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Real Time Color Image Enhancement with a high regard for restoration of skin color by using Raspberry Pi

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ABSTRACT: Raspberry Pi is employed as a basic embedded system and being a low cost single-board computer, it has emerged to be immensely popular in recent times. This paper mainly deals with natural color of an image including human faces in HSI color space. In this kind of image, it is necessary to describe skin color accurately hence we go on to restore the image based on this criterion. Histogram equalization (HE) is a popular technique for contrast enhancement of images. In order to vary the enhancement degree to get proper skin color, HE with variable enhancement degree (HE-VED) is introduced. The enhancement degree of HE-V ED is controlled by intensity and saturation parameter and JI respectively. Dark and low contrast images were captured using the Raspberry Pi camera module and HE-VED was applied to enhance the objective image in a particular enhancement degree automatically with help of Raspberry Pi. Lastly HE-VED was extended to a complete image and appreciable results were obtained which could be further enhanced using different pseudo coloring techniques.

KEYWORDS: Histogram equalization, HSI color space, Python image library, Raspberry Pi, skin color.

1. INTRODUCTION

Histogram equalization is a very common technique usually employed for enhancement of grayscale images. It is preferred because of its simplicity. It is advantageous because it yields desirable results in most cases, but this concept cannot be directly applied to color images in HSI color space. HSI color space describes an image using three parameters, i.e. hue, saturation and intensity [1], [2]. HE has been used in various enhancement techniques [3] and has been extended to 3-D by Trahanias et al. [4]. Most of the current methods [5]-[7] provide enhanced results in most cases but fail to do that in case of images with human skin, reason being that if HE is applied to the hue component, the skin tone gets altered which is absolutely undesirable. Hence we restrict the application of HE to saturation and intensity parameters only. If we directly apply HE, some regions become too dark and some regions remain too bright because HE fails to adapt with the local brightness of the image [3]. When HE was applied to some images captured in poor lighting conditions, the image was found to be highly pixilated and the original color of the image was lost as represented in Fig. 8(b). So the degree of HE needs to be controlled so that the original skin color is retained. Hence we use HE-VED [8], [9] which computes the hue, saturation and intensity components of the desirable skin color from a given reference image and then modifies the target image accordingly.

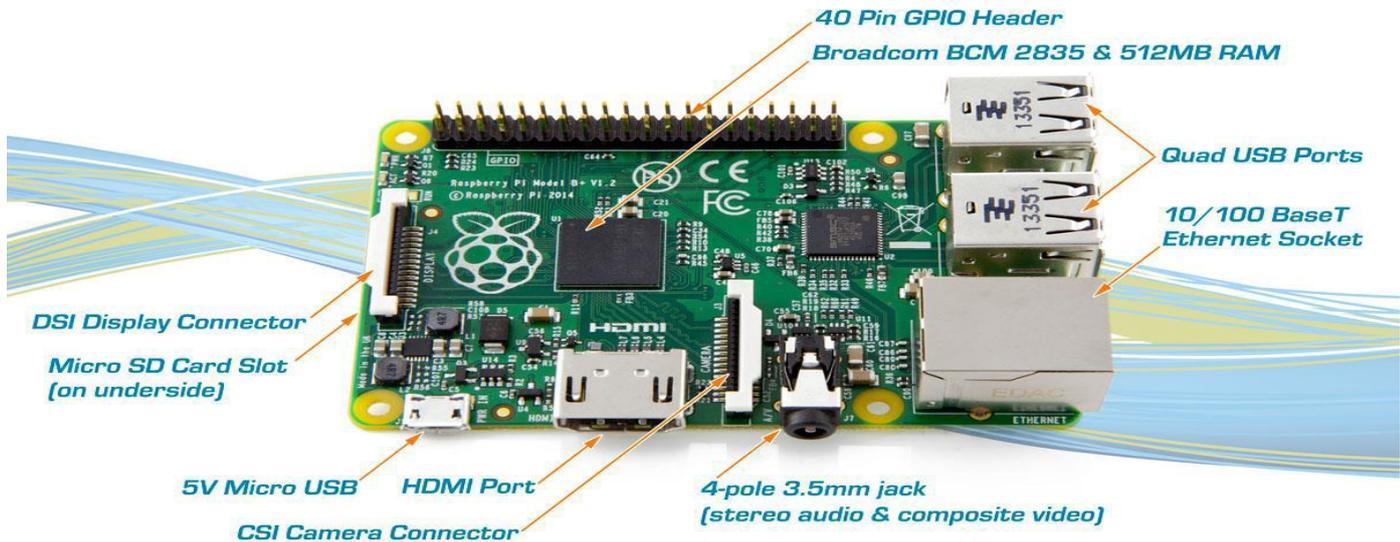


Fig.1. Raspberry Pi board (Model B).

For this paper, of course you will need a Raspberry Pi board. The version of the board or the model (A or B) doesn't really matter, but keep in mind that you will have to connect it to your local network, so you will need a Wi-Fi dongle if you are using the A model which doesn't have an Ethernet port. In this paper, we used a Raspberry Pi model B with the Wi-Fi dongle.

The Raspberry Pi is a credit-card-sized single-board computer developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools. The Raspberry Pi has a Broadcom BCM2835 system on a chip (SoC), which includes an ARM1176JZF-S 700 MHz, Video Core IV GPU, and was originally shipped with 256 megabytes of RAM, later upgraded to 512 MB. It does not include a built-in hard disk or solid-state drive, but uses an SD card for booting and long-term storage.

Now also to check that your Raspberry Pi is connected to the Internet. Again, this will depend on your configuration (Ethernet or Wi-Fi) and your router, but is usually really easy. If you are using the Ethernet connection, simply connect a cable to your router and it should work automatically. If you're using a Wi-Fi dongle, the easiest solution is to use the GUI that comes with Raspbian to find your wireless network and enter your WEP/WPA password. For implementing the proposed enhancement algorithm we have used the Raspberry Pi (Fig.1). The Raspberry Pi is a low cost, **credit-card sized computer** that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

II. SYSTEM CONFIGURATION

The basic hardware requirements are a Raspberry Pi board (model B), a USB hub, a USB keyboard and mouse. An HDMI enabled display device is also required along with a micro USB charger to power the board. An SD card is required to boot the Raspberry Pi.

A) Preparation of SD card for Raspberry Pi.

Raspberry Pi lacks a very important feature, i.e., Basic input output system (BIOS). So the Pi always needs a SD card loaded with a snapshot of an operating system to boot up. After downloading the image, we must prepare a snapshot of the image on the SD card for the Pi to boot [10], [11].

B) Network configuration.

Network configuration should be done for the Pi to enable installation of different packages, dependencies and to regularly update and upgrade the operating system.

III. HISTOGRAM EQUALIZATION WITH VARIABLE ENHANCEMENT DEGREE

A) Histogram Equalization is mostly applied to grayscale images with poor contrast and yields enhanced results for most type of images. Assume original image $g(i, j)$ consisting of discrete gray level values in the range of $[0, L-1]$. The histogram of the original image $g(i, j)$ is represented by $h(x)$ ($0 \leq x \leq L-1$) where x is the gray level value. The number of pixels is assumed to be N . According to the HE, the gray level x is converted to y as follows. Here $H(x)$ is the cumulative histogram and f_{HE} is the transformation function.

$$Y = f(x) = [H(x). (L-1)/N]$$

B) To obtain the results in different enhanced degree we have used HE-VED

$$ha(x) = \alpha \{h(x)-(N/L) \}+(N/L)$$

$$ya = f_{HE-VED}(x) = [Ha(x).(L-1)/N]$$

$$ya = f_{HE-VED}(x) = \alpha f_{HE}(x)+(1- \alpha).x$$

If α is set to 0, the enhanced image is equal to the original image. On the other hand, if α is set to 1, the HE-VED is equivalent to HE [9]. Thus we can see that the HE-VED is changeable from identity operation to HE which gives us sufficient flexibility to adapt it to the target image.

C) Flowchart of proposed HE-VED method is given below:

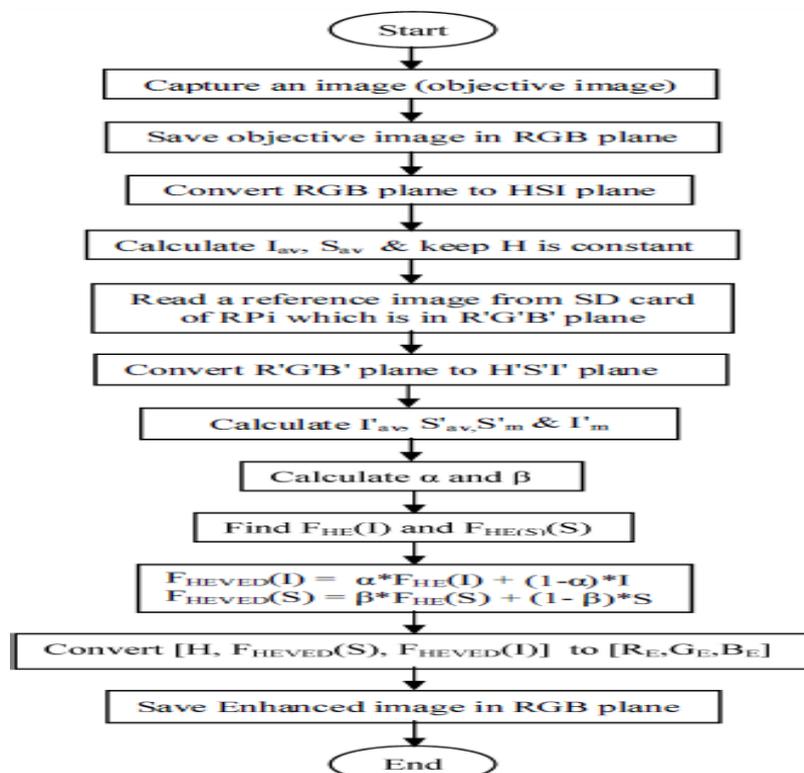


Fig.2. Flowchart

We have stated the step by step procedure and results for the implemented HE-VED algorithm.

IV. EXPERIMENTAL RESULTS

This step involves the capturing of a target image by the Raspberry Pi camera module. Usually this image should be captured in poor lighting conditions to observe the enhanced results clearly. The captured image was saved in the RGB color space and then converted to HSI color space. After conversion the resultant image was stored in a file. The average of the intensity I_{av} and the average of saturation S_{av} were calculated for the captured objective image.

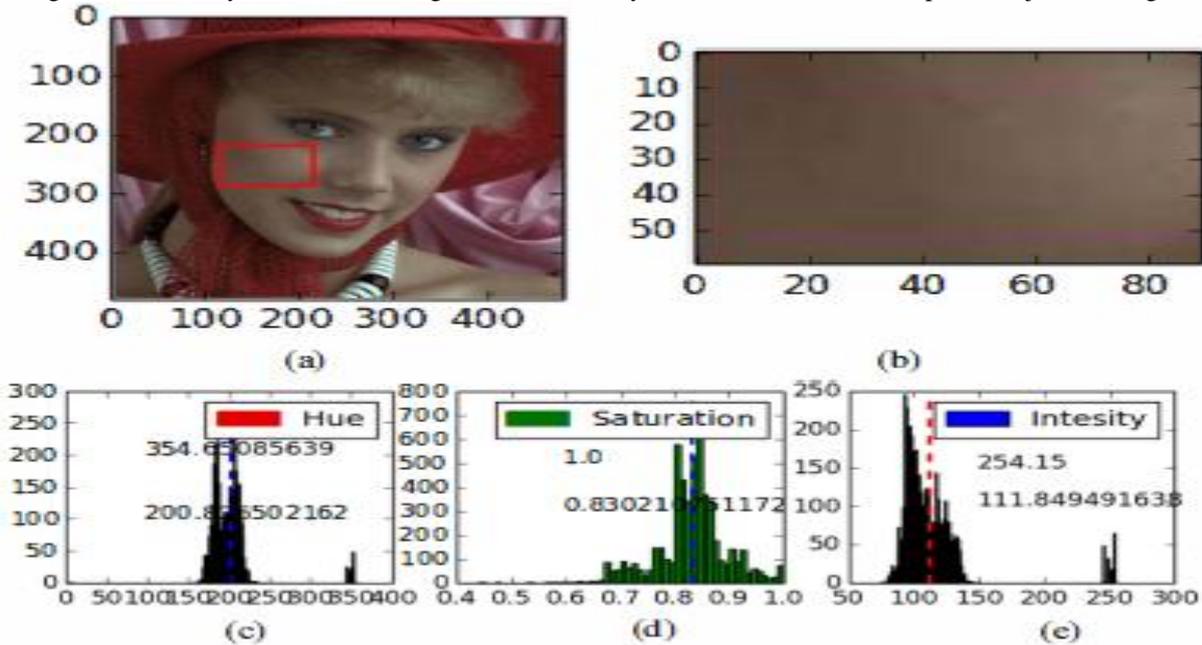


Fig.3. Objective Image and its histogram (a)Objective Image (b) Section of the image used for histogram and calculation of α and β (c) Hue histogram (d)Saturation histogram (e) Intensity histogram.

In this case the values were found to be $S_{av} = 0.83021075117$, $I_{av} = 111.8495$, $S_m = 1.0$, $I_m = 254.15$.

Now the reference image is read from the SD card of the Raspberry Pi which too is initially in RGB color space. It was converted to HSI color space. Then the average of saturation S'_{av} and average of intensity I'_{av} were calculated along with their maximum values S'_m and I'_m .

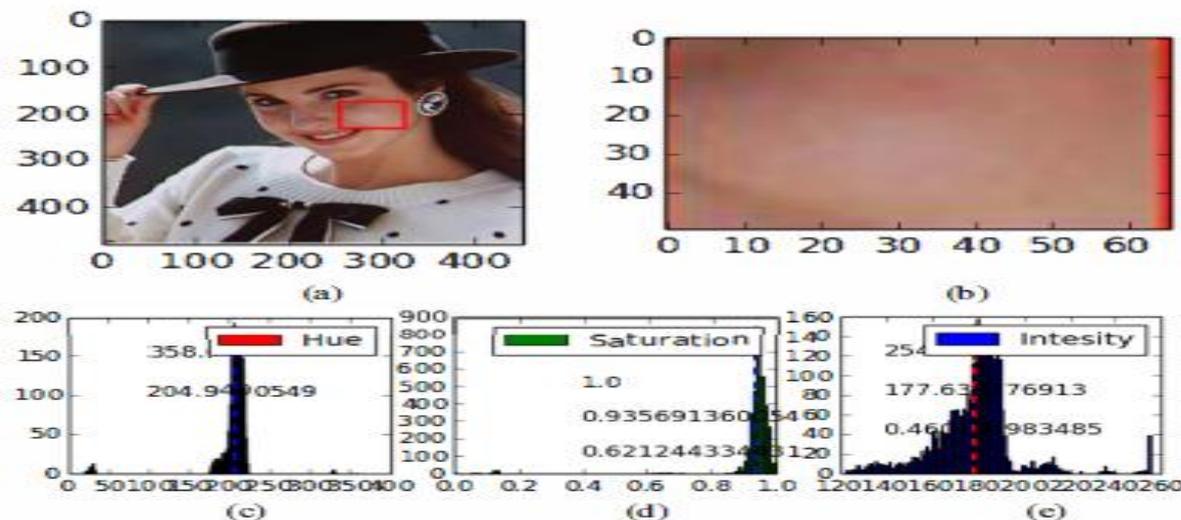


Fig. 4. Reference Image and its histogram (a) Reference Image (b) Section of the image used for histogram and calculation of α and β (c) Hue histogram (d)Saturation histogram (e) Intensity histogram.

In this case the values were found to be $S'_{av}=0.93569136, I'_{av}=177.64, S'_m=1.0, I'_m=254.8$

This is the most important step. Now we need to calculate α and β where α represents the degree of HE for the intensity parameter and β represents the degree of HE for the saturation parameter. If α and β is set to 1 then the operation is identical to HE and if it is set to 0 then it results in identity transformation. They are calculated as follows.

$$\alpha = \frac{I'_{av} - I_{av}}{I'_m - I_{av}}$$

$$\beta = \frac{S'_{av} - S_{av}}{S'_m - S_{av}}$$

Using the above formulae we can calculate the saturation and intensity values so as to resemble the reference image as closely as possible.

Since we are enhancing the image with special regard to skin color so we use a section of the image instead of the entire image which has the desirable and correct skin color for plotting of histogram and calculation of α and β . Now we find $F_{HE}(I)$ and $F_{HE}(S)$ for intensity and saturation.

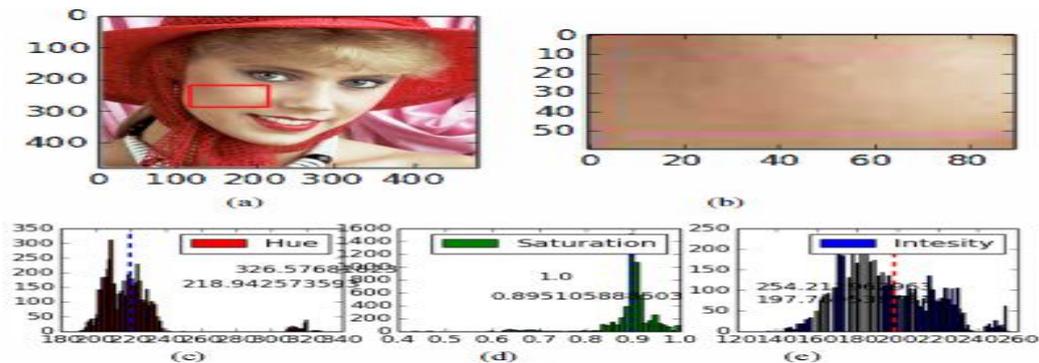


Fig.5. Objective Image after HE and its histogram (a) Objective image after HE (b) Section of the image after HE (c) Hue histogram (d) Saturation histogram (e) Intensity histogram.

Now we shall apply HE-VED to intensity and saturation components. α and β are defined as variable parameters of HE-VED for intensity and saturation, respectively. To compute the intensity component of HE-VED $[F_{HE-VED}(I)]$ and the saturation component $[F_{HE-VED}(S)]$ as follows.

$$F_{HE-VED}(I) = \alpha * F_{HE}(I) + (1 - \alpha) * I$$

$$F_{HE-VED}(S) = \beta * F_{HE}(S) + (1 - \beta) * S$$

Finally we convert $F_{HE-VED}(S)$, $F_{HE-VED}(I)$ and H back to RGB color space as R_E, G_E, B_E . The R_E, G_E, B_E component will give the result enhancement image. After obtaining the enhanced image in RGB color space we save it to a file.

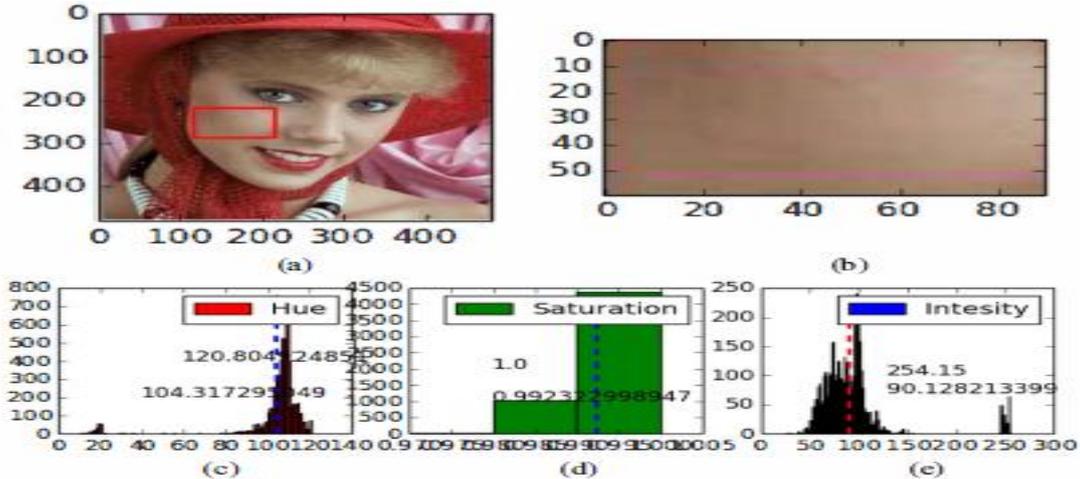


Fig. 6. Objective Image after HE-YED (a) Objective Image after HE-YED

(b) Section of the enhanced image after HE-VED (c) Hue histogram (d) Saturation histogram (e) Intensity histogram. Results for comparison

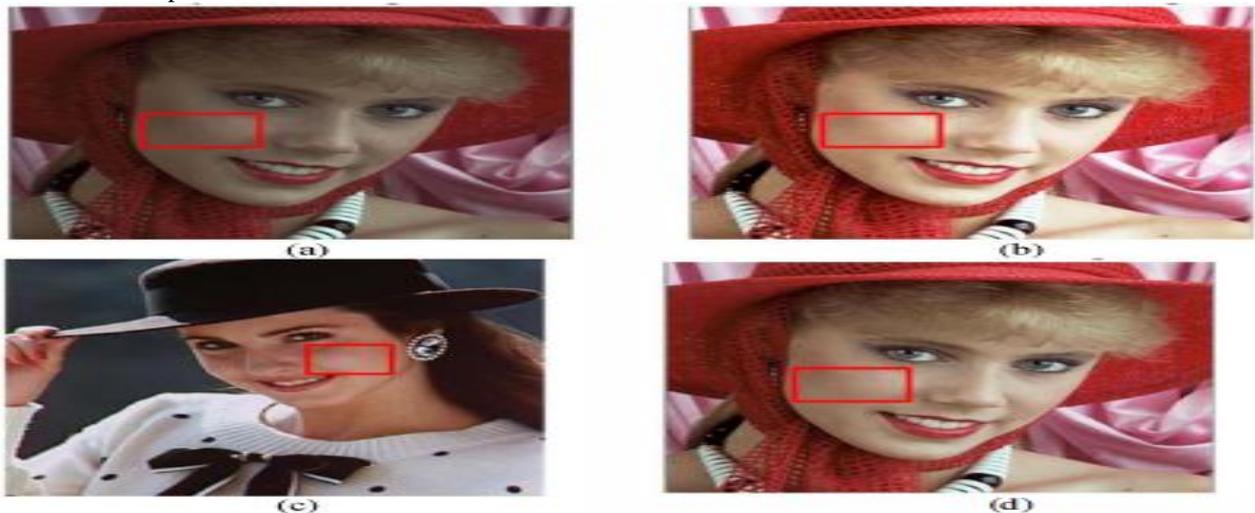


Fig.7. (a) Objective Image (b) Enhanced image (c) Reference Image (d) Enhanced result Image.

V. REAL TIME IMPLEMENTATION OF HE-VED TO COMPLETE IMAGE

For the purpose of real time simulation the Raspberry Pi running the latest version of Rasbian Wheezy was used. The development environment was Python 2.7.5 and Open CV 2.3.1. Once the user captures the objective image and specifies the reference image, the rest of the process is completely automatic and there is no need for user intervention. Here the algorithm has been applied to the complete image.

VI. CONCLUSION

We implemented the algorithm to enhance an image in different enhancement degree. It was found that the algorithm developed for the Raspberry Pi executes successfully and gives a very colorful image.

In this Paper, the parameters vary in order to restore human skin and it enhances a color image in a particular enhancement degree to restore original color. Therefore we conclude that the proposed method enhances color image in a particular degree effectively.



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