Color Scheme Support System Enhancing Users' Creativity Using Interactive Evolutionary Computing

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Abstract—This paper presents a color scheme support system that enhances users' creativity. With this system, an ordinary person who does not have skill of coloring can decide color scheme and perform graphic design. This system uses interactive evolutionary computing in order to extract tacit ability of the graphic design from its user. The user repeatedly selects better ones from a set of graphic designs that the system presents and finally obtains the fine one that he/she hoped unconsciously.

Index Terms—color scheme, interactive evolutionary computing, subjective assessment, user's creativity

I. INTRODUCTION

In recent years, it has become popular for people to design color scheme on personal computers, for example in web and presentation design. The design tool is easy to handle with, but the result of color scheme by amateur designers is not satisfactory enough; the result is not so sophisticated as that by professional designers. They may design the color in a satisfactory way, if they use some templates of good color design, but in this case, the results become similar to each other and less individual, not respecting the taste and sense of each person. From this point of view, some methods have been proposed to adopt interactive evolutionary computing (IEC)[1] in the color scheme[2]. These methods aim at enabling general users to design the color scheme optimally considering their taste and mind. In these systems, the optimal color scheme is obtained by selecting some samples of color designs on the basis of the user's subjective assessment, from the color design samples created by the genetic algorithm (GA). Here, all the values of the color indeterminant are expressed as binary data to make individuals, which corresponds to chromosomes, and then a genetic algorithm is applied to update the values. The renewal of the generation is performed on the basis of the human subjective criteria concerning how satisfactory the output color design is. Finally, the parameters are set so that the most satisfactory color design is obtained for the user.

These systems can theoretically offer the most satisfactory color design, however the output tends to be too colorful, which is not close to the user's taste and mind any more. This is because the GA create the candidates of the color design randomly. The satisfactory color design may be obtained if the number of generation change is increased, but it takes time and increases work loads of the users. Especially in web design, the color scheme is required to represent appropriately the user's mind and intention that which part of the web page should be emphasized and which should be retreated.

In this paper, a method for color scheme support system enhancing user's creativity which appropriately represents such user’s intention and makes fast convergence to the optimal color design is proposed, using IEC. This method utilizes the initial color design created by the user beforehand. The system keeps the brightness of the initial color design in each area unchanged in the generation change in GA. Since the area which the user intend to emphasize has the brightness where primary colors can be appeared and that which the user intend to retreat is dark, the color design can represent the user's intention effectively by keeping the brightness of the initial images. Moreover, by preparing the initial image so that the difference of the brightness between the adjacent areas be large enough, the designed colored image by this method is valid to color-handicapped people, since they can recognize the difference of the brightness.

In 2. the principle of the color scheme system using IEC is presented. In 3. the principle of the proposed color scheme system using IEC which preserved the brightness of the initial color design by users is proposed. In 4. the application of this method to universal design that the output image is valid to...
color-handicapped people, while its color design is satisfactory to physically unimpaired people, is mentioned. Finally in 5 computer simulations of this system are shown to verify its high performance.

II. COLOR SCHEME SYSTEM USING INTERACTIVE EVOLUTIONARY COMPUTING

A. The Principle of the Interactive Evolutionary Computing

IEC is a method to design a system optimally using the genetic algorithm (GA) on the basis of human subjective criteria. In this method, the system parameters to be set are coded as a binary number which represents an individual, that is a chromosome. Each bit corresponds to a gene. The algorithm to optimize the system parameters is as shown in Fig. 1. First, M individuals are made randomly to create a population. Second, system outputs are made M times using the M sets of parameters corresponding to the M individuals. Third, the user of this system observe the M outputs and select S satisfactory ones (S<M) from them on the basis of he/she subjective criteria and taste. Here, if at least one of them is satisfactory enough, the system output is obtained as the final output of this system. Else, \( T_1 \) new individuals are made from the selected S individuals by crossover and \( T_2 \) new ones are made from the \( S+T_1 \) individuals by mutation. Then the newly made \( T_1+T_2 \) individuals are added to the S survivals to make the new population and repeat making system output, selection, and generation change until the system output satisfactory enough is obtained. Here, we suppose that M is equal to \( S+T_1+T_2 \). Thus, IEC is the special case of GA in the point that the fitness function is not obtained quantitatively but subjectively.

B. Application of Interactive Evolutionary Computing to Color Scheme

Suppose that a line drawing as shown in Fig.2 is given and each area A~D is to be colored. Color information is usually expressed with three parameters, such as RGB, YUV, and HLS. Since these parameters are expressed as numbers, GA can be applied to set these parameters by expressing the numbers as a binary sequence, which corresponds to an individual. Suppose that HLS is adopted to express the color, each individual is expressed as Fig.3. In this figure, binary numbers, which corresponds to the hue, lightness and the saturation of the areas A~D, are contained in the boxes. First, these numbers are randomly generated to make M individuals and the line drawing is colored in M ways with the M sets of colors represented by the M individuals. The obtained M colored images are shown on the computer display. Then the user observe the M images and select S of them from he/she subjective criterion. Crossover and mutation are performed to make new individuals and second stage begin. By repeating this procedure, the satisfactory color scheme is obtained.

III. COLOR SCHEME SUPPORT SYSTEM ENHANCING USER’S CREATIVITY

In order to make fast convergence to the optimal color scheme which reflects user’s intend and taste, the following methods are proposed. Here, we suppose that HLS color expression is adopted.

A. Preparation of the initial image by the user.

The proposed system uses the initial colored image as the input, which is made by the user; the user first colors the line drawing with his/her certain intention and taste. GA works so that some of the color information is kept unchanged in the generation exchange as is described in the following sections.

B. Preparation of color palette

If all the space of hue and saturation are considered and uniformly coded, the variation of color is difficult to appear,
part of it is supposed to appear. Moreover, some colors are difficult to be recognized as different ones although the quantities for these colors are different. Therefore, a color palette composed of 12 hues which are easily distinguished by human vision is proposed to be used, here. These hues are selected by a professional graphic designer. Fig. 4 shows the color palette of 12 hues. As to saturation, either 50% or 80% is adopted, since 100% is too vivid for our sight and the color is difficult to be distinguished if the saturation is less than 50%. Moreover, it is meaningless to prepare more levels between 50% and 80% for our sight, because the difference of the saturations is not large enough visually and the created colors look similar, if such intermediate levels are considered.

C. Keeping the lightness of the initial image unchanged

In the color information in each area, especially the lightness is kept unchanged. Only the hue and saturation in each area are changed in GA. Generally, the user’s intention and taste tends to be shown in the lightness. People tend to have taste that this certain part should be bright or dark. Moreover, the area which is to be emphasized tends to be colored with bright color, while the area which is to be retreated, such as an unselected button, to be colored with dark. Thus, the intention and the taste of users can be preserved in the GA generation exchanges by keeping the lightness.

First of all, M individuals are generated randomly to make M colored images in which the lightness in each area is the same as that in the initial image. The hue in each area in each image is selected from the color palette and the saturation is set at either 50% of 80% randomly. Here, the middle part of the individuals as shown in Fig. 3, corresponding to the lightness, is fixed to that of the initial image. This part is not updated during GA process. The individual as in Fig. 3 represents more general case, but this middle part can be omitted when the lightness is fixed.

D. Crossover

Crossover is realized by selecting pairs of individuals randomly in the parent population, and for each pair, two child individuals are made by exchanging some part of the chromosomes each other. Here some parts of the chromosome of the newly born individual are from one of the parent individuals and the other parts are from the other. There are several methods for crossover, but here uniform crossover is adopted. In this method, the binary sequence in each area in the child individuals comes from the corresponding part the binary sequence of either of the parent individuals at the rate 50%. Fig. 5 shows an example of the uniform crossover expressing this procedure. Each block corresponds to the binary sequence in each area. Since each block is not divided, sudden color change does not occur in this crossover.

E. Mutation

Generally, the mutation corresponds to reversing some of the bits in the individual binary sequence randomly. But if this method is adopted, the output image is obtained in the way that only a small amount in the image is changed, which has little influence in human vision, or some parts of the image does match the other part at all. Thus a new type of mutation is proposed. Here, the colors in all the areas are changed totally, while keeping the relationship of the hue difference unchanged. Suppose that the hue in the k-th area in the m-th individual in the n-th generation is denoted as H(k,m,n) which is an integer taking a value form 0 to 11 corresponds to the 12 hues in the color palette. The individuals in the n-th generation mean the parent individuals selected in the (n-1)-th generation, and new total of the individuals made by the crossover here. In the proposed mutation, some of the individuals in the n-th generation are chosen randomly and the hue in each area k is set as follows.

\[ H(k, m', n) = H(k, m, n) + L \pmod{12} \]  

(1)

Where m denotes the number of each individual chosen, and m’ the number allocated to the newly generated individual from the m-th individual. L is a number randomly set from 1 to 11. Here, the saturation is reset in each area at either 50% or 80% randomly. In this way, quite different types of color scheme are obtained, while the relationship of the color in each area is kept satisfactory.

IV. APPLICATION TO UNIVERSAL DESIGN

The color scheme method proposed here can be applied to design images which are understandable for color-handicapped people, since it keeps the lightness of the initial image unchanged. If the initial image is made so that the lightness in the adjacent area is different enough and people can recognize the image in grayscale mode, the image can be recognized by the color-handicapped people as well. By adding color information using IEC as described in III, the output image is not only satisfactory enough to usual people but also to color-handicapped people.

Fig. 4 The color palette used in the system. The numbers above denote the degrees of the angle in the hue space.

Fig. 5 An example of uniform crossover.
V. COMPUTER SIMULATIONS

A. Usual color scheme

Fig.6(a) shows an example of the initial image made by a user. This image is applied to the color scheme system as mentioned in III. Fig. 6(b) shows the final output image obtained by this system. We can see that the dark part is kept to be dark, while bright part is kept bright. We can also see that the unsellected tabs are darker and seem to be more retreated than the selected tab.

Fig. 7(a) shows the images made in the first generation in which the lightness of each area of all the images are the same as that of the initial image Fig.6(a), but the hue and the saturation are set randomly. Here M is set at 12. Three of them are selected as circled on the basis on the user’s subjective assessment. Fig.7(b) shows the images made in the second generation using the three selected in the first generation. Here, the three selected ones are allocated at the top. All the combinations of the two of the three are used for the crossover. Accordingly six child individuals are generated, the images of which are shown below the three parent images. Finally three of the nine images are selected and the mutation is performed to generate three new child images. The number of images included in the second generation is 12 in total. \( S = 3, T_1 = 6, \) and \( T_2 = 3. \) Also, three of the images in the second generation are selected as circled and the procedure as mentioned above is repeated till fully satisfactory image is obtained.

B. Subjective assessment of this system

Subjective assessment of this system is performed for 6 people. They first color the initial image using a graphic tool as they like, and then operate this system. After they obtain the final image, the colors of which they think are satisfactory enough, they answer the following questionnaire with the score from 1 to 5, where score 1 denotes definitely negative, 2 negative, 3 Medium, 4 positive, and 5 definitely positive.

1. Is the obtained color scheme satisfactory?
2. Is the part you want to emphasize actually emphasized, and is the part you want to retreat actually retreated?
3. Is the obtained color scheme better than the initial one?
4. Is the system easy and comfortable for operation?

The average scores of the 6 subjects for each questionnaire are shown in table 1. We can see that all the scores are higher than medium, especially, the items (2) and (4) are highly estimated.

Moreover, all of the subjects agree with the idea that this system is useful when they have to make another color scheme for a given colored picture. A half of them agree that they do not usually think of such color scheme as the obtained one, but the obtained color scheme is unexpectedly good enough.

C. Color scheme for color-handicapped people

Fig.8 shows an example to apply this system to color scheme design for color-handicapped people. Fig.8(a) is the initial image made by the user considering that the color-handicapped people can recognize it. This image is input to the proposed system as the initial image and the final output image is obtained as Fig.8(b) with colors. In this case, the output image can be satisfactory for usual people in color design, while it is recognizable to color-handicapped people.

VI. CONCLUSIONS

A color scheme method using IEC is proposed so that the user’s intention and taste be considered in the color design. This method adopts an initial image made by a user, roughly expressing his/her intention. For instance, the user tends to put a strong color on the area where he/she wants to emphasize it, and an unattractive color where he/she wants to retreat; the strong color is allocated in the middle level and the unattractive color in the low level in the parameter L in the HLS color expression. IEC is applied while keeping the lightness of each area in the image unchanged from that in the initial one. Only the hue and the saturation are updated by IEC. Since the user’s intention and taste tend to be expressed in the lightness, the output image comes to express them effectively. Moreover, fast convergence to the satisfactory result is obtained by restricting the lightness. In order to set variety of colors effectively, a color palette composed of 12 colors is prepared.

The proposed system is shown to be effective enough for color scheme by subjective assessment.

Moreover, color scheme for universal design, that is a design for color-handicapped people, can be realized by this method. In this case, the initial image is made as such that can be recognized in gray-scale mode.

Computer simulations show the high performance of this system. In this paper, only the lightness in the initial image is considered to be preserved, but consideration for other color information such as the saturation and the hue is for further research.

REFERENCES

Fig. 6 The initial image made by the user and the final output image obtained from this system.

Fig. 7 Images made in the first and the second generations. These images are shown on the display and the user select three of them as circled.

Fig. 8 The initial image designed for color-handicapped people and the final output from it.

TABLE I

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<th>(1)</th>
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