IMAGE RECOLORING FOR COLOR BLINDNESS CONSIDERING NATURALNESS AND HARMONY

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ABSTRACT

There are many existing methods of recoloring images with different effects. However, some problems are still exposed, such as unnatural and discordant colors of the converted objects in the image. To address these issues, we explore a set of methods to achieve image recoloration. Our method enables the resulting images to have the three properties of naturalness, harmonization and distinguishability, thus satisfying the needs of colorblind people. Our method is divided into two parts, one is the recommended palette generation part and the other is the image recoloring part. The former can learn the color distribution of various objects in nature, and the latter can recolor the image in combination with the recommended palette. The results show that our method outperforms the existing methods to a certain extent and deserves further study.

***Index Terms*—** recoloration, colorblind, natural color, color harmonization

1. INTRODUCTION

With the development of the times, diseases such as colorblindness have gradually entered our field of vision. Colorblind patients may be limited in choosing majors, occupation, and driving license exams. Color blindness can be divided into completely colour blindness and dichromatic blindness and color weakness, of which dichromatic blindness is more common. Dichromatic blindness is divided into protanopia, deuteranopia, and tritanopia.

We start from the perspective of computer vision and conduct image recoloration research for colorblind people.We found that there are some problems in the existing methods, such as the color of the converted object is not suitable enough, the color is not harmonious enough, and even the color distinction of adjacent areas is not obvious enough. Given this situation, we explore a set of methods to achieve image recoloration. We have three main contributions:

- We introduce naturalness constraints and harmonization constraints in the colorblind recoloring process.
- We explore a set of methods, first adjusting the foreground color through natural color transfer, then changing the background color to match the foreground harmonization, and finally filtering the image with the best distinction between foreground and background as the result.
- We demonstrate the effectiveness of our method through objective evaluation and subjective evaluation.

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2. RELATED WORKS

Palette-based color manipulation refers to editing images through palettes, which can be roughly divided into two types. One[1] is that the original palette and the target palette are required. The common implementation method is to extract the key colors of the original image by clustering to form the original palette, and train or define the target palette in advance. The second[2] is to only need the target palette, which can be useful for things like image recoloration and color theme enhancement.

Image recoloration for colorblindness refers to changing the color of a color image through computer processing algorithms, changing the contrast ratio between different colors.The first category is based on grayscale [3, 4]. According to the objective function obtained from the pixel point difference value, the color image is grayed. The second category is based on image segmentation [5, 6]. The common practice is to first segment the image, find the color area that colorblind patients cannot perceive, and replace it with a color with a high degree of discrimination. The third category is based on color conversion[7, 8] . This method is mainly to preserve color information, and the conversion operations in LMS, LAB, HSV, and other color spaces are involved. The fourth category is based on neural networks. X. Zhang [9] used a generative adversarial network to control the direction and recolor by adding constraints.

Many years ago, based on the principle of human cone cells receiving light signals, researchers proposed a colorblind simulation model. The model is based on the three-channel model.The colorblind simulation methods used in this paper is J.-B. Bao's method[10].

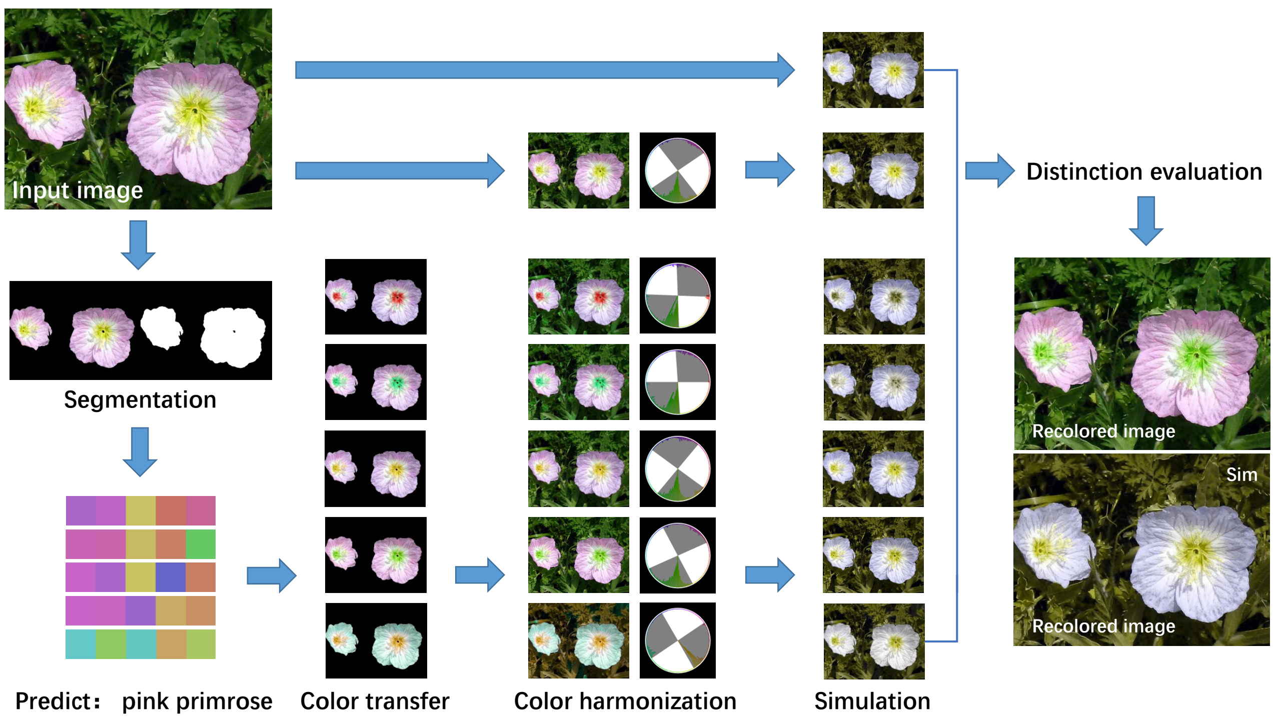

Fig. 1. Flowchart of our method. Note that the example shows the image processing results for deuteranopia, which can be achieved by adjusting the parameters of the colorblind simulation module to achieve the image recoloring results for different colorblind patients.

3. APPROACH

Our method includes a recommended palette generation part and an image recoloring part. In the recommended palette generation part, the palette of an image is first obtained by clustering. Then, the palette is extracted from other images of the current category. Finally, several representative palettes are obtained by clustering. In the process of image recoloring, first input an image, use segmentation technology to obtain the foreground and mask of the image and perform fine-grained identification to obtain the category of the foreground. Then, use the weighted recommended color palette for the natural color transfer of the foreground, and adjust the harmonization to adapt the background to the harmonization of the foreground. Later, use the colorblind simulator to calculate the colorblind simulation image, calculate the degree of discrimination between the foreground and background of the simulation image, and use the normal image of the simulation image with the highest degree of discrimination as the final result. The flowchart is shown in Fig. 1.

We use the clustering method twice to generate the palette. First, train the color palette for each image. The second step is to conduct multidimensional clustering for all the palettes of each type of image to obtain several recommended palettes. To make the recolored objects more realistic, we borrowed E.Reinhard's[11] method to adjust the H channel of the foreground HSV space combined with the information of the recommended palette.

$$I = \frac{\sigma_t}{\sigma_s}\left(S^H - mean\left(T\right)\right) + mean\left(T\right) \qquad (1)$$

S represents the original image. T represents the weighted processed hue palette matrix. H represents the H color channel, mean represents the mean. σ represents the standard deviation. I represents the adjusted hue matrix, which is the same size as the S^H.In this method, it conforms to the color characteristics of the palette and satisfies the naturalness (see examples in Fig. 2).

We changed the color of the foreground in the color transfer part. However, the problem is that the color theme of the background will not be in harmony with the color of the foreground. Based on this situation, we use the method of D. Cohen-Or [12] to adjust the harmonization of the background.First, perform harmonization template matching of the foreground to get the best matching template name and rotation angle. Note that we have added a judgment here. If the optimal palette of the foreground is a single shadow area template, the optimal rotation angle should be added by 180. This is to make the background and foreground more distinguishable. Then, the background harmonization operation

Fig. 2. Several sets of color transfer examples.

is performed according to the best template information. A group of harmonization examples are shown in Fig. 3.

We use a simulation program to simulate the colorblindness of the color-harmonized image and the original image to obtain simulated images. And then, we evaluate the distinction between the foreground and background of simulated images. For each image, extract the hue histogram of the foreground and background, and then use the Bhattacharyya distance [13] to calculate, using the Bhattacharyya distance as the distinction metric. The larger the value, the better the distinction. Finally, we select the simulated image with the largest distance, and take its normal image as the optimal result.

4. EVALUATION

To demonstrate that our method is superior to previous methods, we select several methods to compare with our method. The first method is W. Woods's method [14] based on color transformation, which adjusts the LAB space characteristics of images to enhance the color contrast of colorblind patients. The second method is S. Choudhry's method [15] based on color transformation, which can adjust the scale of color processing according to the severity of color blindness. The third method is Y.Wang's method [16] based on color transformation, which adds three constraints of detail, naturalness, and reality to the HSV space to control the direction of recoloring. The comparison methods are objective evaluation of metric analysis and subjective evaluation of filling in questionnaires. Note that the images used in the evaluation are all from the oxford flower dataset [17].

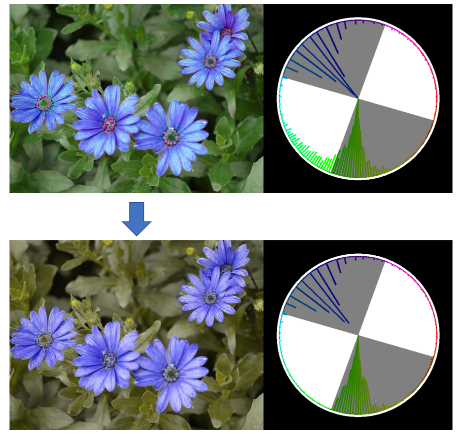

Fig. 3. Color harmonization example.

4.1. Objective evaluation

There is no suitable metric for the results of image recoloration for colorblindness. From the perspective of image processing, we use four metrics to quantitatively measure: the distinction between foreground and background, harmonization, structural similarity, and peak signal-to-noise ratio. The harmonization metric calculates the distance from the color distribution to the best harmonization template. The smaller the distance, the more harmonious the image is. Table 1 and 2 show the mean measurement results of 15 randomly selected images from the dataset.

Table 1. Quantitative results

Methods	Distinction↑	Harmonization↓	SSIM↑	PSNR↑
W. Woods[14]	0.356667	1067.949	0.637333	15.36733
S. Choudhry[15]	0.349333	7593.663	0.883333	18.26267
Y.Wang[16]	0.5078	2247.085	**0.982667**	**31.37333**
Ours	**0.782933**	**328.476**	0.905333	20.25333

Table 2. Ablation study

naturalness constraint	harmonization constraint	Distinction↑	Harmonization↓
√		0.717333	3270.105
	√	0.593533	**103.665**
√	√	**0.782933**	328.476

The distinction and harmonization are the primary metrics, and the SSIM and PSNR are the secondary metrics.

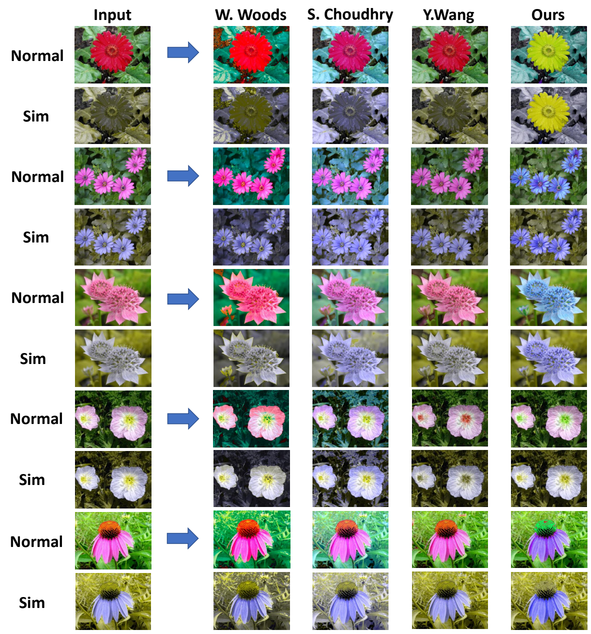

Fig. 4. Examples of objective evaluation. A total of four sets of images are included. Normal represents the normal view image. Sim represents the simulated image.

According to the evaluation data, it can be seen that our method got the highest score for the primary metrics and the second-highest score for the secondary metrics. Regarding the SSIM metric and PSNR metric, Y. Wang's method outperforms ours, which only indicates that their method changes less information about the image. But his distinction metric and harmonization metric both lag behind ours. In a word, our method makes the foreground and background more distinguishable and ensures the image is more harmonious, which is the optimal method. Fig. 4 shows several sets of samples from the objective evaluation.

In addition, the naturalness constraint and harmonization constraint were analyzed in the ablation study. The results show that the optimal degree of distinction and the suboptimal degree of harmonization can be obtained by including two constraints simultaneously. Overall, it is better to include both constraints than a single one. Therefore, both constraints are valid.

4.2. Subjective evaluation

We conducted a questionnaire that assessed four items. Ten sets of images are included in total, and each set consists of the results obtained by several different methods and our method. Measures include naturalness, harmonization, distinction and comprehensive consideration. It is worth noting that because color blind people are not common in life, we decided to find people with normal color perception to fill out the questionnaire from the perspective of respecting privacy and considering the actual situation. We gave out a total of 20 out of order questionnaires, and the mean scores is shown in Fig. 5.

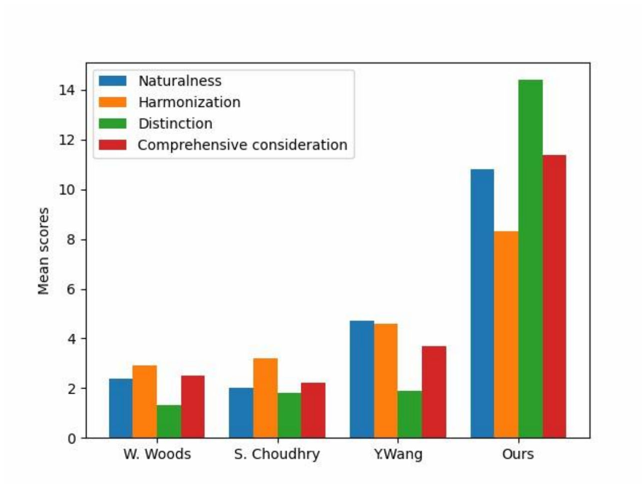

Fig. 5. Mean scores for each method. The x-coordinate represents three other methods and mine. The y-coordinate represents the average of the selected cases for each method result (divided by the number of groups by 10), with a range of 0 to 20.

According to the subjective evaluation, our method is recognized by the respondents in terms of naturalness, harmonization and distinction, especially for the item of distinction. Our method produces multiple images to be selected in the process, and the optimal image is calculated by the discrimination algorithm as the result. Therefore, our method was evaluated as expected.

5. CONCLUSIONS

Given the shortcomings of the existing colorblind recoloration technology, we have explored a set of methods to achieve image recoloration. Through the modules of foreground naturalness adjustment, harmonization adjustment, and distinction evaluation of foreground and background, good results are obtained. Please note that our approach focuses on illustrating the workability of the entire process. The advantages and disadvantages of each branching module technique are not the focus. Of course, there are still some shortcomings in our method. Next, we intend to improve the segmentation part first, so that it can automatically recognize multiple objects and adjust the color of each of them. Then, optimize the algorithm to increase the processing speed. Finally, we wanted to create an electronic device (color blindness aid) that would find a balance between speed and quality to enable real-time recoloring for colorblind patients.

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