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RESEARCH ON DESIGN DECISIONS MODEL FOR REQUIRING GROUPS DRIVEN PRODUCT MAIN COLOR DESIGN

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ABSTRACT

The efficiency and quality of product conceptual design is essentially about product development as well as in a rapidly changing and keenly competitive environment. In this paper, an intelligent product main color decisions method and model in connection with requiring groups driven is developed to make the design phase more objective and scientific. First, the paper has analyzed the features of color design and color design decisions. Second, the framework of the requiring groups driven product main color decisions intelligent optimization model has been established. And this paper has studied its algorithm mechanism and the supporting technologies on this basis. Finally, the color design process of a kind of special vehicle is employed to demonstrate and test the method.

Keywords: *Color Design, Requiring Groups, Color Clustering Analysis, Design Decisions*

1. INTRODUCTION

Color is one of the important factors of product, and the product color design is also an important dimension to lay the overall feeling and style features. The excellent product color design can not only improve the appearance of the product, but will also largely affect the product sales and market share.

The color of product is generally divided into main color and secondary color. Main color often determines the basic features. The secondary color can play a role in heightening the main color and making the product more attractive. When the main color determined, we will select the secondary colors according to the variety of color reconcile rules. In order to determine the main color of the product, we need comprehensive consideration of the product function features, product using environment, target consumers, fashion color, taboos and preferences, the corporate identify colors and so on. The main color design of the product will be limited by many requiring factors, and the essence of color design is coordination to the requiring groups. Hence, the intelligent configuration of the product main color, which integrated use of digital technology and artificial intelligence technology, will greatly enhance the success rate and efficiency of the product color design starting from the point of requiring groups.

The academics and researchers at home and abroad have done a lot of work on computer-aided color design. As early as the 1980s, some scholars have paid attention to computer-aided color design technology, and they have designed and developed the prototype system further. In literature [1], Luo et al. developed an Ultra-Colour intelligent tinting system according to the color seasons taxonomy proposed by Wright. Literature [2] proposed an antagonism color theory based on Practical Color-ordinate System and it is employed in household products, after further investigation of the hue and color vision characteristics. Literature [3] constructed a color geometric framework based on Lab color space and Munsell color harmony theory and realized the function of quick searching for reconcile color. Literature [4] designed a color matching method, which defined the simple polynomial relations between H, S, I and the color semantics first and computed color scheme according to the given semantic words, based on imagery of the product. In literature [5], the author brought up a product color evaluation method based on the imagery theory. Although the studies have

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made a great breakthrough above, but the most recent work focused on the three-dimensional color space or intelligent matching colors based on color harmony theory, and the choice of the main color still depends on the knowledge, experience and subjective judgments of the designers, the existing computer-aided color design systems are unable to give the designer much support. Therefore, it is necessary to propose a more objective product main color processing methods on the basis of limited sample space that can make the emotional and fuzzy color design process intellectualized and achieve the adaptive optimization of the product color through limited training. Thus improves the quality and efficiency of the product color design greatly.

In this paper, an intelligent decision-making model for product main color selecting driven by requiring groups is developed to match the problem of the main color selecting in the product color design process. Section 2 presents the train of thought of the product main color intelligent decision-making on the basis of analyzing the features of the product color design. In section 3 and section 4, we present the algorithm mechanism and the integral technological processes. In section 5, the color design process of a Tank Truck is employed to verify the validity of the method. In related researches at present, Liu et al. (in literature [6]) presented a product shape design method based on the requiring of human sitting comfort and Wang et al. (in literature [7]) proposed an intelligent product form conceptual design optimization model driven by design constraints starting from design needs.

2. RESEARCH FRAMEWORK

According to the TOP TO DOWN color design mode which is popular at present and the color harmony theory, the designers need to determine the main color of the product firstly, then they can obtain secondary colors derived from the main color using the computer-aided design system for the purpose of color harmony. The secondary colors generated by the system automatically are colors that meet the reconcile rules of the main color, and the secondary colors can change dynamically with the change of main color. Finally, the designers edit the relationship between color concept design and parts of the product, and decide the collocations between the main color and the secondary color. The article is mainly to solve the problem of main color selection decision-making in the design process of TOP TO DOWN. We change the single designer's decisions to the designers and experts groups' decisions under the guidance of requiring groups. The main research framework is shown in Fig 1.

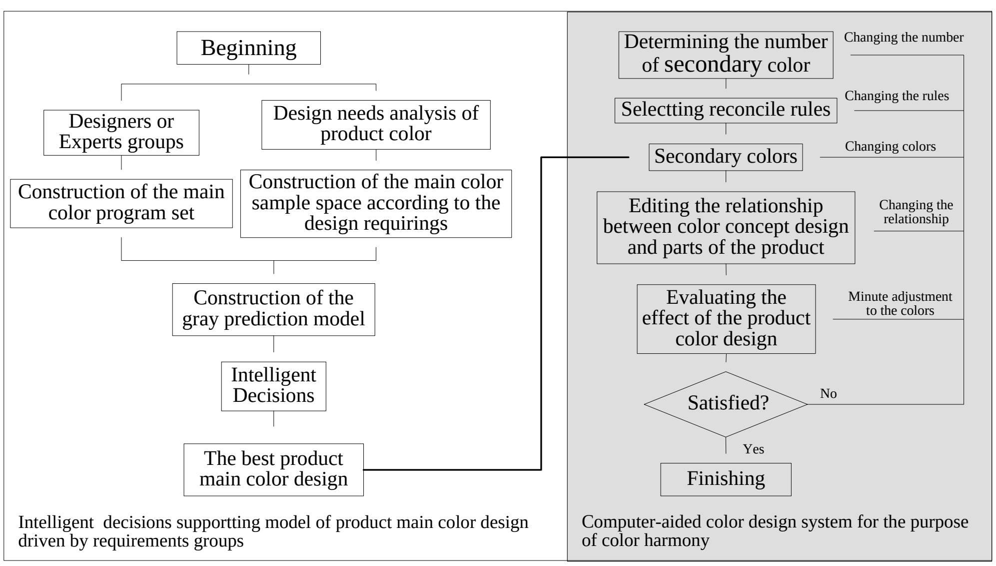

Fig.1 The Research Framework

In the study, we determine the specific needs of product color design firstly through group decision by the design team and construct the hierarchy framework of needs according to the background and characteristics of the target market of the product. After that, collect the similar products that well meet the individual design requirements on the market, and classify them to construct sample maps and the main color accordance with the hierarchy framework of needs. Furthermore, put the collected colors into the PCCS color analysis system and achieve the work of numerical encoding of the main

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color sample maps and get the main color sample space. Finally, create the gray prediction model. When Designers enter the N kinds of designs into the prediction model, they can obtain the associate degree of every design to the requiring groups. When the associate degree reaches a certain level, we can think that there is a better matching of the color design.

3. CONSTRUCTION OF THE MAIN COLOR SAMPLE SPACE

3.1 Color analysis of the product examples based on PCCS

The most obvious advantage of PCCS (Practical Color-ordinate System) is the introduction of the concept of color tones; it integrates the three basic attributes of color including hues, lightness and saturation into two variables, hues and color tones. The designers not only can get a variety of different color series using hues and color tones, but also observe the color distribution visually, which can facilitate color matching greatly.

After the analysis of the design requirements, there are a certain number of color design cases that can meet it greatly to every requirement; the cases are mainly the similar products on the market. Then, put the color design cases into the PCCS color analysis system to construct the main color analysis map. And a color analysis map of existing products for Tank Truck is shown in Fig. 2.

Fig.2 Color analysis map of existing products for Tank Truck

3.2 Construction of the main color sample space

In the PCCS color analysis system, every design case is corresponding to unique coordinate values Represented by $C=\{H, T\}$ according to its main color. In the formula, H indicates hue of the color, T indicates tones of the color and $T=\alpha_1 L+\alpha_2 S$, L and S respectively represent lightness and saturation, α_1 represents conversion factor between lightness and the color tones, α_2 represents conversion factor between saturation and the color tones.

Set hues, lightness and saturation of color as the encoding factor of the main color sample space, and be marked $C=\{H, L, S\}$, so the design cases in Fig. 2 can constitute the main color sample space of the Tank Truck which showed in Tab. 1.

Tab.1 Sample statistics of the main color for Tank Truck

No	H	L	S	No	H	L	S	No	H	L	S
1	13bG	8.5	2.0	7	12G	7.5	3.0	13	14bG	4.0	8.0
2	2R	4.5	7.0	8	17B	8.0	2.0	14	8Y	5.0	5.0
3	8Y	5.0	8.0	9	18P	8.5	2.0	15	16gB	4.5	6.0
4	16gB	4.5	6	10	23rP	5.5	4.0	16	14bG	8.0	2.0
5	17B	6.0	4.0	11	14bG	8.0	2.0	17	16gB	5.0	5.0
6	11yG	5.5	5.0	12	8Y	4.5	5.0	…	…	…	…

3.3 Defining the group grade of membership of the design requirements

The group grade of membership also named as the weight of design requirement represents the importance degree of single design requirement in the group to the overall goal. And defining the group grade of membership is one of the key steps in the scientific decision-making process. Sign the group grade function of membership as $w_i(x)$, $w_i(x)$ is scored by exports and valued in [0， 1]. The magnitude of the value reflects the importance of the design requirement to the overall design goal. When the value of $w_i(x)$ close to 0 reflects that the No i design requirement has a low importance; when the value of $w_i(x)$ close to 1 reflects that the No i design requirement has a high importance and has a great impact to the final results.

4. INTELLIGENT CLUSTERING CALCULATION OF THE MAIN COLOR

The problem of product main color design driven by requiring groups constitutes a typical Grey System, because it is difficult to predict the correlation between the given color and the whole design requirements group and it is easier to obtain the correlation between the given color and single design requirement[8]. So, the Gray System Theory provides an effective way for intelligent simulation of the product main color design. In the relevant fields, the document [9] has put forward a group Decision-Making method and constructed optimization model according to the minimum difference among the decision-makers to achieve the clustering of the judgments. Luo Dang and his partners[10] from Nan-jing University of Aeronautics and Astronautics constructed the gray group Decision-Making model using power method and entropy model and used the mode in the process of design evaluation. The document [11] has proposed a gray number distance calculation method based

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on gray degree. The gray prediction model and the clustering calculation method for the problem of product main color design have been presented in this paper using the following procedures.

4.1 Construction of the gray correlation predict-tion model

The uncertain correlation between things is known as grey correlation. Considering the influence from the group weight of different design requirement on the final result, the paper adopts the weighted gray correlation prediction model to calculate the value of the correlation.

Let $\left(X_0(j)\middle|j=1,2,\cdots n\right)$ be the reference sequence for cooperation, $\left(X_0(j)\middle|j=1,2,\cdots n\right)=\left\{\max(r_{i1}),\max(r_{i2}),\cdots,\max(r_{in})\right\}, i=1,2,\cdots,k$; and let $\left(X_i(j)\middle|j=1,2,\cdots n\right)$ be the comparative sequence, $\left(X_i(j)\middle|j=1,2,\cdots n\right)=\left(r_{ij}\middle|j=1,2,\cdots n\right)$; then the formula, which can be used to calculate the correlation of the No j index in the No i comparative sequence relative to the optimal value, shows below.

$$\vartheta_{ij}=\frac{\min\limits_i\left(\min\limits_j\left|X_0(j)-X_i(j)\right|\right)+\zeta\max\limits_i\left(\max\limits_j\left|X_0(j)-X_i(j)\right|\right)}{\left|X_0(j)-X_i(j)\right|+\zeta\max\limits_i\left(\max\limits_j\left|X_0(j)-X_i(j)\right|\right)} \quad (1)$$

In the formula (1), ζ is the correlation coefficient that can be valued in the interval of $[0,\ 1]$, and can also be expressed as: $\zeta\in[0,\ 1]$. Generally, the recommendable setting is $\zeta=0.5$, and the decision-makers can choose different value of ζ to calculate according to personal preferences too.

Suppose that there are n number design requirements, so the weights vector can be signed by the formula (2).

$$w=\left(w_1,w_2,\cdots,w_n\right) \quad (2)$$

$\sum_{i=1}^{n}w_i=1$, w_i represents the weight of No i design requirement.

Now, the average correlation can be calculated in the following model.

$$r_k=\left(w_1,w_2,\cdots,w_n\right)\cdot\left(\vartheta_{k1},\vartheta_{k2},\cdots,\vartheta_{kn}\right)^T\Big/n=\frac{1}{n}\sum_{i=1}^{n}w_i\vartheta_{ki} \quad (3)$$

4.2 Construction of the main color evaluation set

In this paper, we make use of the distance in PCCS between target main color and the colors in the main color samples space to measure the correlation of them. And construct the whiten-ing function according to the image semantics words, such as close, middle, and far that can distinguish the distances vividly. Since it is difficult to gauge the designs only according to the fuzzy description, so the grey correlation and its quantitative analysis must be carried out. The paper has used 5 graduation scale method and the fuzzy description has been quantified by using the integer between 0 and 4. The 4 represents very close and the 0 stands for very far. It can be expressed as formula (4).

"Very far, far, middle, close, very close" = {0, 1, 2, 3, 4} (4)

4.3 Intelligent clustering calculation

Gray correlation prediction is a method based on the whitening function, and the essence is plenty use of known information to replace the unknown and non-ascertain information. The procedure is shown below.

Suppose that comparative sequence in the group decisions is signed as C , C is composed by the product cases corresponding to the requiring groups $C=\{C_1,C_2,\cdots,C_n\}$. And let $w=\left(w_1,w_2,\cdots,w_n\right)$ represent weight vector of the design case relative to the requiring groups and $\sum_{i=1}^{n}w_i=1$.

1) Construction of the reference sequence and comparative sequence

Let $X_0\in A$, $A=\left\{A_1,A_2,\cdots,A_n\right\}$ represent the main color designs set, and let $X_i=C_i$, X_i contains all the colors in the main color sample space. The comparative sequence can be constructed as formula (5).

$$\begin{aligned} X_0&=\left(x_0(1),x_0(2),\cdots,x_0(n)\right)=\left(H_0,L_0,S_0\right)\\ X_1&=\left(x_0(1),x_0(2),\cdots,x_0(n)\right)=\left(H_0,L_0,S_0\right)\\ &\cdots\cdots\\ X_i&=\left(x_i(1),x_i(2),\cdots,x_i(n)\right)=\left(H_i,L_i,S_i\right)\\ X_m&=\left(x_m(1),x_m(2),\cdots,x_m(n)\right)=\left(H_m,L_m,S_m\right) \end{aligned} \quad (5)$$

2) Calculating the correlation coefficients

Calculating the correlation coefficients use formula (6).

$$\vartheta_{0i}(k)=\frac{m+\zeta M}{\Delta_i(k)+\zeta M},\ \zeta\in(0,\ 1) \quad (6)$$

In the formula, $k=1,\ 2,\ \cdots,n$; $i=1,\ 2,\ \cdots,m$, $\Delta_i(k)$ is the difference sequence of the comparative sequence, and M is the maximum difference, m is the minimum difference.

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3) Calculating the degree of correlation

Calculate the degree of correlation of the designs applying the following formula on the basis of correlation coefficients.

$$r_0(k) = \frac{1}{m}\sum_{i=1}^{m} \vartheta_{0i}(k)\cdot w_i,\ i=1,\ 2,\ \cdots,\ m \qquad (7)$$

w_i in formula (7) represents the weight of the design requirement relative to the requiring groups. And the degree of the comprehensive correlation can be calculated by formula (8).

$$r_0 = \frac{1}{n}\sum_{k=1}^{n} r_0(k),\ k=1,\ 2,\ \cdots,\ n \qquad (8)$$

The larger of the value of r_0 demonstrates that there has better coordination and matching between the selected main color design and the sample space of design requirements groups. And the design will have a better design requirements satisfaction. We can employ it as the criterion for final decisions.

5. APPLICATION OF THE MODEL

The color design process of a kind of Tank Truck is employed to demonstrate and test the method. The design process is shown below.

Step 1: Defining the research object

We will select the following colors shown in Fig.3 as the alternatives according to design requirements of the overall coating design.

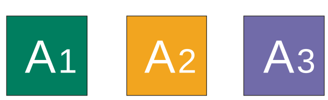

Fig.3 The options of main color

A_1=(12G, 3.5, 4.0)

A_2=(8Y, 5.0, 8.0)

A_3=(21bP, 7.5, 7.0)

Step 2: Defining the main color sample space

We chose three colors from the main color sample space involved in computing in order to simplify the calculation process.

X_1=(13bG, 8.5, 2.0)

X_2=(2R, 4.5, 7.0)

X_3=(8Y, 4.5, 8.0)

And let $w=(w_1, w_2, w_3)=(0.25, 0.4, 0.35)$.

Step 3: Determining the comparison quantities of assessment between elements

Tab.2 The evaluation value statistics table of the factors

The comparison quantities of assessment of A_1			
X_1	0	3	1
X_2	4	1	2
X_3	2	1	3
The comparison quantities of assessment of A_2			
X_1	1	2	4
X_2	2	0	0
X_3	0	0	0
The comparison quantities of assessment of A_3			
X_1	4	1	2
X_2	2	2	0
X_3	3	2	0

Step 4: Calculating the degree of the comprehensive correlation

Let ζ=0.5 and the results are shown as follows.

$r_0(A_1)$=0.1850

$r_0(A_2)$=0.2694

$r_0(A_3)$=0.2045

$r_0(A_3) < r_0(A_1) < r_0(A_2)$

So, the second color has a better matching to the design requirements. In actual operation, the designer should choose the second color as the foundation for further design. And A_2=(8Y, 5.0, 8.0) is in the area of that the designs are relatively concentrated in PCCS.

Step 4: The final color effect

According to the results of the design decisions and rules of color reconcile, let the number of secondary color be 2, and the final color effect is shown in Fig. 4.

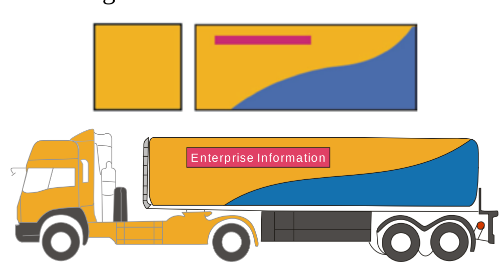

Fig.4 The final color effect

6. CONCLUSIONS

In the circumstances of the increasing homogenization of quality and technology, the

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competition among enterprises has changed from quality and technology gradually transformed into design. How to achieve rapid product design by efficient design means will be one of the difficult problems in brand building and development of the corporate. The intelligent design decisions model for product main color design driven by requiring groups will give designers some support in fast color design, and make the emotional, fuzzy color design process became more scientific.

This paper provides a description of the intelligent design decisions model for product main color design driven by requiring groups from the perspective of industrial design, and verifies the validity of the method by the color design process of a Tank Truck. It provides a reference for product color rapid design and color design education. But the breadth and depth of this theory has yet to be further discussed, and the next work can be developed in the following aspects: 1) Research on the algorithm of derivative design for secondary color; 2) Research on the intelligent learning and reasoning mechanism of the product main color design decisions driven by requiring groups; 3) Research on the coupling technology between the form and the color of product driven by requiring groups and lay the foundation for construction of products intelligent rapid design platform further.

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