Expert Systems with Applications 39 (2012) 2927–2938

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

TrendPerceptor: A property–function based technology intelligence system for identifying technology trends from patents

Janghyeok Yoon, Kwangsoo Kim *

Department of Industrial and Management Engineering, Pohang University of Science and Technology, San 31, Hyoja-dong, Nam-gu, Pohang, Kyungbuk 790-784, Republic of Korea

ARTICLE INFO

Keywords:
Technology intelligence
Property
Function
Patent mining
Patent analysis
Social network analysis
TRIZ trend
Natural language processing

ABSTRACT

Technology intelligence systems are vital components for planning of technology development and formulation of technology strategies. Although such systems provide computation supports for technology analysis, much effort and intervention of experts, who may be expensive or unavailable, is required in gathering processes of information for analysis. As a remedy, this paper proposes *TrendPerceptor*, a system that uses a property–function based approach. The proposed system assists experts (1) to identify trends in invention concepts from patents, and (2) to perform evolution trend analysis of patents for technology forecasting. For this purpose, a module of the system uses grammatical analysis of textual information to automatically extract properties and functions, which show innovation directions in a given technology. Using the identified properties and functions, a module for invention concept analysis based on network analysis and a module for evolution trend analysis based on TRIZ (Russian acronym of the Theory of Inventive Problem Solving) trends are suggested. This paper describes the architecture of a system composed of these three modules, and illustrates two case studies using the system.

1. Introduction

Modern economies emphasize the role of research and development (R&D) that promotes the creation, diffusion and accumulation of intellectual properties within economic systems. In general terms, R&D refers to "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of knowledge to devise new applications" (OECD, 2008). As a method to improve the effectiveness of R&D activities, technology intelligence has been introduced to plan technology development and formulate technology strategies. Technology intelligence is "the capture and delivery of technological information as part of the process whereby an organization develops an awareness of technological threats and opportunities" (Kerr, Mortara, Phaal, & Probert, 2006). Technology intelligence includes technology monitoring, technology assessment, and technology forecasting (Lichtenthaler, 2004). As technology lifecycles shorten and business environments become more globalized, technology intelligence capabilities have become increasingly important for experts such as researchers, practitioners and R&D policy makers.

Technology intelligence tools have several advantages over expert-based approaches (Yoon, 2008), including:

1. Ability to analyze large quantities of information which cannot be analyzed by humans alone.
2. Ability to generate much useful information which humans cannot produce. For example, they can visualize the relationship between technology and companies, and analyze the characteristics of technology using statistical analysis.
3. Ability to support decision making processes with relevant information including technology assessment and technology forecasting.

Technology intelligence tools assist experts to make strategic technology plans. With respect to content analysis of technical documents, many technology intelligence tools have been actively developed to identify technology trends and give technological insights. The Theory of Inventive Problem Solving (Russian acronym: TRIZ) (Altschuller, 1984) has been used as a tool for technology intelligence (Schuh & Grawatsch, 2004). Among its many tools, TRIZ trend analysis identifies the evolutionary status of systems to predict further improvement of technology by using defined system evolution patterns called TRIZ trends (Mann, 2002, 2003). Thus, TRIZ trend analysis gives decisive information to determine the threats and opportunities presented by competing technologies (Schuh & Grawatsch, 2004). Although tools exist to facilitate identification of TRIZ trends, they rely heavily on skills and knowledge of TRIZ experts in gathering TRIZ trend-related information and determining specific TRIZ trends and trend phases (Verhaegen, D'Hondt, Vertommen, Dewulf, & Duflou, 2009). Diva (Morris,

* Corresponding author. Tel.: +82 54 279 8231.
E-mail addresses: janghyoon@postech.ac.kr (J. Yoon), kskim@postech.ac.kr (K. Kim).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.08.154

DeYong, Wu, Salman, & Yemenu, 2002), a bibliometric analyzer of collections of scientific literature and patents, is a computer program that visualizes patent clusters and gives insight into trends in the technological field of interest. Patinformatrics tools (Trippe, 2003) such as VantagePoint and Aureka can cluster data, mapping document clusters and generate co-occurrence matrices so that analysts can discover relationships or trends in a given technology. In addition, Techpioneer (Yoon, 2008), an expert system for excavating potential technology opportunities, uses text mining and morphology analysis; the system outputs valuable information such as the trends of keywords and the morphology of existing technology, and identifies promising opportunities for technology development. However, in the aspect of content analysis of technical documents, these tools require that the set of keyword or key phrase patterns be defined in advance; this task relies heavily on the knowledge and effort of domain experts, who may be expensive or unavailable. Furthermore defining keyword or key phrase patterns of adjacent or emerging technology areas may be a difficult task even for experts, because their knowledge cannot extend over all technology areas. Fundamentally, these experts need to more concentrate on their knowledge activities that identify technology trends and promising technologies, but too much of their effort and time should not be consumed in gathering processes of information for technology analysis.

To eliminate these dependencies on effort of experts, this paper proposes *TrendPerceptor*, a system that uses a property–function based approach. The proposed system assists experts (1) to identify trends in invention concepts from patents, and (2) to perform evolution trend analysis of patents for technology forecasting.

Properties and functions imply invention concepts of a system (Dewulf, 2005, 2006; Verhaegen et al., 2009). Properties, which are the specific characteristics of a system or its sub-systems, are usually expressed using adjectives; functions, which are useful actions of a system or its sub-systems, are usually expressed using verbs (Dewulf, 2006). By exploiting these grammatical relationships, properties and function can be obtained using grammatical analysis of textual information. To this end, *TrendPerceptor* uses natural language processing (NLP) to automatically extract properties and functions from patent documents. This system facilitates experts to analyze technological trends of a given technology by providing a network composed of the identified properties and functions. Additionally, the system assists experts to predict further improvements of a system by automating the processes of TRIZ trend analysis. The final output of TRIZ trend analysis consists of evolutionary potential radar plots which show the evolution status of patents related to a technology; they can be used as valuable input for technology forecasting based on TRIZ trends.

Chapter 2 presents the groundwork of this research. On the basis of the groundwork, chapter 3 describes the system architecture of *TrendPerceptor* in detail, and chapter 4 introduces two case studies using the proposed system. Finally chapter 6 presents conclusions and future work.

2. Groundwork

2.1. Property–function analysis

Dewulf (2006) presented a property–function based approach to identify connections among products, processes and systems in different domains: a property addresses 'what a system is or has' and expresses a specific characteristic of a system or its subsystems; a function addresses 'what a system does or undergoes' and expresses a useful action of a system or its subsystems. On the basis of investigation of about 16,000 patents from the U.S. Patent and Trademark Office (USPTO), he found that properties are generally expressed using adjectives, whereas functions are generally expressed using verbs (Dewulf, 2006). This means that properties and functions can be identified using grammatical analysis of textual information (Dewulf, 2006). However, using only adjectives and verbs does not sufficiently represent concreteness of technology domains because this research aims at identifying technological trends from specific technology areas. Therefore this paper proposes representing properties and functions in the form of binary relations, which are simple but concrete two-word expressions: properties are expressed as 'adjective + noun' forms, and functions are expressed as 'verb + noun' forms. Using the extracted properties and functions, *TrendPerceptor* facilitates technology trend analysis such as invention concept analysis of patents and evolution trend analysis of patents.

2.2. Stanford dependencies representation and Stanford parser

Because properties and functions can be identified by analysis of the grammatical structure of textual information, this paper uses the Stanford parser to automatically extract information concerning properties and functions. The Stanford parser is an NLP parser that provides a JAVA-application programming interface and is based on the Stanford dependencies representation. The Stanford dependencies representation for English was designed to provide a simple description of the grammatical relationships in a sentence that can be easily understood and effectively used by people who have no linguistic expertise (de Marneffe & Manning, 2008B). Currently, the dependencies are categorized into 55 grammatical relations, which are all binary: a grammatical relation holds between a governor and a dependent (de Marneffe & Manning, 2008A). Any grammatically correct sentence can be represented by the Stanford dependencies (Fig. 1) and, conversely, the Stanford parser can extract specific binary relations from the sentence. In this paper, the proposed system uses the Stanford parser to preprocess texts of patents for further analysis.

2.3. Network analysis

Network analysis is a popular method for identifying technology trends in bibliometrics (Lee & Jeong, 2008), which is a set of tools used to study or measure texts and information. Network analysis using technology keywords encompasses (1) defining a set of keyword patterns or key phrase patterns, (2) generating a network that codifies the relationship between occurrences of the patterns, and (3) identifying technological trends by interpreting the network (Lee & Jeong, 2008; Yoon, 2008; Chang, Wu, & Leu, 2010). The network allows identification of priorities and relationships among the patterns by applying social network analysis (SNA), which maps and measures relationships and interactions among people, groups, organizations, computers or other connected entities (Hanneman & Riddle, 2005). For invention concepts analysis of patents, the system proposed in this paper organizes a network by using co-occurrences of properties and functions, and outputs files that are formatted appropriately for further analysis using external SNA tools such as NetMiner, UCINET and Pajek.

2.4. TRIZ trend analysis

Originally, eight laws of technical system evolution were identified (Altschuller, 1984), but recently an updated list of 35 TRIZ trends was presented, incorporating new domains and reflecting new innovative solutions (Mann, 2002). These trends are grouped into space (12 trends), interface (17 trends) and time (6 trends). These evolution laws show specific evolution sequences of systems (Petrov, 2002). TRIZ philosophy follows the concept that systems evolve toward increasing ideality, where ideality = (conceived