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Product Creative Design Method Based on the Strategy of Problem Solving

[1,2]Kai Zhang, [1]Wu Zhao, [1]Chen Wang, [1]Ling Chen and [1]Junsong Zhang
[1]School of Manufacturing Science and Engineering, Sichuan University, Chengdu 610065, China
[2]Sichuan Aerospace Polytechnic, Chengdu 610100, China

Abstract: Based on the characteristics of product innovation design, product innovation was designed into several stages: requirements analysis, problem-finding, problem-analyzing, problem-solving, innovative solution-generation and solution-evaluating. To help designers find problems, analyze the problems and solve the problems, the innovation model based on problem-solving was developed and the approaches to find problem were presented. In addition, different types of problems in product innovation design were analyzed; a systematic model supporting problem representation was put forward. Based on internal variable of the problem, the problems were divided into four grades and the strategies for solving each grade of problems were presented. Besides, several examples were cited to demonstrate the feasibility of the models and methods. Finally, a preliminary prototype software system of computer-aided design for product innovation was developed.

Key words: Product creative design, problem-finding, problem-analyzing, problem-solving

INTRODUCTION

Creativity Product Design Process (CPDP) is a progress for finishing a creativity product design program for a specific product's function, which should be based on series design rules and strategies. In the fiercely competitive economic setting, the speed for a new product into the market plays a pivotal role in achieving competitiveness in a company. Product innovation is a key factor of enterprise innovation and creative design is the core of product innovation.

How do designers conduct a creative design? What factors affect creative design? How could designers' creativity be enhanced? What kind of tools could be applied to enhance the designers' creativity? Regarding to these issues, many researchers have done a lot of works from different perspectives of knowledge (Li *et al*., 2009; Tu *et al*., 2009), psychology (Zhang *et al*., 2010; Tan and Liu, 2009) and the theory of inventive problem solving (Altshuller, 2008; Goldenberg and Mazursky, 2002). However, those methods still have such-and-such limitations for carrying out creative design practically. Which studied innovation method generally from a single perspective, does not indicate how to incorporate creative thinking, knowledge and invention principle to aided innovation design research. Moreover, traditional design methods mainly focus on product or technical system themselves, while seldom recognize and plan the design process from the problem solving process, which includes finding the problem, analyzing and solving it.

This study describes a new approach in CPDP based on the process of problem-finding, problem-analyzing and problem-solving. Different kinds of problems in CPDP were studied. In order to assist the designers to find a creativity product design program, the models for problem representation and problem solving have been developed.

PRODUCT INNOVATION DESIGN MODEL

Creative design means to find a proper approach to reach the purposes which were previously set. When one wants to achieve a certain purpose under the condition that the suitable approach is not directly available, the activities that are taken are called problem-solving (Li *et al*., 2005). Therefore, the main task of innovation design is problem-solving. Product design process should be classified by assignment-planning, which is based on the problem-solving process. To start with, the designer should find the problems, then analyzing the problems, which different solutions and creative strategies should be taken based on the types of design problems. Finally, it is the solution evaluation. Based on the study of the problems in new product design process, the innovation model can be described as Fig. 1.

The model contains the thinking activity layer, task layer and knowledge layer. Thinking activity layer shows how to guide the creative thinking of the designers in CPDP; Task layer shows the designers' tasks in CPDP, including problem-finding, problem-analyzing, problem-solving and solution-evaluating; The knowledge

Corresponding Author: Kai Zhang, School of Manufacturing Science and Engineering, Sichuan University, Chengdu, 610065, China Tel: +86-028-85405307

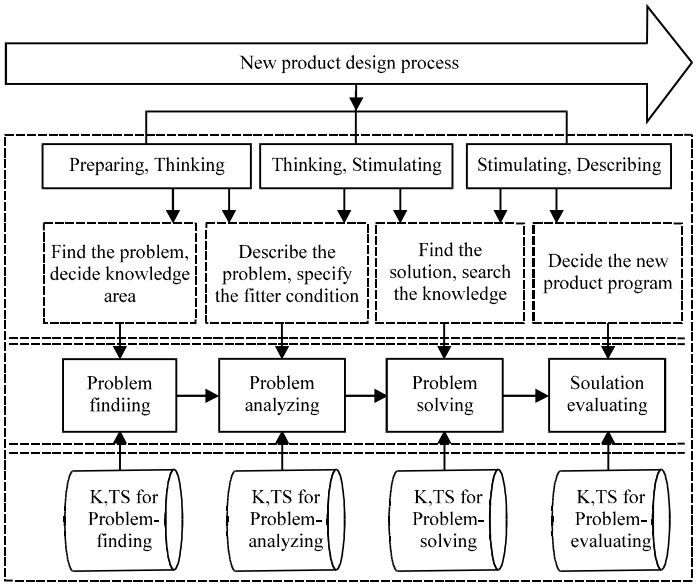

Fig. 1: Innovation model based on problem-solving

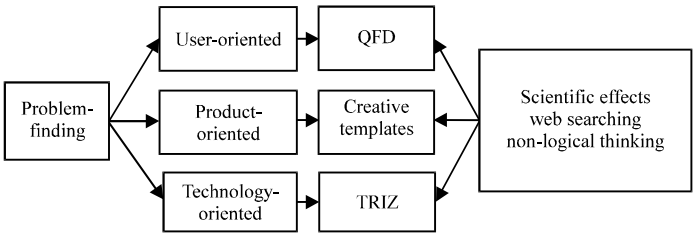

Fig. 2: Problem-finding classification and strategies

layer demonstrates how to incorporate creative thinking, knowledge and invention principle to aided innovation design research (In this study, product innovation design methods shall be considered to be a part of the knowledge).

PROBLEM-FINDING

For the problems in CPDP, most of the time, not couldn't solve the problem but rather don't know what the problem is. Therefore, finding problems would be the first step of p roduct innovation design. Problems are found in relation to user demand, product and the available technology, so the designers should consider how to find problems from these three angles. The angles of finding problems and strategies should be taken to find the problems are illustrated in Fig. 2.

The strategies of problem-finding can divide into three types:

- **User-oriented:** The ultimate aim of product innovation is to meet the demands and the market and problems are often implicit in demands. After getting user demands, designers should translate these demands in order to match the user demands and product performance. Quality Function Deployment (QFD) is an effective tool for demand conversion. It can connect the user demands and the technical properties of the products systematically, thus designers can specify the source of the problems. For instance, in the face of the environmental requirements requested by the users, designers should consider the material selection of products
- **Product-oriented:** The problem is the product function need to be improved. For product function improvement, the strategy taken is to improve the product itself using the methods of functions-follow-forms. The Creative Templates (CT) are a good method to fulfill this strategy. Product

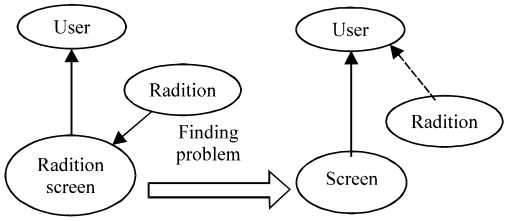

Fig. 3: Example of element control template

configuration environment element and external environment element can be shown out through configuration diagram

The designer can find the problems by analyzing various elements harmful effects and beneficial effects. For example, the template elements control method of CT, which lists the entire external environment element which has a direct physical connection to product configuration environment. Through the analysis of adverse factors that may result from external environment element, the designer could find out the adverse link and then the problem. Here is an example shown in Fig. 3.

- **Technology-oriented:** For the improvement of the overall performance of the product, designers need to find conflict in the products, which is the problem that would be affect product performance. TRIZ is a comparatively better method to implement the strategy. For example, the designer could find physical contradiction or technical contradiction in the product by comparing the performance parameters of the product to the 39 general engineering parameters in TRIZ

PROBLEM-ANALYZING

Before looking for a solution to the problem, designers need to pass through a series of thinking activity to remove the doubts in their minds, so that thinking in the minds becomes clear, which is a key process of analysis of the problem. Analysis of the problem means to define and represent the problem, which can reduce thex solution space. Figure 4 shows the strategies for the analysis of problems.

- **Interpretative problem representation:** Interpretive problem refers to a phenomenon that puts forward some theoretical explanation and analysis and the explanation of the phenomenon of the law relationship, mechanism or the cause. To solve this kind of problems, it is necessary for the designers to

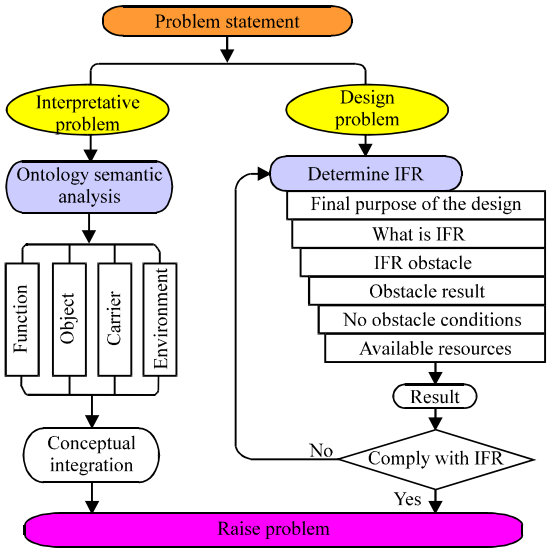

Fig. 4: Problem representation model

Table 1: Example of interpretative problem representation

Function	Object	Carrier	Environment
Ironing	Clothes	Iron	Ironing clothes

use ontological semantic analysis method for the problem representation. Thus, the "function", "object", "carrier" and "environment" in the problem system can be separated to help designers understand the essence of the problem. Taking ironing lined clothes as an example, one potential problem of this particular setting is the loss of control of the heated iron and the semantic analysis for this situation is shown in the Table 1

- **Design problem representation:** The design problem is to put forward a feasible design scheme for some practical and specific question. To solve a certain problem, designers need to use IFR (Altshuller, 2008) (Ideal Final Result) for the problem representation, which can make the problem statement more clearly from the final purpose design, the ideal state and the barrier of ideal state. For instance, to design a container for universal solvent, the ideal state is not to put requirements on the container but to make sure that the solvent does not need any container

PROBLEM-SOLVING

The problems of creativity design cover a wide range and it easily blinds the designers in the solution process. So it is very important to classify the problems of creativity design. Making categories would make it easier for the design ers to define the problems as well as to find the solutions with the help of knowledge database. It also

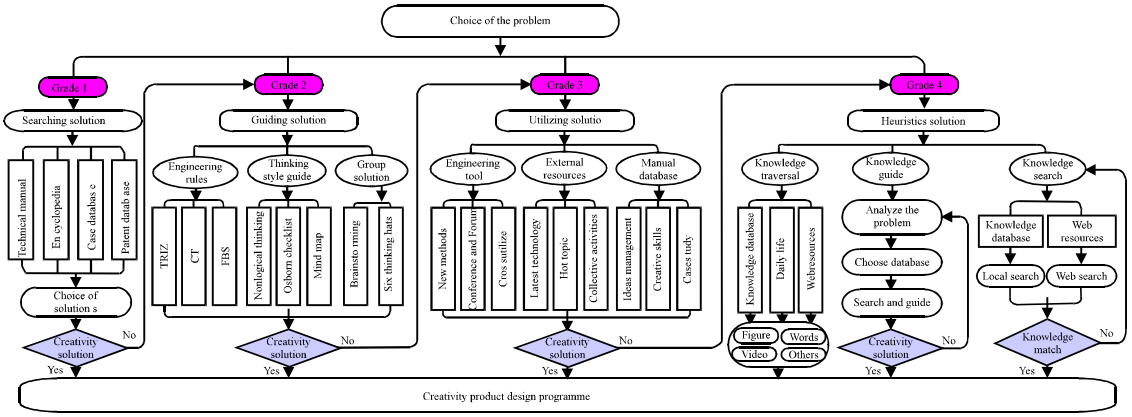

Fig. 5: Strategies of solving problems

Table 2 :Four grades of the problems

Grade	Change	Variables
Grade 1	Quantitative change	One or several
Grade 2	Partial qualitative change	Dozens
Grade 3	Qualitative change	Hundreds
Grade 4	Change to a new theory	Thousands

improves the efficiency of problem-solving. Based on the system, characters and other variables, the problems of creativity design could be divided into four grades in the design process of product innovation, which is shown in Table 2.

According to the classification of the problems of the creativity design, the designers could determine the grade of the problem accurately and then choose a proper method to solve the problem. Thus the designers could improve the success rate and efficiency when they solve the problem, because it can help the designers to avoid the process trying to solve the problem from the grade 1 to the grade 4. The strategies of solving problems are shown in Fig. 5.

- **The problems solutions in grade 1:** The problem in this grade is relatively simple and can it could be solved with the solution searching, which does not require an in-depth analysis of the problem. The designer can collect information which is related to the problem by searching information concerning the solution in the patent database, case database, mechanical technical manuals and encyclopedias. For example, if the problem is to save the transport cost, the designer could search for the result directly and find it helpful to use heavy trucks instead of light ones
- **The problems solutions in grade 2:** The problem in this grade is relatively complex and it is recommended to solve these problems mainly by instructions, applying the developed innovation tools. Or the designer could transform his or her way of thinking by talking about it with other people. Through conversation can designers sometimes break the old thinking pattern and be creative and ultimately find innovative solutions.

Guiding solution contains three modes: (a) Engineering rules, to solve the problem by the innovation method relates to product design rule, such as TRIZ, creative template and FBS, etc. (b) Thinking style guide, to help the designers with organizing their thinking and expressing their ideas effectively by using Osborn checklist, non-logical thinking and the mind map (c) Group solution, to stimulate the more creativity of the designers through collective discussion, commonly used methods are brainstorming and six thinking hats. For example, treadmill was designed with the guidance of the reverse effect principle in TRIZ.

- **Problems solutions in grade 3:** The knowledge relates to this kind of problem is generally beyond the common knowledge of the designers and the solution requires them to utilize different areas of knowledge and innovative tool

Utilizing solution consists of three models: (a) Engineering tool, finding the new method in the engineering field and focusing on recent innovation forum and interdisciplinary subject report, so that designers can draw lessons from the related fields of technology in solving the problem (b) External resources, paying attention to the latest trends and hot topics of the study about the problems, in order to generate creative ideas (c) Manual database, using the previous ideas to solve the problem by querying creative management method, innovative skills and innovation cases, etc. For example, an inventor is thinking about how to design a harvester

and later in a barber shop he learned about the structure of the hair clipper and he linked it with the structure of harvester. With this surprising combination of knowledge he invented a new type of harvester with reference to an interdisciplinary theory of clipper.

- **Problems solutions in grade 4:** The solutions of this kind of problems often put the designers in a quandary and many designers do not know how to start with when they face such problems. This study provides some options and solving steps based on thinking inspired

Heuristics solution consists of three models: (a) Knowledge traversal and the designers need to browse a lot of knowledge (including images, text, video, animation, etc.), when they need to use it to solve the problem, this knowledge can help designers to generate creative ideas; (b) Knowledge guide, which helps the designers' innovative thinking effectively, so that designers can according to the different innovation demand focused for problem-solving (c) Knowledge search, this is a matching process between the knowledge resource and knowledge requirement, which the designers need in order to constantly search from a large number of knowledge resources and obtain the intersection. For example, once Luban's hand was cut by grass, he carefully observed the fine tooth shape of grass edge and linked it with woodworking tools and then he invented the saw (Luban is an ancient Chinese inventor). Although it is a common experience that fingers are cut by grass, Luban alone was inspired by this experience and made an important invention

Computer aided creative product design: The computer aided creative product design platform is the key attribute of creative product design model-supporting tools. Meanwhile, it also is a work platform for computer aided creative design. The key function of the computer aided creative product design platform is to promote the creativity of the designer in creative design and its focal point is that computer aids and supports the creative activities of the designer, instead of the automation of conceptual design. It offers a useful tool for designers in the scheme design phase. Figure 6 is the block diagram of the computer aided creative product design platform. On this basis, a preliminary prototype system has been developed with Java technology.

System includes the following main modules:

- **Problem-finding:** Indicate the direction of creative product design from the user demand, product and the available technology, in order to help the designers find the problems needed to solve
- **Problem-analyzing:** Define he problems with different methods in order to help the designers understand their own problems more clearly
- **Problem-solving:** Solve the specific problem with the strategies of solving problems in order to help the designer to find innovative design scheme
- **Scheme management:** Help the designers evaluate the innovation design scheme

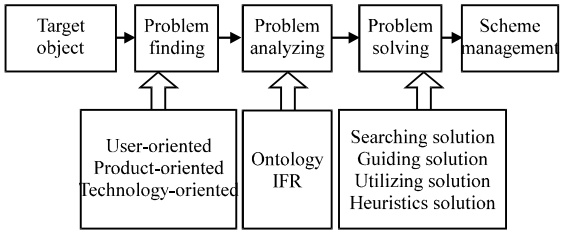

Fig. 6: Block diagram of computer-aided creative product design

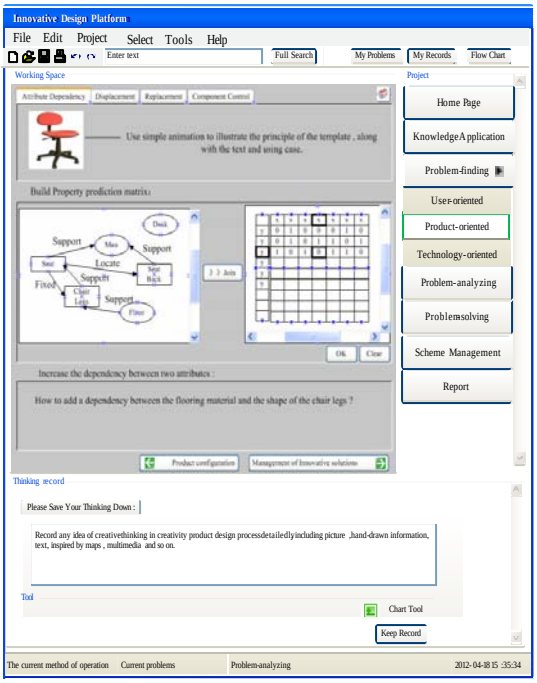

Fig. 7: Problem-finding based on creative templates

All the modules are organized according to the procedure illustrated in Fig. 6. Figure 7-9 are several graphic presentations of the modules in the computer aided creative product design platform (as space is limited, only small amounts of interfaces are listed).

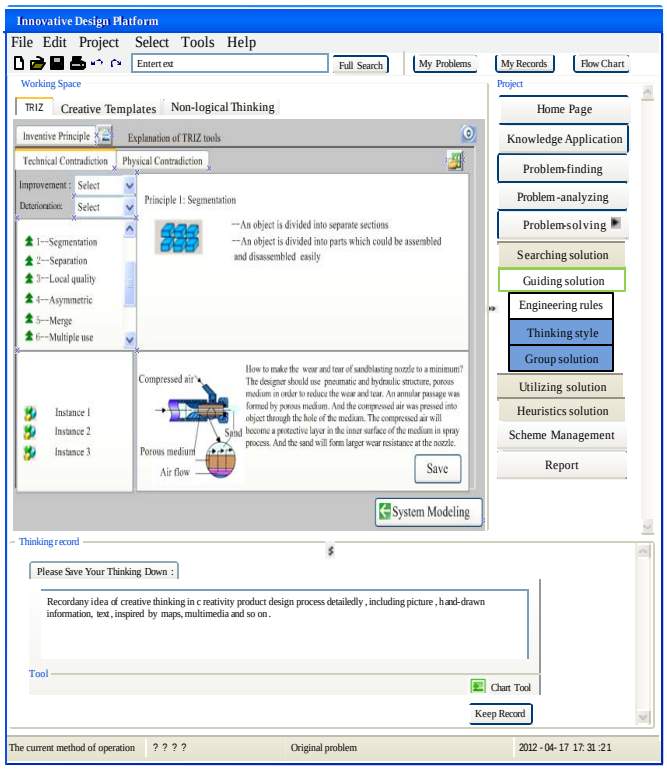

Fig. 8: Problem-solving based on TRIZ

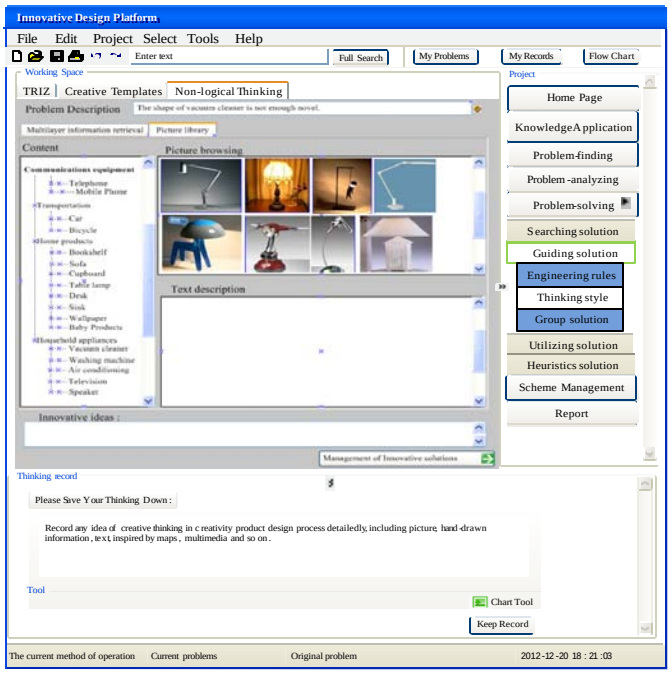

Fig. 9: Problem-solving based on non-logical thinking

CONCLUSIONS

For kinds of problems are in CPDP, which are based on the process of problem-finding, problem-analyzing and problem-solving, this study describes some approaches to problem-finding. Then the strategies of problem representation were put forward. Based on problem representation, the problems of creativity design have been divided into four grades. And the strategies for solving each grade of problems were presented, which can help designers to improve the efficiency and success rate of product innovation design. The approach presented in this study, which provided some theoretical exploring experiences and corresponding applicable methods for product creative design. It is also to lay a good foundation for the development of the computer-aided innovation software and make it be an important means for designers to propose creative design scheme with high efficiency and quality CPDP. In the future work, we will study the problems solving process of grade 3 and grade 4 in more focused manner in order to find a specific and efficient method to solve these problems.

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