A Product Design Approach by Integrating Axiomatic Design and TRIZ

Shiaw-Tsyr Uang[1,*], Cheng-Li Liu[2], and Mali Chang[1]

[1] Department of Industrial Engineering and Management, Minghsin University of Science and Technology, Hsinchu, Taiwan
[2] Department of Management and Information Technology, Vanung University, Taoyuan, Taiwan
uang@must.edu.tw

Abstract. The purpose of this research intends to integrate the strengths of axiomatic design (AD) theory and theory of inventive problem solving (TRIZ). This study establishes a systematic product design model by adopting some major tools from AD and TRIZ such as functional requirements, design parameters, design matrix, contradiction matrix and inventive principles. Furthermore, the proposed model's efficiency is analyzed and evaluated by a case study of a Handheld GPS product. Results indicate that the design model which combines with two theories can find out the usability problems and solutions efficiently. When applying the proposed model on product redesign or new product development may avoid the cost waste and increase the design efficiency and usability during the product design and development processes.

Keywords: Theory of Inventive Problem Solving, TRIZ Theory, Axiomatic Design, AD, Human-Machine Interface Design, Product Development, Hand-held satellite omniselector.

1 Introduction

Nowadays, there are different kinds of products in the consuming electronic markets, and the competitions among these industries are severe fiercely. Thus, in order to gain a significant market share in the world, products have to be not only innovated efficiency but also fitting the consumer requirements effectively.

Axiomatic design (AD), developed by Nam Pyo Suh, is a human-machine interface design tool using matrix methods to systematically analyze and transform customer needs into functional requirements (FRs) and design parameters (DPs) [2]. The relationship between functional requirements and design parameters is represented in a design matrix. Good (decoupled) designs can be represented by nxn triangular matrices, e.g., all entries above the main diagonal are zero. The best (uncoupled) designs can be represented by nxn diagonal matrices [2], [5], i.e., all entries off the main diagonal are zero. On the other hand, a coupled design is undesirable, because when a DP is modified, there is no effective solution for undesirable change on multiple FRs.

* Corresponding author.

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Previous studies indicated the powerful function of AD may enhance product and process design abilities of the Research and Design department. Axiomatic design may help designers to structure and understand design problems [5]; however AD doesn’t provide inventive principles or design suggestions to product designers [6], [7], [11], [12].

Theory of Inventive Problem Solving was developed by Genrich Altshuller and his colleagues, and is now being developed and practiced throughout the world. "TRIZ" is the acronym for this theory in Russian [1], [10]. TRIZ is a dialectic way of thinking in finding a suitable solution while facing a design predicament [4], [8]. The contradiction matrix of TRIZ provides designers which of the 40 inventive principles have been used most frequently to solve a problem that involves a particular contradiction [3], [9].

Therefore, unlike AD, TRIZ can provide concrete design suggestions. However, TRIZ does not locate design problems based on users needs like AD does. The purpose of this research intends to integrate the strengths of AD and TRIZ. This study wants to establish a systematic product design model by adopting some major tools from AD and TRIZ such as functional requirements, design parameters, design matrix, contradiction matrix and inventive principles. In addition, the proposed model’s efficiency is analyzed and evaluated by a case study of a Handheld GPS product.

2 Methods

The proposed product design approach is shown in Figure 1 and briefly introduces in the following sections.

The first step is to analyze consumer needs of an existing or new product by AD’s FRs and DPs. After completion of drawing the hierarchical diagrams of FRs and ADs, a design matrix may build based on the relationships between FRs and ADs. The items which need to be decoupled or uncoupled on a design matrix indicate the design issues to be addressed to increase usability.

Second, designers may consider these design issues and examine related engineering parameters one by one. The engineering parameters want to improve and may get worsened can locate design contractions by TRIZ’s contradiction matrix. Then, designers may find out and adopt suggested inventive principles from TRIZ’s contraction matrix to redesign or design products.

Finally, designers reconfirm the relationship between FRs and DPs of a new design on a design matrix until the contradiction is solved. In other words, a more decoupled or uncoupled design matrix represents this design solution with higher usability and users satisfactory.

The above procedures of the proposed model’s efficiency is analyzed and evaluated by a case study of a hand-held satellite omniselector (Model number: GPSmap 60CSx) of the Garmin Corporation in Taiwan (http://www.garmin.com.tw/) (see Figure 2). Detailed description is illustrated in the Results section.

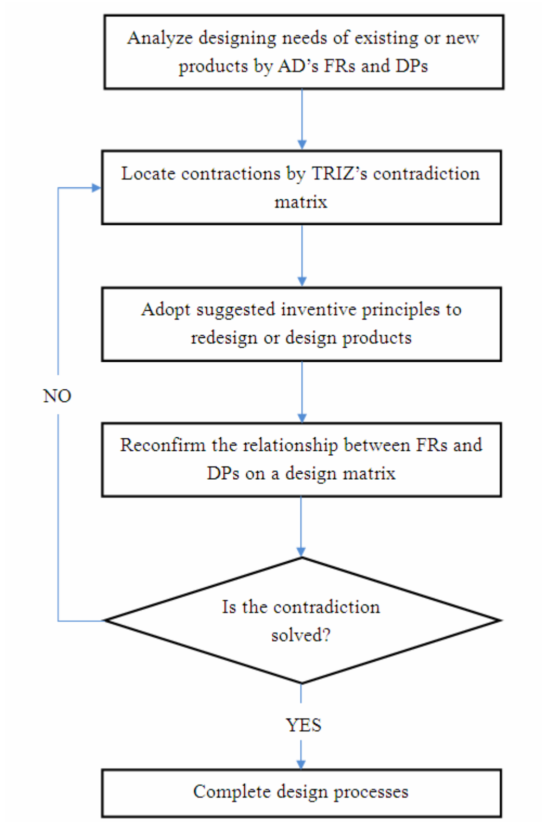

Fig. 1. The flowchart of our proposed product design model

Fig. 2. The satellite omniselector (GPSmap 60CSx)

3 Results and Discussions

In order to examine our proposed product design model, a case study of a hand-held satellite omniselector (GPSmap 60CSx) is conducted.

First, we analyze the main functions needed while using this product and we obtain nine main functions as below and the hierarchical diagram of the functional requirements is shown in Figure 3.

- FR1: Adjust map size, including zoom in (FR11) and zoom out (FR12).
- FR2: Power switch, including power on (FR21) and power off (FR22).
- FR3: Adjust display brightness, including brighter (FR31) and darker (FR32).
- FR4: Select functions, including function confirmation (FR41), quit (FR42) and cursor movement (FR43).
- FR5: Switch to main interface.
- FR6: Mark current position, including position confirmation (FR61) and Chinese characters input (FR62).
- FR7: Search destinations.
- FR8: Call sub-functions.
- FR9: Navigation.

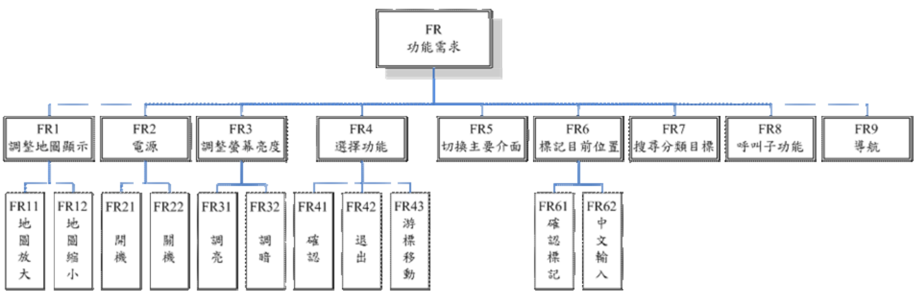

Fig. 3. The hierarchical diagram of the functional requirements (FRs) of the satellite omniselector (GPSmap 60CSx)

Next, this study analyzes the design parameters (DPs) of the current omniselector. There are ten control buttons on it as shown in Figure 4. Some control buttons may only use “press and release” to trigger their functions such as Zoom in (DP1), Zoom out (DP2), Find (DP3), Enter (DP6), Mark (DP7), Page (DP8), Quit (DP9) and Menu (DPa) keys. Both “press and release (DP41)” and “press and hold (DP42)” may use to initiate different functions of the Power key (DP4). “Press up (DP51)”, “press down (DP52)”, “press left (P53)” and “press right (DP54)” of the Rocker key (DP5) indicate the movement of a cursor to up, down, left and right directions. The hierarchical diagram of the design parameters is shown in Figure 5.

Afterwards, the functional requirements are mapping to the design parameters and the design matrix of original satellite omniselector is obtained as shown in Table 1. We can recognize from this design matrix that FR62 (Chinese characters input) and FR9 (interface in navigation) need to be decoupled to improve usability.

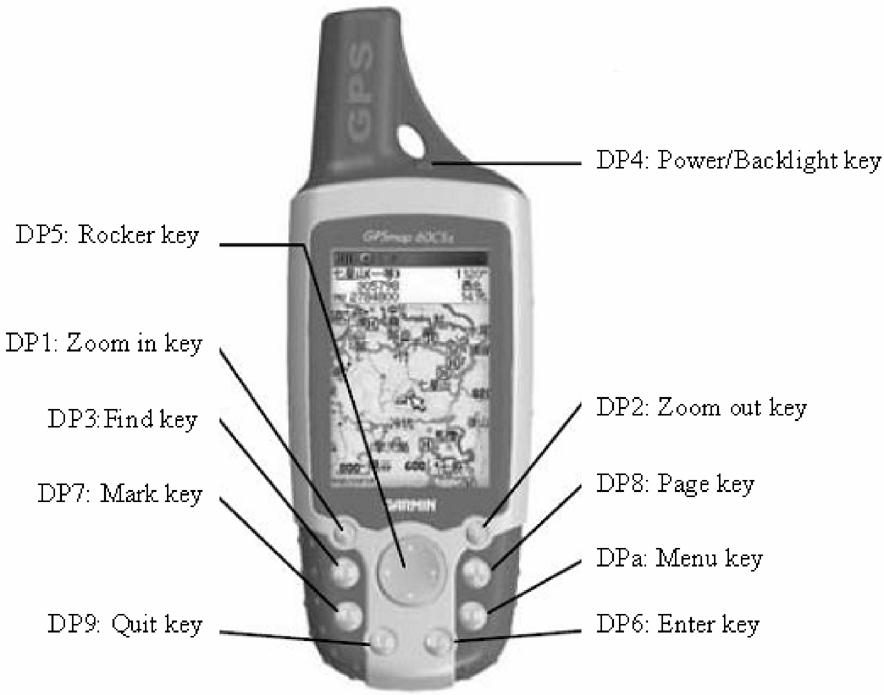

Fig. 4. The control buttons of the satellite omniselector (GPSmap 60CSx)

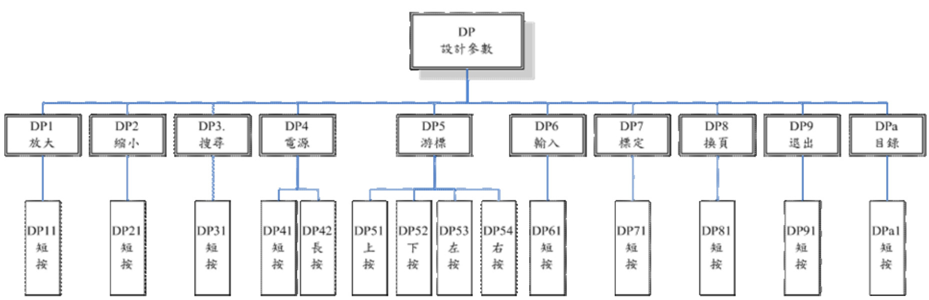

Fig. 5. The hierarchical diagram of the design parameters (DPs) of the satellite omniselector (GPSmap 60CSx)

Hereafter, we consider while redesigning FR62 and FR9, the features want to improve and the features may get worsened in terms of TRIZ's 39 engineering parameters. Then, the improved features and worsened features can be used to find out the suggested inventive principles on TRIZ's contraction matrix. Table 2 lists all the improved features, worsened features and inventive principles generated.

Table 1. The design matrix of the satellite omniselector (GPSmap 60CSx)

	DP11	DP21	DP42	DP41	DP61	DP91	DP51	DP52	DP53	DP54	DP81	DP31	DPa1	DP31
FR11	X													
FR12		X												
FR21			X											
FR22			X											
FR31				X										
FR32				X										
FR41					X									
FR42						X								
FR43							X	X	X	X				
FR5											X			
FR7												X		
FR8													X	
FR61														X
FR62					X	X	X	X	X	X				
FR9					X	X	X	X	X	X		X	X	

The suggested inventive principles are then used to stimulate design ideas. For example, principle #2 (extraction) implies we may separate navigation function from other functions to reduce user confusion.

Table 2. The suggested TRIZ's inventive principles while redesigning FR62 and FR9

Improved features	Worsened features	Inventive principles
6. Area of a stationary	12. Shape	-
	32. Manufacturability	40,16
	36. Complexity of a device	1,18,36
9. Speed	12. Shape	35,15,18,34
	29. Accuracy of manufacturing	10,28,32,25
	32. Manufacturability	35,13,8,1
26. Amount of substance	6. Area of a stationary	2,18,40,4
	12. Shape	35,14
	32. Manufacturability	29,1,35,27
	36. Complexity of a device	3,13,27,10
33. Convenience of use	29. Accuracy of manufacturing	1,32,35,23
35. Adaptability	20. Energy spent by a moving object	-
	22. Loss of energy	18,15,1
	29. Accuracy of manufacturing	-

After comparing feasibility, costs and convenience among design ideas, we decide to add two design parameters (DPb1 and DPc1) to decouple FR62 and FR9. The design matrix after redesign is shown in Table 3.

Table 3 is a decoupled design matrix. Even though a decoupled design is worse than an uncoupled one, it still allows the exact adjustment of the functional requirements. Especially Table 3 is obviously better than Table 1 in terms of usability. Our results indicate that the proposed product design approach can find out the usability problems as well as solutions efficiently.

Table 3. The design matrix of the satellite omniselector (GPSmap 60CSx) after redesign

	DP11	DP21	DP42	DP41	DP61	DP91	DP51	DP52	DP53	DP54	DP81	DP31	DPa1	DP31	DPb1	DPc1
FR11	×															
FR12		×														
FR21			×													
FR22			×													
FR31				×												
FR32				×												
FR41					×											
FR42						×										
FR43							×	×	×	×						
FR5											×					
FR7												×				
FR8													×			
FR61														×		
FR62					×	×									×	
FR9														×		×

4 Conclusions

This research demonstrates that we can locate design problems related to usability by AD's methods and generate design ideas from TRIZ's inventive principles. By combining these two theories, the proposed product design approach can find out the usability problems as well as solutions efficiently. When applying the proposed model to product design or new product development may avoid the cost waste and increase the design efficiency and usability during the product design and development processes.

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