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Research on Optimization of TRIZ Application Driven by Design Needs and Targets

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Abstract

The algorithm for inventive problem solving (ARIZ) provides methods and routes for designers in practical product design. However, ARIZ is a higher skill demanding large amount of professional knowledge for ordinary designers whose design skill were restricted by their insufficient professional knowledge and personal experience. To promote the efficiency of design work, this thesis provides a renovated application tactics for theory of innovative problem solving (TRIZ) which emphasize on differences existed in design needs and targets. Its main feature is based on one characteristic in application of TRIZ in practical design where different TRIZ tools may have different instructive effects on the problems belonging to different design types. In other words, the designers can choose the most suitable tool from toolkit of TRIZ to solve a certain design problem, the provided tactic with a workflow is able to help designers locate the promising TRIZ tools in accordance with design problems. The workflow contains several steps: Firstly, analyze the cognitive process of designers; secondly, propose an application method which is based on ontology to analyze innovative design problems; thirdly, utilize a mapping method between design problems' targets and needs with certain TRIZ tools to help designers locate the suitable tools to solve design problems. Presenting two sample design examples to verify the practicability of optimized method proposed in last part of article.
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Keywords: Optimized ARIZ ;Ontology modeling; Mapping process;

1. Introduction

ARIZ is as an effective tool to solve innovative problems once the main design target has been identified by designers [1]. The main function of ARIZ lies in its workflow for innovative problems solving, which combine all the innovation tools from TRIZ and instructions to locate the appropriate tools to the problem for designers [2, 3]. Unfortunately in real situation problems are seldom clearly defined in their early stage, which make it a strenuous job to indentify key methods to fulfill the design target [4]. The problems need to be reprocessed before designers choose the right TRIZ tool to solve the problems, if wrong tool has been chosen, all the prepared work is in vain[5]. Therefore, it is vital for designers to locate the most matched tool based on design needs at the very beginning of design [6]. Some applicable methods combined with theories had been presented for designers with demanding of the sophisticated TRIZ knowledge [7, 8]. To make it easy to handle, we propose a new method based on the ontology as well as a mapping strategy between certain innovative TRIZ tools and various design needs or targets. The theory of ontology with its cognitive philosophy background has been extensively embedded in conceptual design studies [9-10]. The methodology proposed in this paper includes two main parts, one of which is the sorting scheme related to design targets, the other part is a mapping strategy for locate suitable TRIZ tool to solve design problems. With the basic idea extracted from the ontology [11]. We can divide all designs into five types which are in accordance with five layers of innovation in TRIZ [12], then we present this five types related to the differences existed in the design targets. The mapping strategy we proposed works as a quick paring tool for inventive problems solving. With the joint effort of the two parts we can simplify the working process of ARIZ for improving the chance to find the most appropriate

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tool chosen from the TRIZ toolkit. To verify its actual efficiency we use two simple engineering examples to specific this new method we presented.

2. The classification method as design needs by ontology

The theory of ontology is a philosophy notion proposed as a measure for cognition the essence of matters [13]. Its main advantage is providing a neutral way to standardize the conditions of design problems. In this paper, we embed the basic idea of ontology in the primary stage of TRIZ problem solving and propose a method to discern the type of the design through analyzing its design needs and targets.

2.1. Five types of design classified by its design needs or targets

Entities, attributes and relations are three key elements to express the engineering system based on ontology [14]. We use the symbols in table1 to represent the elements in product to define design needs and targets.

Table 1. the table of ontology symbols for defining design needs and targets.

Name of element in ontology	Symbol of element
Entity	
Attribute	
Relation	

There are five types of design problems according to the difference in design needs, we can represent design problem by means of ontology symbols proposed in table1.

The first type aims at changing an attribute of certain entity in product. Its model is expressed in figure1. Its design problem mainly exists in the relation between certain entities with their own attributes, for example the color of paper is too bright to read in sunlight, therefore it is better to change the attribute "color" in entity "paper". This design type belongs to the 1st level of innovation in TRIZ.

The second design type is changing attributes that connecting different entities, for example the rub coefficient between sliding table and track in lathe. The main feature of this type emphasizes on the attribute that work as a bond or interface that connecting different product's parts. The model of the second type is shown in figure2, which belongs to 1st or 2nd innovation level in TRIZ.

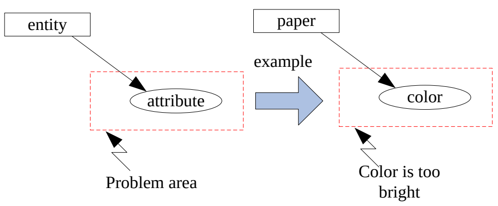


Fig. 1. Symbol model for the first design type

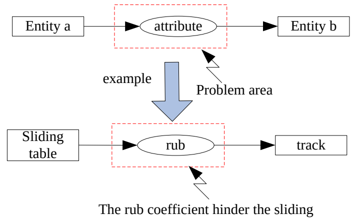


Fig. 2. Symbol model for the second design type

The third design type mainly means operating on the entities with advantages and disadvantages, such as the Freon used in the refrigeration system like air-conditioners or refrigerators. Its symbol model is shown in figure 3. In most situations, designers always need to resolve the technological or physical conflicts to achieve design targets. The third type usually belongs to 2nd or 3rd level innovation in TRIZ.

The forth design type aims at renovating sub-chain or sub-system in known product systems, such as utilizing an electronic timer to replace a mechanical one as well as building a new form of product system through updating the inner connections among the entities in product. We use figure 4 to represent the feature of the forth design type usually belonging to 3rd or 4th innovation level in TRIZ.

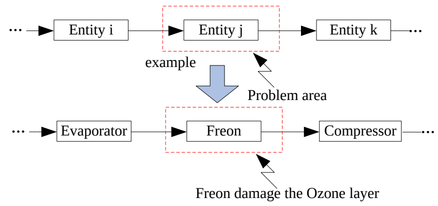


Fig. 3. Symbol model for the third design type

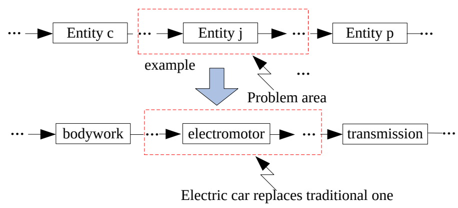


Fig. 4. Symbol model for the forth design type

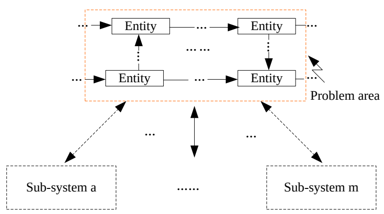


Fig. 5. Symbol model for the fifth design type

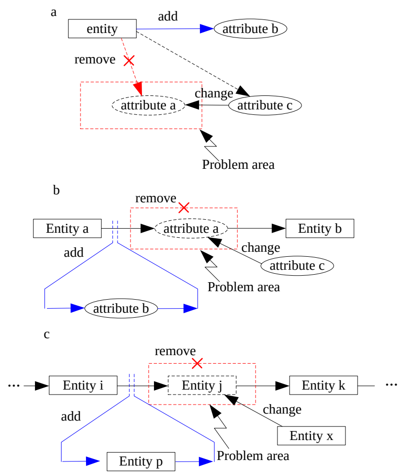


Fig. 6. (a) The strategy for 1st design type, (b) The strategy for 2nd design type,(c) The strategy for 3rd design type.

The fifth design type is the highest level of innovation problem in TRIZ, its symbol model shown in figure 5. The main feature of fifth type is aiming at creating a new core product with its supplements making up new products system. The examples representing the fifth type are computer and network and flying cars with new regulation of traffic in the near future.

2.2. Main strategy for each type of design

To find solutions to various types of design problems, there are three most widely used operations: adding, removing and changing the target attributes or entities. In most situations, designers meet design problem belonging to 1-3rd innovation level in TRIZ [15], so the following strategy mainly emphasizes on the 1-3rd design type proposed in this paper, and the result of fourth or fifth type can be achieved by the joint work of 1-3rd type's strategies. We use figure 6 as an illustration to represent the strategies to resolve design problems of various design types.

3. The mapping network between TRIZ tools and various design needs and targets

This part of study work composes three aspects: the first part is the analysis of the inventive tools in TRIZ based on the design targets; the second part is building the mapping strategy which connects the design type and its appropriate TRIZ tools; the last one is presenting a workflow to guide designers to use proposed schemes.

3.1. Analyze the features of TRIZ inventive tools

The traditional ARIZ such as ARIZ-85 AS is a long string process [16], so the users need to solve the TRIZ problem according to the workflow step by step, therefore the efficiency of ARIZ has potential to improve.

We choose the innovative tools in TRIZ as the main objects for study. These tools are technical and physical conflicts, effects, 76-standard solutions (76-SS), resource and ideality respectively. Among these tools, conflicts as well as effects and 76-SS are the basic innovation tools with complete process, whereas the ideality and resource are important supplements in innovation. We analyze the three features of every chosen tool: Reprocessing which is preparatory work for using the tool; core idea and expected targets, and analysis result list in table 2.

Table 2. The table of analysis features of TRIZ tool.

Tool	Reprocessing	Core idea	Expected target
Conflicts	Define the domain of problem	Find key parameter	principle as the trend for innovation
Effects	Find the area with the problems	Analyze the flow of function	New principle to meet the function
76-SS	Substance-field analysis(SFA) for product under design	Confirm standard solution	Renovated SFA model
Resource	Choose the basic tool	Build list of resource	Provide material for innovation
Ideality	get result of innovation	Define the ideal stage for problem	Evaluate innovation result

3.2. Build mapping network between TRIZ's tools and design types

The technical and physical conflicts are the most common TRIZ inventive tools to locate key parameters causing conflicts which may lie in entities of product to design. Therefore, innovation principles are adapted to the 1st or 2nd design types which emphasize on entities' attributes.

The effect often handles the problem of flows' conversion which focus on the attributes of entities that work as the connection among the products' components, thus it has a wide scope of application and can support the 2nd, 3rd and 4th design type.

76-SS also adapts to a wide range of design types. It handles the problems caused by inappropriate structure in the entities of product. It has potential assistance to 1st-4th proposed design types.

The resource and ideality are often used as the supplement methods in innovative problems solving. The resource works as a library for inspiring designers to find available solutions to innovation problems, while ideality is always used as the method to evaluate the ideal state of design results.

With the analysis of the features of TRIZ innovation tools and their relation with five design types, we present a mapping connection of more detail information about the network between design types and available TRIZ tools. The presented mapping network is shown in Fig7.

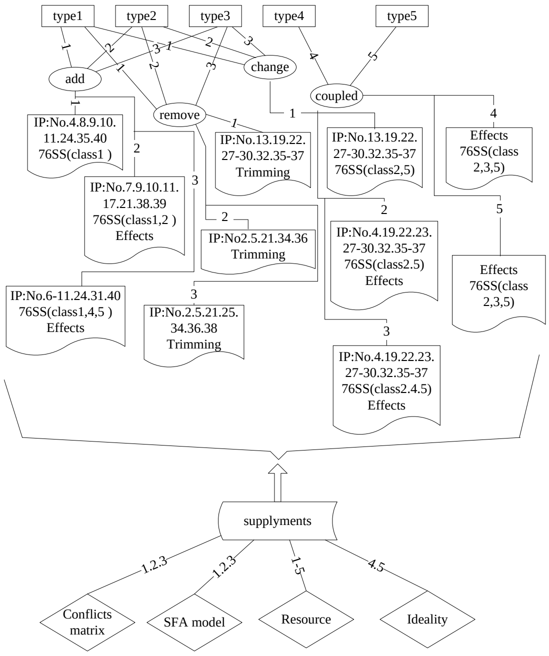


Fig. 7.Mapping connection of design types and TRIZ innovation tools

3.3. The workflow for application of TRIZ based on design needs and targets

The classification of design type as well as the mapping network connecting its appropriate TRIZ tools can be integrated into traditional ARIZ to cut down its original routes with a more efficient one. We present the new scheme shown in figure 8 as an improvement for traditional ARIZ.

This new scheme only has 5 steps and just 2 judgments other than 9 steps workflow and 5 judgments in original ARIZ. The whole workflow is shown in Fig 8.

There is brief description about five steps:

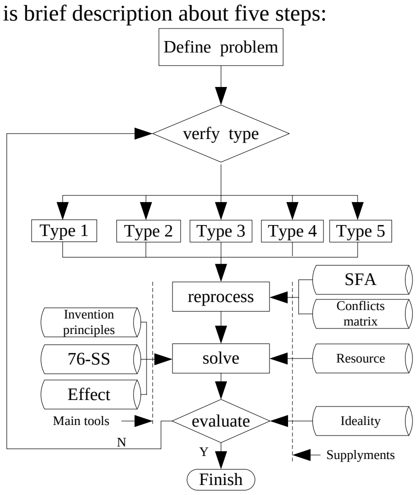


Fig. 8.New workflow of combination of proposed method

Step1: Define the design problem

Step 2: Discern the design type of problem to solve by means of the method proposed in section 2.

Step 3: Reprocess the design problem by the reprocessing method listed in figure 7.

Step4: Solve the design problem by appropriate TRIZ tools from figure 7 with the help of mapping network.

Step 5: Evaluate the design result, if the result meets the requirements, then finish the design work or go to step 2 to choose another type.

4. The engineering examples

4.1. Refine design for electric plug

Step1: Define design problem

The electric plug is an accessory but indispensable part for appliances, in most situations the connection between electric plug and socket is too tight to easily detach, and detaching may cause damage to the plug. A new electric plug with detachable attribute that can help detach the plug from the socket is needed. So the design problem was defined as add detachable attribute in plug.

Step2: Build the analysis model and verify its type

Build ontology model shown in figure 9 for problem to design. From the information in the model we can sort it to type 2 for adding an attribute which help release plug and works as an accessory attribute to the plug.

Step3: Solve the problem by the corresponded TRIZ tools

We choose the NO.7 invention principle combined with the No.46 from the 76-SS according to figure7, and build the new function architecture of the new electrical plug shown in figure 10. We add a releasing mechanism in the traditional plug to help detach the electric plug from the socket. Design result of the new product is shown in figure 11.

Step4: Evaluate the design result

Even though the complexity of plug is improved, the detachable attribute make it convenient to detach plug from socket to meet the deign needs.

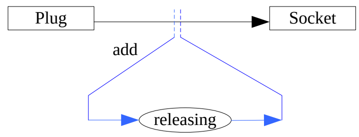


Fig. 9.The ontology model for the design target

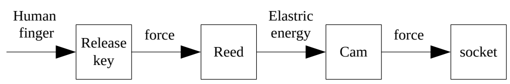


Fig. 10.The function architecture of the refined electric plug

1. Release key, 2.plug, 3.reed, 4.cam

Fig. 11.Design result of plug with detachable accessory

4.2. Design for a new kind of suction disc with a glue cavity

Step1: Define the design problem

The suction disc is often used as a convenient tool to provide a connection between objects and smooth surface. The main effect for the suction disc is producing a small vacuum cavity to sustain the weight of object, but the vacuum cavity is often unstable. Therefore, when we want to hold something for an eternal connection, the traditional suction disc may invalid. The target of design can be generalized as creating a new kind of suction disc which can produce long-time and stable connection.

Step2: Build the analysis model and verify its type

We build the ontology model for design problem and its result is shown in figure 12. From the feature of the model, we can redefine the design problem as 3rd design type.

Step3: Solve the problem by the corresponded TRIZ tools

We use the corresponded TRIZ tools from figure7 and build a new product by joint effort of effects and 76-SS class 4 get a proposal product shown in figure13. Furthermore, we build the prototype for our new design suction disc by the 3D printer and its image is shown in figure 14.

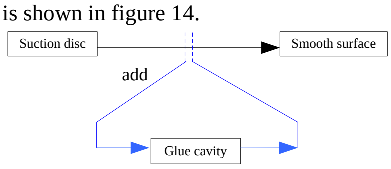
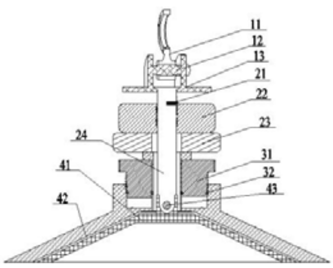


Fig. 12.The ontology model for analysis the design target for suction disc



11.working part,12.connect pin,13.connect base,21.limit device,22.operate knot,23.shims,24.sucker connect rod,31.glue press knot,32.seal ring,41.disc body,42.disc shell 43.rivet

Fig. 13. Main components for the new suction disc

Fig. 14.The prototype of new suction disc with glue cavity by 3D printer

Step4: Evaluate the design result

The effectiveness of new suction disc prototype has been improved 30% than traditional suction disc throughout experimental measurement.

4.3. The advantages and limitations of proposed method

Form the above two design examples we can arrive at the conclusion that this new method presented in this paper help cut short the work routes of known ARIZ and improve efficiency of low level innovation, especially from 1st to 3rd level innovation in TRIZ. The main advantage of proposed method is reducing the difficulty for the TRIZ beginners with the basic knowledge of innovation and product design to solve the simple innovation problems in TRIZ. Moreover, the idea and method proposed here make it possible for TRIZ Learners just mastering partial of TRIZ tools other than a good command of the whole methodology to carry out the innovation, which make practical sense for further popularize application of TRIZ in future.

5. Conclusion and discussion

In this paper we present a new way that emphasize on the design's need or targets to utilize the innovation tools in TRIZ combined with the traditional ARIZ. To make it friendly to TRIZ beginners, we divided the design into five types by design needs based on the idea of ontology. To improve the efficiency of proposed method we also built a mapping strategy between the certain design types and their corresponded TRIZ tools it can save a lot of time for users especially the beginners to find the appropriate TRIZ tools to solve their problems. We also give the method workflow bring a simplified routes as supplements for the traditional ARIZ.

The main contribution of this piece of work is providing a simplified method aiming at settle the low level innovation in TRIZ. Unfortunately, this method is fail in support for high level innovation in TRIZ that can be achieved by ARIZ. Another contribution of the paper is reducing the requirements for users who want to utilize TRIZ to innovation, with the help of method and tools we presented they can get a good design result without a sophisticated knowledge of TRIZ methodology, in other words, it lower the threshold for application of TRIZ compared with traditional ARIZ.

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