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An ideation method for generating new product ideas using TRIZ, concept mapping, and fuzzy linguistic evaluation techniques

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ABSTRACT

The quality of initial ideas is considered a critical determinant for successful new product development (NPD). This study presents an ideation method for generating new product ideas. The aims of the proposed method are (1) to clarify and identify potential problems involved in the knowledge domain of the product design through the Su-field enhanced concept mapping diagram; (2) to abstract inventive problems and generate novel product ideas by means of the theory of inventive problem solving (TRIZ) methodology; and, (3) to develop an effective decision aiding method for evaluating alternative ideas and determining promising product ideas using fuzzy linguistic evaluation techniques. The applicability of the ideation method is demonstrated through a case study of an air purifier design. The theoretical and practical implications of the ideation method are also discussed.

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1. Introduction

New product development (NPD) is the complete process of bringing a new product to market. Since a new product cannot emerge without new product ideas, research on idea generation for new products has mainly been centered on the notion of creativity. How to effectively generate novel and useful product ideas continues to be a critical issue for both design scholars and practitioners. Ideation is the initial process of generating and identifying the core ideas of a concept. It encompasses all stages of a thought cycle, from creative formulation to innovative manifestation of ideas. Various ideation methods have been developed and employed in the literature, such as brainstorming, lateral thinking, and synectics. These techniques generally increase the idea productivity of participants by guiding the direction and quality of their thoughts; however, relatively little emphasis has been given to structuring the outcomes of these techniques. Structured methods used to generate ideas include attribute listing, forced relationships, and morphological analysis, all of which seek to restructure a problem to facilitate creative solutions. Pictorial methods for organizing knowledge and developing creative thinking include mind maps and concept maps. The former is based on radial hierarchies and tree structures denoting relationships with a central governing concept, whereas the latter is based on connections between concepts in more diverse patterns.

Previous research has indicated that the difficulty with idea generation techniques in general is that there is very little theoretical and empirical evidence that clearly points out direct benefits from their use [1,2]. Conventional ideation methods for generating new product ideas are sensitive to the demographic profiles and life style biases of respondent groups. Most of them involve intuitive belief systems with more or less arbitrary sources rather than empirically validated theory. Previous research has also suggested that a prerequisite for developing better idea generation procedures is to achieve a fundamental understanding of how ideas actually come into being through conceiving the characteristics of the cognitive processes and structures [3,4]. On the other hand, theory treats idea generation in design as a special type of problem solving activity, which is grounded on ill-defined problems [5,6]. Problem solving is a mental and cognitive process that includes problem finding and problem shaping. Problem definitions play a vital role in the problem solving and idea generation process since the quality of idea solutions depends highly on precise problem definitions. However, conventional ideation methods emphasize the importance of a contextual survey with respect to problem solving; most of them resolve problems based on paradigmatic problems (e.g., 5WH, SCAMPER, and Compass), and do not provide a conceptualized reflective manner for defining problems.

In addition to idea generation, a holistic ideation method requires an effective evaluation to identify promising ideas. Idea evaluation is a systematic determination of merit, worth, and significance within the alternative ideas using criteria against a set of rules or standards. It is a distinct process, in contrast to idea

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generation, and as such involves uniquely identifiable mental operations [7–9]. There are a variety of idea evaluation tools and techniques that are commonly employed in the literature, such as NAF (Novelty, Attractiveness, and Feasibility) study, PMI (Plus/positive, Minus/negative, and Interesting) analysis, force field analysis, and impact analysis. Although these techniques are simple to use, their weakness is that the evaluations are often based on the evaluators' subjective opinions. AHP-based approach is a sophisticated technique for evaluating ideas; however, it involves complex procedures for deriving the weights of criteria and requires that evaluators remain consistent in making pairwise comparisons among numerous decision criteria [10–14]. Idea evaluation involves the human perceptual interpretation with some uncertainty and imprecision, and can be iterated a few times since the ideas derived during the idea generation process are often abstract, conceptual, non-quantifiable, and unpredictable. How to develop an effective method to assist designers in evaluating product ideas is a critical issue for both academic and industrial circles.

A holistic ideation method involves both the generation and evaluation of ideas. The former is focused on using insight to formulate an idea, while the latter is concerned primarily with the manifestation or implementation of the proposed idea. Conventional ideation methods mainly focus on the effectiveness of problem solving and idea generation but do not provide a structured conceptualization manner to formulate potential problems, avert trial-and-error iterations, and identify promising product ideas. Accordingly, this paper presents an ideation method for generating new product ideas, the purpose of which is to develop an effective idea generation and evaluation method that integrates TRIZ, concept mapping, and fuzzy linguistic evaluation techniques into a holistic methodology. This method can be used to assist designers in developing novel product ideas based on semantic technologies. The remainder of this paper is organized as follows. Section 2 introduces the theoretical background of TRIZ, concept map, and fuzzy linguistic evaluation, respectively. Section 3 describes the proposed ideation method. An empirical study is conducted in Section 4 to verify the applicability of the proposed method. A discussion is given in Section 5 and conclusions and recommendations for further research are offered in Section 6.

2. Related work

2.1. TRIZ

TRIZ, a Russian acronym, translated into English as "Theory of Inventive Problem Solving (TIPS)", was introduced by Altshuller in the mid-1940s [15]. It is a scientific methodology for creative problem solving, which seeks to eliminate conflicting problems and provides a range of strategies for finding solutions in the NPD process [16]. The philosophy of TRIZ is based on five key elements, namely ideality, functionality, resources, contradiction, and evolution, which together make TRIZ distinct from other problem-solving strategies. TRIZ scholars recognize that many innovative solutions involve resolving contradictions and increasing ideality with useful resources. Moreover, the evolution of technical innovation is predictable, and can be used to guide further development of functionality of a system. As such, TRIZ provides a systematic way of thinking to identify problems and links between them, analytical tools for problem modeling, analysis, and transformation, and knowledge-based tools for system change and resolution development [17]. Over the past few decades, it has gained much commercial acceptance, and has proven to be useful and powerful in the development of innovative products [18–21].

The aim of TRIZ is to provide designers with a strategic problem-solving process to advance further in the direction of the specific inventive solution with a minimum number of trial-and-error iterations. The TRIZ problem solving process comprises the following four steps: (1) problem definition; (2) problem classification and tool selection; (3) solution generation; and, (4) evaluation. Problem definition is aimed at clarifying common design questions and involves analytical tasks that are conducted using TRIZ analytical tools such as project definition, functional modeling and functional analysis, technological evolution analysis, ideality and ideal final result (IFR) analysis, and S-curve analysis. After having finished problem definitions, designers have to classify the problems into categories and then select appropriate tools for the problems. For each problem category, there are some knowledge-based tools available to resolve the problems, such as 39 design parameters and the contradiction matrix, 11 separation principles for physical contradictions, 40 inventive principles for technical contradictions, 76 standard solutions for substance-field (Su-field) analysis, and 8 evolutionary patterns for forecasting technology trends [22]. By using the corresponding tools, many possible solutions can be generated and then evaluated to determine the best solution to the problem.

Contradiction problems often occur in a new product design process. In TRIZ, there are two main types of design contradictions, namely physical contradictions and technical contradictions. A physical contradiction is a situation in which a subject or an object has to be in two mutually exclusive physical states, whereas a technical contradiction is a situation in which efforts to improve some technical attributes of a system can lead to the deterioration of other technical attributes. Conventional design methods treat contradiction problems based on the philosophy of compromises and trade-offs. Contrary to these methods, TRIZ offers various tools to overcome design contradictions. Among these tools, the contradiction matrix and the 40 inventive principles are the most commonly used, and provide designers with guidelines to facilitate the development of useful concepts of solutions for innovative situations [23]. Substance-field (Su-field) analysis is another popular tool for functional modeling and functional analysis. In a Su-field model, the desired function represents the output from an object or a "substance" (S_1) caused by another object (S_2) with the action or means of a "field" (F). Any functional system can be modeled with a complete Su-field triangle, which can be used to identify potential problems through the analysis of undesired models. Taking advantage of the 76 standard solutions, the potential problems can be resolved.

TRIZ is a systematically structured approach based on the evidence emerging from the analysis of a large number of patented inventive solutions. It includes a well-established system of tools that provides designers with strategic and pattern-based guidelines to solve problems and generate ideas. Although the TRIZ methodology does not provide a strict sequence or specific procedure in the application of the tools, ways of structuring the system of tools are suggested to provide some clarity on how the corresponding tools should be applied to abstracting inventive problems and solving specific problems [24].

2.2. Concept map

Cognitive structures refer to a set of concepts and the relationships among these concepts [25]. The presence of certain knowledge structures in individuals' minds largely determines their ability to characterize a particular problem domain and their problem-solving performance [26,27]. The concept map technique, developed by Novak in the 1970s, is a graphical tool for organizing and representing knowledge [28]. It makes concepts, as well as propositions composed of concepts, the central elements in the representation of knowledge structures and the construction of meanings [29]. A concept is defined as a perceived regularity in

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