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An ANP-based technology network for identification of core technologies: A case of telecommunication technologies

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Abstract

There have often been attempts to examine technological structure and linkage as a network. Network analysis has been mainly employed with various centrality measures to identify core technologies in a technology network. None of the existing centrality measures, however, can successfully capture indirect relationships in a network. To address this limitation, this study proposes a novel approach based on the analytic network process (ANP) to identification of core technologies in a technology network. Since the ANP is capable of measuring the relative importance that captures all the indirect interactions in a network, the derived "limit centrality" indicates the importance of a technology in terms of impacts on other technologies, taking all the direct and indirect influences into account. The proposed approach is expected to allow technology planners to understand current technological trends and advances by identifying core technologies based on limit centralities. Using patent citation data as proxy for interactions between technologies, a case study on telecommunication technologies is presented to illustrate the proposed approach.

Keywords: Analytic network process (ANP); Technology network; Core technology; Centrality; Patent citation

1. Introduction

Due to the intractable complexity and volatility of modern technologies, it becomes more important to photograph the overall structure and internal linkage of technology networks with the aim of grasping technological trends and advances. Identifying and assessing technological advances critical to the company's competitive position is now recognized as a crucial activity for achieving and maintaining competitive positions in a rapidly evolving environment (EIRMA, 2000). Since technology systems are characterized by strong interdependence (Archibugi & Pianta, 1996), there have often been attempts to examine technological structure and linkage as a form of network (Shin & Park, 2007; Wartburg, Teichert, & Rost, 2005; Yoon & Park, 2004).

What is at the core of measuring technological interdependence or linkage is patent information (Kim, Suh, & Park, 2007). Patents have been the representative proxy for technology (Trajtenberg, Henderson, & Jaffe, 1997). A number of studies have been conducted to identify current technology structure and make a projection of technological future trends by using patent analysis (Archibugi & Pianta, 1996; Basberg, 1984; Basberg, 1987; Chen, Chang, Huang, & Fu, 2005; Gangulli, 2004; Grupp, Lacasa, & Schmoch, 2003). Several measures have been employed for measuring technological linkage with patents, such as co-classification (Breschi, Lissoni, & Maleraba, 1998; Grupp, 1996), co-word (Courtial, Callon, & Sigogneau, 1993), and keyword vector similarity (Yoon & Park, 2004). Among those, citation analysis has been the most popular one in spite of controversial discussions about its validity. The underlying assumption is that there exists a technological linkage between the two patents if a patent cites another patent.

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Network analysis has often been used in conjunction with patent citation analysis with the aim of grasping the overall relationship and structure in a network. What is at the center of interest is to identify important or core technologies in a technology network (Shin & Park, 2007). As a quantitative measure of importance in a network, centrality measures can be used in network analysis. Among various measures, degree centrality has been implicitly deployed as an indicator of importance of technologies in the previous studies (Trajtenberg et al., 1997). However, it does not mirror indirect relationships despite the fact that indirect citations as well as direct citations play a crucial role in characterizing technology networks (Wartburg et al., 2005). There are other centrality measures that mirror indirect citations such as eigenvector centrality (Bonacich, 1972) and reachability out-degree (Wartburg et al., 2005). None of the measures, however, can successfully capture indirect relationships and produce meaningful results for identifying core technologies in a patent citation-based technology network.

To address these limitations, this study proposes a novel approach based on the analytic network process (ANP) to identification of core technologies in a technology network. Since the ANP is capable of measuring the relative importance of technologies that captures all the indirect interactions in the technology network, the derived "limit centrality" can be used as an implicative centrality measure characterizing a technology network and showing core technologies in the network.

The remainder of this paper is organized as follows. Section 2 deals with the previous studies on patent analysis and centrality measures in network analysis. The underlying methodology of the proposed approach, the ANP, is briefly introduced in Section 3. The proposed approach is explained and illustrated with a case study in Section 4. The paper ends with conclusions in Section 5.

2. Background

2.1. Patent analysis

Patents and patent statistics have long been used as technological indicators (Grilliches, 1990). Although patents have been the representative proxy for technology as direct output of R&D activities, there has been a ceaseless controversy about the use of patent analysis since patents have advantages and disadvantages like any other technological indicator (Archibugi & Pianta, 1996). The pros and cons of patent analysis are not explained here in detail, but can be found in the literature by Grilliches (1990), Archibugi and Pianta (1996), and Ernst (2003).

The most common method for early patent analysis was to simply count patents and to compare how many patents had been assigned to each entity, e.g. nations, firms, and technological fields (Wartburg et al., 2005). The basic idea is the more patents belong to different entities, the more important the entity is. Due to the highly skewed distribution of patent values, however, judgments on importance based on simple patent counts could be biased to a large extent in many cases (Harhoff, Scherer, & Vopel, 2003). It is also incapable of measuring importance that mirrors influences or linkages among entities.

Thus, what has become the center of interest in patent analysis is citation information. Patent citation analysis is based on the examination of citation links among different patents (Narin, 1994). The use of citation information in patent analysis boosts studies from various streams. One of the main research topics is to measure the values of patents based on the number of citations of patents in subsequent patents. It is validated by a number of evidences that more frequently cited patents have higher technological and economic value (Breitzman & Thomas, 2002; Narin, Noma, & Perry, 1987; Trajtenberg, 1990). In this context, many studies have employed the number of citations as an indicator of patent quality (Ernst, 2003; Hirschey & Richardson, 2001; Lanjouw & Schankerman, 1999; Reitzig, 2004). Firm's value can also be measured based on the values of patents belonging to the firm (Hall, Jaffe, & Trajtenberg, 2001). Another subject of studies with patent citation information is to identify similarities between technologies. The similarity information can be used for identifying technology overlaps with collaborative firms (Mowery, Oxley, & Silverman, 1998), and proposing a new classification system by clustering patents (Lai & Wu, 2005).

The use of patent citation information in this study is in line with the other research stream, analyzing technological knowledge flows or technological linkages based on patent citation relationships. However, patent citation analysis alone cannot grasp the overall relationship and structure among all the patents because it merely captures individual links between two particular patents (Yoon & Park, 2004). To address this limitation, network analysis, which will be dealt with at the next section, has often been used in conjunction with patent citation analysis to measure technological knowledge flows between entities and identify important or core entities. A number of studies have been conducted at various levels, such as national level (Jaffe & Trajtenberg, 1998), industry level (Han & Park, 2006), firm level (Ham, Linden, & Appleyard, 1998), and technology class level (Shin & Park, 2007).

2.2. Network analysis and centrality measures

In general, the interactive relationships among actors can be portrayed as a network composed of actors (nodes) and interactions (edges) (Gelsing, 1992). The structure of relations among actors and the location of actors in the network provide rich information on diverse aspects of an individual actor, a group of actors, and an overall network (Marseden & Laumann, 1984). Thus, network