Research to Compare Emotional Image Evaluation Models of Product Form Based on Neural Network

Su Jianning*, Zhang Shutao**, Wang Peng***, Liu Gang****

** School of Design Art, Lanzhou University of Technology, Lanzhou 730050, China, sujn@lut.cn*
*** School of Mechanical & Electronical Engineering, Lanzhou University of Technology, Lanzhou 730050, China, adiu1984@163.com*
**** School of Design Art, Lanzhou University of Technology, Lanzhou 730050, China, plw521@126.com*
***** School of Design Art, Lanzhou University of Technology, Lanzhou 730050, China, liuganglz@126.com*

Abstract: The research on consumers' emotional image evaluation method is important to construct the efficiently intelligent design systems of product form. Artificial neural network is a kind of information processing system which can be applied to solve the multi-dimensional nonlinear problems. Its characteristic is fit to simulate consumers to evaluate the emotional image preference of product form. With used BP three-layer Neural Network and improved BP four-layer Neural Network, different product form image evaluation models are developed to establish the relationship between the product form design elements and the consumers' emotional image perception. Two Neural Network models are trained via the result of Semantic Difference questionnaires. The trained network models can forecast consumers' kansei image values of the new designed product form. The practice example of goblet image evaluation shows that two Neural Network models are definitely feasible and practical, but improved BP four-layer Neural Network model is the most efficiency and accuracy. The results furthermore validate the overall organization, the constant memory and the identifiable discrimination characteristics of Gestalt psychology what is complied with when the consumers perceive the product form.

Key words: Product form, Kansei image, Neural Network, Evaluation models, Gestalt psychology

1. Introduction

Since the 1970s, with the development of world economy and the improvement of people's living standards, more and more consumers pay attention to the original and spiritual level feelings when they select and purchase products, and the products that reflect the personality, identity, hobby, values and other personal characteristics have become the pursuing object. The products are no longer just as a function carrier because consumers pay more attention to the spiritual feeling that the products bring, it is kansei image. Therefore, if the designers can grasp the psychology feeling and requirement of consumers, they are able to successfully develop some good products [1], and the market competitiveness of enterprises will be improved. Accordingly Kansei Engineering [2] theories and models are put forward to guide the development of new products.

Kansei Engineering is a theory and method that explores the relationship between the human sensibility and the design characteristics of objects with the engineering and technical means [3]. In the product design, it can express the human's emotional image to the objects with the quantitative or semi-quantitative way. Thus the product design should associate with the human feelings. The products which meet the expectations of the human will be

developed [4]. At present, how to estimate the consumers' or designers' satisfaction degree to the design results and how to apply artificial intelligence techniques to improve the Kansei Engineering application system [5] are focus in the theoretical research.

The artificial neural network is an information processing model that imitates the biological neural processing system and the human cognitive behavior [6]. Due to its non-linear information processing technology, it can improve the ability for intuitive information processing. So it is commonly used to establish the complex relationship between the input variables and the output variables, also it is successfully applied in product design [7]. In the product design process, the relationship between the design elements and the consumers' perception is a black box model and it cannot be accurately described, but the neural network can be applied to establish the relationship between them.

Based on the analysis of the product image perception, the research applies BP neural network and improved BP neural network to construct the image evaluation system which simulates the consumers' emotion to the products, and presents comparative analysis with application examples. It is expected to obtain a more accurate product form image evaluation method, which will be a foundation to develop the intelligent design system of product image form.

2. Product form image

2.1 Product form

Each object has its own unique characteristics. These objects of different form make up the human's living environment and enrich our life. When an object is mentioned, the product form characteristic is almost recalled. Product form design is an important research content in the modern industrial design. Product form includes two meanings: one is the external form what is consisted with point, line, surface, color, and so on; another is the emotional expression, namely sensibility or perception which people can perceive from the product form. People can receive the visual impact from the external form, and then they obtain the perceptual cognition of product.

2.2 The cognitive processes of product form image

Image is a consciousness activity excitated by the external stimulation, and it can produce memory, association and feelings of objects. The product form image comes from the cognitive processes for product form. It can come into being the communication language between the product form and the consumers [8].The consumers' perception to product form is based on human's visual and perception characteristics, its characteristics can be summarized as the overall organization, constant memory, simple regulating and identifiable discrimination according to the Gestalt principle [9].

(1) Overall organization. The product is consisted by different parts, but it is perceived as an integral organization in the cognitive thinking and not perceived as individually isolated parts. When the consumers watch the product, they firstly make a quick scan integrally and obtain a whole appearance and early attention. Then they will observe its detail. Usually, the early cognitive process has the overall imagery priority and dominates the detailed observation.

(2) Constant memory. When the users perceive a product, the perceptual impression remains relatively unchanged because the experience plays an important role in the cognitive thinking. The product is always

cognized according to the impression, knowledge and experience in their memory. When they observe the same object, the perceptual impression remains relatively constant although the external conditions may be different.

(3) Simple regulating. In cognitive thinking, the users have the psychological characteristics that they like the simple information and dislike the complex information. The simple and clear sensation information can be easily recognized and accepted. Also the simple, complete and comparative information is firstly obtained when they face the complex product what includes many vision information groups. Therefore, the users have a tendency to simplify the product form when they cognize the product. Then the product information is transferred more quickly and directly, and recognized and memorized more easily.

(4) Identifiable discrimination. There are much information to act on the vision and perception at the same time when the users perceive the product. But it's impossible to perceive all information in thinking at the same time or perceive each detail clearly. They will quickly identify the information based on their personal experience, preferences and interests, also filter and exclude the information they are not concerned. Therefore, the user always identify a part of information as perceiving object initiatively in cognitive thinking, and obtain a prominent and clear perception impression.

Therefore, in the perceptual processes of product form image, the users firstly organize all design elements as a system, and then simplify it to identify some important information, which will come into being the kansei image of the product form according to the impression, knowledge and experience in the memory thinking. The research presents the comparative analysis what applies the different neural network model to simulate the users' evaluation to product form image based on the human's cognitive processes.

3. Neural Network model to simulate users' kansei image evaluation

The consumers' cognitive evaluation process to product form image is a typically intelligent activity of many thinking [10]. When it is simulated, two following problems have to be solved.

(1) Perception simulation. Perception is the most basic process in cognitive thinking activity. Its simulation process is to express the perceptual information effectively. Presently, the visual perception simulation of product form image is mainly based on the model method [11], in which the sensor information is used to reconstruct the product form. Firstly the target product form must be reasonably simplified according to the perception characteristics of simple regulating. Based on the perception characteristics of overall organization, the input mode of perception information can be constructed as parameter-part-system.

(2) Knowledge expression and learning memory. The solution of artificial intelligence problem must be based on the reasonable expression of knowledge. In other words, it translates the gained knowledge into computer's internal code and gives a reasonable description and storage. It can use the neural network to express the knowledge in the perception process system of product form image. The learning process can adopt the error back propagation algorithm, which is BP Neural Network. Its memory information expresses the perception characteristics of constant memory. Its value of weights expresses the perception characteristics of identifiable discrimination.

The research applies BP Neural Network and improved BP Neural Network to construct intelligent evaluation model based on the users' cognitive image to product form.

3.1 BP Neural Network model of product image evaluation

In currently related research [12-14], the relation between the product form design parameters and the kansei image is built with three-layer BP neural network, and the model is shown in Figure 1. The input is the form design parameters of the product, and the number of nodes is equal to the number of controlling parameters. The output is the users' kansei image, and the number of nodes is equal to the number of vocabulary pairs which reflect consumers' perceptual image cognition. All the input layer neurons nodes and the output layer neurons nodes are connected by the middle layer. The neurons number of middle layer is usually the half of the sum neurons of input layer and output layer.

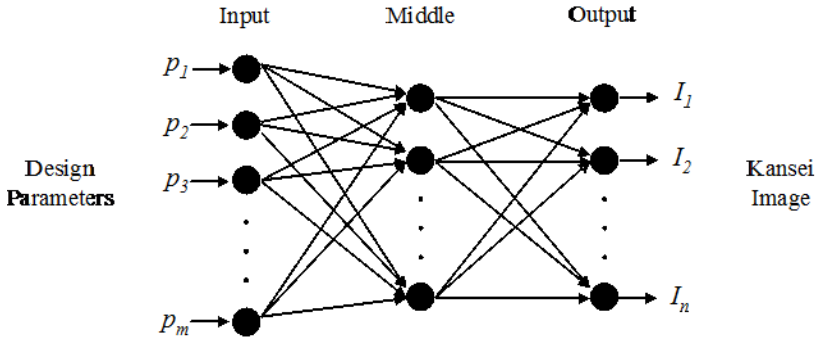

Figure.1 The product image evaluation model based on BP neural network

3.2 Improved BP neural network model of product image evaluation

The improved BP neural network model of product image evaluation is shown in Figure 2, which has a four-layer network structure. The input date of parameter input nodes are all design parameters. The input date of part input nodes are all parts of product. The design parameters of the part are connected with this part. Otherwise, the parameters that do not belong to the part are not connected with this part. The output is the users' perceptual image. The middle layer connects with the part input layer and the output layer. All nodes of part input layer are linked with all nodes of middle layer, also all nodes of out layer are linked with all nodes of middle layer.

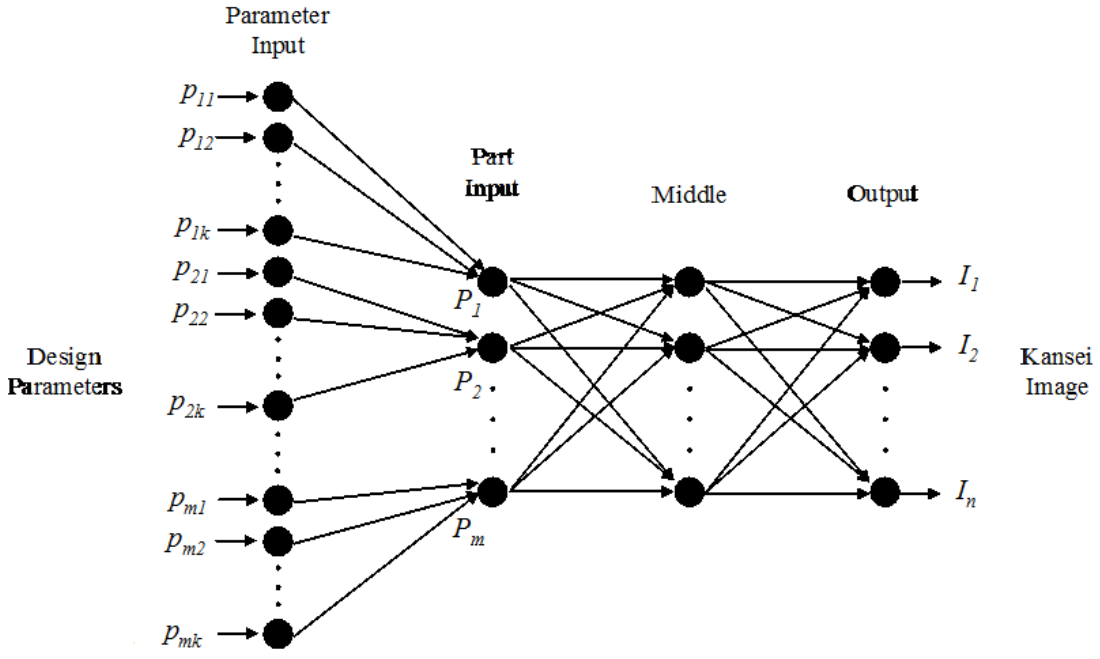

Figure.2 The product image evaluation model based on improved BP neural network

The matter, the thing, and their relationship can be described by the formalization language with Extenics [15]. The thinking objects belong to matter element. Based on the overall scanning, the users' perception can obtain the corresponding parts of product (thinking element). However, each part is controlled by the design parameters, and the design parameters which do not belong to this part do not affect the thinking elements.

The semantic difference method is used to survey the kansei image that the subjects perceive the product form in a period. Two neural network models are trained with the normalized values of the design parameters and the kansei image. The weights of learning memory represent the constancy memory of the subjects' image evaluation to the product form. The parameter-part-system structure of the improved BP neural network reflects the characteristic of overall organization. The weights value between the parameter input layer and the part input layer represent the identifiable discrimination to these parameters. The weights value between the part input layer and the middle layer represent the identifiable discrimination to these parts.

4. Examples of comparative analysis

The researchers take the goblet that needs the higher image requirement as the study object, and a comparative study of the two evaluation models is presented.

4.1 Preparation

The researchers collect 48 goblet pictures after primary selecting and obtain 12 representative samples after removing similar pictures. The 12 representative samples are remodeled and rendered, as shown in Table 1.

Table 1. 12 representative samples

Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
					
Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
					

The researchers collect 15 kansei image vocabularies that fit to describe the goblet. A questionnaire survey is carried out, and then 4 pairs of vocabularies that apply to describe the goblet are picked out with cluster analysis: personality-ordinary, feminine-masculine, lively-steady, elegant-vulgar.

The goblet form is analyzed with the morphological analysis method. Its elements include rim, body, leg and base, and its profile curve is controlled by 6 points, as shown in Figure 3.

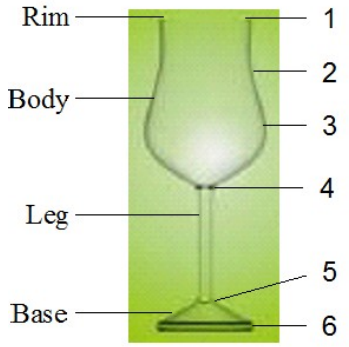

Figure.3 Morphological elements and control points of goblet

A five-level SD questionnaire survey is presented with 12 representative samples and 4 pairs of vocabularies. The survey results is analyzed with the quantification-I theory [16]. The result shows that the base and the leg thickness less influence the goblet image. So the base and the leg thickness are assumed to remain unchanged. Therefore, the thinking elements of the goblet can be described with the rim, body and leg. The value of $[x_1]$ denotes the rim, $[x_1, y_1, x_2, y_2, x_3, y_3, y_4]$ denote the body, and $[y_4, y_5]$ denote the leg.

On the bases of 12 representative samples, the researchers redesign 38 new samples according to the design parameter ranges. The second SD questionnaire survey is presented with 50 product samples and 4 pairs of kansei image vocabularies. 52 subjects take part in the survey and 50 effective questionnaires are obtained. The survey result is processed to be normalized, and the normalized date is used to train and test the neural network models.

4.2 To establish intelligent evaluation system of goblet image

(1) Intelligent evaluation system of the goblet image with BP neural network

The model structure is shown in Figure 1. According to the quantitative analysis, there are 8 parameters to control the goblet form, so the neurons nodes are 8 in the input layer. There are 4 pairs of adjectives to describe the goblet's emotional image, so the neurons nodes are 4 in the output layer, and each node corresponds to an emotional image. The neurons nodes are 6 in the middle layer.

(2) Intelligent evaluation system of the goblet image with improved BP neural network

The model structure is shown in Figure 2. There are 8 neurons nodes in the parameter input layer. The part input layer contains 3 neurons nodes that are rim, body, leg. The node x_1 in the parameter input layer connects to the first node of the part layer. The nodes $x_1, y_1, x_2, y_2, x_3, y_3, y_4$ in the parameter input layer connect to the second node of the part input layer, and the nodes y_4, y_5 in the parameter input layer connect to the third node of the part input layer. The output layer contains 4 neurons nodes. The middle layer contains 4 neurons nodes to connect the part input layer and the middle layer.

Taking the former 46 samples as training samples and the remaining 4 samples as test samples, the researchers train both neural network models respectively.

4.3 The comparative analysis of two kinds of evaluation systems

(1)To test two evaluation system

The researchers test both neural network models with the 4 test samples to validate the prediction effect. The errors are expressed with the absolute value. The result is shown in Table 2.

Table 2. The test results of both neural network models

The product image intelligent evaluation system based on BP neural network					
Emotional vocabularies	Error Analysis	Sample 47	Sample 48	Sample 49	Sample 50
Personality-ordinary	Subject score	0.49	0.53	0.41	0.36
	NN score	0.46	0.39	0.46	0.33
	Absolute error	0.03	0.14	0.05	0.03
Feminine-masculine	Subject score	0.51	0.51	0.43	0.33
	NN score	0.54	0.52	0.41	0.46
	Absolute error	0.03	0.01	0.02	0.13
Lively-steady	Subject score	0.59	0.53	0.39	0.45
	NN score	0.49	0.52	0.58	0.50
	Absolute error	0.11	0.01	0.19	0.05
Elegant-vulgar	Subject score	0.68	0.53	0.31	0.38
	NN score	0.54	0.55	0.34	0.54
	Absolute error	0.14	0.02	0.03	0.16
Convergence	The convergence rate is slow, and about one-third of the training precisions don't reach 10^{-3}.				
The product image intelligent evaluation system based on improved BP neural network					
Emotional vocabularies	Error Analysis	Sample 47	Sample 48	Sample 49	Sample 50
Personality-ordinary	Subject score	0.49	0.53	0.41	0.36
	NN score	0.48	0.44	0.47	0.40
	Absolute error	0.01	0.09	0.06	0.04
Feminine-masculine	Subject score	0.51	0.51	0.43	0.33
	NN score	0.52	0.52	0.51	0.49
	Absolute error	0.01	0.01	0.08	0.16
Lively-steady	Subject score	0.59	0.53	0.39	0.45
	NN score	0.56	0.57	0.55	0.52
	Absolute error	0.03	0.04	0.16	0.07
Elegant-vulgar	Subject score	0.68	0.53	0.31	0.38
	NN score	0.59	0.58	0.52	0.52
	Absolute error	0.09	0.05	0.21	0.14
Convergence	The convergence rate is fast, and all the training precisions reach 10^{-3}.				

(2)To define reasonable error

In this study, the level of perceptual evaluation is divided into five classes that are defined as 5 points on the axis. The normalized numbers are 0, 0.25, 0.5, 0.75, and 1. According to the semantic differential method, if the value of perceptual evaluation is in the interval from -0.125 to 0.125, it belongs to the level represented by the point. For example, the number 0.25 represents the second class, as shown in Figure 4. If the perceptual evaluation is in the region of 0.125 to 0.375, it is considered that the perceptual evaluation is including the second level. Therefore, when the error absolute value between the forecasting value of NN and the evaluation value of subjects is less than 0.125, the predicted results can be accepted.

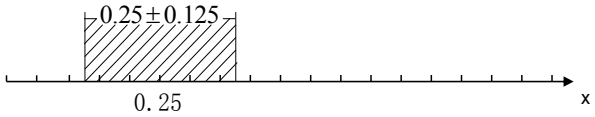

Figure.4 Reasonable error range

According to the test results, the used BP neural network accurately predicts 15 items, and the accuracy is 75%, and the training accuracy is relatively poor. The improved BP neural network accurately predicts 16 items, and its accuracy is 80%, also the training accuracy is better. The result proves that both neural network models can obtain ideal prediction accuracy, but the improved BP neural network is more suitable to evaluate the product perceptual image. Therefore, the test result further proves that the image perception of consumer is in accordance with the perception characteristics of overall organization, constant memory and identifiable discrimination of the Gestalt principle.

5. Conclusions

The product image form design method is one of the more effective ways to improve product competitiveness. The specific ability of neural network can built the nonlinear correlation between the consumers' perceptual image and the product design parameters. Based on the cognitive analysis of product image, the research has built the product emotional image evaluation models with BP neural network and improved BP neural network, which can simulate consumers' emotional image evaluation. With the comparative analysis of goblet image evaluation, the result has shown that the product image evaluation system with improved BP neural network is much better, which is in accordance with the perception characteristics of overall organization, constant memory and identifiable discrimination of the Gestalt principle. It will establish a theoretical foundation for intelligent design system based on design cognition.

6. Acknowledgments

The authors would like to extend our sincere thanks to all those who contributed to this study, especially the participants who took the trouble to respond to the questionnaires. The project is sponsored by National Natural Science Foundation of China (51065015), Foundation of Postgraduate Supervisor of Gansu Education Office in China (1007ZTC081) and Scientific Research Foundation for the Returned Overseas Chinese Scholars of State Education Ministry ([2010]1561).

7. References

[1] Jonathan, C. and Craig, M. V. (2002) *Creating Breakthrough Products-innovation from Product Planning to Program Approval*, Prentice Hall PTR, New Jersey.

[2] Nagamachi, M. (1995) *Kansei Engineering: a New Ergonomic Consumer-oriented Technology for Product Development*, International Journal of Industrial Ergonomics, vol. 15, no. 1, pp 3-11.

[3] Nagamachi, M. (2002) *Kansei Engineering as a Powerful Consumer-oriented Technology for Product Development*, Applied Ergonomics, vol. 33, no. 3, pp 289-294.

[4] Su Jianning, Jiang Pingyu, Zhu Bin and Li Heqi. (2004) *Research on Kansei Engineering and Its Application to Product Design*, Journal of Xi'an Jiaotong University, vol. 38, no. 1, pp 60-63.

[5] Schutte, S. (2005) *Engineering Emotional Values in Product Design - Kansei Engineering in Development*, Department of Mechanical Engineering, Linkopings University, Linkoping.

[6] Haykin, S. (2004) *Neural Network: A Comprehensive Foundation*, 2nd Ed., Chine Machine Press, Beijing.

[7] Su Jianning, Jiang Pingyu and Li Heqi. (2009) *Research on Kansei Image-driven Method of Product Styling Design*, International Journal of Product Development, vol. 7, no. 1/2, pp 113 -126.

[8] Hung-Cheng Tsai, Shih-Wen Hsiao and Fei-Kung Hung. (2006) *An Image Evaluation Approach for Parameter-based Product Form and Color Design*, Computer-Aided Design, vol. 38, pp 157-171.

[9] Kurt, K. (1997) *Principle of Gestalt psychology*, 1st ED., Zhejiang Education Press, Hangzhou.

[10] Zhang Yanhe, Yang Ying, Luo Shijian and Pan Yunhe. (2010) *Mental Construction of User Perception Image in Product Design*, Chinese Journal of Mechanical Engineering, vol. 46, no. 2, pp 178-184.

[11] Kang Wenke, Zhang Quan and Zhang Dinghua. (2009) *Research of Composite Thinking in Product Color Intelligent Design*, Application Research of Computers, vol. 26, no. 6, pp 2083-2085.

[12] Su Jianning, Wang Peng and Zhang Shutao. (2012) *Research on the Kansei Image of Shape Based on Harmonic Representation and Neural Network*, International Conference on Kansei Engineering and Emotion Research , pp 195.

[13] Hsin-Hsi Lai, Yang-Cheng Lin and Chung-Hsing Yeh. (2005) *Form Design of Product Image Using Grey Relational Analysis and Neural Network Models*, Computers & Operations Research, vol. 32, pp 2689-2711.

[14] Su Jianning, Fan Yuefei, Zhang Shutao and Ouyang Linzi. (2011) *Research on the Product Form Design Based on Kansei Engineering and Neural Network*, Journal of Lanzhou University of Technology, vol. 37, no. 4, pp 47-50.

[15] Cai Wen. (1995) *From Matter Element Analysis to Extenics*, 1st ED., Scientific and Technical Documentation press, Beijing.

[16] Su Jianning and Li Heqi. (2005) *Investigation of Relationship of Form Design Elements to Kansei Image by Means of Quantification-I Theory*, Journal of Lanzhou University of Technology, vol. 35, no. 2, pp 36-39.