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Subject–action–object-based morphology analysis for determining the direction of technological change

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ABSTRACT

Morphology analysis, despite being a strong stimulus for the development of new alternatives, largely relies on domain experts and neglects the relationships between keywords in the construction of morphological structures. In addition, there are few systematic approaches to prioritize the morphological configurations. To address these issues, a hybrid approach is proposed, which enhances the performance of morphology analysis by combining it with subject–action–object (SAO) semantic analysis. Initially, a keyword co-occurrence patent set for subsequent SAO analysis is prepared based on keywords frequency vector analysis. Then, SAO structures are extracted and semantic analysis is performed to identify the relationships between keywords, which help to build morphological structures more objectively. In addition, a well-defined evaluation system that contains eight sub-indexes is proposed to evaluate the morphological configurations. Finally, to demonstrate and validate the proposed approach, the dye-sensitized solar cells technology is employed as the case study. Results indicate that the most promising combination we predict appears frequently in 2012–2014 and the distribution of it is also close to the fact in 2012–2014. Accordingly, the proposed method can be used to effectively determine the direction of technological change and to forecast technology innovation opportunities.

1. Introduction

Technology forecasting anticipates the direction and rate of technology change and thus facilitates decision making in managerial issues such as setting priority, resource allocation and risk reduction for technology development. Therefore, technology forecasting can satisfy both public and private needs (Yoon and Park 2007). Numerous techniques have been developed to support technology forecasting. Broadly, technology forecasting techniques can be divided into two categories: exploratory and normative methods. Morphology analysis, a normative technology forecasting method, is considered a strong stimulus for the development of new alternatives (Xu and Leng 2012; Yoon et al. 2008).

When compared with other methods, the strength of morphology analysis lies in its speed and ease of application because the process can be implemented and quickly evaluated and does not require excessive amounts of data (Yoon and Park 2007). It has two key elements: construction of morphological structure and evaluation of morphology configurations. However, morphology analysis cannot operate independently, i.e. it must either be supported by or used as a facilitator in support of the forecasting process of other technology forecasting methods. Therefore, in recent research, computerized algorithms and text mining technology have been introduced into morphology analysis to identify future technology opportunities (Yoon et al. 2014).

However, two aspects of current research require improvement. First, instead of a keyword-based method, a semantic-based method is required to build technology morphological structure. In previous research, the construction of morphological structure has been primarily dependent on expert knowledge and intuition. To reduce this dependency on domain experts and manual expertise, several studies have introduced keyword-based methods to construct morphological structure (Xu and Leng 2012; Yoon and Park 2004). However, a keyword-based method can only identify connections between keywords. It cannot clearly represent what kind of relationships they are and is unable to identify the purpose of a technology. Therefore, a method with semantic analysis is needed to enhance the accuracy of morphological structure.

Second, a systematic and comprehensive technology evaluation index system is needed to evaluate morphological configurations. Yoon and Park used patent citation analysis and conjunction analysis to prepare priority lists for morphological configurations (Yoon and Park 2007). Based on Yoon's method, Xu and Leng added the frequency of keywords and factor contribution to evaluate morphological configurations (Xu and Leng 2012). In fact, due to an absence of citations or citation delay, some patent technology might impose limitations during patent citation analysis. Therefore, based on citation analysis, a systematic and comprehensive technology evaluation index system is required to identify all feasible forms of new technology development and forecast the most promising combinations.

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To address these issues, this study proposes an improved morphology analysis approach for technology forecasting based on subject–action–object (SAO) semantic analysis and text mining method.

SAO structure is a key concept that can show the relationship between components used in a relevant patent (Cascini et al. 2004a). If we connected SAO structures in a chain fashion, the relationship between each S/O can be identified by analysing the action (A). Therefore, in the proposed method, we use SAO chain semantic analysis and text mining to construct technology morphological structure. Based on patent analysis and bibliometrics analysis, a well-defined process that utilizes quantitative data is proposed to support evaluation of morphological configurations. In this process, we synthetically build two indexes, a technology importance index and a technology development potential index, which include eight evaluation sub-indexes in total. Relative to data selection, patent documents and literature data are integrated for consideration. Note that the dataset is divided into three parts, i.e. training data, validating data and test data, to validate the proposed method.

This remainder of this paper is organised as follows. In Section 2, works related to morphology analysis and SAO semantics are defined. In Section 3, the concept and framework of the hybrid method is proposed and explained in detail. In Section 4, a dye-sensitized solar cell (DSSC) case is examined to illustrate and validate the proposed method. Finally, concluding remarks, limitations of the current research and future considerations are discussed in Section 5.

2. Background

2.1. Morphology analysis

Morphology analysis was introduced by Zwicky in the 1940s to structure and investigate the total set of relationships contained in multi-dimensional, non-quantifiable problem complexes (Zwicky 1969). It is a method to structure rather than solve a problem. A system is typically composed of a number of subsystems, each of which may be shaped in a number of different ways. Therefore, morphology analysis can be used to identify the various shapes that each dimension takes. By combining these shapes, it examines all possible alternatives that a system may adopt (Wissema 1976).

In traditional morphology analysis, the construction of morphological structure primarily depends on expert knowledge and intuition (Ritchey 1998). To reduce the dependency on domain experts and manual expertise, several computer-aided methods have been introduced to improve morphology analysis. Ritchey introduce advanced computer support for morphology analysis (Ritchey 2003). Meanwhile, other methods, such as scenario laboratories (Ritchey 2009), bayesian networks (Waal and Ritchey. 2007), are introduced into computer-aided morphology analysis for strategic decision support. Besides, Yoon and Park proposed a patent text keyword-based morphology analysis approach. They used conjoint analysis to eliminate infeasible combinations and list the remaining combinations in order of importance (Yoon and Park 2007). Yoon, Park and Coh further introduced text mining method into morphology analysis to explore technology opportunity (Yoon et al. 2014).

In these approach, the computerized algorithms and text mining technology help a lot for technology forecasting. However, the keyword-based method cannot represent how keywords are related and is unable to identify the purpose of a technology. Therefore, in this paper, we introduced SAO semantic analysis to compensate for the limitations of keywords-based approaches.

2.2. SAO semantic analysis

SAO structures are composed of Subject (noun phrase), Action (verb phrase) and Object (noun phrase). It emphasizes the "key concepts" and can provide various technology information on their semantic relationships (Cascini et al. 2004b; Choi et al. 2012a).

Generally, the SAO structures are extracted from technology literature or patent documents. Consequently, SAO structures can offer a significant amount of technology information. In particular, in SAO structures, subjects and objects may refer to components of a system, and actions may refer to functions performed by and on components (Choi et al. 2012b). Thus, this syntactically ordered sentence can explicitly describe a relationship between components that appear in the relevant article (Yoon and Kim 2011a). It can also state partitive relationships among products or technologies. Besides, an SAO structure can be organized in a problem–solution format if the action–object (AO) forms the problem and the subject (S) states the solution.

Several researchers have attempted to use SAO structures for meeting various needs, including inventor analysis (Moehrle et al. 2005), patent infringement risk analysis (Bergmann et al. 2008), patent similarity measure (Cascini and Zini 2008), technology monitoring (Chang et al. 2010), product forecasting (Gerken et al. 2010), construction of technical trees (Choi et al. 2012c), technology trends analysis (Yoon and Kim 2011a; Choi et al. 2011), patent function network analysis (Choi et al. 2010), R&D planning (Yoon and Kim 2011b) and technology opportunity analysis (Yoon and Park 2005; Yoon and Kim 2012).

With its unique advantages, SAO semantic analysis can provide more valuable information than a keyword-based method. Therefore, in this study, the SAO semantic analysis method is used for the construction of morphological structure.

3. Methodology

3.1. Basic concepts

In this paper, to address the limitations of traditional keyword-based method, we introduce SAO method to determine the relationship between product and components/materials. For example, a typical case of SAO structure is 'thin film cells composed of MnPc and monoazo dye'. In the sentence, 'thin film cells' is the product, and 'MnPc' and 'and monoazo dye' are its materials. Thus, the relation between product and material can be identified.

The SAO-based morphology analysis approach for technology forecasting primarily includes four modules (Fig. 1). The basic concept is as follows.

First, based on keywords frequency vectors, we identify a patents dataset that includes two or more keywords in a patent text. We then extract SAO structures from these patent texts and connect SAO structures based on the similar words from the subject and object. Thus, we can identify the relationship of keywords based on the action (A). Simultaneously, the SAO structures are extracted from the entire text of selected patents. Therefore, the words beyond the list of keywords may also appear in SAO structures. Thus, the words and relationship are not confined to the list of keywords. Note that some low and

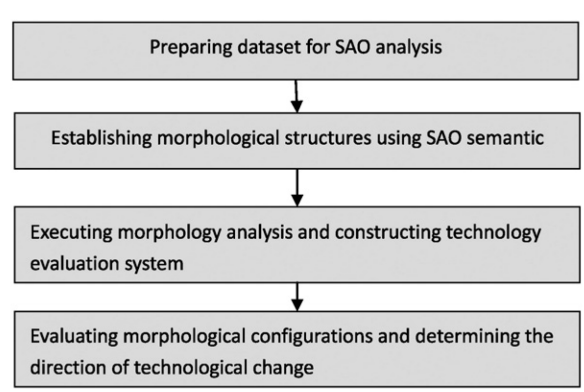

Fig. 1. Framework of the SAO-based morphology analysis approach.