[1]Yubin Wu

Reference Image Aided Color Matching Design Based on Interactive Genetic Algorithm

Journal of Electrical Systems

Abstract: - This paper proposes an interactive genetic algorithm to assist designers in color selection and match different color combinations extracted. Then, based on the CorelDraw development environment, this paper establishes a graphic-based man-machine dialogue model. Through simulation experiments, genetic algorithms such as random selection, hybridization, variation, color region adjustment, etc. Finally, the best color combination is obtained and combined with the image. Within the scope of color extraction value, designers can use interactive genetic algorithm rules to view color planning from a holistic perspective. Under the influence of human-computer interaction, each scheme is optimized step by step, so that the color ideas matching the designer can be found quickly.

Keywords:Color Matching Design; Interactive Genetic Algorithm; Color Image; Reference Image

I. INTRODUCTION

In the process of graphic art creativity and product development, color matching is an indispensable part. By constructing the color image model, constructing the corresponding relationship between color image and color matching strategy, using digital technology and image index, searching the color choice that meets the requirements. In this way, the color selection problem can be transformed into a general optimization problem. Several intelligent algorithms, such as neural network, genetic algorithm, ant algorithm, etc. are introduced into clothing color design, and a series of research results are obtained. Because the color image is very complex, restricted by many factors such as carrier type, function, form, use environment and so on, it is difficult to integrate it into the color matching image model, so even if the same color design, there will be great differences in different scenes. Interactive genetic algorithm is an important part of evolutionary algorithm, and its basic feature is to obtain the fitness value of the population through manual evaluation. Because it is widely used in complex design fields such as art, design, music and creation, and also meets the requirements of human-machine collaborative intelligence in color matching design, it is widely used in the field of color design [1]. Due to the role of human factors, its calculation speed is slow, and it can not carry out thousands or even tens of thousands of iterations as the traditional evolutionary algorithm. Due to the short iteration time, the problem is that the scope of the solution can not be searched completely, and it is likely to miss some good potential solutions. For this reason, many researches on genetic algorithms mainly seek the equilibrium between fast convergence and early convergence, and use human evaluation information to model it, with a view to achieving artificial evaluation instead of manual evaluation. The existing genetic algorithms based on color recognition have many uncontrollable errors in color conversion. Although some researchers have applied Bayesian decision method, Markov method, wavelet transform method, neural network method and particle swarm method to configuration optimization, they are all based on production layer examples, and similarity method is mostly used when selecting similar examples. For the design of complex product configurations such as vehicles, the existing research still has the following defects: (1) Most of the same configurations are oriented to the product level, which cannot reflect the superiority of mass customization. (2) When determining similarity, the weight of each index is determined mainly by experience; (3) It is difficult to determine whether the sample selection is appropriate threshold. Because of its excellent performance in solving product structure optimization problems, it has gradually become one of the most important research directions in the design field. However, in solving the mass customization environment, the classical GA faces a common problem: customer requirements contain both technical and non-technical requirements, and there is a lot of interaction between the requirements and customers, so the conventional genetic algorithm does not have the ability. Some scholars have proposed an interactive evolutionary algorithm based on human subjective evaluation. Due to the integration of human intelligence, each person's adaptation value is set according to the user, so it is especially suitable for solving the optimal problem with implicit performance index, and has important applications in computer graphics, industrial design, music creation, automatic control and robotics [2]. However, the algorithm also has limitations, that is, when the user needs to set the suitable value through the man-machine interface, too frequent operation will

[1]*Correspondingauthor:Guilin University of Aerospace Technology, Guilin 541004, China

cause user fatigue. Therefore, reducing user fatigue in interactive genetic algorithm is a very important research topic.

Interactive evolutionary algorithms based on classical evolutionary algorithms have been widely used. Dawkins first proposed the concept of an interactive evolutionary algorithm in 1986 and used it to construct biological images. Since the 1990s, human-computer interaction evolutionary algorithm has been used for parameter optimization of imaging and control systems, and has gradually been widely used. Japan's Takagi conducted in-depth research on interactive gene algorithm in 2001, which promoted people's in-depth research on interactive gene algorithm. Some scholars have proposed a general evolutionary search strategy with human-computer interaction function. Some scholars put forward the evolutionary strategy, that is, the adaptive evolution of individuals in the evolutionary process is based on the subjective evaluation of humans [3]. At present, interactive gene optimization problems for engineering design, knowledge mining, assisted teaching and art creation have been widely used. Some researchers use interactive genetic algorithms to optimize the color of the image, so that the resulting color is consistent with the user's subjective emotion. Some researchers have used interaction-based genetic algorithms to automate speech generation. Some researchers use interactive genetic play to tune hearing AIDS based on users' assessments of sound effects. Some scholars have proposed a genetic algorithm based on interaction to generate melody and rhythm of songs and realize the personalized creation of songs. In the actual design, interactive genetic algorithm is used to carry out the layout of components, micro-motor system design, clothing design, trademark design, appearance design, etc. Interactive gene play technology is applied to pharmaceutical engineering to design drug molecules with special functions. Among them, interactive gene play method uses users to evaluate the evolution process objectively, which is suitable for image-based image retrieval and image emotion search. Some scholars have also developed a children's composition system that combines interactive gene play technology with three-dimensional computer graphics teaching.

The existing research results mainly focus on how to build an agent-based user preference model. Some scholars proposed an adaptive agent modeling method based on multiple user evaluation data, and used the agent model to substitute users for adaptive evaluation of massive unlabeled data, thus reducing the evaluation pressure on the agent system. Some scholars use SVM to learn positive and negative category selection, and then find other personalized recommendation schemes that meet their preferences, so as to accelerate users to find personalized recommendations that meet their preferences and reduce their work intensity. Many researchers have trained SVM in various ways, built proxy models, and then demonstrated samples with high fitness. Some scholars have established an agent evaluation model based on association feedback in SVM. Some researchers have compared the operation results of agents constructed using SVM with those based on fuzzy rules through experiments, and the results show that SVM is slightly less efficient. Some studies have used RBF network to estimate the fitness of populations. In this method, the fitness of each generation is taken from the largest population as the core for clustering, so as to obtain the parameters of RBF network. Some researchers use ANN to simulate people's assessment of individuals, thereby reducing the assessment of individuals over the course of evolution [4]. There have been studies using RBF networks to train users' estimates and then build a model of financial markets. This project explores the use of genetic algorithm-based methods for purposeful optimization from three levels: original population construction, color scheme generation, and interaction effect evaluation.

II. IMAGE-INSPIRED COLOR MATCHING METHODS

Due to the differences in designers' personal, cultural, social and other aspects, even the same theme may present the color combination preferences of the opposite sex in various environments, so it is difficult to use a single method to guide the color selection of various design scenes. Taking color inspiration from a beautiful picture and then applying it to the color design of the clothing is a way that designers often use. In the aspect of image color matching reuse, many researchers have done corresponding research. One scholar has created a system that can apply butterfly colors from pictures to color matching on sneakers, and show similarities between the original pictures and the color strategy by comparing the fuzzy associations between the two. Some scholars use fuzzy C-Means clustering method to extract the unique ethnic characteristics of the islands in the South Pacific and apply them to the cultural and creative goods they develop. In graphics-based color design, the most important thing is to choose the best color scheme, in this process, the designer often has to evaluate, screen and correct the color to achieve the purpose of continuous improvement [5]. There are hundreds or even thousands of color combinations in reference images, and designers cannot compare and select one by one, and often add their own perception when evaluating them. At present, the acquisition of reference images mainly depends on the designer's intuition and design ability. The image-inspired color design process and problems are shown in Figure 1 (image cited in Appl.Sci.2022, 12(5), 2467).

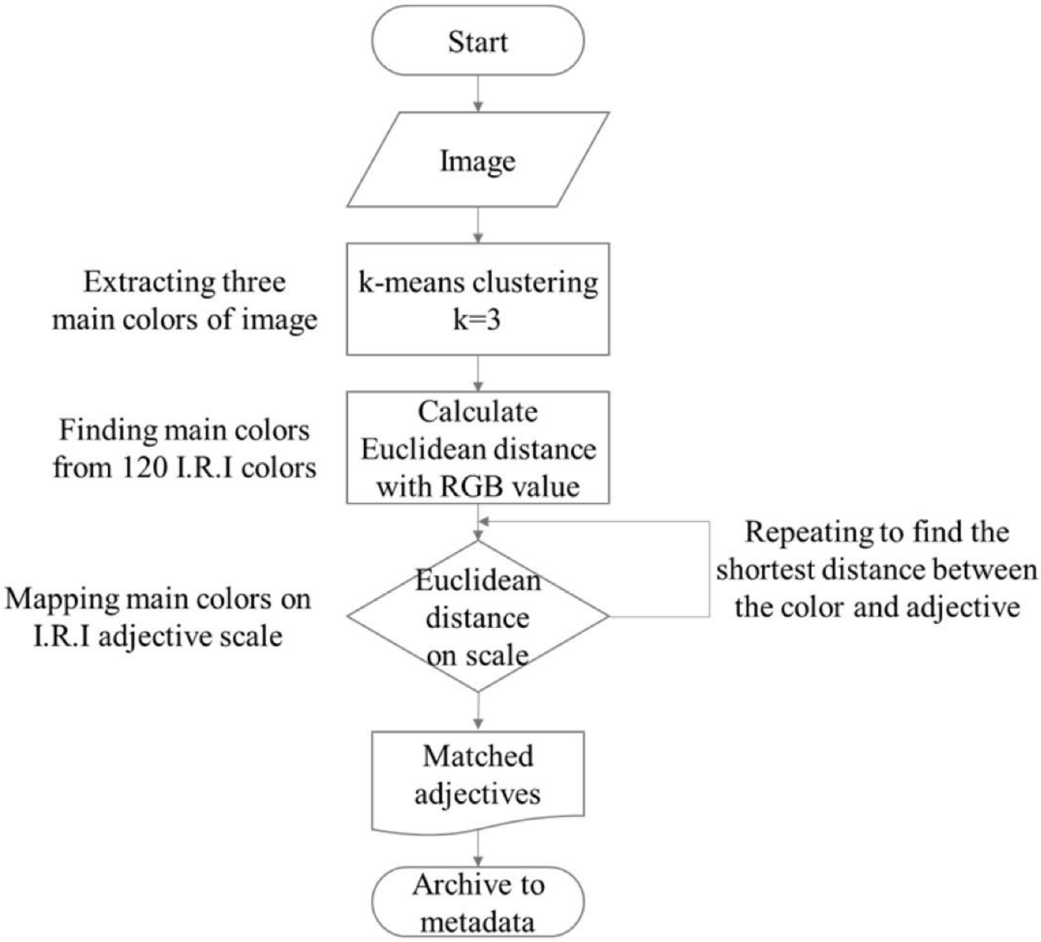

Fig.1 Image-inspired color matching design process and its problems

III. Genetic algorithm auxiliary process and technical framework

There are several applications of interactive genetic algorithm in color matching design:

1) Product interactive gene color scheme based on color semantics: fuzzy mathematics is used to construct semantic set of color synthesis. Factor analysis is used to classify each color, and each color is marked semantic, so as to build the corresponding relationship between color and semantic. An evaluation method of harmony of color combination based on color area difference is proposed. Use a visual color semantic dictionary as a data source [6]. The color coordination evaluation mechanism is constrained by interactive genetic algorithm. The semantic contribution degree of color and the results of interactive evaluation are used as evolutionary conditions for color selection and optimization.

2) Interactive gene color matching method based on user perceived noise: The system establishes a perceived noise model that integrates user awareness and fatigue. Then, based on the similarity measure between the evaluation value and the color value, the system calculates the corresponding adaptive color matching strategy.

3) Non-allelic recombination interactive Genetic Algorithm (NA-IGA) method: color combination between different pairs is allowed to avoid invalid solutions and improve the operation speed. The method also designs interactive methods to extend the traditional IGA evaluation model.

A. Genetic algorithm's auxiliary process for designers

This method can not only effectively improve the efficiency of the designer's color matching work, but also show the characteristics of the traditional genetic algorithm which is not easy to model in the way of human-machine interaction in color selection. The steps of using genetic algorithms to assist designers in color matching are shown in Figure 2 below (picture cited in Appl.Sci.2023, 13(2), 710).

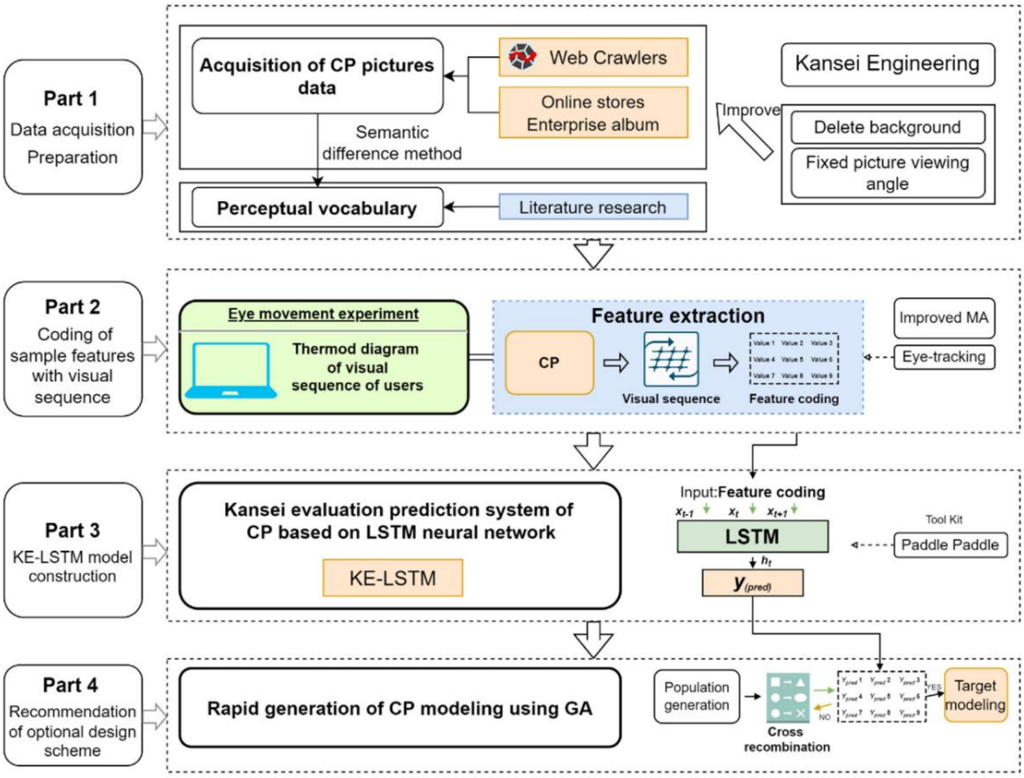

Fig.2 Genetic algorithms assist designers in the color matching process

First of all, the paper should consider the influence of various external factors on color; The second is to process the color object, which involves the division of the color zone, the automatic generation of the file, etc. Third, for the reference source of color matching, the required image index is displayed in the way of image; The fourth is to intervene in the evolution process by interactively evaluating or adjusting the color design.

B. Technical architecture of genetic algorithm

This paper focuses on the following analysis of the process framework for the specific requirements of color matching based on the traditional genetic algorithm. This paper uses CorelDraw to select graphic designers [7]. Many times, the choice of color is derived from the combination of colors in certain images, which is also a method of genetic play, that is, the method of establishing the original population. Using the image given by the designer, the characteristic colors of multiple colors are extracted, and then the computer automatically selects multiple colors to fill these colors, so as to get the original group. This interactive mode is mainly manifested in the designer's evaluation of each project, and scoring is the most commonly used one. The population size of the genetic show is generally between 8 and 40, and if arranged in order, it will increase the workload of the designer. According to the characteristics of CorelDraw itself, an algorithm based on "default score + batch score" is proposed, so that designers can quickly grade a certain group in the shortest time. Different from the conventional design problem, the optimal solution can be found by switching the colors of different color regions. Genetically speaking, the essence of this trait is the rearrangement of unequal genes [8]. In this paper, a "shuffle" method is proposed, that is, different types of heredity are recombined, so that designers can interactively adjust between different colors to obtain the ideal effect. Through the above analysis, the evolutionary operation flow of color matching genetic algorithm can be obtained (Figure 3 is quoted in A review on genetic algorithm: past, present, and future). Using the function library of Corel Draw VBA, the functions of color extraction, color scheme generation, display and user interaction evaluation are completed.

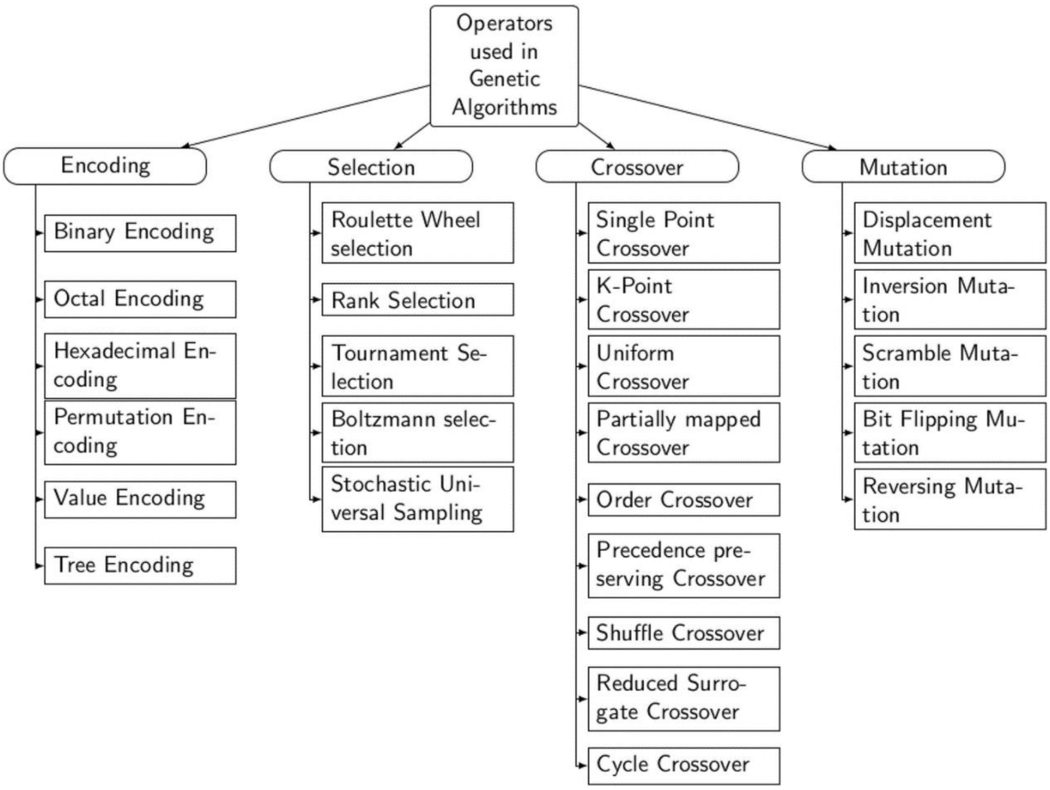

Fig.3 Evolutionary operation flow of color matching genetic algorithm

IV. EXTRACTION AND DRAWING OF COLOR THEMES

A. Extract the color theme from the original image

Usually, the color scheme of a product includes three parts: the number of colors, the color value (RGB mode represented by red, green, blue or CMYK represented by four colors such as blue, magenta, yellow, black, etc.) and the proportion of each color in the visual form of the design. At present, the original pictures used for product color matching are mostly 16-32 bits, and there are usually only 4 color choices for products. It is necessary to analyze and summarize the color characteristics of the original image to determine the number and size of colors to be extracted [9]. The processing of the original image includes two parts: the first part is fusion, which uses fuzzy algorithm to fuse similar colors. The second is to simplify, that is, to maintain a larger proportion of color, while ignoring a smaller proportion of miscellaneous colors, which is an important method. The steps to extract color patterns from the original image can be represented by the flow in Figure 4 (image is referenced to Fully automatic image colorization based on semantic segmentation technology).

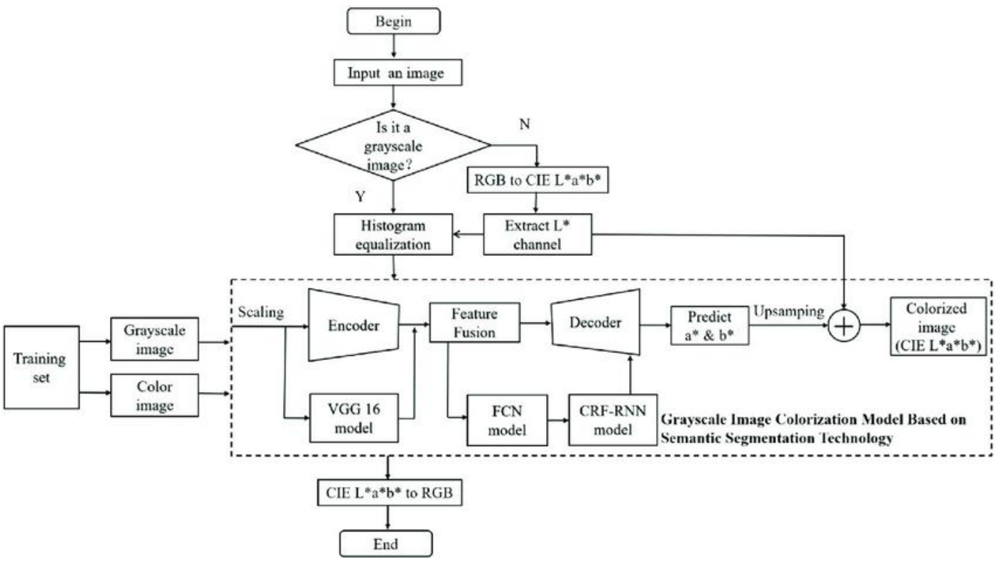

Fig.4 Process of color pattern extraction

The method of color synthesis is relatively mature, and the commonly used graphics processing software can be well realized. Perform color weights on the combined images according to formula (1).

$$\lambda_i = \frac{q_i}{MN} \quad (1)$$

λ_i is the specific gravity value of the combined colors. q_i is the number of color pixels. M, N is the width and height of the image. Two thresholds of color gravity are set in the process of color scheme extraction. Λ_1 is the threshold of noise, which is used to filter noise. If it is less than this value, it is filtered as noise. Λ_2 is the threshold of "eye color", which is because there is such a situation in the color of the picture, that is, the color of the use of low density, high contrast [10]. In this case, it is necessary to determine the content of the color selection, and according to the logical relationship between the color of the small area and other colors to be extracted, determine whether the color is to be maintained, or is a miscellaneous color without consideration.

The color proportion is greater than Λ_1 and less than Λ_2 for the eye color judgment. For the color representation mode of RGB mode, the logical distance between colors can be expressed by formula (2).

$$S_{ij} = \sqrt{(U_{sj} - U_{si})^2 + (U_{hj} - U_{hi})^2 + (U_{\sigma j} - U_{\sigma i})^2} \quad (2)$$

Where S_{ij} is the logical distance between the i color and the j color. $U_{si}, U_{hi}, U_{\sigma i}$ is the RGB value of the i color. $U_{sj}, U_{hj}, U_{\sigma j}$ is the RGB value of the j color in the color scheme. If the smallest of the calculated S_{ij} values is less than the logical distance threshold S, this color is regarded as a miscellaneous color, which can be ignored, and on the contrary, it can be saved as the eye color [11]. Through the processing of the above process, the color style of the original picture is maintained to the greatest extent, the influence of noise is eliminated and the number of colors is reduced. This allows it to be used directly in product design. Formula (3) can be used to illustrate the color selection scheme obtained from the source image.

$$F = \{(z_1, \lambda_1), (z_2, \lambda_2), \cdots, (z_m, \lambda_m)\} \quad (3)$$

Where z_i, λ_i is the color value and specific gravity value of the color respectively. m is the color number of the source scheme.

B. Mapping of color schemes

There are many ways to map a resource plan to the look and feel of a product. Before the color design is generally in accordance with the material, process and other needs to color the product, so the formula (4) can be used to represent the color scheme of the product.

$$F_T = \{(z_{t1}, \lambda_{t1}), (z_{t2}, \lambda_{t2}), \cdots, (z_{tn}, \lambda_{tn})\} \quad (4)$$

Where z_{ti}, λ_{ti} is the color value of the color and the specific gravity of the color region in the total surface area, respectively. n is the color number of the target scheme, $n < m$. Since the surface color area of the product in process has been segmented, the choice of the targeting scheme is the choice of color tone. The color value of the target plan can be expressed as: the weight of the colors in the product color zone according to the original plan code, as expressed in formula (5).

$$z_{ti} = g(F, \lambda_{ti}) \quad (5)$$

When color selection is based on formula (5), it should be considered from three perspectives.

a. Selection of color components

The number of colors in the original mode is usually greater than the number of colors in the target mode, and the software selects a certain number of colors in the original mode as the final design scheme according to the number of color ranges generated. In general, to ensure visual coherence, the most important colors and highlights in the original image should be displayed.

b. Color scheme

Color proportion is a key element that reflects the original design style, and color combinations with the same color but different proportions will have very different results. Because the weight values of each color region in the original scheme and the target scheme have been determined, people use the method of color weight sorting to match [12]. Arranges the color weight value in the original scheme with the color weight value in the destination scheme. When the color of the destination scheme is determined, the original scheme color to be mapped is selected according to the order of its arrangement. This allows the color ratio of the original image to be roughly the same so that the style of the original image can be reproduced.

c. Create elements at will

Because the segmentation of the color zone between the original picture and the appearance of the product is very complicated, unexpected results often appear in the conversion process of the two colors [13]. Therefore, when implementing the map function, it is necessary to add some randomness in order to find the best solution as far as possible. The random factor is mainly reflected in the color selection of the source scheme and the random change of the selected color value.

C. Selection and selection Color selection

Targeted color design should not only consider the user's visual experience, but also consider the type, function, shape and scale of the product. The same color combination, used on different products, will give people a very different feeling. Therefore, evaluating and weighing goal plans is a highly participatory process. There are many influence factors in color design, so it is difficult to form a set of automatic solutions for color design, and these specifications meet some problems in practical application [14]. For this reason, a genetic performance method based on interaction is proposed in order to obtain the optimal color scheme suitable for a particular commodity. When using interactive genetic algorithm, it can give full play to its optimization ability in the optimization process, and overcome the problem that the traditional optimization method is difficult to determine. The designer's personalized thought is introduced into the optimization, so as to ensure that the optimization results match the designer's design concept. Due to the intervention of designers, this method faces new challenges in solving problems.

Because human-computer interaction is carried out directly by the designer, and because of the constraints of human work intensity, it cannot evolve hundreds of generations like ordinary gene optimization before reaching the purpose of convergence. Subject to the constraints of human perception, the population should not be too large. Unlike automated solutions that are limited to the abstract code level, the color scheme needs to be presented to the designer in a visual way to ensure the rationality of the solution [15]. Due to the limitation of computing speed, interactive computing needs fast convergence speed. Due to the limitation of population size, the interactive algorithm cannot solve a large number of solution sets, or it is difficult to ensure global search due to the limitation of population size. It is necessary to present the whole image of the whole group in front of the designer, and this method is feasible. The color selection is coded using formulas (3) and (4). The solution space is a variety of feasible solution methods based on code construction. The corresponding solution set needs to be constructed without destroying the original color characteristics, and its solution space can be represented by (6).

$$\begin{aligned} F_d &= \{(z_{d1}, \lambda_{d1}), (z_{d2}, \lambda_{d2}), \cdots, (z_{dm}, \lambda_{dm})\} \\ z_{di} &= [z_i(s) \pm g_s\Delta, z_i(h) \pm g_s\Delta, z_i(\sigma) \pm g_s\Delta] \end{aligned} \tag{6}$$

Where λ_{di} is the specific gravity serial number of each color. z_{di} is the color value, and $z_i(s), z_i(h), z_i(\sigma)$ is the RGB color value of z_i in formula (3). g_s is a function that generates a random number from 0 to 1. Δ is the size of the blur area of color. The optimization process of color scheme based on Interactive genetic algorithm is shown in Figure 5 (the image is quoted in Interactive genetic color matching design of cultural and creative products considering color image and visual aesthetics).

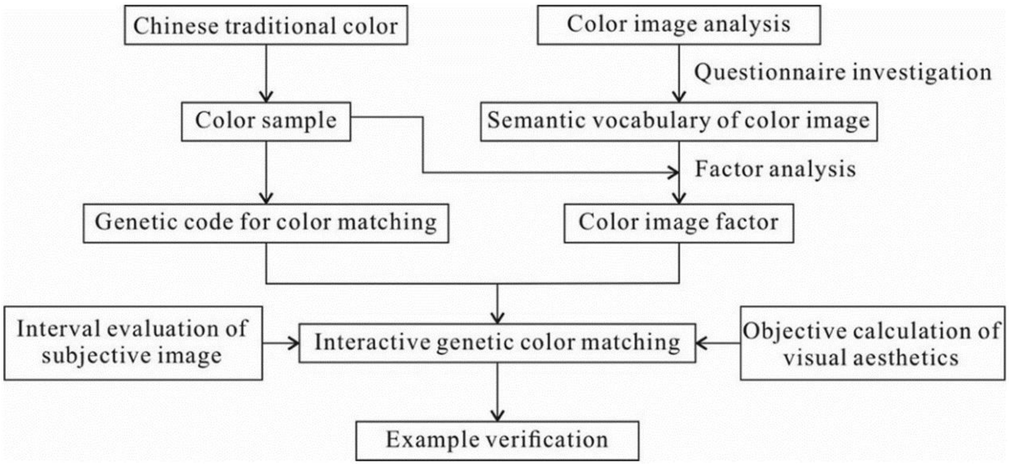

Fig.5 Optimization process of color scheme based on interactive genetic algorithm

A color generation method based on genetic algorithm is proposed, which can effectively improve the performance of the algorithm. The software applies the resulting color patterns to 3D product styling and creates 3D styling examples for each design project. Finally, all the cases are put together, so that designers can see and choose from different perspectives [16]. However, there are often coding mismatches between the existing multiple target modes. For example, if a certain color of the same color is selected in multiple target modes, it will inevitably lead to color deviation if the common genetic algorithm is directly used for interactive mutation. This paper presents a new method to construct the descendant code. First, the color code of each selected scheme is extracted and the origin of each selected color is given. A color source sequence parameter is added to formula (4), resulting in the following formula (7).

$$F_T = \{(z_{t1}, \lambda_{t1}, N_1), (z_{t2}, \lambda_{t2}, N_2), \cdots, (z_{tn}, \lambda_{tn}, N_n)\} \quad (7)$$

Where z_{ti}, λ_{ti} is the color value of the color and the specific gravity of the color region in the total surface area, respectively. n is the color number of the target scheme, $n < m : N_i$ is the serial number of the source color of color z_{ti} in the source scheme coding, and N_i is calculated according to the value of λ_{ti} and λ_d in equation (6), so as to keep the proportion of the color in the target scheme and the source scheme as consistent as possible [17]. The program encodes the subspace of the source solution space according to the extracted color scheme, as shown in equation (8).

$$\begin{cases} F_T = \{(z_{T1}, \lambda_{T1}, N_{T1}), (z_{T2}, \lambda_{T2}, N_{T2}), \cdots, (z_T, \lambda_{Tn}, N_{Tn})\} \\ z_{Ti}(s) \in [s_{Ti\min}, s_{Ti\max}] \\ z_{Ti}(h) \in [h_{Ti\min}, h_{Ti\max}] \\ z_{Ti}(\sigma) \in [\sigma_{Ti\min}, \sigma_{Ti\max}] \end{cases} \quad (8)$$

Where $s_{Ti\min}, s_{Ti\max}$ refers to the minimum and maximum of the s color value component of color z_{Ti} in the scheme code selected by the user, and the same applies to the rest. N_{Ti} is the serial number of the source color of color z_{Ti} in the source scheme [18]. The program extracts the color combination pattern information from the selected coding scheme group, such as the source scheme has m color, the target scheme has n color $(n < m)$, then the number of possible color combination patterns

$$C_m^n = \frac{m!}{n!(m-n)!} \quad (9)$$

The software calculates the selection of each color in the selected code and builds the corresponding evaluation function. A new round of progeny fitness is calculated. By calculating the color correlation coefficient of each alternative scheme, the degree of color deviation in each alternative scheme can be quantitatively reflected. The software analyzes and computes the selected code according to the designer's choice. Choose the best pattern as the basis for the generation of offspring [19]. This leads to smaller and smaller solutions. Finally, a satisfactory color selection was obtained after a certain amount of interaction.

V. Case Application

The use of color to express their own national characteristics is a kind of design expression technique that designers should think about when making color matching. The design content of this example is the color scheme of the plane figure shown in Figure 6, and its color is consistent with the color image in the painting [20]. First of all, the colors in the painting were extracted from the painting library. The gallery and its extracted colors are shown in Figure 7.

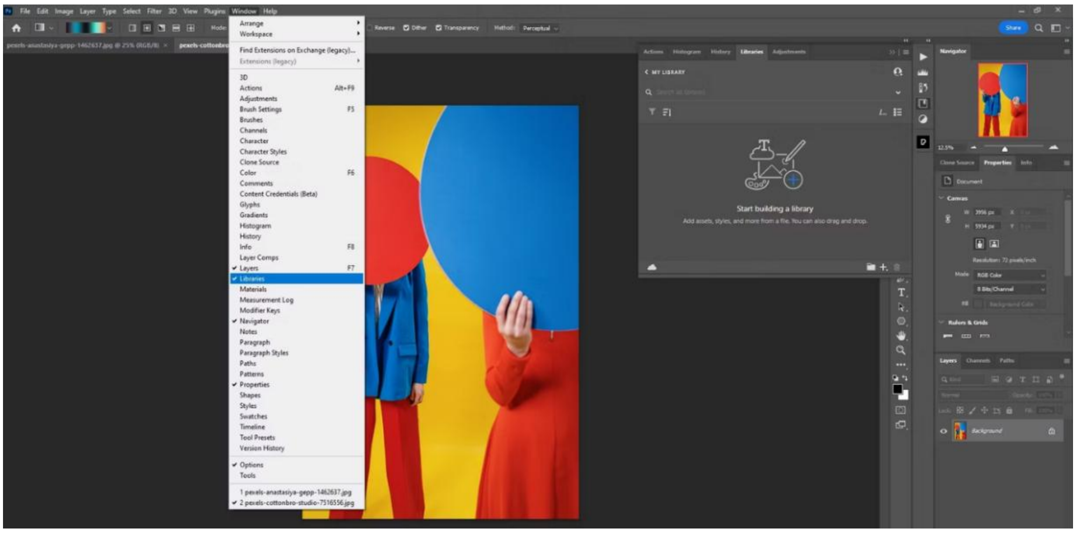

Fig.6 Flat pattern

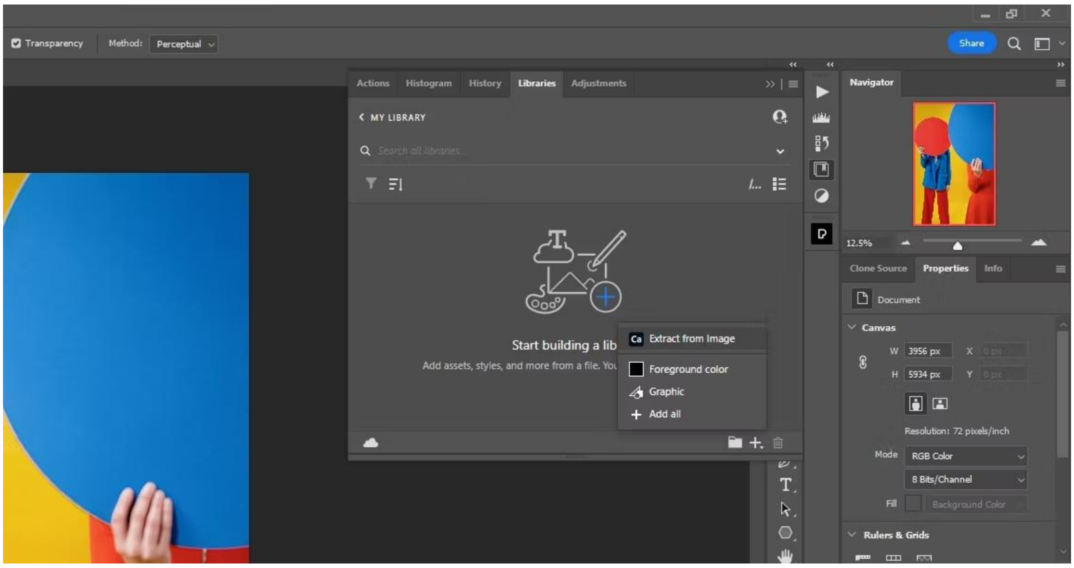

Fig.7 Dunhuang mural gallery and its extracted colors

Then the characteristic colors of eleven colors are extracted from the image library, and the coexistence relationship between them is represented by a network structure. The original population based on genetic algorithm is constructed by selecting 11 feature colors [21]. The initial population based on extracted colors is shown in Figure 8.

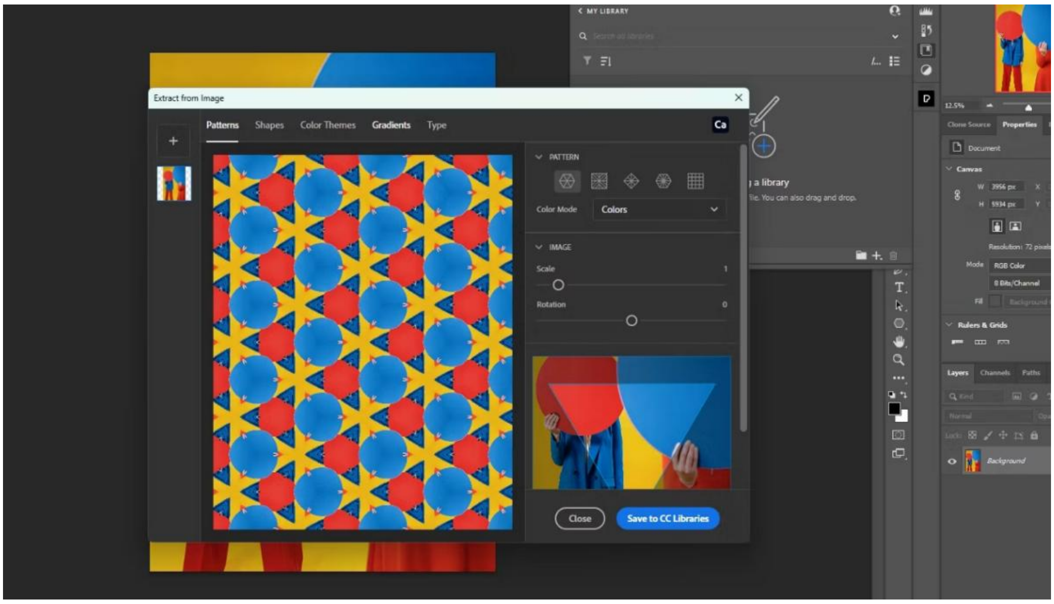

Fig.8 Initial population based on extracted color

In the genetic algorithm, the population has a mutation, resulting in a rosy red color that the original algorithm does not have. The designer felt that such a color would make the whole color look more coordinated, so it was selected to "shuffle" it, so as to obtain a new generation of groups. This group will continue to evolve until the designer finds a suitable solution, which can be fine-tuned according to the complexity of the color. In this case, the designer ended up with a satisfactory color choice (Figure 9).

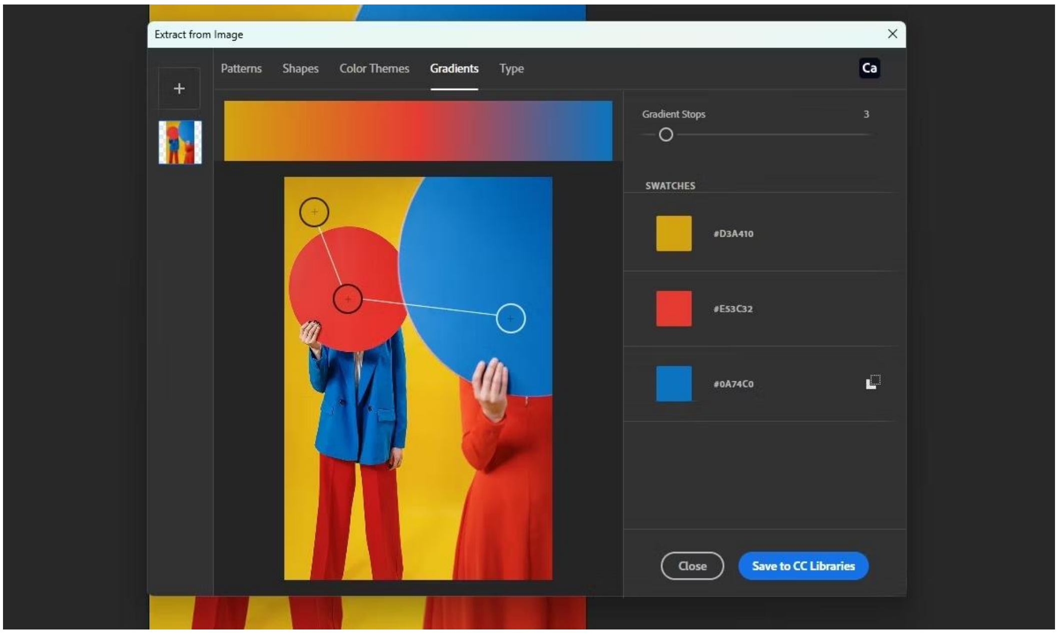

Fig. 9 Satisfactory color scheme

VI. Conclusion

This paper discusses from three perspectives based on the practice of fashion color design. First, a set of interactive gene algorithm program for color design is proposed, and the corresponding application system is developed based on common vector images, and its application in color design is tested. Second, the "image" index, which is often used in color matching, adopts an indirect method; The designer selects one or more images with color image characteristics, and then the software extracts and uses them automatically, which avoids the difficulty of establishing the model. Third, interactive GA can not only simplify the evaluation method of designers, but also reduce the evaluation uncertainty caused by user fatigue. Through "shuffle" operation, designers can implement flexible and active intervention in group planning. This approach gives the designer more power to "assist" rather than "replace" the function. However, the color selection method introduced in this paper also has some limitations. First, some parameters in the evolution process are not known by the designer, for example, the evolution ratio is set to 20%. Second, when dealing with non-allelic hybridization by "shuffling", there exists the problem of two different color regions in the subsequent synthesis. This leads to useless planning and slows down the system. Third, the existing algorithm is only suitable for the color selection of graph objects, if it is used in other fields, such as commodity color selection, it needs to be refined and adjusted for specific problems.

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