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Content Preserving Medical Image Enhancement by DC Coefficients Scaling in LAB-DCT Domain

Sumit Narayan Jarholiya[1], Shachi Awasthi [2], Shashi Jarholiya[3]
[1, 2] Jayoti Vidyapeeth Women's University, Jaipur, India, [3] NES College, Jabalpur,India

Abstract: Medical images are acquired from different modalities thus captured medical images usually suffers from noise low contrast and medical images are used for the human health monitoring and disease diagnosis thus it is essential to improve the contrast for the better image quality before being analysed and diagnosed. In this paper to preserve the colour content a modified method of DC coefficient scaling in the compressed DCT domain is proposed to enhance the contrast of the images. For colour preservation, it is proposed to implement DC coefficient scaling in the CIE-Lab colour space. The contrast is only enhanced using the L component and chrominance information is preserved. This improves the entropy over the standard DC coefficient scaling method. The performance of three methods is compared based on SNR, absolute standard deviation difference (ASDD) and entropy analysis. Based on entropy analysis the order of the Twicing function is varied for better DC coefficient enhancement. The methods are tested on various medical images from different environment.
Keywords: DCT, RGB Colour space, Y-Cb-Cr Colour space, CIE-Lab Colour space, Twicing function, Entropy, SNR

I. INTRODUCTION

The body parts identification and their analysis under the low illumination conditions are improved by using contrast enhancement techniques. Researchers have designed many methods Viz. [1, 3, and 4] to improve the visual quality of medical images. Contrast enhancement is most common method for enhancing the quality of medical images [1]. Since contrast is perceived difference amongst the colours having close proximity to each other thus contrast enhancement may improve the information among the images. Efficient contrast enhancement stage differentiates the high level design from each other's. The content of image looks pleasant to every viewer by using colour contrast enhancement technique.

A. Challenges for Multi-Modal Medical Image Processing

With invention of the various imaging modalities images of the different body parts are captured using different modalities. Multi sensors are used for the this purpose thus developments in the field of multispectral high resolution and cost effective medical image enhancement have become the choice for researcher to overcome the issues with sensor technologies.

The colour image enhancement techniques are classified into two groups as spatial domain methods and compressed transform domain methods. In spatial domain contrast limited adaptive histogram equalization is the popular enhancement method known as CLAHE [5]. The most common transform domain methods are DWT [2] and DCT [1]. DCT based methods are extremely common in use for true colour image enhancement. One of the popular methods in compressed DCT domain is to scale the DC coefficient in the DCT domain coefficients [1] in Y-Cb-Cr colour space.

The colour images are enhanced using the DCT based DC coefficient scaling a common method. But the performance of this method is in consistent for the different images. Method may increase contrast but may also increase the mean brightness significantly. The performance of standard DC coefficient scaling method in the Y-Cb-Cr colour space and DC coefficient scaling in CIE-Lab colour space for true colour images have compared in this paper.

Colour opponent space is name of CIE-LAB because it mimics way which our human visual system reads the colour. This is why other colour spaces are having less perceptual uniformities as compared to CIE-LAB space. This space alloys balanced colour corrections and more accurate contrast adjustments. Entropy of enhanced image and the information contain are improved by using CIE Lab colour space.

Remaining paper is organized as follows: Section II reviews the existing work on various contrast enhancement methods. Section III various types of colour spaces is also explained. A standard compressed domain method using DC coefficient scaling is described in detail in section IV. Section V explains our modified enhancement scheme. The results of all these methods are compared in the Section VI. Conclusion and future work are described in section VII.

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II. LITERATURE REVIEW

Different types of method are explained in literature for enhancing the images such as local region based enhancement, using the image histogram, and transform domain methods. In this section paper reviews the method of true colour medical images for enhancing in relevant form. Broad classifications of the contrast enhancement methods are given in the Figure 1.

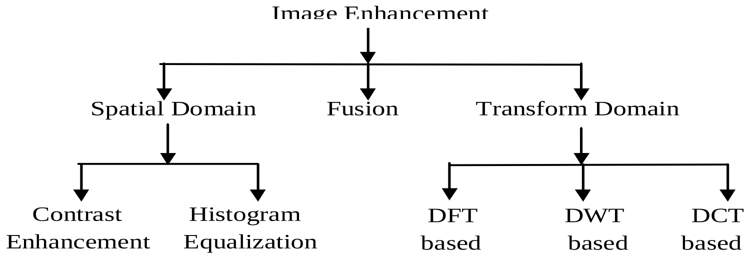

Figure 1 A broad classification chart of the image contrast enhancement methods

A. Review of Contrast Enhancement Methods

One of the most widely used algorithms is global histogram equalization (HE).

Table 1
Comparison of Existing Methods

Author/ reference	Method Used	Kind of images (application areas)	Used colour spaces
Jayanta M.[1]	Compressed DCT	True colour images with low contrast	Scaling the DC coefficient in Y-Cb-Cr Space
Prateek et al [2]	Compressed DWT and DCT	True colour Images	Scaling the DWT coefficient in Y-Cb-Cr Space
Kapinaiah et al. [4]	Compressed DCT	Low contrast Brain Tumor images	Scaling DC coefficient in Y-Cb-Cr Space and Power law transformation
Amina et. Al. [14]	DWT domain	Low contrast	Image fusion based enhancement
Adrian et al. [19]	Feature based	Various kind of image database	Image Categorization in LAB- colour space
Our proposed work	Compressed DCT	Different colour images with low contrast	Scaling DC coefficient in LAB space for improving the gradient based Fusion quality

A method of 3D histogram equalization using the RGB cube was proposed. Disadvantage of global HE is that method may not be applied for local context and, it significantly changes the mean brightness of an image thus the true colour is changed. Similarly, Thomas et al. [7] have also modified and proposed enhancement method by using the local correlation between saturation and luminance of the image components. The Contrast limited adaptive histogram equalization (CLAHE) method by K. Zuiderveld [5]. Hitam et al. [6] have presented a combination of CLAHE in RGB and HSV colour spaces for underwater images by Paresh et al. [9, 15] have used different Histogram based enhancement methods and also the wavelet fusion for enhancing the image quality. The above mentioned methods are useful for colour image enhancement. However, colour shifting and brightness of the images' colour change is major problem. Colour shifting is used to change one colour into another. Irene et al [3] used CIE-Lab colour space for the detection of the optical disc in retinal images.

However, in the last decade the compressed format of the images are increasingly available. Therefore, various enhancement algorithms are developed in the compressed domain [1, 12, and 13]. Among these method of scaling the DC coefficient in the block DCT domain Jayanta et al. [1], has recently being popularly used. In this paper three enhancement techniques are comparing by SNR and mean square error parameter. The comparison between the methods of colour image enhancements is presented in the Table 1. It is clear that explained method of image enhancement replaces Y-Cb-Cr with CIE-Lab colour space. Narasimhan et al. [13] have compared the performance of various compressed transform based contrast enhancement methods for low illumination images. Method mentioned that DCT transform methods can be used for improving contrast in any type of illuminations and also defined various performance measures.

Jaspreet et al. [8] have proposed an novel method of image enhancement using the scaling of DC and AC coefficients in CT domain for colour image enhancement. Kapinaiah et al. [4] have proposed the DC coefficient scaling in DCT transform domain along with the power transformation to enhance the medical images of Brain Tumors. Although the method is efficient but still scope of improvement is there. The information content is required to preserve for brain Tumors images.

III.REVIEW OF THE COLOUR SPACES

Many colour models have been designed by the researchers for improving the visual representation of colour images. Colour space is used for defining a particular combination of a colour model plus a mapping function associated to colour images. Colour model and colour spaces are complementary to each other. Gray images contain less precise information than the colour image, mixing of the primary colours pigments are used for generating the large number of colours. RGB [6] and Y-Cb-Cr colour spaces [1] are most commonly used colour spaces. The CIE has developed a new colour space called CIE-Lab colour space. Selection of the colour model depends on the kind of image application and its requirements.

A. RGB Colour Space

This is a tri colour space called as RGB (red, green and blue) colour space. The RGB colour model can be approximated as cube of red, green and blue and it can be considered as the X, Y and Z axis as shown in Figure 2.

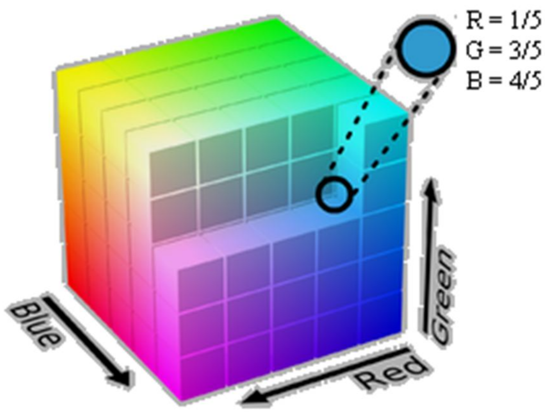

Figure 2 RGB Colour space as cubic model

In image compression RGB colour space is widely used. In RGB format every image contains three 2D images each corresponds to the Red, Green, and Blue colour spaces. But for enhancement it doesn't gives such a good result and may tends to change the original colour quality.

B. Y-Cb-Cr Colour Space

In colour image enhancement the captured input colour image is converted into other format like HSV or Y-Cb-Cr formats. To process the true RGB colour image directly is difficult and it is computationally complex too. Y-Cb-Cr format is less complex than the HSV format so it is most prefer. In Y-Cb-Cr colour format, Y indicates the pixel's actual brightness thus called luminance signal, the Cb and Cr represent the chrominance signals where b and r represents the blue and red colour respectively. The Y-Cb-Cr colour space conversion allows greater compression without a significant effect on perceptual image quality. RGB images are converted to the Y-Cb-Cr formats in most of the compressed domain methods.

C. CIE-Lab Colour Space

A CIE-Lab Colour space [16] is represented in the Figure 3. In the Figure the Lightness, are defined by the vertical L axis between 0-100. The horizontal axis represents a* and b* colour channels respectively. These colour channels are at orthogonal to each other and intersects each other at the centre, which is the neutral grey, black or white colour. They are based on the principal that a colour cannot be both red and green, or blue and yellow

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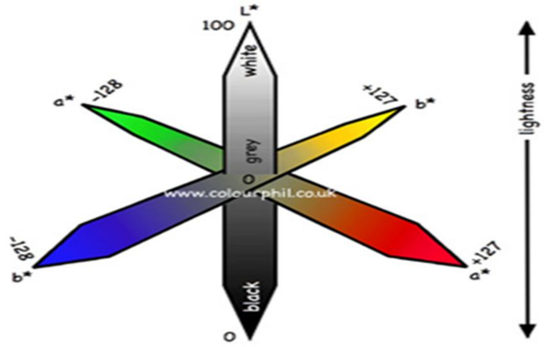


Figure 3 Colour representation of the LAB space

The LAB colour space is generating colours as similar to as our human visual system which is the significant advantage of the LAB colour space. This can be clearly observed from the comparison of all three colour spaces as shown in the Figure 4. The images are shown for the Skin_3 medical image containing the injurious segment. It can be observed from the Figure that chrominance signals A and B, contains the more colour information as compared to C_b and C_r components. Thus using LAB space may improve the visual appearance better.

LAB colour spaces are extensively used in industries. Some of the application areas are; providing exact colour shades for paints for automotive and house hold industries, used in dyes in textiles industries. Object segmentation applications [3, 15] used these colour spaces.

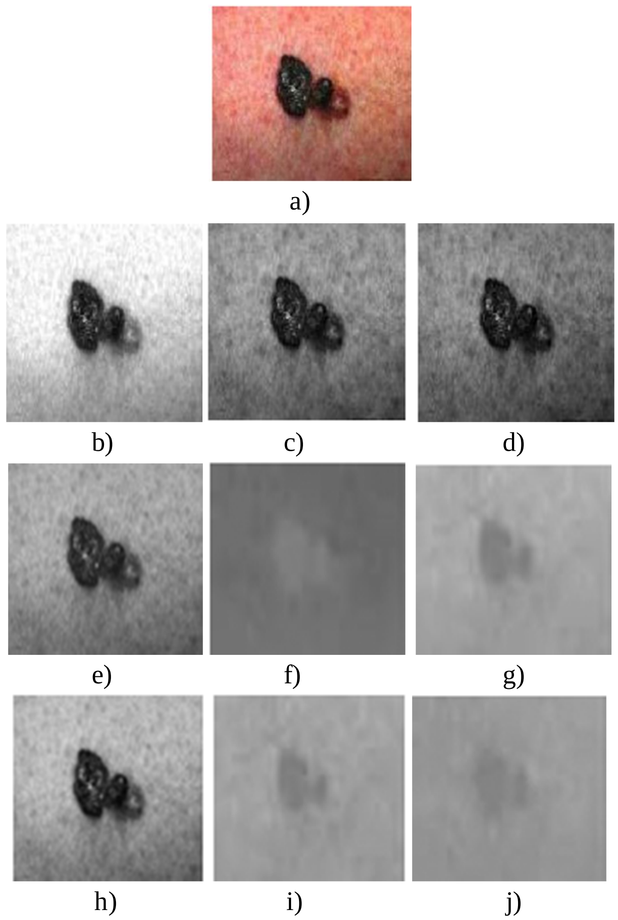


Figure 4 Comparison of the colour components a) Skin 3 image b) Red component c) Green. component d) Blue component e) Y component f) C_b component g) C_r component h) L component i) a component j) b component

IV. STANDARD DC COEFFICIENT SCALING METHOD OF IMAGE ENHANCEMENT (TW-CES)

Compressed domain contrast enhancement methods using the discrete cosine transform (DCT) [1, 12] and discrete wavelets transform (DWT) [2, 14] are designed by researchers. The improved visual appearances of the images are demonstrated by these methods. Various methods are given in this literature, designed for both coloured and gray scale images. DCT based method is used to convert an image from R-G-B to Y-Cb-Cr colour space. In this Luminance and Chrominance components are used to represent the colour thus provide a better platform for enhancing the colour images. In this paper, the compressed DCT domain method is used by scaling of DC coefficients for enhancing true colour of the images. The performance of the method is compared with existing spatial domain methods.

Method finds the DCT coefficients of the Y components using 8X8 blocks. Then the local background illumination is adjusted by the DC coefficient of each DCT block. Since the average of the brightness distribution of the block are given by the DC value. The brightness values to the value in the desired range are mapped by the adjustment value. This mapping function should be monotonic in the given range. Let us find the maximum brightness value of the input image I as reference.

$$\max(I) = I_{max} \tag{1}$$

The mapping function which must be capable of keeping the variations of the DC coefficients smooth or continuous are used to map the DC coefficient is done using Twicing function [1] as the mapping function.

$$DC = \tau(x) * I_{max} \tag{2}$$

Where mathematically Twicing function $\tau(x)$ can be defined as;

$$\tau(x) = x * (2 - x) \tag{3}$$

Find the DC coefficients and then scale the only DC efficients of the DCT coefficients as;

$$K = (f\left(\frac{Y(0,0)}{NI_{max}}\right))/(\frac{Y(0,0)}{NI_{max}}) \tag{4}$$

Basic concept of contrast enhancement by scaling the DC coefficient in DCT domain algorithm [12], is to filter the image by scaling the DCT coefficients according to the defined contrast measure. Paper adjusts the DC coefficient of the 'Y' component of the image. This is done because majority of the information are contain in the DC coefficient (Y(0,0)). DCT technique also works faster than the spatial domain techniques as computing DCT coefficients is a faster process than working in the spatial domain.

V. PROPOSED ADAPTIVE CSE METHOD

In order to improve the performance of the described standard DC coefficient scaling method, this dissertation enhances the image contrast in CIE-Lab colour space instead of Y-Cb-Cr. The block diagram of the proposed method is given in Figure 5. Using CIE-Lab space before image enhancement method increases the aesthetic appearance of the images. This allows enhancing the colour feature of the structural components across the different spectral channels of the image. The DC coefficients are enhanced in lightness component L only and the colour information in a* and b* channels are kept unchanged for preserving the colour information. Finally the Lab colour spaces are converted back to RGB images. The flow chart is shown is Figure 6.

Moreover, in a block DCT space, the algorithm attempts to exploit the advantage of having localized information from the DCT coefficients. Then to preserve the brightness wavelet image fusion is used in the final stage.

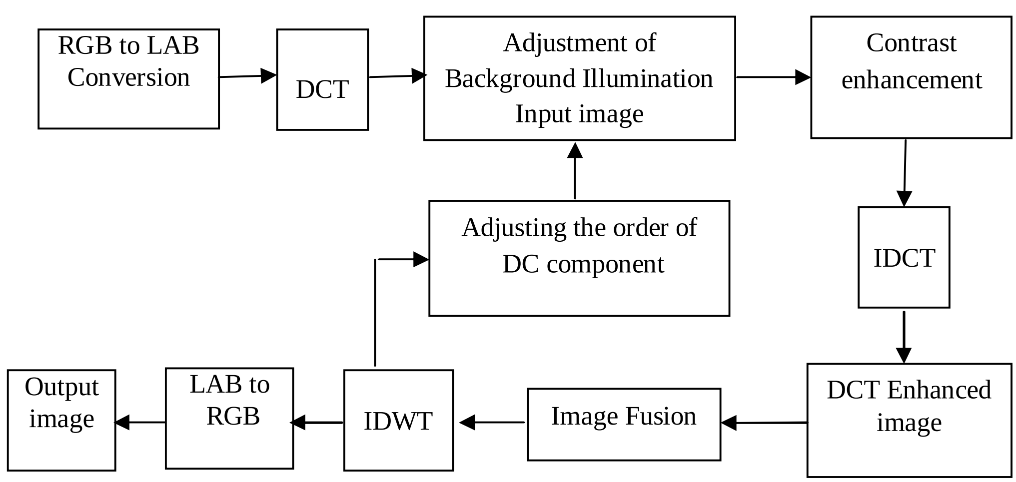


Figure 5 Block Diagram of the proposed adaptive enhancement method

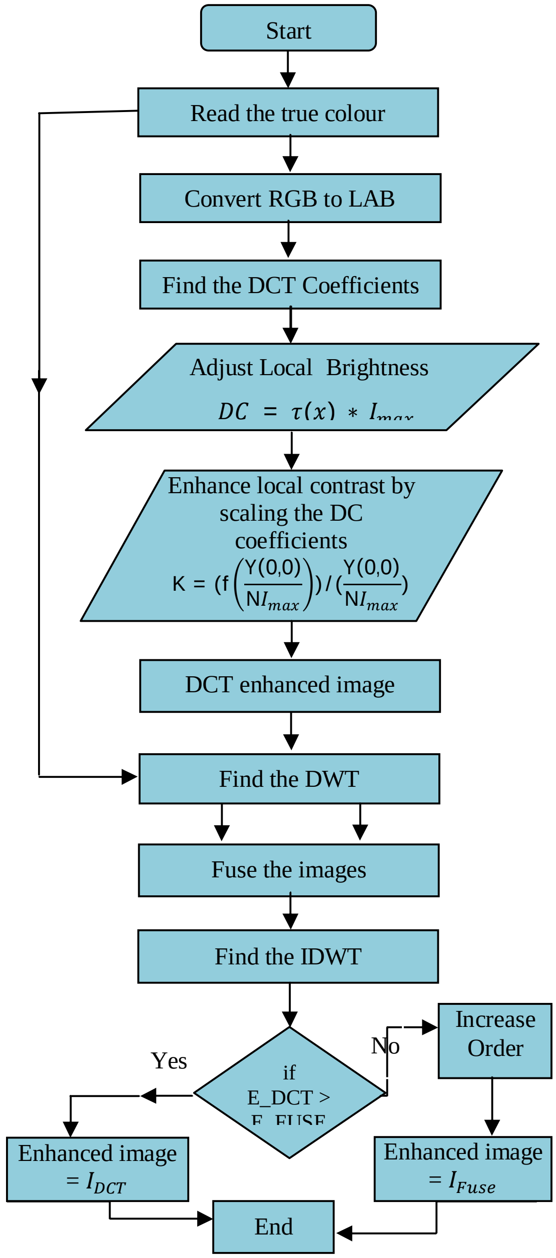


Figure 6 Flow chart of the proposed method

A. Algorithm

For calculating scaling factor for DCT based technique in the LAB colour space is given as follows:

Input: Take the luminance L component of the LAB image as the input for DC coefficient scaling and preserve the A and B component.

Input Parameters: The various input parameters for the algorithm are scale factor k, maximum brightness I_{max}, and the block size blk.

B. Output: DC adjusted L component.

Decompose the L component of the given input image into block of images of the given block size bl*k*.

Compute maximum intensity 'I_{max}' for each blocks of 'I' and determine the scaling factor 'k' for each block as described below:

$$z = dct(I); \quad (5)$$

$$y = z/N \quad (6)$$

Original $DC = y(0,0)$

$$x = \frac{y(0,0)}{I_{max}} \qquad (7)$$

Mapped DC component is calculated as;

$$DC = \tau(x) * I_{max}, \qquad (8)$$

Where Twicing function is defined as

$$\tau(x) = x * (2 - x), \qquad (9)$$

Now set the scale as;

$$k = mapped\ DC / original\ DC., \qquad (10)$$

Scale the coefficients: Now scaling factor is calculated, which is multiplied with the DC component of every block and thus results the enhanced image.

$$Original\ DC = k * original\ DC., \qquad (11)$$

Compute the IDCT for each of the block and then merge it back to form single block of the image.

Convert the LAB image to RGB image. End of algorithm

In the data flow diagram the block of Increase order function improves the power of the Twicing function by 0.5 and then again enhances the image using the mentioned algorithm. The proposed method only adopts the order when the entropy of the enhanced image is less then, the entropy of the input image

C. Content Preservation

The proposed method only changes the luminance L component and keeps the chrominance components (A and B) unaltered respectively. Though in the LAB colour space the chrominance components are more de-correlated than that in the R-G-B colour space. Increasing L while keeping A and B unchanged reduce the (R/G) and (G/B) factors. Therefore our proposed method preserves the colour of the image.

D. Wavelet Fusion

The original image and enhanced image by adjustment of local background brightness in LAB-DCT domain are fused together using the simple pixel based wavelet fusion. This not only reduces the blocking effects but preserves the brightness and simultaneously improves the contrast of the image.

But for the few images still the enhanced image does not have better entropy then original image then experimentally it is found that for each such images increasing the power or the order of the original DC component may improve the contrast of the enhanced image better. Although for some images it might not be needed to increase the order of DC component.

E. Order Adoption Rule

In order to adopt the order the entropy of the original input image is compared to the entropy of the enhanced image using the fusion method.

1) If the entropy of the fused image is greater than the entropy of the original image there is no need to change the order of the original DC component and the algorithm will stop
2) If the entropy of the fused image is less than the entropy of the original image then the order of the original DC component is increase by the step of 0.5 and algorithm is repeated for original input image using the increased order of the Twicing function. Repeat the procedure till the entropy of the enhanced image become greater than the original image entropy. Usually within 2-3 iterations the desired entropy is achieved.

VI. RESULTS AND DISCUSSIONS

Section presents the few of our experimental results of the proposed method in combination of scaling the DC coefficients of every DCT block in transform domain using the LAB colour space. Then further, the wavelet fusion is used for improving the colour contrast enhancement quality. this method first DCT of L component of the input medical image is calculated using 8 x 8 block size. Then colour contrast is enhanced using method of DC coefficients scaling of the DCT blocks. Although, the DCT based method performs better for true colour images for medical images the MSE and SNR performance of the standard DCT method degrades, and also method gives the higher mean brightness as illustrated in Table 2.and Table 3. It can be observed that our proposed method gives better preserved mean brightness and also enhances the image better to give the maximum entropy always

Thus in order to improve the brightness performance and to preserve the colour contents of images the input images are fused with the DCT enhanced image in LAB space using wavelet fusion. For efficient content preservation in this work the entropies of the input and enhanced images are compared and adaptive decision is taken to adopt the order of the scaling function. Based on entropy comparison the order of Twicing function changes by 0.5 factors, for every iteration.

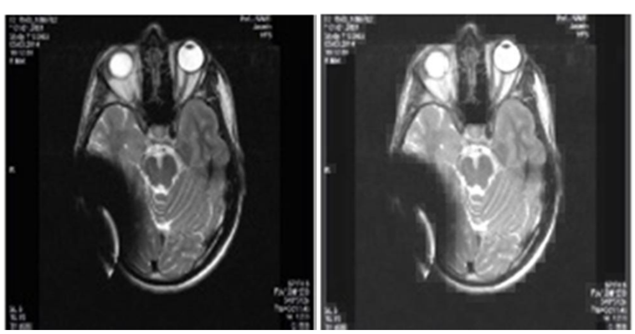
The comparisons of result are shown in Figure 7and 8 for the two distinct images input medical images. It can be observed from Figures that, standard DC coefficient scaling method not only improves the contrasts but also increases the brightness. Hence, here it is proposed to use the LAB colour space for enhancement which preserves the information better as shown in the Figure 7(c) and Figure8(c). In order to further improve brightness performance the results of our enhanced images and the original image is fused using the pixel level wavelet fusion. This can be observed from the parametric performance of the medical images given in Table 1 that fused image gives the better entropy thus preserve more information.

Table 2
Parametric Comparison of the Enhancement Methods for Medical Image

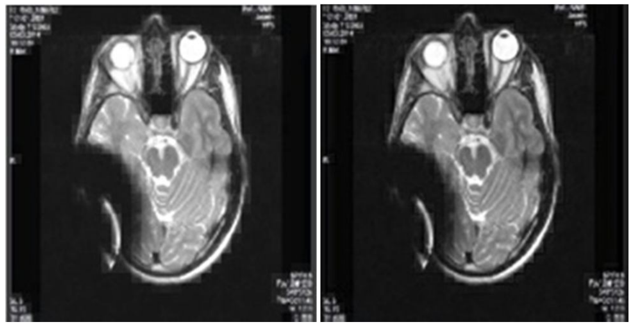
Parameters	Images	Original	Enhancement with DC coefficient Scaling Jayanta [1]	Enhancement with DC coefficient Scaling In LAB space	Proposed method with Fusion
Entropy	Patient image 1 MRI	5.9226	6.3668	6.3915	6.4834
	MRI 2	4.59716	5.1013	5.2168	5.9533
	Skin 3	7.63961	6.5219	6.5898	7.5891
	Brain Tumor 1	7.31096	6.8736	6.9873	7.3996
MB	Patient image 1 MRI	45.5869	85.2821	70.8203	58.1495
	MRI 2	51.9516	90.8853	79.6074	65.6768
	Skin 3	137.986	161.011	161.011	149.482
	Brain Tumor 1	105.2468	157.3552	149.3409	127.2639

Table 3
Comparison of the Mean Brightness (MB) of enhancement methods for medical images

Images		Enhancement with DC coefficient Scaling Jayanta [1]	Enhancement with DC coefficient Scaling In LAB space	Proposed method with Fusion
SNR	Patient image 1 MRI	1.6775	2.1613	4.2997
	MRI 1	1.9301	2.2245	4.4079
	Skin 3	5.7315	5.7315	11.451
	Brain Tumor 1	2.34478	2.5852	5.1435



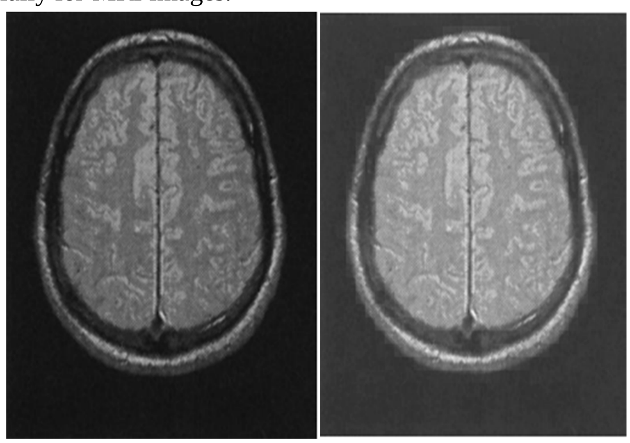
a) Original MRI patient image b) enhanced by Jayanta,et al.[1]



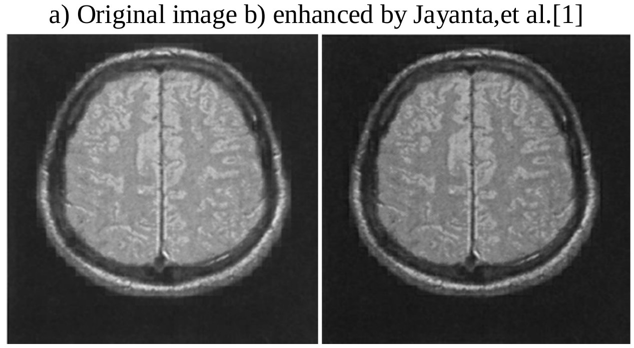
b) by DC coefficient scaling in Lab space d) by our final Fusion

Figure 7 Comparisons of the results for original MRI_patiant image 1 a) original image, b) enhanced by standard DC coefficient scaling method by Jayanta,et al.[1], c) enhanced by our modified DC coefficient scaling in LAB space d) with fusion of a) and c)

In order to check the colour preservation performance the skin 3 image is enhanced and comparative results are presented in Figure 9.this can be verified from the parametric values of entropy from Table 2 also. The proposed method gives the best entropy improved by significant amount especially for MRI images.



a) Original image b) enhanced by Jayanta,et al.[1]



c) DC coefficient scaling in Lab space d) by our final Fusion

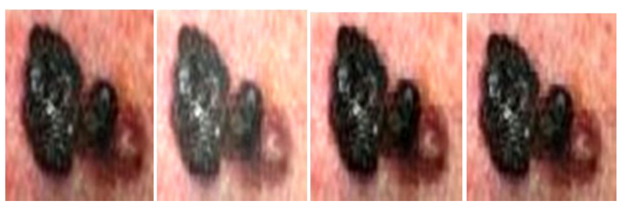
Figure 8 Comparisons of the results for original Axial Brain MRI 1 image a) original image, b) enhanced by standard DC coefficient scaling method by Jayanta,et al.[1], c) enhanced by our modified DC coefficient scaling in LAB space d) with fusion of a) and c)

It can be observed from Table 3 that the proposed method gives significant improvement in SNR compared to standard DC coefficient scaling method in Y-Cb-Cr space. For example for Skin_3 image the SNR is improved to 11.451 from 5.7315. Mean brightness is much preserved from proposed method.

The Figure.10 presents the results of enhancement where, clearly our proposed technique provides better visual results by preserving the contents in the Brain Tumor region of the image for further analysis and processing

a)Original Skin 3 image b) enhanced by Jayanta,et al.[1]

a)By DC coefficient scaling in Lab space d) by our final Fusion



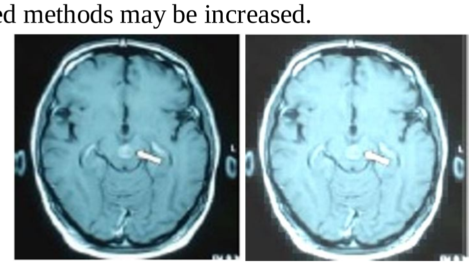
e) f) g) h)

Figure 9 Results for Skin 3 colour medical image. Where e), f),g) and h) are the cut section of respective images. Showing that, the enhanced method preserves the content better as verified by entropy.

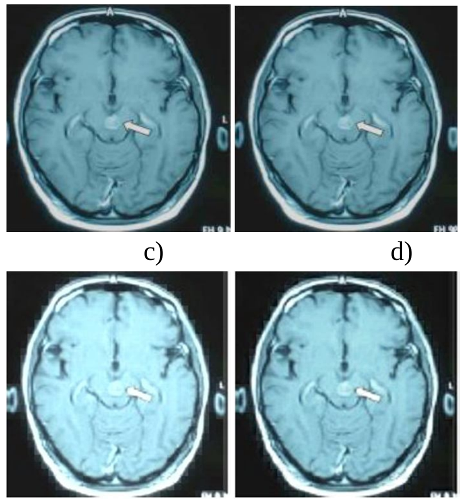
VII. CONCLUSIONS

In this paper a novel modified DC coefficient scaling in DCT domain method is proposed to enhance the quality of the Medical images. It is found the proposed method is capable of preserving the mean brightness better thus improves the entropy of the medical images. This is why the overall information is increased. This is because of using the Lab colour space better represents the colours. It is found that the standard DC coefficient scaling method improves the contrast but also increases the mean brightness simultaneously. Therefore, it is required to develop new method of scaling. In this paper a novel combination of scaling the DC coefficient in Lab space along with wavelet fusion for brightness preservation. Method is capable of adopting the order of the mapping Twicing function based on entropy analysis.

The proposed method gives significant improvement in SNR and increases the entropy, but simultaneously preserves the mean brightness. I future efficiency of fusion based methods may be increased.



a) B)



c) d)

e) f)

Figure 10.Comparision of the original brain tumor image results with existing Kapinaiah et al. [4] and our results. a) Original Image (b) TW-CES [1] (c) SF-CES with Power law γ=0.97 [4] (d) TW-CES with Power law γ=0.97 [4], (e) TW-CES-LAB space our result (f) TW-CES- LAB with our proposed Fusion.

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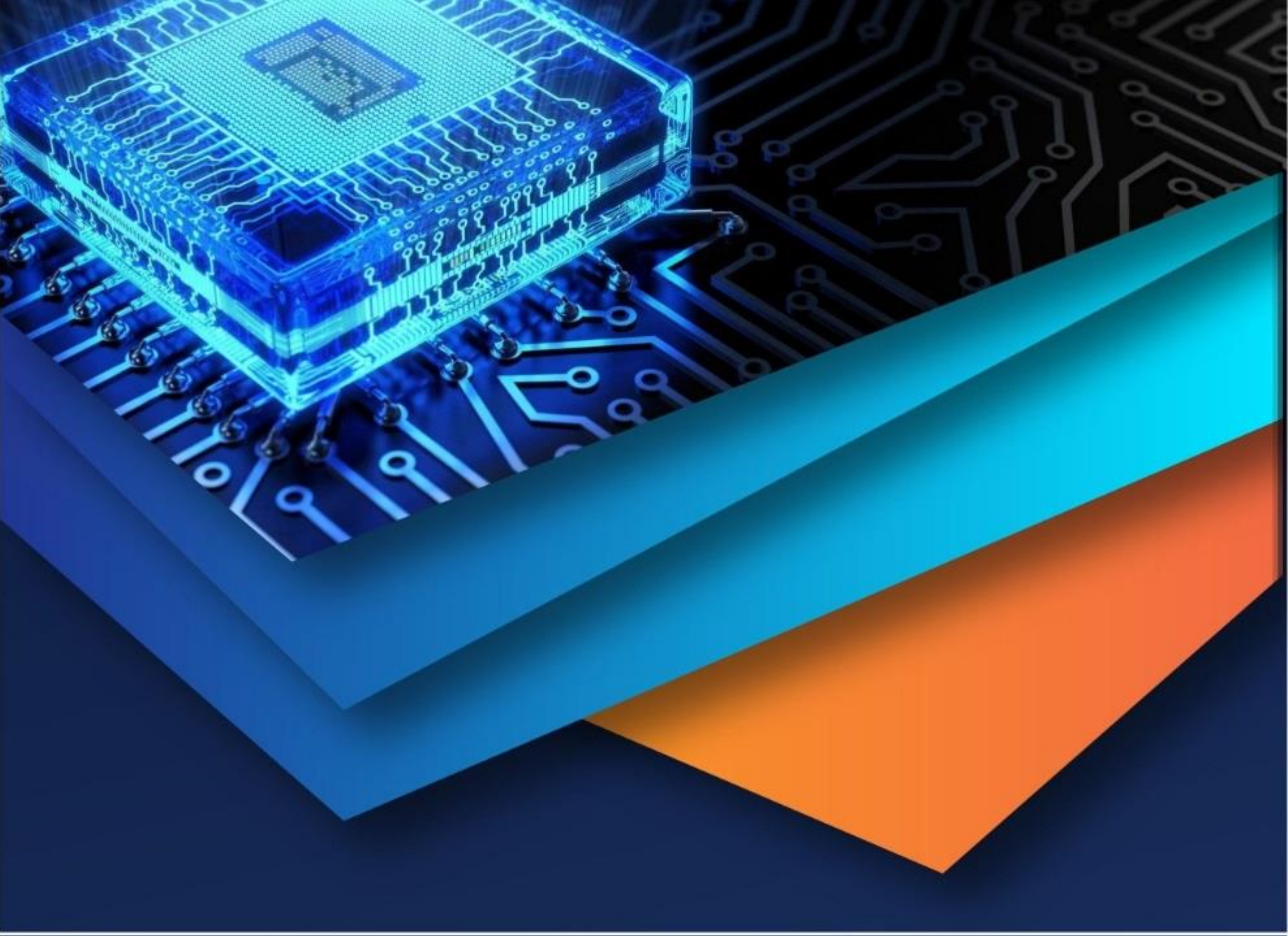

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