Development of a Practical Tool for Exploring the Map of Technology

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Abstract: This study suggests a way to utilize the map of technology as a guide to find new technology component. Recent studies of mapping knowledge mainly focused on analyzing the map as a result of technological innovation rather than utilizing the map for exploring the world of technological innovation. The preliminary result of a case study suggests that a firm can find possible technology components that can be combined with own technology component. The map of technology comprises the nodes of International Patent Classification (IPC) main groups and the links presenting the co-assign relationship between the IPC main groups.

1 INTRODUCTION

A well-defined strategy for research and development (R&D) activity accelerates technological innovation, resulting in developing new products or streamlining processes. Understanding the structure of knowledge underlying technologies helps to set which a R&D strategy is proper. The knowledge can be represented as a network due to its own correlational and retrieval-interpretative property (Saviotti, 2004). The nodes of network represent knowledge components and are connected by the links representing the correlation or dependence of any two connected nodes. For a decade, researchers have tried to map not only the knowledge base of a specific technology or science but also global technologies or sciences.

Recent literatures of mapping science and technology mainly have focused on analyzing the structure and variation of the map as a result of technological innovation rather than utilizing the map for exploring the world of technological innovation. One of basic functions of map is to guide explorers. If the map of technology is comprised of various technology components as nodes and paths between the nodes, it can guide an explorer from the starting point to the destination in the view of technological innovation.

On the basis of the literature, this study suggests a new way to utilize the map of technology as a guide to find a new technology component. The new technology component can be the innovation opportunity in itself and also one of the materials for recombination of technologies toward the innovation. This study aims to develop a practical tool to create and explore the map of technology. A case study using our tool demonstrates the logical basis of the tool.

2 RESEARCH BACKGROUND

2.1 Research Question

Two questions motivate us to start this study.

- Is the map of technology able to guide a researcher or a firm to the potential area of technological innovation?
- How can we find the best path to the target technology from an existing one of a researcher or a firm for recombination or transition?

Creating the map of technology is the start point to find the best path from one technology component to another component. The map comprises a number of nodes (technology components) and links (relationship between them). We have to choose what particular fact assigns the link between two

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technology components. Previous studies have dealt with the map of technology and its rationale in related literature for decades. The next subsection reviews those studies.

2.2 Related Literatures

In the last decade, several studies introducing the global map of knowledge have come into the spotlight. Schoen and his colleagues (Schoen et al., 2012) created the global map of technology using the 389 technological fields extended from the WIPO's 35 classes of technology. Leydesdorff and Rafols later suggested the global map of science using the subject categories of journals (Leydesdorff and Rafols, 2009). Approaches to map the technological or scientific knowledge base were fulfilled from macro to micro level, such as investigating a particular domain of technology (Krafft et al., 2011), analyzing a knowledge base of a particular firm or an organization (Özman, 2007), and further illustrating characteristics of a firm's R&D activity or strategy using the firm's knowledge base (Sakata et al., 2009).

Although a handful of studies tried to utilize the map of technological knowledge, the interests of the studies were restricted to the structure and variation of the map. They suggested that the technological innovation may emerge from the recombination of existing technology components (Fleming and Sorenson 2004). The map of technology of a particular firm was created using the classification system of patent documents and the citation relationship between the documents. The map was used to identify the elements of recombination and evaluated with the innovation as a result from the recombination.

What is assigned to the relationship between two technologies is an interesting topic in the research area of technology mapping. A citation relationship is one of the common examples to connect two technological nodes. Researchers utilized the citation relationship between patents to measure the technology spillover from an industrial sector to another (Verspagen, 1997) or to trace the evolution of technology (Verspagen, 2007). However, patent citation may be inappropriate to illustrate the relationship between technologies or the distance between them (Hinze et al., 1997). A co-classification relationship in patent classification such as the International Patent Classification (IPC) provided by WIPO is another example to connect two nodes. Some researchers connect two technologies represented by IPCs in which a patent is co-classified (Krafft et al., 2011; Scheon et al., 2012; Sakata et al., 2009).

3 MODEL FRAMEWORK

3.1 Map of Technology

In this paper, we regard IPC codes assigned a patent as technology components comprising the invention presented in a patent. These IPC codes are nodes of the network in the map of technology. In the hierarchical structure of IPC, this study uses a main group to illustrate a particular technology component whereas previous studies considering the global map of technology uses class level (3-digit) or subclass level (4-digit). Class and subclass levels are too broad to describe a particular technology component of a patent. Although subgroups are at the most specific level, because of the differences in the levels of technologies, IPC subgroups cannot be compared each other on the same hierarchy.

Co-classification of IPCs in the same patent assigns links between the two IPC nodes in the map of technology. The weight of link can be calculated by various methods such as a similarity between two IPC codes (Leydesdorff, 2014), or a relatedness between them (Nesta and Saviotti, 2005).

3.2 Search and Evaluation in the Map

The network of technology component with nodes of IPC main group has a very complex structure because a particular node of technology component can be connected to several nodes among thousand nodes in the map and each pair of nodes may have multiple routes to connect them. To guide an explorer on the technology map efficiently, multiple routes have to be compared in terms of weight.

If the start and destination are determined, the shortest path search algorithms can help the process of comparing multiple routes and select the most appropriate route. When the destination is not decided, the explorer should consider multiple nodes for the destination and compare the routes for each candidate destination repeatedly.

Previous works have produced a number of studies for searching nodes and evaluating attributes of links in a complex network for decades (Newman, 2003). Social scientists have focused on searching nodes and finding paths in the social network studies including recommendation algorithm (Kautz et al., 1997; Wu et al., 2013)

In this study, we modified the breadth first search (BFS) algorithm to search the connected nodes (technology components). The BFS is an algorithm for searching nodes exhaustively in the network or graph. The BFS provides one of the shortest paths between nodes without considering weights of paths. The modified BFS prioritizes the node have a higher weight such as a co-assigned frequency or a link-creation year with the start node. The discovered nodes as a result of the modified BFS form the tree of technology candidates to transit from the start node or to be combined with the start node.

Figure 1 compares the original and the modified BFS algorithm. In original BFS (a) and modified BFS (b), an explorer starts from node S can find nodes A, B and C as the first destination in the first step. However, node j in the second step is connected with node B in modified BFS instead of node A in original BFS because the weight of link between node B and j is greater than it between node A and j.

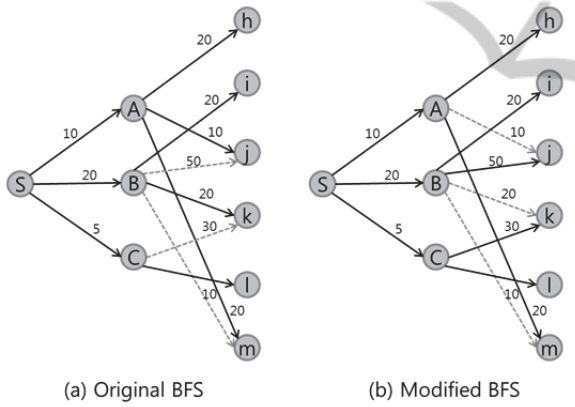


Figure 1: The original and modified BFS.

4 CASE STUDY

4.1 Data

We analyzed all patents granted by USPTO from 2007 to 2011. 10,054 IPC main groups are extracted from total 1,052,974 patents granted. The number of IPC main groups is around seven thousand in a particular version of IPC according to the WIPO's announcement on their website. Ten thousand of main groups of this study contain main groups defined by different versions of IPC in order to cover the main groups exhaustively during the time period of analysis.

The number of unique links connecting two IPC main group nodes directly is 3,017,065, and it means that a particular IPC main group node has 6 connections to the other node on average per year. In the case study, only 1,217,206 links are regards as effective links created by which two IPC main groups are co-assigned to the same patent at least 5 times for 5 years.

The global map of technology cannot be presented in this study because of the huge number of nodes and links. This paper, instead, shows a local map of routes from the determined start to multiple destinations. The case study illustrates the process to search candidate destination nodes and to compare their routes.

4.2 Preliminary Results

What technology components are good candidates for a firm to combine with its existing technology components? Let us assume that an imaginary company "A" mainly producing fluoropolymer coated films seeks new technology components that can be combined with the existing one. Most of A's patents are classified as B32B 7/00 among the IPC main group. Then, company A can explore the map of technology from B32B 7/00 main group as the start node.

WIPO defines the IPC main group B32B 7/00 as follows:

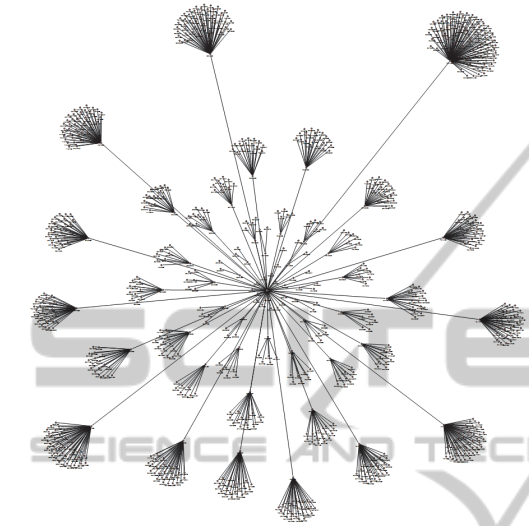
- Layered products characterised by the relation between layers, i.e. products essentially comprising layers having different physical properties or products characterised by the interconnection of layers

From 2007 to 2011, 977 granted patents have been classified as B32B 7/00 by USPTO and the compound average grow rate of the patents was 14.85%. Major assignees were Nitto Denko Corporation, 3M Innovative Properties Company, Avery Dennison Corporation, Lintec Corporation and so on.

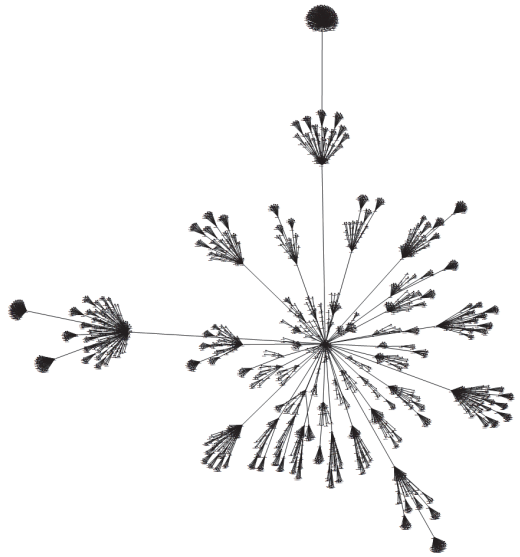
B32B 7/00 was co-assigned to the same patent with 64 other main groups in the first step during five years granted patent data. It means that 64 technology components have been combined with the technology component described by B32B 7/00 main group at least five times within five years. B32B 7/00 ranks top 15% in the number of co-assigned main groups that have been combined with it at least once.

From the second step, the process of finding candidate destination nodes adopts the modified BFS. In the second step search, 794 unique main

group nodes were discovered with 2,345 direct routes from 64 main group nodes discovered in the first step. 1,615 unique nodes were identified with 6,856 routes in the third step search. Figure 2 presents the global view of searching process in the second and the third steps.



(a)



(b)

Figure 2: Searching trees from B32B 7/00 main group to the second step (a) and the third step (b).

Table 1 shows highly ranked technology components in the number of patent co-classified as the start (B32B 7/00) and the first destination IPC main groups (co-assigned frequency). It also presents the average year of patents granted. The top nine components are similar technology components to the start main group. C08K 5/00 and B05B 5/00 are far from the start and belong to other subclasses and classes. WIPO describe two main groups as follow.

- C08K 5/00: Use of organic ingredients
- B05D 5/00: Processes for applying liquids or other fluent materials to surfaces to obtain special surface effects, finishes or structures

Table 1: Top 10 IPC main groups in the first step.

Rank	1st Destination	Average year	Frequency
1	B32B 27/00	2009.20	205
2	B32B 15/00	2009.33	140
3	B32B 3/00	2009.49	121
4	B32B 5/00	2009.25	107
5	B32B 9/00	2009.66	98
6	B32B 37/00	2009.48	58
7	B32B 33/00	2009.73	52
8	B29C 65/00	2009.89	35
9	B32B 17/00	2009.48	25
10	C08K 5/00	2010.22	23
10	B05D 5/00	2009.61	23

Table 2 shows highly ranked technology components in the second step in the co-assigned frequency. It presents the second destinations with the average year (Av. year) and the number (Freq.) of patent granted in the second step. Further, it also presents the first destinations discovered by the first step search and the sum of frequencies of the two steps (Sum of freq.).

The result from the second step shows that the start technology component can reach very dissimilar technology components. In top 10 components, H01L 31/00 and 27/00 are combined with the start recently. The following WIPO descriptions illustrate these two main groups.

- H01L 31/00: 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 27/00: Devices consisting of a plurality of semiconductor or other solid-state components formed in or on a common substrate

Table 2: Top 10 IPC main groups in the co-assigned frequency in the second step.

Rank	2nd Destination	Av. year	Freq.	1st Destination.	Sum of freq.
1	H01L 29/00	2009.37	1645	H01L 21/00	1654
2	C23C 16/00	2009.36	786	H01L 21/00	795
3	H01J 63/00	2009.29	649	H01J 1/00	654
4	H05K 7/00	2009.00	570	H01L 23/00	578
5	C23F 1/00	2009.36	546	H01L 21/00	555
6	G11B 21/00	2008.88	546	G11B 5/00	552
7	H01L 31/00	2009.44	500	H01L 21/00	509
8	H01L 27/00	2009.56	480	H01L 21/00	489
9	G02B 6/00	2008.83	391	G02F 1/00	400
10	C08L 63/00	2009.27	180	B32B 27/00	385

Table 3 shows highly ranked technology components in the second step in the average link creation year. B60K 15/00 and C08G 67/00 are in the set of most recently combined with the start and co-assigned frequently. The following WIPO descriptions illustrate these two main groups.

Table 3: Top 10 IPC main groups in the average link creating year in the second step.

Rank	2nd Destination	Av.year	Freq.	1st Destination.	Sum of freq.
1	C07D 235/00	2010.60	5	C09B 67/00	10
2	C08L 29/00	2010.50	14	C08L 33/00	21
3	C09B 57/00	2010.20	5	C09B 67/00	10
4	C08L 55/00	2010.16	6	C08L 33/00	13
5	C08L 47/00	2010.00	5	C08L 33/00	12
6	A21C 3/00	2010.50	6	B29C 47/00	16
7	B60K 15/00	2011.00	5	C08K 5/00	28
8	C08G 67/00	2010.75	8	C08K 5/00	31
9	C08G 61/00	2010.15	13	C08G 73/00	18
9	C07F 1/00	2010.28	7	C07F 7/00	12

- B60K 15/00: Arrangement in connection with fuel supply of combustion engines; Mounting or construction of fuel
- C08G 67/00: Macromolecular compounds obtained by reactions forming in the main chain of the macromolecule a linkage containing oxygen or oxygen and carbon, not provided for in groups C08G 2/00-C08G 65/00

After exploring the map of technology, company "A" producing coated films may consider the technology component contributing to develop solar cell represented by IPC main group H01L 31/00 and other technology components represented by IPC main groups discovered through exploring process.

5 DISCUSSION

This study mainly focuses on utilizing the map of technology as well as creating it. The preliminary result of the case study suggests that a firm can find potential technology components that can be combined with existing technology component by creating and exploring the map of technology comprising the nodes of IPC main groups and the links that present the co-assign relationship between the IPC main groups.

It is the limitation that the frequency and average year of co-assign relationship is one of possible criteria to assign links between two technology components. If the future study considers various and appropriate criteria such as similarity in terms of patents or assignees and citation relationship between IPC main groups to assign links between technology components, the study can contribute to the literature in the aspect of developing a practical tool for utilizing the map of technology.

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