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An Innovative Product Design Approach Based on TRIZ's Inventive Principles

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Abstract

A systematic design approach with effective and efficient guiding principles is pivotal for developing versatile and innovative products, which then lead to product success. This research aimed to propose an innovative product design approach that incorporates TRIZ principles. This newly proposed approach started with identifying design issues or problems by conducting a comprehensive literature review with respect to the targeted product. The revised three-step inventive problem solving procedure of Shulyak's then formulated potential design problems to generate the problem statement in a structured way. The three steps for solving an inventive problem were: determining product's characteristics that should be improved or eliminated, stating characteristics needed to be improved to locate the potential contradictions of the problems, and eliminating the contradictions by employing contradiction matrix to identify the proper inventive resolutions. The solution concepts, as suggested from TRIZ's principles, were generated after working through the procedures. They can serve as design directions to improve and re-design the original product. Case studies were conducted to demonstrate how this approach works. Study results show that the proposed approach can help product designer or relevant profession develop innovative products effectively and efficiently, resulting in gaining better competition in the marketplace.

Keywords: Innovative Product Design, Inventive Problem Solving, Systematic Innovation, TRIZ.

1. Introduction

The Product design generally determines more than 70% of the total cost in the whole product development (Boothrody, et al., 2002; Dowlatshahi, 1992; Miller, 1995; Shetty, 2002). This suggests that mistakes or successes in the conceptualization of a product often have the greatest impact throughout the product development. Furthermore, they tend to be amplified over the course of the product development. Due to the nature of the product development in the early phases, chaotic, unpredictable and unstructured activities are often expected and inevitable (Koen, et al., 2002). These typical scenarios normally post great challenges for a product to be designed and developed effectively and successfully in the end. A sound product design can then be highly rewarding, which will eventually lead to a successful product that can be producible, marketable, and profitable.

Product design can be considered as a process for problem solving (Cross, 2000). A common strategy used in this problem-solving process is random search that is generally no apparent plan. This solution search strategy is generally constraint to past experiences and own specialties and disciplines that will influence and dominate the search directions for solutions. These never-ending random trials take huge effect to locate the potential solutions, which are likely not existed in the search region. And they couldn't be very helpful to deal with uncertainties in the earlier phases of the product development and provide the needed information and responses in a timely manner. To address this issue, a systematic innovation approach is necessitated to help point out the most promising solution directions by enlarging solution search space and directing appropriate solution search across inter-disciplines.

TRIZ, a Russian acronym meaning theory of inventive problem solving, can serve as one of the promising candidates to meet this requirement. Based on analyzing numerous patents, TRIZ theory suggests that design problems can be solved in predictable ways and 95% of the inventive problems in any particular field have already been solved in some other fields (Terninko, et al., 1998). Therefore, solving design problems can be effective and efficient when the appropriate solutions are found and implemented by following TRIZ principles. However, design problems are mostly not well defined and relevant information is normally limited. The classic TRIZ theory does not provide tools to define problem situation and formulate the problem. These post the difficulties for classic TRIZ theory to deal with problem statement and situation analysis effectively (Dwyer, 2005; Terninko, et al., 1998). Teaming up with problem formulation tools, TRIZ then can serve better to offer innovative solution concepts.

The remainder of this paper is structured as follows. Firstly, TRIZ theory, as the core of the proposed approach, is introduced. This is followed by description of the TRIZ-based systematic innovation product design process in details. Thirdly, case studies are provided. Finally, conclusions are presented.

2. Introduction to TRIZ

After reviewing and analyzing more than several millions of patents, Genrich Altshuller, a former Soviet Union inventor and scientist, introduced TRIZ. In the era of cold war between east and west, TRIZ theory was regarded as the state secret of the Soviet Union all the time, the western countries knew little about it. After the fall of Soviet Union, many TRIZ researchers and practitioners have migrated to western countries such as U.S. and Europe. In addition, Kishinev School, known for its great reputation in teaching and researching TRIZ in the Soviet Union, has established branch schools in the western countries to continuously promote and develop TRIZ (Terninko, et al., 1998). TRIZ then begun to popularize and further develop in the western countries rapidly. Many international companies, such as, Ford, GM, Chrysler, and Xerox, have been sponsored the development of TRIZ and integrated TRIZ to their product design and development, resulting in gaining great benefits (Domb, 2013; Dwyer, 2005). Companies, such as Samsung from South Korea, were recovering from the verge of bankruptcies after employing TRIZ.

The main theories of TRIZ include contradiction analysis, substance-field method, ideal final result, ARIZ (algorithm of inventive problem solving), etc. (Ideation International Inc., 1999; Mann, 2007; Terninko, et al., 1998). Among them, contradiction analysis is one of the most popular ones in application. Altshuller indicated that every innovative patent was the result to solve an inventive problem, which normally contains some contradictions (Altshuller, 1998; Altshuller, 1999). Contradiction is classified into physical and technical contradictions (Altshuller, 1998; Altshuller, 1999). Physical contradiction is the conflict within the same parameter that has the opposite states co-existing at the same time. To eliminate physical contradiction, separation principles are employed (Mann, 2007; Terninko, et al., 1998). When improving one parameter is causing the deterioration of another, the conflict is named technical contradiction. To eliminate technical contradiction, contradiction matrix, made up by a 39 by 39 matrix, is utilized (Mann, 2007; Terninko, et al., 1998). An innovative problem solving method should be the one that can eliminate conflict or contradiction in a problem effectively and efficiently and help generate innovative solution. And TRIZ is the one to serve this purpose well.

3. A TRIZ-based Method

Based on the creative design approach proposed by Yang et al. (2010), this research proposed a structured and systematic innovation design process that incorporates both TRIZ principles and a revised three-step inventive problem solving procedure. Although the original three-step inventive problem solving process proposed by Shulyak (1997) is a sound problem formulation method to help solve inventive problems in conjunction with both contradiction matrix and inventive principles of TRIZ, the forms (Form F-1 & Form F-2) from the completion of the 3-step process are designed with engineering terminologies, which make them not friendly to some professions in product design and development field, such as industrial designers. To address this issue, a revised 3-step process, designed from the perspective of the product design and development, was proposed.

This research started with a comprehensive literature review on a targeted product to identify the potential problems. The revised 3-step process was then employed to translate the initial problem description into the conflict or contradiction such that the contradiction matrix of TRIZ can be introduced to resolve the problem and provide solution concepts. The revised 3-step process for solving an inventive problem is described in the following:

(1) The first step, completed by filling out the Form F-1, was to formulate the initial problem description and analyze the product to determine characteristics

that should be improved or eliminated. In this step, there are five items to work with step by step. Item one is to list the product name. Item two is to define the goal of the product and how the product is designed for. Item three is to list the main elements and their corresponding functions. Item four is to describe how to use the product. Based on the information provided above, the last item is to determine characteristics that should be improved or eliminated.

(2) By following the analysis results of the first step, the second step, completed by filling out the Form F-2, was to analyze positive or negative characteristics needed to be improved or eliminated in order to identify the potential contradictions in the problem for resolution. In this step, there are two items to work with step by step. Item one is to determine the characteristics to be improved from TRIZ's 39 generic characteristics for product improvement, based on the product's goal from Form F-1. Item two is to determine the deteriorated characteristics with respect to the characteristics to be improved.

(3) The third step, completed by filling out the Form F-3, was to eliminate the contradictions, identified from second step, by applying TRIZ's problem solving tool – contradiction matrix to locate appropriate inventive principles for resolving the problem. In this step, there are two items to work with step by step. Item one is to identify the suggested principles from TRIZ's 40 Principles, after applying contradiction matrix analysis. Item two is to determine the proper inventive principles, which are from the suggested principles of Item one, with respect to each element of the product for design improvement.

The suggested principles or solution concepts can serve as design directions to improve and re-design the original product with innovative ideas. If any of the contradictions cannot be clearly identified after the problem formulation, Liu's method (Chen & Liu, 2001; Liu & Chen, 2013) can be employed to help locate the proper solution concepts. Another approach to deal with no contradiction situation is to go through every inventive principle and choose the most desired solution concepts (Shulyak, 1997).

4. Case Studies

The daily writing instrument, such as pen and pencil, was selected as to demonstrate how this approach works. From the intensive literature review, three major issues concerning daily writing instrument design are needed to be improved. They are: assisting people to write easily and smoothly, avoiding muscle injury during the writing process, and assisting in guiding people to use the correct writing posture (Chang, et al., 2010). To deal with these issues, the revised 3-step process was applied to formulate the initial problem description and to help construct and verify the conflict or contradiction. By completing each item of Forms F-1 (shown in Table 1), the initial problem description was formulated to identify product's characteristics needed to be improved. They were core, grip, and shaft of a pen. A typical writing instrument can be improved by introducing a better core, grip, or shaft design. To promote easily and comfortably writing experience, our aim was to design a better housing or grip of the writing instrument. By completing Form F-2 (shown in Table 2), all of TRIZ's 39 characteristics were investigated one by one with respect to the design goals (item 2 from Table 1) and the product elements to be improved (item 5 from Table 1). The characteristic #12, i.e., shape, was then identified as the sole one needed to be improved, while the deteriorated characteristics were #7 (volume of a mobile), #13 (stability), #32 (manufacturability), and #35 (adaptability). Four technical contradictions were formulated as follows:

(TC-1) If the shape (characteristic #12) design of the housing or the grip can be improved by introducing a better one, then the volume of the writing instrument (characteristic #7) will get worse.

(TC-2) If the shape (characteristic #12) design of the housing or the grip can be improved by introducing a better one, then the stability of the writing instrument (characteristic #13) will get worse.

(TC-3) If the shape (characteristic #12) design of the housing or the grip can be improved by introducing a better one, then the manufacturability of the writing instrument (characteristic #32) will get worse.

(TC-4) If the shape (characteristic #12) design of the housing or the grip can be improved by introducing a better one, then the adaptability of the writing instrument (characteristic #35) will get worse.

Finally, the contradiction matrix of TRIZ was applied to eliminate the contradictions specified above and provides totally 15 inventive principles for resolving the problem (shown in Table 3).

After carefully reviewing the suggested principles with the consideration of three major design issues (item 2 from Table 1) and main product elements (item 5 from

Table 1) of writing instrument design improvement, the researchers, with the aim of designing a better housing or grip, made the judgment call to consider four of the suggested principles as the most promising ones and choose them as the re-design directions for design improvement. The chosen principles (#1, #4, #14, and #15) were employed to assess the potential improvement of daily writing instrument (shown in Table 3). Based on the product analysis from Form F-1 and previous study (Chang, et al., 2010), it was found that the shaft (or housing) of the writing instrument holds the main influence on design improvement, following by grip (or grip area) and core, which are all utilized to support writing in an easy and comfortable manner. The applicable chosen principles were assessed with respect to the components of a writing instrument mentioned above. Selected examples on applying the inventive principles to generate feasible design directions are in the following.

Table 1. Formulation of Product's Characteristic to Be Improved.

F-1: Formulation of Product's Characteristic to Be Improved	
1. State the name of the product:	
A typical writing instrument	
2. Define the goal of the product. The product is designed to:	
** Assisting people to write easily and smoothly* ** Avoiding muscle injury and writing strain during the writing process* ** Assisting in guiding people to use correct writing posture*	
3. List main elements of the product and their functions:	
Element	Function
Core	*To be applied to a surface of writing*
Grip	*To support comfortable writing*
Housing	*To be hold in writing*
4. Describe the operation of the product:	
A typical way to hold a writing instrument is three-finger grasp. The writing instrument lies on the middle finger and is controlled using the thumb and index finger.	
5. Determine the element of the product should be improved or eliminated:	
Core, Grip, or Housing (To improve the typical writing instrument by introducing a better core, grip, or housing design.)	

Table 2. Formulation of Technical Contradiction.

F-2: Formulation of Technical Contradiction		
1. State the characteristic that should be improved, based on the goal from F1:		
#12.Shape		
2. State a characteristic that is getting worse under previous conditions: (State the technical contradictions)		
Name of Technical Contradictions	Improved Characteristic	Worsen Characteristic
TC-1	*#12 Shape*	*#7 Volume of moving object*
TC-2	*#12 Shape*	*#13 Stability of object*
TC-3	*#12 Shape*	*#32 Manufacturability*
TC-4	*#12 Shape*	*#35 Adaptability*

Table 3. Formulation of Solution Concept.

F-3: Formulation of Solution Concept			
1. List suggested principles by eliminating the contradictions:			
Name of Technical Contradictions	Coordinates in the Contradiction Matrix	Suggested Inventive Principle	Name of the Principle
TC-1	*#12 x #7*	*#14*	*Spheroidality*
		#4	*Asymmetry*
		#15	*Dynamicity*
		#22	*Convert Harm into Benefit*
TC-2	*#12 x #13*	*#33*	*Homogeneity*
		#1	*Segmentation*
		#18	*Mechanical Vibration*
		#4	*Asymmetry*
TC-3	*#12 x #32*	*#1*	*Segmentation*
		#32	*Changing the Color*
		#17	*Transition Into a New Dimension*
		#28	*Replacement of Mechanical System*
TC-4	*#12 x #35*	*#1*	*Segmentation*
		#15	*Dynamicity*
		#29	*Pneumatic or Hydraulic Construction*
2. Determine the proper principles for design directions:			
#1. Segmentation , #4.Asymmetry, #14.Spheroidality, and #15.Dynamicity			

(1) Principle 1 - Segmentation

For better writing results, the core of a writing instrument can be divided into parts. The refillable pen or pencil in the marketplace, such as the one shown in Fig. 1, is a good example by applying this idea.

Fig. 1. Refillable Pencil (Pacific Writing Instrument, Inc., 2010).

(2) Principle 4 - Asymmetry

Without the proper guidance, the existing symmetrical barrel design is difficult to promote the correct writing position. We normally have to accommodate the existing design while writing, resulting in writing strain. An asymmetrical shaft design could serve as holding guidance to promote the correct writing position. Handy Birdy Minny (as shown in Fig. 2), designed by Tripod Design in Japan, is a good example by applying asymmetry principle.

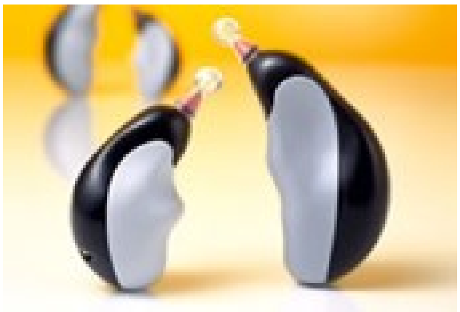

Fig. 2. Handy Birdy Minny (Tripod Design, 2013).

(3) Principle 14 - Spheroidality

The typical barrel design can be replaced with spherical shapes to provide support while holding the writing instrument in the writing process. This design should help reduce writing strain and provide better and more comfort control throughout the writing. A good example to demonstrate this idea is U-Wing Pen (as shown in Fig. 3), design by Tripod Design in Japan.

Fig. 3. U-Wing Pen (Tripod Design, 2013).

(4) Principle 15 - Dynamicity

To accommodate all users, the grip or support area can be designed to adjust for various writing positions dynamically. Yoropen (as shown in Fig. 4), designed by Yoropen Corp. in Taiwan, is a good example to demonstrate this idea.

Fig. 4. Yoropen (Yoropen, 2013).

In addition, to further demonstrate how this method could work on generating new design concepts for writing instrument, several student designers were recruited to participate in pen re-design based on the proposed approach. The design goals and the typical pen design analysis were provided and explained. The four chosen principles (#1, #4, #14, and #15) with detailed descriptions and examples were provided as the re-design directions. Student designers employed the suggested inventive principles as the stimuli to develop the design concepts. The proposed design concepts are shown in the following:

(1) Concept One

Concept one in Fig. 5 employed a combination of two principles from the chosen ones, which were #4 and #15, to re-design the typical pen. By applying asymmetry, the grip or support area was designed asymmetrically and ergonomically to direct user fitting in the more appropriated writing position and help relaxed writing comfort. The dynamicity principle was applied to develop the flexible profile on the pen shaft in order to let the pen rest well and comfortably in the hand, which can serve as both writing position guidance and relaxed writing.

(2) Concept Two

Three principles from the chosen ones, which were #4, #14, and #15, were incorporated in generating concept two (as shown in Fig. 6) to re-design the typical pen. By applying asymmetry and spheroidality, the typical grip and barrel design was replaced by asymmetrical and spherical shapes to provide optimal support for relaxed writing comfort. The dynamicity principle was also applied in this design to develop the dynamic profile for pen length adjustment, resulting in accommodating all users for various pen grapping positions.

(3) Concept Three

Instead of re-designing the whole writing instrument, concept three in Fig. 6 designed merely the extender for pencil by employing a combination of three TRIZ's inventive principles of #1, #4, and #15. With applying the design direction of segmentation, extender was designed for used pencils. With its asymmetrical and triangular design, the extender can also be used to hold other pens for resting comfortably in the hand and guiding the writing position. The dynamicity principle was also applied in this design to develop the retractable feature to slide the used pencil to the right place.

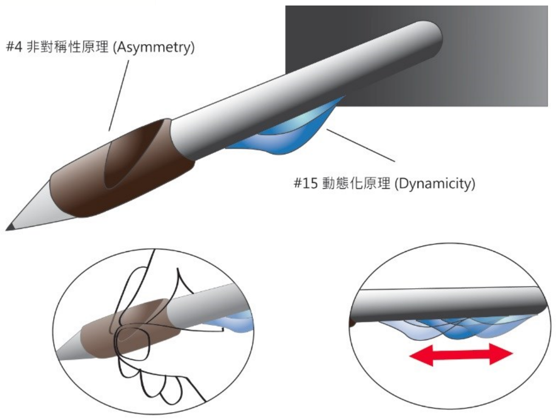

Fig. 5. Concept One.

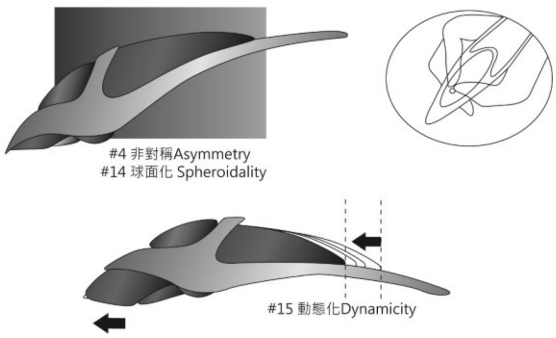

Fig. 6. Concept Two.

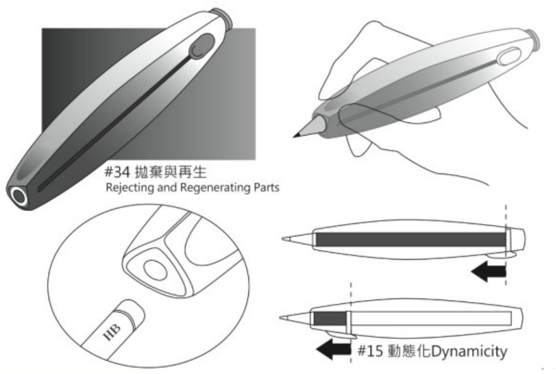

Fig. 7. Concept Three.

5. Discussions & Conclusions

By adopting the existing products as examples, the first part of case studies section demonstrated how this newly proposed approach works step by step. And it also shows that this TRIZ-based method can be used to analyze the existing products to gain some product development insights, resulting in developing new product concepts. The second part of case studies recruited student designers to practice writing instrument re-design exercises with the help of this TRIZ-based method. During the design activities, the only instruction was to ask them to employ the chosen inventive principles of TRIZ as re-design directions and stimuli to generate new design concepts of typical writing instrument. From the re-design results, it is found that the student designers tended to apply multiple inventive principles within a design concept. This compound design strategy is worth to be studied in the later research.

The intensive literature review from this research helped summarize the common problems in writing (Chang, et al., 2010). Previous studies (Chang, et al., 2010) show that diameter, length, cross-section, and grip area of a writing instrument are major factors to influence writing performance. While handwriting, user has to rely on holding or grasping the shaft or housing of the writing instrument. Poor writing instrument design with respect to factors mentioned above can normally cause writing strain and performance. The design of a writing instrument, without any guidance or support to help correct finger and hand positions, can easily cause writing strain and performance. To resolve these issues, this research introduced the revised three-step inventive problem solving process to formulate the design problems and determine the conflict or contradiction. The contradiction matrix of TRIZ was then employed to eliminate the contradiction and provide solution concepts for improving the writing instrument design. By incorporating the revised three-step inventive problem solving process, this newly proposed TRIZ-based innovative product design can help product designers, product planners and relevant professionals to solve design problems and generate innovative solutions in an effective and efficient way.

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