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HUE Preserving Color Image Enhancement without GAMUT Problem using newly proposed Algorithm

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Abstract: ***In this paper work have been suggested an effective way of tackling the gamut problem during the processing itself. It is not necessary to bring back the R, G, and B values to its bounds after the processing. The proposed algorithm does not reduce the achieved intensity by the enhancement process. The enhancement procedure suggested here is hue preserving. It generalizes the existing gray scale image enhancement techniques to color images. The processing has been done in RGB space itself and the saturation and hue values of pixels are not needed for the processing. The objective of contrast enhancement is to increase the visibility of details that may be obscured by deficient global and local lightness. The goal of color enhancement can be either to increase the colorfulness, or to increase the saturation. This method is also likely to avoid out-of-gamut or unrealizable colors.***

Keywords: image, RGB space, Hue, Gamut, Histogram**.**

1. Introduction

Image enhancement refers to accentuation, or sharpening of image features such as edges, boundaries, or contrast to make a graphic display more useful for display and analysis. The enhancement process does not increase the inherent information content in the data. But it does increase the dynamic range of the chosen features so that they can be detected easily. Image enhancement includes gray level and contrast manipulation, pseudocoloring, and so on. The greatest difficulty in image enhancement is quantifying the criterion for enhancement. Therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results.

Hue, saturation and intensity are the attributes of color. Hue is that attribute of a color which decides what kind of color it is, i.e., a red or an orange. In the spectrum, each color is at the maximum purity (or strength or richness) that the eye can appreciate, and the spectrum of colors is described as fully saturated. If a saturated color is diluted by being mixed with other colors or with white light, its richness or saturation is decreased. For the purpose of enhancing a color image, it is to be seen that hue should not change for any pixel. If hue is changed then the color gets changed, thereby distorting the image. Consider the case where the pixel values go out of bounds after processing, due to the nonlinear nature of the uniform color spaces, conversion from these spaces with modified intensity and saturation values to RGB space generates gamut problem. In general this problem is tackled either by clipping the out of boundary values to the bounds or by normalization. Clipping the values to the bounds creates undesired shift of hue and normalization reduces some of the achieved intensity in the process of enhancement which is against its objective.

2. Literature Survey

A new technique for multispectral images has been developed. Multispectral and true-color images are often enhanced using histogram-based methods, usually by adjustment of color components after transformation to a selected secondary color system [1-3]. Efficient techniques are developed for bypassing the costly coordinate transformations when only the luminance or only the saturation is to be modified. Experimental results using histogram equalization support the theoretical analysis [4]. There are two novel color image contrast enhancement approaches which operate in three dimensions and aim for full gamut utilization. One is an extension of the histogram explosion algorithm to operate in CIELUV color space, intended to produce perceptually improved results compared to the original RGB method. The other is a new and very efficient recursive method, “histogram decimation,” whose output is roughly similar to that of the RGB histogram explosion algorithm. A direct comparison follows, based on processing a set of standard test images. By this performance analysis we can quantitatively compares the computation time and the mean-squared error in the cdf vs. an ideal, uniform distribution [5]. While joint processing of color components can generally utilize the full display gamut, such approaches generally produce greater computational complexity and execution times [6].One way of enhancing color image contrast is to feedback high-frequency spatial information from the saturation component into the luminance component [7]. The contrast of the image produced by saturation clipping is much better than those produced by other clipping approaches [8].

Transforming from one space to another and processing in these spaces usually generate gamut problem, i.e., the values of the variables may not be in their respective intervals. Enhancement techniques for color images are studied here theoretically in a generalized setup. A principle is suggested to make the transformations' gamut problem free in this regard. Using the same principle a class of hue preserving contrast enhancement transformations are proposed, which generalize the existing grey scale contrast intensification techniques to color images. These transformations are also seen to bypass the above mentioned color coordinate transformations for image enhancement. The developed principle is used to generalize the histogram equalization scheme for grey scale images to color images . Histogram equalization (HE) has been a simple yet effective image enhancement technique. However, it tends to change the brightness of an image significantly, causing annoying artifacts and unnatural contrast enhancement. The technique provides hue preserved, gamut problem free color contrast enhancement in accordance with the gray-scale contrast enhancing function it generalizes [9-12].

3. Material and Methods

3.1 Image

An image can be defined as a two-dimensional signal (analog or digital), that contains intensity (grayscale), or color information arranged along an x and y spatial axis. Practically, everything around us involves images and image processing.

3.2 Need of Image Processing

Improvement of pictorial information for human perception. Image processing for autonomous machine application. This has various applications in industries particularly for quality control, in assembly automation and many such applications. Efficient storage and transmission.

3.3 Image Enhancement

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing `better' input for other automated image processing techniques. The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer. During this process, one or more attributes of the image are modified. The choice of attributes and the way they are modified are specific to a given task. Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods. There exist many techniques that can enhance a digital image without spoiling it.

These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values.

Image enhancement is applied in every field where images are shall to be understood and analyzed. For example, medical image analysis, analysis of images from satellites etc.

The spatial domain processes discussed in this thesis are denoted by the expression (3.1):

g(x,y) = T[f(x,y)] **(3.1)**

where f(x,y) is the input image, g(x,y) is the output (processed) image, and T is an operator on f, defined over a specified neighborhood about point (x,y). Image enhancement means simply transforming an input image f(x,y) into processed image g(x,y) using T, where T is the intensity or gray-level transformation function (see figure 1). These two terms are used interchangeably, when dealing with monochrome (i.e. gray-scale). The values of pixels in images f(x,y) and g(x,y) are denoted by r and s, respectively.

So simply we said that the pixel values of r and s are related by the expression (3.2):

s=T(r) **(3.2)**

where T is a transformation that maps a pixel value r into a pixel value s. and r denotes the intensity of f(x,y) and s the intensity of g(x,y), both at any corresponding point (x,y) in the images.

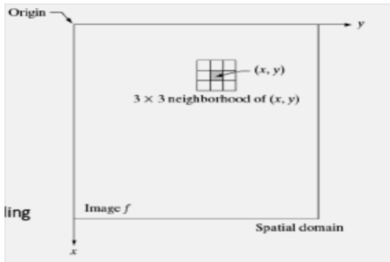

Figure 1: A 3*3 neighborhood about a point(x,y) in an image in the spatial domain.

The results of this transformation are mapped into the gray scale range as we are dealing here only with grey scale digital images. So, the results are mapped back into the range [0, L-1], where L=2k, k being the number of bits in the image being considered. So, for instance, for an 8-bit image the range of pixel values will be [0, 255]. A digital gray image can have pixel values in the range of 0 to 255.

3.4 Basic Intensity Transformation Functions

Intensity transformations are among the simplest of all image processing techniques. The values of pixels, before and after processing, will be denoted by r and s, respectively, see expression (3.2).

The most basic and simple operation in digital image processing is to compute the negative of an image. The pixel gray values are inverted to compute the negative of an image. For example, if an image of size R x C, where R represents number of rows and C represents number of columns, is represented by me (r, c). The negative N(r, c) of image I(r, c) can be computed as

N(r, c) = 255 – I(r, c) **(3.3)**

where, $0 \le r \le R$ and $0 \le c \le C$

It can be seen that, see expression (3.3), every pixel value from the original image is subtracted from the 255. The resultant image becomes negative of the original image. Reversing the intensity levels of an image in this manner produces the equivalent of a photographic negative. Negative images are useful for enhancing white or grey detail embedded in dark regions of an image.

The negative of an image with gray levels in the range [0, L-1] is obtained using negative transformations which is given by the expression (3.4):

s = (L – 1) – r **(3.4)**

There are three basic types of functions (transformations) that are used frequently in image enhancement. They are: Linear, Logarithmic and Power-Law, shown in figure 3.16.

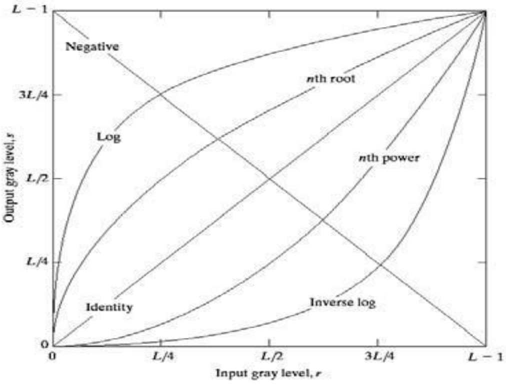

Figure 2: Figure shows basic grey level Transformations

The general form of the log transformation shown in figure 2 is:

s = c log (1 + r) **(3.5)**

where c is a constant, and it is assumed that $r \geq 0$.

The shape of the log curve in figure 2 shows that this transformation maps a narrow range of low gray-level values in the input image into a wider range of output levels. The opposite is true of higher values of input levels. We would use a transformation of this type to expand the values of dark pixels in an image while compressing the higher-level values. The opposite is true of the inverse log transformation. Any curve having the general shape of the log functions shown in figure 2 would accomplish this spreading/compressing of gray levels in an image. In fact, the power-law transformations discussed in the next section are much more versatile for this purpose than the log transformation. However, the log function has the important characteristic that it compresses the dynamic range of images with large variations in pixel values.

The log transformation maps a narrow range of low input grey level values into a wider range of output values. The inverse log transformation performs the opposite transformation. Log functions are particularly useful when the input grey level values may have an extremely large range of values. The log transformation maps a narrow range of low input grey level values into a wider range of output values. The inverse log transformation performs the opposite transformation.

Power-Law Transformations, The n^{th} power and n^{th} root curves shown in figure 2. A can be given by the expression:

s = cr$^{\gamma}$ **(3.6)**

where c and γ are positive constants. Sometimes expression (3.6) is written as $s = c(r + e)^{\gamma}$ to account for an offset (i.e. a measurable output when the input is zero). However, offsets typically are an issue of display calibration. As in the case of the log transformation, power-law curves with fractional values of γ map a narrow range of dark input values into a wider range of output values, with the opposite being true for higher values of input levels. Unlike the log function, however, we notice here a family of possible transformation curves obtained simply by varying y. As expected that curves generated with values of $\gamma > 1$ have exactly the opposite effect as those generated with values of $\gamma < 1$. Finally, we can reduces to the identity transformation when $c = \gamma = 1$.

This transformation function is also called as *gamma* correction. For various values of γ different levels of enhancements can be obtained. This technique is quite commonly called as Gamma Correction. If you notice, different display monitors display images at different intensities and clarity. That means, every monitor has built-in gamma correction in it with certain gamma ranges and so a good monitor automatically corrects all the images displayed on it for the best contrast to give user the best experience. The difference between the log transformation function and the power-law functions is that using the power-law function a family of possible transformation curves can be obtained just by varying the *γ*. These are the three basic image enhancement functions for grey scale images that can be applied easily for any type of image for better contrast and highlighting. Using the image negation formula given above it is not necessary for the results to be mapped into the grey scale range [0, L-1]. Output of L-1-r automatically falls in the range of [0, L-1]. But for the Log and Power-Law transformations resulting values are often quite distinctive, depending upon control parameters like *γ* and logarithmic scales. So the results of these values should be mapped back to the grey scale range to get a meaningful output image. For example, Log function s = c log (1 + r) results in 0 and 2.41 for *r* varying between 0 and 255, keeping *c*=1. So, the range [0, 2.41] should be mapped to [0, L-1] for getting a meaningful image.

One of the simplest piecewise linear functions is a contrast-stretching transformation. Low-contrast images can result from poor illumination, lack of dynamic range in the imaging sensor, or even wrong setting of a lens aperture during image acquisition. The idea behind contrast stretching is to increase the dynamic range of the gray levels in the image being processed.

3.5 Hue Preserving Transformation

Hue preservation is necessary for color image enhancement. Hue is what most people think of when we say "color." Hue is the name of a distinct color of the spectrum—red, green, yellow, orange, blue, and so on. It is the particular wavelength frequency.

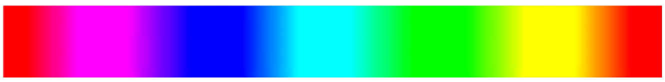

Figure 3: This strip shows a range of hues. It is easy to point to "red", "blue" or "yellow"

Distortion may occur if hue is not preserved. The hue of a pixel in the scene before the transformation and hue of the same pixel after the transformation are to be same for a hue preserving transformation. Our aim is the development of a general hue preserving transformation for contrast enhancement.

To explain scaling and shifting in a mathematical fashion let us denote the normalized grey values for R, G, and B components of a pixel of an image $\boldsymbol{I}$ by a vector $\hat{y}$, where $\hat{y}=(y_1,y_2,y_3)$, y_1,y_2,y_3 correspond to the normalized *red, green* and *blue* pixel values respectively. That is $0 \leq y_k \leq 1$, k=1,2, 3.

A transformation which is a combination of scaling and shifting can be written as

$$\hat{y}' = (\alpha y_1 + \beta, \alpha y_2 + \beta, \alpha y_3 + \beta) \qquad (3.7)$$

Note that in expression (3.7), $\hat{y}'$ is linear in $\hat{y}_k$ for all k, and α and β are not dependent upon ŷ. It can be shown that the transformation, as given in expression (3.7), is hue preserving.

The expression of hue considered here is the hue as defined in HSI space.

Note that in expression (3.7), α and β are not dependent upon $\hat{y}$. A general transformation in which α and β vary with each but same k for all 1, 2, 3, is defined as

$$\boldsymbol{y'_k = \alpha(\hat{y}) y_k + \beta(\hat{y})} \qquad \textbf{(3.8)}$$

3.6 Gray Scale Contrast Enhancement

The gray scale contrast enhancement techniques involve scaling and shifting operations; the net result of these operations on an image is that all its pixels with gray values above a certain reference point, with respect to that particular image, are pushed to a higher value while all the pixels with gray level below that point are pushed to lower gray values. Generally, the farther a gray value from that point, the more outward (with respect to that point) it is pushed. Notice that if the above mentioned reference point occurs at either of the upper or lower boundary, all gray levels are pushed in one direction only, in which case, contrast is enhanced by stretching of the gray levels in the gray domain.

3.7 Gamut Problem

The range, or gamut, of human colour perception is quite large. The two colour spaces discussed here span only a fraction of the colours we can see in figure 4. Furthermore the two spaces do not have the same gamut, meaning that converting from one colour space to the other may cause problems for colours in the outer regions of the GAMUTs. This illustration clearly shows the different GAMUTs of the RGB and CMYK colour spaces. The background is the CIE Chromaticity Diagram (representing the whole gamut of human colour perception).

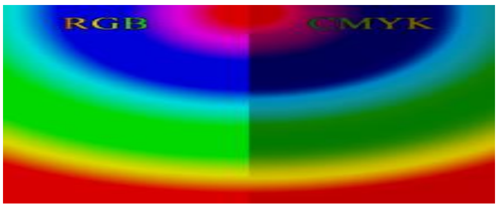

Figure 4: Different GAMUTs of the RGB and CMYK colour spaces.

The problem encountered in the intensity based generalizations is the gamut problem, in which the factor calculated from the intensity value, by which each of the R,G and B values is scaled, scales a very high R,G or B value out of its allowed domain. None of the above referenced techniques solve this problem except. To take care of the R, G, and B values exceeding the bounds, Wang *et. al.* suggested normalization of each component using (255/max(RGB)). This technique, however, makes the image darker. Yang *et. al.* have developed clipping techniques in LHS and YIQ spaces to take care of the gamut problem. Clipping is performed after the enhancement. Clipping however distorts the hue of the image which is not desirable.

4. Result and Discussion

All the work has been implemented in MATLAB 7.10. MATLAB is a software package developed by Math Works. The proposed hue preserving color image contrast enhancement algorithm not only avoids the gamut problem but also the drawback of intensity based generalization drawback. Furthermore, by taking care of the simple architectural principles of processors, the proposed algorithm has been made computationally very efficient and fast.

4.1 Proposed Algorithm

A threshold value have been chosen as 0.25 (normalized range 0-1) for developing the algorithm, making the use of hue transformation function. Following the steps of developing the proposed algorithm:

Step 1: Repeat for every pixel.
Step 2: Collecting required information.
Find the maximum, minimum and intermediate out of the R, G and B values xmin, xmax and xinterm respectively.
Step 3: Contrast Enhancement
para=128 ('=' is for assignment)
If (xmax – xmin) < para
Then:
[xnorm = (float)xintermediate / 255
alpha = grayFunc(xnorm) / xnorm
If (alpha* (float)xmax) > 255
Then:
{xnorm = xmax / 255
alpha = grayFunc(xnorm) / xnorm}
Step 4:
x1 = alpha * x1
x2 = alpha * x2
x3 = alpha * x3

4.2 Simulation and Results

The image shown in figure 5 is used for testing the above algorithm. This image had a poor contrast. It is important to mention here that the single algorithm proposed in this work is equally good for both linear and nonlinear functions. Figure 6 shows an RGB image enhanced by the proposed algorithm using a linear contrast enhancing function and very well indicates the improvement of the image shown over the figure 5. Figure 7 and figure 8 show the histogram of input and output images respectively.

Figure 5: The original RGB color image

Figure 6: The R,G,B image enhanced by applying the proposed algorithm

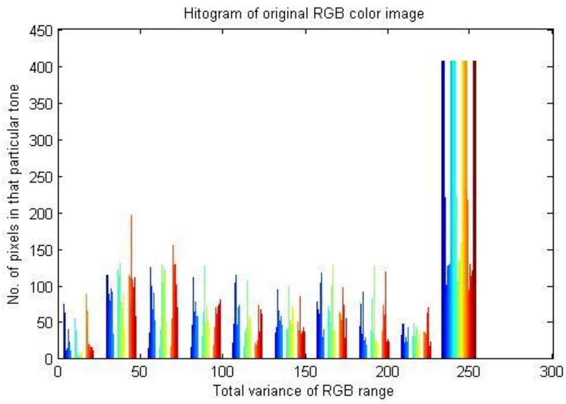

Figure 7: Histogram of the original RGB color Image

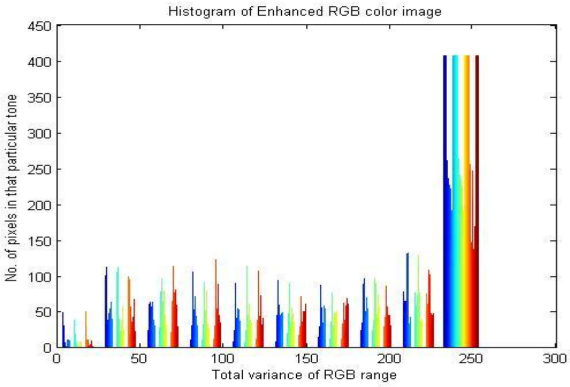

Figure 8: Histogram of the R,G,B image enhanced by applying the proposed algorithm

5. Conclusion and Future Scope of Work

The main contribution is to develop the proposed algorithm to generalize any grey scale image enhancement method to color images without encountering gamut problem. The overall enhancement obtained by the proposed scheme is mainly dependent on the already existing different contrast enhancement functions for grey scale images. These contrast enhancement functions for grey scale images are generalized to enhance the intensity of the color images, keeping the hue intact.

Work has been focused on a novel proposed algorithm to avoid gamut problem arising during the process of enhancement. This algorithm is used to enhance the intensity of color images using hue transformation function for contrast enhancement. The proposed algorithm developed is an efficient and reliable technique for hue preserving, gamut problem free contrast enhancement of colored images.

Further work can be extended for other images than grayscale images to obtain better result with accuracy.

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