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A Novel DWT Based Techniques for Underwater Image Enhancement

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Abstract: - **In Recent years, the underwater image processing area has received a great attention from researchers. In the oceanic environment, capturing a clear underwater image is having a crucial importance. Underwater images are usually degraded due to the effects of absorption and scattering. The quality of underwater images is affected by the color cast, poor visibility, foggy appearance and misty. In order to overcome those limitations, an underwater image enhancement technique built on a DWT method is proposed. The main aim of the proposed algorithm is to increase the quality of underwater images. In this paper, 100 different images are used to perform the comparison of the proposed technique with the previous techniques. The performance of the proposed method of DWT is evaluated using the Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM) and Absolute Mean Brightness Error (AMBE). Performance measurement of the Wavelet techniques produces better enhancement results than previous techniques like Contrast Limited Adaptive Histogram Equalization (CLAHE).**

Keywords: **Image enhancement; wavelet techniques; peak signal-to-noise ratio (PSNR); structural similarity measure (SSIM); Absolute Mean Brightness Error (AMBE).**

I. INTRODUCTION

Underwater image processing is challenging due to the physical properties of the underwater environment. In many cases, captured underwater images are degraded by absorption and scattering. Additionally, the underwater image brings unwanted noise and increases the effects of scattering. The degree of absorption depends on different wavelengths of light (red,blue,green) which leads to the color cast of underwater images. In this, there are two kinds of scattering: first one is forward scattering that leads to blurring and the second one is backward scattering that causes low contrast. Capturing a clear and high quality underwater image is not an easy work. Since, underwater images are suffering from the above properties. However, there are many image-base methods in underwater image enhancement. Global and local image contrast enhancement is widely used to improve the appearance of underwater images.

Improving the underwater image quality can be divided into two different problems . They are, the image restoration problem and the image enhancement problem.

In order to deal with underwater image processing, we have to consider first of all the basic physics of the light propagation in the water medium. Physical properties of the medium cause degradation effects not present in normal images taken in air. Underwater images are essentially characterized by their poor visibility because light is exponentially attenuated as it travels in the water and the scenes result poorly contrasted and hazy. Light attenuation limits the visibility distance at about twenty meters in clear water and five meters or less in turbid water. The light attenuation process is caused by absorption (which removes light energy) and scattering (which changes the direction of light path). The absorption and scattering processes of the light in the water influence the overall performance of underwater imaging systems. Forward scattering (randomly deviated light on its way from an object to the camera) generally leads to blurring of the image features. On the other hand, backward scattering (the fraction of the light reflected by the water towards the camera before it actually reaches the objects in the scene) generally limits the contrast of the images, generating a characteristic veil that superimposes itself on the image and hides the scene.

Absorption and scattering effects are due to not only to the water itself, but also to other components such as dissolved organic matter or small observable floating particles. The presence of the floating particles known as "marine snow" (highly variable in kind and concentration) increase absorption and scattering effects. The visibility range can be increased with artificial lighting but these sources not only suffer from the difficulties described before (scattering and absorption), but in addition tends to illuminate the scene in a non uniform fashion, producing a bright spot in the center of the image with a poorly illuminated area surrounding it. Finally, as the amount of light is reduced when we go

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deeper, colors drop off one by one depending on their wavelengths. The blue color travels the longest in the water due to its shortest wavelength, making the underwater images to be dominated essentially by blue color. Chong-Yi Li, Ji-Chang Guo et al. (2016)[1] have discussed a new method specifically developed for enhancing the underwater images. To overcome the limitations of, a systematic underwater image enhancement method, which includes an underwater image dehazing algorithm and a contrast enhancement algorithm, is proposed. An effective underwater image dehazing algorithm is proposed to restore the visibility, color, and natural appearance of underwater images. An effective contrast enhancement algorithm is proposed based on a kind of histogram distribution prior, which increases the contrast and brightness of underwater images . Miao Yang, Member and Arcot Sowmya.(2015)[2] have discussed a new method specifically developed for measure the underwater image enhancement. In this paper, UCIQE is an effective metric to measure the image enhancement results. Colour Image Quality Index (CIQI), which is a linear combination of colourfulness, sharpness and contrast metrics. But the metric value does not linearly correspond to human perceptions. Colour Quality Enhancement (CQE),which is measured with different colourfulness, sharpness and contrast metrics. Colour Root Mean Enhancement (CRME) to measure the relative difference of the colour cube centre and all the neighbours in the current colour cube. Underwater Color Image Quality Evaluation (UCIQE) metric has comparable performance to the leading natural color image quality metrics and the underwater grayscale image quality metrics. The UCIQE gives the best result when compare to the CIQI,CQE and CRME .

Yafei Wang, Xueyan Ding et al.(2017) [3] have discussed a new method specifically developed for image enhancement. In this paper, an efficient fusion-based underwater image enhancement approach using wavelet decomposition is presented.The proposed fusion process involves two inputs which are represented as color corrected and contrast enhanced images extracted from original underwater image. Both the color corrected and contrast enhanced images are decomposed into low frequency and high frequency components by three-scale wavelet operator. The low frequency and high frequency components are fused through a multiscale fusion process. The low frequency components are fused by weighted average and the high frequency components are fused by local variance. These fused low frequency and high frequency components can be reconstructed as final enhanced image.The experimental results show that the proposed algorithm can improve the visibility of underwater images.

John Y. Chiang and Ying-Ching Chen. (2012) [4] have discussed a new method specifically developed for image enhancement. The WCID algorithm is proposed in this paper can effectively restore the image color balance and remove haze. The haze removing and color balancing capabilities of the proposed wavelength compensation and image dehazing (WCID) over traditional dehazing and histogram equalization methods. Lintao Zheng, Hengliang Shi et al.(2016) [5] have discussed a new method specifically developed for image enhancement . in this , the proposed algorithm is based on a single degraded underwater image, which does not require specialized hardware and any knowledge about the underwater conditions. In this paper, a pixel-based fusion algorithm is employed to effectively improve the visibility of underwater image. The Contrast-Limited Adaptive Histogram Equalization (CLAHE) is first applied to the degraded underwater source image and generating the first input of the fused image. Next, Unsharp masking(USM) is applied to the degraded underwater source image to create the second input of the fused image. The proposed method is proposed by fusing the output from two well-known image enhancement algorithms CLAHE and USM. Kashif Iqbal, Rosalina Abdul Salam et al.(2007) [6] have discussed a new method for underwater image enhancement. In this paper, we have used slide stretching algorithm both on RGB and HSI colour models to enhance underwater images. In order to indicate the usefulness of our approach, we have developed an interactive software tool to be used for underwater image enhancement. First, it performs contrast stretching on RGB colour model. Second, it performs saturation and intensity stretching on HSI colour model. The advantage of applying two stretching models is that it helps to equalize the colour contrast in the images and also addresses the problem of lighting .

Dithee Dev.K, S.Natrajan. (2015) [7] have discussed a new method for underwater image enhancement. In this paper, we have used Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm for enhancing the underwater images and performs the illuminant estimation due to the presence of artificial light. The CLAHE algorithm that effectively performs the better clarity of the image,the hazy effect cause in presence of scattering and color changing. It gives better result compared to another methods like wavelength compensation and image dehazing(WCID), polarization analysis etc. and also the enhancement methods effectively improves the visibility of underwater images and produce the lowest MSE values and the highest PSNR values. Ghada S. Karam, Ziad M. Abood et al.(2013) [8] have discussed a new method for underwater image enhancement. In this paper, we have used image enhancement algorithm for underwater image by using FHE system. The contrast stretching of RGB algorithm to equalize the color contrast in the images are used. The L*a*b model provides a wider color range by controlling the color elements of the image. Using this technique the RGB color images convert to L*a*b image to great more range. Then the fuzzy histogram equalization (FHE) was applied. FHE method not only give a better equalization but also improves the contrast of image. Shivika Saini, Pawan Kumar Mishra (2017) [9] have discussed a new method for underwater image enhancement. In this paper, a new image enhancement technique based on CLAHE and L*A*B color space is presented . To overcome the problem of the uneven illumination in the CLAHE output image has been removed by utilizing the image enhancement unsharp masking filter. The idea of proposed technique is to enhance the edges of the different underwater image by using sharpen filter. We have highlighted various measures like MSE, PSNR.

II. PROPOSED METHOD

Normally, for better visual quality of natural images the distribution of its RGB components should be uniform but this may not be possible in case of underwater image where in the colors of particular wavelengths gets destroyed with increase in water depth. So, in order to remove the effect of this color loss and low contrast from underwater images, these needs to be preprocessed by means of some enhancement techniques Discrete Wavelet Transform (DWT) has been proposed.

2.1. The discrete wavelet transform (DWT)

Discrete wavelet transforms, which transforms a discrete time signal to a discrete wavelet representation. As with wavelet transforms, a key advantage it has over Fourier transform is temporal resolution, it captures both frequency and location in time. A 2-D discrete wavelet transform coefficients are calculated efficiently in discrete by applying the associated 1-D filter bank to each column and each row of the resulting coefficients. In proposed method two level decompositions are used. In the first level of decomposition, one approximation coefficients (LL1) and three detail coefficients (LH1,HL1,HH1) are created. In the second level of decomposition, the approximation coefficients is further decomposed into one approximation coefficients (LL2) and three detail coefficients (LH2,HL2,HH2) .

The proposed algorithm is as follows:

Step 1: Read the input image(RGB).
Step 2: Split the input image into RGB components.
Step 3: Apply DWT on individual RGB components.
In this method two levels decomposition are used.
Step 4: Collect the approximation coefficient for each level of decomposition.
Step 5: Collect the detailed coefficient for each level of decomposition.
Step 6: Modify the approximation coefficient of the coarsest scale(Jth level) by using Eq.(1,2,3,4).
Step 7: Modify the detailed coefficient by using the approximation coefficients by using Eq.(5).
Step 8: Compute the approximation coefficient by using IDWT.
Step 9: Apply color correction technique on approximation response of finest scale(J-1th level).
Step10:Apply IDWT on approximation coefficient and modifying detailed coefficients.
Step11: Finally, enhanced images are obtained.

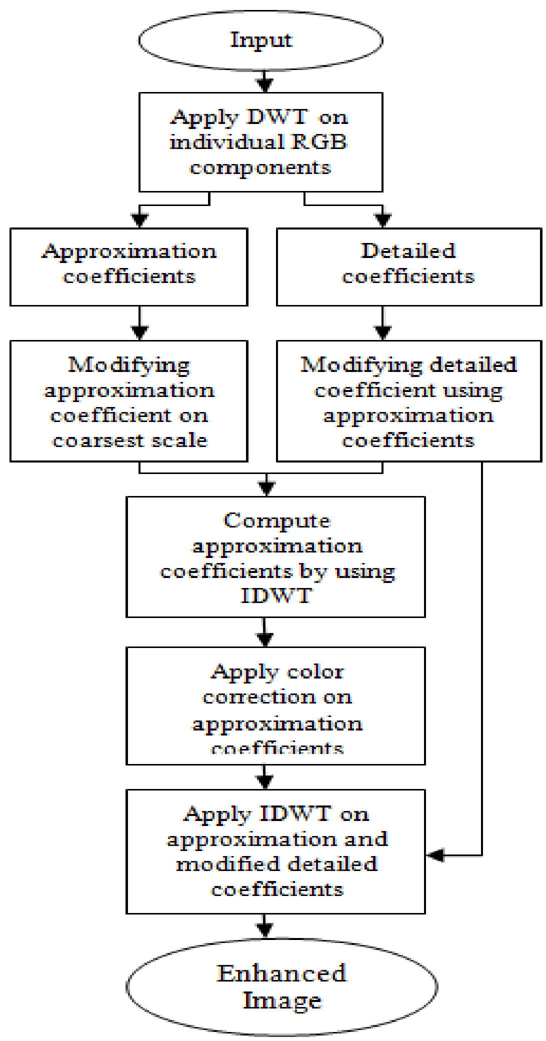


Fig.1. Flowchart of proposed algorithm.

2.2. Modifying Approximation Coefficients in Wavelet Domain

The average approximation coefficient is calculated in the wavelet domain at the scale J is calculated as,

$$a\_avg_j = \frac{1}{3}\sum_{i=1}^{3} LL_{ij} \tag{1}$$

where, LL approximation coefficients, i indicates RGB components and j represents decomposition level.

Jth scale approximation coefficients are modified. The average values at the Jth scale are balanced by the adjustment of the original values through convex linear combinations are given by,

$$LL_{RJ} = \alpha * a\_avg_j + (1-\alpha)LL_{RJ} \tag{2}$$

$$LL_{GJ} = \alpha * a\_avg_j + (1-\alpha)LL_{GJ} \tag{3}$$

$$LL_{BJ} = \alpha * a\_avg_j + (1-\alpha)LL_{BJ} \tag{4}$$

Where, LLJ is the approximation coefficient of the Jth scale.
Assign α=[0,1] is a suitable learning rate.

2.3. Modifying Detailed Coefficients in Wavelet Domain

To enhance the contrast local in the wavelet domain, the local contrast enhancement functionalities are at the Jth scale. The detailed coefficient is given as,

$$D_{IJ} = D_{IJ}^{\ 0} + W_j\left(\frac{LL_{IJ}}{D_{IJ}}\right) \tag{5}$$

Where DIJ() is absolute value of original coefficients.

2.4. Removal of Color Cast in Underwater Imagery

Color enhancement in underwater imagery is obtained by minimizing the functional such as Adjustment to the average intensity value and Local contrast enhancement. Adjustment to the average intensity value is obtained by modified the coarset approximation coefficients. Local contrast enhancement is obtained by minimizing an enegy functions of detailed coefficiens. Color cast removal is obtained by applying color correction on approximation coefficients of finest scale and set detailed coefficients as constant.

i).To calculate the maximum and average values on approximation coefficients of each RGB components are

$$R_{avg} = \frac{1}{N}\sum_{i=1}^{N} R; G_{avg} = \frac{1}{N}\sum_{i=1}^{N} G; B_{avg} = \frac{1}{N}\sum_{i=1}^{N} B; \tag{6}$$

Where maximum values on approximation coefficients are Rmax, Gmax, Bmax and average values on approximation coefficients are Ravg, Gavg, Bavg.

ii).To calculate the maximum and average luminance of image (Lmax, Lavg) with the YCbCr color model.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.5 \\ 0.5 & -0.81 & -0.81 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{7}$$

Where Y represents the luminance and Cb, Cr represents the blue and red chrominance components.

III. CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION

The Contrast Limited Adaptive Histogram Equalization is used to limit the noise amplification. For high saturation images, which get dense toward one or two closely related colors i.e., those which are harder to differentiate, might tend to mask minor details of information which do not get noticed explicity between the highly-saturated colors. Thus, these high saturation images obtained in their true color space, i.e., RGB space are transformed into HSV color space which has a separate channel containing saturation values. This channel can be singled out from the HSV image and can be operated upon independently without affecting the other two channels – Hue and Value channels.In order to even out the dense saturation of images and thereby increasing the dynamic range, Contrast Limited Adaptive Histogram Equalization is made use of. This enhancement technique is used to highlight those hidden pieces of information that get masked between dominating colors in high saturation images. After this technique is used, the three constituent channels are then concatenated into a new HSV image with adapted Saturation channel. Then, the adapted HSV image is converted into RGB image format. Then we get the output image in RGB image format.

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 12, December 2017

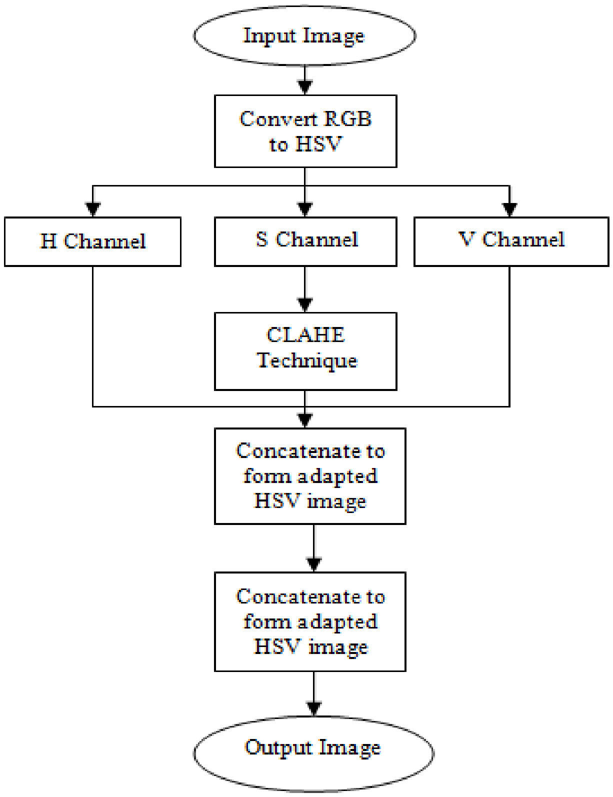


Fig.2. Flowchart of CLAHE Method.

The CLAHE algorithm is as follows:

Step 1: Read the Input RGB Image.
Step 2: Convert the RGB to HSV Image.
Step 3: Split the HSV as individual channel.
Step 4: Apply CLAHE Technique on S channel.
Step 5: Concatenate the H , CLAHE and V channel to form Adapted HSV.
Step 6: Convert HSV Image to RGB format.
Step 7: Finally, Enhanced Image is obtained.

IV. PERFORMANCE EVALUATION

In Performance evaluation, four measurements are calculated such as Peak-Signal-to-Noise Ratio (PSNR), Structure Similarity Index Measure (SSIM), Entropy and Absolute Mean Brightness Error (AMBE).

4.1. Peak-Signal-to-Noise Ratio

The term, PSNR is the mean square error between original image and enhanced image. It is an approximation to human perception of enhanced quality of an image. A higher PSNR denotes that the enhanced of higher quality.

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j)-K(i,j)]^2 \quad (8)$$

$$PSNR = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (9)$$

Where I is the original image, K is the enhanced image and MAXI is the maximum possible pixel value of the original image.

4.2. Structure Similarity Index Measure

SSIM is a method for measuring the similarity between two images.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (10)$$

Where μ_x , μ_y is the mean values, σ_x, σ_y is the standard deviation of window x and y.

4.3.Absolute Mean Brightness Error

AMBE is used to quality of the degree of brightness preservation and used to calculate difference in mean brightness between two images. For good brightness preservation, the value of AMBE should be as low as possible.

$$AMBE(x,y) = |Mean_x - Mean_y| \quad (11)$$

Where $Mean_x$ and $Mean_y$ are the mean brightness of input image (x) and enhanced image (y).

V. EXPERIMENTAL RESULTS

The proposed method was implemented in MATLAB and the performance evaluation are calculated such as PSNR, SSIM and AMBE for 100 different images.
The results are shown in below.

(a)

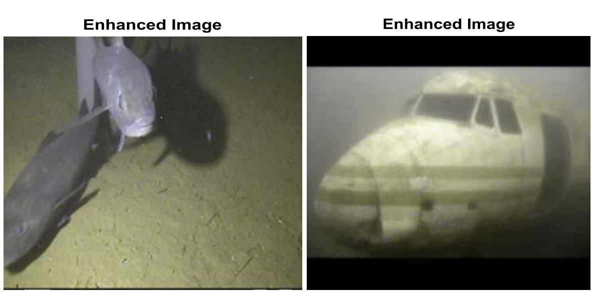
International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 12, December 2017

(b)

(c)

(d)

Fig.5.1. (a) Input image1, (b) Input image2, (c) Input image3, (d) Input image4



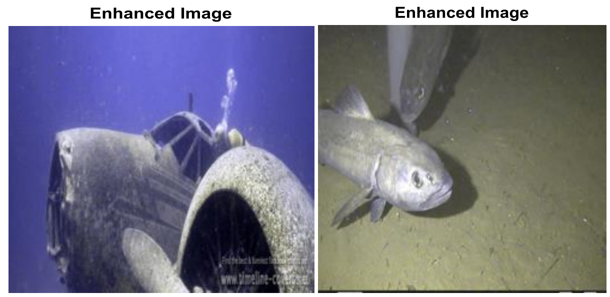


Fig.5.2. Output Images of DWT Method

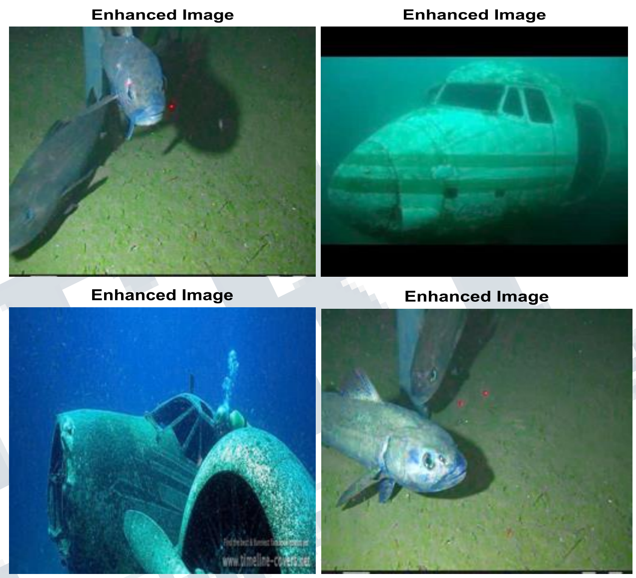


Fig.5.3.Output Images of CLAHE Technique

TABLE.1. Average Values of PSNR, SSIM and AMBE for 100 different images

Methods	PSNR	SSIM	AMBE
Proposed	20.1552	0.8296	12.5825
CLAHE	18.8180	0.3252	24.9439

VI. CONCLUSION

In this paper, underwater image contrast enhancement algorithm for restoring the visibility and natural appearance of underwater images with less computational complexity. The DWT method is applied on approximation and detailed coefficients to improve the visual quality of underwater images. The DWT method perform best performance when compared with previous techniques of CLAHE methods.

The DWT method offers good performance in terms of better contrast verified by improving PSNR value with less computational complexity, less value of Absolute mean brightness error (AMBE). Lower AMBE indicates that the brightness is better preserved and thus, a small AMBE value is desired, and a zero AMBE value is the best result. The information content in the image is verified by comparing entropy values of input image and contrast enhanced output image.

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