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Product Form Identification Technology Based on Cognitive Thinking

Shutao Zhang[1], Jianning Su*[1], Chibing Hu[1], Peng Wang[2]
[1]School of Mechanical & Electronical Engineering, Lanzhou University of Technology
[2]School of Design Art, Lanzhou University of Technology
No. 287, Langongping Road., Qilihe District, Lanzhou, Gansu, PRC. Postal code: 730050
*Corresponding author, e-mail: adiu1984@163.com

Abstract

In this paper, based on the analyzing of the selecting and distinguishing characteristics of cognitive thinking, the product design elements are analyzed with the theories of Kansei Engineering, and the corresponding mathematic model for the analysis is developed based on the quantification-I theory to quantitatively discuss the relationship between product form design elements and the psychological kansei image of the users. With foregoing investigation result, practicable program software has been developed as a solver tool to subsequent design. Finally, a practical application of testing machine is presented, and the results show that the method is reasonable and feasible as well.

Keywords*: product design, quantification-I theory, kansei image, cognitive thinking*

1. Introduction

In today's highly competitive market, the strategy of products design has already translated from producers-oriented to user-oriented [1]. Good products no only need to meet the functional requirements, but also need to satisfy the users' psychological demands [2]. Therefore, the inner feelings of users caused by product form get increasingly attention in this era.

Perception is the most basic cognitive thinking activity form [3, 4], and the users get the perception image of the product form according to the visual perception [5]. On the basis of the gestalt principle [6], there are a lot of information effect visual perception at the same time in the process of users getting the perception of the product, but the users can't clearly perceive every detail of these information, they select the information according to the personal experience, preferences and interest, and reject the information that go unexamined. So, the users always actively choose some information as perceptual object in cognitive thinking and get clear perception impression to them.

In the design process, because the product form design involves the human subjective feeling, there is no certain standards to judge the correctness of the design and whether the proposal meet the users' feeling, and designers design product without clear principles. So, this research quantifies users' perceptual cognition with the theories of kansei engineering technology [7], and investigates the relationship between the users' feeling and product form, and chooses the design elements that influence the image deeply to help the designers to create the product form that meets the users' feeling with the most efficient method.

2. The Cognition of Product Form

There are a lot of information act on the vision and perception at the same time when the users perceive the product. It's impossible to perceive all information or every detail clearly at the same time [8]. Users will quickly identify information according to their personal experience, preferences and interests, and exclude the information they are not concerned. Therefore, users always identify a part of information as perceiving object initiatively, and obtain a perception impression that is prominent and clear.

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Therefore, in the perceptual processes of product form, users firstly organize all design elements as a system, and then simplify it to identify some important information, which will help to produce the kansei image of the product form according to the impression, knowledge and experience in their memory. The research presents the analysis that applies the Quantification-I theory to identify the design elements that influence the product form image deeply.

3. Quantification-I Theory

Multivariate analysis methods are based on observation data to study the relationship between some random variables [9]. Through the analysis of data, the research reveals the rules and relationship between the variables. Quantification-I theory is used to study the relationship between a set of qualitative variable *x* (independent variables) and a set of quantitative variable *y* (dependent variable) [10], and establish the mathematical model between them, so as to predict the dependent variable *y*. This study investigates the corresponding relationship between the users' feeling and product design elements with the kansei engineering technology in order to improve the product quality.

4. Research Process

On the basis of the positioning research of the kansei image in the product design, the researchers screen the product sample, and conduct a questionnaire survey, and analyze the products form to pick up the product design elements, and then analyze the corresponding relationship between the users' perceptual image and product design elements according to the results of the survey based on quantification-I theory.

4.1. Design Research

Firstly the researchers screen the product samples, secondly make the product samples into questionnaire survey samples and number them in a certain way, and then make questionnaire according to the adjectives that express the perceptual image based on the perceptual image positioning, finally take the investigation.

4.2. The Analysis of Product Design Elements

A product is made up of different design elements according to the system concept, and every design element includes many different forms. The researchers collect a large number of product samples to summarize and classify the product design elements with morphological analysis.

4.3. The Mathematical Model

The product design elements are independent variables *x*, and the kansei image evaluation is dependent variable *y*. It is supposed that the number of the form design elements is *r*, the category number of the *m*th design element is r_m, $\delta_i(j,k)$ is reaction of the *k*th category of the *j*th item to the *i*th sample.

When the qualitative date of the the *j*th item to the *i*th sample is the *k*th category, the value of $\delta_i(j,k)$ is 1, or, its value is 0.

It defines the $n \times p$ matrix X as reaction matrix, then,

$$X=\{\delta_i(j,k)\}, \quad (1)$$

$i=1,2, \ldots, n,\ j=1,2, \ldots, m,\ k=1,2, \ldots, r_j$

It is supposed that the relationship between dependent variable and item and category comply with the following linear model,

$$y_i = \sum_{j=1}^{m} \sum_{k=1}^{r_j} \delta_i(j,k) * b_{j,k} + \varepsilon_i \quad (2)$$

The $b_{j,k}$ is constant coefficient that depends on the *k*th category of *j*th item. ε_i is random error to the *i*th sample. According to the principle of least squares, the least squares is used to estimate $b_{j,k}$ to make the *q* in the following formula reach its minimum value.

$$q = \sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} \left[y_i - \sum_{j=1}^{m} \sum_{k=1}^{r_j} \delta_i(j,k) * b_{j,k} \right]^2 \tag{3}$$

The necessary condition of the minimum value meets the following formula.

$$\frac{\partial q}{\partial b_{u,v}} \equiv -2 \sum_{i=1}^{n} \left[y_i - \sum_{j=1}^{m} \sum_{k=1}^{r_j} \delta_i(j,k) * b_{j,k} \right] \delta_i(u,v) = 0 \tag{4}$$

u=1, 2, ..., m, v=1,2, ... , r_u,

If $\hat{b}_{j,k}$ is the minimum value of $b_{j,k}$, it meets the previous formula and the following formula.

$$\sum_{j=1}^{m} \sum_{k=1}^{r_j} \left[\sum_{i=1}^{n} \delta_i(j,k) * \delta_i(u,v) \right] \hat{b}_{j,k} = \sum_{i=1}^{n} \delta_i(u,v) * y_i \tag{5}$$

The predictive value of kansei image of first given samples is $\hat{y}_i$.

$$\hat{y}_i = \sum_{j=1}^{m} \sum_{k=1}^{r_j} \delta_i(j,k) * \hat{b}_{j,k} \tag{6}$$

Or,

$$\hat{y}_i = \hat{y} + \sum_{j=1}^{m} \sum_{k=1}^{r_j} \delta_i(j,k) * b^*_{j,k} \tag{7}$$

$\hat{y}$ is the average value of y_i. $b^*_{j,k}$ is standardized coefficients, and the relationship between $b^*_{j,k}$ and $\hat{b}_{j,k}$ is shown as following formula.

$$b^*_{j,k} = \hat{b}_{j,k} - \frac{1}{n} \sum_{k=1}^{r_j} n_{j,l} * \hat{b}_{j,l} \tag{8}$$

And,

$$\sum_{l=1}^{r_j} n_{j,l} = n \tag{9}$$

The multiple correlation coefficient *R* is used to evaluate the forecast accuracy.

$$R=\left[\frac{\sum_{i=1}^{n}\left(\hat{y}_i-\bar{y}\right)^2}{\sum_{i=1}^{n}\left(y_i-\bar{y}\right)^2}\right]^{\frac{1}{2}} \tag{10}$$

In order to calculate the contribution of each item to the dependent variables, the following formulas are supposed.

$$x_i^{(j)}=\sum_{k=1}^{r_j}\delta_i\left(j,k\right)*\hat{b}_{j,k} \tag{11}$$

$$s_{t,w}=\sum_{i=1}^{n}\left(x_i^{(t)}-\bar{x}^{(t)}\right)\left(x_i^{(w)}-\bar{x}^{(w)}\right) \tag{12}$$

$$t,w=1,2,\cdots,m,m+1$$

$$x_i^{(m+1)}=y_i \tag{13}$$

$$\bar{x}^{(u)}=\frac{1}{n}\sum_{i=1}^{n}x_i^{(u)} \tag{14}$$

Here, $x_i^{(j)}$ is quantitative date of the *j*th item to *i*th sample. And a sample correlation matrix *H* is supposed.

$$H=\begin{bmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,m+1} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,m+1} \\ \vdots & \vdots & \vdots & \vdots \\ h_{m+1,1} & h_{m+1,2} & \cdots & h_{m+1,m+1} \end{bmatrix} \tag{15}$$

And,

$$h_{t,w}=\frac{s_{t,w}}{\sqrt{s_{t,t}*s_{w,w}}} \tag{16}$$

Here, $h^{t,w}$ are elements of H^{-1}. And ρ_{yt} is the partial correlation coefficient between dependent variable *y* and the *t*th item.

$$\rho_{yt}=\frac{-h^{t,m+1}}{\sqrt{h^{t,t}h^{m+1,m+1}}} \tag{17}$$

4.4. The Results Analysis

The analysis results include the partial correlation coefficients of the design elements to perceptual images, the standard coefficients of the categories of every design element, and the multiple correlation coefficient based on quantification-I theory. The partial correlation coefficients indicate the contribution of the design elements to the emotional image. The standard coefficients indicate the contribution of the design element categories to the emotional image. And the multiple correlation coefficients indicate the accuracy of the mathematical model. In the product design process, if designers want to design a product with a higher perceptual image value, they should firstly pay attention to the design elements with higher partial correlation coefficient, and choose the design elements category with higher standard coefficient.

5. Case Study

The researchers take the testing machine as the study object, and the case study comes from the Tianshui Hongshan Testing Machine Ltd. Firstly, 35 product models are selected as the initial samples, and 50 image adjectives are collected to describe the image of testing machine from network and magazine. The product samples and image adjectives are excluded by KJ method. 20 product samples and 2 image adjectives (plain-modern, feminine-masculine) are selected. According to the SD method, a five point rating scale questionnaire is made to survey Kansei image of those samples. The form of testing machine is analyzed with the morphological analysis method. And its design elements include the design of light bars and screw on the top, rings, the top view of beam, the front view of beam, the aspect ratio of baffle, the ratio of upper and lower, the number ratio of light bars and screw. According to morphological analysis, the categories of beam are shown in figure 1.

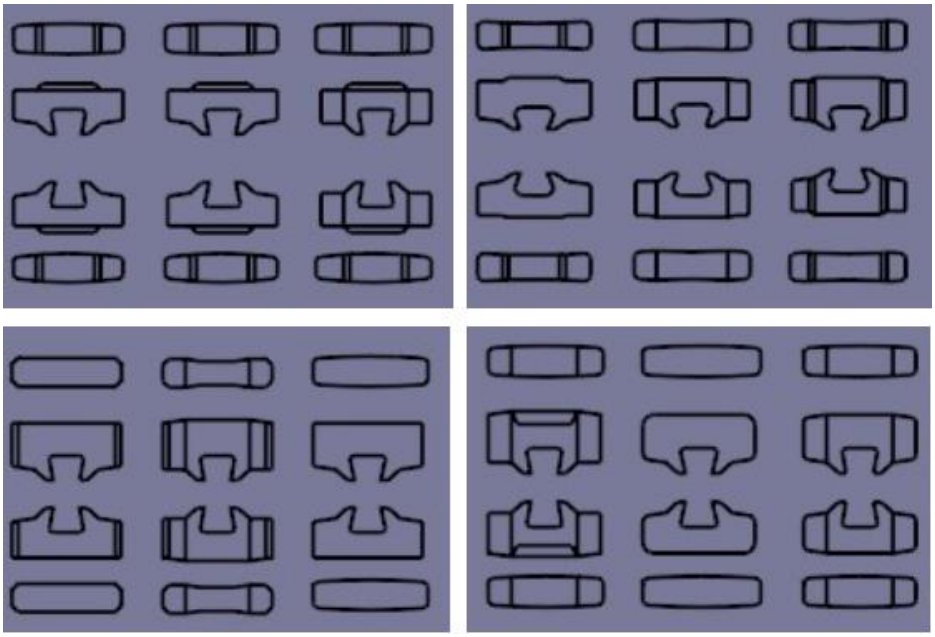

Figure 1. The Categories of Beam

A SD questionnaire survey is taken. The results of morphological analysis and survey are analyzed with the quantification-I theory. Taking the image adjectives “plain-modern” as example, a part of the analysis result is shown in table 1.

The partial coefficients in the table 1 show that the number ratio of light bars and screw has a great influence to the perceptual image of “plain-modern”. When the number ratio is 1, the perceptual image tends to be neutral. When the number ratio is 2, the perceptual image tends

to be “modern”. The multiple correlation coefficients is 0.8365, it shows that the accuracy of the model is high. So, if the designers want to design the testing machine with the perceptual image of “modern”, they should ensure that the number ratio of light bars and screw is 2. Similarly, the researchers infer the relationship between the other perceptual images and design elements.

Table 1. Analysis Result

Design elements	Categories	standard coefficients	partial correlation coefficients
The aspect ratio of baffle	<1	-0.1768	0.6989
	=1	-0.1213	
	>1	0.5216	
	without	0.7579	
The number ratio of light bars and screw	1	-0.1938	0.7229
	2	0.6782	
The multiple correlation coefficient		0.8365	

Figure 2. The Testing Machine Design

Based on the analysis result, the researchers design a testing machine for Tianshui Hongshan Testing Machine Ltd. It is shown in figure 2. The sales show that the design is successful, and the product identity is improved.

6. Conclusion

The product image form design is one of the effective ways to improve product identity. Based on the cognitive analysis of product image, the research has built the product perceptual image identification model with the quantification-I theory. With the case study of the testing machine, the result has shown that the product image identification method is feasible. It will be helpful to establish intelligent design elements identification system based on cognition.

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References

[1] Nagamachi M. Kansei Engineering: a New Ergonomic Consumer-oriented Technology for Product Development. *International Journal of Industrial Ergonomics*. 1995; 15(1): 3-11.
[2] Su Jianning, Fan Yuefei, Zhang Shutao, et al. Research on the Product Form Design Based on Kansei Engineering and Neural Network. *Journal of Lanzhou University of Technology*. 2011; 37(4): 47-50.
[3] Kurt K. Principle of Gestalt psychology. First Edition. Hangzhou: Zhejiang Education Press. 1997.
[4] Xian Guangming, Zeng Biqing, Yun Qiaoyun, et al. Non-specific person continuous speech identification in second language using BPR. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(7): 1604-1609.
[5] Yong Ching Yee, Sudirman Rubita, Chew Kim Mey. Colour perception on facial expression towards emotion. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(4): 723-733.
[6] Nagamachi M. Kansei Engineering as a Powerful Consumer-oriented Technology for Product Development. *Applied Ergonomics*. 2002; 33(3): 289-294.
[7] Haykin S. Neural Network: A Comprehensive Foundation. Second Edition. Beijing: Chine Machine Press. 2004.
[8] Hung-Cheng Tsai, Shih-Wen Hsiao and Fei-Kung Hung. An Image Evaluation Approach for Parameter-based Product Form and Color Design. *Computer-Aided Design*. 2006; 38: 157-171.
[9] Su Jianning, Jiang Pingyu, Zhu Bin and Li Heqi. Research on Kansei Engineering and Its Application to Product Design. *Journal of Xi'an Jiaotong University*. 2004; 38(1): 60-63.
[10] Kang Wenke, Zhang Quan, Zhang Dinghua. Research of Composite Thinking in Product Color Intelligent Design. *Application Research of Computers*. 2009; 26(6): 2083-2085.