Research on the Transformation of User Perceptual Knowledge to Design Knowledge in Product Design

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Abstract. The representation relationship between the user perceptual knowledge and the design knowledge is discussed. The model of transformation of the user perceptual knowledge and the design knowledge is built. And the key technologies of it are analyzed. The four design dimensions are proposed, namely, the design process dimension, the design goal dimension, the design organization dimension and the design starting point. Taking the shape design of vacuum cleaner for example, this paper utilizes the oral analysis method and the semantic differential method to analyze the transformation from the user perceptual knowledge to the design knowledge. The model of the transformation is validated. It is helpful for improving the computer aided industrial design and the network collaborative design of the electric appliance products

1. Introduction
In the era of knowledge economy, how to make use of the existed knowledge of product design to create more value is the key issue for designing and manufacturing enterprises.[1] In the process of product conceptual design, the user knowledge and the design knowledge are two important parts. The user knowledge exists firstly. With the progress of the design, the design knowledge becomes the continuation of the user knowledge in the design. There is a causal relationship between the two parts. The emergence of the user knowledge leads to the generation of the design knowledge. It is an inevitable result of the design. As a process of knowledge transformation, the purpose of design is to meet the needs of users by creating products. According to the access of the user knowledge, it can be divided into the conceptual knowledge and the perceptual knowledge. The perceptual knowledge is that owned by human beings but cannot be easily described, such as skill, judgment, intuition, insight, inspiration, visual perception and experience. This kind of knowledge is subjective, random and fuzzy. It is a difficult key of the product design to transform it to the design knowledge accurately. It leads to the design information or knowledge of the product design process has the characteristics of uncertainty, imprecision and incompletion.[2] However, it is the product description information that the design knowledge must capture accurately. It is the starting point of the design process. It is right or no directly relates to the matching degree of product function and user demand. It affects the
accuracy of the results of the product function directly. Therefore, how to realize the reasoning or transformation in different knowledge spaces is the content of this paper.

2. Main Problems in the Process of the User Perceptual Knowledge Transforming to the Design Knowledge

At present, the process of transformation from the user perceptual knowledge into the design knowledge has such problems as: (1) The organization structure of the knowledge transformation scheme can not ensure the correctness. (2) The transformation model cannot accurately express the user needs and fails to analyze and mine the user perceptual knowledge in-depth. Aiming at the above problems, this paper generates the transformation model that interacted by organization structure, consistency check, semantics expansion and conversion match.

3. Related Work

Maurer[3] utilized the method of the user’s conceptual knowledge transformation to research the cognitive characteristics of furniture design. The semantic differential method proposed by Osgood[4] is a commonly used method. Chen[5] proposed an experience knowledge representation and reasoning method based on the ontology. Stucken schmidt[6] defined a form expression way of the modular ontology based on the distributed description logic. And he proposed a framework that support the ontology local through perceptual axiom. Hsu[7] analyzed cognitive differences between the users and the designers through the telephone style. Feng Yixiong[8] pointed out that utilizing the existed design knowledge effectively to maintain the low production cost and shorter delivery time. Liu[9] proposed a repair method of inconsistent and uncertain reasoning ontology. In order to effectively capture the dynamic information of user requirement, Li Jingfei[10] proposed a density matrix transformation framework and further developed an adaptive QLM ranking model, and utilized extensive comparative experiments to show the effectiveness of the session quantum language models. In order to define fuzzy information granules from the user’s conceptual semantics, Castiello C. [11] proposed a methodology for designing interpretable fuzzy models. Their research demonstrated that it was possible to design models that exhibited the user perceptual knowledge to semantics with high interpretability.

4. Transformation Model from the User Perceptual Knowledge to the Design Knowledge

The main difference between the knowledge transformation and the knowledge retrieval is that the knowledge retrieval just list and return the knowledge meet the retrieval conditions. However, the knowledge transformation not only provides user the knowledge, but also finds the logical relationship in it, and organize the knowledge in the form of solution scheme. [12] It requires that the knowledge transformation system has a certain thinking ability, that is, utilizing knowledge for reasoning and problem solving. This paper puts forward a model of knowledge transformation from the user knowledge to the design knowledge. It is as shown in Figure 1.
Its BNF definition is as follows:

- Cognitive matching = Match; <satisfaction>
- Matching means: = <Ergonomics><Function Selection> <Color Analysis>
- User knowledge: = <Product Expectation> <User’s Knowledge Description>
- Design knowledge: = <Product Structure Information> <Product Semantic Information> <Product Function Information> <Color Information> <Style Information>

The process of the user perceptual knowledge transformation to the design knowledge includes modeling and analysis of the user perceptual knowledge, the decomposition and reasoning of the perceptual knowledge, the consistency checking, the generation of matching model and transformation matching. In this paper, the knowledge transformation decomposition and the generation of matching model are mainly based on four dimensions, namely, the design process dimension, the design goal dimension, the design organization dimension and the knowledge object dimension. The preliminary organizational structure of the conversion scheme is formed by process dimension and object dimension in the design. It is checked consistency through the oral analysis and reasoning to ensure the correctness of program structure. Finally, the transformation matching model is formed through semantic expansion of the four dimensions and the reasoning form of criterion.

5. Case Study
This paper takes the design of a vacuum cleaner required by a customer as an example. The matching relationship between the user knowledge and design knowledge is discussed.

5.1 Acquisition of the User Perceptual Knowledge
In this paper, the oral analysis method is utilized to obtain the user perceptual knowledge.

The 5 men and 5 women are selected from the customer as the subjects. They are involved management, marketing, design, engineering and other fields. The purpose of the test is to allow the participants to describe the shape of the vacuum cleaner. Before the test, the tester introduced the purpose of the test to the participants, and explained the relationship between the semantic and product appearance. During the test, the test clerk carefully records the oral report and action of the participants, does not guide and intervene any thinking activities on the subjects.

According to the subjects' oral report, the appearance recognition can be summarized as "modern", "concise", "whole", "harmonious" and so on.
5.2 Characterization of Design Knowledge
This study utilizes the "semantic difference method". It is developed by the American psychologist Osgood. He utilized the relative adjective such as "warm-cold" to indicate a psychological continuum.

According to the needs of user, combined with the international vacuum cleaner design samples, 18 kinds of appearance program are designed. All of them are displayed in neutral color so as to eliminate the influence of color on the subjects. The 8 senior designers are selected as subjects. From the perspective of evaluation factors, potential factors and activity factors, they selected the coincidence of anti-sense semantic adjectives, put positive words on the left side of the psychological measurement, and put the negative words on the right side of the psychological measurement. The scores on the measurement from left to right is 0-6.

The sample plan is projected on the white wall. According to the design sample the subjects give the score based on the psychological measurement. In the process of computer multivariate analysis, the figure of 0-6 input, the two-dimensional coordinate figure can get. According to the coordinate, image scale distribution map of the vacuum cleaner characteristics is shown in Figure 2.

According to the above distribution chart, we can utilize the "Unified-Varied", "Fashion-Traditional" to summarize the characteristics of the program appearance distribution.

5.3 User Evaluation
As 30 schemes are designed, all schemes are delivered to the customer for evaluation and selection. The customers are required to pick out 3 appropriate programs. The results are shown in Figure 3.

According to users own requirements, they score for the selected 3 programs in accordance with the 10 scoring system. The statistical results are shown in table 1.

| Number | Score  |
|--------|--------|
| 12     | 9.2    |
| 10     | 8.6    |
| 4      | 6.7    |

According to the actual level of manufacturing technology and the appearance of such factors, finally the No.12 is chosen by the customer.
5.4 Feature Analysis
According to the user evaluation and selection of the program, we found that the 3 programs selected by the users in the Y axis. There are 8 samples belong to (--X) Y range (44%), that is "Unified "and "Fashion "range. There are 3 samples belong in the XY range (16.6%), that is," Unified" and" Traditional" interval. In the (-X) Y range, the appearance of these sounds are fashion, simple and uniform. The sense of the general appearance is unity and harmony, the production process is not complicated. The design of the appearance is in line with the requirements of the user perceptual knowledge.

6. Conclusions
6.1 Before design the product, the study of the user perceptual knowledge. And their common characteristics are conductive to improve the success rate of the design program.

6.2 The perceptual knowledge can be made explicitized by means of semantic difference method, oral analysis method and so on. The following research work is to make this perceptual cognition into regular models, to lay the foundation for improving the computer aided industrial design(LAID) and sound net work collaborative design.

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