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Color Harmony Algorithm in Computer Aided Industrial Design

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Abstract. Computers provide accurate and scientific descriptions of colors, but they cannot judge the perception of colors. If design tools can assist designers in expressing their emotional intentions, industrial design will be a great improvement. This paper takes industrial product design as the application object, designs and implements color semantic eye tracking experiments, obtains visual behavior data generated by color stimulation and semantic cognition, and combines rough set theory, information expression system, membership degree calculation. The data are processed to complete the quantification of the color semantics, and the mapping relationship between the three color attributes and the semantic value is established based on the artificial neural network, and the color harmony algorithm is optimized. Finally, use the above methods to develop auxiliary color design tools, and use auxiliary tools to carry out the color design of industrial products. The semantic value input in this method is compared with the results of the questionnaire survey to verify that the auxiliary color design scheme is reasonable and effective. Through the research of this article, the optimization method of color harmony algorithm is proposed, and the auxiliary design method that meets the color design characteristics of industrial products is provided, and the reliable color design reference is provided for users.

Keywords: Computer aided; industrial design; color harmony; algorithm optimization
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1 INTRODUCTION

Color plays a very important role in design activities. It is a bridge for humans to judge the state, emotion and feeling of things in addition to form and size. The color design process is a very complex and profound process. In the process, the divergence and convergence of thinking are in a state of constant alternation and integration, and there is no fixed law to follow [1]. At present, in the construction and evaluation of computer color design models carried out by researchers, the most used methods are gray theory, neural networks, genetic algorithms, and gray correlation analysis methods. Model optimization methods include bee colony optimization algorithms and hybrid intelligent methods. On the basis of theory, different types of color design auxiliary systems have been gradually developed [2]. The application principle of the current color design auxiliary system is more based on the color digital model to select colors and color matching based on the theory of harmony.

The use of computer-aided color design for various creative activities in the field of color design has become an inevitable trend in the development of color design [3]. Ding et al. [4] had conducted a wide range of theories and applications in color measurement science, image appearance and quality, spectral color reproduction, visual color coding, and color science of cultural heritage since its establishment in the year. Jhamb et al. [5] have studied the color group selection problem in the computer interface for the lack of color selection tools and blending tools with various existing software systems. Zhang [6] combined artificial neural network and expert system to establish a computer-aided paint color matching system with neural network as the core, and discussed the design idea, theoretical basis and system basics of paint color matching expert system for color design in industrial design structure. O'Kane [7] conducted research on knowledge representation, knowledge acquisition strategy, color matching reasoning mechanism, color scheme evaluation model and color emotional effect quantification of electromechanical product color design, and introduces expert system technology in the field of artificial intelligence into the field of electromechanical product color design. An expert system for color design of electromechanical products.

In order to improve the efficiency and quality of the color-assisted design process, by analyzing the color design thinking process, a color design cognitive process model is constructed to provide a reference for simulating the color design thinking process. From the aesthetic point of view, product color design should be harmonious, aesthetic, and in line with human aesthetics; the carrier on which the color is attached can be perfectly integrated with the external environment and meet the color preference of the target user. When designing product color, designers often need to continuously make multiple color matching attempts and compare color schemes to obtain the best color matching effect [8]. Therefore, it is extremely necessary to use computer technology to assist the designer to complete the color design and improve the designer's efficiency. This article provides a color design assistance system for professional designers and even those who do not have good professional quality or color design quality, which can effectively improve design efficiency and quality, so that products can more closely meet the expectations of target users and have a strong market share.

2 RESEARCH METHODS OF COLOR RECONCILIATION ALGORITHM

2.1 Color Harmony Algorithm Factor Selection

Building a color design model based on basic color knowledge. As showed in Figure 1, this is a parallel model structure, and the behavior of "analyzing graphics" is accompanied by the entire color design process. After understanding the design requirements, the designer first analyzes the design object that is about to be color-designed, and then determines the number of colors of the conceptual color scheme. After selecting the coloring area. Directly select the corresponding color in the color editor to fill the area. In this process, designers rely on their own basic knowledge of color to directly select colors in the color editor, and adjust and modify unsatisfactory colors and color relationships after evaluation.

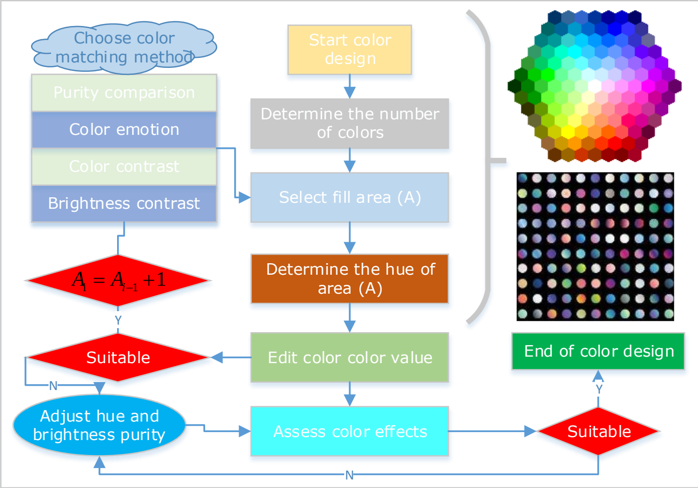

Figure 1: Color design process.

Park et al. [9] studied the construction of color design models based on color harmony theory. The color design process model based on color harmony theory is also a parallel structure model. After analyzing the target graphics, the designer determines the number of colors in the color scheme, then determines the main color, selects the color area to fill the main color, according to the main color and graphics. To select the color harmony law, determine the color of other areas by controlling the main color and adjust the color relationship by using the color harmony law. The design process is shown in Figure 2.

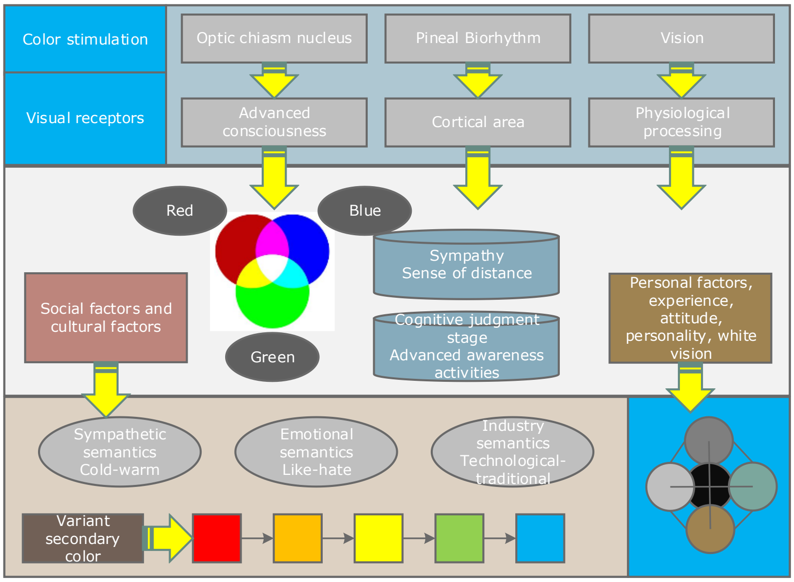

Figure 2: Color design process model.

After receiving the color stimulus, the first physical processing is carried out. Under the comprehensive effect of psychology, behavior, emotion and judgment, color images are produced, including psychological activities such as feelings, associations, and symbols, and then under the influence of the same social and cultural factors next, form a unified color semantics and describe colors. By establishing a color semantic mapping model, it is possible to clarify the origin and classification of color semantics, clarify the relationship between color and semantics, and provide a theoretical basis for selecting color semantics as the research object.

For a better understanding, the color semantic collection can be expressed in the form of a two-dimensional table. The rows of the table are semantic information and the columns are color objects; each row contains the semantic description expression of the color, and there is one for each color and its semantics. Value as its description, here chooses HSB color model as the color three attribute values, as showed in Table 1.

Color object(S)	H Attributes	S Attributes	B Attributes	Security semantics	Temperature semantics	Shrink semantics
Red	0	120	120	Danger	Warm	Swell
Yellow	12	120	120	Danger	Warmer	More expansive

Table 1: Two-dimensional table form of color semantic set S.

2.2 Research on Realization of Color Reconciliation Algorithm

Each color object belongs to a certain semantic fuzzy interval, and the color objects in the same fuzzy semantic interval have the same semantic level. This is the need to introduce the concept of color semantic membership, and analysis that each color object pair is located in the fuzzy interval semantics. The degree of membership of semantic words at both ends. Definition 2G=U_a=G_{aa} is the set of membership degrees of the color object to the semantics of the level a, and A represents the set of each level of color semantics. From the semantic level of division, we can see that A = {1.0, 0.50, 0.0, -0.50, -1.0}. From the analysis of each experimental index, it can be seen that G is determined by the gate time. The longer the gaze of the color object, the higher the degree of membership with related semantic words. The calculation formula for the degree of membership is shown in formula (1).

$$G_{\mathrm{ij}} = K_{ij} / K_{j_{\max}} + \beta * K_{\mathrm{i}\max} \qquad (1)$$

There is no ambiguity in the mapping relationship between the color of a specific product and the semantics of each color, that is, when the color belongs to a certain semantic fuzzy interval, it will not belong to another semantic fuzzy interval. Determine the upper and lower semantic values, calculate the semantic value of the color object of M_i in the semantic fuzzy interval, and the calculation formula of the semantic value is shown in formula (2).

$$M_{ik} = H_{j+1} + H_j - 0.5 * \alpha * (N_{ij+1} - N_{ij}) / 2, 0 < \alpha \leq 1 \qquad (2)$$

Saturation F is the ratio of the difference between the color light H_M with the most content and the color light H_m with the least content in the mixed color light to H_m, and its value range is 0-100%. The mathematical expression is:

$$F = \frac{H_M - H_m}{H_M} * 100\% + \sum_{\mathrm{m}=0}^{M} \frac{H_m}{H_M} \qquad (3)$$

Set the two colors to be blended at the endpoint color, one as the starting color and the other as the ending color, named R_{first} and R_{last} respectively. Let R_{first} be the R component of the starting color of the color mixing, Rend the R component of the ending color, and H_{nm} the number of mixed colors. In the RGB color mode, the variation range of the three color components R, G, and B is all [0, 255]. Then the calculation formula of the red component R_k of the mixed color F_i is:

$$R_k = R_{first} + \alpha * \beta * (k-1) * (\frac{R_{last} - R_{first}}{H_{nm} - 1}), 0 < \alpha, \beta \leq 1 \quad (4)$$

Suppose two endpoint colors are S_{first} and S_{last} respectively, S_{first} is the S component of the color of the starting point of the color mixing, S_{last} is the S component of the ending color, and Num is the number of mixed colors. In the HSV color space, the variation range of H is [0, 360], and the variation range of S and V is [0, 100].

$$\begin{cases} S_k = \mu * S_{first} + \lambda * (k-1) * (\frac{S_{last} - S_{first}}{H_{nm} - 1}), S_{last} \geq S_{first} \\ S_k = \mu * S_{first} + \lambda * (k-1) * (\frac{(255 - S_{first}) + S_{last}}{H_{nm} - 1}), S_{last} < S_{first} \end{cases} \quad (5)$$

2.3 Color Harmony Algorithm Analysis Method

From the results of multi-dimensional scale analysis, it is more appropriate to divide image adjectives into six dimensions. At this time, Stress (stress coefficient) is 0.03142, and RSQ (coefficient of determination) is 0.97568. These two indicators are data fitting indexes after multi-dimensional scale analysis. According to these two values, the best configuration of distance can be measured. RSQ represents the percentage of the variance of the actual data explained by the Euclidean distance model. The larger the value, the greater the dimensionality reduction effect. Stress is a dimensionless number that measure the degree of closeness to the target. The smaller the value, the closer to the target [10]. Guidelines for using stress coefficient values provided by Kruskal show that when Stress < 2.51%, the fitting effect is excellent, and when Stress <5%, the fitting effect is good. Therefore, when the image adjectives are divided into 6 dimensions, the fit is good and the most appropriate. The goodness of fit of each dimension is shown in Table 2.

Dimension	Stress	RSQ
1	0.14976	0.86645
2	0.06152	0.96714
3	0.04872	0.95916
4	0.03917	0.98514
5	0.03391	0.98792
6	0.31248	0.99264

Table 2: Goodness of fit after data processing.

3 ANALYSIS OF RESEARCH RESULTS OF COLOR RECONCILIATION ALGORITHM

3.1 Color Harmony Case Analysis

Figure 3 shows the average and standard deviation of the perceptual evaluation of 10 color samples for six images. The standard deviation value refers to the degree of dispersion of the opinions of the participants in the experiment. The smaller the standard deviation, the smaller the difference in the evaluation values given by the participants in the evaluation of the color matching sample, and the more consistent feelings of the sample; Conversely, the larger the standard deviation, the more inconsistent the subject’s perception of the sample. The number of samples with a standard deviation of more than 1 in the "modern-classical" imagery evaluation value is 12, accounting for 59.6% of the total sample, indicating that the participants have a large difference in the evaluation of this imagery word. The number of samples with a standard deviation of more than 1 in the "warm-cold" imagery evaluation value is 3, accounting for 7.51% of the total sample, which shows that the subjects feel more consistent with this image pair.

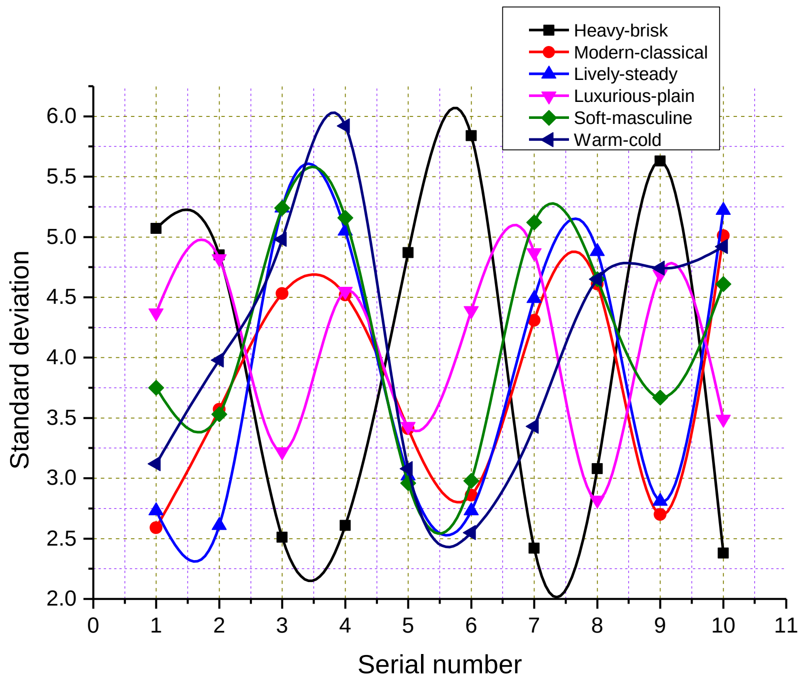

Figure 3: Evaluation of color matching examples.

From the statistical results of the corresponding relationship between the image and the color attribute, the overall image of the achromatic collocation is cold and simple, and tends to be modern. The main color of white or light gray color matching gives people a soft and light feeling. This is because high-brightness white had a particularly large impact in color matching. The combination of white and light gray with high-brightness and low-purity colors looks simple and warm, and if matched with high-purity colors, the whole product will look dynamic and lively. Large areas of black or dark to give a sense of stability, masculinity, and maturity, and the combination of high-purity and high-brightness warm colors will make the whole product more luxurious and classic. The image perception of the matching between colors is much more complicated. The high-brightness main color determines the first feeling of the person, it will give people a brisk feeling, and similar colors will tend to be soft. Obtain RGB value information of the product color from Photoshop, open the system color image evaluation interface, and enter the product type and the RGB value of the main and auxiliary colors. After the system intelligently calculates, the output image evaluation value results are visualized, as showed in Figure 4.

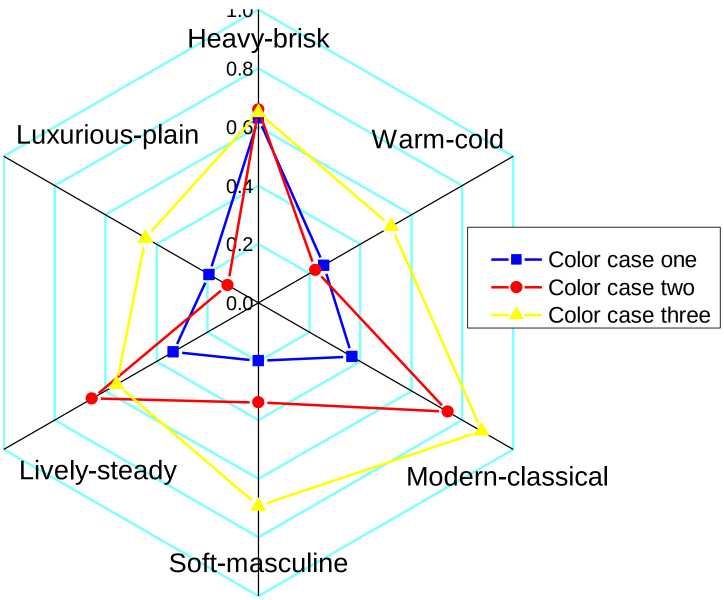

Figure 4: Multi-dimensional scale evaluation results.

3.2 Cognitive Analysis of Color Harmony Algorithm

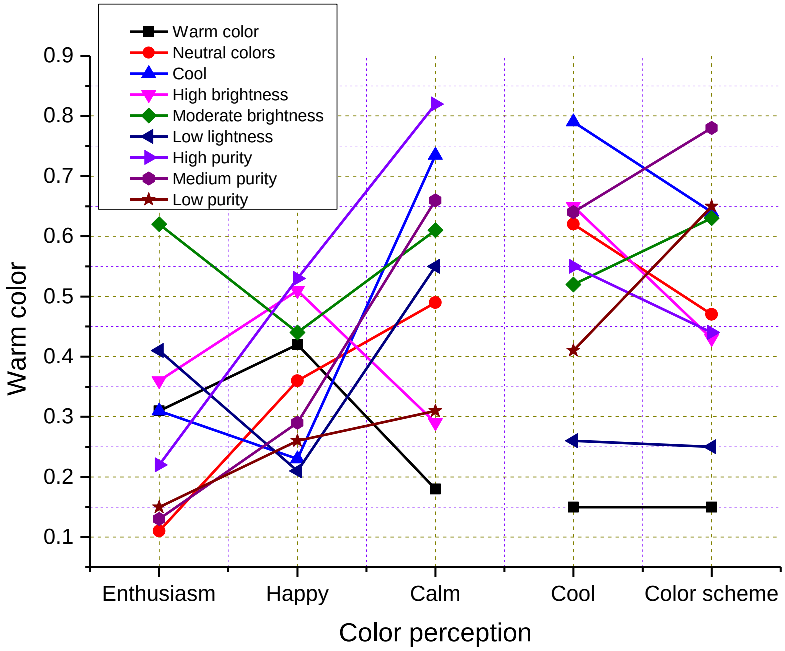

Figure 5: Color index analysis.

Obtain a clearer design direction through design experience or search for relevant information. In this stage, the development of strategy formulation is aimed at observing how the subjects deal with different problems, formulating related solutions, and exploring how the subject's search for stimuli to inspire inspiration. Through the observation of the experimental process and the identification and analysis of the steps, three color design strategies are obtained. The designer's allocation strategy for his own existing knowledge resources, that is, the designer's knowledge called for different design problems during the design process for Reserve strategy. Process control strategy, that is, use existing design methods to guide the design and the allocation of design time. Strategy for the use and allocation of external resources, that is, after the designer searches for a mature design plan, combining the design purpose, the strategy of identifying and extracting the features of mature color schemes and applying them to the design. No strategy is perfect. In the design process, various strategies are used alternately in parallel and are inseparable from each other. This stage is the most active stage of thinking activities. To determine which color impression the color scheme belongs to is "enthusiasm, pleasure, calm, and cool", the analysis results are shown in Figure 5.

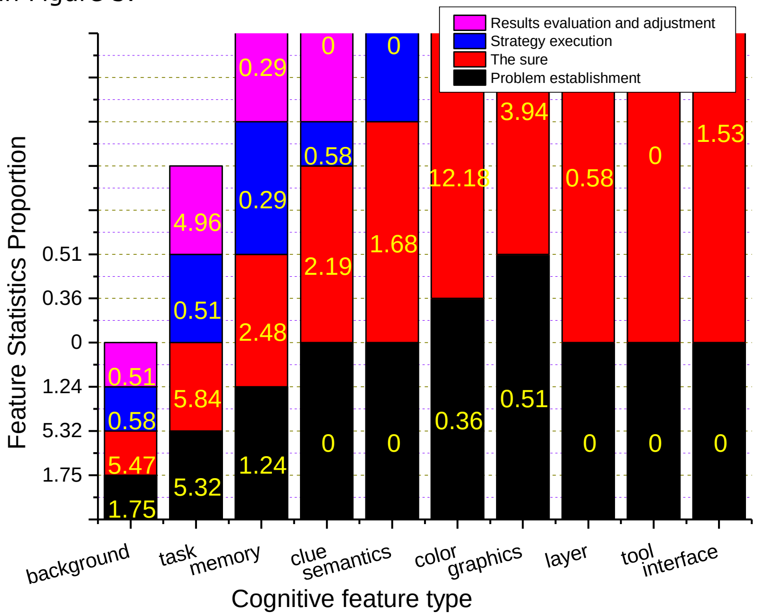

Figure 6: Cognitive characteristics statistics at each stage of color matching design behavior.

Figure 6 reflects that in the 1124 cognitive activities counted, different cognitive activities present different occurrence frequencies (percentages) in different stages of the navigation process model. From this, the following conclusions can be drawn. All four stages are present Cognitive characteristics include: task demand cognition, working memory cognition, background knowledge cognition, color cognition and figure cognition. It shows that these four types of cognitive features have a certain coverage in the color matching the design process. Color cognition covers a wide range, and the frequency of occurrence is also the highest, indicating that the understanding of color plays a very important role in the color matching the design process. Graphic cognition occurs more frequently in the strategy formulation and strategy implementation stages. In this stage, the graphics are analyzed in depth to arrive at the color matching strategy, which shows that in the color design process, one cannot only focus on the relationship between colors and the relationship between graphics and colors. Relationships are also an important point that cannot be ignored. Three cognitive characteristics of interface cognition, clue cognition, and tool cognition occur in the three stages of strategy formulation, strategy implementation, and evaluation adjustment stages, among which clue cognition and interface cognition occur in the strategy formulation and strategy implementation stages. The vocal frequency of these two kinds of cognitive characteristics is relatively low, and it is speculated that they are cognitive characteristics that exist with inspiration.

3.3 Color Harmony Algorithm Model Analysis

For this type of training with multi-dimensional and small sample data in this article, conventional data division methods cannot be used. Therefore, the K-fold cross-validation method needs to be adopted, that is, the sample is evenly divided into K parts, and K-1 parts are selected in turn for training, and the remaining part is used for verification. Finally, the results of K time of training are averaged as the basis for selecting the optimal model. According to the color semantic value calculated in Section 3.1, there are a total of 500 training samples. All samples are divided into 9 small training samples, each containing 13 training samples, and a training sample set is selected every 12 samples. One group is taken as an example, one is selected as the validation set, the remaining data are used as the training set for the neural network, and one of the samples is used as the validation set. The model analysis result is shown in Figure 7.

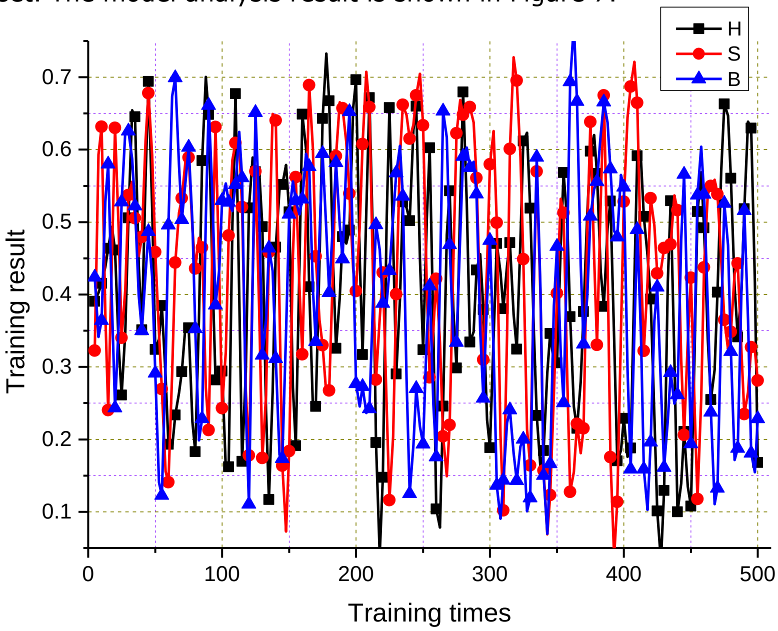

Figure 7: Model verification results.

4 CONCLUSIONS

This research mainly focuses on the color harmony algorithm in industrial product design, combined with computer science to study the design process and model of the color harmony algorithm; and proposes a multi-dimensional color harmony algorithm based on the color harmony fuzzy method, and establishes a color harmony map Model; then collect industrial product color harmonization evaluation dimensions by analyzing the color design characteristics of industrial products, design color harmonization algorithm analysis model, analyze the investigator's cognitive data of industrial product color harmonization, establish a color quantification model, and propose a color semantic quantification This algorithm, the color knowledge expression system based on rough set theory can solve the problem of color semantic fuzzy interval based on experimental data, and establish a one-to-one correspondence between color objects and color semantics. Industrial product design is a work that requires the fusion of perceptual and rationality. Due to the limited research time of the author and certain limitations in the data obtained by research, the amount of analysis data in the color harmony model is insufficient, and there is still a lot of content for color design and product image need to be researched.

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