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A Study on the Application of TRIZ to CAD/CAM System

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***Abstract*—**This study created new graphical icons and operating functions in a CAD/CAM software system by analyzing icons in some of the popular systems, such as AutoCAD, AlphaCAM, Mastercam and the 1st edition of LiteCAM. These software systems all focused on geometric design and editing, thus how to transmit messages intuitively from icon itself to users is an important function of graphical icons. The primary purpose of this study is to design innovative icons and commands for new software.

This study employed the TRIZ method, an innovative design method, to generate new concepts systematically. Through literature review, it then investigated and analyzed the relationship between TRIZ and idea development. Contradiction Matrix and 40 Principles were used to develop an assisting tool suitable for icon design in software development. We first gathered icon samples from the selected CAD/CAM systems. Then grouped these icons by meaningful functions, and compared useful and harmful properties. Finally, we developed new icons for new software systems in order to avoid intellectual property problem.

***Keywords*—**Icon, TRIZ, CAD/CAM**.**

I. Introduction

At present, innovation and creativity are underscored in all respects. By creation and not following the traditions, success can be easily achieved as long as there is innovative thinking. For example, the recently introduced Nintendo console-Wii overthrows traditions by introducing an innovative way of playing game in a completely different game pattern. And Wii has gained popularity in an unprecedented way. This study expects to solve problems effectively by implementing TRIZ method on CAD/CAM software systems.

This study tried to analyse and discuss the functions operations and icons representations of the CAD/CAM software systems on the market. By classfying the command icons of popular CAD/CAM software systems on the market, we created new icons from a scientific procedure, and added the innovation TRIZ method on functions, such as how to apply an innovative operational way to functions for easier operation. By analysing the operating steps from different popular CAD/CAM software systems, we redesigned a new function with a more efficient implementation in CAD/CAM systems. The innovation and design of these two subjects are the main purpose in these study.

For 50 years, Altshuller and his TRIZ team have proposed many analyses and problem-solving tools for innovative and creative problems. These tools are generally called TRIZ method collectively, which include: 39 contradictions matrix and 40 innovative problem-solving Principles, 76 Standard Solutions, Substance-field analysis, 8 Evolution of Technological Systems, technological effects. The 39 contradictions matrix and 40 innovative problem-solving principles were employed as the main methods for study.

Contradictions and conflicts are difficulty dilemmas to people, thus they often feel confused and trapped when facing contraditions. However, contradictions and conflicts are often the starting point of innovation and creation. There are types of different contradictions in our daily life that are of various aspects and are uncomputable. Working actively on how to solve these contradictions and conflict, people have obtained more in-depth understanding of the origin and nature of contradiction, and thus have developed methods to solve the different contradictions and conflicts. To solve the contradictions and conflict in the engineering field, Altshuller determined the general engineering contradiction and conflict solving pattern, and developed solutions of innovative principles. He aruged that problem solving is the opportunity for innovation and creation.

TRIZ innovative method seeks to eliminate conflict. Altshuller, from patent analysis, summarized 39 parameters, which would form technical contradictions, and listed the characteristics of the 39 contradictions in a matrix. To solve these contradictions, he summed 40 innovation and creation principles; for each contradiction respectively, several recommended principles were proposed. The problem solving method can be found by direct selection of related principles.

Generally, the problem is categorized into two types of contradictions: the physical contradiction and the technical contradiction. Regarding the physical contradiction, TRIZ offers four types of major separation principles:

1. Separation in space.
2. Separation in time.
3. Separation between the whole system and its parts.
4. Separation based on different conditions.

Regarding the technical contradiction, the integrated cause-effect diagram, 39 parameters and 40 principles will be followed to solve the problem.

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Since its introduction, TRIZ has made great progress in the recent decades. In addition to engineering fields, it has been studied by scholars from other academic fields, including business [1], finances [2], marketing and advertising [3], quality control [4], food science [5], sociology[6], microelectronics [7], chemistry [8], chemicals [9], reverse operation management[10], service operation management [11], and so on. TRIZ is employed in the present study to discuss software applications.

With regard to software, Kevin [12] summarized the application of 40 innovation rules of TRIZ method as well as the integration of theory and practice in software application of TRIZ method. In addition, Michael Schuster [13] also proposed the study on the application of TRIZ method in writing programs by PERL language.

The decision-making technology that applies Engineer Agents on the Knowledge Network platform for the decision-making, so as to provide knowledge network to carriy out that integration mechanisms of related technologies, and used TRIZ methods as auxiiliary methods for decision-making and mechanism driving.

With respect to engineering application and software, applications of TRIZ method in solving engineering problems include contradiction matrix and 40 innovation rules, substance-field analysis, useful functional interests' explanations, idealization, innovation status questionnaire to analyze and modify the problems. However, these are passive modifications of problems by TRIZ methods. In the present study, some active modifications were made on the contradiction matrix and 39 engineering parameters. The modification and analysis regarding the problems will be described in detail in the study method.

II. Analytical Innovation

This study conducted analysis of the TRIZ innovation rules to produce new innovation, which including the modification motive, modification method, sample collection, and example illustration.

Regarding the modification motive, the 39×39 matrix of the 39 contradiction matrix engineer parameters is not convenient for use due to its rather big size. In addition, not all the engineering parameters are involved in the problems. The engineering parameter closest to the problem was selected according to different directions of demands. Taking into consideration of these two points, the present study made slight modification on the selection of engineering parameters and contradiction matrix.

After confirming the problems for modification, this study first analyzed the problem, then confirmed the issues, and finally related the problems for modification with 39 engineering parameters. Several engineering parameters (set as 10 in the present study) closest to the modification problems were selected among 39 engineering parameters. Next, these parameters were put into the matrix, which size and range depend on the number of parameters selected.

The present study collected samples from CAD/CAM software covering icons and functions. The icons were captured by software, and were moved, copied, rotated, offseted, and trimmed in the editing functions of various software systems.

The five functions are defined as follows:

1. Move: move to icon to any place in the drawing area.
2. Copy: copy is to reproduce the original object by copying.
3. Rotate: select the rotate function; the selected object rotates around the self-given benchmark point.
4. Offset: move the object in parallel inward or outward in equal distance; the copied object is in a parallel distance.
5. Trim: remove the unnecessary parts of the object by trimming.

Fig. 1 illustrates a contradiction matrix of selected engineering parameters, of which the sequence is different from that of the original one. The engineering parameters in orange box in the figure are to improve the engineering characteristics and avoid deterioration. And the recommended rules after crossover are in the bright green box.

		Characteristic that is getting worse			
		Shape	Brightness	Loss of information	Loss of time
Characteristic to be improved	Shape		13 15 32		14 10 34 17
	Brightness	32 30		1 6	19 1 26 17
	Loss of information		19		24 26 28 32
	Loss of time	4 10 34 17	1 19 26 17	24 26 28 32	

Fig. 1 Illustration of contradiction matrix crossover

The matrix modification employed in the present study is illustrated by a simple example: first, the engineering parameters were selected for improvement and deterioration avoidance, in this example, the following are selected:

Engineering parameter to avoid deterioration: shape.

Engineering characteristics to improve: brightness.

The selected parameters were inputted into the contradiction matrix of modification for crossover to obtain the recommended number of the 40 innovation methods: 32 change color, 30 flexible case or membrane. The recommended number was applied as: 32 "change color" in icon design, and was able to make changes from the icon background color.

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III. Icon Design

A. Icon Classification

Icon is a considerably important part in user interface. It means that users can understand the function represented by the icon and further learn how to use the function. If it is properly designed, it is easy for users to identify the functions.

Icon interface can reduce the trouble of memorizing functions for users, and effectively reduce the operational complexity and error rate. It can be regarded as a breakthrough in computer technology. The icon user interface mainly includes four components:

1. Window
2. Icon
3. Menu
4. Pointer

The icon is to convey the meaning of function to users without text explanation, making it more efficient in terms of computer operation and function implementation. When learning how to use a software, the role of icon is clear that it can help the users learning faster and operating the software intuitively. Hence, the importance of icon can be recognized.

When designing icon, it is often more than a command, but classified design according to functions. The icon categorization principles are proposed as follows:

1. Identification: the operational icon as a functional symbol represents the specific meaning of certain software function. The image and shape need to be closely linked with function in design to let user understanding the functional meaning immediately at sight of the operational icon.
2. Consistency: although operational functions may differ in computer software systems, leading to different icon designs, the consistency of design need to be taken into consideration. Only in this way, can the consistency of image color and sense be achieved.

B. Icon Innovation and Improvement

After learning the definition, classification and conveyance of icons, we have a solid base for icon design. The following scholars proposed the procedure of icon design:

In 1991, Kaneko et al. [14] experimentally validated the method on how to design icon for easy understanding. The icon design flowchart, as shown in Fig. 2, was first defined in his study. The icon design flowchart proposed by Horton [15] in 1994 is as shown in Fig. 3.

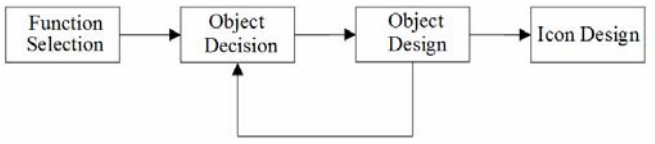


Fig. 2 Icon design flowchart A

This study discussesd the icons of the CAD/CAM software systems available in the market, and analyzed by the command icons of AutoCAD 2007, AlphaCAM V6, Mastercam 9.0, and LiteCAM Version 1. From the editing functions of the above four software systems, 5 icons were taken as samples with their functions as move, copy, rotate, offset and trim, respectively.

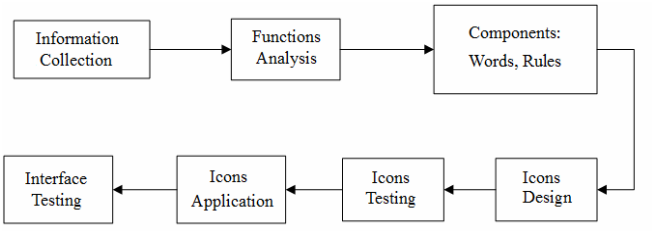


Fig. 3 Icon design flowchart B

Software / Command	LiteCAM	AutoCAD	AlphaCAM	Mastercam
移動(move)				
複製(copy)				
旋轉(rotate)				
偏置(offset)				
修剪(trim)				

Fig. 4 Icon sample collections

The icon samples captured are as shown in Fig. 4.

Modifications were made in accordance with the recommended rules. Fig. 5 illustrates the LiteCAM Version 1 icon before/after modification comparison. It can be found that in icon identification, the modified icon can be express functional meaning more clearly due to the design in consieration of the results of the functions. Because the background color, color of object before/after editing were coherent, it is considered consistent.

Command / Icons	移動(move)	複製(copy)	旋轉(rotate)	偏置(offset)	修剪(trim)
Before					
After					

Fig. 5 Comparison of icons before/after modification in LiteCAM

IV. Function Design

A. Analysis of the Recommended Rules

This section discusses the analysis and modification on center rotate function of the LiteCAM Version 1. Under LiteCAM Version 1, there are two types of rotate function: one is the base rotate and the other is the center rotate. The center rotate function is first introduced hereby.

As a special function, the operation of the center rotate function completely differs from that of other software systems. The function requests no base point; instead, the center of the object is regarded as the base point. The directional keys are for the rotate control in operation. In AutoCAD 2007, the simplest rotate operation is to select the command, then select the object to rotate, and press the right key to enable the rotate function. A base point is requested before moving the object to rotate to the given position, and then the right key is pressed to confirm to

finish the rotate command. Fig. 6 illustrates the operational flowchart.

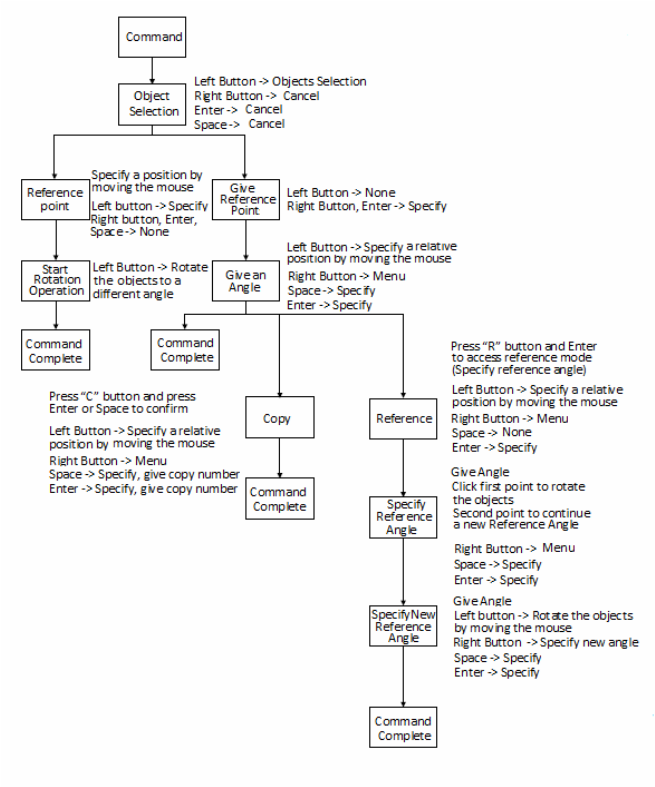


Fig. 6 AutoCAD 2007 operational flowchart

By rotate function analysis, we can have a clear understanding of the operational characteristics when implementing software functions. To software users, in addition to correctness, the operational convenience is another consideration for continuous use of the software. This example employed the TRIZ method to analyze and discuss the rotate function of LiteCAM Version 1 to improve its convenience.

Fig. 7 shows the number of rotate function operation statistics. The table records and compares the operations necessary for the rotate function. It shows that longer the time, more complex the operations.

Operation / Software	Left Click	Right Click	Enter Button	Keyboard Operation	Total Number
LiteCAM(Base)	3	1	-	-	4
LiteCAM(Center)	1	2	-	1	4
AutoCAD	3	1	-	-	4
Solidworks	2	2	-	-	4
AlphaCAM	5	1	-	-	6
AutoCAD (Rotate + Copy	2	1	2	2	7
AutoCAD (Ratate + Reference)	2	1	3	3	9
AlphaCAM (Rotate + Copy)	5	1	1	1	8

Fig. 7 Number of operations of Rotate function statistics

As shown in Fig. 8, after penalty weighing, it can be found from AutoCAD 2007, LiteCAM(base) and Solid Works 2006 that the simplest sequence of the rotate function is: 4 mouse clicks (left->right->left->left). After weighing, the weights are all 4.5 with the weight of LiteCAM(center) as 5.

Operation / Software	Left Click 1	Right Click 1	Enter 1.5	Keyboard Operation 2	Dialog Operation 2.5	Moving Mouse 0.5	Total Penalty
LiteCAM (Base)	3	1	-	-	-	1	4.5
LiteCAM(Center)	1	2	-	1	-	-	5
AutoCAD 2007	3	1	-	-	-	1	4.5
Solidworks 2006	2	2	-	-	-	1	4.5
AlphaCAM V6	5	1	-	-	-	1	6.5

Fig. 8 Rotate function convenience comparison

Although the LiteCAM(center) operational method is the simplest sequence in compliance with rotate function, the steps are controlled by keyboard, which definitely has a rather large weight in terms of convenience. Hence, its convenience is poorer than other software operational methods. After operational convenience analysis, the LiteCAM center rotate function has room for improvement. Hence, convenience modification will be conducted regarding the center rotate function of LiteCAM Version 1.

B. Results after Modification

The center function of the rotate command in LiteCAM is to use mouse to select the object. The center of the selected object is the base point for the rotate function. The left and right directional keys of the keyboard are used to accomplish the rotate function.

The analysis on linking the rotate function with the recommended "change mechanical system" showed that, the original operational pattern of using keyboard and mouse can be changed into using the mouse only.

Hence, regarding the parts controlled by the mouse, there are two proposals as follows:

1. Use mouse wheeler

The center function is to rotate around the center of the object, thus, the object center can be regarded as a base for recognition. When the object rotates to the left, click the right key on the left of the object center. It rotates to the left, and the mouse is used to accomplish the rotate function. Otherwise, the object would rotate clockwise.

2. Use mouse to move

Use the mouse to guide the rotate function. When the mouse moves to the left, it rotates anti-clockwise; otherwise, it rotates clockwise.

Both proposals above are feasible, yet for operational convenience, the first proposal of mouse wheeler requests an increase of mouse clicks while the second one is more convenient to users as it requests operating the mouse only.

After modification of using the mouse to move, the weight comparison was conducted again to see whether there is any improvement in terms of convenience.

In Fig. 9, it can be found after inputting the center rotate function into the weight table after modification that, the weight is 3.5 after modification, which considerably improves user convenience.

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Operation / Software	Left Click 1	Right Click 1	Enter 1.5	Keyboard Operation 2	Dialog Operation 2.5	Moving Mouse 0.5	Total Penalty
LiteCAM (Base)	3	1	-	-	-	1	4.5
LiteCAM(Center)	1	2	-	1	-	-	5
LiteCAM(New)	2	1	-	-	-	1	3.5
AutoCAD 2007	3	1	-	-	-	1	4.5
Solidworks 2006	2	2	-	-	-	1	4.5
AlphaCAM V6	5	1	-	-	-	1	6.5

Fig. 9 Function convenience weight comparison after modification

V. Conclusion

Regarding icon innovative modification, it is effective to implement the contradiction matrix by using TRIZ method for icon design. In a given environment, it helps non-professional designers systematically considering types of possibilities in the directions recommended by the 40 innovation rules and avoid producing icons similar to those of the existing software systems, and thus avoid the intellectual property problems.

During the icon design process, design that aimed at functional results is effective in making the functions understandable. It is considerably helpful to overall appearance if proper color and contrast in color matching can be incorporated.

With respect to functional innovative modification, usage convience is the focus of adaptability. Before modification, some users may be confused because the operation comprises partially keyboard and partially mouse. After the modification of design method as proposed in this study, the operations become consistent in terms of use. Hence, it is easier for users and improves convenience effectively.

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