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Monitoring the organic structure of technology based on the patent development paths

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ABSTRACT

As the strategic importance of understanding changes in technology for successful business of most firms increases, the ability to analyze and monitor the current stage and history of technology is reckoned as a critical asset both for gaining competitive advantage and identifying promising niches. Patent citation networks have been widely used for systematic and empirical analysis of technology development. Understanding of technology's detailed changes in large patent citation networks, however, is difficult to achieve because of these networks' large and complex structures. To overcome this problem, we suggest an algorithm that identifies patent development paths from a large patent citation network by evaluating the weight of citations between patents. We then apply this algorithm to flash memory patents in an empirical study. Our algorithm is a new methodology that can be used to analyze the dynamic and complex structure of individual technologies.

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1. Introduction

Technology is one of the most important elements for providing companies with remarkable revenue in the current competitive environment. Even when a company dominates a competitive market based on its technological advantage, the company should continue technology development activity to create dominant products or services by identifying, adopting, and leading the changes in technology in the competitive field. Hence, companies operating in competitive environments demanding new product development, process improvement, and technology-enhanced services must obtain and organize information on emerging technologies [1].

Firms may conduct research and development (R&D) activities and invest in technology, but it is not easy for firms to orient their strategies to this technological environment and use them to their own benefit [2]. This is why investing based on forecasts of promising markets, preparing products, and selecting emerging technologies for those products is very risky. In this process, one of the critical factors for firms to establish technological strategies is to identify and understand the technological development trends. The increasing importance and benefits of technology have led to a wide range of applications and studies examining the management of technological forecasting. The objective of these applications and studies is to track developments in a particular area that may serve to forecast technology [3], set up research-funding priorities [4], investigate product development history [5], monitor technology trends [6], integrate technology management processes [7], identify technological opportunities [1], and visualize technological information [8].

Previous approaches to analyzing and forecasting technological development, however, have several limitations. First, these approaches cannot provide systematic information about the technology development process based on objective technological data. Objective information is a critical factor in successful technological forecasting. It is, however, very difficult to explain the

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Table 1
Technological forecasting techniques [15].

Technique	Characteristics	Description
Consensus method	Subjective procedure	Panel of experts debate the subject face-to-face. It is an intuitive procedure
Delphi method	Subjective procedure	Panel of experts answer several rounds of questionnaires, but they usually do not meet each other face-to-face. It is
Structural models	Quantitative procedure	Attempting to develop a mathematical or analytic model for accomplishment of the forecasting
Scenarios	Combined procedure of subjective, cognitive and quantitative procedure	It is not a formal technique. It serves as a guide which helps to foresee the future. It tires to identify treats and opportunities for the firms
Technological vigil	Combined procedure of subjective, cognitive and quantitative procedure	It is the administration of the flow of the scientific, technical and technological information, in order to aid the innovation process

detailed processes of technology development using traditional forecasting methodologies. Hence, providing sufficient information about technological change is still necessary for successful technological forecasting. Second, a systematic approach is necessary to explain the detailed development processes of technology. Even though various methodologies such as statistical analysis, diffusion modeling, and trend extrapolation can be applied to technological forecasting to enhance the objectivity of analysis results, they cannot explain the complex structure of the detailed development of technologies. They can describe only the overall directions and processes of technological development at the macro level. To overcome these limitations, we take a systematic approach to identifying organic and complex structures of current technology.

In this context, we propose a technology development map to analyze changes in technology in detailed micro-level. This map is developed using patent analysis, because this is the most widely used methodology in formalized and systematic approaches to identifying and managing technological change. Patents are the primary output of the R&D activity of firms. The utilization of patent data, however, is not limited to protecting the legal right to developed technology. Patents and patent data can support many aspects of technology management [9].

In the remainder of the paper, first we describe technological forecasting, patent analysis, and patent citation analysis as the background for this research, in Section 2. Second, the proposed algorithm to identify the patent development path is explained in Section 3. As an example and application of the suggested approach, development paths for flash memory system patents are presented and discussed in Section 4. The implications of this research are discussed in Section 5. Finally, in Section 6, we conclude with a summary and the implications of our results.

2. Background

2.1. Technological forecasting

Technological forecasting is of great interest for both theory and practice in the establishment of technological strategy and planning. Technological change requires a new set of engineering and scientific principles. It may reinforce the dominance of firms in the market or open up new market [7,10–12]. On the other hand, many studies show that an inadequate reaction to technological change may lead to the demise of established company [10,13,14]. Insufficient information on technological trends and managerial incompetence are the main reasons for failure in the market. Hence, societies, scientists, planners and decision-makers should endeavor to discover the current status of technology and anticipate future events [15]. This has been called technological forecasting.

Many researchers have suggested various observations of technological trends to forecast technological change at an early stage and increase the effectiveness of technological decision-making. In the literature, many terms are used for this process of acquisition, assessment and communication of information on technological trends to detect opportunities and threats in a timely manner [7]. Furthermore, a detailed analysis of studies that were carried out in different industries shows that the ability of firms to forecast technological change is a major factor in managing the risk of organizational failure in the face of rapid technological development [16,17].

Porter et al. (1991) argued that the cornerstone for technological forecasting is identification of current technology [18]. It is vital in its own right to comprehend "who is doing what now" with respect to a given technology. This underpins forecasting in two critical ways — forthcoming technological change is foreshadowed by current developments and will be influenced by changes in related technologies, and relevant contextual influences are the most essential ingredients in effective technological forecasting [19].

Typical techniques for identifying and forecasting technological change are the consensus method, the Delphi method, structural models, scenarios and technological vigilance. The characteristics of these techniques may be described with subjective procedure, quantitative procedure and combined procedure as shown in Table 1 [15]. First, the consensus method and the Delphi method are subjective procedures. The subjective procedure depends on the experts' qualitative and intuitive knowledge. This, however, may be biased because of the subjectivity of experts' knowledge and opinion. Moreover, even after a basic innovation, some experts may be too pessimistic about progress because they are familiar with the problems and difficulties of new technology [20,21]. The structural model, as a representative quantitative procedure, may eliminate these subjective factors. This model isolates certain elements that are important to the technological generation process, explaining and expressing mathematically some of the functional relationships among the elements involved. These models, however, tend to be abstractions. Omissions of

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