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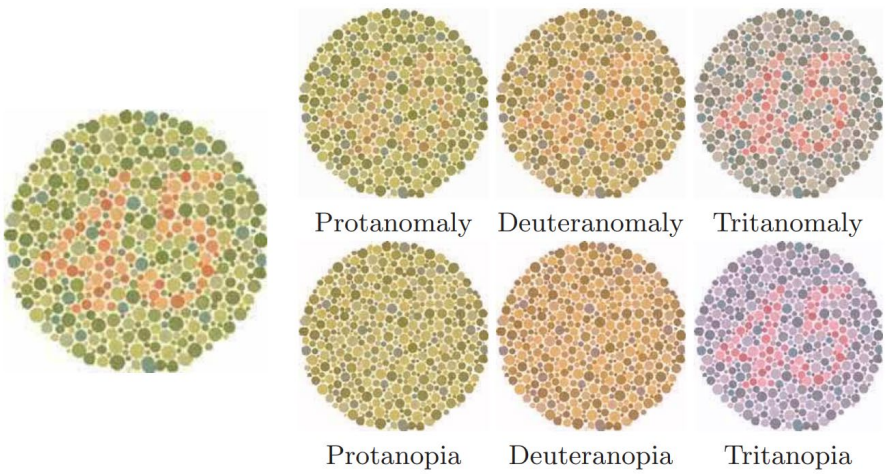
1. INTRODUCTION

1.1 Introduction to the topic

Among the many tasks the eye can perform, one of the eye's key tasks is to aid in the determination of the many variations of color. Color perception is one of the essential functions of human vision. Color is a powerful feature that eases communication among humans. The colors are detected based on the absorption of combinations of wavelengths through the retina which allows the brain to perceive the different variations of color. The cone cells present in the retina are responsible for identifying colours. Color blindness can happen when one or more of the color cone cells are absent or not working. A person with color vision deficiency (CVD) cannot distinguish one or more colors from red, blue, green, and yellow.

CVD has different types and degrees of severity depending on the type and the number of affected photoreceptor cells of the eye. It can be classified into three types namely, anomalous trichromacy (Protanomaly, Deuteranomaly, and Tritanomaly), dichromacy (Protanopia, Deuteranopia, and Tritanopia), and monochromacy. People with anomalous trichromacy are 'weak' in perceiving a specific color whereas dichromats are a specific color blind. People with monochromacy either perceive all colors in grayscale shades.



2. ABSTRACT

People with color vision deficiency (CVD) cannot distinguish between colors due to the damage of color reception nerves. In this work, I have presented the working of simulation of images (color blind view) and implemented image enhancement approach that increases the contrast and brightness of the image to assist colorblind people to identify the colors they are not able to distinguish naturally. Used pix-pix GAN for implementing the recoloring algorithm to produce new datasets. The image recoloring algorithm is based on equalizing certain components in the image color space. The experimental results show that my approach is useful for the recognition and separation of the CVD confusing colors in natural scene images

3. PROBLEM STATEMENT

GAN for CVD

Creation of a data set for CVD since the data sets for CVD are very limited and setting up 2-3 GANs for recoloring images for the colorblind in an optimized manner. The optimization function would involve identification of the confusing colors, identification of the replacement color, and color compensation in optimized time.

4. OBJECTIVE

My main oobjectives in this project are, to implement an existing recoloring algorithm and try to produce better results with the same. To use general adversarial networks to apply the recoloring algorithm so that it becomes easy for creating large, new datasets and better recolored images.

5. MOTIVATION

As much as 5% of the population suffer from color vision deficiency, most of them being men. Since there is no cure for this so far, the best thing that can be done is to help color blind people in distinguishing the colors better and contributing to further research in this field. Color vision deficiency can affect a person's life well beyond simply being unable to see specific colors. This issue becomes even more pertinent due to the increasing availability of multimedia content in the computational environment. Aware of this problem, a number of CVD research works came up in the literature in the past two decades to improve color perception. Since the research had only begun recently the algorithms are yet to be efficient enough and there is a lack of datasets in the field.

6. METHODOLOGY

In brief, for proceeding with the project, initially, a detest of flowers containing 20,000 images was obtained from the website of the university of oxford. We made a new set of 1000 images which mostly contained red and green components since red blindness was considered an example all throughout the project. Using this smaller dataset, we produced a set of simulated images (protanope's view). I have applied a slightly changed version of Huang et al's method to the simulated images and finally got the recolored images in which the contrast and brightness were improved. The dataset of original images of flowers and the final recolored images will be used to train the GAN that results in the production of better-recolored images and also creates new examples from the existing ones.

7. EXPERIMENT

7.1 Image processing and Recoloring

Image processing is the process of performing certain operations to get some useful information from it. There are five main types of image processing:

- Visualization
- Recognition
- Sharpening and restoration
- Pattern recognition
- Retrieval

Image recoloring/enhancement can be considered as a part of the image processing techniques. Image enhancement is the process of bringing out and highlighting certain features of interest in an image that has been obscured. This process for color vision deficiency mainly involves working with the intensity (contrast, brightness etc.) of the image so that the colour-blind people can better distinguish between different colors.

7.2 Simulation

Before getting into the implementation part of the recolouring algorithm we should first be able to know how the color blind people view the images. This simulation is a very important aspect to understand. For example, consider a person with red blindness (protanopia) [hereafter read blindness will be considered for the examples] below is the original image of a flower.

Original image

The following images shows how a red blind person would see the flower:

'Coblis'(Online simulator)

Coded

In the simulation algorithm, initially, the RGB color space can be converted to the XYZ color space using a transformation matrix MsRGB. This can then be converted from the XYZ color space to the LMS color space using the Hunt-Pointer-Estevez transformation matrix MHPE. In short, MsRGB and MHPE can be multiplied to calculate one transformation matrix T for converting colors from the Linear RGB color space to the LMS color space. Protanopes are missing L cones so lc=0. This modified color in LMS color space can then be converted back to Linear RGB using T−1 and applying gamma correction.

7.3 Recoloring Algorithm

In the past two decades, a significant number of recoloring algorithms for CVD people have been proposed. Recoloring methods must satisfy three perceptual requirements

- contrast enhancement
- color consistency
- color naturalness

in order not to disturb that much the perceptual learning of CVD people. Though these are the important conditions, not all the methods satisfy these three properties. In fact, there has been no method that satisfies all three conditions together. A specific recoloring method is suitable only for a certain type of color vision deficiency.

The Recoloring algorithms can be broadly classified into the following categories based on the type of color space used in the algorithm:

- LMS based

- RGB based
- HSx (HSV, HIS, HSL) based
- CIE based

HSx color models (HSI, HSL, and HSV) are known as mind representations of colors; color components are the hue (H), saturation (S), and brightness (i.e., intensity (I), lightness (L), or value (V)). In the case of protanopy, the dichromat condition leads to a significant reduction of the image contrast because of which a HSx-based algorithm can give better results.

Protanopes mainly confuse reddish and greenish colors. Thus, most HSx-based methods focus on discriminating these confusing hues.

Huang et al.'s method-

This method applies to both anomalous trichromacy and dichromacy. It is a compensation recoloring method by remapping the hue components in the HSV color space. Therefore, the recoloring pipeline is as follows:

$$(R, G, B) \rightarrow (H, S, V) \rightarrow (H', S, V) \rightarrow (R', G', B').$$

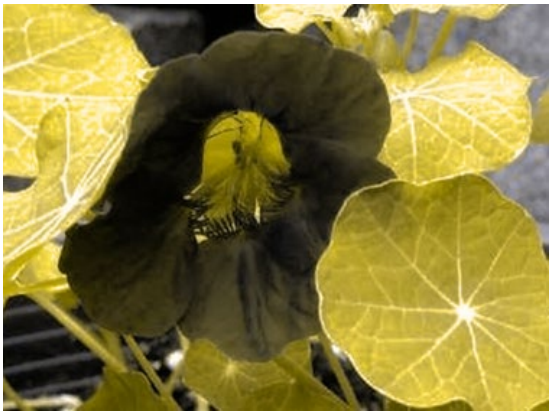
The remapping of the hue components in the HSV color space is performed using a histogram transformation, which has the effect of enhancing the hue contrast. Histogram Equalization is an image processing technique that adjusts the contrast of an image by using its histogram. It stretches out the intensity range of the image.

The slight changes made to The Huang et al's method are, the initial image was converted into a BGR color space from the RGB color space before converting it into HSV color space. Equalized 'V' component along with 'H' component for better brightness. Below are the

results obtained from applying the recoloring algorithm on the simulated (protanope's vies) image.

Protanope's view [1]

Recolored image [2]



Protanope's view of the recolored image [3]

Image [1] is how a red blind image views the images of a red flower and finally after applying the recoloring algorithm, the view of the color-blind person changes to the image [3]. Hence it can be concluded the ultimate goal of the algorithm was achieved which was to increase the contrast and also the brightness of the image.

7.4 Recoloring using GAN

A generative adversarial network is a type of learning that involves automatically discovering and learning the regularities or patterns in input data in such a way that the model can be used to generate or output new examples that plausibly could have been drawn from the original dataset. The GAN model architecture involves two sub-models:

- *generator model*: for generating new examples
- *discriminator model:* classifying whether generated examples are real, from the domain, or fake, generated by the generator model.

The Cycle GAN used in the current project is a technique that involves the automatic training of image-to-image translation models without paired examples. The models are trained in an unsupervised manner using a collection of images from the source and target domain that do not need to be related in any way.

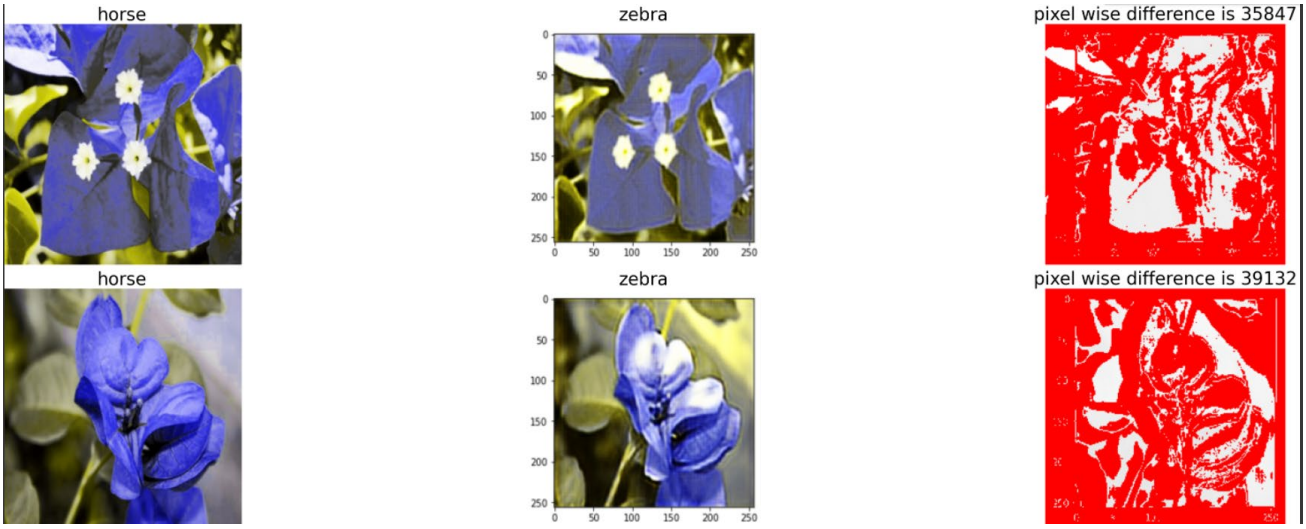
Using the GAN architecture for recoloring images has been proven to produce efficient results. First, a CVD simulation module is introduced and integrated with recoloring algorithms. A color-to-gray module is added to eliminate the distortion. Multiple GANs i.e., pix2pix-GAN, Cycle-GAN, Bicycle-GAN are used for colorblind data conversion. These datasets provide some help for color-blind image recoloring.

As shown in the following, the first row shows the original images, and the second row shows the GAN generated recolored images.

8. RESULTS AND DISCUSSION

An algorithm has been used to compare the recolored image produced from the recoloring algorithm and the recolored image produced using GAN, assuming they have the same dimensions and compares the two images pixel by pixel. This model is sensitive to a lot of factors (operating system, GPU, drivers, …) and works best when testing is done on the exact same machine with the exact same configuration. As shown below, we applied pixel by pixel algorithm to Recoloring Algorithm generated images and GAN generated recoloring

images, we got 35,847 pixel-wise differences for the first set of images and 39,132 pixel-wise differences for the second set of images. The pixel difference can be decreased if we increase the number of epochs for a given GAN algorithm, as we get better images.



9. CONCLUSION

For proceeding with this project, initially, a detest of flowers containing 20,000 images was obtained from the website of the university of oxford. I made a new set of 1000 images which mostly contained red and green components since red blindness was considered as an example all throughout the project. Using this smaller dataset, I produced a set of simulated images (protanope's view). I have applied a slightly changed version of Huang et al's method to the simulated images and finally got the recolored images in which the contrast and brightness were improved. The dataset of original images of flowers and the final recolored images will be used to train the GAN that results in the production of better-recolored images and also creates new examples from the existing ones.

Hence it can be concluded that as expected, the images produced had high contrast and improved brightness after applying the recoloring algorithm. Though the hue contrast got better the color naturalness may not be held for all images, because the hue rotation may result in an entirely different hue. In some cases, the color consistency may not be preserved too, because the remapping of a given hue depends on the frequency (i.e., number of times) of each hue in the image. The research on using general adversarial networks for color vision deficiency had only begun as recently as 2 years back. Multiple GANs are being evaluated against recoloring and it has been proven that using any GAN architecture can provide us with better results.

10. LIMITATIONS

Research around this area about recoloring algorithms for the color-blind has only started in the recent times and it still has not been extended extensively into algorithms for recoloring videos and dynamic images. There are a smaller number of datasets available for researchers to review any past research work or to test their algorithm in large numbers. There's no direct tool to convert a large set of images into recolored images directly. Yet, there are no recoloring algorithms that can be used for all types of color-blindness. Moreover, in the available algorithms often there is a trade-off between preserving the naturalness and contrast of the original image when it is recolored.

11. FUTURE SCOPE

This research field on recoloring algorithms to aid people with color vision deficiency is still in its early stage and hence has a larger scope in the near future. One of the main extensions that I would like to work on is, applying recoloring algorithms to videos and not-still images as most of the current algorithms only support recoloring of still images. Also, instead of just adjusting and increasing the contrast in still images, I will try working with recoloring algorithms that preserver the naturalness and intensity of the original image to produce better results. Building a frontend tool where the user can upload desired set of original images and obtain recolored images of the same, combined with newer and better recolored images will be very useful for researchers who want to check the working of their algorithm and also this leads to an increase in the number of datasets making it easy for reviewing the past data in research.

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