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Application of Support Vector Machine Model based on Particle Swarm Optimization for the Evaluation of Products' Kansei Image

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Abstract: With the development of science and technology and ever complicating process of design objects, scientific methods are needed for the evaluation of products' Kansei image. This present quantitative experiment proposed a SVM model based on PSO for the evaluation of Kansei image as reflected in the Computer numerical control (CNC) machine. For the first place, we obtained the average scores of Kansei image evaluation of the CNC machine by the questionnaire survey. Then the form elements of the CNC machines were analyzed. Lastly, comparison was made concerning the accuracies of the three methods, namely, BP neural networks, SVM based on cross-validation method and SVM based on PSO in the evaluation of CNC machine's Kansei image. The research used 35 sets of samples for training as the experimental group, and five other groups as the control group. The results showed that statistics obtained from SVM based on PSO came closer to the mean value from the questionnaires than the other two methods, thus justified its role in intervening consumer's evaluation on the Kansei image of products.

Keywords: Evaluation, kansei image, particle swarm optimization (PSO), support vector machine (SVM).

1. INTRODUCTION

With the development of economy and the improvement of people's living standard, consumers' demand for products moves from the functional satisfaction to the psychological satisfaction of Kansei image. Products' qualification urges higher standard accordingly. In order to enhance the intrinsic value and emotional qualities of products, we need to pay more attention to the specific emotions and the values conveyed by product. Thus, impact upon the spiritual aspects of the human from the style of Kansei image caused by the product form becomes increasingly important [1].

Product Kansei image refers to the instinct feeling of the consumer on the form of products, such as the perception of line, color, texture and structure. In other words, the consumers feel the product form through a visual way, which ensue a subsequent influence on the perception of the product form. Research shows the consumers' perception of product Kansei image usually presents a relatively stable psychological tendency and habit, and the favorable attitudes generated usually dominate the consumer's behavior tendency on the selection of products [2]. Therefore, accurate knowledge of consumers evaluation of the product Kansei image has become a hotspot in the field of product design and evaluation.

As product design involves human subjective experience, there is no fixed standard to judge the correctness of the design, the quality and extent of compliance with the people's feeling.

With the development of science and technology and the complexity of the design objects, we should not evaluate the Kansei image of product simply by intuition and experience, but adopt advanced and scientific methods to make a comprehensive and scientific evaluation. Methods from engineering science to study the relationship between product design elements and product Kansei image could quantify consumers' Kansei image of products, thus will help designers to analyze and understand objectively preferences of consumers for different product forms, and reflect the feelings and consumer awareness in the Kansei image evaluation as accurately as possible.

Currently, the evaluation methods of product Kansei image are mainly objective weighting method, such as the quantification-1 theory [3], Cluster Model [4], artificial neural network [5]. Some scholars analyzed the relationship between each product design elements and Kansei image by using quantitative mathematical methods and Cluster Model, and achieved good results. However, there are numerous factors affecting the human subjective experience and perception. So these methods can hardly describe the relationship between product design elements and Kansei image of consumers in an accurate manner. With a strong self-learning ability, fault tolerance and non-linear approximation capability, the artificial neural networks can imitate human brain to process information to some extent. It offers a new way to solve this problem. In the patent CN 102413605 B (Zhi Tao *et al.* 2012) [6], the inventors designed a Intelligent street lamp energy-saving control system. It implemented the intelligent power control in accordance with the surrounding environment of each street lighting unit, and reduced the energy consumption effectively on the premise of meeting the lighting requirements. Method for evaluating video quality based on artificial neural net was provided by the patent application CN 100559881C (Xiuhua Jiang *et al.* 2008) [7]. The method can calculate the extent of the damaged image by analyzing the spatial characteristics and temporal characteristics of the video image, and its acquired results were highly consistent with human visual perception. In the patent CN 101188847 A (Zhiyong Huang *et al.* 2008) [8], the inventors designed a experience evaluation method for mobile communication service user based on artificial neural network. According to the characteristics of mobile communication services and actual users, it can extract the basic characteristics of the end-users' experience of quality, and establish the mapping relation between the basic indicators of end-users' experience quality and the quality indicators of the mobile communication service accurately, so as to forecast the users' experience and improve the accuracy of network operation and maintenance and optimization. But the artificial neural network has some shortcomings. The more complex the network structure, the stronger its ability to learn. But the generalization is weak and prone to overlearning phenomenon. On the contrary, when the network is simple, its learning ability becomes insufficient, and one can hardly find laws from a limited sample. In addition, when solving high-dimensional problems, the training and test results of artificial neural networks have greater randomness. Its output tends to converge to local minima. In order to solve the above problems, Vapnik and others proposed a new type of machine learning method which is based on structural risk minimization (SRM) principle on the basis of statistical learning theory -- SVM. It can effectively solve the practical problems which are diverse, high-dimensional or nonlinear, and is easy to be generalized. A application method of fuzzy support vector machine in telephone traffic prediction was provided by the patent CN 102438257 A (Yu Peng *et al.* 2012) [9]. It used priori knowledge in linguistic variables or fuzzy sets described, added to the design of the kernel function, and then accessed a new class of kernel functions to be applied in traffic forecast. In the patent CN 101994001 A (Long Liu *et al.* 2011) [10], the inventors designed a method of predicting vibration aging effect based on Support vector machine algorithm. It established a support vector machine algorithm to predict the effect of VSR. Based on a small amount of test data to build the predictive models, you can input the actual time parameters into these models, and calculate the residual stress level of the structure, thus assess the real-time quantitative effect of VSR.

Because of the solid theoretical foundation and excellent performance of SVM, we use it to explore the relationship between product design elements and Kansei image of the consumers. We use it in the evaluation of product kansei image and explore the relationship between product design elements and Kansei image of the consumers.

2. THE RESEARCH

2.1. Data Collection and Questionnaire Making

Step 1. Extensively collect product form pictures. To collect the sample products on sale as many as possible. If the number of samples is too big, classify and sift the samples, choose the representative ones and encode the sample in a certain way.

Step 2. Collect adjectives about this kind of product through various channels, such as client-customer conversation and related magazines. Dictionaries are also good choices if the number is not sufficient**,** then use the subjective way to evaluate these adjectives, exclude the unusual or similar expressions, and put the two adjectives of opposite meanings in a group as an adjective-pair. Then let the target consumers pick out the adjectives which are more suited to describe the Kansei images of the products so as to find out the most appropriate Kansei-images adjectives for these products.

Step 3. Use semantic differential method (SD method) to build a seven semantic differential scale between sample pictures and Kansei-images adjectives for the questionnaire.

Step4. Investigate a certain amount of the potential target customers. Let the respondents rank corresponding Kansei image ratings for each product. Use an Excel spreadsheet to calculate the average of the Kansei image for each product.

2.2. The Decomposition of Product Form Elements

In order to further investigate the correlation between the various parts of the design elements and product Kansei image, we should decompose an industrial product into various form elements and pick out the modeling elements that are essential to the Kansei image. We can use the morphological chart method for the decomposition, and list all design elements step by step. The process can be discussions between the team members and designer, interview with the consumers. In principle, a detailed list of all the possible affecting the Kansei image should be given. Because of the limitation of the sample quantity, we can also gradually cut out unimportant form elements by using statistical methods.

2.3. Results and Analysis

Design elements of products are mathematically arranged as the inputs and the average score of the Kansei image by questionnaire are taken as the output. Use SVM model to analyze the impact of various factors on the Kansei image of each product form. To further improve the performance of SVM, use PSO algorithm to optimize the parameters of SVM. Then verify the evaluation model by using the known sample data. The research process is as Fig. (**1**).

3. THEORETICAL FRAMEWORK

3.1. SVM

An SVM is a general learning method developed from statistical learning theory with a better performance than many other routine methods [11]. Compared with traditional machine learning methods, SVM follows the structural risk minimization principle to learn from the known samples. It takes both account of the error and risk of structure. Therefore, SVM can effectively solve the small sample, nonlinearity, high dimension of practical problems, and has a strong generating ability.

SVM can obtain the unknown relationship between input and output of the system according to the given sample data. When another set of input is given, SVM can estimate the value of the output of the system. The basic block diagram of SVM is shown in Fig. (**2**).

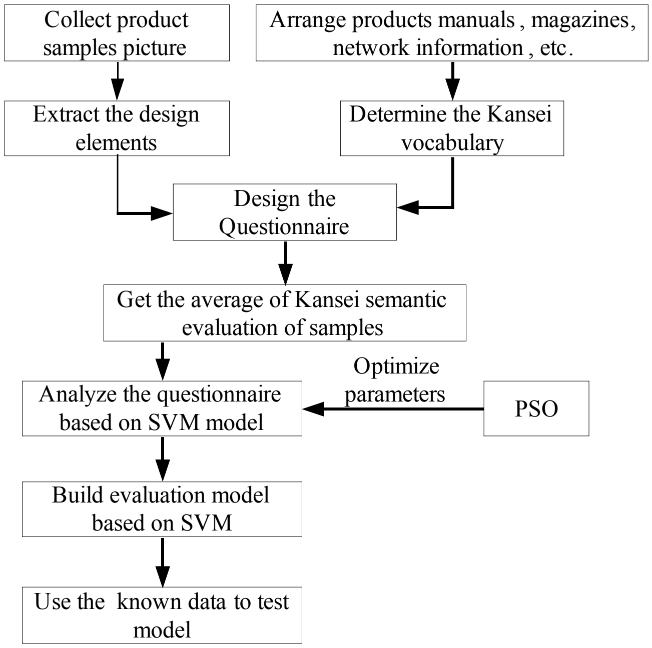


Fig. (1). The process of research.

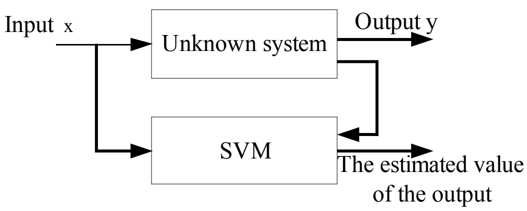


Fig. (2). The basic block diagram of SVM.

On the issue of nonlinear regression, we used a mapping $\phi(x)$ to convert nonlinear problems into linear problems in a high-dimension space. The known training sample set is $D=\{(x_i,y_i)\}$, where $i=1,2,\cdots n$S, $x_i \in R^d$, $y_i \in R$. We used $f(x)=(\omega\cdot\phi(x))+b$ fit relationship between input x_i and output y_i of the training sample set. When fitting accuracy is ε, then:

$$\left|f(x_i)-y_i\right| \le \varepsilon \tag{1}$$

$$s.t.\quad \min_{\omega,b} \frac{1}{2}\|\omega\|^2 \tag{2}$$

Such a regression is transformed into convex quadratic programming problem whose global optimal solution can be obtained. After introduce slack variables ζ_i、ζ_i^*, we got Eq.3 and Eq.4:

$$\begin{cases} (\omega\cdot\phi(x_i))+b-y_i \le \varepsilon+\zeta_i \\ y_i-(\omega\cdot\phi(x_i))-b \le \varepsilon+\zeta_i^* \\ \zeta_i \ge 0£¬\zeta_i^* \ge 0 \\ i=1,2,\cdots n \end{cases} \tag{3}$$

$$st.\ \min_{\omega,b,\zeta_i,\zeta_i^*}\{\frac{1}{2}\|\omega\|^2+C\sum_{i=1}^{n}(\zeta_i+\zeta_i^*)\} \tag{4}$$

With Lagrange multiplier method, we obtained Eq.5:

$$\begin{aligned} f(x) &= (\omega\cdot\phi(x))+b \\ &= \sum_{i=1}^{n}(\alpha_i^*-\alpha_i)K(x_i,x)+b \end{aligned} \tag{5}$$

x_i is support vector(SV), $K(x_i,x)$ is the Kernel, Usually use radial basis function (RBF) $K(x_i,x)=\exp\{-\frac{\|x-x_i\|}{\sigma^2}\}$, where σ is the width of the RBF kernel, which determines the influence area of the SVs over the data space [12]. We can know that the parameter ε, regularization parameter C and the width parameter of the kernel function σ will affect the performance of SVM.

3.2. PSO Algorithm

In order to improve the accuracy of SVM, we used PSO algorithm to optimize the parameters of SVM. PSO algorithm is a bionic optimization algorithm which imitates the migration and foraging of birds. With high search speed and efficiency, PSO algorithm has been widely used in various types of parameter optimization of continuous problem and discrete problems [13]. According to the channel capacity differences of different power distribution within the cell matrix, in the patent CN 101820671 A (Kai Niu *et al.* 2010) [14], the investors designed a distributed power distributing method based on particle swarm algorithm used for OFDMA system. It can find the optimal power allocation matrix for each cell, maximize the channel capacity of the system at a lower cost, and then improve the system spectral efficiency and channel capacity. To solve a n dimensional problem, we should initialize a group of free-moving particles and use a n-dimensional vector $X_i=(x_{i1},x_{i2},\cdots,x_{in})^T$ to represent the position of the *ith* particle. Each position represents of a potential optimal solution for the problem we need to solve. The particles update their velocity and position by the information of individual best particle and group best particle according to Eq. 6and Eq.7 [15], as follow:

$$\begin{aligned} V_{id}^{k+1} &= \omega V_{id}^{k}+c_1 r_1(P_{id}^{k}-X_{id}^{k}) \\ &\quad +c_2 r_2(P_{gd}^{k}-X_{id}^{k}) \end{aligned} \tag{6}$$

$$X_{id}^{k+1}=X_{id}^{k}+V_{id}^{k+1} \tag{7}$$

Where c_1, c_2 is non-negative constants, r_1, r_2 is random number between $[0,1]$, ω is inertia weight, which is used to balance the global search ability and local search ability. After k times of iteration, the particles track the individual best particle P_{id}^{k} and the group best particle P_{gd}^{k} to update the position and velocity of their own to find the global optimal solution of X_{id}^{k}.

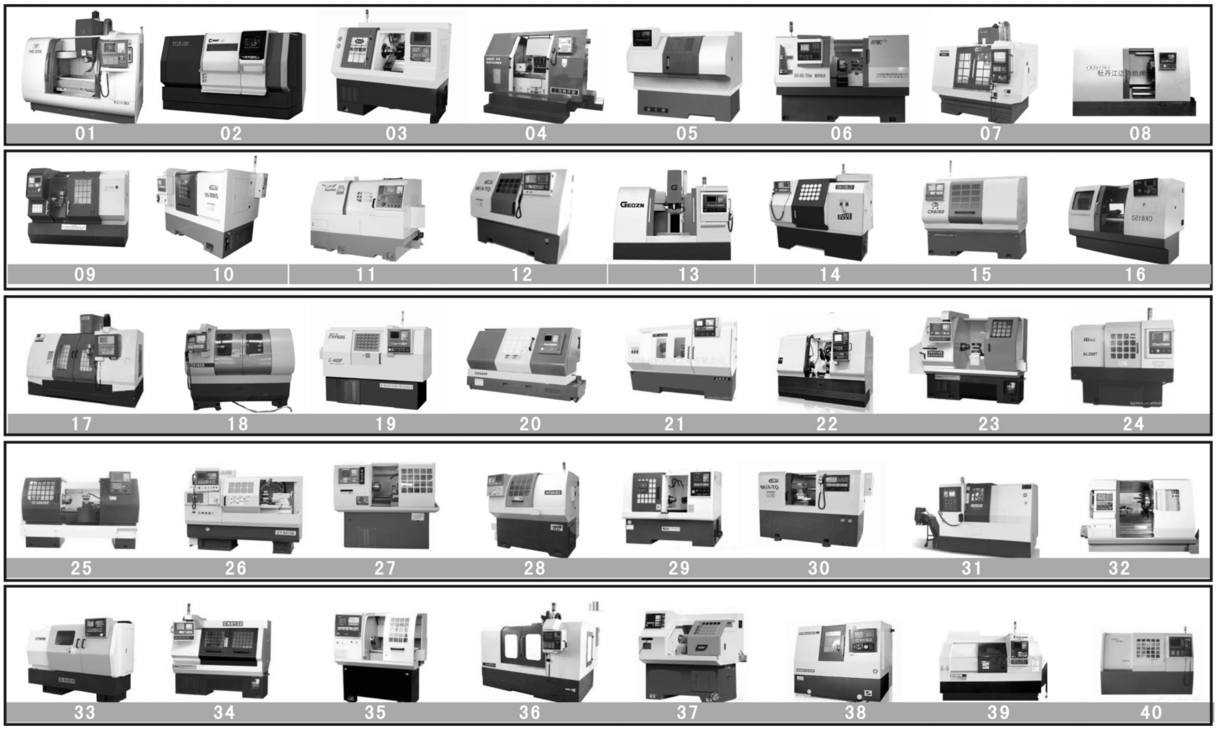


Fig. (3). Selected representative samples.

3.3. Optimize SVM Model by PSO Algorithm

The main steps of using PSO algorithm to optimize the parameters of SVM can be listed as follows:

Step 1. Initialize a group of particles, and assign their value to the parameter ε , regularization parameter C and the width parameter of the kernel function σ

Step 2. Put the parameters represented by the particle positions into SVM for operation

Step 3. Update the velocity and position of particles.

Step 4. Use $fitness = \| f(x_i) - y_i \|$ as fitness function to evaluate the result of the operation

Step 5. When fitness values reach the desired targets or the maximum number of iterations is reached, terminate the operation. Otherwise repeat step2.

Repeat the above steps, after several times iterative calculation, you can find the right parameters to further improve the performance of SVM.

4. APPLICATION EXAMPLES

4.1. The Selection of Representative Samples and Vocabulary of CNC Machine

We collected the pictures of CNC machine through the network, magazines, brochures and other means, and gathered the pictures of CNC machine on the market as many as possible. We arranged the samples initially and excluded the samples of high similarity, bad visual angle and too big or too small ones. Then we got the 220 sample pictures of CNC machine. We ultimately selected 40 representative samples by multidimensional scaling analysis and cluster analysis. To avoid the positive influence upon the evaluation from color issue, all the samples are transferred into black and white, as Fig. (**3**).

Through brainstorming, product brochures, Internet, magazines, dictionaries, dictionaries and other ways, we collected 300 adjectives to describe Kansei images. We used subjective evaluation methods to exclude the adjectives which are not commonly used and not the similar expressions, and organized the adjectives of opposite meanings in 50 adjective pairs.

In order to better reflect the Kansei images of the CNC machines, we organized enterprise technicians, workers and students of design class to pick out 6 pair of adjectives as follow: precious - rough, simple - complex, technological - mechanical, gracious - callous, flexible -clumsy; modern - traditional.

4.2. Establish the Semantic Imagery Space and Process the Data

The questionnaire is composed of a 7 semantic differential scale established by SD method and the sample pictures which are rearranged. The questionnaire is shown in Table **1**.

The questionnaire including 40 samples of CNC machines was conducted on the spot. To make the subjects visualize the sample pictures with clarity, the samples were shown in sequence on multi-media when conducting the questionnaire. All the 35 questionnaires assigned were collected and proven valid. We used Excel to calculate the average of 40 samples of Kansei semantic evaluation of CNC machines.

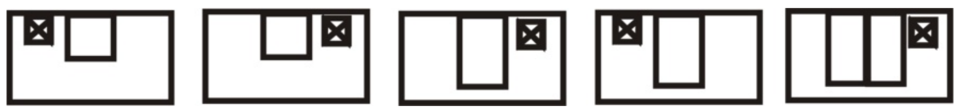
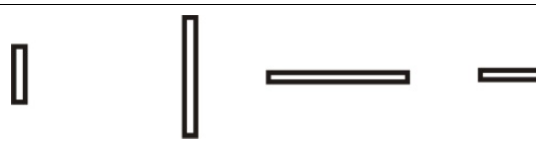
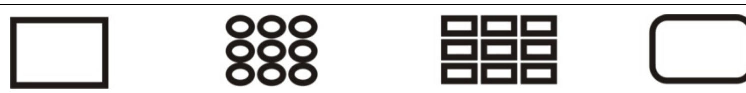
4.3. The Selection of Design Elements

In order to further explore the correlation between various design elements of CNC machine and the Kansei adjectives,

Table 1. SD scale of sample 28.

 28	Precious 3 2 1 0 -1 -2 -3 rough Simple 3 2 1 0 -1 -2 -3 complex Technological 3 2 1 0 -1 -2 -3 mechanical gracious 3 2 1 0 -1 -2 -3 callous flexible 3 2 1 0 -1 -2 -3 clumsy modern 3 2 1 0 -1 -2 -3 traditional

Table 2. Main form elements of CNC machines.

Number	Project a	Category e
1	relative position a_1	 e_{11} e_{12} e_{13} e_{14} e_{15}
2	side view a_2	 e_{21} e_{22} e_{23} e_{24} e_{25}
3	door handle a_3	 e_{31} e_{32} e_{33} e_{34}
4	base a_4	 e_{41} e_{42} e_{43}
5	observation window a_5	 e_{51} e_{52} e_{53} e_{54}

we analyzed form features elements of CNC machine by morphological analysis, arranged form features elements by category order, and established the form feature elements of decomposition table as questionnaires. Considering the respondents should have a certain expertise in industrial design, we launched 16 questionnaires among 30 graduate students in the class of industrial design in our university. All of the questionnaires handed out are valid.

As the structure of CNC machine is a collection of a number of design elements, it can be divided into several independent form projects, such as the relative position of the monitor and door, side view, door handle, base, observation window. In order to determine the feature elements of CNC machine, each project was subdivided into a number of feature elements (category) [16]. The results of decomposition is shown in Table **2**.

4.4. Data Analysis Based on PSO-SVM

For quantitative analysis, each feature element in TABLE II was encoded to make sure that a product composed of different feature elements can be represented by an ordered set of real numbers. For example, $X_{28} = (1,5,4,3,3)$ represents the CNC machine which is composed of the feature elements: e_{11}, e_{25}, e_{34}, e_{43} and e_{53}. We can know that the evaluation average of Kansei adjective " gracious - callous " of sample 28 is $Y_{28} = 0.52$ from Table **2**. In this work, we obtained 40 sets of sample data (X_i, Y_i) through questionnaires, including $i = 1,2,3,\ldots,40$. We randomly selected 35 group of samples to train the SVM and use X_i as the input, Y_i as the output. The remaining five groups of samples was used for testing SVM model. With the help of professor Chih-Jen Lin's LIBSVM 3.17 toolbox, we processed the data by MATALB. The topology diagram of SVM is shown in Fig. (**4**).

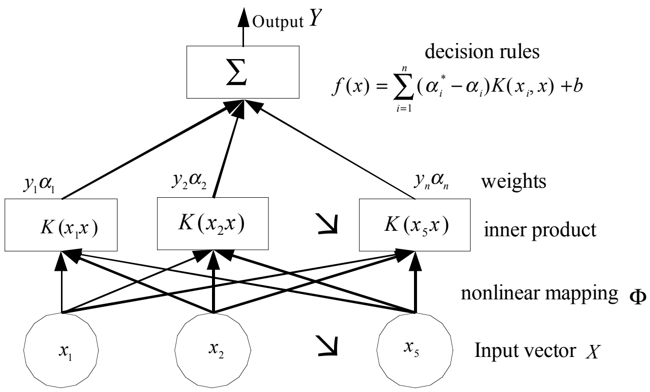


Fig. (4). The topology diagram of SVM.

In Fig. (**4**), the kernel function of SVM is radial basis function $K(x_i,y_i)=\exp\{-\|x-x_i\|^2/\sigma^2\}$

In the PSO algorithm, we took the initial inertia weight $\omega_0=0.9$, learning factor $c_1=c_2=2$, the maximum number of iterations *Iter* = 60, the size of the initial population Swarmsize=100, speed range of particle is [-1.1]. The range of parameter ε, regularization parameter C and the width parameter of the kernel function σ is $\varepsilon\in[0,0.7]$, $C\in[1,10^6]$, $\sigma\in(0,2)$.

In order to verify the evaluation model, we used the following three evaluation models to evaluate the Kansei image of"gracious - callous" of he CNC machine, respectively.

(1) BP neural network;

(2) SVM based on cross-validation method;

(3) SVM based on PSO

Through 20 times of iterations, particles of the third evaluation model found the right parameters and ceased further variation. The fitness curve is shown in Fig. (**5**).

After the training of the three models was completed respectively, we used the remaining five sets of data to test the model. The result is shown in Fig. (**6**).

After the test, the absolute error between predict value of the three evaluation models and the actual value of the questionnaire was obtained, as shown in Table **3** respectively.

5. CURRENT & FUTURE DEVELOPMENTS

The current design concept has gradually changed from form follows function to design follows the Kansei image. So product Kansei image design has become an important content of industrial design. In order to reduce the designer's personal subjective feeling and wrong judgments, we should objectively evaluate the Kansei image of product form from the consumer's view. After analyzing the commonly used evaluation methods, we applied SVM model based on PSO to evaluate Kansei image of product form. Through the simulation results we can obtain the following conclusions:

(1) The SVM model based on PSO is the most accurate among the three evaluation methods. The result of SVM model based on PSO is very close to the average of questionnaire. If a targeted survey is launched and the number of questionnaire is increased, we can further ensure the accuracy of the evaluation. Therefore, this method has some significance for industrial product design.

(2) SVM follows the structural risk minimization principle, and strive to seek a balance between complexity of

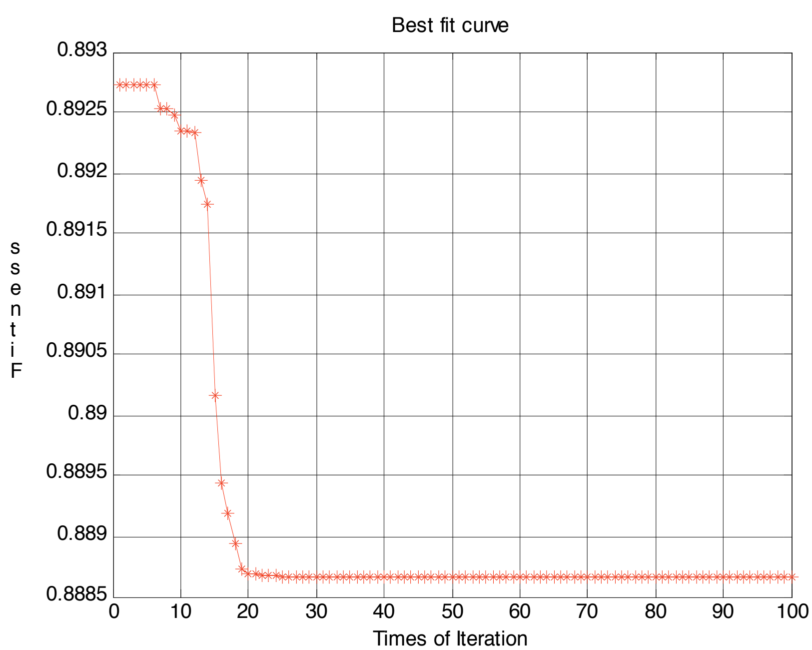


Fig. (5). The fitness curve of PSO algorithm.

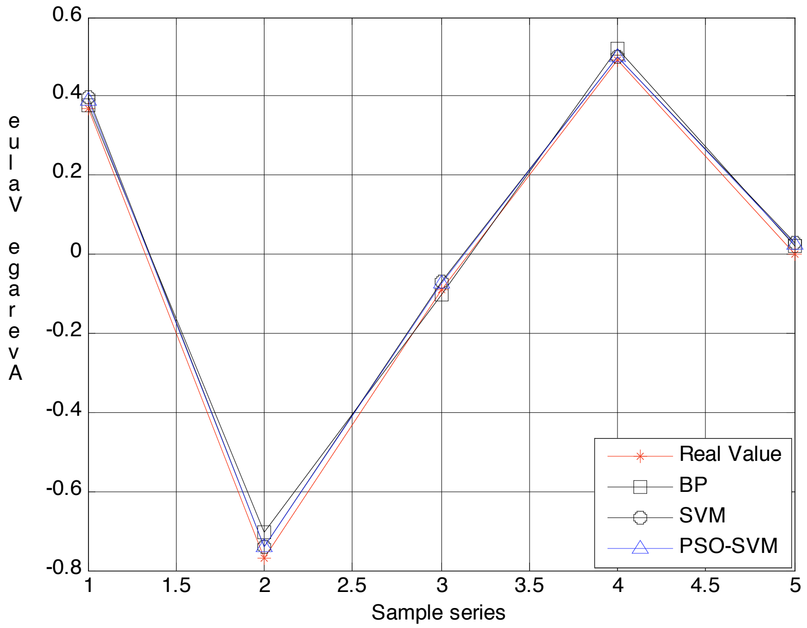


Fig. (6). Comparison of result between three model.

Table 3. Absolute error of three evaluation model.

Samples	1	2	3	4	5
BP	0.0088	0.0675	-0.0128	0.0287	0.0200
SVM	0.0288	0.0275	0.0192	0.0099	0.0283
PSO-SVM	0.0188	0.0275	0.0172	0.0087	0.0243

model and empirical risk. So it has a better generalization ability than BP neural network. Especially in the case of small numbers of samples, it is more practical than the BP neural network.

(3) Simulation results show that the PSO algorithm will find the better parameters than the cross-validation method provided by LIBSVM 3.17 toolbox.

By using the analysis of consumer modeling image and the support Vector Machine Model based on Particle Swarm Optimization, this paper achieves the perceptual image evaluation of CNC machine products. From the experimental results, it can be seen that this method can be well applied to evaluation of product modeling image.

It is important to note that different consumers show different psychological feelings of the product modeling image. Limited to time and cost of this survey, the quantity of the consumer sample is limited and the crowd is not subdivided. But in the evaluation of real products, consumers' perceptual image need to be surveyed and data analysis need to be taken according to the specific characteristics of consumers so as to guarantee the emotional characteristics reflected in the design may achieve consistency with the actual feelings of target groups.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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