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Abstract

Purpose – The purpose of this paper is to provide a framework for understanding core technological competencies and identifying the trends on the technological convergence of a business ecosystem using the patent information of leading firms in the system.

Design/methodology/approach – The proposed framework is composed of two steps: time-sequential text clustering analysis for comprehending changes in general technological fields and association rule analysis for identifying the trends of convergences in each field. The authors applied the proposed framework to the patents applied to United States Patent Trademark Office by Samsung Electronics, a market leader of the electronics industry, during the period from 2000 to 2011.

Findings – In the sequential text clustering analysis, trends of 14 technological fields such as data storage medium and data processing, mobile, lights and heats and memory are identified. Moreover, changes of technological convergence in each field are identified using association rule analysis. For instance, in the case of technologies related to lights and heats, convergences occurred between radio transmission systems and modulated-carrier systems during the period from 2000 to 2001. However, recent convergences appeared between technologies regarding controlling lights and liquid crystal materials since 2008.

Originality/value – Utilization of the framework will suggest new business opportunities to SMEs in a business ecosystem by identifying the trends of technological convergences.

Keywords Business ecosystem, Technological convergence trend

Paper type Research paper

1. Introduction

Recently, leading firms in various markets have constructed business ecosystems as a strategy by creating platforms for services, products or technologies due to the diverse benefits (Lansiti and Levien, 2004; Li, 2009). A business ecosystem is an economic group which involves various stakeholders which are co-related to each other (Moore, 1996). In the ecosystem, SMEs are influenced by various factors of the ecosystem including technological change. Technological change enhances the competitiveness of a firm (Porter, 1985). Moreover, technological capability is a significant factor for industrial and international competitive power (Pretorius and de Wet, 2000; Chen *et al.*, 2007). In this context, understanding the technological trends of business ecosystems is important for SMEs. It can enhance the competitiveness of an enterprise (Jun *et al.*, 2012).

An important issue of SMEs that need efficient utilization of their capacities for their R&D activities due to a lack of resources is how to identify and understand technological trends in terms of convergence in the business ecosystem. First, a technological convergence can create new industries (Karvonen and Kässi, 2011), and this emergence may enhance the capability of business diversification based on the

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new converged technologies. Second, according to Gambardella and Torrisi (1998), business diversification is positively associated with a firm's performance; thus, comprehending technological convergence is beneficial to enhance a firm's performance. For these reasons, technological convergence provides a guideline for choosing significant emerging technologies which can be considered as the main area for R&D activities (Patalinghug, 1999). In order to understand the trend of technological convergence in a business ecosystem, one method is to analyze the patent information of leading firms which is in the center of an ecosystem.

Because identifying and understanding the technological trends of a market become significant, many studies have investigated those trends with patent information such as citation relationships (Gupta and Pangannaya, 2000; Von Wartburg *et al.*, 2005; Gress, 2010; Li *et al.*, 2011), abstracts (Yoon *et al.*, 2011; Jun and Park, 2013) and the Derwent World Patents Index (Wilson, 1987; Canongia *et al.*, 2004). However, studies on technological convergence trends with patents have not focussed on those issues in a business ecosystem.

The goal of this paper is to provide a framework for understanding core technological competencies and identifying the trends on the technological convergence of a business ecosystem using the patent information of leading firms in the system through text mining and association rule analysis with keywords from the text information and international patent classification (IPC) code of patents for SMEs in the ecosystem. The results of study are expected to help SMEs with following technological trends to survive in business ecosystems and markets, and to find appropriate opportunities for new businesses.

The organization of this paper is as follows. In Section 2, we review the literature related to technological convergence and discuss the need for understanding technological convergence trends of leading firms which are a representative of a business ecosystem for SMEs in Section 3. In Section 4, we review the related literature regarding text clustering analysis and association rule analysis. Then, an overall demonstration of the proposed framework is given in Section 4. Next, we identify technological convergence trends with the proposed framework in Section 5. Finally, in Section 6, we conclude the study and discuss future challenges.

2. Technological convergence

Technological convergence or technical convergence is defined as the process where two different industrial sectors become sharing a common knowledge and technological base (Athreye and Keeble, 2000). Moreover, recent innovation trends which are merging and overlapping of technologies are considered as technological convergence (Mowery *et al.*, 1998; Borés *et al.*, 2003; Geum *et al.*, 2012). Technological convergence appears when two or more distinguishable technologies combine (Schnaars *et al.*, 2008). This process, technological convergence, features intense dynamics and it provides various ways to create new competitive opportunities where different variables become significant (Nicita *et al.*, 2005).

The technological convergence redefines the boundaries of existing industries (Athreye and Keeble, 2000) and it creates new products or entire industries (Schnaars *et al.*, 2008; Karvonen and Kässi, 2011). In addition, the influence of technological convergence is not only related to creating specific industrial sectors but also related to emerging of the dominance of particular "generic" technologies (Athreye and Keeble, 2000). As a result, the technological convergence causes a complicated situation for firms (Von Tunzelmann, 1995). This phenomenon cannot only be a new opportunity to

companies which are ready for changes caused by technological convergences but also be big problems to others that are not prepared for the technological convergences. Technological convergences let companies which are not ready for changes encounter problems of technological access and of market access (Athreye and Keeble, 2000). This problem can be quite critical to survival of those companies, especially SMEs which are not with plentiful resources. Therefore, the comprehension of trends of technological convergences is highly important to SMEs.

In order to comprehend the technological convergence, many researchers have utilized patent information. These researchers mainly focussed on the technological convergence in relationships among technologies using patent citations and co-classification with USPC. Sung *et al.* (2010) proposed the measurement of technological convergence with the numbers of backward and forward citations of patents. Karvonen and Kässi (2011) tried to comprehend the technological convergences among specific fields involved in RFID technologies by key players in the value chains of RFID industries. Geum *et al.* (2012) investigated two levels of technological convergences of information technology and biotechnology. First, researchers conducted patent citation analysis to comprehend technological convergences among categorized technology fields by them and they selected converging technology fields. Second, they performed patent co-classification analysis to identify the relationships between technologies with USPC and they chose significant convergences with the increasing amount of convergence intensify.

3. Technological convergence trends of a business ecosystem for SMEs

In this section, we discuss the significance of understanding the technological convergence trends of a business ecosystem for SMEs which are components of the system.

The concept of a business ecosystem was proposed by Moore (1996). The business ecosystem is defined as "an economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world" (Moore, 1996, p. 9). According to Moore (1996), the system contains various stakeholders including customers, competitors and others.

Business ecosystems are constructed by leading firms by creating platforms for services, tools or technologies – and other stakeholders can use those platforms to maximize their profits (Lansiti and Levien, 2004). According to the structure of the business ecosystems, the leaders of the business ecosystems are more likely to be large companies which can afford the expenses for constructing an ecosystem. Most of the SMEs are the following members of the business ecosystems. In business ecosystems, leading companies, usually large firms, can enhance their efficiencies of their managerial issues by providing platforms (Lansiti and Levien, 2004) and other members, usually SMEs, can be nurtured in a business ecosystem (Kanter, 2012) within the platforms.

In a business ecosystem, the most significant component is the leadership of companies which lead the ecosystem (Moore, 1996; Lansiti and Levien, 2004) because those leading companies in business ecosystems have strong influences on overall processes (Moore, 1996). Leading firms can exert their influence on other members in the ecosystem through their platforms. In this context, leading firms' technological convergence trends can affect whole components which includes SMEs in the ecosystem. Therefore, SMEs must be able to identify and understand the technological convergence trends of leading firms and should prepare for changes caused by leading firms in the ecosystem.

4. Methods

In this section, we introduce the flow of the analysis which consists of three parts: selection of the patent data, text clustering and association rule analyses. First, the proposed framework, leading firms' patent information, is extracted from a patent database based on the application dates of the patents, and the extracted patent information is divided into several data sets by unit period. Next, text clustering analysis is time-sequentially applied to the titles of patents over an individual periodical data set to find the trends in the technological fields of leading firms, which have notable effects on the ecosystem, at the product level. In this part, leading firms' capabilities, the product portfolio of a company, are shown in terms of their products by text clustering analysis, and the trend of each product can be understood. Moreover, interesting patterns can be identified based on this analysis. Lastly, technological convergence trends in the identified technological fields of interest in the products are investigated by association rule analysis in order to understand them. The overall analysis process is shown in Figure 1.

4.1 Selection of patent data

In order to analyze the tendencies of general technological fields in an ecosystem, the patent information of leading firms is utilized, and the analyzed trends of leading firms represent the trends of a business ecosystem. Moreover, general technological trends of a business ecosystem are represented as the trends of leading firms' core competencies. The patent information of leading firms can be obtained from a patent database.

The extracted patent information is divided into several data sets depending on the periods to obtain the time-sequential results from the analysis. In the patent information, titles and IPC codes of the patents are used in the text clustering analysis and association rule analysis, respectively. Patent information is selected based on the application dates of the patents from a database. There are two reasons for gathering patent information with application dates. First, there is a shorter time lag between R&D activities and application dates than a time difference between R&D activities and registration dates. Therefore, application dates are more likely to reflect the timing of concentration of a company's technological competence. Second, the number of selected patents based on application dates reflects the amount of investment in focussed technologies more than the number of registered patents because some patents are rejected in the process of patent registration. Moreover, we consider all statuses of applied patents such as alive, expired, reissued, terminated and withdrawn patents because we want to reflect the maximum amounts of a company's investment in those technological trends.

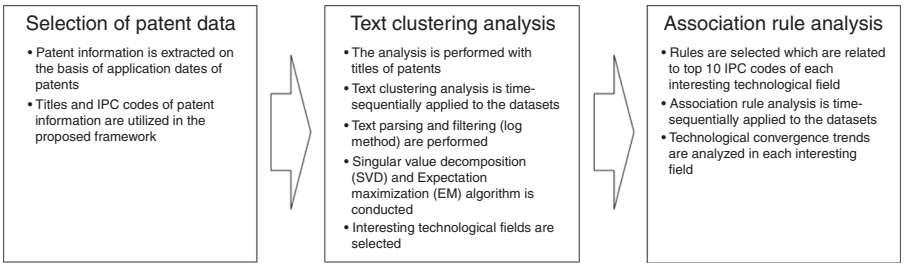

Figure 1.
Framework to find a firm's trends of general technological fields and technological convergences

4.2 Text clustering analysis

Text clustering analysis is a text mining method to group similar documents together based on terms in documents. Text clustering analysis has been applied to various fields (Zamir *et al.*, 1997; Koller and Sahami, 1997). In this study, text clustering analysis has the role to identify and understand the trends of technological fields of leading firms at the product level. The technological capabilities of leading firms are expressed as the products of the firm; thus, stakeholders can comprehend the trends easier. Moreover, technological trends at the product level can be a middle stage for understanding the specific trends of each product. Text clustering analysis is conducted with the titles of patents for each data set which is divided into several periods because titles have proper information that represent technological fields at the product level. There are two reasons for choosing text clustering analysis with patents' titles instead of using IPC codes, the claims or the abstracts of patents for the text clustering analysis.

First, an IPC code has difficulty describing leading firms' technological fields at the product level. A patent has several IPC codes, and a combination of several IPC codes is possible to express different technological fields. For example, two patents, which are US7907391 and US7130188, have the same combination of IPC codes which are H05K-005/00 and H05K-007/00. H05K-005/00 is a classification for casings, cabinets or drawers for electric apparatuses, and H05K007/00 is a code for constructional details common to different types of electric apparatuses. However, the two patents belong to different technological fields. The first patent, US7907391, is for a display device having a detachable base part, and the second patent, US7130188, is for a locking apparatus and method between a portable terminal and a cradle for the terminal. Second, although the abstracts and the claims of patents contain more information than that of the titles, abstracts and claims are not adequate to classify the leading firms' technological fields at the product level, and the titles of patents are more proper to achieve our objectives. In this study, text clustering analysis is used to comprehend general technological capabilities (or technological areas) of leading companies before the detailed analysis for finding technological convergences through the association rule analysis with IPC codes. Titles of patents which do not contain specific contents of patents are appropriate to achieve our goal. On the other hand, the function of abstracts is focussed on explaining the structures or principles of a technology briefly and the function of claims is concentrated on specific explanations of a patent's ranges of rights (Wu *et al.*, 2010); thus, abstracts and claims contain specific words which are not used to express general technological capabilities (or areas). Therefore, we choose titles to conduct the clustering analysis because of the two reasons stated above.

In the first phase of text clustering analysis, text parsing and filtering reduce the number of terms and find the important expressions. In the text parsing process, only nouns and noun groups are parsed in order to acquire obvious technological fields. After that, in order to eliminate insignificant terms, we used the log method to dampen terms which appear in abstracts frequently and used the entropy method, which has good performance in general (Forman, 2003), to reduce the influence of terms which occur repeatedly in all documents. Through these processes, a weighted term-by-document matrix with n (number of documents) rows and p (number of terms) columns is created.

Next, singular value decomposition (SVD) is conducted to reduce the dimension of weighed term-by-document matrix because the matrix from the text parsing and text filtering process has a high dimension with n (number of documents) rows and p (number of terms) columns. In this procedure, we set the maximum SVD dimension as

25 which is adequate to conduct clustering analysis (Sanders and Devault, 2004). With the SVD matrix, text clustering analysis is performed. Expectation-Maximization (EM) algorithm, which performs better, is chosen for the text clustering (Abbas, 2008). In the EM algorithm, we use 20 as the maximum number of clusters.

Through clustering analysis, we can obtain several clusters which are composed of similarly classified patents, and each cluster has representative keywords which signify a technological field of that cluster. If a user specifies to show "m" descriptive terms for each cluster, then the top $2 \times m$ most frequently appearing terms in each cluster are utilized to conclude the descriptive terms. For each $2 \times m$ terms, a binomial probability for each cluster is calculated. Consequently, the "m" descriptive terms are shown based on the descending order of binomial probabilities. A technological field of each cluster is specified based on representative keywords of each cluster, and those clusters have proportions which represent the number of patents included in a cluster. In this part, we assume that those technological fields are promoted technological areas of a leading company in each period; thus, a proportion of each cluster represents an amount of concentration of R&D capabilities. Moreover, those proportions are analyzed time sequentially by each cluster, and the result of this analysis gives us the trends of the focussed technological fields. Within the time series analysis, we can find interesting technological fields of a leading company. If a remarkable technological field is specified, we make several data sets of a specific technological field based on the periods.

4.3 Association rule analysis

In the third phase, association rule analysis is conducted. The goal of this analysis is to find technological convergences in selected interesting technological fields from the text clustering analysis. We investigated those convergences among technological areas represented by IPC codes. Moreover, the reason for using IPC codes instead of USPC codes in the association rule analysis is that researchers are able to manipulate the level of technological convergence with IPC codes more specifically depending on their purposes. An USPC code comprises two levels of classifications which are class and subclass thus; researchers only can comprehend two levels of technological convergences with USPC codes. However, an IPC code is composed of five levels of classification. Therefore, it is more suitable to comprehend various levels of technological convergences with IPC codes and researchers can find more valuable results with IPC codes depending on researcher's goals.

The association rule analysis was proposed by Agrawal *et al.* (1993) to find purchasing patterns which are represented as relationships among buying products in a supermarket. There are various studies which used association rule analysis to find relationships among several events (Ahn *et al.*, 2003; Buddhakulsomsiri *et al.*, 2006; Buddhakulsomsiri and Zakarian, 2009; Na and Sohn, 2011). In the association rule analysis, relevant rules which satisfy some constraints including lift, support and confidence were selected (Agrawal and Srikant, 1994; Lin and Lee, 2004; Buddhakulsomsiri *et al.*, 2006; Na and Sohn, 2011).

Let $T = (T_1, T_2, \ldots, T_m)$ is a set of transactions and T_k is a kth transaction. In this study, a transaction is a patent. Moreover, let $I = (I_1, I_2, \ldots, I_n)$ is a set of items which are IPC codes and each transaction (patent) T_k contains one or more items (IPC codes). Based on these assumptions, association rule analysis finds some sets of items (IPC codes) in transactions (patents) which satisfy some criteria (confidence, support and lift). The resulting conditional relationships become rules in the analysis.

Confidence of rule $I_i \rightarrow I_j$ is a concept of conditional probability which is measured by the proportion of transactions containing I_i also containing I_j (Lin *et al.*, 2002):

$$Confidence\ (I_i \rightarrow I_j) = \frac{P(I_i \cap I_j)}{P(I_i)}.$$

Support of rule $I_i \rightarrow I_j$ is the proportion of the transactions that involve all items both in I_i and I_j (Lin *et al.*, 2002):

$$Support(I_i \rightarrow I_j) = P(I_i \cup I_j).$$

Lift is a proposed concept to modify a limitation of decision-making procedure for selecting meaningful rules with only two measures, confidence and support (Lin *et al.*, 2002). If a proportion of one item is large and a rule contains that item with high levels of support and confidence values, proposed rules are not meaningful because those rules are so trivial. In order to discover significant rules, lift is proposed as follows:

$$Lift\ (I_i \rightarrow I_j) = \frac{P(I_i \cap I_j)}{P(I_i)P(I_j)} = \frac{confidence\ (I_i \rightarrow I_j)}{support\ (I_j)}.$$

A specific application of association rule analysis in this study is as follows. First, IPC codes are extracted from patent data sets which are selected as interesting technological fields from the results of the text clustering analysis. Second, the top 10 IPC codes based on the number of patents are investigated for each technological field of interest. Next, the classification level of the IPC code is reduced to medium level because the full IPC code presents too specific technological fields and causes difficulties in making rules for technological convergence. Lastly, for each interesting field, only rules related to the top 10 IPC codes are selected among the rules derived from the association rule analysis in order to investigate convergences which start from the main technologies of a market leader. Moreover, those selected rules are investigated time sequentially to represent the convergence trends of a market leader.

Through these three stages in the framework, SMEs can realize not only the changes of leading firms' core competencies but also identify interesting technological fields which can be related to their potential profits. Moreover, SMEs are able to find convergence trends which are beneficial to their business.

5. Analysis

5.1 Selection of patent data

In this study, we applied the proposed framework to the data resource, in particular, the patent information of Samsung Electronics which is a market leader of the electronics industry. Samsung Electronics has enormous influences on other members in a business ecosystem of the electronics industry with its products such as smartphone, TV and semiconductors. We obtained the data used in this study from the United States Patent Trademark Office (USPTO) with the Wisdomain database which is a company with patent information solutions because the market in the USA is a representative market in the world thus; we consider patents in USPTO as representatives of the technological capacity of a firm. Patents that were applied for by Samsung Electronics during the period between 2000 and 2011 were collected and are shown in Figure 2. According to Figure 2, Samsung Electronics applied for patents most frequently in 2006. Moreover, Table I shows that H01L-021, which is a field for

processes or apparatuses specially adapted for the manufacture or treatment of semiconductors or solid-state devices or of parts thereof, is mainly a developed technological field of Samsung Electronics during the period between 2000 and 2011.

The data are divided into six periods which contain the patent information of two years, an unit period, to analyze the time sequential change of a company's invested technological fields because the number of patents in a year is not enough to find meaningful results.

5.2 Text clustering analysis

First, in order to comprehend the trend of Samsung Electronics' technological area based on its technological capacities, we conducted text clustering analysis with the titles of patent. Some clusters that show similar technological areas were combined together. As shown in Table II of the clustering analysis, one can see that, from 2000 to 2011, Samsung Electronics invested in 14 kinds of technological R&D fields. Moreover, we describe the detailed changes of technological capabilities which occupy big proportions or show interesting patterns.

In the case of data storage medium and data processing, the proportion of related patents in each period decreased until the period of 2008-2009, and it was refocussed during the period 2010-2011. Specifically, from 2000 to 2007, technologies regarding optical recording medium such as optical discs, hard disk drives and disc cartridges were developed.

The proportion of mobile technologies including mobile terminal and mobile communication gradually increased from 2000 to 2011. In particular, from 2000 to 2003, technologies related to code division multiple access (CDMA) were developed, and passive optical network was investigated during the period of 2002-2003.

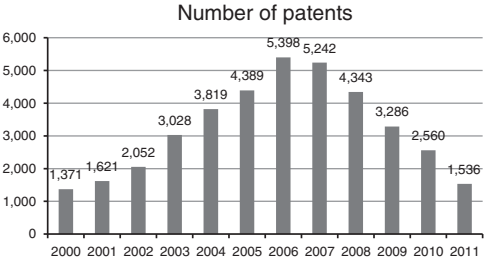

Figure 2. Number of USPTO patents applied for by Samsung Electronics from 2000 to 2011

IPC codes	Frequency
H01L-021	4,537
G02F-001	2,208
H01L-029	2,169
H04N-005	1,369
G06K-009	1,218
G03G-015	1,171
H01L-023	1,078
H04B-007	1,013
H04B-001	958
H01L-031	927

Table I. Top 10 IPC codes of Samsung Electronics' patents over all periods

Table II.
Time sequential change of Samsung Electronics's technological fields

		2000-2001	2002-2003	2004-2005	2006-2007	2008-2009	2010-2011
Data storage medium and data processing	Percentage (%)	22.96	16.02	12.21	11.43	3.13	16.58
	Notes	Defect management, disk cartridge, optical disc	Optical record medium, compact disc	Optical disc, computer program	Optical disk, hard disk drive	Graphic data	Analogue-to-digital converter
Computer	Percentage (%)	11.70					1.64
	Notes	Power consumption, portable computer					Netbook
Semiconductor device	Percentage (%)	7.99					2.08
	Notes	Structure					Stacked semiconductor package
Mobile	Percentage (%)	9.09	12.87	16.02	18.53	27.34	28.37
	Notes	CDMA	CDMA, passive optical network	Cellular phone	Cellular phone	Broadband wireless, cellular phone	Cellular phone, camera, netbook
TFT-LCD	Percentage (%)	10.19	9.35	7.25	17.12	3.08	6.64
	Notes	TFT, LCD	TFT, LCD	LCD	TFT, LCD	TFT	Organic TFT
Circuit	Percentage (%)	4.85	4.65	16.15	9.71	5.13	
	Notes	Circuit board		Integrate circuit	Integrate circuit	Circuit board	
Lights and heats	Percentage (%)	4.71	14.78	16.65	23.50	13.27	15.87
	Notes	DVD player	DVD player		DVD player, LCD, LED, OLED	Panel, LED, LCD, DVD player (blue-ray)	Compact zoom lens, DVD player (blue-ray)
Photosensitive polymer	Percentage (%)	2.27					
	Notes						
Home appliance	Percentage (%)	1.70	5.53	2.70		16.83	
	Notes	Microwave oven	Microwave oven, others				
Charge transport compound	Percentage (%)		1.20	16.23			
	Notes						

(*continued*)

		2000-2001	2002-2003	2004-2005	2006-2007	2008-2009	2010-2011
Home network	Percentage (%)			3.87	5.77		
	Notes						
Memory	Percentage (%)	10.49	25.06	8.91	8.36	16.70	23.49
	Notes	Flash memory, ferroelectric memory device	Ferroelectric memory device	Flash memory, ferroelectric memory device	Flash memory, phase change memory device	Flash memory, phase change memory device, variable resistive element	Magnetic memory device
Image	Percentage (%)	14.04	10.53		5.57	11.05	5.35
	Notes	Bubble jet, electrophotographic printer	Printer, toner, photosensitive ink		CMOS image sensor, inkjet image, human visual characteristic	CMOS image sensor	CMOS image sensor
Energy	Percentage (%)					3.47	
	Notes					Fuel cell, solar cell	

Table II.

Moreover, from 2004 to 2011, technologies regarding cellular phone devices were continuously advanced, and broadband wireless technologies were intensively researched between 2008 and 2009. Lastly, Samsung Electronics started widening the area of mobile terminals from cellular phone to other devices including cameras and netbooks after 2010.

According to the results, we can recognize that thin film transistors-liquid crystal displays (TFT-LCD) has been intensively invested by Samsung Electronics because it constructs a cluster although the TFT-LCD is a specific technological field. Samsung Electronics invested in two components of TFT-LCD, and those are TFT and LCD. First, TFT were steadily invested in until 2009 except for the period of 2004-2005. After 2009, Samsung Electronics developed technologies related to organic TFT.

Investments in technologies regarding lights and heat were steadily applied during the period from 2000 to 2011. Specifically, Samsung Electronics concentrated on digital video disc (DVD) players at first and then invested in apparatuses regarding LCD, light emitting diodes (LED), display panels and compact zoom lens. Moreover, technologies associated with blue-ray were started to be developed in 2008. Photosensitive polymers are chemicals for semiconductors and technologies related to those substances were especially developed only during the period of 2000-2001.

Samsung Electronics was continuously interested in memory devices from 2000 to 2011. Specifically, technologies for flash memory were invested from 2000 to 2009; ferroelectric memory devices were researched from 2000 to 2005, and phase the field of change memory devices were intensively invested during the period between 2006 and 2007. In addition, magnetic memory devices were focussed on during the time between 2010 and 2011.

According to Table II, Samsung Electronics reduced R&D investments for some technologies such as optical storage medium in the data storage medium and data processing field, printer technologies in the image field and home network technologies. Optical recording medium is not frequently used these days because the role of those items are satisfied by universal serial bus storage and external data storage; thus, investments in those items decreased. However, with the issue of analogue-to-digital converters for analogue televisions, the data storage medium and data processing field was reissued. Moreover, the division of printers in Samsung Electronics had strong competitors traditionally, Xerox, Hewlett-Packard and Canon, in the printer business. Therefore, R&D activities for printers diminished.

From the results of Table II, we selected four interesting fields: data storage medium and data processing, mobile, lights and heat and memory fields which have had continuously high interests from Samsung Electronics or which have shown unusual trends recently. In order to identify and understand more specific trends, we conducted association rule analysis on those technological fields. Before conducting the association rule analysis, we investigated the top 10 IPC codes in each interesting field to obtain technological convergence trends in the main streams and those to ten IPC codes are shown in Table III. Descriptions for these IPC codes are in Appendix 1.

5.3 Association rule analysis

After selecting interesting technological fields, we conducted association rule analysis with the IPC codes to in order to comprehend specific convergence trends among technologies in interesting fields. In the association rule analysis, we choose rules that

Technological fields	IPC codes 2000-2001	2002-2003	2004-2005	2006-2007	2008-2009	2010-2011
Data storage and data processing	H04N-005	G11B-007	G11B-007	G11B-005	G11B-007	G11C-007
	G11B-007	G11B-005	G11B-005	H04N-005	H04N-005	H03K-019
	H04N-007	H04N-005	H04N-005	G06K-009	G06K-009	H01L-029
	G11B-005	G11B-017	H04N-007	H04N-007	H04N-007	G11C-011
	G06K-009	H04L-012	G11B-017	G06F-003	G11B-005	G06F-012
	H03M-013	G06K-009	H04J-003	G11B-007	G06F-017	H03L-007
	G06F-015	H04N-007	G06K-009	G06F-017	G06F-011	H04N-005
	G03G-015	H04B-001	H04L-012	G11B-021	H04N-009	H01L-021
	G06F-011	G06F-012	G06F-011	G09G-005	G06F-012	G06F-003
	H04B-001	H04Q-007	G11B-021	G06F-015	G06F-015	G06F-013
	H03M-007 (tied for 10th)					
Lights and heat	G11B-007	H04N-005	G03G-015	H01L-021	G02F-001	G02F-001
	H04N-005	G11B-007	G06K-009	G02F-001	H01L-021	H01L-021
	H04B-001	G06K-009	B41J-002	G09G-003	H01L-023	G02B-015
	H04B-010	G09G-005	H04N-007	H01L-029	H01L-029	G09G-003
	H03L-007	H04N-007	H04N-005	H04N-005	G09G-003	H01L-029
	H04L-007	H01L-021	G03G-021	G06K-009	H01L-031	G03G-015
	H04N-007	H04B-001	H04N-001	H04N-007	C09K-019	H04N-005
	H04B-007	G03B-021	H04N-011	G06F-003	G11B-005	G02B-007
	H04N-009	G03G-015	G03B-021	G09G-005	G03F-007	G06K-009
	H04J-011	G09G-003	G06F-003	H01L-023	H01L-027	C09K-019
	G11C-007 (tied for 10th)					G09G-005 (tied for 10th)
						G03B-017 (tied for 10th)
Memory	G11C-007	H01L-021	H01L-029	G11C-011	H01L-021	H01L-021
	G11C-008	H01L-029	G11C-011	H01L-021	G11C-011	H01L-029
	G11C-016	H01L-023	G11C-007	H01L-029	G11C-016	G11C-011
	H01L-021	G11C-007	H01L-021	G11C-016	H01L-029	G11C-016
	H01L-029	H01L-031	G11C-016	G11C-007	G11C-007	G11C-007
	H01L-027	H01L-027	G11C-008	G11C-008	H01L-027	H01L-023
	G11C-011	G11C-016	G11C-005	G06F-012	G06F-012	H01L-027
	G11C-005	G11C-008	H01L-031	G11C-029	H01L-023	G11C-005
	G11C-029	G02F-001	G06F-012	G06F-013	H01L-031	H01L-033
	G06F-013	G11C-011	G11C-029	H01L-027	G11C-005	G11C-008
Mobile	H04Q-007	H04Q-007	H04B-007	H04B-007	H04B-007	H04W-004
	H04B-007	H04B-007	H04M-001	H04W-004	H04W-004	H04B-007
	H04B-001	H04L-012	H04B-001	H04B-001	H04B-001	H04N-005
	H04J-003	H04B-001	H04L-012	H04M-001	H04L-012	H04B-001
	H04L-012	H04M-001	H04Q-007	H04L-012	H04J-003	G06F-015
	H03M-013	G06F-015	H04W-004	H04J-003	G06F-015	G06K-009
	H04M-001	H04J-003	H04J-003	H04L-027	H04L-027	H04L-012
	H04L-027	H03M-013	H04L-027	H04Q-007	H04M-001	G06F-003
	G06F-015	H04L-027	H04J-011	H03M-013	G06K-009	H04M-001
	H04N-007	H04J-014	H04N-005	G06F-015	G06F-003	H04J-003

Table III.
Top 10 IPC codes of each interesting field by each period

satisfy two standards. First, rules have lift values that are larger than 1. Second, rules have confidence values that are larger than 60. We set the criteria so that the rules can contain a maximum four IPC codes and three consecutive sequential codes. The results of those interesting fields are shown in Tables IV-VII. Descriptions of the IPC codes are in Appendix 2. We reduced the number of rules that express the same convergences patterns.

Table IV.
Association rules for data storage medium technology field

Interesting fields	Period	Rules
Data storage medium and data processing	2000-2001	H04N-011 + H04N-007 ========> H04N-005
		H04N-009 + H04N-005 ========> H04N-007
		H04N-011 ========> H04N-005
		H04N-011 ========> H04N-007
	2002-2003	H04N-011 ========> H04N-007
	2004-2005	No rule
	2006-2007	No rule
	2008-2009	No rule
	2010-2011	No rule

Table V.
Association rules for lights and heat field

Interesting fields	Period	Rules
Lights and heats	2000-2001	H04B-007 ========> H04B-001
		H04L-027 + H04B-001 ========> H04B-007
	2002-2003	H01L-021 + C23F-001 ========> C23C-016
		H04N-011 + H04B-001 ========> H04N-007
		G03B-013 ========> H04N-005
		H04J-003 ========> H04B-001
		C23F-001 ========> H01L-021
	2004-2005	H04N-011 ========> H04N-007
	2006-2007	H04N-011 ========> H04N-007
		H01L-031 ========> H01L-029
	2008-2009	G09G-003 ========> G02F-001
	2010-2011	G06K-009 ========> H04N-005
		C09K-019 ========> G02F-001

Table VI.
Association rules of memory technology field

Interesting fields	Period	Rules
Memory	2000-2001	H01L-031 ========> H01L-029
	2002-2003	No rule
	2004-2005	H01L-031 ========> H01L-029
		H01L-029 + H01L-027 ========> H01L-031
		G01R-031 ========> G11C-029
	2006-2007	H01L-031 ========> H01L-029
	2008-2009	H01L-031 ========> H01L-029
	2010-2011	No rule

First, the technological field related to data storage medium and data processing technologies had the smallest number of convergences. From 2000 to 2003, convergences occurred among technologies related to television systems (H04N-005, H04N-007, H04N-009 and H04N-011). In specific, these convergences were mostly related to motion detection technologies in video sequences. In reality, Samsung Electronics produced closed-circuit television with motion detection functions before 2004 and seriously started to participate in digital video recorder (DVR) market based on the convergence regarding motion detection (Lee, 2004). Moreover, Samsung Electronics commercialized smart TVs which can be manipulated by hand gestures in 2011.

Second, in the field of technologies regarding lights and heats, there had been more various types of convergences than in any other field. At first, from 2000 to 2001 specifically, various types of transmission systems such as radio transmission systems and modulated-carrier systems were involved in convergences. During the period from 2002 to 2003, diverse convergences appeared. First, etching and chemical coating technologies converged on semiconductor manufacturing processes. Second, technologies regarding televisions converged with each other. Moreover, in particular, a viewfinder technology for an automatic focussing system was applied to television technologies. After this period, especially the period from 2002 to 2003, the number of convergences decreased. During the period between 2004 and 2005, only technologies related to televisions caused technological convergences. From 2006 to 2007, technologies regarding televisions and semiconductors made convergences. After 2008, technological convergences occurred between Samsung Electronics technologies regarding controlling lights and liquid crystal materials. Among various technological convergences, particular convergences are related to satellite radio-navigation systems during the period from 2000 to 2001 and moving pictures encoding/decoding during the period from 2004 to 2005. Samsung Electronics intensively produced the products with navigation systems in 2005 (Samsung Electronics, 2005). Meanwhile, technologies regarding moving pictures encoding/decoding contributed to DVR businesses of Samsung Electronics.

Third, few technological fields were included in the technological convergences in the memory technology field. From 2000 to 2009, convergence between semiconductor devices for rectifying, amplifying, oscillating or switching and semiconductor devices which are sensitive to radiation were continuously focussed on. Moreover, the technological convergence occurred between technologies regarding plurality of semiconductors and between technologies regarding testing stores during the period between 2004 and 2005 only. After 2009, there were no significant technological convergences. In this field, continuous technological convergences regarding various

Interesting fields	Period	Rules		
Mobile	2000-2001	No rule		
	2002-2003	No rule		
	2004-2005	H04M-009	= = = = = = = >	H04M-001
	2006-2007	H04B-007	= = = = = = = >	H04W-004
		H04B-007	= = = = = = = >	H04B-001
	2008-2009	No rule		
	2010-2011	H04N-003	= = = = = = = >	H04N-005

Table VII. Association rules for mobile technology field

memories have been contributed to leading position of Samsung Electronics in memory market (LaPedus, 2010).

Fourth, in the mobile technology field, from 2004 to 2007, Samsung Electronics concentrated on technological convergence between infrastructure technologies and basic technologies for mobile devices such as wireless communication networks. Moreover, convergence occurs between technologies regarding radio transmission systems and services or facilities for wireless communication. After that, from 2010 to 2011, convergences occurred between technologies related to television systems and scanning details or a combination thereof with the generation of supply voltages for television systems. Among various convergences, particular interests were in design of mobile apparatus started from 2004. Samsung Electronics produced various types of cellular phones such as bar, slide and folder types.

In the future, we can expect that boundary of the camera industry will widen from cameras to various mobile devices. Moreover, developments of cameras will more likely to focus on the functions of correction of images and manipulation of cameras than with the pixels of cameras. Meanwhile, mobile communication will be more efficient in both levels: systematical level and device level.

6. Conclusion

Identifying and understanding the trends of technological convergences of a market is highly significant to SMEs which are involved in a business ecosystem in order to survive in a market and find new business opportunities. In this study, we proposed a framework for investigating the trends of technological convergences of a market leader and analyzed the technological convergence trends of a market leader within the patent information. We applied the proposed framework, consisting of the selection of patent data, the text clustering and association rule analyses of patent information, to Samsung Electronics which is a leading company of the electronics industry for a case study. First, Samsung Electronics' patents during the period between 2000 and 2011 were extracted from the USPTO database. Moreover, titles and IPC codes of the patents were utilized in the text clustering and association rule analyses, respectively.

Text clustering analysis constructs some clusters which express technological fields of a period, and time sequentially analyzed clusters show the trends of a market leader's technological fields. In the case of Samsung Electronics, 14 kinds of technological fields (data storage medium and data processing, computers, semiconductor devices, mobile, TFT-LCD, circuits, lights and heats, photosensitive polymers, home appliances, charge transport compounds, home network, memory, image and energy) were investigated. Using the time sequential text clustering analysis, we recognize the trend of each interesting field. Moreover, we compare the technological trends appeared on patents to the commercialized outcomes in the market.

Among the technological fields, we selected the interesting technological fields for which the proportions increased or those proportions were large. In this study, four technological areas including data storage medium and data processing, mobile, lights and heats and memory were selected from the 14 technological fields.

By extracting association rules from these selected fields, trends of technological convergences were comprehended. However, it needs caution for SMEs to refer this information because influences of technological convergences can vary depending on various factors such as market conditions and divisions of leading companies that are responsible to recognized technological convergences. For instance, motion detection technologies can be applied to various business areas or products thus;

without thorough market research, SMEs cannot expect the future direction of Samsung Electronics. In this case, it is recommended for SMEs to investigate the technology trend of Samsung Techwin, Samsung Electronics' family company, which provides security services that needs motion detection technology. Therefore, multiple points of view related to technological convergence are the best way to prepare for the future caused by technological convergences.

This proposed framework has several contributions. First, this framework helps SMEs to identify and understand technological trends at the product level, which is hard to express with IPC codes which are frequently used in existing studies. Moreover, for an in-depth investigation, association rule analysis was conducted with IPC codes to find technological convergence trends in the technological trends of each product. In these prior processes, stakeholders can understand the trends of technological fields that they are interested and the technological convergences in each interesting technological field. Moreover, based on these results, stakeholders can prepare for those changes in several ways such as buying related technologies and enhancing related divisions in their companies. This study is expected to help SMEs which are members of business ecosystems to identify and understand trends of technologies in terms of the core competencies of leading firms and specific technological convergences in particular technological areas. Therefore, SMEs can make decisions on whether to extend products or technology portfolios and on the disposal of technologies based on the analyzed results from the changes in a business ecosystem with the proposed framework.

This study proposed a general framework to identify and understand technological trends in terms of technological convergence with text clustering and association rule analyses. Applying this framework to different business ecosystems and making a comparison between the characteristics of trends from different ecosystems can provide meaningful results. For this reason, we are left with further research areas such as a comparison between the technological trends of diverse business ecosystems by applying this framework. Moreover, in order to sustain an ultimate ecosystem, further studies are needed to narrow down the gap between the SMEs' willingness to sell their technology product and customers' willingness to pay for them (Sohn *et al.*, 2013).

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Further reading

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Appendix 1

IPC codes	Descriptions
B41J-002	Typewriters or selective printing mechanisms characterized by the printing or marking process for which they are designed
C09K-019	Liquid crystal materials
G02B-007	Mountings, adjusting means, or light-tight connections, for optical elements
G02B-015	Optical objectives with means for varying the magnification
G02F-001	Devices or arrangements for the control of the intensity, color, phase, polarization or direction of light arriving from an independent light source, e.g. switching, gating or modulating; non-linear optics
G03B-017	Details of cameras or camera bodies; accessories therefor
G03B-021	Projectors or projection-type viewers; accessories therefor
G03F-007	Photomechanical, e.g. photolithographic, production of textured or patterned surfaces, e.g. printed surfaces; materials therefor, e.g. comprising photoresists; apparatus specially adapted therefor
G03G-015	Apparatus for electrographic processes using a charge pattern
G03G-021	Arrangements not provided for by groups G03G 13/00-G03G 19/00, e.g. cleaning, elimination of residual charge
G06F-003	Input arrangements for transferring data to be processed into a form capable of being handled by the computer; output arrangements for transferring data from processing unit to output unit, e.g. interface arrangements
G06F-011	Error detection; error correction; monitoring
G06F-012	Accessing, addressing or allocating within memory systems or architectures
G06F-013	Interconnection of, or transfer of information or other signals between, memories, input/output devices or central processing units
G06F-015	Digital computers in general; data processing equipment in general
G06F-017	Digital computing or data processing equipment or methods, specially adapted for specific functions
G06K-009	Methods or arrangements for reading or recognizing printed or written characters or for recognizing patterns, e.g. fingerprints
G09G-003	Control arrangements or circuits, of interest only in connection with visual indicators other than cathode-ray tubes
G09G-005	Control arrangements or circuits for visual indicators common to cathode-ray tube indicators and other visual indicators
G11B-005	Recording by magnetization or demagnetization of a record carrier; reproducing by magnetic means; record carriers therefor
G11B-007	Recording or reproducing by optical means, e.g. recording using a thermal beam of optical radiation, reproducing using an optical beam at lower power; record carriers therefor
G11B-017	Guiding record carriers not specifically of filamentary or web form, or of supports therefor
G11B-021	Signal processing not specific to the method of recording or reproducing; circuits therefor
G11C-005	Details of stores covered by group
G11C-007	Arrangements for writing information into, or reading information out from, a digital store
G11C-008	Arrangements for selecting an address in a digital store
G11C-011	Digital stores characterized by the use of particular electric or magnetic storage elements; storage elements therefor
G11C-016	Erasable programmable read-only memories
G11C-029	Checking stores for correct operation; testing stores during standby or offline operation
H01L-021	Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid-state devices or of parts thereof
H01L-023	Details of semiconductor or other solid-state devices

Table AI.
Top 10 IPC codes of interesting fields

(*continued*)

IPC codes	Descriptions
H01L-027	Devices consisting of a plurality of semiconductor or other solid-state components formed in or on a common substrate
H01L-029	Semiconductor devices specially adapted for rectifying, amplifying, oscillating or switching and having at least one potential-jump barrier or surface barrier; capacitors or resistors with at least one potential-jump barrier or surface barrier, e.g. PN-junction depletion layer or carrier concentration layer; details of semiconductor bodies or of electrodes thereof
H01L-031	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; processes or apparatus specially adapted for the manufacture or treatment thereof or of parts thereof; details thereof
H01L-033	Semiconductor devices with at least one potential-jump barrier or surface barrier specially adapted for light emission; processes or apparatus specially adapted for the manufacture or treatment thereof or of parts thereof; details thereof
H03K-019	Logic circuits, i.e. having at least two inputs acting on one output
H03L-007	Automatic control of frequency or phase; synchronization
H03M-007	Conversion of a code where information is represented by a given sequence or number of digits to a code where the same information is represented by a different sequence or number of digits
H03M-013	Coding, decoding or code conversion, for error detection or error correction; coding theory basic assumptions; coding bounds; error probability evaluation methods; channel models; simulation or testing of codes
H04B-001	Details of transmission systems, not covered by a single one of groups; details of transmission systems not characterized by the medium used for transmission
H04B-007	Radio transmission systems, i.e. using radiation field
H04B-010	Transmission systems employing electromagnetic waves other than radio-waves, e.g. infrared, visible or ultraviolet light, or employing corpuscular radiation, e.g. quantum communication
H04J-003	Time-division multiplex systems
H04J-011	Orthogonal multiplex systems
H04J-014	Optical multiplex systems
H04L-007	Arrangements for synchronizing receiver with transmitter
H04L-012	Data switching networks
H04L-027	Modulated-carrier systems
H04M-001	Substation equipment, e.g. for use by subscribers
H04N-001	Scanning, transmission or reproduction of documents or the like, e.g. facsimile transmission; details thereof
H04N-005	Details of television systems
H04N-007	Television systems
H04N-009	Details of color television systems
H04N-011	Color television systems
H04Q-007	Selecting arrangements to which subscribers are connected via radio links or inductive links
H04W-004	Services or facilities specially adapted for wireless communication networks

Table AI.

Appendix 2

Table AII.
IPC codes of technological convergence rules

IPC codes	Descriptions
C09K-019	Liquid crystal materials
C23C-016	Chemical coating by decomposition of gaseous compounds, without leaving reaction products of surface material in the coating, i.e. chemical vapor deposition (CVD) processes
C23F-001	Etching metallic material by chemical means
G01R-031	Arrangements for testing electric properties; arrangements for locating electric faults; arrangements for electrical testing characterized by what is being tested not provided for elsewhere
G02F-001	Devices or arrangements for the control of the intensity, color, phase, polarization or direction of light arriving from an independent light source, e.g. switching, gating or modulating; non-linear optics
G03B-013	Viewfinders; focussing aids for cameras; means for focussing for cameras; autofocus systems for cameras
G06K-009	Methods or arrangements for reading or recognizing printed or written characters or for recognizing patterns, e.g. fingerprints
G09G-003	Control arrangements or circuits, of interest only in connection with visual indicators other than cathode-ray tube
G11C-029	Checking stores for correct operation; testing stores during standby or offline operation
H01L-021	Processes or apparatus specially adapted for the manufacture or treatment of semiconductor or solid-state devices or of parts thereof
H01L-027	Devices consisting of a plurality of semiconductor or other solid-state components formed in or on a common substrate
H01L-029	Semiconductor devices specially adapted for rectifying, amplifying, oscillating or switching and having at least one potential-jump barrier or surface barrier; capacitors or resistors with at least one potential-jump barrier or surface barrier, e.g. PN-junction depletion layer or carrier concentration layer; details of semiconductor bodies or of electrodes thereof
H01L-031	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; processes or apparatus specially adapted for the manufacture or treatment thereof or of parts thereof; details thereof
H04B-001	Details of transmission systems, not covered by a single one of groups H04B 3/00-H04B 13/00; details of transmission systems not characterized by the medium used for transmission
H04B-007	Radio transmission systems, i.e. using radiation field
H04J-003	Time-division multiplex systems
H04L-027	Modulated-carrier systems
H04M-001	Substation equipment, e.g. for use by subscribers
H04M-009	Arrangements for interconnection not involving centralized switching
H04N-003	Scanning details of television systems; combination thereof with generation of supply voltages
H04N-005	Details of television systems
H04N-007	Television systems
H04N-009	Details of color television systems
H04N-011	Color television systems
H04W-004	Services or facilities specially adapted for wireless communication networks

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