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Triggering navigators for innovative system design: The case of lab-on-a-chip technology

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ABSTRACT

Technology innovation is critical for organizational and economic development and thus has been widely discussed. In spite of the extensive research, however, the research community has made few efforts to guide the direction of innovation, considering the general evolutionary patterns of technical systems. Therefore, this research suggests a novel approach to predict prioritized directions of innovation as well as to create the most promising design of practical concept design. For the purpose, firstly, we analyze the main functions of a target system using function analysis techniques. Then we develop an evolution opportunity map based on the Laws of Technical Systems Evolution in TRIZ, from which we generate the most suitable concept for a next-generation system. Finally, we analyze technical challenges that might arise in realizing the concept using Su-field analysis, which can help to obtain a feasible solution for it. Samsung Advanced Institute for Technology in Korea adopted the suggested approach to the new technology generation process, and verified its practicability and utility. We expect this research to be useful for those in charge of innovation management or new product development processes.

1. Introduction

Organizational and economic development, growth and wealth require technology innovation (Feldman & Desrocher, 2003; Ritsila, 1999). Usually, new technologies and processes contribute to a better utilization of resources, higher quality of routine tasks and higher productivity. Innovation is the process of implementing new technologies and new processes (Porter, 1990; Rogers & Shoemaker, 1971; Voss, 1994) and companies that use innovative technologies and processes can generally create better quality and cheaper products, thereby enjoying high potential growth (Bonnardel & Zenasni, 2010; Minitti, Bygrave, & Autio, 2006). Especially in the global marketplace where the pace of technology change rapidly reduces product and service lifecycles, new product introduction through continuous innovation is crucial for a firm to survive (Oliver Dostalerb, & Dewberry, 2004). Consequently, innovation has been widely discussed and attracted extensive research efforts particularly on how to search for the possibilities of innovation (Isaksen & Ekvall, 2010). Various approaches to creating innovation by examining functions of products and then trying to improve them, such as Quality Function Deployment (QFD) (Cohen, 1995), Functional Analysis and Systems Technique (FAST) (Kaufman & Jerry, 1977), the Kano model (Kano, Seraku, Takahasi, & Tsuji, 1984), conjoint analysis (Huertas-Garcia & Consolacion-Segura, 2009) and Morphology Analysis (MA) (Yoon & Park, 2007) and other innovative design methods (Chen & Feng, 2009), have been studied actively in marking, product engineering and technology management areas. Although these studies are meaningful in that they suggest a systematic process that can help thinking about the possibilities of new products, they are seldom interested in pointing out the desirable direction of improvement or the possible directions of innovation. Customer information can lead to the way to improve as in QFD, Kano model or conjoint analysis, but its usage is limited to market-driven products for which customer needs are clear and well-specified. For high-tech products and services, the role of technology is critical in their innovation (Bonnardel & Zenasni, 2010; Burkhardt & Lubart, 2010) and different strategies to find innovation opportunities are required.

This research suggests a way of predicting priority directions of innovation as well as creating the most promising design of practical concept design especially for technology-based products. The Theory of Inventive Problem Solving (TRIZ) was adopted as a main method to facilitate creativity, which purposes to solve technical problems and offers innovative product structures by employing a knowledge base built from the analyses of approxi-

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mately 2.5 million patents (Alshuller, 1984). Since it was first proposed, TRIZ has gained a wider application area and its success has attracted many people in academia (Cong & Tong, 2008; Ishihama, 2003). Also in practice, many large manufacturing companies such as Ford Motor, Motorola, Boeing and NASA are trying to use TRIZ to increase their creativity (Moehrle, 2005). Nevertheless, there is limited knowledge of how to find new technology opportunities using TRIZ in the context of technology management, because most of TRIZ research has emphasized case studies, not a TRIZ-based new technique, through there are some exceptions (Jiang, Sun, & Shie, 2011; Li & Huang, 2009). As part of an effort to link TRIZ to technology management tools, this research proposes a novel approach to identifying technology innovation opportunities by utilizing MA together with TRIZ. MA is used to analyze the system functions before the TRIZ techniques are applied to the map and an Evolution Opportunity Map (EOM), which is a map to help identify innovation opportunities, and a main idea of this research. The suggested approach was applied to the new technology generation process in Samsung Advanced Institute for Technology (SAIT), a private research centre in Korea, and verified its feasibility and utility. This research can be considered as an effective and powerful approach to support creating innovative ideas and also be practical since it was conducted from the perspective of company needs.

The remainder of this paper is organized as follows. In Section 2, two main techniques used for this research are explained briefly. Then, in Section 3, an approach to identify new technology opportunities is described, followed by a case study on Lab-On-a-CD (LOD) by SAIT in Section 4. Finally, the limitations and future direction of this research are discussed in Section 5.

2. Background

2.1. System function analysis

System function analysis techniques have been the main focus of value engineering. We review three representative techniques here. Firstly, *FAST* is a technique to systematically organise and represent the functional relationships of a technical system. In FAST, the system functions, both the basic and the secondary, are a fundamental concept and are displayed graphically in a *FAST diagram*, which emphasises the "how – why" relationships between them. The diagram shows the whole structure of a technical system with the inter-relationships of its functions and the system's relationships to the external system of which it is a part. This helps everyone to understand the system as comprehensively as possible.

FAST is a powerful technique to decompose a system, while *Morphology Analysis* (MA) is a technique to create a new idea from the decomposed system. MA was developed by Zwicky (1969) and can design solutions for multi-dimensional and non-quantifiable problems where casual modeling and simulation do not function well (Pidd, 1996). Basically, a system is composed of sub-systems, each of which can be shaped in different ways. MA identifies the various shapes that each sub-system may take and, by combining those shapes, examines all possible alternatives that the system may adopt. The number of alternatives may be reduced by eliminating illogical combinations using cross consistency assessment (Ritchey & Zwicky, 1998), which increases the practicability of MA. This technique is applicable to a wide spectrum of scientific disciplines in zoology, geology, linguistics (Huckvale & Fang, 2002), astrophysics (Zwicky, 1969), product engineering (Belaziz, Bouras, & Brun, 2000) and scenario planning (Rhyne, 1995). MA enables one to model a complex problem but only has a limited capacity to solve it. In other words, it only has a limited capacity to offer a desirable combination among alternatives.

On the other hand, *Quality Function Deployment* (QFD) technique can produce the most desirable system concept. It is a method to transform user requirements into quality design and relevant functions, and to guide someone along the way to achieving the design quality into subsystems, components, and ultimately specific elements of the manufacturing process. Now, QFD has extended its analysis beyond quality development to include cost, reliability, products and services, components, manufacturing and technology deployments.

Those functions can be linked to technologies using the *Technology Tree* (TT) abstraction. TT is used as an abstraction of technology and science, usually in the hierarchical visual representation of technologies associated with system functions. The tech tree is the representation of all possible paths of research with concerns the system. The TT concept has been implemented at an R&D division of large companies but the approach to develop TT is different by companies. For example, in Siemens, TT is an open process allowing all engineers the possibility of initiating their own knowledge network for a promising technology of their own choice (Heiss & Jankowsky, 2001). In Samsung Electronics, all R&D planning processes have included TT since 2000. After a function deployment is completed, each function is connected to patents and other technology information as a part of TT process, based on which R&D project work breakdown is produced and R&D strategy is established (Cheong, 2006). Once the system functions are well defined, making the decisions on how to improve the systems will be easier. Accordingly, this research deals with the issue of combining system function analysis techniques with TRIZ, a tool for innovative design, to direct the way to improve the system and ultimately to lead to technical innovation.

2.2. TRIZ

TRIZ is a data-based approach to solving difficult problems innovatively. The realization that nearly all innovative patents contained a solution to some type of contradiction – technical or physical – is at the foundation of the theory and overcoming contradictions solves both simple and complex problems. The basic tools of TRIZ include the contradictions, 40 inventive principles, the contradiction matrix, ideal final results, ARIZ (Algorithm of Inventive Problem Solving), the Laws of Technical Systems Evolution and the Su-field analysis. The latter two are mainly used in this research.

2.2.1. Technology system evolution

Analysis of emerging technologies and their potential opportunities for business should provide reliable guidelines to provide the most appropriate strategic decisions with minimal risk in the future. There are more than fifty methods for prediction (Porter, 2004) and a number of studies have suggested their own methods to predict the future. Out of them, TRIZ provides a powerful scheme to interpret and predict a technology evolution trajectory. Altshuller (1996) found that technical systems followed a foreseeable pathway that intersected with all fields of science based on the observation of long term technical system evolution. For instance, one of the basic axioms of TRIZ is "increasing the degree of ideality", which is defined as a benefit of the technical system compared to a harmful effect or a cost of the system. A technical system tends to evolve towards increasing ideality. In another example, TRIZ assumes that a conflict comes from uneven development of a system and an effort to overcome the conflict drives the evolution of a technical system. The basic laws of evolution are summarized in Table 1. Whatever the law may say, it is based on the assumption that once involved in the technological evolution