A Design System Integrating TRIZ Method and Case-Based Reasoning Approach

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Abstract: Today's industrials are facing numerous product development challenges and pressures as a result of an increasingly competitive market. It creates an enormous need for a constantly growing supply of new ideas and solutions. The computer support used by designers still lacks the ability to use experiential knowledge in a rational way. Therefore, pursuit of designer is utilizing innovative design methods and problem-solving approaches to systematically simplify design problem, and hence accelerate the design process. This paper proposed to integrate TRIZ method into CBR process and aims at exploring the possibility to use TRIZ method as a complement to enhance performance of CBR in product design. Wall lighting design problem is used as example, and an interactive CBR system is not only built to provide designers a computational tool to efficiently retrieve usefulness design cases but also assist designers systematically in finding creative ideas.

1. INTRODUCTION

Today's industrials are facing numerous product development challenges and pressures as a result of an increasingly competitive market. It creates an enormous need for a constantly growing supply of new ideas and solutions. Launching an innovative product, producing high quality products, and simultaneously reducing time to market and product cost, are major factors to be successful for all the companies. In all the design domains, designers can follow normal design processes to solve the domain problems. Many

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well-know systematic design methods are exist to assist designers to accomplish successful design. But design success is often heavily weighted on personal experience and innate ability. (Bryant, McAdams, et al., 2005)

As a designer, it is crucial to be able to provide innovation solutions and the product development process to support such abilities is very important. The process of product development includes understanding the problem, generating concepts and searching for solutions. Within this process, generating design concepts depends on the creativity of designers. However human designer's behavior and design thinking are extremely complicated (Gero, 1994). Therefore, the ways designer used to generating new concept are always changeable and unreasonable. Ultimately, designers rely heavily on individual bias and experience embedded in their practice. With all the reasons, designers are deficient in systematic capability to solve problems. In addition, each idea proposed by designers can not certainly be able to fulfil all the requirements of design. These issues can be overcome through computational support. Nevertheless, the computer support used by designers at this time still lacks the capability to apply experiential knowledge in a rational way.(Johansson and Popova, 2002)Since the knowledge from this phase is incomplete, inexact, even unknown. Consequently, this study explored the goal of computer-aided innovation via design methods and aims at exploring the possibility to use Theory of Inventive Problem Solving (TRIZ) method as a complement to enhance performance of Case-based Reasoning (CBR) in product design.

In this paper, a framework to integrate TRIZ into CBR design system is proposed. Wall lighting design problem is used as example, and an interactive CBR system is presented to provide designers a computational tool to efficiently retrieve usefulness design cases. Once, the cases storing in the case library is conformed to the target problem. The system, based on a contradiction matrix, will prepare the case list which is ordered by the weights assigned by designers at the beginning. The computational tool offers a promising application for designers because it can overcome the problem about accuracy of target source. Through a prescriptive procedure, the system can assist designers systematically in finding creative and innovative ideas. The overall time of design will be reduced dramatically, and the design efforts could be saved by finding the ideas conformed to the requirements.

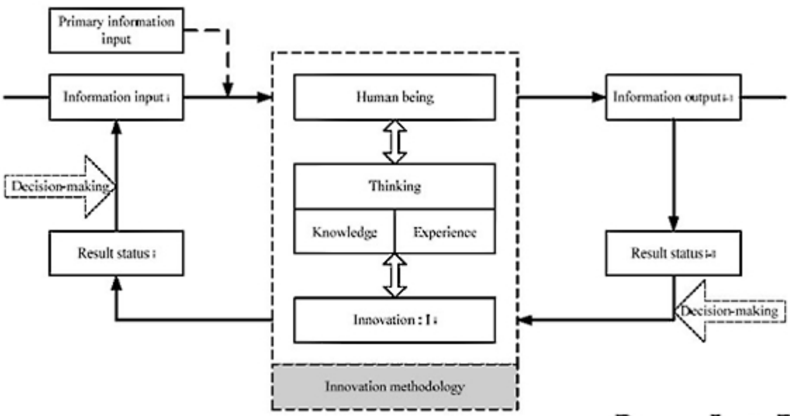
2. BACKGROUND

2.1 The concept of innovation

Product development is often described as an iterative process to find solutions that fulfil a given requirement specification. Innovation is a critical factor in the success of companies in order to get innovative products to the marketplace quickly. The concept of innovation is used in connection with the analysis of processes of technological change. Traditionally the process of technological change was characterized as consisting of three different stages: invention, innovation and diffusion.(Cooke, 2001)Nowadays, scholars give a broader definition of innovation which includes all activities of the process of technological change: problems of awareness and definition, the development of new ideas and new solutions for existing problems, the realization of new solutions and technological options as well as the broader diffusion of new technologies.(Cooke, 2001)Despite creating breakthrough innovations is a key strategy for every company. But an important precondition for the development of substantially new products is the identification of breakthrough ideas for problem solutions in the front end of the innovation process.(Schild, Herstatt, et al., 2004)It seems likely that find a good idea in the innovation process should depends on the strong support. The factor of innovation process will be presented in the following section.

2.1.1 Innovation thinking and Analogies

Innovation thinking means a breakthrough action, which can re-structure the related knowledge and experience to get a brand new and valuable achievement. It can be seen in figure 1.(Gao, Huang, et al., 2005)



$$Rs_i = I_i + Rs_{i-1}$$

Figure 1. Innovation thinking.

Innovation thinking is in an iterative process which based on knowledge and experience. The figure 1 point out ‘primary information input’ can be transformed into ‘information output’ with innovation action ‘I’. ‘Rs’ means the ‘Result status’ of thinking. Then, in an innovation thinking circle, the following formula can be gotten. This study emphasize that thinking in the innovation process is not only rely on experience and knowledge but also depend on human innate ability.

In the product development phase, designer constantly think how a problem can have best solutions via a systematic process. Schild et al. (2004) believe that analogies can trigger breakthrough ideas and also indicate a fundamental cognitive mechanism to retrieve existing knowledge and to apply this knowledge to new problems. Additionally, Schild et al. (2004) proposed that a key problem in using analogies for problem solving in innovation projects is to relevant analogies early in the process. Several methods and procedures exist which can be used to generate ideas for product concepts based on analogies. Those ways can lead user approach easily.

2.2 Design methods

2.2.1 TRIZ: the Theory of Inventive Problem Solving

TRIZ, the Russian acronym for the theory, developed in the former Soviet Union by Genrich S. Altshuller (1926-1998) and his co-workers. TRIZ method originated from extensive studies of technical and patent information. It began in 1946 when the Russian engineer and scientist Genrich discovered that the evolution of a technical system is not a random process, but is governed by certain objective laws. These laws are used to predict how a certain system will develop in the next phase. The laws can be a useful tool in product planning by providing support for technological forecasting. TRIZ classifies innovative problems and offers corresponding problem-solving methods for each class of problem. It can provide some useful tools for us to analyze the problem, including Ideal Final Result, Laws of Engineering System Evolution, Altshuller's Matrix, Separation Principle, 76 standard solutions, Effects, etc.(Nakamura, 2001; Gao, Huang, et al., 2005)Yang and Zhang (2000) deemed that TRIZ offers a wide-ranging series of tools to help designers and inventors avoid trial-and-error in design process and solve problem in a creative fashion.(Yang and Zhang, 2000)

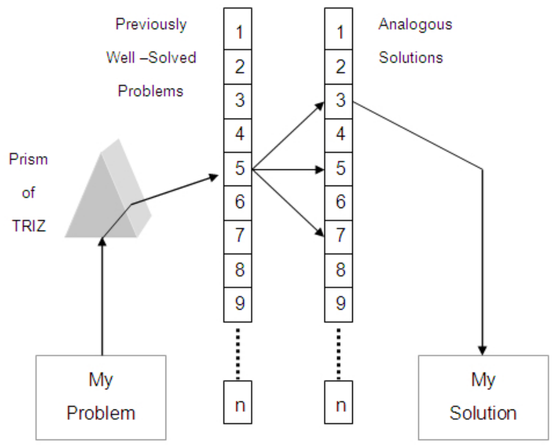


Figure 2. Innovation thinking.

Figure 2 shows the process follows in TRIZ for problem solving. The process used by human beings to solve problems. In this whole process can take a look in four phases.

- Identifying my problem
- Formulate the problem: the Prism of TRIZ
- Search for Previously Well-Solved Problem
- Look for Analogous Solutions and Adapt to My Solution

First of all, the mechanism of TRIZ proposed to think innovative situations, such as operating environment, resource requirements, primary useful function, harmful effects and ideal result. In the second phase, review the problem and identify problems that could occur and distinguish physical or technical contradictions. Then, problem may accord to 39 standard technical characteristics to find the principle that needs to be changed. Indeed, problem might occur analogous solution in the table of contradiction which created by Altshuller. You can adapt a solution that from contradiction Matrix listed the appropriate inventive principles to solve the problem lastly.

2.2.2 Contradiction

The contradiction is one of the most common problems in our daily life, In the TRIZ method was also an important subject. Altshuller was interest in investigating contradictions that were resolved without compromise. He proposes that technical problems could be solved by utilizing principles previously used to solve similar problems in other inventive situations. On account of discovering correlation, Altshuller was able to identify 40 such principles from his analysis of successful inventions. He also identified 39 universal characteristics of technical systems that generate contradictions; moreover, used this information to develop the contradiction matrix. (Altshuller, 1998) There are two type of contradiction. One is technical contradiction and another is physical contradiction. Occurrence of technical contradiction is to overcome the condition when improving one characteristic or parameter of a technical system and cause another characteristic or parameter of the system to deteriorate. A physical contradiction appears when two opposite properties are required form the same element of a technical system or from the technical system itself. Contradiction table (Contradiction Matrix) is a TRIZ tool to resolve technical contradictions which includes 39 engineering parameters and 40 inventive principles offering the possible solutions. It can be shown in Figure 3.

Undesired Result (Conflict) / Feature to Improve		1…	9…	..39
		Weight of moving object	Speed	Force
1	Weight of moving object		2, 8, 15, 38	8, 10, 18, 37
2... 39	Weight of stationary object			8, 10, 19, 35

Figure 3. Contradiction Matrix (Altshuller, 1998).

The outcomes of the TRIZ-based technology intelligence can be used to determine the threats and opportunities of competing technologies.(Schuh and Grawatsch, 2003) On this basis, the critical technologies can be further used for any design strategies. That will be very useful for designers.

2.2.3 Case-Based Reasoning

Case-Based Reasoning (CBR) is a computer technique that is attracting increasing attention in many researches. CBR combines the knowledge-based support philosophy with a simulation of human reasoning when past experience is used, i.e. mentally searching for similar situations happened in the past and reusing the experience gained in those situations (Leake, 1996). Aamodt and Plaza (1994) also have indicated that reasoning by reusing past cases is a powerful and frequently applied way to solve problems for humans. A general CBR cycle may be described by the following four processes:(Aamodt and Plaza 1994; Mansar, Marir, et al., 2003) The CBR cycle is illustrated in figure 4.

- **RETRIEVE** the most similar case or cases.
- **REUSE** the information and knowledge in that case to solve the problem.
- **REVISE** the proposed solution.
- **RETAIN** the parts of this experience likely to be useful for future problem Solving.

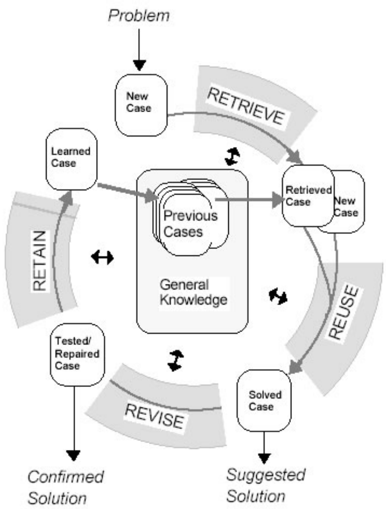


Figure 4. The CBR cycle.

An initial step is to define a new case for problem. A new problem is used to retrieve from one or more previously experienced cases. The retrieved case is combined with the new case via phase of reuse to be a solved case. Intention of Revising is in order to let the proposed solution test for success and being a confirmed solution. During retain, useful experience is retained for future reuse, and also the new experience into the existing knowledge-base (case-base) by incorporating. Case base updated stand on a new learned case or by modification of some existing cases.

2.2.4 Case Based Design

Case based design (CBD) is an application of CBR to support design problem solving. The further explanation can be defined as: the process of creating a new design solution by combining and/or adapting previous design solution(s).(Watson and Perera 1997)The content and knowledge structure of design cases as well as the organizational structure of case memory is an important aspect of a CBR system because it influences subsequent retrieval and adaptation of design cases (Maher, Balachandran, et al., 1995)There are two processes in the framework of a CBD model. It shows in figure 5.

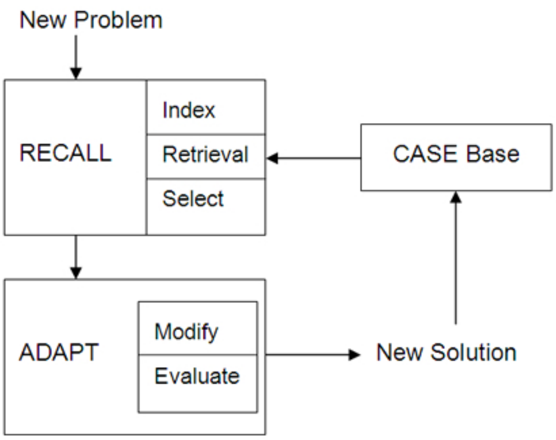


Figure 5. Model of CBD (Maher, 1995).

- **The recall process:**
  This process includes indexing, retrieval and selection. When a new problem entry, indexing that retrieval previous cases from case base via key feature. Select the retrieval cases for ranked and into next step.

- **The Adapt process:**
  This process includes modification and evaluation. Compare the new case with selected case. Modifying case is in order to fit the new aspect. After evaluation, put new solution into case base.

Watson and Perera (1997) pointed out CBD systems can be used in a manner that would enable the human designer to improve designs by enhancing creativity. Therefore, the CBD methodology can be used to reason the design process as a solution searching mechanism in finding innovation ideas.

2.3 Concept of TRIZ-CBR approach

This related study made by Robles et al. (2005). The synergy between TRIZ-CBR is explored to produce a conceptual model (figure 6) where the main advantage of each approach will be integrated. They use TRIZ as a point of view and discuss deficiency and produce a result that a symbiosis between TRIZ-CBR could be useful to offer a better structure.

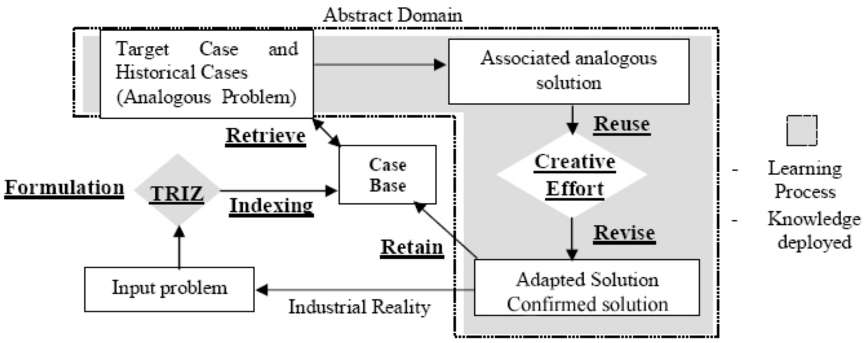


Figure 6. The TRIZ-CBR process.

TRIZ-CBR offers a better structure to: (Robles, 2005)

- Capture, index and store the knowledge deployed and created while solving problems.
- Offer a way to export inventive solutions.
- Capture and make available the solver's TRIZ experiences to solve new problems, among others.

The result indicated TRIZ-CBR synergy could make up deficiencies and approach the industrial reality.

3. INTERGRATING TRIZ AND CBR APPROACH

In this research, a framework to integrate TRIZ into CBR design system is proposed. Design field in CBR process emphasized two points of view, one is recall and the other is adapt. For this reason, this research describes entries that TRIZ method involves in from those two perspectives. Figure 7 shows the system process can separate into three phases: (1) Analysis of design problem. (2) Identifying of problem (3) Acquirement of innovation idea. Therefore, execution of tasks to support TRIZ method into CBR will illustrate as following.

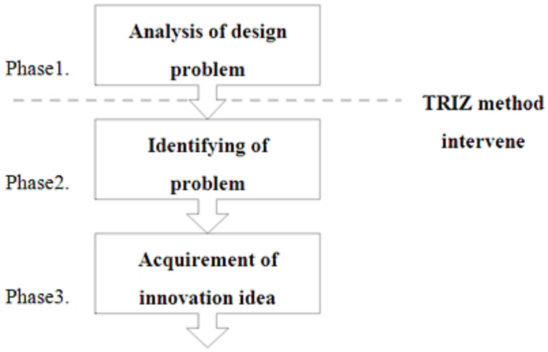


Figure 7. Main tasks of wall lighting design system.

There are brief descriptions for each phase:

Analysis of design: in this stage, designer should think all kind of possible design requirements and decides which problems could be entry to find solution lastly.

Identifying of problem: the purpose of this stage is use index to assist designer retrieving target case. Design requirements would formulated by system and mapping grouping of 39 characteristics in order to increase accuracy of case retrieval.

Acquirement of innovation idea: after reuse case, in order to adjust parameter to tally with the original requirements, this phase should adopt aid of contradiction matrix which is developed from TRIZ method. Designer can analyze all related parameter of 39 characteristics and acquire innovation solutions in 40 principles through the computational way.

Case retrieval and case adaptation

Apparently, the initial problem statement given to our designers was ambiguous, incomplete, contradictory, and under constrained. (Leake 1996) Hence, how to grasp the key feature and retrieve case in favor of problem mapping from case base was important. This research proposed redescribing a problem in the vocabulary of the indexing. As figure 8 shows below, In order to increase the accuracy of target case, grouping of 39 characteristics of TRIZ tool could be key feature in index phase. Designer can handle the idea's requirements and picked the cases which conform to the concept of TRIZ.

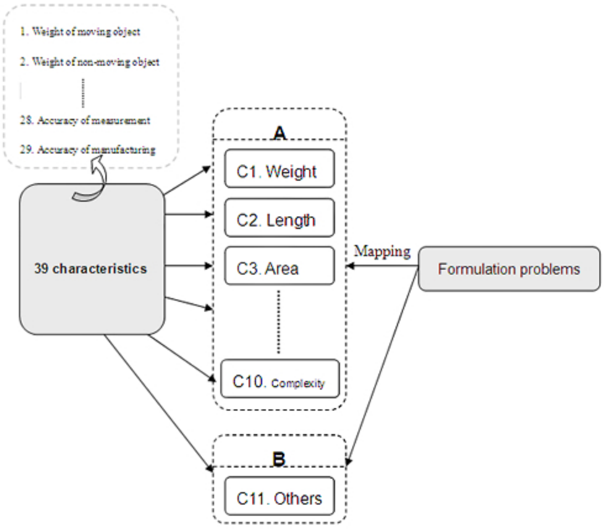


Figure 8. Design problem mapped into grouping of 39 characteristics.

Figure 9 shows a framework that Integrate TRIZ into CBR design system. All of design problem might flood with conflicts and problems also variable. Thus, this research apply contradiction matrix to intervene in adaptation of CBR process for the purpose of providing innovation principles. TRIZ-CBR synergy could encourage designer idea continually and get results more efficiently.

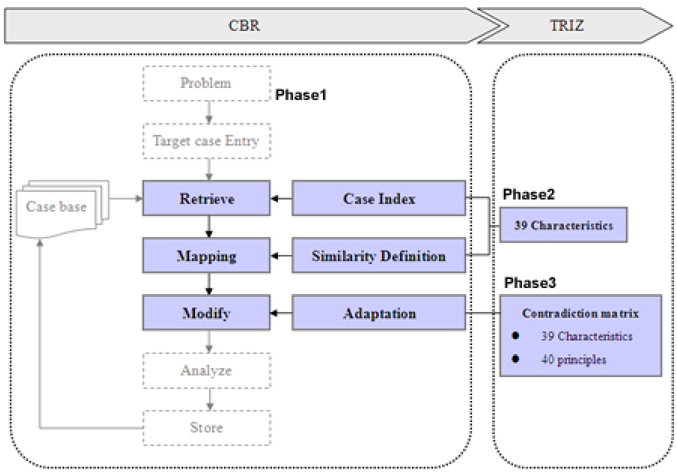


Figure 9. Integrate TRIZ into CBR design system.

4. PROTOTYPE IMPLEMENT

Our system is divided into three parts, which include CBD, TRIZ knowledge base, and a graphical user interface (GUI) application. Figure 10 shows the architecture of our system.

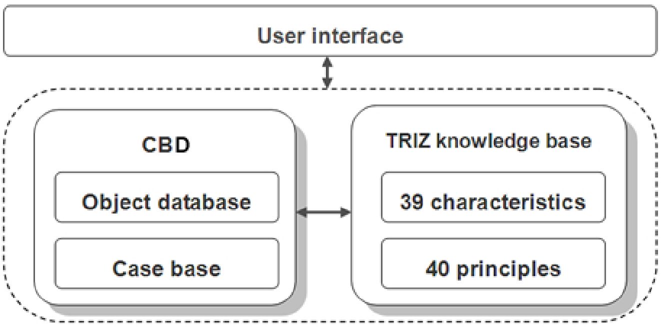


Figure 10. System architecture.

The system has been implemented by Java, an object-oriented language, to fully take advantage of accessibility through multiple platforms and capability to connect the system in any place and adopts MySQL to be the database system.

Figure 11 illustrate the system operation flow. Parts of the system GUI will be represented for operation explaining.

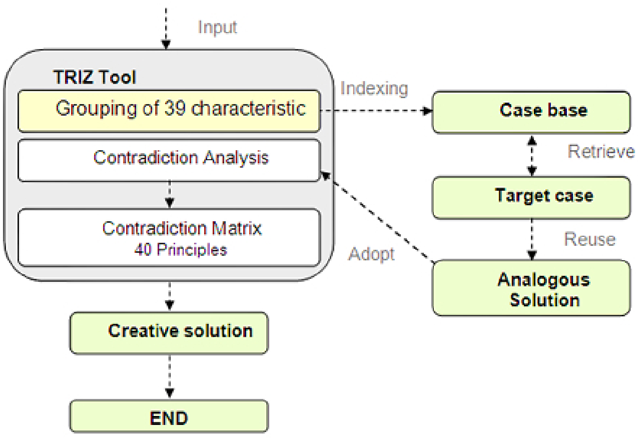


Figure 11. System operation flow.

Figure 12 shows the GUI of problem entry, Designer refers to all kind of possible design requirements of lighting domain. For example, the designer is working on a Wall Lighting design problem. The requirements are include: Setting is easy, Avoid deformation of lampshade and Waterproof material. System will then map the problem descriptions into the indexes grouping from 39 characteristics.

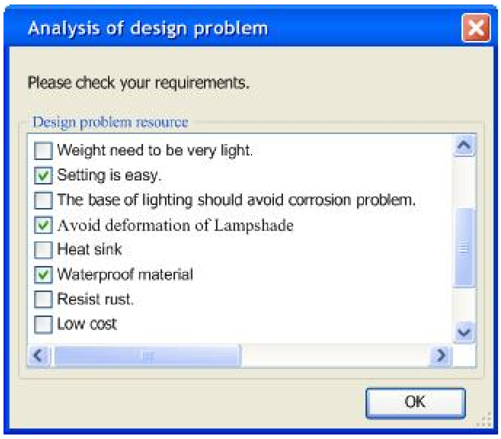


Figure 12. GUI of problem entry.

The siftings of target case appears in figure 13. System listed all analogous case for designer to reuse and adopt.

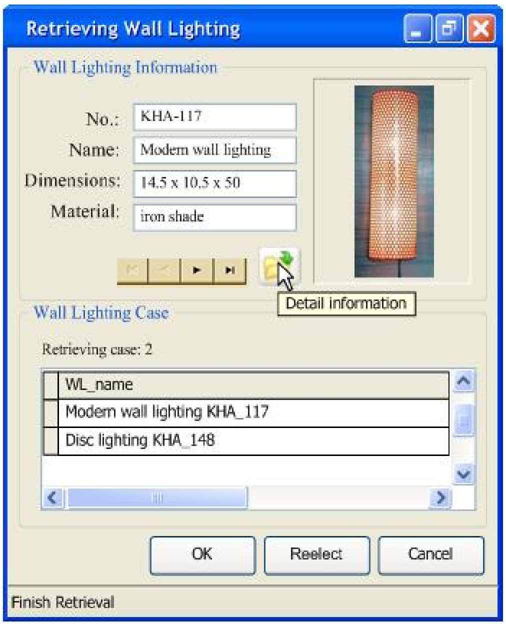


Figure 13. GUI of analogous case.

Figure 14 shows the results of innovation principles which developed by referring to the contradiction matrix. Designer refers to initial problems and also thinks about related factors in whole design process. For example, appearing of relatedness characteristic has a connection with initial problems. The related characteristic are include: shape, strength, convenience of use, complexity of device and complexity of control. Designer checks strength and complexity of device to be conditions of analysis. The system replies four principles to assist designer innovating: Extraction, Do it in reverse, Self service and Replacement of mechanical system. Base on contradiction matrix of TRIZ, designer could acquire the solving principles to find a suitable solution in lighting design.

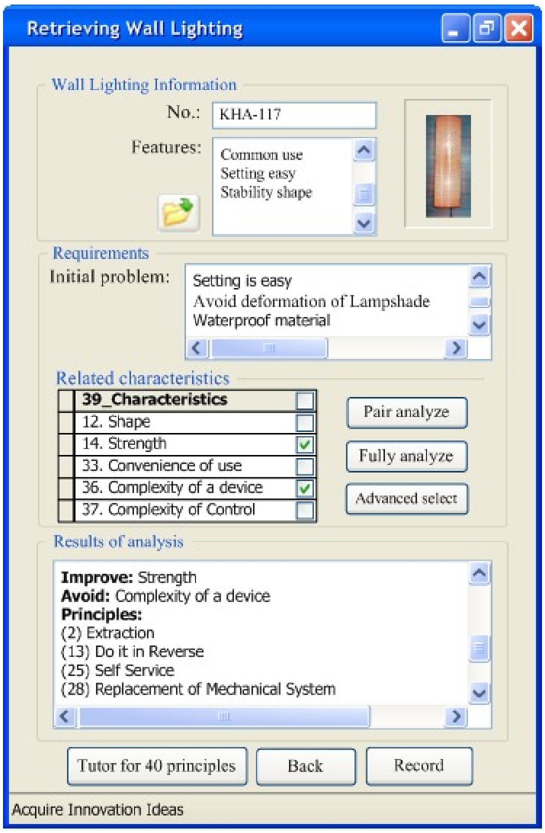


Figure 14. GUI of innovation principles by contradiction matrix.

5. CONCLUSION

As mentioned at the beginning, TRIZ offers solutions have been synthesized from a large variety of domains; hence it is easier to find new solutions from specific problems among CBR process. One major idea behind this approach is systematically using innovation knowledge in a rational way. This study proposes a new way of applying TRIZ to intervene CBR which according to another knowledge-based method. The prototype test practice that computational tool could encourage designer idea continually by pervious case and TRIZ method. We believe that the effectiveness of using TRIZ in CBR process can be further enhanced. But this result still needs more practices to achieve.

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