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Technology opportunity discovery (TOD) from existing technologies and products: A function-based TOD framework

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ABSTRACT

Research into deriving technology opportunities from existing technologies or products (ETPs) is useful to technology-based firms, which have to expand their technology portfolios with limited resources. Therefore, this study proposes a function-based framework for technology opportunity discovery (TOD) from a firm's ETPs. This framework consists of: (1) a TOD knowledge base that structures information on products, technologies, and their functions, which has been extracted from 223,603 patents in various technical fields, and (2) a TOD logic that derives potential technology opportunities from an ETP using semantic functional similarities between technologies or products. This framework returns technology opportunities in terms of the four types of TOD paths: existing technology (eT) to technologies that can be developed by modifying eT, eT to products that can be produced by using eT, existing product (eP) to products that can be developed by modifying eP, and eP to technologies that can be adopted to improve eP. We implement the proposed framework in a prototype system, and demonstrate TOD cases, using several ETPs. This framework will contribute to creating systematic TOD based on current technological capability over a wide range of technologies, and become a basis for developing future automated technology intelligence systems.

1. Introduction

Recent global technology competition can be summarized as the process of discovering technology opportunities and exploiting them before competitors do. Accordingly, the ability to identify technology opportunities is positioned at the core of R&D competence for both nations and private firms (Zhu and Porter, 2002). Technology opportunities are defined by their promise of technological progress or their potential ability to drive technological advances within specific fields or over different industries (Yoon et al., 2013a; Lee et al., 2013). Technology opportunity discovery (TOD) is thus the process that identified opportunities with potential business value by developing and utilizing technologies and products. As competing technologies and products increasingly appear in the market and their life cycles shorten, firms' TOD capability, which promotes new profit creation for sustainable development, will be more important than ever before.

Directions for TOD can be largely divided into two types: forecasting new technologies and products, and applying existing technologies and products (ETPs) (Yoon et al., 2013a). The former is related to anticipating new technologies and products that have not been developed yet in a particular field or that are likely to emerge in the future (Daim et al., 2006), while the latter is related to the concept of open innovation

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(Chesbrough, 2010) and mainly focuses on new opportunity analysis that can be derived by utilizing ETOs that a firm currently possesses. Because the latter considers a firm's ETPs as the starting point for TOD, its results are more specific to and dependent on the present technology portfolio of the firm, compared to the generic characteristics of new TOD. However, TOD from ETPs would be useful and practical for technology-based firms, which could expand their R&D portfolios with limited resources. For example, TOD from EPTs could help small and medium enterprises (SMEs) continue to present new products in the market for long-term survival, despite the lack of technology resources, such as facilities, human experts, and investments. In this case, a TOD approach that modifies, reuses, or applies ETPs for new technology opportunities would be a good strategic alternative to improve a firm's R&D practicality and performance, and reduce the level of R&D investment risk (Yoon et al., 2013a).

Although experts' judgment remains important in TOD, research has revealed that experts are not always right and may be less reliable due to the increase in technical data and fragmented technology domains (Lee et al., 2013; Shibata et al., 2008). Therefore, many studies have aimed to develop analytical TOD methods that make full use of objective data, such as bibliographic and textual information of patents, to provide decisive input to decision makers. Growth curves have been used to forecast emerging technologies that will replace existing technologies based on publications of patents or journal articles (Daim et al., 2006; Bengisu and Nekhili, 2006), and convergent technologies among different technical fields have been anticipated using citations and patent classifications (Curran and Leker, 2011; Karvonen and Kässi, 2013). Recent TOD methodology incorporated text mining techniques and innovation theories to overcome the limitations of simple bibliometric analysis, including citation lag. Text mining-based patent network indicators (Yoon and Park, 2004; Yoon and Kim, 2011) and patent novelty assessment indicators (Geum et al., 2013; Gerken and Moehrle, 2012) have been suggested to identify opportunities presented by new technologies in rapidly evolving technological trends. There have also been attempts to quantify the process of TOD through visualization methods, such as patent maps (Yoon et al., 2013b) and vacuums (Lee et al., 2009), and systematic innovation theories, such as (Yoon and Park, 2005; Yoon, 2008), disruptive innovation (Yoon and Kim, 2012a), and system evolution patterns (Yoon and Kim, 2012b).

Despite the contributions, the prior TOD studies have some limitations. First, most studies focused on promising or new technologies, regardless of the present technology portfolio of firms, or their ETPs. The results of TOD have thus been generic in terms of technology and industry, and consequently may not be appropriate or applicable for most firms. Second, from the methodological perspective, most studies have identified technology opportunities within specific technical fields, but did not explore potential opportunities that may exist over a wide range of technology fields or even in different technology sectors. Third, the prior studies claimed to quantify and automate their methods for TOD, but they in fact depend on frequent subjective interventions of human experts; for example, selecting technical data, preprocessing the data, defining keywords, and incorporating similar keywords. Such subjective requirements would impede technology analysts from reproducing the methods to identify technology opportunities, and these methods are therefore inappropriate for implementing practical TOD systems.

To remedy these problems, this study proposes a new TOD framework based on the concept of function. The function, which means the action that affects any object or changes its attributes (Savransky, 2002), can be identified from a sequentially ordered sentence of subject-action-object (SAO) by natural language processing (NLP) of technical documents (Cascini and Russo, 2007; Bergmann et al., 2008). The function contains the key concepts regarding what a system does (Bergmann et al., 2008) or the purpose for which it is designed (Dewulf, 2006). The proposed framework extracts functions from 223,603 patents over a broad range of technical fields, thereby constructing a TOD knowledge base that relates functions to technologies, and technologies to products. The framework also includes the TOD logic that derives technology opportunities from a given ETP, using semantic functional similarity analyses. Building on the TOD knowledge base, the TOD logic returns technology opportunities in the form of product or technology in terms of the four types of TOD paths: existing technology (eT) to technologies that can be developed by modifying eT, eT to products that can be produced by using eT, existing product (eP) to products that can be developed by modifying eP, and eP to technologies that can be adopted to improve eP. This study implements the proposed framework as a prototype system, and demonstrates its use in practical TOD cases based on several EPTs for TOD paths.

The contribution of this study is threefold. First, the proposed framework can identify specific technology opportunities to which a given ETP can be applied, and which improve the EPT. Second, such opportunities can be derived without restriction of technical fields through functional similarity analyses among pairs of technologies (or products). Third, by using the TOD knowledge base and TOD logic, the framework provides a mechanism for automated computational analysis, called B-to-Y automation; all steps for TOD in our framework are automated, except (A) defining an ETP with functions and (Z) examining the identified opportunities. This framework will contribute to systemizing the TOD based on firms' ETPs, and could become a basis for developing future practical technology intelligence systems.

The organization of this paper is as follows. We present an overview of SAO-based patent analysis and its applications, followed by the TOD framework to support four types of TOD paths and TOD examples using a prototype system. Finally, we conclude the paper with discussions and future research topics.

2. Backgrounds

2.1. Function and SAO structure

The concept of function, which has been used for the structured analysis and specification of a system (DeMarco, 1979), is a major element that explains “what a system does” or “what a system is for” (Dewulf, 2006). Functions have been described as the desired output of a system (Suh, 1990) and are strongly related to the objectives that a system or its components should accomplish (Yoon et al., 2011a). Functional analysis, in fact, has a long history in the design of products and information systems because it assists designers in decomposing a complex system into more manageable