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An Icon Design Approach Based on Symbolic and Users' Cognitive Psychology

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Abstract

In order to explore the usability and ease of use of icon design, the icon design method based on the combination of semiotics and user cognitive psychology is raised. Based on the principle of matching the icon design knowledge and user knowledge, the icon design process is analyzed from four dimensions, namely the semantic expression of elements, the structure of elements, the interface and cultural context, and the user cognitive characteristics. An icon assistant design system CDIPV1.0 is structured, it can realize knowledge sharing, rapid icon designing, and professional evaluation based on the combination of semiotics and users' cognitive psychology. The theory is verified through it.

Keywords: computer, interface, icon, design

1. Introduction

Icon is a visual symbol that has symbolic meaning, conveys information and is easy to recognize and remember. It can be divided into many types. According to the platform it can be divided into computer icon, mobile phone icon, website icon, game icon. In the same platform it can be divided into the program icon, toolbar icon and button icon; on the same operating system it can be divided into system icon and application icon. Icon is an important part of the graphical interface. It is "a kind of the language used by interface designers that particular application users can understand [1]. It eliminates the communication barriers between the user and the computer [2-3]. The icon design requires simplicity, nature, friendliness, convenience and uniformity. The design concept of "human first" should be reflected. And a perfectly designed icon [4], allows users to prefer reading [5], and it will be identified and remembered effectively [6].

A good icon often reflects the certain information of an interface or a producer. Especially for a commercial interface, you can basically understand the type or content of the web site. In a network link page full of all kinds of icons, it will be highlighted. When an audience wants to find a site with specific content in a lot of websites, anicon will have obviously great advantage that one can easily understand the type and the content of the web site it represents. In this paper, an icon design method based on a combination of users' cognitive psychology and semiotics is raised. The design elements are divided into four dimensions such as the semantic expression, the composition of the elements, icon usage enviroment and user cognitive characteristics. Based on the cognitive psychology and symbol theory, icon design process and user research are recognized and innovated on the integration. It provides a reference for designers.

2. Related Work
2.1. Icon Design Principles

The basic principle of icon design is to make full use of its the advantages of the icon: it is more intuitive and more beautiful than text, and to reduce its shortcomings: it is not as accurate as the expression of text. So the basic principle can be sumed up as following.

2.1.1. The Principle of Recognition

The principle of recognition is that the graphics of the icon should be able to accurately express the corresponding operation. That is, when you see an icon, you will understand what it means. It is the primary principle of icon design.

2.1.2. The Principle of Differences

For instance, there are six icons in a screen. The differences among them should be recognized at first glance. It is a very important principle in icon design. However, it is the most easily overlooked principle during the design process. Compared with the text, the superiority of icon is more intuitive; therefore, its superiority would not exist without this principle.

2.1.3. The Principle of Unified Style and Context

Icon does not exist alone. It plays a role when it placed in the interface. Therefore, when design an icon, the environment should be considered. For example, whether such an icon is suitable in such an interface? If the interface is the forest and the earth, you may consider using stones, wood, or mushrooms, wild flowers as the design elements of the icon.

2.1.4. The Appropriate Fineness and the Number of Elements

The pursuit of visual effect should be based on the satisfaction of other principles, such as the recognition principle, the discrepancy principle, and the unity principle. The basic functional requirement should be considered before the higher level of requirements - emotional needs. The main function of the icon is used to express information; the beauty is the next persuit. However, the icon designers tend to fall into a misunderstanding, pursuit fine, high light and texture one-sided. In fact, compared with the fine degree, the change of availability of the icon is something like the peak of a curve. In the initial stage, the icon availability will increase with the raise of the fine. However, when reaching a certain degree of precision, the availability of the icon will tend to decline with the fineness of the icon.

2.1.5. The originality

The originality of icon design must be modest. Because there are a lot of commonly used icon styles currently, however, the highly easy-used styles are just not so many. The excessive pursuit of originality and artistic effect may cause the reducing of the easy-using of the icon that is the so-called beautiful icon with less pacticity. Of course, it depends on the focus of your product, if you tend to consider emotional design and perfect artistic effect. It does not to be blamed.

2.2. Research Area of Icon Design

The scholars have achieved much progress in the icon design research. It mainly displays in three aspects: design research, the research of psychology and symbolic studies, in which design and psychology research accounted for the majority.

2.2.1. Design and Semiotics Study of Icon Design

At present, the semiotics research of icon design mainly includes three categrates, namely the semiotics of product design, the semiotics of environmental design and the semiotics of visual design. [7] In the field of icon design, in order to reduce the cognitive distance of user and icon, Zhang Tao [8] used the icon algebra theory to optimize icon structure in the map. Chen Ming-Shi [9] utilized Hierarchical clustering analysis (HCA) to evaluate the importance of each of the different functional menus and categories. Then they generated five PDA menu–icon interface design alternatives that meet the proposed design guidelines, and they evaluated each for their respective feasibilities. The evaluation results showed that the preferred design was option PDA5, a hierarchical and separated menu–icon layout style that featured a two-layer menu structure. Huang Shih-Miao researched the factors affecting the design of computer icons. He extracted nineteen elements related to icon design from the principles, criteria and guidelines for GUI design. Results from the principal components analysis showed that the subjects' importance ratings for computer icon design elements were affected by five factors: styling quality, message quality, meaningfulness, locatability, and metaphor. In addition to comprehensibility and identifiability, the results have found to be important icon design considerations; styling quality may also be important [10]. Besides the

quantitative study on the details of the icon, many scholars summarized the icon design principles through bonding experiments and user qualitative interviews, such as Huang SM [11] and Huang H [12]. Through questionnaire survey, principal component analysis, semantic differential method they got the influence factors of icon design, including semantic, familiarity, form quality, information quality and metaphor etc.And prove them with PDA (personal digital assistant).

2.2.2. Cognitive Psychology Research OF Icon Design

The psychology research of icon design mainly aims at the user's cognitive habits, abstract thinking ability, tacit knowledge, cultural background, etc. Shepard and Anderson believed that people's memory capacity contains two kinds: memory and recognition. Their psychological experiments showed that the recognition ability of the human is much stronger than that of the memory. For example, one can only recall 5or6 words from 600 words they had seen, however, the words they can identify are almost 540, accounting for about 88% [13]. People's recognition ability of graphics is much stronger than the recognition ability of characters.The seventy percent of them can be identified after 10000 paintings had been seen [14] Kolhoff [15] achieved visualization of non visual documentation by establishing graphics generation system based on content through metaphor. At the meantime, he verified the feasibility of metaphor method combined with the user psychology. According to the research of user cognitive psychology with different cultural background, Sraufer found that if a larger screen area is occupied with the use of English words, the redundancy of the character of English vocabulary is about 70%. Therefore, the abbreviations commonly used do not affect people's understanding. The distribution of visual attention of human on the screen is uneven. Miller [16] utilized the icon to make the menu more structured, clear, and can meet his "magic number" 7 ± 2[17] more easily. The literature indicates that the short-term memory capacity of human visual is 7 ± 2 information blocks. Each menu item or icon is viewed as a piece of information. User need to recall the icon menu structure and layers. The experimental results showed that [18] the menu width is better than depth and the number of layers is not more than three. The operation of the menu structure has less than three steps. The speed of operation is accurate and high. The users prefer to use. Through experiments combined with analysis of variance Passim verified that the rules that icon cognitive and user experience are proportional, the realistic icon is more easily connected with the function of association, and the using situation of icon is smaller influence to cognitive. Through experimental investigation [19] Fleetwood showed that the quantity and quality of icon (according to the color and shape, namely, the degree of the curvature of the visual features) has relationship to the response time of the user's visual.

2.2.3. Research on Art and User Participatory of Icon Design

Through inducting and analyzing the evolution and development of interface icons on various mobile phones with different systems, DuYi discussed the icon form, development trend of style and design features based on the art. Based on the case study, he studied several aspects of early users of the phone icons, such as research and analysis, element extraction [20] style positioning and visual effect. Shieh KK explored the effects of display characteristics such as target/background color combination, single/simultaneous presentation, and individual differences by sex, and design specialty on preferences of VDT icon design. The results indicated black targets (black-on-white, black-on-yellow) and black backgrounds (red-on-black, yellow-on-black) were the most popular and white targets (white-on-red, white-on-black) and white backgrounds (blue-on-white, red-on-white) were the second most popular. As for the chromatic color combinations, yellow-on-blue was the most favored. Subjects rated color combinations under single presentation higher than those under simultaneous presentation. Women rated purplish targets and rated purplish and blue backgrounds higher than men.[21] Donald pointed that the designer's emotional performance in the icon design is a coding process. The public will have some psychological feelings in the face of a product. It is a kind of process of decoding or aesthetic psychological induction. Finally, the designers get some clues and inspiration from the audience's psychological experience and them satisfact the audience's psychological needs to maximization in the icon [22]. In order to achieve good results in the literature, medical device graphics interface designers invited doctors, nurses and patients to participate in the equipment of icon design and interface architecture design. Through the

experiments, the high usability of the design result is verified. In the interaction design, the theory that adhere to the "user centered"is often able to obtain excellent results [23]

The above research promoted the development of icon design. Based on these results these paper expanses the icon design in the following aspects: 1) Research on the matching relationship between the dealing of icon design elements and the user cognitive characteristics. The previous icon design research is only on a single aspect such as user psychology, symbol or design theory. However, icon design is comprehensive practice with many disciplines, its core is the match between dealing of the various design elements and the user cognitive characteristics. So it will be the focus of this paper. 2) Analyze the icon by combing with psychological characteristics of user recognition and semiotics. With the icon design examples, icon design structure model is get. Based on this model the design method and the step is proposed.It aides the icon design personnel.

3. The Method of This Paper
3.1. Study on the Cognitive Psychology of Icon

The purpose of using icons is to help users operate. Designing icon stressed on the understanding of users and in line with the user's way of thinking. It involves a very complex psychological research. The designer should adopt the investigation method and observe user operation process based on the knowledge of psychology. Through interviewing, the user's ideas should be understand in depth. For example, how to view the screen and find icon, how to understand the icon and how to operate it, in which circumstances user prone to make error, what characteristics does the users' learning process have, etc. The designers should also carry out two aspects, such as written and statistical investigation. The investigation has to consider the characteristics of the user's operation process and the characteristics of the psychological factors of the operation. The survey results are summered, the user model is established, and the user's psychological needs are satisfied with the method. Itis the core of icon design.

In this paper, a kind of icon design method based on a combination of user cognitive psychology and semiotics is discussed. The icon design interpreted from four dimensions, namely the design elements of semantic expression, the structure among the elements, cultural context and the user's cognitive characteristics. Its structure is as shown in Figure 1.
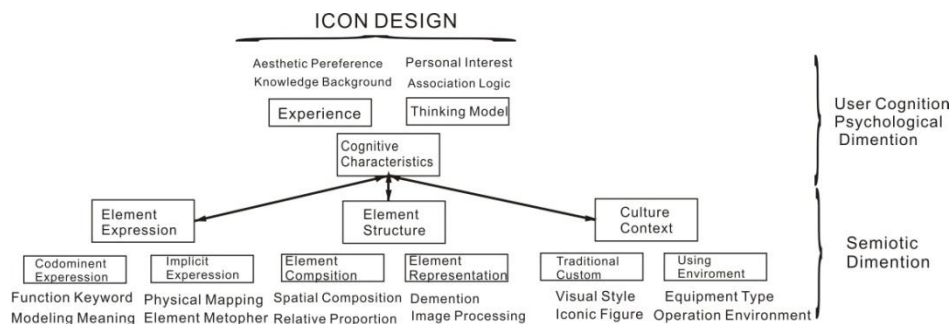

Figure 1. Structure

1) **The Semantic Expression of Design Elements** The effect semantic elements expression is the basic condition of the successful completion of creative design. In which the creative design elements must to have the clear referential function and the rich design connotation. The creative design elements are capable of producing a mapping between the designers and the audience. So the audience can think, feel and understand in perception, then he can understand and accept the designer's design intent. Therefore it needs to be studied combined with users.

2) **The Structure among the Elements** It includes the icon element expressing and icon element structure. This is the composition rules of icon meaning set and cognitive

combination. Firstly, the space structure and the space proportion of the iconic elements should be determined; secondly, the expressing form of the icon elements be set(including the perspective of view, proportion and delicacy); when the icon with multiple elements is pressed, the structural relationships among the elements should be reasonable arranged.

3) **Interface and Cultural Context** It includes a graphical environment and user's cultural background and environment. It can be divided into two aspects. One is cultural customs that is a mode of life passed on from generation to generation in social life. It is a collective habit of language, behavior, and psychology, and is normative and binding to the members of the collection. The other is environmental identity. It refers to a society's various regulations and restrictions on verbal communication activities. Icon needs to be visually combined with the overall environmental style of the graphical interface and the environment of different cultures. It also needs to take into account the shape, size, color, material, details, command feedback form, etc.

4) **The Users' Cognitive Characteristics** Cognitive process is the process of dealing information. It is the mental activity that reflects the characteristics of the objective things and the inner connections from the outside to the inside from phenomenon to essence. It is a very complex process. It consists of human feeling, perception, memory, thinking and imagination. Attention is an important feature in the psychological activities. It includes the user's mental model, associative logic and cultural background. Icon design adhers to the "user centered" design method in the interaction design. The users' tacit knowledge being dominanted is helpful to generate the icon design with more pertinence. Thereby the cognitive distance between the users and the icon is reduced and the cognition accuracy augmented.

The commonly used business icon, for example, from four dimensions of the semantic expression elemennts and structure elements, the cultural context and the user's cognitive characteristics, the process of design symbols deconstruction is as shown in Figure 2.
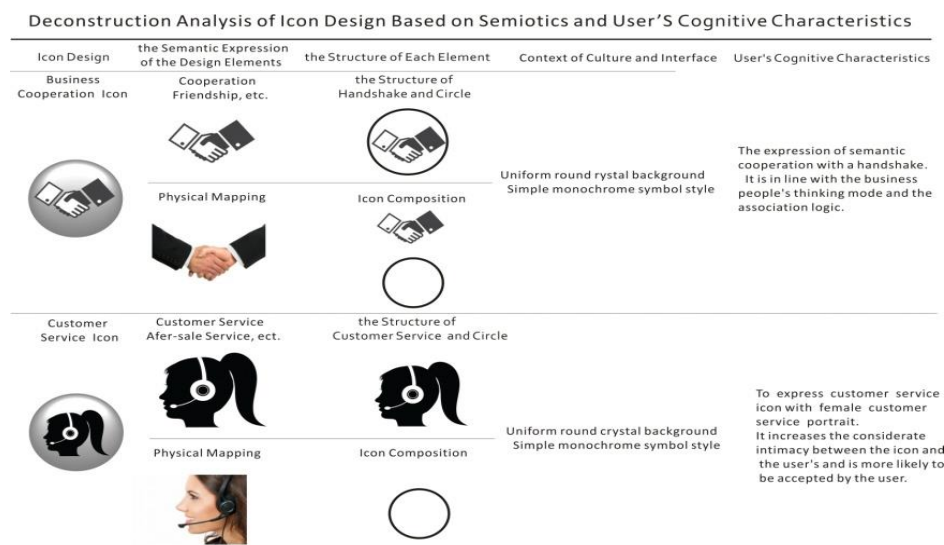

Figure 2. Symbols Deconstruction

According to the specific requirements of the function, the main elements of the icon can realize the function of expressing the specific meaning in the form of singlity or combination. Based on the determined semantic, each element's way of dealing and the visual style form a certain style to apply to the using context. The aesthetic of the designer in this stage plays an important role. The icon needs to be artistically treated and get a variety of programs. User's cognitive characteristic thinking mode and culture in the design process plays a constraint effect on the graphic elements, visual style selection and so on.

Therefore, icon design should apply from the matching relation between the users' cognitive characteristics and design elements. It should be considered from four dimensions such as the design elements of semantic expression, the structure among the elements, cultural context and the user's cognitive characteristics.

3.2. Icon Design Process Based on Cognitive Psychology and Semiotics

Barreto A B [24] suggested a design application of the icon algebra principle in the icon semantic dimension.

$$X.[is]a \begin{Bmatrix} COM \\ CON \\ ENH \\ MAR \\ INV \\ IDX \end{Bmatrix} Y.[is]b = Z.[is]c$$

XY represents the icon design elements scheme, Z is icon design, XY's semantic a and b get Z's semantic c accurately with various graphics operations, such as combine context, enhance, mark, Ivert, index. It provides the auxiliary reference for the designer in the actual operation. But the model has some limitations. Each the combination of elements in the actual design rarely used in isolation. The designers often use some of them to treat comprehensively. And what's more, the considerations of using of context and user psychological characters level cannot reflect in this approach. Therefore the usability of the design results is also challenged.

Based on of icon design theory user psychological characteristics and design semiotics, combined with the principle of icon algebra, the icon design program can be expressed as

Icon (S_{EE} , S_{EC}, S_{CC} , S_{UK})
$S_{EE=}$ {S_{EE1} , S_{EE2},……,S_{EEa}} ,
$S_{EC=}$ {S_{EC1} , S_{EC2},……,S_{ECb}} ,
$S_{CC=}$ {S_{CC1} , S_{CC2},……,S_{CCr}} ,
$S_{UK=}$ {S_{UK1} , S_{UK2},……,S_{UKs}} .

In which, S_{EE} indicates element expression set in the element semantic expression layer, S_{EC} indicates element struction set of element structured composition layer, the S_{CC} indicates cultural content set in the infacial and cultural context level, S_{UK} indicates user knowledge set of user cognitive characteristics level. The change of S_{EEa}, S_{ESb}, S_{CCr} and S_{UKs} will cause variations in the Icon that is there are many kinds of design programs in the same function. According to the principle of icon algebra, the relationship of S_{EEa} , S_{ESb}, S_{CC} and S_{UK} can be expressed as:

$$S_{UK} = S_{CC}(S_{EE}, S_{EC}) = S_{EE1} \begin{Bmatrix} S_{EC1} \\ S_{EC2} \\ \vdots \\ S_{ECb} \end{Bmatrix} S_{EE2} \begin{Bmatrix} S_{EC1} \\ S_{EC2} \\ \vdots \\ S_{ECb} \end{Bmatrix} \cdots\cdots S_{EEm}$$

In which, a≥1, b≥1. In the icon design process, several S_{SEs} combinate according to specific constitute rule of S_{EE}. Theoretically, there is no upper limit on the number of S_{EE}, however, due to the limitation of S_{EC} in practical application, usually 1 ≤a≤4, and S_{CCr} S_{UKs} depend on the subjective intention of the user. S_{CCr} decides (S_{EEa}, S_{ESb}) the visual style, S_{UKs} indicates knowledge map and effects on S_{EEa}, S_{Esb} and S_{CCr}. Summery, the icon design processes of the based on semeiology is as shown in Figure 3.
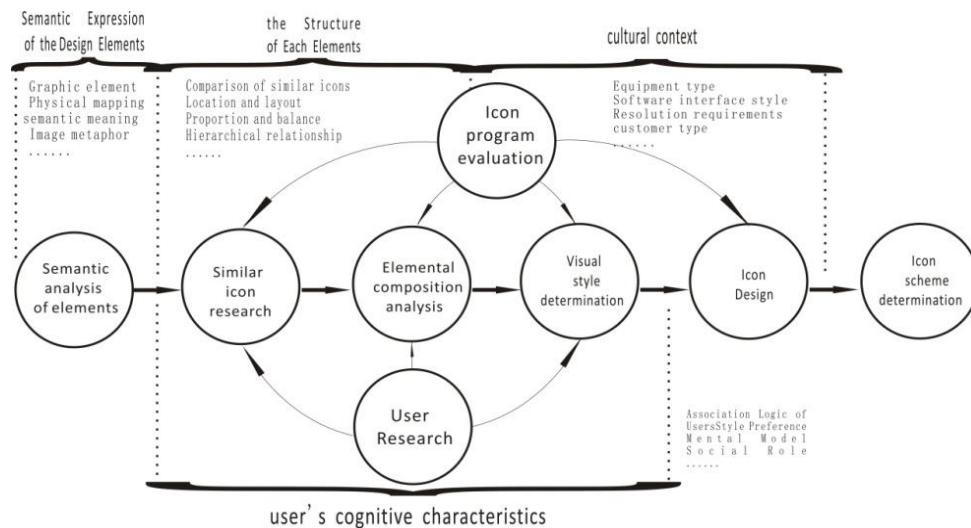
Figure 3. Processes of the based on Semeiology

The specific process of icon design based on the user's psychological characteristics and Design Semiotics method is as follows:

1) The Semantic Expression of Element In this level, the appropriate design elements should be selected according to the user's perception of the specific function.The relationship of physical mapping or metaphor between design elements and cognitive function should be ensured. Thus the foundation of icon construction is made.

2) The Element Structure Composition It indicates consideration of the factors of design elements combination. Firstly, it contains the space layout, the element size and propotion. Secondly, it contains interspersed relationship among them, and the visual depth. Finally, the basic structure of an icon program is obtained.

3) Interface and Cultural Context In this level, the equipment type, the resolution requirements, the overall style of the interface, user background, cultural context and other factors are considered comprehensively. Give the proper style and the visua rendering to the elements combination with the basic structure.

4) User's Cognitive Characteristics although, concern and consideration of the user's cognitive psychological characteristics does not form an independent step in the design, it exists in the entire process of icon design and is essential. That is fully in all of the above design step, designer must consider experience, the user's mental model, associative logic, aesthetic preference. And after determining the overall design scheme, the program should get psychological acceptance and usability testing in the user. Then it is finalized.

In the whole process, according to certain steps the design continues in 4 dimensions. Each dimension restricts and affects each other. Similarly, the evaluation of icon design can also expanse based on design semiotics and user cognition psychology, and analyze layer by layer. Firstly, from element semantic expression dimension, the function interpretion of the icon is tested. Secondly, from element structure dimension, the coodination of element proportion, size, and other details is evaluated. Then evaluate from the perspective of usability and cognitive psychological acceptance combined with the target user resesrch. With the above four aspects the final evaluation results of the icon scheme can be obtained. It is different from the the traditional experimental evaluation method. This method can make the rapid evaluation, so as to improve the efficiency. It can help designers make rapid optimizational Diego Generation in the design process of icon.

From the icon design process based on Semiotics and user recognition psychology it shows that element semantic expression and element structure dimensions determine the basic structure of the icon scheme, which belongs to the important step of the icon design process.

4. Application Example

With the technology.NET, we utilize the language Java to establish the prototype system CDIPV1.0 on the platform of Windows 7 for an icon of CAD. This system is developed for the icon designers and the system engineers. The purposes are: 1) As a computer aided icon design tool, it can provide a convenient and professional reference to the icon designers, reduce the failure rate during the design process, improve the quality of design; 2) For the icon design has been completed, it can evaluate the matching degree between the structured factors of icon and the user requirements from the field of the semiotic and user cognitive psychology.Then it can analyze the availability and ease of use of icon program in essence, and put forward suggestions for improvement.

4.1. Brief Introduction of CDIPV1.0 System

CDIPV1.0 system is mainly divided into three parts. The first part is the interactive knowledge base for organization and management of the icon design material data. The others are the design module based on knowledge base, and the evaluation module based on semiotics and users' cognitive psychology. The former establishes of a number of icon programs, and the latter evaluates these programs and prompts the availability of the best. In which, data accumulation of the knowledge base is very important. It relates to the matching efficiency of design knowledge, and then directly affects the quality of the design. As shown in Figure 4, the whole system services for icon usability tester, system engineer and icon designer. It is the knowledge base that organize and manage icon design resources, and from an interactive interface platform that generate and evaluate icons online.
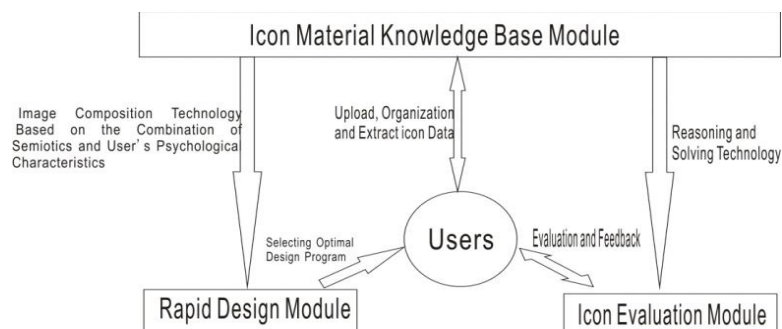

Figure 4. Knowledge Base That Organize and Manage Icon Design Resources

4.1.1. Knowledge Base Module

The knowledge base module is an open database of the icon design elements.The knowledge base provides platform that require the senior icon designers upload all kinds of programs, matching creative ideas, graphics, descriptions, dismantling details and evaluations in the perspective of semiotic and user cognitive psychology. And it adds the labels of the function, graphics, combination and style in order to search easily. So it can update according to the factors such as the change of society, different cultural context and style.It can also evaluate the icons from the dimension of design semiotics and users' recognition sychology.The characteristics of the knowledge base is to set up the mapping relationship between the icon design and user cognition based on tags of icon, graphic elements and icon keywords. It can aid designer to evaluate the designed icon. After the knowledge base reaches a certain scale, the user can obtained design reference program through the key word matching. In addition, the system is open, it allows the icon designer modify icon evaluation results according to the changes of society and consumer preference. As is shown in Figure 5, it supports icon design.

In this paper, we have invited 30 senior designers to get the initial data of the knowledge base through the experiements:

1) **Creative Ideas:** The match between the semantic elements icon and functional requirements are analyzed from the perspective of elements semantic expression. And the direction of thinking of icon design will be get.

2) **Content Description and Details Spliting:** The structure of the icon is analyzed from the perspective of the composition of the elements. The tags are added each elements, so that the search for the match is easier.
3) **Deconstruction and Reorganization of the Elements in the Icon:** Get a variety of programs for the same function icon and to form a contrast matrix.
4) **Icon Evaluation:** Evaluate and score the icon program after considering above factors comprehensively.

As the time goes by, the knowledge base will be continuously updated and rich, thus to meet the needs of users.

Figure 5. Supports Icon Design

4.1.2 Icon Design Program Module

Icon design program module is based on design knowledge base. It achieves the visibility of icon element structure with the technology of parametric design, satisfies scheme generation, combination, display and comparision of several program in the real time. It enhances the innovative design ability of designing and engineering staff. The user should only input vocabulary related to icon function in the rapid design module interface of CDIPV1.0 system shown in Figure 6, and then select the different main elements and auxiliary elements from accessional icon design elements. The system will generate an icon program automatically in accordance with the predesigned rules; compare with multiple icon reference program and modificate the program in the real-time. Keywords search function in the icon design program module involves processing fuzzy reasoning technology.In this paper; the fuzzy reasoning technology mainly adopts the label matching data in the early. After it upgrade in the late, the system will utilize the technology that the reasoning module based on the instance simulate the design process of designer. The core is to utilize the program that has been designed to find the most suitable solution according to the new demand. The reasoning module algorithm based on the instance can meet the similar material matching module of the evaluation system, and make the data pushed by the system more flexible and enlightening.

Figure 6. Design Module Interface of CDIPV1.0 System

4.1.3. Evaluation Module Based on the Combination of Design Semiotics and User's Cognitive Psychology

The evaluation module based on the combination of design semiotics and user's cognitive psychology evaluates the icon by utilizing the icon design examples in the knowledge base. As is shown in Figure 7, it collects the usability evaluation of each dimension by senior icon designer. The interface module is facilitating to compare and select optimal program for the designers. It can also deepen the icon design professional knowledge for engineers.

Figure 7. Evaluation Module

4.2. CDIPV1.0 System Usage Evaluation

According to the software process, IDEASI. 0 system generates a set of basic function icons. The 30 ordinary users are invited to test the cognition of the set of icons. The test result showes that the icon design generated from the IDEASI. 0 system has good awareness and availability as shown in Figure 8 by viewing the visual and cognitive error rate and cognitive speed of icon as the evaluation criteria.
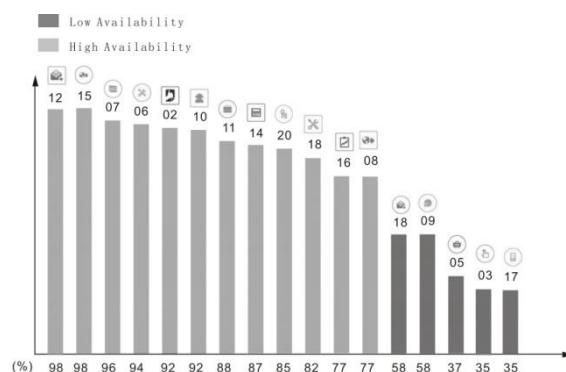

Figure 8. The Visual and Cognitive Error Rate

The CDIPV1.0 system is a primary theoretical application. In order to promote the development of the intelligent system, we will optimize the system on the next step. For example, we will introduce network social platform system, update the knowledge base and the system as a whole, and promote the intelligent system, etc.

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