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Research on Texture Design Methods of Clothing Material Based on Kansei Engineering

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Aiming at the issue of how to reflect the emotional needs of the consumers in the design of clothing materials, this paper studies the methods of texture design based on Kansei Engineering. Through filtering and counting the description vocabulary of the clothing material features, a group of typical sensorial words can be confirmed. Through semantic quantitative survey of clothing material samples, and using BP neural network, the images and feelings characteristics of clothing material can be modeled. Genetic algorithm can be used to achieve the evolution of the design scheme to meet the emotional design objects. The experimental results show that the methods can effectively achieve the requirements of the specific design objects of clothing material texture.

1. Introduction

Along with the progress of the society, the fashion design has gradually shifted from the early concept of emphasizing the modeling style, to the designer-oriented design concept which pays more attention to the consumer's needs. This ideological trend of consumer-centered design has been widely accepted. Design is no longer just the superficial form, it is the intangible value that can touch people's hearts feeling (Han et al., 2012). Therefore, how to further create a design method that attracts the consumers' sense, has become one of the keys of the current design. Clothing material is attached to the human body, so it must maximize the satisfaction of customer’s needs. Therefore the clothing material design should emphasize on the interactive experience connecting human and clothing and merges all sensory image information obtained after the overall feeling, and better promotes the clothing’s intrinsic value, by embodying the clothing’s emotional traits, expressing emotions of the specific design with different materials and reflecting the value orientation of the clothing.

Kansei Engineering was introduced by Japanese design community in the late 1980s, and became one of the new design directions and new subjects since 1990s. Dr. Mituo Nagamachi of Hiroshima University defined Kansei Engineering in his works as “a customer positioning oriented product development technology, a translation technology that converts customer’s feeling and intention into design elements" (Nagamachi, 1995). In this paper, the relationship model of the clothing material quality and the feeling experience of apparel products is established by means of Kansei Engineering. The paper puts forward the methods of designing the texture of the clothing material, investigates the customer’s sensory feelings of the material, and discovers the way to express emotions through clothing design. The whole design process includes: the evaluation and determination of emotional vocabulary, modeling the relationship between sensory image and design elements, and the evolutionary design based on the sensory model. Through Kansei Engineering, the design and development of clothing material are based on the needs and responses of the wearer itself. The wearer’s idea, aesthetic taste, emotion, physiology and other feeling elements are all the research objects. This kind of design is to feel the clothing texture perfectly in the wearer's angle of view. (Li et al., 2009)

2. Research methods

This research takes the texture of clothing material as the research object. The research methods include these: determining the typical sensory image vocabulary group after filtering and counting the words which can describe the material characteristics of the clothing; Surveying the sensory feeling of the consumers to

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acquire the semantic vocabulary; Modeling sensory feelings and the characteristics of clothing material with the BP neural network; Using genetic algorithm to achieve the evolution of the design of clothing materials to meet the emotional design objects.

2.1 Design orientation of clothing products

This research takes material design of women's winter coat as an example. The target user groups are those young urban consumers of 26-30 years old who received higher education, have certain economic basis, and are willing to accept new things and follow the trend. Comparing with other customer groups, they have bright psychological characteristics in purchasing behavior including chasing for innovation and beauty, enjoying fashionable and characteristic clothing to express themselves, and to win the praise and admiration from others.

2.2 Sample selection of clothing materials

There are several ways to collect samples including investigating in clothing stores, browsing magazines, manuals of clothing products and websites. After this, the first 120 women's new winter coat samples are collected. And then through multivariate scale analysis and clustering analysis, the final selection of 20 representative samples are selected (see Figure 1), including Vero moda, Peoleo, ONLY, Eni:d, Five plus, Ochirly and other hot brands of products. In order to avoid the influence of color factors on the emotional feeling of clothing material in this study, the representative samples receive color-removing processing.

Figure 1: Twenty typical winter coat samples

3. Research steps

3.1 establish the emotional vocabulary to describe the feeling of clothing materials

In order to regulate the consumer's fuzzy sensory evaluation of the clothing material, the method of determining, evaluating and counting the feeling vocabulary can be carried out. By means of statistical method, the relationship between the sensory feelings of the consumers and the characteristics of the clothing materials are understood and mastered. Through the dictionary, newspapers, magazines, product catalogs, related websites, a wide collection of emotional vocabulary can be achieved. Take questionnaire survey from the ordinary consumers to filtrate the words, and get the final selection of 50 emotional words which best fit the 20 samples of clothing materials. Through clustering analysis method, the emotional vocabulary is finally divided into several perceptual semantic groups, and the word near the center point of the group becomes the representative of the group. By clustering, the number of intention words and the correlation degree are decreased, therefore the complexity of the follow-up analysis and the interference of the related words can be reduced. 120 participants are invited to make sensory image semantics cluster analysis. The clustering is based on their own subjective feelings to these 50 sensory image semantics. Construct a 50×50 matrix, and fill in the matrix with the number of times that each two words are normalized to the same group. Then normalize the number to the [0, 1] interval. This value represents the distance between the two lexical samples and is the basis of clustering. According to the Iterative Self-Organizing Data Analysis (ISODATA) algorithm (Yin, 2015), 50 sensory image lexical samples can be divided into 10 vocabulary groups, as shown in Table 1.

Table 1: Sensory image vocabulary clustering result

Group #	Sensory image description vocabulary
Group 1	Safe, practical, tough, durable, popular
Group 2	Natural, fresh, bright, lightweight, clean
Group 3	Luxurious, flowery, fantasy, classical, advanced
Group 4	Transparent, metallic, abstract, humorous, flat
Group 5	Simple, simple, plain, simple, neutral
Group 6	Rough, thick, smooth, crisp, heavy
Group 7	Warm, elastic, smooth, rounded, soft
Group 8	Thin, elegant, soft, hollow, gorgeous
Group 9	Elegant, chic, elegant, delicate, pure
Group 10	Artificial, monotonous, smooth, cold, flat

3.2 Modeling the relationship between consumer perception image and texture feature

According to the material type and material quality factor, the computer modeling is carried out for different clothing materials. Then we get a batch of typical samples, as samples for the questionnaire survey. In order to establish the relationship between the sensory image of the user and the feature of the material, the sample's material feature must be quantified. Each feature is quantified by a certain standard and normalized to [0, 1] interval.

A questionnaire survey based on semantic differential method (G et al., 1996) is carried out which contains five evaluation grades and the chosen ten typical sensory image words, and takes the established women's winter coat material as samples. For the chosen 50 typical samples and 120 consumers surveyed, use statistical averaging method to get the quantized value of evaluation with the ten sensory image words. For each sample, the corresponding average value of evaluation with the ten words D=(d1, d2, ···d10). Due to the fuzziness of the consumer's sensory cognition, the relationship between the features of material texture and the sensory image description is a nonlinear fuzzy relation. The neural network method is appropriate for such a complex relation. In this research, the mentioned relationship is analyzed by the classical BP neural network (Sun et al., 2002). Construct a three-decker BP network (Hornk et al., 1989), and do the training with the data obtained from the questionnaire survey. For each survey sample, the corresponding value of the material feature is used as the input vector, which generates the output of the hidden layer and output layer. Suppose the input vector $X=(X_1, X_2, \cdots, X_n)^T$, hidden layer vector $Y=(Y_1, Y_2, \cdots, Y_m)^T$, the output layer output vector $O=(O_1, O_2, \cdots, O_m)^T$. For each survey sample, the expected output of the network is D. Through the training of BP network, the difference between the actual output and the expected output is minimal, and the relationship between sensory image and the material texture is modeled.

3.3 The evolution process of the clothing material texture

Base on the model of the consumer's sensory image and the clothing material texture, genetic algorithm can be used to design the texture of clothing material. The main steps include: Quantitatively describe the design object with the consumer's evaluation of sensory image. Do gene encoding with the design scheme of the clothing material texture. Randomly generate a batch of design plans as the mother generation to multiply. Get the final design scheme through competition.

3.3.1 Determination of gene

The specific issue of clothing design (Holland, 1962) can be transformed into corresponding gene expression parameters through the gene strand encoding. The structure is as follows:

$X=[X_1, X_2, \cdots X_i, \cdots X_n]$

$X_i=[X_{i1}, X_{i2}, \cdots X_{ij}, \cdots X_{ik}]$

In the formula, X represents the total gene strand of the design, X_i represents the genetic fragment of the design section of the apparel product, and X_{ij} represents the corresponding part of a specific material (material type, color, texture, etc.). As a result, a specific design gene strand represents an integrated material selection design scheme for the garment.

3.3.2 Selection, crossover and mutation of genetic operators

(1) Selection algorithm

In this study, the individual selection probability is calculated by the Monte Carlo method (Wang et al., 2002). Supposing n is the number of individuals, and F_i is the fitness of the individual i, then the choice probability P_i and cumulative probability P_i^t can be calculated as follows:

$P_i = F_i / \sum_{i=1}^{n} F_i \qquad P_i^t = \sum_{j=1}^{i} F_i / \sum_{j=1}^{n} F_j$

After calculating the choice probability of each individual, the choice of paring is carried out based on the roulette wheel selection strategy. In each round, a random number k is generated in [0, 1] interval, and the individual with the cumulative probability to the nearest of k is selected.

(2) Gene crossover and recombination

Gene crossover and recombination is the operation that the partial structure of two parents are replaced and recombined to generate an offspring. In this paper, the genetic gene uses real encoding, so we choose a linear restructuring method suitable for floating-point gene encoding. Supposing the allelic gene values of parent No.1 and No.2 are G_1 and G_2, then the corresponding gene value of the offspring is:

$G_o = G_1 + \alpha \cdot (G_2 - G_1)$

In the formula, a proportional factor α can be generated randomly in the interval of [-d, 1+d]. d is the range of the interval which is 0.25 in the example.

(3) Variation

The sub-generation variation can change the genetic characteristics of the offspring, so that the genetic algorithm has the ability of local random search, and can ensure the genetic diversity of the population, and prevent immature convergence. For the floating-point gene encoding, we use inhomogeneous mutation operator to do the variation operation (Qingfu et al., 2005). Suppose p_j is the probability of mutation for generation j, D is the length of gene string, the number of genetic variants can be:

$N = \mathrm{INT}\,(p_j \cdot D)$

In the formula, INT () is the Rounding Function. Randomly choose N genes in the whole gene cluster and do mutation operation with them. The value of the texture features is in [0, 1] interval, so the gene value after mutation can be:

$G_{new} = G_{old} + k \cdot \alpha_j$

In the formula, k is a random number equally distributed in [0, 1] interval, and α_j is the mutation ratio of the generation.

3.3.3 Fitness function design

Fitness is used to represent the individual's quality in genetic algorithm and is the basis for choosing offspring. In this paper, the gene values in the gene strand through genetic algorithm are used as the input of the BP network. The output of the network is compared with that of the expectation and the fitness of the individual's gene is evaluated according to the result.

$F = \frac{1}{\Sigma(E - O)\ \ N}$

In the formula, F is fitness, E is the expected value of the sensory image, O is the BP network output value of the sensory image, and N is the number of values.

3.3.4 Experimental results

In order to verify the validity of this method, we choose women's winter coat as an object to design texture of the clothing product. First we set the goal of the product's emotional design, which is to show exquisite and simplicity feelings through the product. And we determine the quantitative index of its sensory image (see Table 2). The winter coat can be decomposed to four parts, garment body, sleeves, collar, and pockets. Each part contains eight kinds of material feature (hue, lightness, purity, roughness, hardness, gloss, weaving density and material type). Then we can generate 32 genes and form ten gene strands through random number generation which represent the initial design schemes and perform genetic evolution as parents. After 60 generations of evolution, 40 offspring are obtained, and eight of the solutions have the smallest error which are shown in Table 2.

From table 2 it can be seen that the optimal solution is the fourth. According to the material feature values that the fourth solution's genetic gene strand presents, a model can be made as a sample. And then make another questionnaire survey with 20 consumers. The consumers' evaluation value of sensory image, the evaluation value through genetic algorithm and the design object are compared in table 3. The table 3 shows that the average error between the optimal solution of the algorithm and the survey result is merely 0.008, and the average error between the design object and the actual survey result is just 0.015. It proves that the algorithm has basically met the design requirements, and has achieved the composite design scheme of clothing material corresponding to the design object.

Table 2: Eight solutions of genetic algorithm

Solution	Practica	Luxurious	Simple	Exquisit	Neutral	Monoto	Warm	MSE
Object	0.5	0.25	0.75	0.75	0.25	0	0.5	-
Solution I	0.5231	0.2791	0.7893	0.753	0.2801	0.0025	0.5209	0.0247
Solution 2	0.5328	0.2533	0.7512	0.7704	0.2703	0.0005	0.5016	0.0438
Solution 3	0.5163	0.2693	0.7519	0.7621	0.2711	0.0238	0.5232	0.0484
Solution 4	0.5099	0.252	0.7503	0.7576	0.2645	0.0126	0.5024	0.0231
Solution 5	0.5328	0.2662	0.7647	0.7618	0.2551	0.0226	0.5234	0.0527
Solution 6	0.5243	0.2669	0.7687	0.754	0.265	0.0239	0.5297	0.054
Solution 7	0.5091	0.2582	0.7782	0.7578	0.2768	0.0303	0.5075	0.0519
Solution 8	0.5079	0.2518	0.7526	0.7714	0.2564	0.0281	0.5056	0.0373

Table 3: Comparison of the optimal solution and the survey result

Solution	Practical	Luxurious	Simple	Exquisite	Neutral	Monotonous	Warm	Error
Object	0. 5	0. 25	0. 75	0. 75	0. 25	0	0. 5	0.008
Algorithm	0.5099	0.252	0.7503	0.7576	0.2645	0.0126	0.5024	0.015
Survey	0. 554	0. 251	0. 758	0. 745	0. 262	0. 017	0. 518	-

4. Conclusions

We make use of Kansei Engineering to construct a model with the clothing texture feature and the consumers' emotional feeling and use genetic algorithm to achieve the revolution of the design of material texture. We combine engineering science and design technology together and discuss the relationship between human and objects on the basis of engineering science in order to design the products with humanized design method (Songqin et al., 2007).

From the experimental results, it can be seen that this method can help a design scheme meet the emotional design object. It should be noted that different consumer groups have different psychological feelings of the product texture, which is mainly reflected in the modeling of the consumer's sensory image and the clothing's material texture. Because of limited time and cost, the number of consumers in the survey is still relatively limited, and there is no crowd segmentation. In the product design process, surveying and modeling should be based on the sensory image of proper consumer group, which ensure that the emotional feature of the design can be identical to the actual experience of the target population.

According to the quantitative sensory survey for the product samples, and the model of sensory image and clothing material feature, we established a relationship between consumer perception and clothing material features. On the basis of this, the evolution of the texture elements of the clothing material is realized by genetic algorithm, and the results of the evolutionary design which meet the sensory design object are obtained. This research provides methods to the designers to grasp the relationship between the clothing materials features and the consumers' emotional cognition, and finds a way to effectively complete the products' texture design. And a feasible scheme is carried out to quantitatively describe consumer's sensory feelings, which is of good use and reference value in the domains of emotionalized design or cognition of emotion of clothing products.

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