario projection for the South China Sea: further experience with field anomaly relaxation, Futures 28 (3) (1995) 269–283.
[42] R. Rhyne, Field anomaly relaxation: the arts of usage, Futures 27 (6) (1995) 657–675.
[43] I. Schellner, Japanese File Index classification and F-terms, World Patent Inf. 24 (3) (2002) 197–201.
[44] S. Iwasaki, IPC and other classification systems: Japanese classification system (FI, F-terms) and quality of reclassification, International Patent Classification (IPC) Workshop, Geneva, Switzerland, 2008.
[45] B. Coh, Technology Analysis and Patent Information Analysis, Korean Intellectual Property Office, 2002.
[46] C.D. Manning, P. Raghavan, H. Schütze, Introduction to Information Retrieval, Cambridge University Press, 2008.
[47] BIR Research Group, 2012's Trends and Technology Development Strategy in New Growth Engines of the Equipment Industry — Display, LED Equipment Industry Fields, BIR, 2012.

Byungun Yoon is an Associate Professor in Department of Industrial & Systems Engineering of Dongguk University. His work experience includes an IT consultant in LG and a visiting scholar in the Centre for Technology Management (CTM) of the University of Cambridge. His theme of study has involved patent analysis, new technology development methodology and visualization algorithms. His current interest is in enhancing technology roadmapping and product designing with data mining techniques. He has authored articles published in Research Policy, R&D Management, Technological Forecasting and Social Change, Technology Analysis & Strategic Management, among others.

Inchae Park is currently a PhD candidate in Department of Industrial & Systems Engineering of the Dongguk University. His theme of study has involved technology forecasting, data mining and patent analysis.

Byoung-youl Coh is a researcher of the Korea Institute of Science and Technology Information. He has PhD degree from Seoul National University. His theme of study has involved technology intelligence, scientometrics and R&D selection.