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Research of Product Design Optimization Based on Supporting Vector and Artificial Fish Swarm Algorithm

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Abstract

In order to meet customers' demand for perceptual cognition of product form, this paper proposes method to optimize the design of product form based on supporting vector and artificial fish swarm algorithm. First, determine features of targets, representative samples and modeling design parameters for product perceptual design survey; and then, use supporting vector to obtain the mapping relation between "styling design parameters — product perception", and use artificial fish swarm algorithm to establish product styling optimization design system with refrigerator profile optimization design for the case study. The results show that this method well stimulates the design thinking, thus it can provide effective aid and support for product concept design.

Keywords: *Product styling; Supporting vector; Artificial fish swarm algorithm*

1. Introduction

With the advance of science and technology, material products are abundant, and homogenization of products on the market is becoming more and more obvious. Users' demand for products has already risen from the material satisfaction to spiritual satisfaction, and concept of product design is gradually changing to that "form follows emotion", thus this paper proposes that users' feeling and experience should be regarded as the starting point of design.

The formation of product styling design comes from people's recognition of products. Accurate expression of design can improve effective communication between designers, products and consumers. Thus, currently, design to optimize product styling has already become the hotspot of both domestic and foreign researches. Literature [1] proposes three methods for product innovation, among which, Third method is based on the creation of the shortcomings of the existing products on the market analysis and the corresponding extension transformation, formed the design of new products, and finally the goodness of an innovative method for evaluating optimal scenario was selected ... Literature [2] for the product form is coded using target weight of participatory evaluation model parameters; according to the weight of the order modeling of the product design coding levels are graded by degraded mode on the original solution space for data processing, each downgrade using interactive genetic algorithm to search for optimal solutions step by step to complete the design of the detailed design. Literature [3] proposed for solving multi-objective constrained optimization model of Firefly algorithm constructed structure with common variable ability of artificial Firefly individual expression patterns for solution of optimization model of product family can be adjusted. Optimization design of General Motors product family simulation to verify the validity of the proposed model and algorithm. Literature [4] presented by means of genetic algorithm for global optimization BP neural network optimization, build hybrid GABP algorithm and should be used for design evaluation. Literature [5] based on the support vector machine and

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Particle Swarm Optimization algorithm for product image form optimization design methods. Literature [6] designed a nested two-stage heuristic algorithm of simulated annealing algorithm. The first stage is to determine the location of collection points-storage-distribution process of joint policymaking; second stage Recycle Center location-transport process of joint policymaking, iterations in two stages, in order to achieve the optimum solution search. By comparison with genetic algorithm, proved that two-stage heuristic algorithm is an effective method.

The above research mainly focuses on simulating the design process. In terms of simulating users' hidden emotional evaluation, a large amount of investigation samples are needed to establish a good evaluation mechanism; in terms of simulating designing thoughts, the parallel thinking is not well demonstrated. Vectors are to propose solutions to effectively solve nonlinear problem aiming at small sample problem. Particle Swarm Optimization algorithm is an optimization algorithm developed in recent years, has good parallelism. Simulation based on vector machine product design evaluation method of product modeling and Particle Swarm Optimization provides new ideas for product modeling design. Process of the research is as shown in Figure 1.

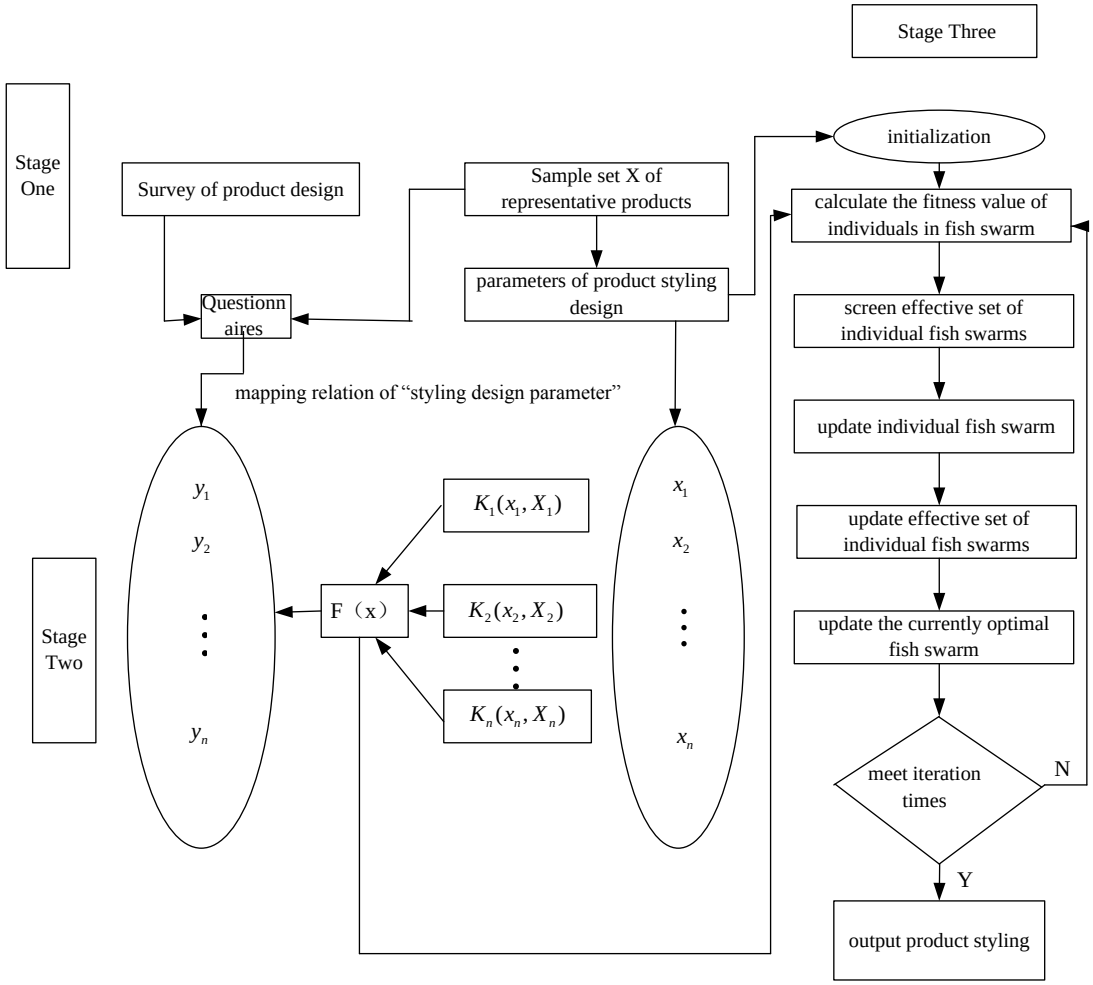

Figure 1. Process of Product Optimization Design

2. Analyze Product Styling and Product Samples

(1) Perceptual Design of Targets

Perceptual vocabulary is a common form to directly reflect perceptual designs. In order to accurately grasp customers' perceptual demand for design objects, gather perceptual

vocabulary through the Internet, magazines, research of shopping malls and direct communication with consumers, and the preliminarily screen the large amount of perceptual vocabulary that have been gathered and analyze them through questionnaires to obtain target perceptual design set:

$$A=\{A_1,A_2,\cdots A_j\} \quad (1)$$

(2) Samples of Representative Products

Through websites, magazines, products can be designed to gather comprehensive product sample pictures in the form of repeat or similar samples removed, in many ways, such as through expert interviews to pick a representative sample sets:

$$X=\{X_1,X_2,\cdots X_j\} \quad (2)$$

Make quantitative description of each representative product's samples to get parameter set of product styling design:

$$x=\{x_1,x_2,\cdots x_j\} \quad (3)$$

Then, parameter matrix of representative product sample' styling design is:

$$X=\begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_n^1 \\ x_1^2 & x_2^2 & \cdots & x_n^2 \\ \cdots & \cdots & \cdots & \cdots \\ x_1^m & x_2^m & \cdots & x_n^m \end{bmatrix} \quad (4)$$

Herein, m refers to the amount of representative product sample, and n refers to dimensions of product styling design's parameters

(3) Investigation of product perceptual design. Combine the target perceptual design set A with parameter matrix X of representative product sample's styling design for questionnaires with semantic differential method, and determine the corresponding average design value of each product sample through analysis and statistics to provide training and validation data for establishing evaluation system of product styling.

3. Establish Product Styling Evaluation Based on Supporting Vector and AFSA

3.1. Basic Artificial Fish Swarm Algorithm

Artificial fish swarm algorithm (AFSA) imitates the foraging and following behaviors of fish swarms with strong search ability and fast search speed. Typical behaviors of fish swarms are as follows:

(1) Foraging behaviors. Suppose the current state of artificial fish swarm is Xi, and choose a state Xj at random within the scope of its vision. If the food density Yi<Yj, make one step forward towards this direction. Otherwise, choose the state Xj at random again to judge whether it meets the condition for progressing; after testing for nj times, if the condition for progressing can still not be met, then, move one step at random, the mathematical expression of which is:

$$\begin{cases} X_{i|next}=X_i+Rand()\cdot Step\cdot\dfrac{X_j-X_i}{\left\|X_j-X_i\right\|} & Y_i<Y_j \\ X_{i|next}=X_i+Rand()\cdot Step & otherwise \end{cases} \quad (5)$$

In the formula, Rand () is a random number within the scope (0,1), and Step is the length of pace.

(2) Clustering behaviors. Suppose the current status of artificial fish is Xi, the number of partners within the scope of vision is nf, and the central location is Xc. If Yc/nf>δYi,

and δ is the density factor, it indicates that there is much food at the center of partners and it is not so crowded, then move one step forward towards the partner center, otherwise implement the foraging behavior, the mathematic expression of which is as follows:

$$\begin{cases} X_{i|next} = X_i + Rand() \cdot Step \cdot \dfrac{X_c - X_i}{\left\| X_c - X_i \right\|} & ,Y_c / n_f > \delta Y_i \\ findfood & otherwise \end{cases} \quad (6)$$

(3) Following behaviors. Suppose the current state of artificial fish swarm is Xi, and the location of artificial fish with the most density of food Yj with the scope of vision as Xmax. If Yj/nf> δ Yi, it shows that the partner Xmax has relatively higher density of food and it is not crowded in its surrounding, then, move one step forward towards the partner Xj, otherwise implement the foraging behavior.

$$\begin{cases} X_{i|next} = X_i + Rand() \cdot Step \cdot \dfrac{X_{\max} - X_i}{\left\| X_{\max} - X_i \right\|} & ,Y_{\max} / n_f > \delta Y_i \\ findfood & otherwise \end{cases} \quad (7)$$

(4) Random behavior. Artificial fish chooses a state at random within the scope of vision, and then move towards this direction, which belongs to the default behavior of foraging behavior.

(5) Bulletin. Bulletin is used to record the state of the optimal artificial fish.

AFSA is a random search algorithm, and for complex issues, it also has the defects like low efficiency at the later stage of searching and being easy to fall into local optimum, *etc*.

3.2. Establishment of AFSA-SVM Product Model

(1) Encoding Rules

For a given network with characteristics of m-dimensional data set D, feature selection is designed to select a target optimal feature subset of R, we use binary encoding rules, artificial fish location x values in binary representation of every dimension, taking the characteristics of selected as 1, and 0 otherwise.

(2) Food Density

Food quality evaluation based on artificial fish density is location, which feature performance evaluation criteria, intrusion signatures targeting includes two aspects: ① network intrusion detection rate higher; ② feature dimension at least as far as possible, the objective function (food densities) by the size of the selected subset of features and the detection rate is composed of two parts. Food density calculation formula is as follows:

$$FC = \lambda P_{error} + (1-\lambda)\frac{d}{D} \quad (8)$$

In the formula, d is the dimension of selected feature subset; D intrusion detection feature original dimension; Perror represents a 5-fold cross-validation detection rate SVM training model; λ is the detection accuracy of the weighting factor.

(3) Scope of Vision

If the field of view (Fv) is too small, prone to fish within Fv there are no artificial partners, random foraging probability is too large, leading to blindness enhanced search algorithm, but if Fv too, swarming behavior and increase the probability of rear-end behavior, not conducive to exploring new feasible solution space area. The studies indicate the degree of similarity between the two states by differences in the number of artificial fish status bits. If the similarity between two states with higher scores, it indicates less difference between the positions of the artificial fish. Artificial fish currently visible domain Fv position Xi is defined as:

$$F_v = \left\{ X_j \mid \sum_{k=1}^{L} \sigma_k \le \beta \right\} \quad (9)$$

In the formula, x_{ik} refer to the value of artificial fish at the current location Xi and dimension k,

$$\sigma_k = \begin{cases} 1 & , x_{ik} = x_{jk} \\ 0, & x_{ik} \neq x_{jk} \end{cases}, \quad \beta = 8 \text{。} \quad (10)$$

4. Steps of FSA-SVM Design

(1) Gather information about the product's state, and extract features of products' profile.

(2) Initialize parameters of artificial fish, mainly including location, pace of movement Step, scale of population n, density factor δ, feedback probability Pfb, recession factor of feedback probability θ, and the maximum iteration times max iterate, *etc*.

(3) Generate n artificial fishes with the feasibility range, and set the initial iteration times passed iterate=0.

(4) Calculate food concentration (FC) of initial fish swarm's individuals at the current location, and then rank them and choose the individual artificial fish with the maximum FC value to write on bulletin.

(5) Evaluate results of foraging, following and clustering behaviors of a certain artificial fish. If after one behavior is implemented, state of the artificial fish is superior to current one, this artificial fish move one step forwards towards this direction, and then implement (8).

(6) Produce a random number r, if r<Pfb, artificial fish implement the following behavior, otherwise, implement the feedback behavior and move one step towards the optimal direction in bulletin.

(7) Carry out chaos search into the state of all the optimal artificial fish according to formula (5), (6) and (7) to get the optimal artificial fish state within the current solution range.

(8) Update bulletin, and record the state of optimal artificial fish obtained in (7) into the bulletin.

(9) Update feedback probability according to formula (8).

(10) Judge condition to end the algorithm. If the maximum iteration times are met, end the algorithm and put in state of artificial fish in the bulletin, that is, the optimal featured sub-set. Otherwise, passed_iterate=passed_iterate+1 and turn to implement (6).

(11) Feature reduction based on the optimal feature subset of the training and test sets were obtained after reduction of the training set and test set.

(12) Send training set whose features are simplified to SVM for training, and establish product optimization model.

5. Empirical Research

Take refrigerator styling design as an instance to illustrate the concrete application of algorithm in this paper in product styling optimization design. Choose 50 from 100 representative samples as the training sets, and the rest 50 to verify the performance of system as training set. Use core function of the vector machine as BRF core function to test the standard.

(1) Select perceptual and representative samples of the target, and gather images of refrigerator samples through various ways: 4 perceptual characteristics "dynamic",

"luxury", "athletic" and "grand" in cases with "luxury" and "grand" as the target's perceptual characteristics.

(2) Quantize forms of refrigerator profile samples. Refrigerator shape characteristic line is the main component of the refrigerator modeling, but also on the characteristics of the original concept of the refrigerator and expression. The method of the top line is the expression of the whole shape and control the refrigerator the most informative feature lines, using 1-10 Critical Control Point to the top line and record the coordinate value of the quantization product form, shown in Figure 2.

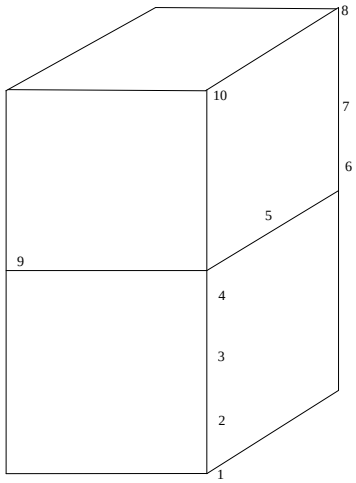

Figure 2. Refrigerator Profile Design

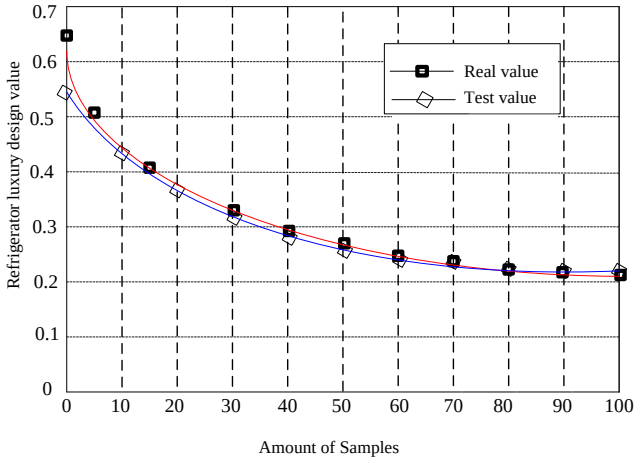

Figure 3. Refrigerator Luxury Design Value Comparison

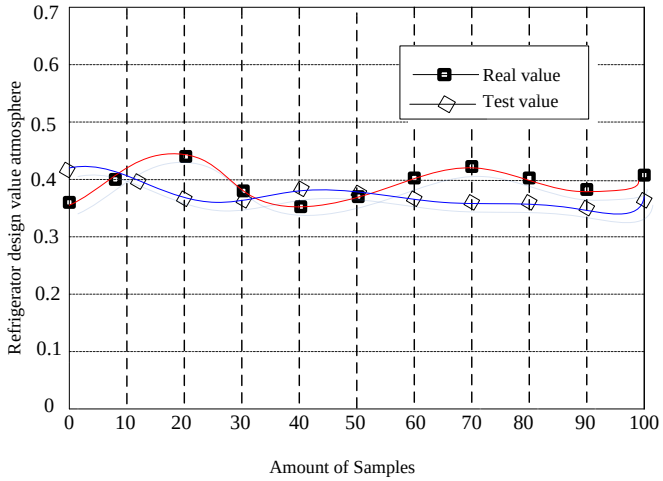

Figure 4. Refrigerator Design Value Comparison Atmosphere

It can be known from Figure 3 and Figure 4 that the prediction accuracy can reach 90%. Therefore, evaluation system of product styling design based on supporting vector machine has good performance, thus it can be applied to calculate fitness of subsequent optimization system.

6. Conclusion

Aiming at customers' demand for perceptual design of product modeling, this paper proposes method to optimize the design of product form based on supporting vector and artificial fish swarm algorithm, which is verifies by taking refrigerator profile optimization design as the instance. The results show that this method can be applied to the modeling design of relevant products.

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