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Application technology opportunity discovery from technology portfolios: Use of patent classification and collaborative filtering

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ABSTRACT

Technology opportunity discovery (TOD), customized to a firm's current technology capability, can be a good starting point to formulate a technology strategy for a firm that lacks technology information, experts, and/or facilities. Although patent-based studies have suggested systematic methods for customized TOD, these methods have limitations such as insufficient consideration of a target firm's technology portfolio and difficulty of method reproducibility due to expert intervention-based text mining. Therefore, this paper proposes an approach to determine application technology opportunities customized to a target firm by applying collaborative filtering to firms' technology portfolios, which are represented as a set of patent classification codes of the firm's patents. The proposed method involves 1) structuring technology portfolios as firm-international patent classification (IPC) distribution vectors using main group-level IPC codes of the applicants' patents, 2) recommending main group-level IPCs untapped by the target firm and with high preference scores by using collaborative filtering, and 3) classifying the recommended IPCs for the firm's strategic decision-making support using indexes of heterogeneity, growth rate, and competition level. To show the workings of this approach, we applied it to a high-tech firm with wireless communication technology, building on the analysis of large-scale patents and their applicants. This approach is expected to contribute to the systematic identification of application technology opportunities customized to firms and across various industries, and to become a basis for developing future technology intelligence systems.

1. Introduction

Providing new technology-based products to the market is one of the significant factors for the successful and sustained growth of firms (Yoon and Kim, 2011; Porter and Detampel, 1995; Park et al., 2013). In particular, by exploring potential technologies outside/inside of the scope of the existing business, most recent technology-based firms are investing significantly in research and development (R&D) activities to develop new technologies and products based on these technologies (Yoon et al., 2014a, 2015; Seo et al., 2016). However, as the funds available for R&D are limited and the life cycles of technologies and products are decreasing, one of the most important tasks in the technology planning process is determining the R&D directions, taking into consideration the firms' present constraints, such as the costs of R&D, technology experts, and facilities (Hauser, 1996; Kim et al., 2014). For example, although small and medium-sized enterprises (SMEs) are aware of the need for technology development to stay competitive, they usually suffer from insufficient information and human resources while facing a high investment risk (Kleinknecht and Reijnen, 1992; Savioz and Blum, 2002; Cho et al., 2016).

Technology opportunities are defined as the promise of technological progress or the potential ability to drive technological advances within specific fields or over different industries (Klevorick et al., 1995; Olsson, 2005). Accordingly, technology opportunity discovery (TOD) indicates the process that identifies opportunities with potential business value by developing and utilizing technologies and products (Yoon et al., 2015; Cho et al., 2016; Galbreath et al., 2016). Early approaches for TOD methods, such as the Delphi method, were based on analysis by experts. Although experts' judgments remain important in TOD, in previous work, researchers have insisted that experts are not always correct and might be less reliable due to the increase in technical data and fragmented domains (Lee et al., 2014). Therefore, many recent studies have developed quantified TOD methods that make full use of objective data, such as patents and articles, to provide decision makers with decisive information for TOD.

The quantified approaches for TOD have advantages, in that they increase the efficiency of the TOD process and are able to provide experts with information beyond their knowledge and their technology domain (Yoon and Kim, 2011; Yoon et al., 2013). Directions for TOD can be largely divided into two types: forecasting new technologies and applying existing technologies (Yoon et al., 2014a, 2015). Forecasting new technologies is related to anticipating new technologies that have not yet been developed in a particular field or that are likely to emerge in

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the future, while applying existing technologies mainly focuses on new opportunity analysis that can be derived by using a firm's existing technologies. In particular, a TOD approach that modifies and reuses existing technologies for new technology opportunities can improve a firm's R&D practicality and performance while reducing the level of R&D investment risk (Yoon et al., 2015; Seo et al., 2016). Therefore, application technology opportunities, which can be developed from a firm's current technology capabilities for TOD, could be a good strategic alternative for those SMEs that lack technology information, experts, and/or facilities (Lee et al., 2014; Yoon et al., 2013).

TOD studies for technology forecasting and new technology identification have been actively carried out for some time, while TOD studies customized to a firm's technology capabilities have only relatively recently been attempted. Patents have been considered as straightforward proxies for identifying the level of technologies due to their feature as up-to-date reliable sources of technological intelligence; prior studies for the customized TOD have therefore used patent data as the main source for analysis and have identified technology opportunities by combining text mining and other techniques, including association rule mining (Seo et al., 2016), collaborative filtering (Yoon et al., 2013), morphology analysis (Yoon et al., 2014a; Leydesdorff et al., 2014), and syntactic and semantic analysis of technical sentences (Yoon et al., 2015; Lee et al., 2014). Their procedure typically involves the first step of defining a given firm's technologies or products; for example, technological capabilities are defined as products, technology keywords, and technology functions (subject-action-object or action-object structures) appearing in the firm's own patents.

Despite their contributions, these prior studies for customized TOD have some limitations. First, in most of these studies, the target firms' technology portfolios were not utilized; rather, their approach uses an individual technology or product as its input to locate technology opportunities. Previous studies suggested that the scope of a technology-based firm's technology strategy is contained in the firm's patent portfolio (Fabry et al., 2006; Lin et al., 2006; Brockhoff, 1992; Ernst, 1998, 2003) and using the firm's patent portfolio enables R&D managers to understand the firm's capabilities and competitive position in a specific technology field (Lin et al., 2006; Ernst, 2003; Song et al., 2016). Thus, using a technology or product alone as the input for TOD may impede the identification of technology opportunities that could have a synergetic effect on the firm's performance through the firm's overall patent portfolio. The second limitation is related to expert intervention-based text mining. In some of the prior studies, technical keywords were selected for analysis based on an expert's opinion, which would impede other technology analysts from methodologically reproducing their approach. In other studies, product names are exploited, but product information in patent text is usually represented as abstract expressions to maximize the application scope of a given patent. Therefore, objective information needs to be used that encompasses the scope of patents owned by a firm.

Therefore, this paper proposes an approach for application technology opportunity identification based on a target firm's existing technological portfolio through the combined analysis of patent classification and collaborative filtering. The proposed method involves 1) structuring firm-international patent classification (IPC) distribution vectors for all applicants using the main group-level IPC codes of each applicant's patents, 2) recommending IPCs untapped by the target firm and with high preference scores by using collaborative filtering, and 3) classifying the recommended IPCs for the firm's strategic decision-making support using indexes of heterogeneity, growth rate, and competition level. To show the workings of the approach, we applied it to a firm with wireless communication technology, building on the analysis of large-scale patents and their applicants.

The advantages of this study are threefold. First, this study suggests a novel approach to identify potential technology opportunities from a target firm's current technology portfolio, which can be defined as a set of IPCs assigned to the patents the target firm currently possesses or a set of IPCs obtained by manual examination for the target firm. Therefore, this study would further extend the coverage of existing TOD studies. Second, prior TOD studies still require frequent intervention by technology experts, but the proposed approach quantifies much part of the TOD process using objective data of patents. Therefore, our quantified approach would be in particular beneficial to SMEs with scare technical resources such as staff and information and thus assist such SMEs in the technology planning process to identify new technology opportunities for their sustainable development. Third, in connection with the first and second advantages, this approach will contribute to the systematic identification of application technology opportunities from a firm's technology capability while becoming a basis for developing future technology intelligence systems.

The organization of this paper is as follows. We present an overview of the groundwork, followed by our recommendation approach and its practical application to identify application technology opportunities. The conclusions with further research topics are then presented.

2. Theoretical background

A methodology is proposed to identify technology opportunities and to suggest R&D directions by using collaborative filtering and the IPC system. Therefore, this section briefly overviews the two theoretical backgrounds.

2.1. Collaborative filtering

Collaborative filtering is a personal recommendation system that seeks to predict the latent preference or rating of untapped items for a particular user by using the historical item preferences of other users (Breese et al., 1998; Goldberg et al., 2001; Herlocker et al., 2002; Groh and Ehmig, 2007). The main aim of collaborative filtering is to recommend items that are suitable for a target user, based on collecting and analyzing the information of users' preferences or their historical purchasing data. As personal information and purchase patterns is increasingly accumulated, a large number of service firms have provided personalized services that recommend favorite items to users by using collaborative filtering; these services have increased customers' satisfaction and firms' profits (Kautz et al., 1997; Linden et al., 2003).

The collaborative filtering procedure consists of two steps: 1) calculating the similarities between a target user and other users and 2) calculating latent preference scores for items untapped by the target user (Breese et al., 1998; Sarwar et al., 2000, 2001). The second step of the procedure follows a typical approach, while the first step should be conducted based on the careful understanding of data attributes. In terms of the data attributes, if user-item vectors are composed of 0 or 1, which refers to a simple purchase history, the Jaccard distance is commonly utilized to calculate the similarity between users. On the other hand, if user-item vectors are composed of preference scores, the cosine distance becomes the measure used to calculate the similarity between users. Some studies proposed methodologies to adapt collaborative filtering when calculating similarity between users. Sarwar et al. (2000) utilized the k-nearest neighbor (KNN) approach to calculate similarity to enhance the efficiency of collaborative filtering (Sarwar et al., 2000). Blei et al. (2003) utilized the Latent Dirichlet Allocation (LDA) technique, which is a topic modeling method for calculating similarity between users (Blei et al., 2003).

In contrast to other recommendation systems such as the contents-based recommendation technique that recommends new items based on item information, collaborative filtering has a number of advantages. First, while the contents-based recommendation technique can recommend items similar to a target user's items, the collaborative filtering technique can recommend unexpected items because this technique is based on other users' historical data. In addition, collaborative filtering does not depend on the information about an item; therefore, it can