Product Appearance Design and Concept Innovation Based on Neural Network

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Abstract. Design, in essence, is a process in which designers use their own design language to explicitly express the needs of users. It is the collision and coupling of design knowledge and user knowledge. Therefore, the study of design knowledge and the realization of knowledge-based COMPUTER-aided design is of positive significance for improving design quality and efficiency. This paper mainly studies the product appearance design and concept innovation based on neural network. In this paper, the comprehensive application of BP neural network and genetic algorithm in the optimization of product appearance modeling scheme to meet the needs of users is studied. Through MATLAB, a BPN model was built to realize the mapping relationship between the product appearance modeling knowledge and the overall image, and the optimized objective function was obtained by combining the image of user demand, thus improving the usability and reliability of product appearance design.

Keywords: Neural Network, Product Appearance, Appearance Design, Design Assistance

1. Introduction
Design innovation is one of the most important link in the product development process, outward appearance modelling innovation has undoubtedly become the main means of new products for users to take market, a new product in the function, principle, layout, shape, color, material, structure, man-machine operation any aspects, such as innovation, will directly affect the overall characteristics of the product, the final quality and market competitiveness [1]. However, there are certain risks in modeling innovation. The reason lies in the fact that the design process incorporates a large amount of personal experience and aesthetic discrimination of designers. If these subjective factors that determine the quality of products can be quantified and selectively reused, the risk of product development can be reduced. Modern product design and development is developing towards an integrated, intelligent and networked mode. An efficient product design system is bound to be an intelligent integrated system of man-machine integration. As an important part of product development process, product appearance design must also be integrated into this integrated system instead of going in an isolated development direction. In this paper, the method of using neural network, based on the existing case modeling, combined with some perceptual knowledge of designers
interaction, to produce a new product modeling scheme. If the designer is not satisfied with the scheme, he/she can manually modify some elements of the appearance characteristics and optimize them again, so as to cycle until the optimization results are satisfied.

At present, many scholars have studied the application of neural network in product design. Santos, the article introduces a kind of glass bottle on-line detection method based on image processing technology, the central idea of this method is to generate suitable for the structure of the object under test median filter, from the original image of the object being detection to estimate standard of "zero defect" image, the standard image compared with the original image, if the gap is bigger that detect defects [2]. Adeel put forward a kind of bearing fault detection based on one-dimensional convolutional neural network method, the feature extraction and classification of the bearing fault detection process, directly to the original data as input, eliminates each time classifying data analysis need to run a separate feature extraction algorithm, while maintaining the high accuracy of fault detection [3].

In this paper, through the front desk for image features of user demand, parameters, such as the background to establish case style knowledge base built neural network model, combined with the user's image needs to establish application in the fitness function, application of neural network global search most meet the demand of image modeling scheme, the final plan satisfaction evaluation on the 3d model.

2. Product Design Applied Neural Networks

2.1. Overview of Product Design

(1) Product Appearance Design Concept

In the epistemological sense, information is a description of the state of motion and the way in which the state changes. When the subject knows the object, it reveals "some" regularity through the information connection, and can apply it to the new situation without direct precedent to follow, which is knowledge. Therefore, knowledge is an abstract product obtained by processing and refining information. As far as knowledge subjects are concerned, product appearance design knowledge is the cognitive way, organizational form and classification structure of product modeling related information according to its internal connection, which can be applied to practical activities such as product planning, design and use [4]. It usually manifests itself in a certain form and is recognized and used in some form.

Product outward appearance modelling design is the designer according to the original like the product model in mind, using design knowledge under certain constraints, it will be for product form, function and structure and layout, color and texture information processing, such as product information was achieved by the combination of the visual symbol of explicit expression, the appearance of finished products, a process that can be used as a product of the encoding process. When users interact with products, based on their psychological model, product information is decoded through experience and current perception [5]. When these two processes are coupled to a certain extent, a complete information codec process is completed between the design and the user. Therefore, product appearance design is actually a process of matching design knowledge with user knowledge.

(2) Organization of Product Appearance Design Knowledge

Product appearance design is a modern design that focuses on product form and human-machine interface, mainly considering people's aesthetic, emotional and experience needs. The problem domain of product appearance design is a typical ill-conditioned structural domain, and the initial state (appearance design requirements), target state (appearance design results), and operation mode (rules or constraints) of the appearance design are not clear. Therefore, the problem of product appearance design needs to be solved through the professional knowledge and experience of designers, and the expert knowledge and experience in the field of product appearance design have greater fuzziness
compared with those in other fields [6]. The existing case product is the externalization of domain expert knowledge and experience and is the most appropriate form of knowledge expression.

Through the classification model of product appearance modeling knowledge, we know that the drawing, structure, connection relationship and use mode of the product will affect the appearance of the product. However, with the development of modern technology, the connection between components is almost seamless, and the connection relationship has little impact on the appearance. The product structure with the same function is basically the same, and no difference can be reflected in the appearance knowledge base.

Using knowledge representation model appearance style product outward appearance modeling design knowledge base, need to further study the model combined with the specific product class, such as how to select representative sample, representative vocabulary, how to screen how to determine the product geometric features, color features, texture features and the relative weight between various characteristics, etc.

2.2. Neural Network

(1) Artical Neural Networks

Artical Neural Networks, referred to as Neural Networks. It is the wisdom result of collective research by experts and scholars, and it has numerous characteristics. Therefore, the current definition of neural network is relatively appropriate and easy to understand: artificial neural network is a non-linear processing system with input layer, hidden layer and output layer formed by a large number of processing units interconnected [7]. Artificial neural network (Ann) is a mathematical model for processing information, which is inspired by the function of human or animal neural network. The mathematical model is similar to the application of human brain to recognize, remember, analyze data and conduct information processing. In the process of information processing, the input layer has different input xi, and for each input XI, there is an associated weight WI corresponding to it. The input enters the neural network from the input layer, passes through the stimulus of weight threshold and the action of weighted sum, and obtains the output yi of this layer under the perception of activation function, and continues the action of the next layer in this way, until the input is output from the output layer, and the error between the output value and the expected value is minimum. That is, it has three basic elements: connection weight, summation unit, activation function [8].

The sigmoID function is generally selected as the activation function:

\[ \phi(z) = \frac{1}{1+e^{-z}} \]  \hspace{1cm} (1)

Or the hyperbolic tangent function tanh:

\[ \phi(z) = \frac{e^z - e^{-z}}{e^z + e^{-z}} \]  \hspace{1cm} (2)

The reason why these two activation functions are selected in most cases is that the two functions are monotonically increasing in the given definition domain by observing the figure. The function increment is simple and clear, and some data with too large or too small jump can be changed into ordinary by sigmoID or TANH change.

(2) BP Neural Network

BP neural network, the full name of which is error back propagation neural network, is one of the most widely used artificial neural network models. It provides practical guidance for solving the learning and training problems of multi-layer neural network, and gives a comprehensive analysis and derivation in mathematics. The network structure of BP neural network is simple. There are three main layers, namely, input layer, hidden layer and output layer.

The BP neural network is vividly understood as the relationship of supervised learning between teacher and student. It consists of the forward propagation of the first stage signal and the back propagation of the error in the second stage. First, the forward propagation is as follows: the given signal first enters the network from the input layer, and then passes through the impetus of the hidden
layer to the output layer, and finally the signal is transmitted from the output layer. The first stage is completed. In the first stage, the weights of the network remain consistent throughout the transmission, and the state of the neurons in the latter layer is only controlled by the neurons in the upper layer. If the result transmitted from the output layer is far from the expected result, it will immediately turn into the second-stage error back-propagation learning process. The process in fact is to reduce the error of process and the actual output values and expectations of difference, the difference and as a new input signal from the output layer, layer to the first input layer back propagation, has been, until the end of expectations is closer to the actual output, the error is minimized, mainly in the process of back propagation, a fixed weights to get ideal results. Among them, the change of other factors also plays an auxiliary role [9-10].

The connection weight between the input layer and the hidden layer in BP neural network is:

\[ w_{ij}(i = 1,2,\ldots,u; j = 1,2,\ldots,M) \] (3)

The weight can also be called the weight vector, and the connection weight between the hidden layer and the output layer is:

\[ w_{kl}(k = 1,2,\ldots,L; j = 1,2,\ldots,u) \] (4)

The magnitude and direction of the two weights may be different. The improved BP neural network can be modified to make it develop towards the desired size.

3. Construction of BP Neural Network Evaluation Model

3.1. Model Construction

(1) Determine the number of BPN layers: Most common BPN layers set the parameters of the network in advance, and the number of hidden layers of BP network can also be determined by the user according to the specific situation. The number of hidden layers can be 1, 2, or more. In the design of this paper, 1 hidden layer is selected.

(2) Determine the number of neurons in the input layer: The input layer is the external interface of BP network to receive external data, and the number of nodes depends on the dimension of the input vector. In this paper, Metadata of appearance feature elements is taken as the input vector, and the dimension of each feature element vector is different. Considering that some elements have little influence on the appearance of the case, in order to ensure the effective number of nodes in the input layer, elements with small weight are omitted here.

(3) Input samples: According to the corresponding class center distance of each product in the analysis result, select a number of products from each category as the input samples of BPN, extract the data of these samples in the knowledge base, and get the input sample parameters according to the coding principle.

(4) Determine the number of neurons and output samples in the output layer: The number of nodes in the output layer depends on the output data type and the size of the data type.

(5) To determine the number of neurons in the hidden layer: The number of nodes in the hidden layer is determined based on previous design experience and continuous experiments of observing data convergence in the training network. Too many nodes affect the computing speed, too few nodes reduce fault tolerance, and the recognition and learning ability becomes worse.

(6) Determine the transmission function: NewFF function is used to create forward BPN; hyperbolic tangential function (Tansig) is used for the hidden layer and linear transfer function (Purelin) is used for the output layer.

3.2. Model Training

Combined with the above setting of BPN model, the expected network error was set as goal=0.005, and MATLAB software was used for training. When the given error is reached in BP network model
4. BP Neural Network Evaluation Model

4.1. Fitness Variation

As shown in Figure 1, the fitness value changes during the optimization process of BP neural network algorithm, it can be seen that the objective function value of the population in the first 50 generations drops sharply and approaches the minimum value. Then, with the increase of iteration times, the fitness value tends to be stable until the minimum value under this algorithm is found.

4.2. Evaluation of BP Neural Network Model

In this paper, the satisfaction degree of the new product model is evaluated. The evaluation index is the 7 elements affected by deformation value in the appearance characteristics of the case. The quantitative standard of 5-level scale method is adopted, 0-1 is very poor. 1-2 is poor; 2-3 is general; 3-4 is better; 4 minus 5 is good.

(1) Overall Appearance

| Test set | Envisage | Side-looking | Looking down |
|----------|----------|--------------|--------------|
| Test set 1 | 4.58     | 3.92         | 4.03         |
| Test set 2 | 4.35     | 4.12         | 3.87         |
| Test set 3 | 3.91     | 3.38         | 3.76         |

As shown in Table 1, BP neural network model is applied in this paper to evaluate the appearance design of three product test sets. In the first test, the elevation evaluation was 4.58, the lateral evaluation was 3.92, and the vertical evaluation was 4.03. In the second product test, the evaluation of centralized elevation was 4.35, the evaluation of lateral elevation was 4.12, and the evaluation of vertical elevation was 3.87. The third product was evaluated as 3.91 in the vertical, 3.38 in the lateral, and 3.76 in the vertical.

(2) Product Details
Table 2. Detailed evaluation of the solution model

| Test set | Color | Line into the cardboard | Draw the cardboard line | Line of outlet |
|----------|-------|--------------------------|-------------------------|--------------|
| Test set 1 | 3.82  | 3.25                     | 3.64                    | 4.24         |
| Test set 2 | 3.96  | 3.69                     | 3.86                    | 3.83         |
| Test set 3 | 4.07  | 3.71                     | 4.17                    | 4.03         |

Figure 2. Detailed evaluation of the solution model

As shown in Table 2 and Figure 2, in terms of detail design, the highest score of color in the test set of the three schemes is 4.07 points in test set 3. The highest score of incoming cardboard is 3.71 points in test set 3. The highest score at the outlet was 4.24 on test set 1. Overall design and detail design of the appearance of the product, the highest score is plan 2, with a score of 3.95, which has reached a relatively good level.

This chapter in case knowledge base system based on the appearance, the advantages of integrated neural network (BPN) model case modeling innovative design system is established, in detail elaborated the system logic functions and the build process, and allow the designer according to the actual need of optimization further modify, until the user requirements and aesthetic experience of the optimal balance.

5. Conclusions

This paper mainly studies the product modeling innovation design method and implementation technology based on the case design knowledge, which is a research work integrating computer application, artificial intelligence, design psychology and other disciplines. This paper integrates modern design methods such as cluster analysis, neural network, genetic algorithm and digital technology, and explores a product modeling innovation method based on case design. This paper established case knowledge product outward appearance modelling characteristic elements and overall appearance image between the BPN model, combines the simulation output and user demand matrix, the construction of product shape optimization of objective function, combined with actual situation allows designers to modify part of the best individual genes, improve the reliability and validity of the design process.

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