Establishment of an Efficient Color Model from Existing Models for Better Gamma Encoding In Image Processing

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Abstract

Human vision is an important factor in the areas of image processing. Research has been done for years to make automatic image processing but still human intervention can not be denied and thus better human intervention is necessary. Two most important points are required to improve human vision which are light and color. Gamma encoder is the one which helps to improve the properties of human vision and thus to maintain visual quality gamma encoding is necessary.

It is to mention that all through the computer graphics RGB (Red, Green, and Blue) color space is vastly used. Moreover, for computer graphics RGB color space is called the most established choice to acquire desired color. RGB color space has a great effort on simplifying the design and architecture of a system. However, RGB struggles to deal efficiently for the images those belong to the real-world.

Images are captured using cameras, videos and other devices using different magnifications. In most cases during processing, in compare to the original outlook the images appear either dark or bright in contrast. Human vision affects and thus poor quality image analysis may occur. Consequently this poor manual image analysis may have huge difference from the computational image analysis outcome. Question may arise here why we will use gamma encoding when histogram equalization or histogram normalization can enhance images. Enhancing images does not improve human visualization quality all the time because sometimes it brightens the image quality when it is needed to darken and vice-versa. Human vision reflects under universal illumination environment (not pitch black or blindingly bright) thus follows an approximate gamma or power function. Hence, this is not a good idea to brighten images all the time when better human visualization can be obtained while darkening the images. Better human visualization is important for manual image processing which leads to compare the outcome with the semi-automated or automated one. Considering the importance of gamma encoding in image processing we propose an efficient color model which will help to improve visual quality for manual processing as well as will lead analyzers to analyze images automatically for comparison and testing purpose.

Keywords: Gamma, Human Vision, RGB, HSI, HSB, Light.

1. INTRODUCTION

A color space can be defined as the mathematical illustration of a set of colors. In the areas of image processing there are different color models available of which RGB (mainly used for computer graphics), YUV, YIQ, or YCbCr (used for video systems) and CMYK (used for color printing) are most popular. However, it is to mention that, for instinctive ideas of hue, saturation and brightness; the above three color models are not directly related at all. For this perspective, HSI, HSV or HSB are suitable color models for programming simplicity, end user manipulation and processing purposes although all of these color models is derived from the RGB information supplied by devices such as cameras and scanners [1,2,3,4].

Color Model	Classifications
Munsell	Device dependent
RGB, CMY(K)	Device dependent
YIQ,YUV, YCbCr	Device dependent
HSI, HSV, HSL	User oriented-Device dependent
CIE XYZ, CIE L*U*V*, CIE L*a*b*	Device independent, color Metric

Table 1: Color Models Classifications.

Color Model	Application Area
Munsell	Human visual system
RGB	Computer graphics, Image processing, Analysis, Storage
CMY(K)	Printing
YIQ, YUV	TV broadcasting, Video system
YCbCr	Digital video
HSI, HSV, HSL	Human visual perception, Computer graphics, processing, Computer Vision, Image Analysis, Design image, Human vision, Image editing software, Video editor
CIE XYZ ,CIE L*U*V*, CIE L*a*b*	Evaluation of color difference, Color matching system, advertising, graphic arts, digitized or animated paintings, multimedia products

Table 2: Application Areas of Color Models.

It is to mention that all through the computer graphics RGB (Red, Green, and Blue) color space is vastly used. Moreover, for computer graphics RGB color space is called the most established choice to acquire desired color. RGB color space has a great effort on simplifying the design and architecture of a system. However, RGB struggles to deal efficiently for the images those belong to the real-world. Moreover, processing images with the help of RGB color model is not an efficient method either.

Various types of color model have been established already. One main color model is RGB color model where 3 different colors are added together in different ways to produce a wide range of colors. As for example for a 24 bit RGB color image, a total number of colors can be $(2^8)^3$ = 16,777,216.

RGB color model is used to represent and display images in electronic systems. It is to mention that RGB color model is device dependent as Red, Green and Blue levels are different from manufacturers to manufacturers. Sometimes these colors vary even in same devices over a period of time and hence without a color management RGB color value does not acts as same in devices.

To display RGB colors in hardware a display card named cathode ray tube (CRT) is used to handle the numeric RGB color values and in most CRT displays do have a power-law transfer characteristic with a gamma of about 2.5. In most occasions it has been observed that gamma remains out of consideration. Under these circumstances, an accurate reproduction of the original scene results in an image that human viewers judge as "flat" and lacking in contrast.

To improve the quality of visual perception for color images, the term image enhancement is an important factor. Image enhancement is needed in many areas such as photography, scanning, image analysis etc. Image enhancement approaches fall into two broad categories such as spatial domain and frequency domain methods. The term spatial domain refers to the image plane itself, and approaches in this category are based on direct manipulation of pixels in an image whereas frequency domain processing techniques are based on modifying the Fourier transform of an image.

Color image enhancement is considered the most frequently used method these days using adaptive neighborhood histogram equalization technique [14]. 3D histogram equalization has been proposed using RGB cube [15]. A new approach considering enhancement problem has been established [13, 20]

There are some more techniques available for wavelength based image enhancement which helps to enhances the image edges [19]. It is generally unwise to histogram equalize the components of a color image independently because it causes erroneous color. A more logical approach is histogram normalization while spreading the color intensities uniformly, leaving the color themselves (eg. Hue) enhanced.

Images can be gray-level images or color images. Comparing with color images gray-level images have got only one value for each pixel as images are made with pixel representation. There are many existing algorithm available which helps to enhance the image contrast for gray-level images considering piecewise-linear transformation function named contrast stretching with normalization, stretching with histogram techniques. Most of these available algorithm are not suitable for color images although they are used widely having poor quality and distorted effects [5].

Gray level transformation is proved to be better approach than any other transformation and hence most proposed methods are based on spatial domain approach. Image enhancement using spatial domain works with gray-level transformation or power law transformation. Power law equation is referred to as gamma.

$s = cr^{\gamma}$; where c and r are positive constants. Value of c= 1 and the value of gamma can vary to set the desired result and the process used to correct power-law transformation phenomena is called gamma correction or gamma encoding.

However, it is to mention that, only enhancing the image does not improve the image quality for better visual perception. Sometimes it is needed to darken the bright images to obtain a better visualization [6]. Gamma is one of the main factor which helps to brighten or darken an image.

The above mentioned techniques are widely used in the areas of image enhancement without much considering the color shifting issues. A color image enhancement technique should not change a pixel value from red to yellow as an example although in some cases color shifting may be necessary while controlling them before it can be applied. Hue is one of the main properties of a color and hence it is not easy to control hue in color enhancement especially in RGB color model. The color shifting issue has been considered in some research by Gupta et al, Naik et al where it has been suggested that hue should be preserved while applying image enhancement method [16, 17, 18]. These methods keeps hue preserved and avoids color shifting but still there are problems. However, enhancement does not resolve human visualization perfectly because sometimes images need to make dark instead of enhancement. In that case enhancement does not help at all.

To resolve the above mentioned for human visualization considering two issues 1) color shifting and 2) human visualization we have come up with an idea that gamma encoding is necessary while decomposing the luminance (is an objective term and it is a measure of the amount of light coming off from a source, or reflected from an object) or brightness (perception of how much light is coming from a source or an object, and depends upon the context as well as the luminance) and for saturation instead of histogram equalization, histogram normalization can be applied.

This research aspires to establish an efficient color model for better gamma encoding in image processing from all the existing color models available at this moment.

2. METHODOLOGY

Our proposed gamma encoding technique is based on spatial domain instead of frequency domain approach.

In RGB color model, there are three primary colors considered named Red, Green and Blue where RGB is defined as additive or subtractive model and hence different colors can be preformed using the combination of these primary colors. But for HIS (hue, saturation, intensity) and HSV (hue, saturation, value) or HSB (hue, saturation, brightness) color spaces were developed to distinguish and understand color by human. Hue is the main attribute of a color and thus decides which color the pixel has obtained. However, hue should not be changed at any point because changing the hue changes the color as well as distortion occurs in the image. Moreover, comparing with color space like CIE LUV and CIE Lab, in HSB it is easy to control hue and color shifting. Our main approach is to preserve the hue and apply better human visualization using saturation and brightness and hence we have chosen HSB color space instead of other color space [21, 22, 23].

It is to mention that for traditional image processing such as histograms, equalization HSI color space is one of the best model [7]. However, HSB color space is one of the best for manipulating hue and saturation (to shift colors or adjust the amount of color) and thus it capitulates a better active range of saturation [8].

3. COLOR MODEL CONVERSION

2.1 RGB to HSB

Below equations describes the conversion from RGB to HSB color space. For easier definition we have used maximum and minimum component values as M and m respectively and R for Red, G for Green and B for Blue and C is the difference between maximum and minimum.

$$M = \max(R, G, B) \tag{1}$$

$$M = \min(R, G, B) \tag{2}$$

$$C = M - n \tag{3}$$

Hue is the proportion of the distance around the edge of the hexagon which passes through the projected point, measured on the range [0,1] or in degree [0,360]. Mathematical expression for hue is

$$H' = \begin{cases} Undefined, & if \quad C = 0 \\ \frac{G-B}{C} \bmod 6, & if \quad M = R \\ \frac{B-R}{C} + 2, & if \quad M = G \\ \frac{R-G}{C} + 4, & if \quad M = B \end{cases} \qquad (4)$$

$$H = 60^o \; x \; H' \qquad (5)$$

2.2 HSB to RGB

Below equations describes the conversions from HSB to RGB.

$$H' = \frac{H}{60^o} \qquad (6)$$

$$X = C\left(1 - \left|H' \bmod 2 - 1\right|\right) \qquad (7)$$

$$(R_1, G_1, B_1) = \begin{cases} (0,0,0) & if \;\; H \;\; is \;\; Undefined \\ (C, X, 0) & if \quad 0 \le H' < 2 \\ (X, C, 0) & if \quad 1 \le H' < 2 \\ (0, C, X) & if \quad 2 \le H' < 3 \\ (0, X, C) & if \quad 3 \le H' < 4 \\ (X, 0, C) & if \quad 4 \le H' < 5 \\ (C, 0, X) & if \quad 5 \le H' < 3 \end{cases} \qquad (8)$$

m= Y’ – (0.30R1 + 0.59 G1 + 0.11 B1) (9)

(R,G,B)=(R1+m,G1+m,B1+m) (10)

This is a geometric warping of hexagons into circles where each side of the hexagon is mapped onto a 60 degree arc of thecircle.

S=0, if C=0 (11)

S=1- min / max, otherwise (12)
S is denoted for saturation

$$I = \frac{1}{3}(R + G + B) \qquad (13)$$

where I is denoted as intensity

B = max (14)

where B is denoted in HSB as brightness.

2.3 RGB to HSI

Equation (1) describes the conversion from RGB to HSI color space.

$$I = \frac{1}{3}(R+G+B) \tag{15}$$

$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right] \tag{16}$$

$$H = \cos^{-1}\left\{\frac{0.5\left[((R\_G)+(R-B))\right]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} \tag{17}$$

If B is greater than G, then $H=360^o$-H (18)

Where R, G and B are three color component of source RGB image, H, S and I it's components of hardware independent on HSI format

2.4 HSI to RGB

As it can be seen that conversion from RGB to HSI is not easy with regard to computing algorithm complexity because it's regarding minimum from three searching (expression 1, as minimum two operators of condition), long cosine function, square root, square computation, additional operation of condition (expression 4) during one pixel conversion. Moreover, it is difficult to convert from HSI color space to standard RGB, where the process depends on which color sector H lies in. For the RG sector ($0^0 \leq H \leq 120^0$), we have the following equations to convert RGB to HSI format:

B=I(1-S) (19)

$$R = I\left[1+\frac{S\cos H}{\cos(60^0 - H)}\right] \tag{20}$$

G = 3I – (R + B) (21)

For the GB sector ($120^0 \leq H \leq 240^0$):

H = H –120^0 (22)

R = I (1– S) (23)

$$G = I\left[1+\frac{S\cos H}{\cos(60^0 - H)}\right] \tag{24}$$

B = 3I – (R +G) (25)

For the BR sector ($240^0 \leq H \leq 360^0$):

$$H = H - 240^0 \tag{26}$$

$$G = I\,(1 - S) \tag{27}$$

$$B = I\left[1 + \frac{S\cos H}{\cos(60^o - H)}\right] \tag{28}$$

$$R = 3I - (G + B) \tag{29}$$

4. GAMMA ENCODER

It is wise to use luma which represents the brightness in an image and can be denoted as Y. Luma is weighted average of gamma-encoding which can be denoted as Y' for R,G and B and hence denoted as R'G'B'.

The equation becomes,

$Y=0.2126R+0.7152G+0.0722B$ for luminance

$Y'=0.2126R'+0.7152G'+0.0722B'$ for gamma encoding

5. SATURATION

To make the color image soft and better human acceptance it is necessary to use saturation adjustment. We have applied histogram normalization instead of histogram equalization because normalize models stretches image pixel values to cover the entire pixel value range from (0-255) whereas equalize module attempts to equalize the number of pixels in a given color thus uses a single row of pixels.

6. PROCESSING STEPS

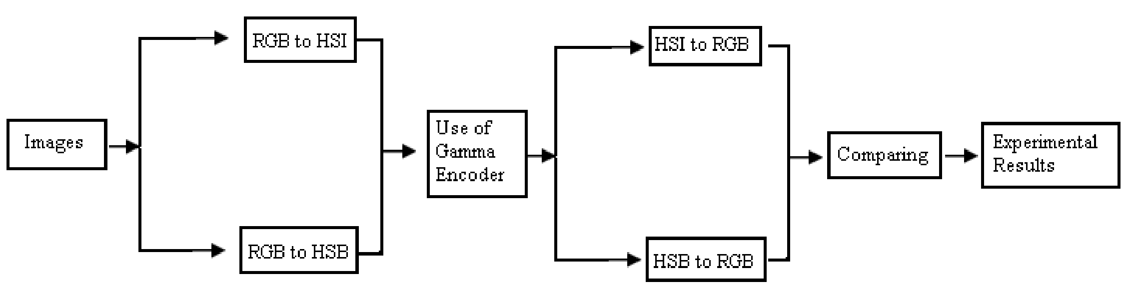

FIGURE 1: Block Diagram of Proposed Work.

7. EXPERIMENTAL RESULTS

To test the performance of our proposed approach we have used three different contrast color images (low contrast or darker from the original outlook, medium contrast or similar to original outlook and high contrast or brighter than original outlook color images). To evaluate the contrast performance we have applied histogram normalization saturation value from 0.4 – 0.6 and gamma correction value ranges from 0.75 – 2.2 in different computers as different computers acts different according to gamma value. It is to mention that gamma value > 1 performs darkening and vice-versa [9, 10, 11, 12].

Figure 2, 3 and 4 images with (a),(b),(c) illustrates that (a) is the original image, (b) is the experimental result obtained using HSI and (c) is the experimental result obtained using HSB.

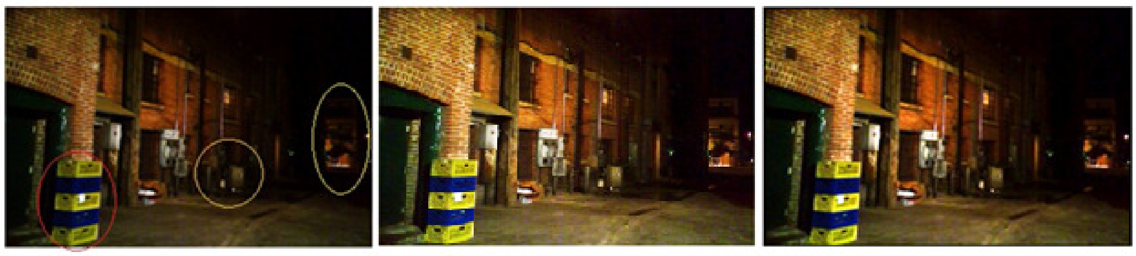

FIGURE 2

FIGURE 3

FIGURE 4

Images used	Using HSI (acceptance rate from users)	Using HSB (acceptance rate from users)	Comparison result
Bright Images (Total 223 images)	83 %	88 %	HSB acceptance rate is high
Dark Images (Total 304 Images)	79 %	89 %	HSB acceptance rate is high

TABLE 3: Detailed comparison between existing approach without gamma and our proposed approach with accuracy. Sample results were collected considering human visual perception.

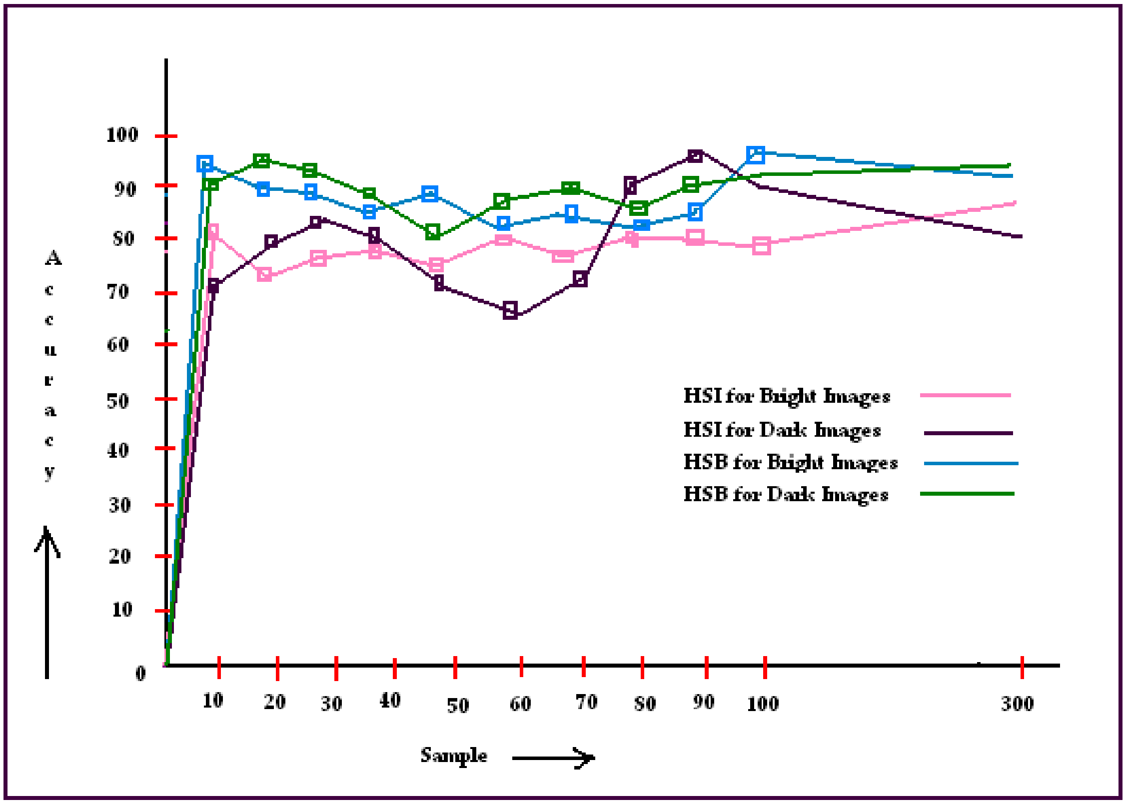

FIGURE 5: (Represents Table 3 in Graphical Form).

From the above Table 3 and Fig: 5; it is clear that HSB works better in compare to HSI for both bright and dark images. Moreover, for dark images using HSI only 79% accuracy is obtained whereas using HSB 89% accuracy has been obtained which proves that especially for dark images use of HSB will be the best approach for image enhancement. For bright images there is accuracy difference of 5% between HSI and HSB and hence it can be said that HSB performs better. However, special care is important when enhancing bright images.

8. CONCLUSION

This paper has proposed an efficient color model for better gamma encoding in image processing from all the existing color models available at this moment. It is difficult to judge an enhanced image result even with a subjective assessment. We claim that HSB color model is more robust than HSI color model or from others because others do produces unrealistic colors and/or over enhanced resultant images. However, there may be still some areas needs to be taken care of as the color enhancement needs to change or shift color using hue although these cases are exceptional and very rare.

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