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Image Chroma Enhancement with Quality Preservation

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***Abstract*— The goal of Image enhancement in general is to provide a more appealing image or video to achieve more vivid or realistic colors and to increase the visibility of details. The chroma enhancements are intimately related to different attributes of visual sensation and it helps to achieve the best possible combinations of colorfulness and contrast in an efficient manner. In practice one of the key issues in the image chroma enhancement applications is the strong contrast reduction of the enhanced image. While there exists several contrast enhancement approaches for improving the image contrast, it is still an active field of research. Nowadays most of the High Definition industrial cameras and projectors offer images with high chroma details. Hence chroma enhanced images along with high visual quality is an important challenge in industrial image processing applications. Two problems are addressed in this paper in order to achieve a better chroma enhanced image. Firstly, how to preserve the contrast of the image while enhancing the image chroma details and secondly, how to improve the overall image quality details inorder to produce more aesthetically pleasing result. This paper introduces a new contrast preserved chroma enhancement algorithm using YCbCr color space whish solves the problem of contrast reduction while enhancing the image chroma. An adaptive local tone mapping algorithm is also proposed, which further improves the overall image quality. To evaluate the performance, these algorithms are applied on a set of test images and few evaluation parameters are calculated, which shows that the proposed algorithm can effectively enhance the perceived image chrominance with image quality preservation compared to other conventional techniques.**

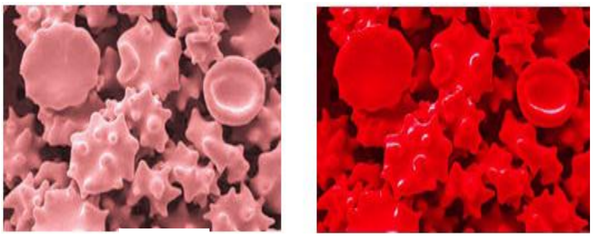
Keywords—image chrominance, contrast enhancement, chroma enhancement, tone mapping, YCbCr color space

I. INTRODUCTION

"A picture is worth a thousand words" refers to the notion that a complex idea can be conveyed with just a single still image. It also aptly characterizes one of the main goals of visualization, namely making it possible to absorb large amounts of data quickly. Image processing is an important component of modern technologies because , human depends so much on the visual information. About 99% information we perceive about the world is obtained with our eyes. In other words, images are better than any other information form for us to perceive. The enhancement of images helps to improve the interpretability or perception of information in images for human viewers or to provide better input for other automated image processing techniques. Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or a machine [1].

The goal of chroma enhancement can be either to increase the colorfulness, or to increase the saturation. The best way to increase the chroma without a lightness change is to use a more sophisticated color model, such as CIELAB or CIECAM02, rather than YCbCr. Any color algorithms using the CIELAB or CIECAM02 models guarantee the same color quality regardless of display color characteristics because the color characteristics of the device are considered during color value calculations. However, such color models are too complicated to be implemented in television applications. Hence the color space YCbCr is used for this study.

The YCbCr color space [2] is one of the most commonly used color spaces for video coding or image processing. The Y signal is known as "luma" and Cb and Cr are known as color difference or chroma signals. It is not an absolute color space; rather, it is a way of encoding RGB information. During the chroma enhancement process of an image using YCbCr, each pixel's Cb and Cr values are increased by some constant values. Fig. 1 shows an example in which the left image is the original image and the right is the manipulated image such that each pixel's Cb and Cr values are increased 1.2 times. Compared to the original, the chroma enhanced image appears more colorful, but also brighter, even though no lightness change was intended. Such an unintended lightness change also affects image contrast. When the lightness level increases, the image contrast automatically decreases. This is a serious issue in most of the chroma enhancement cases.



(a) **(b)**

Fig.1. The Effect of Chroma Enhancement Using the YCbCr Color Space ((a) Test Image (b) Chroma Enhanced Image))

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Therefore a contrast preserved chroma enhancement algorithms using YCbCr signals that preserve the original image contrast while enhancing perceived chroma are proposed in this study. Also the tone mapping technique is performed on the chroma enhanced contrast preserved images. The main goal of the tone mapping technique is to provide aesthetically pleasing images and maximizing the image contrast. Hence the overall image quality can be improved along with the enhancement of chroma value.

This paper is organized as follows. Section II describes the literature review undergone on the previous works done in these fields. Section III discusses one of the previous work in this area for the purpose of comparison. Section IV describes the proposed method, chrominance enhancement with contrast preservation using YCbCr color space. Section V describes the tone mapping method. Section VI gives the Experimental and simulation results using MATLAB. Section VIIconcludes the work.

II. LITERATURE REVIEW

Most of the published works to date focus on color enhancement in digital color images. Many of these techniques can theoretically be implemented for video as well. However, hardware implementation issues can impose serious restrictions for many of these techniques.

In one of the earliest papers on color enhancement, Strickland *et al* [3] recognized that RGB color space did not correspond with the human color perception and so, enhancement algorithms applied directly to RGB images could lead to color artifacts. Enhancing luminance alone could lead to color artifacts in low luminance regions, and thus simultaneous saturation processing was required for proper enhancement. Because of the nonlinear transformation between the two color spaces, some processed colors were at risk of being out-of-gamut when converted back to RGB. In 1994, Hague *et al* [4] presented an approach where histogram equalization was performed on saturation for each hue in the image, taking into account the maximum allowable saturation for a given luminance. This paper shows that Histogram equalization on the intensity component can improve the contrast, but can cause desaturation in areas where histogram equalization results in a large reduction in intensity.

In 2001 Lucchese *et al* [5] presented a two-stage method for color contrast enhancement based on xy chromaticity diagram. All colors with positive chroma values were maximally saturated through shifting to the borders of a given color gamut. In the next stage, the colors were desaturated towards a new white point by an appropriate color-mixing rule. In another attempt to develop an image enhancement method based on the chromaticity diagram, Colantoni *et al* [6] used λSY color space for colorfulness enhancement. This space is derived from xyY color space and is based on the dominant wavelength λ, saturation S and intensity Y. An important limitation of the method is a potential for hue shift because of the curvilinear nature of the constant perceived hue lines in the chromaticity diagram.

Samadani *et al* [7] proposed a method for lightening or darkening of an image where colors were directly adjusted by moving them along specific lightness-saturation curves while leaving the hue unchanged. But this method involves only lightness adjustment and no color enhancement. In a different approach Yang *et al* proposed a hue-preserving graphical approach involving scaling and shifting, that bypassed computationally intensive coordinate transformation during color image processing [8]. This method was intended for cases where only the luminance or only the saturation component needed to be modified.

In 2004 Meylan *et al* proposed a retinex-based method for high dynamic range rendering of natural images [9]. Here the global tone mapping was applied on the linear image and Luminance component was computed. An adaptive filter algorithm based on retinex was applied to luminance data. The method reduced artifacts like black halos around light sources, but the processing time increased significantly. Most of the work on color reproduction in tone mapping is focused on preserving color appearance of the real-world scene, as it is perceived by the human eye, on a computer screen. The common approach to color treatment in tone mapping, introduced by Schlick [10] , is preserving color ratios. Later papers on tone mapping, employing stronger contrast compression, observed that the resulting images are over-saturated. The trilateral filter-based HDR tone mapping technique proposed by Choudhury *et al* is one of the best developed techniques for compressing the dynamic range [11]. This method can preserve edges and smooth high-gradient regions. However, the main limitation of this method is its high computational cost.

Sachin P. Kamat proposed a Low Bandwidth YCbCr Data processing technique for video applications in hand held Devices. YCbCr optimization technique is used in this algorithm for additional frame level optimizations. The method significantly reduces the overheads involved in data transfer and computations thereby improving the performance and thus reducing the power consumed. This paper shows that the rough correspondence between the YCbCr signals and visual attributes makes the YCbCr color space more convenient for image processing than other color spaces.

A great deal of research has been carried out to understand colour appearance phenomena and to model colour appearance. In 1997, the CIE recommended a colour appearance model designated CIECAM97s. In 2002, a new model CIECAM02 [12] was recommended, which is simpler and has a better accuracy than CIECAM97s. The CIECAM02 was developed to predict color appearance under different viewing conditions, especially one for the computer display. The most sophisticated model is CIECAM02 ratified by the CIE (International Commission on Illumination) which predicts not only the perceived brightness, but also chroma, and hue under several illumination conditions.

III. CONTRAST ENHANCEMENT IN THE COMPRESSED DOMAIN

Contrast enhancement produces an image that subjectively looks better than the original image by changing the pixel intensities. This method is a compressed domain image enhancement technique which works with the DCT coefficients. The DCT coefficients are separated into various bands and enhance them using a scaling factor. It uses DC coefficients of the Y component for adjust the background illumination. To preserve the Local Contrast, the AC coefficients of the Y component are scaled appropriately. Let

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the scale factor for the DC coefficient be k_d and the scale factor for the AC coefficients is k_a for a DCT block *Y*. The processed DCT block Y_e is given by (1),

$$Y_e\ (i,j) = \begin{cases} k_d\ Y(i,j),\ i=j=0 \\ k_a\ Y(i,j),\ \text{otherwise} \end{cases} \quad (1)$$

The contrast of the processed image then becomes κ_a / κ_d times of the contrast of the original image. In this algorithm $\kappa_d = \kappa_a = k$ for preservation of the contrast. Similarly for the preservation of color vectors in the DCT domain, the luminance component *Y* of an image is uniformly scaled by a factor *k*. Let *U* and *V* be the DCT coefficients of the C_b and C_r components, respectively. If the luminance component *Y* of an image is uniformly scaled by a factor *k* , the colors of the processed image with Y_e , U_e and V_e are preserved by the following operations:

$$U_e\ (i,j) = \begin{cases} N\left(k\left(\frac{U(i,j)}{N}\ 128\right)\right) + 128,\ i=j=0 \\ k\,U(i,j),\ \text{otherwise} \end{cases} \quad (2)$$

$$V_e\ (i,j) = \begin{cases} N\left(k\left(\frac{V(i,j)}{N} - 128\right)\right) + 128,\ i=j=0 \\ k\,V(i,j),\ \text{otherwise} \end{cases} \quad (3)$$

IV PROPOSED CONTRAST PRESERVED CHROMA ENHANCEMENT METHOD

A contrast preserved chroma enhancement algorithm using YCbCr signals is proposed in this paper, by predicting the amount of luma change needed to compensate for the lightness change induced by chroma enhancement. Firstly, the YCbCr color space is analyzed using a CIECAM02 color appearance model in order to develop the algorithm. CIECAM02 is the latest standard color appearance model that predicts the perceived lightness J, chroma C, and hue angle h, and was proposed in 2002 by CIE. The luma change amounts needed to compensate for the lightness change by the chroma enhancement are calculated and then modeled. A contrast-preserved chroma enhancement algorithm is developed using the lightness change prediction model and its performance is evaluated.

A. *Block Diagram*

Fig.2 shows the block diagram of the proposed contrast preserved chroma enhancement algorithm. The proposed algorithm consists of two main functions: chroma enhancement function and lightness compensation function. The chroma enhancement function enhances the input image chroma value, by multiplying it with a chroma weight w. This makes the resultant image more colorful and also brighter, even though no lightness change was intended. Such an unintended lightness change also affects image contrast. The lightness compensation function calculates Δ luma value and to be added to the input Y value to yield the same CIECAM02 J value with input color, even after chroma enhancement.

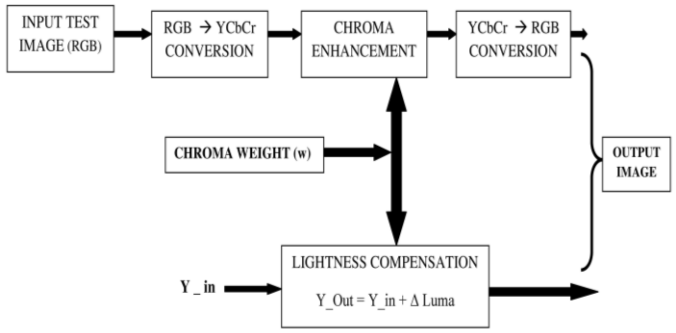

Fig.2. Block diagram of the Proposed Contrast-preserved Chroma enhancement method

B. *Analysis of the YCbCr in CIECAM02*

The YCbCr color space is analyzed using CIECAM02 color appearance model in order to develop the algorithm. The two major parts of ciecam02 are its chromatic adaptation transform, CIECAT02 and its equations for calculating mathematical correlates for the six technically defined dimensions of color appearance: brightness (luminance), lightness, colorfulness, chroma, saturation, and hue. In order to analyze the YCbCr color space in a uniform color space, it is set such that Y has a value between 0 and 255 and Cb and Cr have values between – 128 and 128. The chroma and hue angle in the YCbCr color space are defined as,

$$YCC\_chroma = \sqrt{c_b^{\,2} + c_r^{\,2}} \quad (4)$$

$$YCC\_hue\ angle = \arctan(Cr/Cb) \quad (5)$$

Each YCbCr value is then converted to the CIECAM02 color coordinates J, C, and h values respectively. For this calculation, the RGB-to-YCbCr conversion is performed. Then YCbCr is analyzed in the CIECAM02 color space.

CIECAM02 defines three surroundings - average, dim, and dark, which is given in Table I. A surround is a field outside the background and outside the white border (reference white). Surround includes the entire room or the environment. Surround is not measured directly; rather the surround ratio is determined and used to assign a surround.

TABLE I.
PARAMETER DECISION TABLE OF CIECAM02

Surround Condition	Surround Ratio	F	c	N_C	Application
Average	$S_R > 0.2$	1.0	0.69	1.0	Viewing surface colors
Dim	$0 < S_R < 0.2$	0.9	0.59	0.95	Viewing television
Dark	$S_R = 0$	0.8	0.53	0.8	Using projector in a dark room

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F is the factor determining degree of adaptation, c is the impact of surrounding and N_c is the chromatic induction factor. S_R is the ratio of the absolute luminance of the reference white measured in the surround field to the display area. For intermediate conditions, these values can be linearly interpolated.

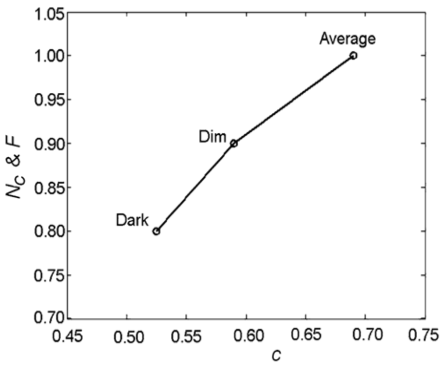

Fig.3. N_c and F Variation with c

C. Chromatic Adaptation Transforms

The most important function of a colour appearance model is chromatic adaptation transform. CAT02 is the chromatic adaptation transformation of CIEAM02 model [13]. A CAT is
capable of predicting corresponding colours, which are defined as pairs of colours that look alike when one is viewed under one illuminant and the other is under a different illuminant. The CAT02 matrix is given by,

$$[M_{CAT02}] = \begin{bmatrix} 0.7328 & 0.4296 & -0.1624 \\ -0.7036 & 1.6975 & 0.0061 \\ 0.0030 & 0.0136 & 0.9834 \end{bmatrix} \quad (6)$$

Inorder to apply the post adaptation transform, the adapted RGB responses must be converted from the M_{CAT02} specification to Hunt Pointer Estevez form (HPE).

$$[M_{HPE}] = \begin{bmatrix} 0.38971 & 0.68898 & 0.07868 \\ 0.22981 & 1.18340 & 0.04641 \\ 0.00000 & 0.00000 & 1.0000 \end{bmatrix} \quad (7)$$

A number of viewing condition components are computed as intermediate values required for further computations. These include the following factors.

$$k = 1/(5L_A + 1) \quad (8)$$

$$F_L = 0.2\,K^4 (5L_A) + 0.1(1 - K^4)^2 (5L_A)1/3 \quad (9)$$

Where L_A is the luminance of the adapting field. Using this equation the luminance level adaptation factor F_L can be calculated. The adapted cone responses are,

$$R'_a = \frac{400(F_L R'/100)^{0.42}}{(F_L R'/100)^{0.42} + 27.13} + 0.1 \quad (10)$$

$$G'_a = \frac{400(F_L G'/100)^{0.42}}{(F_L G'/100)^{0.42} + 27.13} + 0.1 \quad (11)$$

$$B'_a = \frac{400(F_L B'/100)^{0.42}}{(F_L B'/100)^{0.42} + 27.13} + 0.1 \quad (12)$$

D. Lightness Change Calculation

The lightness change induced by the chroma enhancement can be compensated, if the luma value is also changed to a point that has the same lightness as the original color. Therefore, a mathematical model predicting the luma change amount required to compensate for the lightness change is developed in this work. To develop the model, the luma value amount, ΔLuma, which should be added to the original luma to preserve the original lightness, is first calculated. The calculation procedure is as follows:

1. The input test image which is in RGB format is first converted into YCbCr color space.

2. YCC chroma is changed by the multiplication by a given weight, cw. The resulting value will be (Y, cwCb, cwCr).

3. CIECAM02 lightness J values of the (Y, Cb, Cr) and (Y, cwCb, cwCr) data points are calculated.

4. Finally, a ΔLuma value that minimizes the CIECAM02 J difference between the (Y+Δluma, cwCb, cwCr) and (Y, Cb, Cr) data points is found. The correlate of lightness J is,

$$J = 100 \frac{A}{A_w} cz \quad (13)$$

The achromatic response A is,

$$A = [2R'_a + G'_a + (1/20)\,B'_a - 0.305]\,N_{bb} \quad (14)$$

$$z = 1.48 + \sqrt{n} \quad (15)$$

$$n = \frac{Y_b}{Y_w} \quad (16)$$

The value n is a function of the luminance factor of the background and provides a very limited model of spatial color appearance. The value of n ranges from 0 for a background luminance factor of zero to 1 for a background luminance

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factor equal to the luminance factor of the adopted white point.

V TONE MAPPING METHOD FOR VISUAL QUALITY ENHANCEMENT

Tone mapping is a major component of image reproduction. It provides the mapping between the light emitted by the original scene and display values. Tone mapping is a technique used in image processing and computer graphics to map one set of colors to another in order to approximate the appearance of high dynamic range images in a medium that has a more limited dynamic range. Print-outs, CRT or LCD monitors, and projectors all have a limited dynamic range that is inadequate to reproduce the full range of light intensities present in natural scenes. The Human Visual System (HVS) processes the scene radiances in a non-linear manner through different adaptation processes. Electronic devices capture the scene radiances linearly. A tone mapping operator is necessary to non-linearly encode the image as well as to map it to the display characteristics so that the displayed image corresponds to our memory of the original scene.

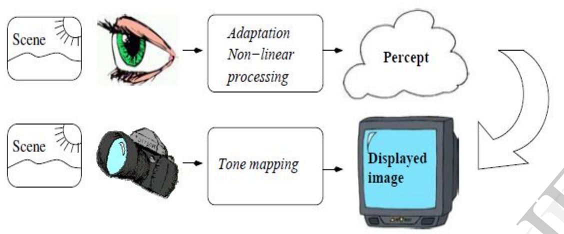

Fig. 4 . Processing of Scene radiances by HVS and Tone mapping operator

A. Purpose and Methods of Tone mapping

The goals of tone mapping can be differently stated depending on the particular application. In some cases producing just aesthetically pleasing images is the main goal, while other applications might emphasize reproducing as many image details as possible, or maximizing the image contrast. The goal in realistic rendering applications might be to obtain a perceptual match between a real scene and a displayed image even though the display device is not able to reproduce the full range of luminance values. Various tone mapping operators have been developed in the recent years. They all can be divided in two main types - Global and Local methods [14].

The global tone mapping algorithms have low computational complexity but provide lower visual quality compared to the local tone mapping solutions. In the case of global tone mapping solutions usually the histogram of the pixel values are build and a tone mapping function is obtained based on the histogram. The local tone mapping methods usually ensure a better visual quality of the processed image but at the expense of increased computational complexity and processing power. The parameters of the non-linear function change in each pixel, according to features extracted from the surrounding parameters. In other words, the effect of the algorithm changes in each pixel according to the local features of the image. Those algorithms are more complicated than the global ones; they can show artifacts (e.g. halo effect and ringing); and the output can look unrealistic, but they can provide the best performance, since human vision is mainly sensitive to local contrast.

B. Tone mapping of Intensity Component

In order to preserve the original colors, the tone mapping is applied only to the intensity component and the output color image is obtained by nonlinear transformation of the original color components. The intensity component of the input image is denoted as Y (i, j) and the output pixel intensity is denoted by Y_0(i, j), with (i, j) being the pixel coordinates. The following function is utilized to map the values of Y (i, j) to the new values Y_0(i , j)[15] ,

$$Y_0(i,j) = \frac{\max + Y_{m(i.j)} + R}{Y(i,j) + Y_m(i,j) + R} Y(i,j) \qquad (17)$$

Where max is the maximum value of Y (i, j), Y_m (i; j) is the smoothed version of Y (i , j) and R is a regularization term that controls the global effect of the mapping process. The parameter R is selected as half of the average of Y (i , j) . The reason for this selection is that small values of R will strengthen the global tone mapping effect and increase more the brightness of the processed image compared to a larger R.

B. Tone mapping Regularization

In order to introduce proposed method lets first analyze (17), where the function used to transform the intensity of the input image is defined. The effect of (17) for two different values of the regularization R is computed first. Let us take $Y_0^{(1)}$ be the intensity computed using R1 and $Y_0^{(2)}$ be the intensity computed using R2:

$$Y_0^{(1)}(i,j) = \frac{\max + Y_{m(i.j)} + R_1}{Y(i,j) + Y_m(i,j) + R_1} Y(i,j) \qquad (18)$$

$$Y_0^{(2)}(i,j) = \frac{\max + Y_{m(i.j)} + R_2}{Y(i,j) + Y_m(i,j) + R_2} Y(i,j) \qquad (19)$$

C. Proposed Tone mapping algorithm

In order to implement adaptive tone mapping method, the following procedure is implemented:

- The input color image with the red, green, and the blue components are transformed first in the YUV domain and only the Y (i, j) component is processed.
- Estimate the optimum size for each pixel Y (i, j). A set of M different window sizes are selected. For a given pixel Y (i, j) compute the corresponding averages Y_m (i, j) for each of the pre-defined window sizes N_k ,k = 1, . . . ,M .
- The image of the local averages Y_m (i , j) is computed using the optimum local window sizes.

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- The computed local averages Y_m (i , j) are utilized to estimate the optimum value.
- The tone mapped component Y_0(i , j) is computed using Y_m (i , j) and optimum value R_{opt}

$$Y_0(i,j) = \frac{\max + Y_{m(i,j)} + R_{opt}}{Y(i,j) + Y_m(i,j) + R_{opt}} Y(i,j) \quad (20)$$

VI EXPERIMENTAL RESULTS

This section deals with the portrayal of the simulation results obtained from the mat lab during the development of proposed method, chroma enhancement with image quality preservation. The proposed algorithm is tested on a set of images of different compositions downloaded from the standard image databases. It is found that the proposed algorithm gives best result compared to other conventional enhancement methods. Image chroma enhancement with contrast preservation is performed first and the performance is evaluated. Thereafter Tone mapping algorithm for improve the visibility details of the contrast preserved image is also developed using mat lab and the performances are evaluated.

A. Test Image preparation

Four different images shown in given Fig.7 were selected as test images. The resolutions of those images are set as 500X500 pixels respectively. Each images chroma was then increased by some weight. The chroma weight can be changed from 0.7 to 1.3. During the chroma enhancement process of test image using YCbCr, each pixels Cb and Cr values are increased by some constant value chroma weight (w). The chroma weight can be selected as any constant values. The best possible chroma weights are varied from 0.5 (50%) to 1.3 (130%) with a 0.1 increment. The effective chroma variation occurs between 0.7 to 1.3. In this work a chroma weight of 1.2 is selected for the effective chroma enhancement. The image color appearance is changed along with the chroma variation. The chroma variation effects in an image are shown in Fig.5.

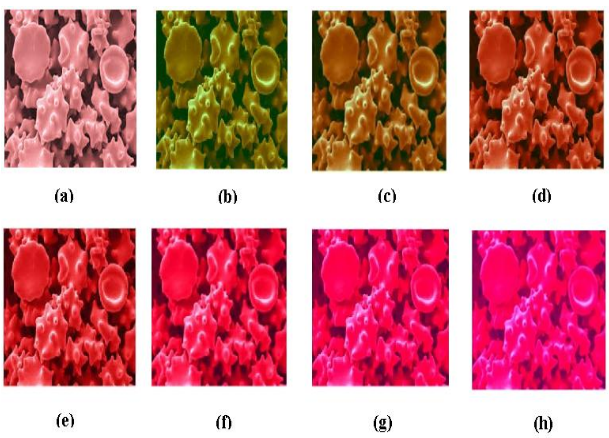

Fig. 5. Chroma weight distribution (a) blood cell test image , (b) chroma enhanced imagen with w = 0.8 , (c) w = 0.9 , (d) w = 1.0 , (e) w = 1.1 , (f) w = 1.2 , (g) w = 1.3 , (h) w = 1.

B. Comparison with Conventional Method

The chroma enhanced images are also analyzed in an existing compressed domain contrast enhancement method. The comparison of the proposed method with this conventional method is also performed in order to show that, in general, the proposed algorithm outperforms the conventional chroma enhancement technique.

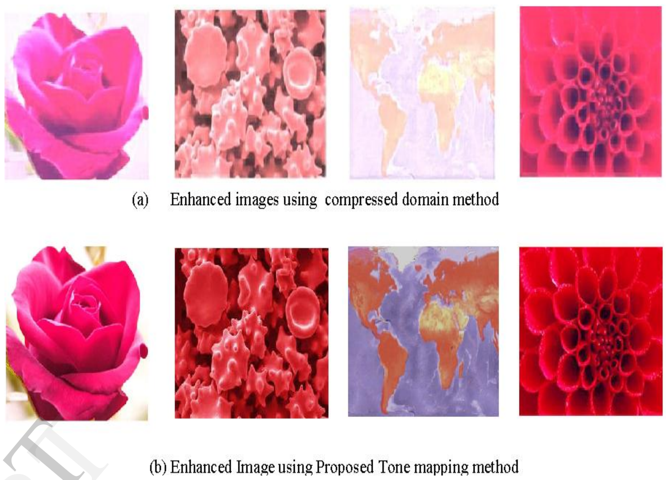

Fig. 6. Comparisons of the Chroma enhanced contrast preserved images using the conventional and proposed algorithm

C. subjective evaluation of proposed method

The images in given figure clearly shows the effect of the proposed algorithm. The original test images are in Fig.7(a). The test images chroma values are enhanced by a weight of 1.2 for each pixels. As a result image contrast decreases due to an unintended lightness change. These results are shown in Fig.7 (b) . The results obtained using the proposed method are shown in Fig.7 (c). The chroma enhanced images are also analyzed in an existing compressed domain contrast enhancement method. The simulation results are shown in Fig.6 . The chroma enhanced images using the conventional compressed domain method look notably lighter and have lower contrast compared to the proposed method. The images resulting from the proposed algorithm revealed that, in general, the proposed method outperforms the conventional contrast enhancement technique, especially for images containing red colors or fine textures.

D. Numerical algorithm Performance test

The goal of the proposed algorithm is preserving the original lightness while the chroma value increases. As a measure, PSNR (peak signal-to-noise ratio) values were calculated for the results in both conventional and proposed method for the different test images. Table II lists the average PSNR values for all four test images. It is clear that there is an image dependency, even though the PSNR values of the

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proposed algorithm images are generally higher than those of the conventional algorithm.

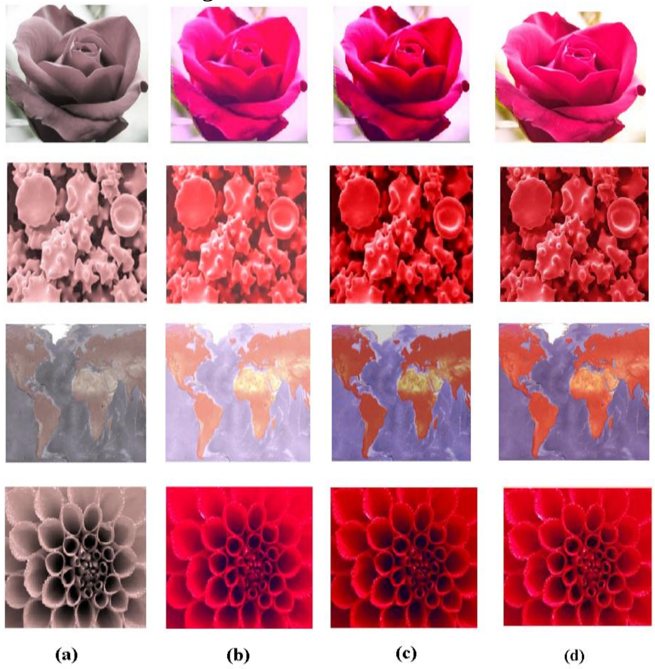

Fig.7. Proposed Contrast preserved Chroma enhancement algorithm Results (a) Test images (b) Chroma enhanced images (c) Image using proposed method (d) Image using Tone mapping method

It is clear that the PSNR values of the proposed algorithm images are generally higher than those of the conventional algorithm, which shows the efficiency of the proposed method.

$$PSNR = 10 \log (255^2 / MSE) \quad (21)$$

Where MSE represents the mean squared error . The average PSNR values for all four test images are given below.

TABLE II.
PSNR (dB) OF THE CONVENTIONAL AND PROPOSED METHODS

PERFORMANCE TEST – PSNR(dB)			
Test Images	**Conventional Compressed domain method**	**Proposed ciecam02 Method**	**Tone mapping**
(a)	11.83	24.67	28.47
(b)	13.26	22.64	25.87
(c)	11.46	16.63	18.27
(d)	15.86	26.24	28.32

VII CONCLUSION

A chroma enhancement algorithm with the preservation of original image characteristics is proposed in this paper. The effect of chroma enhancement on image contrast is considered first. The amounts of luma change needed to compensate for the lightness change by the chroma enhancement are calculated and modeled. This research suggests the possibility that color enhancement algorithms could be developed using the YCbCr color space with performances that are equivalent to the performance achieved when a uniform color space is used ,such as in CIECAM02 . Numerical tests are conducted by calculating PSNR of the resultant images. The results revealed that, in general, the proposed algorithm outperforms the conventional chroma enhancement techniques, especially for images containing red colors or fine textures. In the next section a novel method for local tone mapping of color images is proposed. This method uses two adaptive control parameters to increase the visual quality of the processed images. One parameter is the spatial range of the local adaptation, that is the optimal size N of the neighborhood affecting the global tone mapping effect. The other parameter, R, controls the strength of the local tone mapping function. This value is optimized based on the image variance. Performance comparison of all the methods based on Peak Signal to Noise Reduction is to be carried out, which reveals the efficiency of the proposed method. Thus chroma enhancement of images along with the preservation of contrast with better visibility details can be achieved with the proposed method and, which can solve practical contrast reduction problem due to chroma enhancement effectively.
This thesis considers the lightness changes induced by the YCC chroma change. However, other color distortions also occur due to chroma enhancement. The changes in the luma value produce unwanted chroma and hue changes in addition to the desired lightness changes. Therefore, further research is required to determine a method that can compensate for all such unwanted color distortions by using the YCbCr color space. Also the local tone mapping algorithm involves increased processing power and computational complexity. Therefore local tone mapping algorithm has to be improved further to reduce the computational complexity

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