Compressed Domain Contrast and Brightness Improvement Algorithm for Colour Image through Contrast Measuring and Mapping of DWT Coefficients

M. Prabukumar[1] and J. Cristopher Clement[2]
[1]*School of Information Technology & Engineering, VIT University, Vellore – 632 014, India*
[2]*School of Electronics Engineering, VIT University, Vellore – 632 014, India*
mprabukumar@vit.ac.in, cristopher.clement@vit.ac.in

Abstract

A novel algorithm for enhancing colour images is proposed. Since DWT is used in image compression and image compression reduces storage space, an algorithm is developed to work directly in DWT space. DWT separates image into high and low frequency components. High frequency components define contrast of an image. Enhancement is done in two steps namely local enhancement and global enhancement. Local enhancement is based on contrast measure and improves contrast. Global enhancement is needed for overall image quality improvement. HSV colour space is used of which V components will undergo enhancement, S component will undergo histogram equalization, and H remains the same for preserving the colour.

Keywords: *DWT, Color image enhancement, HSV, DCT, Contrast*

1. Introduction

Enhancement plays a vital role in image processing. Improving visual quality of an image is termed as enhancement. Enhancement could be done on both Gray level and colour images. Many algorithms have been reported to enhance gray- level images viz. Histogram Equalization which equalizes histogram of gray level images for enhancement. Meanwhile Homomorphic filtering, Low pass, and high pass filtering are the other techniques to work in spatial domain [6] and [7]. Later, these techniques were used for enhancing colour images as well.

Increasing need of compression in signal and image processing seeks algorithms to work in compressed domain like DCT, and DWT. One such algorithm which works in DCT domain [1] separates DCT coefficients into various bands and enhances them using a scaling factor. This technique [1] is based on the measurement of contrast. Contrast is defined as the ratio of low frequency contents to high frequency contents of an image. Algorithm reported in [1] works for Gray level image but not for colour images. Alpha rooting [4, 11] and Multi contrast enhancement [5] are the other algorithms to work in DCT space. But these algorithms use non uniform scaling factors to scale the coefficients of same block. In addition, these algorithms do not treat chromatic components.

Colour image enhancement in DCT domain is proposed in [3] which treat both luminance and chromatic components for enhancement. Algorithm in [3] uses same scaling factor to scale the coefficients of any single block.

Algorithm for gray level image enhancement based on contrast measure is reported in [2]. This algorithm [2] treats gray scale images and not colour images, in addition, its enhancement is focused on contrast alone. Fuzzy based image enhancement algorithm is reported in [10].The proposed algorithm is developed using Discrete Wavelet Transform. It enhances local contrast of colour images and globally improves the brightness.

We make use of HSV colour space in this paper. We take third level DWT sub bands to measure contrast. Based on this, contrast of immediate lower level band of V components is improved. This is called local enhancement stage. Mean time global enhancement improves brightness of V component using mapping function. At last S component undergoes histogram equalisation, and H remains same.

The rest of the paper is organized as follows. Section 2 describes Discrete Wavelet transform. Section 3 presents proposed algorithm. Section 4 various quality metrics are discussed, Section 5 presents result and comparative discussion is made thereof, finally Section 6 concludes the paper.

2. 2D Discrete Wavelet Transform (DWT)

Images can be represented both in terms of local spatial and frequency contents using wavelet transforms. The Fourier transform and DCT provides global frequency characteristics of an image, but they fail to provide local frequency characteristics. This drawback is overcome in wavelet transforms by using its scaling property.

Wavelet uses various basis functions. Scaled and shifted versions of these basis functions are used in representing signals. There is no particular mathematic description for wavelets because of various basis functions used in it. But in general, any two dimensional signal can be decomposed into Approximate and detail coefficients as shown below

$$F(x,y) = \sum_{j=0}^{n-1} A_j \phi_{jn}(x,y) + \sum_{j=0}^{n-1} \sum_{k=0}^{n} D_{jk} \psi_{jk}(x,y) \qquad (1)$$

Where ϕ is the scaling function and ψ is the wavelet function. Equation (1) is implemented in discrete domain using decomposition filter banks. Similarly Inverse DWT is performed using reconstruction filter banks. Filter banks consists of Low pass and high pass filters. Approximate coefficients are obtained using low pass filter, and detailed coefficients are obtained using high pass filter.

Wavelet decomposition is executed in horizontal direction and then in vertical direction. The outputs of the filters are then down sampled so that each output is exactly one half the size of the input. Down sampling the output of low pass/high pass filters give both detailed and approximate coefficients. Level of decomposition is increased when the filter bank is repeated several times. We used third level DWT in our algorithm to enhance images. The reason for third level DWT is acceptable enhancement of an image is done in that level, even increasing the level there is no further improvement in the result. The processes of the third level decomposition and reconstruction using discrete wavelet transform are shown in Figure 1(a) and Figure 1(b) respectively.

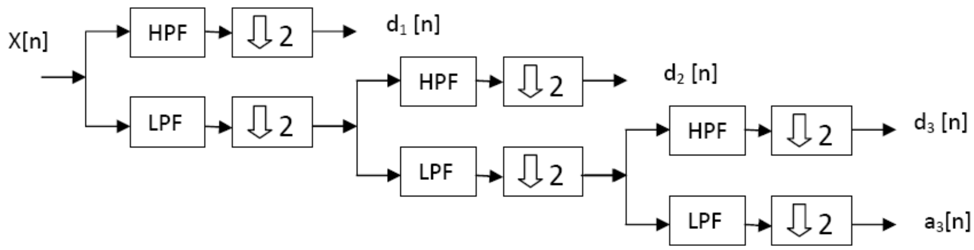

Figure 1(a) DWT Third Level Decomposition

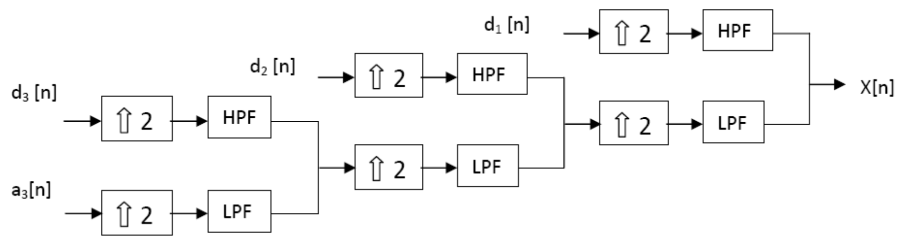

Figure 1(b) DWT Third Level Reconstruction

By executing the wavelet decomposition once, one main band, and three sub bands say LH, HL and HH are created. The main band is a coarser approximation to the original image, containing the overall information about the whole image. The band LH extracts the vertical details, the HL band extracts the horizontal details, and the band HH extracts the diagonal details of the image. Illustration of these bands is shown in Figure 2.

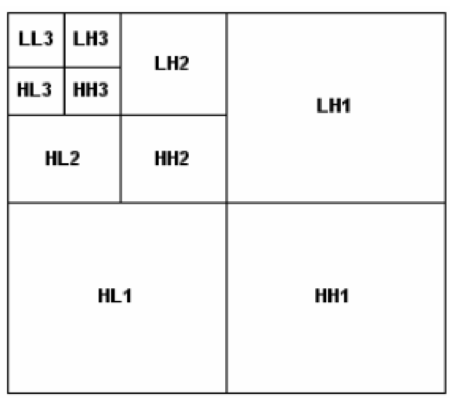

Figure 2. Bands at Third Level Decomposition

3. Proposed Algorithm

We present proposed enhancement algorithm based on DWT decomposition of an image up to third level. Wavelet type used in this algorithm is db1. Enhancement is done in two stages. First stage is local contrast enhancement, and second is global enhancement.

3.1. Local Contrast Enhancement

The proposed enhancement algorithm is based on the contrast measure presented in [2]. Contrast is defined as the ratio of high frequency contents to low frequency contents of an image. Here onwards, let us denote the sub bands as l1, l2 and l3 instead of LH, HL and HH. Contrast at any K^{th} level is defined for any sub band l as,

$$C_{k,l} = \frac{V_{k,l}}{\sum_l V_{k+1,l}/3} \qquad (2)$$

$$V_{k,l} = \frac{\sum_{i,j}\left|I_{k,l}(i,j)\right|}{N} \qquad (3)$$

Where $V_{k,l}$ the average absolute energy and N is the number of sub band coefficients. After performing enhancement contrast is defined as From (5) and (6):

$$\bar{C}_{k,l} = \lambda_{k,l}.C_{k,l} \qquad (4)$$

$$\bar{C}_{k,l} = \frac{\bar{V}_{k,l}}{\sum_l \bar{V}_{k+1,l}/3} = \lambda_{k,l}.C_{k,l} = \lambda_{k,l}.\frac{V_{k,l}}{\sum_l V_{k+1,l}/3} \qquad (5)$$

$$\bar{V}_{k,l} = \lambda_{k,l} Q_k V_{k,l} \qquad (6)$$

$$Q_k = \frac{\sum_l \bar{V}_{k+1,l}}{\sum_l V_{k+1,l}} \qquad (7)$$

In above equations, $\bar{V}_{k,l}$ is the average absolute value of sub band l at level k after enhancement, Q_k is the quality factor, and $\lambda_{k,l}$ is the scaling factor at level k and at sub band l.

In local enhancement, DWT coefficients are adjusted at every level to enhance edges. To do this, at third level, the maximum value of sub band is found using equation (8). Then at immediate lower level, corresponding sub band is increased and other sub band values are decreased.

$$M_k(i,j) = max\left(\left|I_{k,l1}(i,j)\right|, \left|I_{k,l2}(i,j)\right|, \left|I_{k,l3}(i,j)\right|\right) \qquad (8)$$

$$\lambda_{k,l} = \left(1 + \beta_{k,l}\right) \qquad (9)$$

$$\lambda_{k,l} = \beta_{k,l} \qquad (10)$$

Scaling factor in (9) is used to increase and factor in (10) is used to decrease.

Where $\beta_{k,l}$ is

$$\beta_{k,l} = \frac{V_{k+1,l}}{\sum_l V_{k+1,l}/3} \qquad (11)$$

For example, of the three bands, l1, l2 and l3 at level three, say coefficient $(|I_{3,l3}(i,j)|)$ has maximum value. Then the coefficient $(I_{2,l3}(i,j))$ is increased, on the other hand coefficients $(I_{2,l1}(i,j), and\ I_{2,l2}(i,j))$ at other bands are decreased.

By using (3) and (6) new enhanced coefficients in a band l at level k are obtained as follows

$$\bar{I}_{k,l}(i,j) = \lambda_{k,l}.Q_k.I_{k,l}(i,j) \qquad (12)$$

Where $I_{k,l}(i,j)$ are the DWT coefficients of an image.

Since coefficients at kth level are compared to enhance coefficients at (k−1)th level, kth level sub band coefficients will not be changed. Therefore

$$\bar{I}_{3,l}(i,j) = I_{3,l}(i,j) \qquad (13)$$

$$\bar{V}_{3,l} = V_{3,l} \qquad (14)$$

Hence

$$Q_2 = \frac{\sum_l \bar{V}_{3,l}}{\sum_l V_{3,l}} = 1 \qquad (15)$$

$$\bar{I}_{2,l}(i,j) = \lambda_{2,l} I_{2,l}(i,j) \qquad (16)$$

The above process is repeated until lower level band is reached.

3.2. Global Enhancement

Unlike in first stage, enhancement in this stage is done in every level for all three sub bands. The monotonically increasing mapping function from [3] shown in equation (17) plotted in figure.3 is used here to adjust the dynamic range of coefficients. This will adjust dynamic range of pixels as well.

$$y = x.(2 - x) \qquad (17)$$

The coefficients from local enhancement stage are taken for global enhancement. Normalized coefficients are obtained using (18)

$$X_{k,l}(i,j) = \frac{\bar{I}_{k,l}(i,j)}{\max\left(\left|\bar{\mathrm{I}}_{\mathrm{k,l}}(\mathrm{i,j})\right|\right)} \quad \begin{cases} for\ all\ i\,, j, and\ k \\ for\ l = l1, l2, and\ l3 \end{cases} \qquad (18)$$

$X_{k,l}(i,j)$ Values lie between 0 and 1. $X_{k,l}(i,j)$ is mapped as shown in equation (19) into newer values using equation (17).

$$\hat{X}_{k,l}(i,j) = X_{k,l}(i,j).\left(2 - X_{k,l}(i,j)\right) \qquad (19)$$

Factor to adjust every coefficient of a band is calculated as

$$\mathrm{T}_{k,l}(i,j) = \frac{\hat{X}_{k,l}(i,j)}{X_{k,l}(i,j)} \qquad (20)$$

$$\hat{I}_{k,l} = T_{k,l}(i,j) \times \bar{I}_{k,l}(i, \qquad (21)$$

Equation (21) performs global enhancement. $\hat{I}_{k,l}$ are the final enhanced coefficients.

While performing this multiplication some coefficients may exceed the allowable range of representation say 255 for 8 bit plane gray level image. In order to limit the coefficients in the range between 0 and 255 $T_{k,l}(i,j)$ should have a boundary.

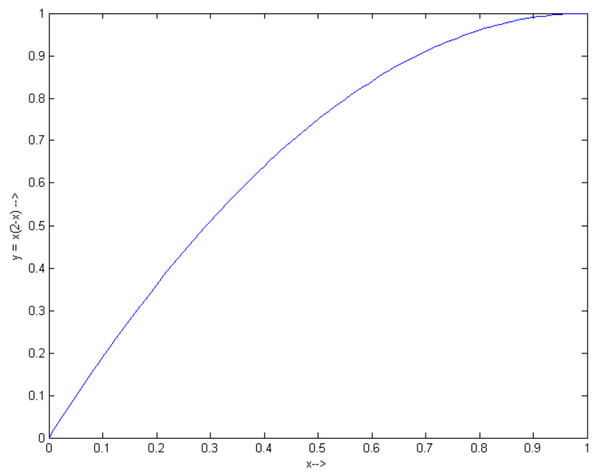

Figure 3. Mapping Function

Explanation is restricted to 1D DWT and it takes the help of Figure 4. Similar Analysis is applicable to 2D DWT for image signals because DWT follows separable property. Block has decomposition stage, followed by global enhancement, and reconstruction stage.

This analysis holds for db1 wavelet only. Discrete Low pass and high pass filters used in db1 type wavelet are also shown inside block. During decomposition down sampling leaves odd sequences and takes only even sequences so that sequence length is reduced to half. At the other end, up sampling interleaves zeros at odd places.

The following mathematics describes convolution, down sampling, scaling, and up sampling processes.

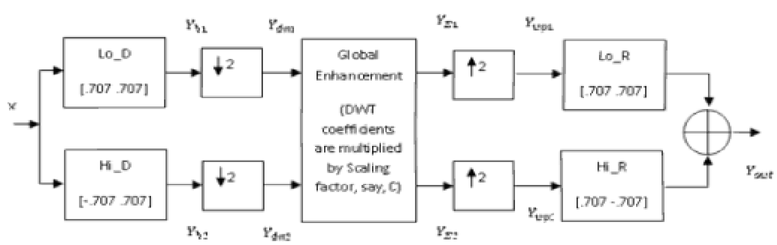

Figure 4. Block Diagram to Find Limiting Factor

$$Y_{h1}[n] = \sum_{k=-\infty}^{\infty} h(k)X[n-k] \qquad (22)$$

$$Y_{h2}[n] = \sum_{k=-\infty}^{\infty} h(k)X[n-k] \qquad (23)$$

After down sampling Y_{dn1} , and Y_{dn2} are represented in matrix multiplication as

$$Y_{dn1} = GH_1 \qquad (24)$$

$$Y_{dn2} = GH_2 \qquad (25)$$

Where $G = \begin{pmatrix} X(0) & X(1) \\ X(2) & X(3) \\ \vdots & \vdots \\ X(n-1) & X(n) \end{pmatrix}$, $H_1 = \binom{h}{h}$, and $H_2 = \binom{h}{-h}$. Y_{dn1}, and Y_{dn2} are the column matrixes of size $\left(floor\left(\frac{N1+N2-1}{2}\right)\right) \times 1$ for even number of input sequences. T Multiplies $Y_{dn1}$and $Y_{dn2}$and up sampling introduces zeros.

$$Y_{E1} = \begin{pmatrix} T.h.[X(0)+X(1)] \\ T.h.[X(2)+X(3)] \\ \vdots \\ T.h.[X(n-1)+X(n)] \end{pmatrix} \qquad (26)$$

$$Y_{E2} = \begin{pmatrix} T.h.[X(0)-X(1)] \\ T.h.[X(2)-X(3)] \\ \vdots \\ T.h.[X(n-1)-X(n)] \end{pmatrix} \qquad (27)$$

$$Y_{up1} = \begin{pmatrix} 0 \\ T.h.[X(0)+X(1)] \\ 0 \\ T.h.[X(2)+X(3)] \\ \vdots \\ 0 \\ T.h.[X(n-1)+X(n)] \\ 0 \end{pmatrix} \qquad (28)$$

$$Y_{up2} = \begin{pmatrix} 0 \\ T.h.[X(0)-X(1)] \\ 0 \\ T.h.[X(2)-X(3)] \\ \vdots \\ 0 \\ T.h.[X(n-1)-X(n)] \\ 0 \end{pmatrix} \qquad (29)$$

Final output Y_{out} is the summation of Y_{up1} and Y_{up2}.

$$Y_{out} = T.h^2 \begin{pmatrix} 0 \\ X(0)+X(1) \\ X(0)+X(1) \\ X(2)+X(3) \\ X(2)+X(3) \\ \vdots \\ X(n-1)+X(n) \\ X(n-1)+X(n) \\ 0 \end{pmatrix} + T.h^2 \begin{pmatrix} 0 \\ X(0)-X(1) \\ -[X(0)-X(1)] \\ X(2)-X(3) \\ -[X(2)-X(3)] \\ \vdots \\ X(n-1)-X(n) \\ -[X(n-1)-X(n)] \\ 0 \end{pmatrix} \quad (30)$$

$$Y_{out} = T.h^2.2 \begin{pmatrix} 0 \\ X(0) \\ X(1) \\ X(2) \\ X(3) \\ \vdots \\ X(n-1) \\ X(n) \\ 0 \end{pmatrix} \quad (31)$$

Note $h^2.2 = 1$ and Y_{out} is the column vector of size $\left(2 + 2.floor\left(\frac{N1+N2-1}{2}\right)\right)$ of which first and last terms are left out. Since similar procedure is applicable to 2D, we will take sequences X(n) as image samples. In order these samples not to exceed dynamic range

$$T.X(n) \leq 2^k - 1 \quad (32)$$

Where k is number of bits used for image representation and is number of pixels

$$1 \leq T \leq \frac{2^k-1}{X(n)} \quad (33)$$

In brief, the algorithms are stated in Table 1 and Table 2.

Table 1. Local Enhancement Algorithm

Local enhancement Input : HSV Components of an Image. Output: Local contrast enhanced DWT Coefficients. Step 1: Compute 3rd level 2d DWT for V component. Step 2: Start from level k=2. Step 3: Calculate $\beta_{k,l}$ from (11). Step 4: Find M_{k+1} from (8), and enhance lower level coefficients $I_{k,l}$ using (16). Step 5: Decrement k and repeat steps 3 and 4 until k becomes 1.

Table 2. Global Enhancement Algorithm

Global enhancement
Input : Local contrast enhanced DWT Coefficients from previous algorithm, S component, and H Component. Output: Globally Enhanced Image. Step 1: Start from level k =3. Step 2: Normalize coefficients of all sub bands using (18). Step 3: Map Normalized coefficients using function shown in (19). Step 4: Find Multiplication factor using (20) and multiply all coefficients with this factor. Step 5: Limit the Multiplication factor using (33). Step 6: Decrement k and repeat steps 2 to 5 until k is greater than 0. Step 7: Perform Inverse DWT of enhanced coefficients. Step 8: Take S component and perform histogram equalization, keep H component as such. Step 9: Convert HSV colour space back into RGB space to get enhanced image.

4. Quality Measure using Performance Metrics

Three types of metric are used here for quality analysis. JPEG Quality Metric (JPQM) verifies the quality of JPEG images as reported in [8]. Wang et al. have suggested [8] a no reference metric for assuring the quality of an image. It is important to note that the value of JPQM should be as close as to 10 for good visibility. Procedure for finding JPQM is described below.

4.1 JPQM

Let the test image signal be $I(x,y)$ for $x \in [1,X]$ and $y \in [1,Y]$. Then the difference signal along each horizontal line is denoted as,

$$d_h(x,y) = I(x,y+1) - I(x,y), \quad y \in [1, Y-1] \tag{34}$$

Average difference across block boundaries is calculated horizontally as,

$$\beta_h = \frac{1}{X\left(\left[\frac{Y}{8} - 1\right]\right)} \sum_{i=1}^{X} \sum_{j=1}^{\frac{Y}{8}-1} |d_h(i,8j)| \tag{35}$$

Activity is measured using two factors. First is the Average absolute difference between in-block image samples, which is defined as

$$\alpha_h = \frac{1}{7}\left[\frac{8}{X(Y-1)} \sum_{i=1}^{X} \sum_{j=1}^{Y-1} |d_h(i,j)| - \beta_h\right] \tag{36}$$

Second activity measure is the zero crossing rates. We define for $y \in [1, Y-2]$.

$$\zeta_h(x,y) = \begin{cases} 1 & horizontal\ ZC\ at\ d_h(x,y) \\ 0 & otherwise \end{cases} \quad (37)$$

Horizontal ZC rate then can be estimated as

$$\xi_h = \frac{1}{X(Y-2)} \sum_{i=1}^{X} \sum_{j=1}^{Y-2} \zeta_h(x,y) \quad (38)$$

Similar procedure is applied in calculating vertical features of B_v, A_v, and Z_v. Then the overall features are calculated as,

$$\beta = \frac{\beta_h + \beta_v}{2}, \alpha = \frac{\alpha_h + \alpha_v}{2}, \xi = \frac{\xi_h + \xi_v}{2} \quad (39)$$

Then the performance metric JPQM is defined to be

$$JPQM = \rho + \eta \beta^{\tau 1} \alpha^{\tau 2} \xi^{\tau 3} \quad (40)$$

Where $\rho, \eta, \tau 1, \tau 2, and\ \tau 3$ are the model parameters with values

$$\rho = -245.9, \eta = 261.9, \tau 1 = -0.024, \tau 2 = 0.0160, and\ \tau 3 = 0.0160 \quad (41)$$

Standard values for these parameters are taken from [8].

4.2 WBQM

This metric assures perceptual quality of an image. WBQM is otherwise called as Wang – Bovic – Quality Metric [9]. If x and y are two distributions, then WBQM between these two distributions can be defined as

$$WBQM(x,y) = \frac{4\sigma_{xy}^2 \bar{x}\bar{y}}{(\sigma_x^2 + \sigma_y^2)(\bar{x}^2 + \bar{y}^2)} \quad (42)$$

Where σ_{xy} is the covariance between x and y, σ_x and σ_y are standard deviations, $\bar{x}, \bar{y}$ are means of distributions x and y respectively.

Values of WBQM will lie between [-1, 1], and images with values close to 1 ensures good perception. WBQM values are found individually for H, S, and V components. It is shown in Table 4, Table 5 and table 6 respectively.

4.3 PSNR

PSNR is one of the quality measure used for images. This section presents a way to find PSNR. Let the actual image be $I_h(x,y)$ and the enhanced image be $E_h(x,y)$ Mean square error between these two image signals is calculated as,

$$MSE = |I_h(x,y) - E_h(x,y)|^2 \quad (43)$$

With MSE calculated as above, the PSNR is expressed as

$$PSNR = 10log\left(\frac{255^2}{MSE}\right) \ dB \quad (44)$$

5. Results and Discussions

We have tested our algorithm for twenty Images of which we presented six images with quality metrics. Results are compared with Histogram equalization and alpha rooting which is proposed in [4]. Test image1 is shown in figure. 5. Histogram equalization as in figure.5.b improves the brightness of an image but fails to improve the contrast. Enhancement using Alpha rooting is shown in figure 5.c. The value of alpha chosen here is 0.98. Alpha rooting does over enhancement and results in unnatural looking of image. As shown in figure 5.d proposed algorithm improves the contrast which is visible in lighting area and border between the building stones. Image shown in figure.6.a is taken from [3]. As usual, histogram equalization improves brightness of an image that could be seen in figure.6.b. Alpha rooting does well in improving contrast but fails in doing the brightness, mean while alpha rooting results in artifacts as shown in the figure 6.c. Result of the Proposed algorithm enhances brightness as well as contrast is given in Figure6.d .It shows that artifacts are very minimal in proposed algorithm. Similar comparisons can be made from natural image shown in figure 7.a where the sky is over enhanced in histogram equalization where as the proposed algorithm preserves natural looking and colour of an image meanwhile increases the contrast. Similar comparative results are shown in figure.8, figure.9, and figure.10 for various test images. We infer from the obtained results that proposed algorithm improves the contrast, brightness, mean while preserves the colour. Since local enhancement stage of our algorithm operates in sub bands, edge details are enhanced and the same improves the contrast. Overall brightness of an image is improved in global enhancement

As discussed in previous section quality metrics JPQM, WBQM, and PSNR are used for ensuring the quality of an image. Values are listed in Table 3, Table 4, Table 5, Table 6 and Table 7 for all shown images. Values ensure the quality of an algorithm.

Table 3. JPQM

Test Image	Techniques		
	Histogram Equalization	**Alpha Rooting**	**Proposed**
1	9.46	9.67	9.87
2	8.9	9.04	9.28
3	8.27	8.86	9.18
4	9.67	9.59	9.97
5	9.15	9.29	9.78
6	9.49	9.61	9.89

Table 4. WBQM_H

Test Image	Techniques		
	Histogram Equalization	Alpha Rooting	Proposed
1	0.59	0.69	0.79
2	0.51	0.57	0.64
3	0.80	0.87	0.90
4	0.61	0.63	0.72
5	0.69	0.69	0.78
6	0.71	0.73	0.79

Table 5. WBQM_S

Test Image	Techniques		
	Histogram Equalization	Alpha Rooting	Proposed
1	0.69	0.69	0.69
2	0.47	0.57	0.60
3	0.53	0.67	0.70
4	0.61	0.69	0.78
5	0.63	0.65	0.79
6	0.81	0.83	0.90

Table 6. WBQM_V

Test Image	Techniques		
	Histogram Equalization	Alpha Rooting	Proposed
1	0.56	0.59	0.63
2	0.62	0.67	0.71
3	0.69	0.69	0.78
4	0.63	0.65	0.79
5	0.69	0.69	0.78
6	0.81	0.87	0.91

Table 7. PSNR

Test Image	Techniques		
	Histogram Equalization	Alpha Rooting	Proposed
1	11.120	11.560	12.890
2	12.107	13.273	13.983
3	8.978	9.327	9.728
4	9.276	9.387	9.865
5	9.9724	9.9812	9.9938
6	14.408	14.03	13.025

a. Original Image b.Histogram Equalized c.Alpha Rooting d.Proposed

Figure 5. Test Image1

a. Original Image b.Histogram Equalization c.Alpha Rooting d.Proposed

Figure 6.Test Image2

a. Original Image b.Histogram Equalization c.Alpha Rooting d.Proposed

Figure 7. Test Image3

a. Original Image b.Histogram Equalization c.Alpha Rooting d.Proposed

Figure 8. Test Image 4

a. Original Image b.Histogram Equalization c.Alpha Rooting d.Proposed

Figure 9. Test Image 5

a. Original Image b.Histogram Equalization c.Alpha Rooting d.Proposed

Figure 10.Test Image 6

6. Conclusion

This paper proposed an algorithm to enhance color images using discrete wavelet transform. Enhancement is done for. Two stage enhancements outperform to enhance Contrast as well as Brightness of an image. Quality of enhanced image obtain from the proposed algorithm is compared with histogram equalization and alpha rooting method of image enhancement. The proposed image enhancement algorithm performs better than other two methods used for comparison in terms of contrast as well as quality metrics value.

Acknowledgements

We thank VIT University, Vellore, India for supporting this research work. We also thank anonymous reviewers for their reviews and feedback on the paper.

References

[1] J. Tang, E. Peli and S. Acton, “Image enhancement using a contrast measure in the compressed domain”, IEEE Signal Process. Lett., vol. 10, no. 10, **(2003)**, pp. 289–292.

[2] A. A. Abdelwahab, M.K. Ahmed and S. H. Hashem, “Image Enhancement Using a Contrast measure in the Discrete Wavelet Transform”, National Radio Science Conference, **(2007)**, pp. c18 (01-11).

[3] J. Mukherjee and S. K. Mitra, “Enhancement of color images by scaling the DCT coefficients”, IEEE Trans. Image Processing, vol. 17, no. 10, **(2008)**, pp. 1783-1794.

[4] S. Aghagolzadeh and O. K. Ersoy, “Transform image enhancement”, Opt. Eng., vol. 31, **(1992)**, pp. 614–626.

[5] J. Tang, J. Kim and E. Peli, “An image enhancement algorithm in JPEG domain for low-vision patient”, IEEE Trans. Biomed. Eng., vol. 51, no. 11, **(2004)**, pp. 2013–2023.

[6] J. S. Lim, “Two-Dimensional Signal and Image Processing”, Englewood Cliffs, NJ: Prentice-Hall, **(1990)**.

[7] R. C. Gonzales and E. Woods, “Digital Image Processing. Reading”, MA: Addison-Wesley, **(1992)**.

[8] Z. Wang, H. R. Sheikh and A. C. Bovik, “No-reference perceptual quality assessment of JPEG compressed images”, in Proc. Int. Conf. Image Processing, Rochester, NY, vol. 1, **(2002)**, pp. 477–480.

[9] Z. Wang and A. C. Bovik, “A universal image quality index”, IEEE Signal Process. Lett., vol. 9, no. 3, **(2002)**, pp. 81–84.

[10] C. -F. Chen, H. -Y. Chang and L. -Y. Chang, “A Fuzzy-based method for remote sensing image contrast enhancement”, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXVII, Part B2, Beijing, **(2008)**, pp. 995-999.

[11] Md F. Hossain, M. R. Alsharif, “Image enhancement using splitting ∝-Rooting method in wavelet domain”, in proceedings of the 23th Inational Conference on circuits/system computers and communications, **(2008)**, pp. 17-20.

Authors

M. Prabukumar currently pursuing his Ph.D. in VIT University, Vellore. He received his Master degree in Computer Science from Amrita University, Coimbatore. His research interests are in computer graphics, computer vision and image processing. He is life time member in CSI. He has published a number of research papers in peer reviewed journals.

J. Christopher Clement received the B.E. degree in Electronics and Communication engineering from Madras University, India in 2000, and M.E. degree in Communication Systems from Thiagarajar College of Engineering, Anna University in 2008.At present He works for School of Electrical Sciences, VIT University, India where he is doing his Ph.D. His research interests include Signal Processing and its applications in modern communication techniques, CODEC design, and Image processing.