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Technological opportunity discovery for technological convergence based on the prediction of technology knowledge flow in a citation network

Inchae Park, Byungun Yoon*

Dongguk University-Seoul, Republic of Korea

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ABSTRACT

As technological convergence has recently become a mainstream innovation trend, technological opportunities need to be explored in heterogeneous technology fields. Most of the previous convergence studies have taken a retrospective view in measuring the degree of convergence and monitoring the converging trends. This paper proposes a quantitative future-oriented approach to technological opportunity discovery for convergence using patent information. In a future-oriented approach, technological opportunities for convergence are suggested by predicting potential technological knowledge flows (TKFs) between heterogeneous fields. The potential TKFs are predicted by a link prediction method in a directed network, which is suggested in this paper to represent the direction of the predicted TKFs by adapting the concept of bibliographic coupling and edge-betweenness centrality. Converging technological opportunities are proposed as incremental and radical technological opportunities by extracting the potential increased knowledge flow links and emerging knowledge flow links. Moreover, the direction and themes of the predicted potential TKFs are provided as technological opportunities for convergence. As an illustration of the proposed method, the technological opportunities between biotechnology (BT) and information technology (IT) are explored. Firms and researchers can use the proposed method to seek out new technological opportunities from various technologies so that R&D policymakers can plan new R&D projects on technological convergence.

1. Introduction

It is critical to monitor technological trends and anticipate the direction of technological change under rapidly changing technological circumstances. Many attempts have been made for technological opportunity discovery (TOD) to identify technological opportunities and threats that could affect future growth and survival because they are considered some of the most crucial issues for companies (Cozzens et al., 2010). The studies on TOD have largely been conducted to anticipate promising technologies that have not yet been developed and to analyze potential new markets that can be created by utilizing existing technologies (Cho, Yoon, Coh, & Lee, 2016).

* Corresponding author at: Department of Industrial & Systems Engineering, School of Engineering, Dongguk University, 30, Pildong-ro 1gil, Jung-gu, Seoul, 04620, Republic of Korea.
E-mail address: postman3@dongguk.edu (B. Yoon).

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Expert-based qualitative TOD approaches such as Delphi, questionnaire survey analysis, and TRIZ (Teoriya Resheniya Izobretatelskih Zadach) have the advantage of easy validation and the disadvantage of expensive costs and of being time-consuming. Quantitative approaches such as computer-based methods and bibliometric analysis can play a complementary role to the disadvantage of the qualitative approaches and propose objective results based on a large volume of data. As massive technological data have been accumulated and analytic techniques have advanced, it is possible to identify technological opportunities using a quantitative approach.

Patent analysis has been employed as a representative quantitative approach for TOD, and additional quantitative analytic techniques such as morphology analysis, text mining, network analysis, and novelty detection have been combined with patent analysis for TOD (Geum, Jeon, & Seol, 2013; Lee, Kang, & Shin, 2015). The TOD studies based on patent analysis in the initial stage have focused on anticipating newly emerging technological opportunities. Recently, a few attempts have been made to identify technological opportunities via technological convergence (An, Kim, Mortara, & Lee, 2018). Thus, TOD research has been extended from technological opportunities in a specific technology area to those merged with heterogeneous technology fields, which are different from the existing technology domain.

Technological convergence is also a critical issue because it can be a technological breakthrough. Many quantitative approaches have been taken to tackle technology convergence using patent analysis. From the perspective of combining the research themes of TOD and technological convergence, the previous quantitative technological convergence studies have some limitations. First, most of the previous studies on technological convergence using patent analysis have analyzed patent data with a retrospective view by measuring the degree of convergence (Geum, Kim, Lee, & Kim, 2012; Takano, Mejia, & Kajikawa, 2016). However, it is necessary to identify technological opportunities for convergence in terms of technology planning for the future. This paper suggests a prospective TOD approach for technological convergence to overcome the limitation. Second, many convergence studies investigate industry- and macro-level technology fusion (Curran & Leker, 2011). It is insufficient to utilize the results at the stage of converging technology development because those studies analyze technological convergence at a high level. Third, from a methodological point of view, patent co-classification has been largely utilized to measure the degree of technological or industrial convergence in the previous convergence studies because patent classification is suitable to represent technologies as a proxy and to measure the overlap between technologies (Bongioanni, Daraio, & Ruocco, 2014). Although patent classification enables the monitoring status of convergence, it is difficult to suggest practical information in terms of a future-oriented perspective for converging technology development.

To overcome the aforementioned limitations, a concept of technological knowledge flows (TKFs) can be utilized because technological opportunities can be diversified by using the TKFs from the heterogeneous technology fields to detect signals of technological convergence for the future (Caviggioli, 2016). Patent co-classification analysis has been utilized in most of the previous convergence studies, whereas patent citation analysis can be utilized because the citation information on patents or scientific papers has been considered a reliable proxy for TKF (Jaffe, Trajtenberg, & Henderson, 1993). In addition, to emphasize the future-oriented view based on the TKF approach, link prediction, which is a technique used to detect missing links in the current networks and to predict new links in future networks, is utilized to identify technological opportunities for convergence.

This research contributes to existing literature in several ways by filling the research gap and overcoming previous studies' limitations. First, a TOD framework for converging technology opportunities is suggested as an extension of existing TOD studies. Second, a future-oriented TOD approach is proposed by overcoming the retrospective view. Third, technological opportunities are suggested at a micro level by subgrouping potential TKFs and suggesting promising technological themes. Finally, a link prediction method is utilized to identify technological opportunities to overcome the methodological limitation.

This paper aims to identify technological opportunities for convergence by predicting potential TKFs between heterogeneous fields using quantitative data analysis. Three research questions are suggested in the present study. First, what are the potential technological opportunities for convergence? Second, what are the characteristics of the predicted technological convergence areas? Third, what are the possible technological themes for technological convergence? To solve the research questions, a new approach to exploring the TOD for technological convergence is proposed by means of link prediction in patent-citation networks and TKF networks, as well as by investigation of knowledge flow properties and technological knowledge themes. In addition, technological opportunities for convergence are discussed with the direction and strength of the predicted potential TKFs.

2. Background

2.1. Patentometric analysis for technology opportunity discovery (TOD)

Technological opportunity is defined as the potential or possibility for technological progress in a general or particular field (Yang, Huang, & Su, 2018). Similar terms, such as technology intelligence (TI) and TOD, have been used to identify technological opportunities. Cho et al. (2016) elucidated the concept of TOD with TI, which was suggested by Kerr, Mortara, Phaal, and Probert (2006), in two perspectives: objects and activity. Although TI focuses on opportunities and threats in the perspective of objects and is interested in information management and an analysis process in the view of activity, TOD concentrates on opportunities and the strategic use of information in terms of objects and activity. In this paper, we used the concept of TOD to identify technological opportunities because we deal with future-oriented opportunities and the strategic use of technological information.