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Research on the Transformation of User's Implicit Knowledge to Design Knowledge in Product Design

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Abstract

The characteristics of the user's implicit knowledge in product design and the relationship between the user's implicit knowledge and design knowledge are discussed. The transformation model of user implicit knowledge to design knowledge is built. And the key technologies of it are analyzed. The four design dimensions which the transformation from user implicit knowledge to design knowledge is based on are proposed, namely, the design process dimension, the design object dimension, the organization dimension and the knowledge dimension. Taking household cleaner as an example, this paper utilizes the oral analysis method and the semantic differential method to analyze the transformation of user implicit knowledge to design knowledge, and validates the conversion model. It is helpful for improving the computer aided industrial design and household appliance products network collaborative design.

Keywords: knowledge, designer, user, design

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1. Introduction

In the era of knowledge economy, how to make use of the existing product design knowledge to create more value is the key issue for all design and manufacturing enterprises [1]. In the process of product conceptual design, user knowledge and design knowledge are 2 important parts. They are usually precedent logically, user knowledge exists firstly. With the progress of the design and involving of the design personnel, design knowledge has become the continuing process of user knowledge in the design. There is a cause and effect relationship between the two parts. The emergence of user knowledge leads to the generation of design knowledge, which is the inevitable result of the design process. As a process of knowledge transformation, the requirement function in the product design process is a description of the relationship that each step carries out every product tasks, from the product user knowledge (customer requirement function, CRF) to the product design knowledge (design requirement function, DRF), until the implementation of specific products. According to the access way of user knowledge, it can be divided into "explicit knowledge" (knowledge explicit) and "implicit knowledge" (knowledge implicit). The implicit 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 converse it to design knowledge conceptually. It leads to the design information or knowledge of the product design process has the characteristics of uncertainty, imprecision and incompleteness [2] for the user's functional needs, the user implicit knowledge is an important expression form of user's expectations to the product. It is the product description information the design knowledge must capture accurately. It is the starting point that the design process, get started at the designers knowledge space. It's correct or not directly relates to the matching degree that the function showed by the product to the user's original needs. It affects the accuracy of the results of the product function directly. Therefore, how to realize the corresponding reasoning or transform under different knowledge spaces based on the user implicit knowledge to obtain design knowledge, is the content of this paper. Main Problems in the Process of Transforming from the User's Implicit Knowledge into the Design Knowledge

At present, the process of transforming from the user implicit knowledge into the design knowledge has such the main problems as: (1) The organization structure of the knowledge conversion scheme can not ensure the correctness; (2) The transformation model cannot accurately express the user needs and fails to analyze and mine the user implicit knowledge in-depth. Aiming at the above problems, this paper generates the conversion model user the implicit knowledge transform into the design knowledge, which is interacted by organization structure, consistency check, semantics expansion and conversion match. In this paper, the knowledge conversion process framework of user knowledge and design knowledge is established. Finally, through designing and developing a household electrical appliance knowledge transformation system, the effectiveness and feasibility of the proposed method is proved.

2. Related Work

Maurer utilized the method of user's implicit knowledge conversion to research the cognitive characteristics of furniture design [3]. The semantic differential method proposed by Osgood is a commonly used method [4]. Through the semantics of the learning objects (including the shape, color and other products), the user's implicit knowledge responded in the Likert scale, then its rule is analyzed by statistical method. Chen proposed a experience knowledge representation and reasoning method based on the ontology: The experience knowledge is expressed by four layer structure model, such as knowledge of know –what, know-how, know-why, know-with [5]. The single layer inference rules and the crossing inference rules based on the experience of knowledge ontology and knowledge representation model are established. And he designed inference algorithms to reason them. Finally, he utilized the pellet 4 interference in the Protégé 3 machine verify the method. Stuckenschmidt defined a form expression way of the modular ontology based on the distributed description logic [6], and proposed a framework that support the ontology local through implicit axiom. The correctness and completeness of knowledge compilation in the different modules can be guaranteed. Hsu analyzed cognitive differences between the users and the designers' through the telephone style [7]. Feng Yixiong pointed out that utilizing the of existing design knowledge effectively to maintain the low production cost and shorter delivery time, is the key to improve product development speed for the enterprise [8]. Through the expansion of the relationship in the ontology, semantic retrieval solved the problem of concept refinement, synonymous with polymorphism, and polymorphism with synonymous perfectly. However, the problem of intelligent reasoning has not been effectively solved. Liu proposed repair method of inconsistent and uncertain reasoning ontology. The inconsistent contradiction of the ontology be repaired firstly [9]. RIO and RIUO algorithm is utilized to calculate the repair set. The inconsistent ontology can be repaired by removing or modifying the candidate repairing axiom. Then, proposed RMU and RMIU algorithm are proposed as a specific querying and reasoning method of inconsistent and uncertain ontology, without changing the original ontology. In order to effectively capture the dynamic information of user's requirement, he proposed a density matrix transformation framework and further develops an adaptive QLM ranking model, and utilized extensive comparative experiments to show the effectiveness of the session quantum language models [10]. In order to define fuzzy information granules from the user implicit semantics, Castiello C. proposed a methodology for designing interpretable fuzzy models through semantic cointension. Their research demonstrated that it is possible to design models that exhibited user implicit knowledge to semantics with high interpretability [11].

3. Conversion Model of User Implicit Knowledge - Design Knowledge

The main difference between knowledge conversion and knowledge retrieval or pushing in that knowledge retrieval or pushing just list and return the knowledge meet the retrieval conditions or some specific requirements the user. However, knowledge conversion knowledge not only provides users the knowledge, but also finds the logical relationship in it, and organizes the knowledge in the form of solution scheme [12]. It requires that knowledge conversion system has a certain thinking ability that is, using knowledge for reasoning and problem solving. According to the demand function in the product, the user implicit knowledge has the characteristics of oral and incompleteness. It may make the design to disjoin the study of

knowledge and designing. The design program needs repeated discussion with users. It delays the time of product design. Therefore, it is necessary to realize the processing and operation on the level of semantic knowledge at the beginning of design, which plays an important role in the quality of knowledge conversion and user's satisfaction. This paper puts forward a model of knowledge conversion from the user knowledge to the design knowledge. It is as shown in Figure 1.

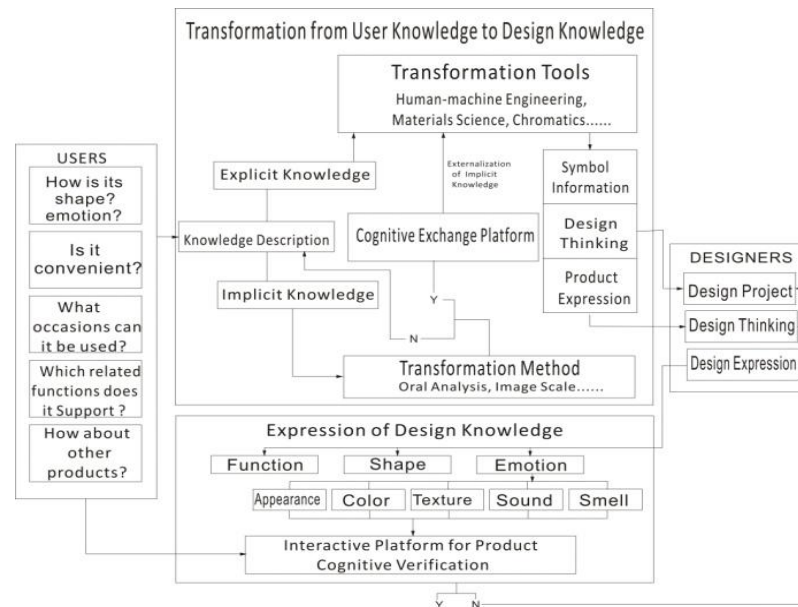


Figure 1. Design Knowledge

Its BNF definition is as follows:

Design knowledge:=<function information><semantic information><symbol information >

User knowledge:=<explicit knowledge> <Implicit Knowledge >

Matching means:=<ergonomics><function composition> <structure layout>

Design knowledge:=Extract;<design experience><user explicit knowledge representation, user implicit knowledge representation>

User knowledge=Extract; <product expectation, user knowledge description>

Cognitive matching =Match; <satisfaction>

The process of user's implicit knowledge transferring to the design knowledge includes the modeling and analysis of the user's implicit knowledge, the decomposition and reasoning of implicit knowledge, the consistency checking, the generation of matching model and transformation matching. In this paper, the knowledge conversion decomposition and the generation of matching model are mainly based on four dimensions, namely, the design process dimension, the design object 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. And finally, the conversion matching model is formed through semantic expansion of the four dimensions and the reasoning form of criterion. The process of knowledge transfer shown in Figure 1 mainly includes the following four steps.

3.1. Acquisition and Decomposition of the User's Implicit Knowledge

The implicit knowledge is tacit knowledge. It is difficult to measure or encode. To obtain it, evolving mutual exchanges and mutual stimulation among users are necessary. It is also necessity to mine the database and knowledge, and to integrate the distributed knowledge. Then the new design knowledge can be created. User's implicit knowledge can be obtained

through questionnaire, interview, oral analysis, semantic differential method, drawing presently, principal component analysis, cluster analysis, multidimensional scaling analysis and other comprehensive methods. This paper utilizes a five-element group (output, resource, input group, restraint object), to express the user implicit knowledge. During acquisition and decomposing of input and output, resources, constraints and objects of the conversion should be obtained firstly. Then the "object" elements in the implicit knowledge model matches and the element in the design objects dimension. The elements that matched successfully of the decomposed according to the design process dimension. So, a large design problem decomposed into a number of steps to solve. A design knowledge hierarchy with the logical structure is forming. It is the basic structure of knowledge conversion scheme.

3.2. Organization, Transmission and Application of Design Knowledge

Based on the analysis of industrial designers and engineers, the main knowledge factors that influence the design include: function, structure, technology, shape, color, environment, cost and human engineering. And design knowledge often performs as the definition of the problem, creative evaluation and solution of the problem in the design activities [13]. The basic structure of knowledge in the field of design, and characteristics of designers' thinking and the computer comprehension process of knowledge products are researched. The design knowledge representation model that according to the characteristics of the design process is established. It is a prerequisite for the transformation of the user implicit knowledge.

Product design is encoding the structural elements of the product (functional information, semantic information and symbol information) Combined with their design experience, domain knowledge and design knowledge base, the designers describe the essence of design with the combination of some visual symbols through its emotional understanding, cultural connotation, practical function, and the connection of material, technology, essence. And then they make the product aesthetic highly cognitive and operable. Meanwhile, the designers help users understand, learn and operate the product that are not familiar with the users, including the appearance, color, texture, sound, smell and environment of the product, by utilizing " simile " and "metaphor" and "association", "analogy", "comprehensive" tactics. In this process, interviews, observation, semantic difference method, and oral analysis can be utilized to research the thinking characteristics and performance of designers, in which, oral analysis is the most often used. Oral analysis method is also called "aloud thinking" experiment [14, 15] with this method, the user implicit knowledge is transferred and externalized (socialization, externalization, combination and internalization), pictures, text, tables, model are formed [10], the design knowledge base is built and the innovative design rules are discovered. The computer support tools (such as CAX, DFX, CAID etc.) should meet the designer use habits. The design knowledge representation model is established. The formality and standardization realize the organization, transformation and application of the design knowledge, and connect the design knowledge with the processing plan and manufacturing.

Consistency Check of the Knowledge Hierarchy Structure Knowledge hierarchy is the general structure of knowledge transfer and organization. It is the embodiment of the logic relation between knowledge. Therefore, it is necessary to ensure its accuracy. Consistency check of the knowledge hierarchy structure involves the integration of industrial design knowledge and engineering design knowledge, and the relationship between them and the user knowledge. It is needed to study the knowledge of industrial designers and engineers about knowing what and knowing what to do [16]. Many researchers have put forward the different knowledge organizational structures. For example, Yu Haitao puts forward the organization and application of knowledge based on the knowledge tree method [17]. Ye Fanbo proposed to match the knowledge in the process of product design based on the map of knowledge, based on the above knowledge [18]. However, the organizational structure mentioned above neither can express the semantic meaning the user's implicit knowledge thoroughly, nor guarantee its correctness and consistency. This paper presents the knowledge hierarchy structure extended from the four dimensions based on the design field, namely the design process dimension, design object dimension, organization design and knowledge object dimension. Meanwhile the consistency check is made through the four dimensions. So the correctness and consistency is ensured. If there are contradictions and inconsistencies, just correct them in time. In addition, to ensure that each level of design knowledge accurately reflects the user's implicit knowledge, the

criteria in the analysis and interpretation module should be utilized to determine. The decision criteria used in this paper has two: the criteria that removed initiatively by the user knowledge requirement and the criteria that weight determined by user's knowledge demand.

Rule 1: The criteria that removed initiatively by the user knowledge requirement: For the obvious contradiction that knowledge expressed by the conversion results and user's knowledge demand the user knowledge requirement should be obeyed primarily, the conversion result should be eliminated initiatively.

Rule 2: The criteria that weight determined by user's knowledge demand: It is assumed that 2 user knowledge demands are UKRb, UKRa. The corresponding weight coefficients are R1 and R2, $R1 > R2$. If these two kinds of knowledge are conflict or overlap, the bigger weight coefficient corresponding the conversion results should be as the standard, namely UKRa. So the high coefficient weight of user knowledge requirement will be guaranteed in the maximum in the design process.

Semantic Extension and Transformation Matching This process is extended and reasoned based on the design knowledge hierarchy to form the final conversion matching model, which is based on the process of extending and reasoning. Each node of the knowledge hierarchy structure of implicit knowledge model has all the four elements of information. The "input" and "output" and "resource" elements in the implicit knowledge model with playing the hypostatic semantic matching and extending in the design object dimension, design organization dimension and design knowledge dimension. Semantic space information that expressed implicit knowledge is formed. And the conversion matching model is formed. Finally, each node of the design knowledge hierarchy structure has a matching model which expresses the full semantic of the node. The model is a network structure. It can express the semantic relations among the knowledge elements. Based on this model, the successfully matched transformation relates to each node of the implicit knowledge hierarchy, and the final conversion scheme is formed. The model matching process is essentially the matching between the semantic spaces. It needs to calculate its structural similarity and concept similarity and attribute similarity. The conversion that its comprehensive similarity is higher than a range is regarded as a successful match.

4. 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.

4.1. Acquisition of the User's Implicit Knowledge

In this paper, the oral analysis method is utilized to obtain the user's implicit knowledge. Related research methods and procedures can be seen in the literature. 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 main tester introduces to the participants the purpose of the test utilized the vacuum cleaner samples, pictures to explain the relationship between the semantic and product appearance. During the test, the test clerk carefully recorded the oral report and action of the participants, did not guide and intervene any thinking activities on the subjects. When the participants are silent or meet obstacles necessary help without directivity was given them.

According to the subjects' oral report, the appearance recognition of the needed product can be summarized as "modern", "concise", "whole", "harmonious" and so on.

4.2. Characterization of Design Knowledge

This study utilized the "semantic difference method" American psychologist Osgood, which utilized the relative adjective such as "warm-cold" to indicate a psychological continuum. With the psychological measurement at 7 points of the multivariate principal component analysis is applied. Detailed discussion can be seen in literature.

According to the needs of users, combined with the international vacuum cleaner design samples, 18 kinds of appearance program are designed. All of them displaying in neutral color so as to eliminate the influence of color on the subjects, and study the shape only. The 8

senior designers were selected as subjects. From the perspective of evaluation factors, potential factors and activity factors, they selected the coincidence of antisense 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 -6-6.

The sample plan was projected on the white wall. According to the design sample the subjects gave the scored based on the psychological measurement. After the test, the average figure of the statistical figures of the 8 subjects were taken. The computer was utilized to and the cumulative characteristic figures were obtained. In the process of computer multivariate analysis, the figure of 0-6 in put, the two-dimensional coordinate figure can get. According to the coordinate, image scale distribution map the vacuum cleaner is get test sample.

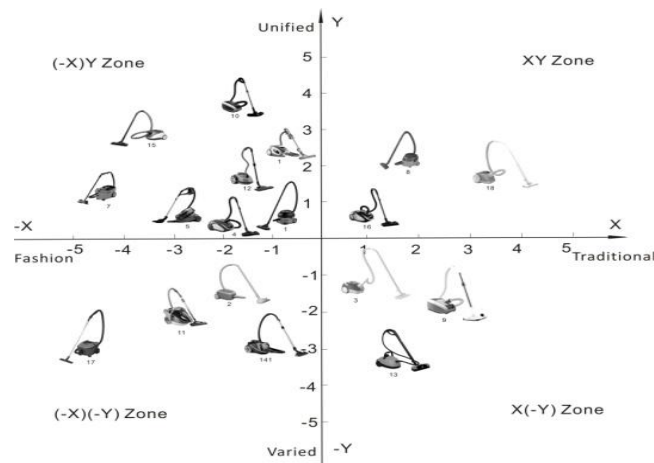


Figure 2. Coordinate

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

4.3. User Evaluation

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



Figure 3. Schemes

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.

Table 1. Score			
Number	12	10	4
Score	9.2	8.6	6.7

According to the actual level of manufacturing technology and the appearance of such factors, the customer finally chose the 12 scheme.

4.4. Feature Analysis

According to the user's evaluation and selection of the program, consult scale distribution the image of the test sample of the vacuum cleaner, we found that the 3 programs selected by the user are distributed in the Y axis, which belong to the unified category. Among them, there are 8 belong to (-X) Y range(44%), that is "Unified "and "Fashion " range, there is 3 belong in the XY range (16.6%), that is, " Unified" and " Traditional" interval. In the (-X) Y range, the appearance of these vacuum cleaners 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 users and the representation of implicit knowledge. It verifies the matching of user knowledge and design knowledge.

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