Machine Vision Prediction Model for Product Color Design by Kansei Engineering

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Abstract: Color is a visual element of people, it can bring people different levels, different feelings, and can make people have associations and emotional resonance. Under the background of Kansei engineering, product color design is an important research field. This paper aims to discuss the predictive model of Kansei engineering in product color design, in order to improve the quality of products and meet the needs of consumers. Through empirical research and user survey, this paper verifies the accuracy and effectiveness of product color perceptual image generated by machine vision prediction model for the elderly products. The survey and experimental results show that support vector machines perform best, with an accuracy of 91% and a recall rate 4% higher than BP neural networks.

Keywords: Color Design, Kansei Engineering, Machine Vision, Prediction Model

1. Introduction

Industrial design is constantly evolving, and product colors are becoming more and more diverse. Color is an indispensable substance in people's lives, which can not only bring visual enjoyment to people, but also bring people a sense of pleasure. Kansei engineering is a method of evaluating the appearance and function of a product through human-computer interaction. It uses knowledge from disciplines such as psychology, behavior, and computer science to better understand user needs and preferences to optimize product design.

In the field of machine vision, color prediction model has been the focus of research. At present, a variety of color prediction models have been developed. Some people believe that neural network model can effectively process nonlinear and non-stationary data by simulating the connection of human brain neurons, so as to realize the recognition and prediction of complex color patterns [1-2]. In addition, it has been proposed that deep learning models have also been widely used in color prediction, such as convolutional neural network model and recurrent neural network model [3-4]. In addition to neural network models and deep learning models, there are several other models used for color prediction. For example, it has also been suggested that support vector machine models can perform classification and regression analysis of data to achieve color prediction [5-6]. In this paper, the color design and Kansei

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engineering of products are studied, and the prediction model of machine vision is explored experimentally.

Firstly, the basic concept and background of Kansei engineering are introduced. Next, the predictive model of Kansei engineering in product color design is introduced in detail, which is based on the principles of psychology and behavior. Through questionnaire survey and data analysis, users' feelings and preferences on product color are evaluated. This paper uses a variety of color preference test methods, including color attraction test, color emotion test and color cognition test. These test methods provide a better understanding of the user's feelings and preferences for product color. Finally, the main conclusions of this paper are summarized.

2. Product Color Kansei Engineering

2.1 Color Image

Color refers to the visual properties perceived by the human eye in the visible spectrum, including color, brightness and saturation. Color space is a mathematical model used to represent and describe colors. Color vision is the human eye's ability to perceive and recognize colors, which involves the relevant knowledge of visual physiology and psychology [7-8]. Color characteristics refer to various attributes and characteristics of color, such as hue, brightness, saturation, contrast, and so on.

Color imagery refers to the subjective emotions associated with specific colors, such as emotions, images, and symbols [9-10]. Color emotion refers to the influence of mood, atmosphere and personality conveyed in a product or environment [11-12]. Color perception is about making the shape and overall design of a product better fit to the emotional needs and expectations of the target group through the correct selection and matching of colors. In emotional product design, the theory of color kansei engineering is combined with related fields of product design such as automobile, home, and clothing to enhance the emotional appeal and user experience of products. Color matching mainly includes the same type of color, adjacent color, contrasting color, complementary color matching. 12 color phase ring is shown in Figure 1.

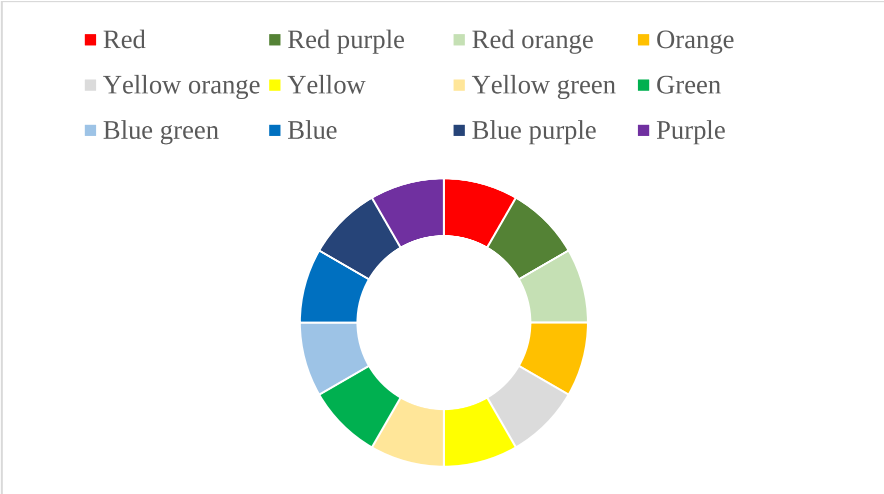

Fig 1. 12 Color phase ring

Perceptual image model is the basic framework for building product color design. It determines the perceptual characteristics of product color by collecting users' perceptual needs and expectations, analyzing and modeling them [13-14]. The selection of perceptual image is to select the most representative image from many possible perceptual images and meet the needs of users as the basis for product color design.

2.2 Kansei Engineering

As a method and theory of product development, Kansei Engineering takes the impression, feeling or demand of consumers on products as the design orientation, and transforms the description of such mental images into design elements [15-16]. Its purpose is to break the previous design concept of paying more attention to product function and form, and strive to improve the attention of users or consumers' intentions and needs in the process of design and development of products. The model system constructed by mathematical research method can get the human factor result from the perceptual statement in the system.

The process is as follows: Based on the relevant theories of human factors engineering and psychology, it measures the impression, feeling and demand of potential users or consumers on products [17-18]. After the measurement test, the description of the perceptual meaning of the product by potential users is obtained, and then the design elements affecting the perceptual intention of consumers are identified by further investigation, statistics, analysis or experiments. Computer-aided analysis modeling methods, such as rough set analysis, linear regression, fuzzy mathematics, neural networks, etc., are used to build research and application models of man-machine systems and Kansei engineering [19-20].

Principal component analysis simplifies and analyzes the data set, so that a small part of the components can represent the majority of the data. It is a method often applied simultaneously in Kansei engineering method research. K-Means clustering analysis determines the category and calculates the Euclidean distance calculation of vector distance:

$$\mathrm{dist}(\mathrm{a}_{\mathrm{i}}, a_k) = \|\mathrm{a}_{\mathrm{i}} - a_k\|_2 = \sqrt{\sum_{v=1}^{m} |\mathrm{a}_{\mathrm{iv}} - a_{kv}|^2} \tag{1}$$

a_{i} is the horizontal coordinate of the vector coordinate system. a_{k} is the vector coordinate ordinate. This paper mainly uses this method to classify the color image words of target products to find the images that meet the product selection criteria. The semantic difference method allows the quantitative scale of semantics to be used as the measurement standard for analysis. In this article, the filter evaluator must use the color-coded value output by the generator as input and the corresponding seventh-order image value as output. In this case, a classification model and a linear regression model can be applied.

2.3 Product Color Design

In order to enable the intelligent color design system of products to creatively generate solutions according to the color design law of target products, a method of product color intelligent design using generative adversarial network is proposed in this paper. The color design examples include not only color design learning examples required to build a generator, but also evaluation examples for filtering the relationship between design requirements and color schemes. According to the concept of color coding, it is also necessary to understand the geometric structure and conversion method of color space. The goal is to establish a mapping between the geometric position of the color code in the color space and the requirements of the filter evaluator. By learning the main color design laws of products, the model is trained to improve the performance of discriminators and generators in the network, so as to build a generator that generates color design schemes with almost the same color design laws. Using the Back Propagation (BP) model, a reversible mapping relationship between color coding and perceptual engineering filtering requirements is constructed to filter the color design schemes generated by the generator. The output of the trained generator network model with stable weights is connected to the input of the filter evaluator network model to form a color design execution system. Random numbers are used on the input side of the intelligent color design system, and color design schemes are generated and filtered on the output side.

An error feedback algorithm can be used to create an image evaluation model. The filter evaluator constructed by adversarial network generator and BP neural network is two independent entities. For any product C, C^X is used in the product color design process to represent the existing set of excellent solutions:

$$C^X = \{C_{\mathrm{i}}^X\}, i = 1,2,\ldots,n \tag{2}$$

The scheme is generated by the color design law of the existing product color scheme C^X to form a new generation scheme set:

$$Q^X = \{Q_k^X\}, k = 1,2,...,n \quad (3)$$

The number of samples generated by the generator is large, and the generated color design files are random. In the process of demand selection and screening, the combination of discrete points in color space and the mapping of image demand are selected.

3. Machine Vision Prediction Model

3.1 Construction of Machine Vision System

The image processing system consists of a computer, a charge-coupled industrial camera, a light-emitting diode light source and a camera obscura. The box design reduces the influence of ambient light on the experimental environment, reduces noise and improves image quality. For a clearer image, a black background card was selected. The first and most important aspect of feature extraction is the method of describing the feature. A texture feature is a form of existence that determines the unique properties of a transaction. Choosing the right analysis method is particularly important for extracting features. In image processing, the properties of an image refer to the spatial distribution of pixels. There are two common methods to describe features: one is the analysis method based on pixel statistics, which is used to calculate the physical frequency and spatial components of pixel values to extract features. The other method is based on Fourier spectrum extraction, because the first method is the simplest and most efficient, and the algorithm is not too complicated. According to the current research experience, the first method is the most commonly used.

In order to process local feature images, the image is first segmented to calculate the properties of each block. Finally, an interpolation operation is performed on each split region to restore the image to preserve the original image. Quadratic neighbor interpolation has the lowest computational complexity, but is often less efficient. Interpolation produces low-quality images and produces Mosaic effects that seriously affect image quality. Three-layer interpolation is achieved by weighting 16 adjacent pixels with high continuity and the highest image quality. However, the computational complexity of this method is too large, which seriously affects the computational speed. Therefore, bilinear interpolation is chosen in this paper.

3.2 Prediction Model Design

To design a predictive machine vision model of product color, it can perform the following steps: Collect a large number of product images with color labels as a training dataset. These images must contain different types of products, covering different colors and their variations. Data preprocessing includes image enhancement, resizing, and color standardization. This can improve the model's ability to extract features from images and reduce redundant information. Convolutional neural networks are used as feature extractors to convert input images into high-dimensional feature vectors. By refining the preformed convolutional network model, the color features of products can be better captured. A feature vector is entered into the classifier to predict the color of the product in the image. Classifiers can be trained using methods that support deep learning models such as vector machines, random forests, and multi-layer sensors. The model was evaluated using a test dataset containing evaluation metrics such as classification accuracy and recall rates. According to the analysis results, the model can be optimized, the model hyperparameters can be adjusted, and the data samples can be increased. The trained model is deployed to the production process for machine vision prediction of product color. It is integrated with other systems through application program interface to realize real-time processing of product image output results. By using the image processing method with product color perceptual image and color data, the matching product color perceptual image is predicted and generated.

3.3 Social Cognitive Assessment Methods

The distribution of questionnaires is mainly carried out in person, by mail and online, with personal distribution being the most effective method. Compared with mailing, this method is relatively easy to fill in, but the scale of respondents is small, and the efficiency of questionnaire filling is relatively low. The advantage of online distribution is that it is easy to collect quantities. This paper mainly combines two methods of face-to-face and online delivery, which effectively meets the requirements of large sample size and high quality. Invalid questionnaires were excluded from the collection, especially those with logical answers to upper and lower questions, those with incomplete answers and those with multiple choice questions. Data collection, statistics and questionnaire analysis use a combination of qualitative and quantitative methods to understand the positioning of the problem. Quantitative questionnaire analysis mainly includes simple analysis of mean value, percentage, frequency, etc. This paper is mainly concerned with the cognitive research of old products. To this end, 15 questions were put forward, among which 6 questions from the questionnaire were collected, analyzed and quantitatively compared to reflect the degree of awareness. A total of 200 questionnaires were collected, 187 of which were valid. The details are shown in Table 1:

Table 1. Relevant Identification for the Questionnaire Analysis

Problem	Question serial number
What are the types of elderly products we know about	Q1
Why purchase elderly products	Q2
Number of elderly products owned	Q3
Are you satisfied with elderly products	Q4
Familiarity with elderly products	Q5
What needs design attention	Q6

The contents of the questionnaire were identified, and then the statistical data results were analyzed. The following results were obtained:

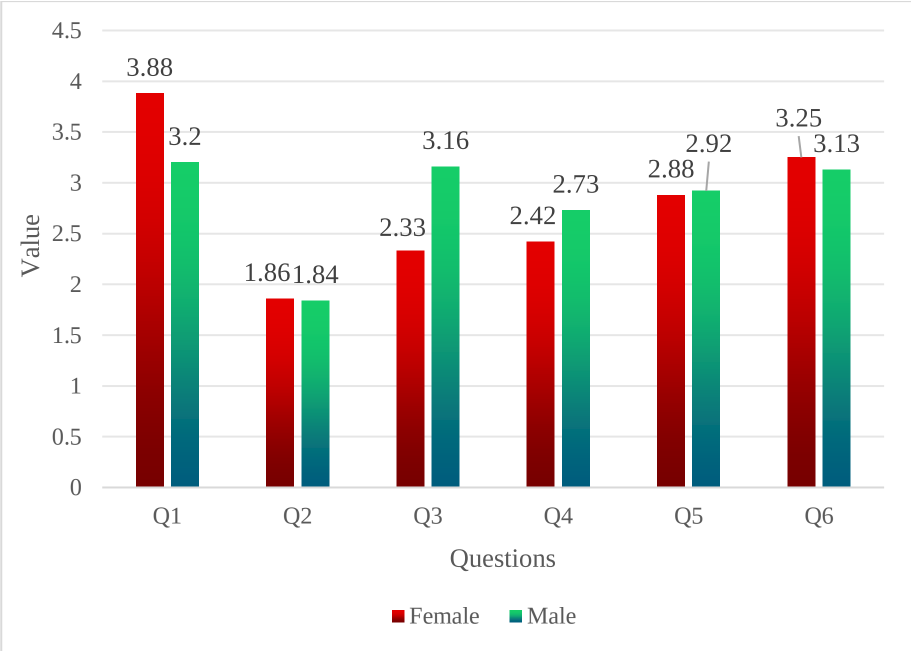

Fig 2. Gender differences in product perception of older adults

As shown in Figure 2, women have higher scores than men in understanding the types of products for the elderly, and women know more types of products for the elderly than men. However, in terms of the number of possessions, men buy more age-specific products than women. In terms of satisfaction, men's satisfaction with the use experience of elderly products is higher than that of women's, indicating that products suitable for women in elderly products have more serious problems and need more design attention.

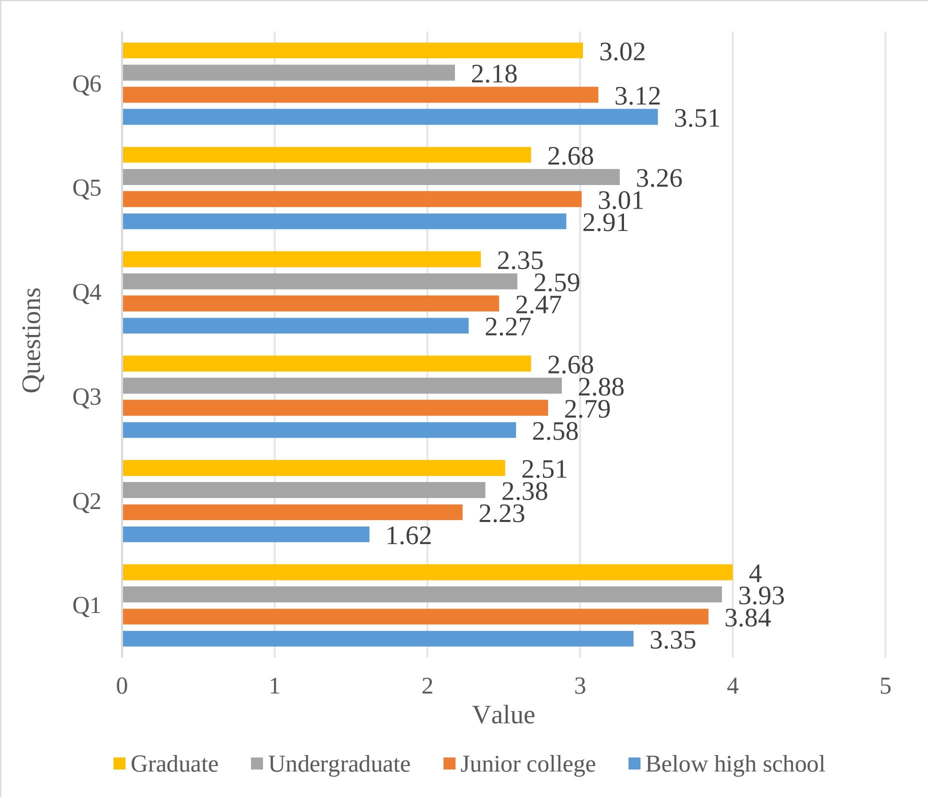

Fig 3. Comparison of educational level and elderly product cognition

As shown in Figure 3, the higher the education level, the higher the social cognition level of the elderly products. Graduate students had the highest scores in Q1 and Q2 and the lowest scores in Q5. At the three cultural levels - undergraduate, junior college and senior high school - the social cognition of products for the elderly increases with the improvement of knowledge level. However, graduate students and above do not reflect a common pattern, and the age limits of the graduate population affect the values of relevant cognitive levels.

3.4 Prediction Results

In this paper, the following machine vision related algorithms are used to analyze the prediction model. Firstly, BP neural network algorithm is used to identify and predict the color of the product. Deep learning is then used to make color predictions. After that, the random forest method was used to extract and predict the color features. Finally, support vector machine is used to classify the product color data and get the prediction results.

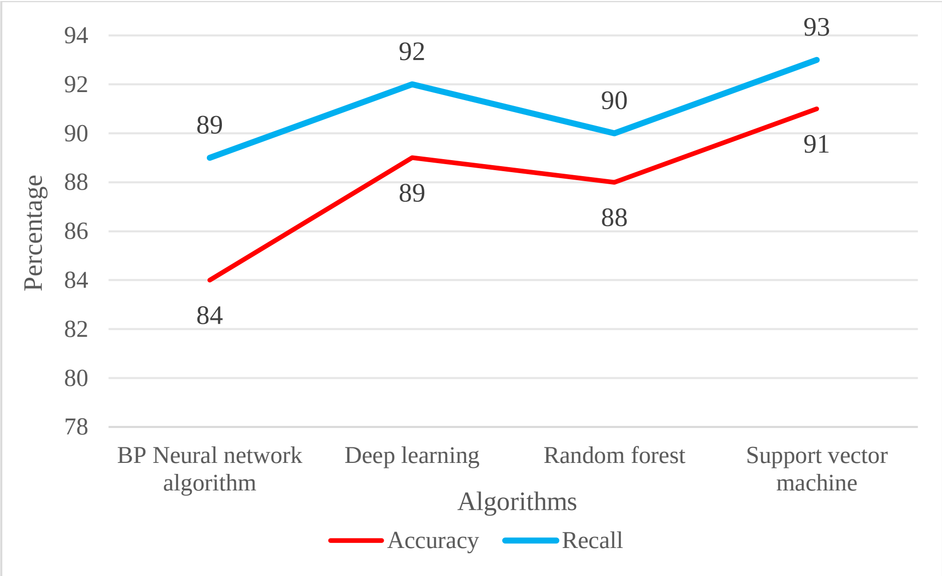

Fig 4. Predicted results analysis

As shown in Figure 4, the performance of BP neural network algorithm in machine vision prediction model is average, with the lowest accuracy and recall rate, only 84% and 89%. The performance of deep learning improved, compared to BP neural network algorithm accuracy increased by 5%, recall rate changed little, improved by 3%. Although random forest models can integrate learning on large amounts of data, so as to obtain better predictive performance. In this predictive model, the performance is mediocre. The random forest algorithm is only 4% more accurate than the BP neural network, and the recall rate is 90%. Both accuracy and recall rate of support vector machine are the highest among the four. By using support vector machine to analyze product color by logistic regression, the binary classification problem can be modeled and the classification prediction can be realized.

4. Discussion of Product Color Design and Prediction Model

This paper investigates a product prediction model that combines color with product design to enhance the visual appeal, user experience, and emotional response of a product. It is based on the impact of color on human emotions and consciousness, choosing and applying the right colors to convey specific emotions and information in product design. In the design of color kansei engineering, it is mainly to analyze and improve the color, graphics and shape of the product. A variety of materials can be used through different colors, so that the product can meet the visual and tactile needs of consumers, which can make people feel comfortable. Color is analyzed through machine vision, and then combined with functional products, so as to achieve the personalized characteristics of the product.

When choosing a color, it can choose the right color based on the product positioning, brand and target group. The choice of color should be in line with the product's function and target market, while taking into account the user's personal preferences and cultural background. Color combinations are very important in product design. Reasonable colors can enhance the overall beauty and visual effect of the product, creating a visual effect that matches the product image and brand. Colors can be applied to product design, interface design, and other aspects to create a specific atmosphere and user experience. Product colors can stimulate users' emotional responses, triggering their preferences, interests, and emotional experiences. By using the right colors, users can feel the emotion and value of the product, enhancing their understanding and emotional connection to the product.

Machine vision pre-models are predictive models based on machine learning and computer vision techniques used to analyze and predict specific information or events in image data. It learns large amounts of training data, extracts image features, and creates mathematical models for prediction and classification. This paper uses a machine vision predictive model to analyze a large number of user images and visual data to understand user preferences and emotional responses to different colors. This can provide product designers with data support about user preferences and market trends, and guide them to make smarter color choices and combinations in product design. In addition, machine vision predictive models can also be used to simulate and optimize product designs. By simulating and predicting different colors and design schemes, evaluating their visual effects and user reactions, it helps product designers choose the most attractive and emotionally appealing scheme in the early stages of design.

5. Conclusions

In everyday life, the effect of color on the senses is very important. The application of color in product design is not only a decoration, it can also cause the emotional response of users and enhance the attractiveness of the product. As a new interdisciplinary discipline, Kansei engineering aims to evaluate product design through users' subjective feelings. As one of the core technologies of Kansei engineering, machine vision plays a crucial role in product color design and evaluation. This paper explores the application of different algorithm models in product color prediction for the elderly. Experimental data show that the performance of SVM can predict color matching more accurately. Color kansei engineering design would have a great deal of development in the coming days.

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