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Underwater Image Enhancement Based on Fusion Technique via Color Correction and Illumination Adjustment

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***Abstract*—Underwater image is affected by absorption and scattering when light propagates through water; resulting in poor visibility, reduced contrast, color attenuation. So before going into any restoration processing activity of an image, it is mandatory to enhance the image first. In this paper, a fusion based technique is introduced, where the method is to use wavelet decomposition. The proposed method has two inputs enhanced from the original underwater image. One is color corrected image and other is illumination adjusted image. Illumination adjustment is done by adaptive histogram equalization, gamma correction and filtering in the proposed system. Histogram equalization and adaptive histogram equalization techniques are used for color correction on the adjusted image. These modified images are then fused based on their maximum coefficient values and the resulted output shows promising result improving the haze of the underwater image. This is a very simple method and the resulted image is clearer than the hazy image.**

Keywords—Underwater image, Color illumination, Color enhancement, Wavelet decomposing, Fusion.

I. INTRODUCTION

In the last few decades, underwater image processing has received considerable attention in ocean engineering. Due to absorption and scattering [1] underwater images (UW) can face different types of difficulties resulting in degradations including color cast, noise, due to floating particles, low contrast, skewing and blurring [2]. In underwater it is hard to notice color, size of an object due to attenuation and mileage [3]. The objective of image enhancement is to recover the explicability of information in underwater images for human viewers, or to give corrected image for other automated image processing techniques [2]. Image enhancement techniques applied for in-air images cannot be applied to underwater images because of different optical properties of air and water. Non-uniform illumination [4] correction problem is ignored by many researchers, degradation by forward scattering is not attempted by most of the researchers [5]. Most of the dehazing techniques by researcher are complex and computation is heavy. So to enhance the underwater images it is necessary to develop algorithm that can correct all the four types of degradation, non-uniform illumination [4] and contrast degradation (caused by back scattering), blur (caused by forward scattering) and diminished colors (caused by scattering and absorption).

Rest of the article is indexed as follows. Section II presents some related article on Underwater Image Enhancement, proposed system architecture is described in section III. Section IV hold the conclusion and future work of this paper.

II. PREVIOUS RESEARCH WORK

In the field of underwater image enhancement, a lot of works have been done in the past to modify the haziness of images taken underwater. Authors in [6] estimated fusion based algorithm with two inputs, one is color corrected image and other is contrast enhanced image. Writers in [7] implemented wavelet based fusion technique to overcome color and contrast issues in underwater images. They employed CLAHE and histogram stretching techniques for contrast enhancement and color correction to address low contrast and color attenuation of the hazy images. Writers in [8] derived different images each having a significant feature by processing the original degraded image and then fuses all the images to get final output image which is a blend of all the features of processed images in it. Authors in [9] proposed a fusion based underwater image enhancement solution built on wavelet decomposition and multiscale fusion principle. Multiscale fusion principle is applied to the low frequency and high frequency components.Quality and reliability of the image processing is affected because of the floating particles of the water and that's why color correction is needed. Writers in [10] proposed a new method to enhance the underwater image depending on Dark Channel Prior. Authors of [11] enhanced the low quality images using unsupervised color correction method. The proposed approach is based on color balancing contrast correction of RGB color model and contrast correction of HIS color model. Writers in [1] proposed image enhancement method via color correction and illumination adjustment. For color correction they used

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simple normalization method and for illumination adjustment component, the Retinex theory is exploited.

III. Proposed System Architechure

Proposed system architecture mainly divided into three sections. Section A portrays illumination adjustment part, section B briefly describe color correction part and section C presents the fusion processing part.

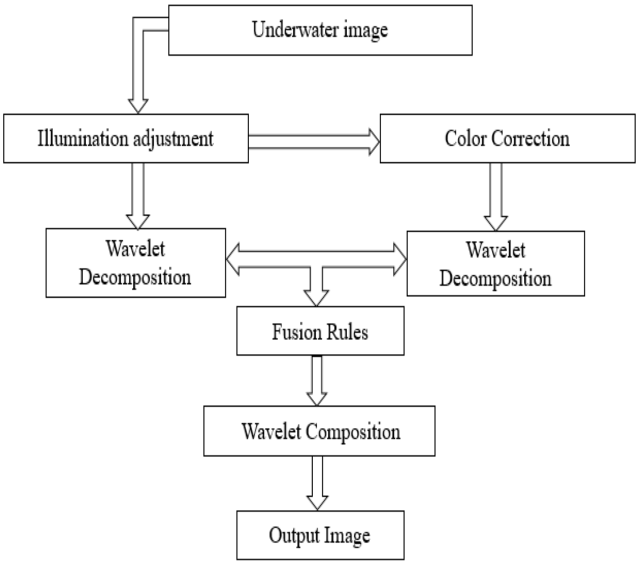


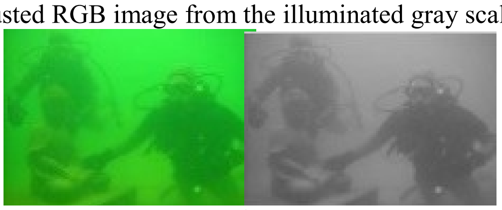
Fig. 1. Architecture of the proposed system.

A. Illumination Adjustment

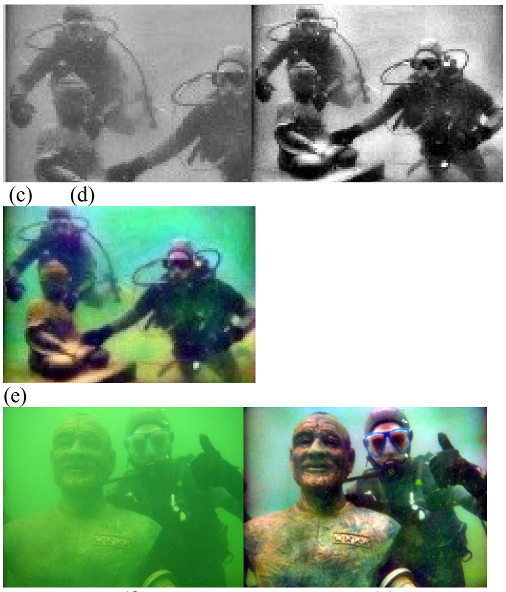
Illumination of an underwater image appears because of propagation of light in water. Illumination of an M×N dimension underwater image can be denoted by illuminant, t_c [3],

$$t_c = k_{\,|\sum_{j=k}^{L-1} h_c(j) > \frac{pMN}{100}\ AND\ \sum_{j=k+1}^{L-1} h_c(j) < \frac{pMN}{100}}$$

To remove illumination from underwater image in this proposed method the original image is first converted into gray scale image. Then Adaptive Histogram Equalization is applied on the gray scale image to manage the local contrast of the pixels from the neighboring areas [10]. The background from the AHE image is then subtracted and gamma correction is applied on the image to correct the images luminance. Median filter is then used on the image to remove any unwanted noise in the image. The process from background subtraction to filtering the image is done again two times (total three time) in order to convert back to the RGB color space of an image. The three resulted filtered images are then combined to produce the illumination adjusted RGB image from the illuminated gray scale image.



(a) (b)

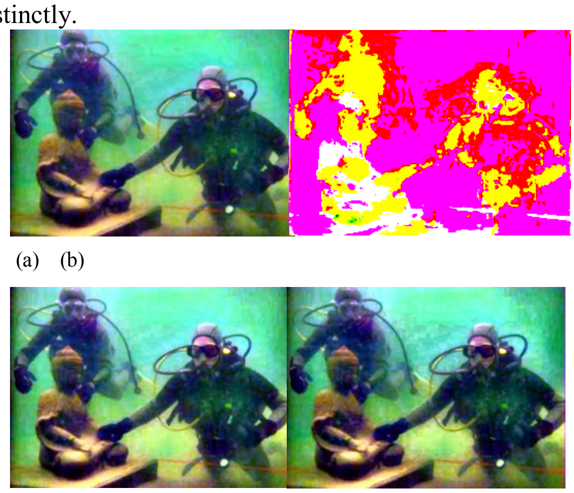


(f) (g)

Fig. 2. (a) Original image 1, (b) Gray scale image for image 1, (c) Adaptive Histogram Equalized image for image 1, (d) Illumination adjusted gray scale image for image 1, (e) Illumination adjusted output image for image 1, (f) Original image 2, (g) Illumination adjusted output image for image 2

B. Color Correction

For color enhancement the input image is the output image of illumination adjustment. In underwater, images are affected by low contrast due to scattering. To enhance the color, illumination adjusted image is first converted to RGB space to HSV space. Hue, Saturation and Value are then processed with max luminance to highlight the higher visibility region in the output. Then histogram equalization is used on the processed image. Histogram equalization which is a useful technique for adjusting image intensities for to enhance contrast. But sometimes it spoils the unhazy parts and gives indiscriminate result. So, Adaptive histogram equalization [9] is then used on the histogram equalized image of the input image of color enhancement. AHE works by taking into account only small regions and based on their local cdf, enacts contrast enhancement of these regions. This technique executes histogram equalization on the intensity values of individual frames of the image and modifies the color of each RGB channel distinctly.



(c) (d)

(e)

(f) (g)

Fig. 3. (a) Input image 1 for contrast enhancement (Illumination adjusted image), (b) HSV image for image 1, (c) Histogram equalized image for image 1, (d) AHE image for image 1, (e) Contrast enhanced image for image 1, (f) Input image 2 for contrast enhancement, (g) Contrast enhanced image for image 2

C. *Fusion Process*

Wavelet transforms are essentially extensions of the idea of high pass filtering. The process of applying the DWT can be represented as a bank of filters. At each level of decomposition, the signal is split into high frequency and low frequency components; the low frequency components can be further decomposed until the desired resolution is reached. The wavelet transform is designed to get good frequency resolution for low frequency components (average intensity values of the image) and high temporal resolution for high frequency components (edges of the image). Illumination adjusted image and contrast enhanced image are decomposed into low frequency and high frequency components. Since the wavelet transform is applied in both dimension, the low pass filter and high pass filter is applied on the rows first and then the columns. When low pass filter is applied on the rows it gives horizontal approximation value and applying high pass filter gives horizontal detail. The sub signal produced from low filter have a highest frequency equal to half of the original. Low pass filter and high pass filters is again applied on the columns of the horizontal approximation and horizontal detail resulting in four sub images [2]: approximate image, vertical detail and horizontal detail, diagonal detail respectively. This is one level decomposition of the input image as shown in figure 4 [8].

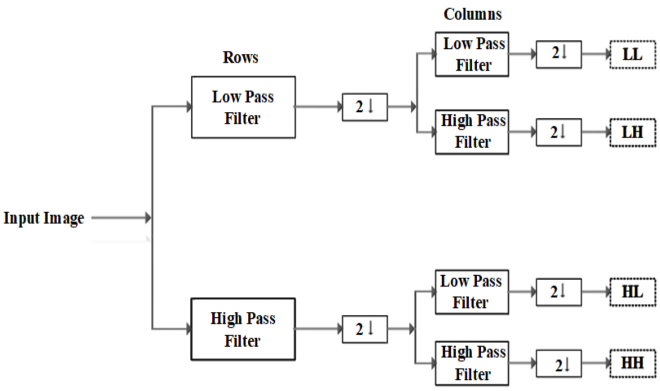


Fig. 4. One-level-2-dimension wavelet based image decomposition [8]

The approximate image which is the decomposed result of the first level becomes the input image and gets decomposed into the wavelet coefficient maintaining the same process as the first level in the second level decomposition. In the proposed method the decomposed wavelet coefficients of both illuminations adjusted image and color enhanced image is used and fused together using the maximum value of the approximation and detail coefficients.

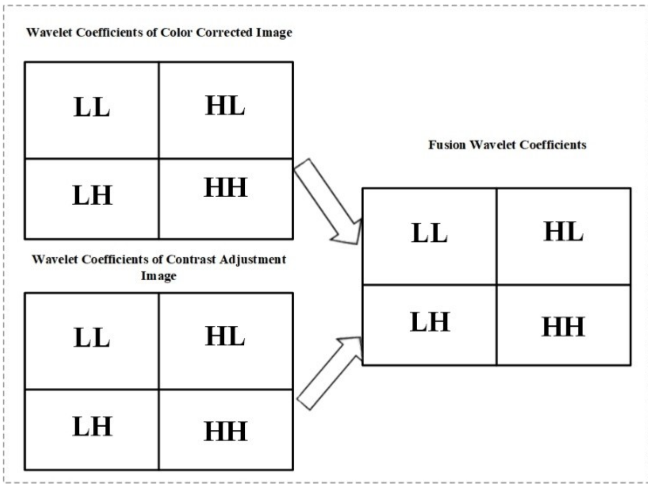


Fig. 5. Two-level-2D wavelet based image decomposition [8]

Every input image is decomposed into its coefficient and inversely composed respectively using wavelet transform to get the modified image as output. The decomposition in wavelet transform is done by down-sampling and up-sampling is used for the inverse composition.

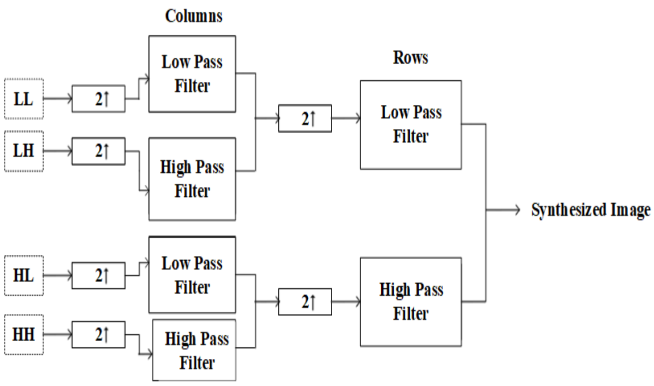


Fig. 6. One-level-2d wavelet based inverse composition [8]

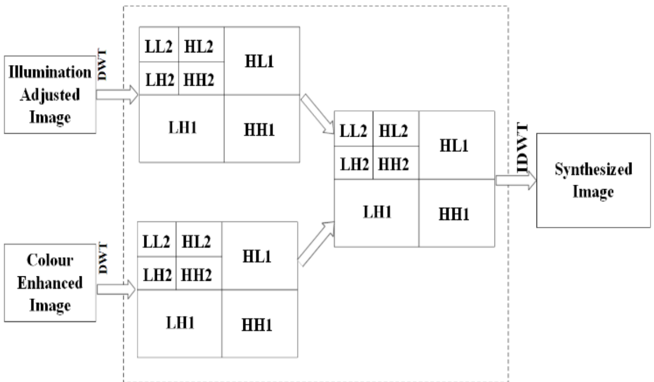


Fig. 7. Two-level-2D decomposition, fusion of coefficients and image synthesizing [8]

In figure 7, the output image of illumination adjusted image and color enhanced image is the input for DWT decomposition. Thereafter inverse transform is applied on the coefficients of its decomposition and fused together using the maximum values of the coefficients.

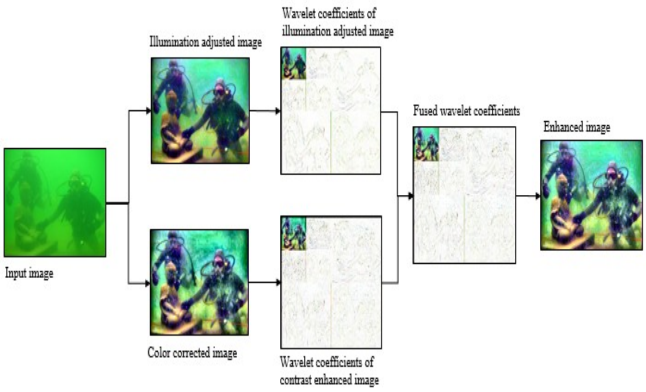


Fig. 8. Two-level-2D decomposition, fusion of coefficients and image synthesized of the proposed method

Histogram of an image illustrates a graph that can be used to appraise the quality of an image by comparing the values of an image before and after enhancement [6]. The histogram of underwater input image is darker and histogram of the enhanced output image has brighter pixel values which is the combination of illumination adjusted image and color corrected image as shown in figure 9.

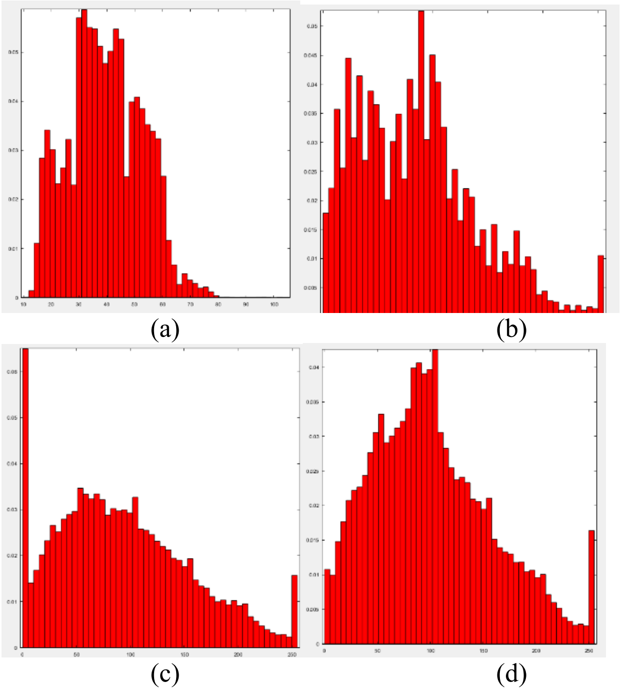


Fig. 9. (a) Histogram of orginal image, (b) Histogam of Illumination Adjusted image (c) Histogram of Color Enhanced image (d)Histogram of Synthesized image

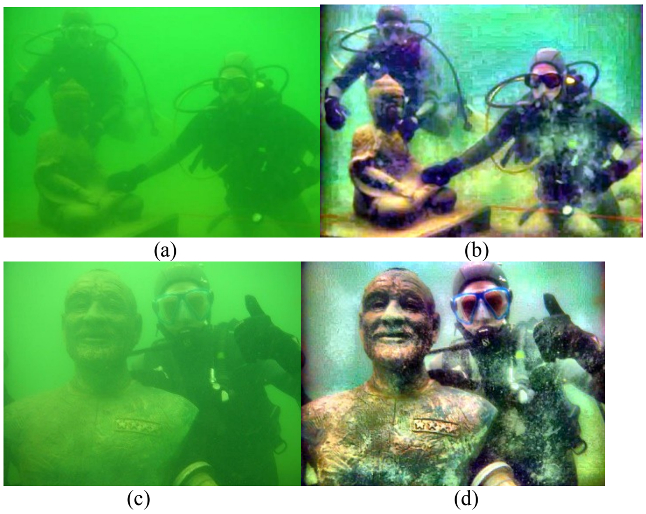


Fig. 10. (a) Input underwater image 1, (b) Synthesized image for image 1,
(c) Input underwater image 2, (d) Synthesized image for image 2

Table 1 Numerical Results of performance measurementparameters: Entropy for image (d) and comparison with Ancutti et al. [13] and Singh et al. [13] method

Image	Entropy		
	Ancutti et al. [13]	Singh et al. [13]	Proposed
d	6.8683	7.5112	7.9053

IV. RESULT AND DISCUSSION

This paper proposed underwater image enhancement based on wavelet based fusion technique which will ensure the effective improvement of visibility of degraded underwater image. The turbid water images are victim of attenuation in water, blurring and scattering. The proposed method faces the problems head on correcting the color and illumination of the image to take two input image and fuses them together. This method generates admissible result and improves clarity for all the test images. The amount of information that stays in the output image is entropy. The amount of distortion is less in the final image if the value of entropy is less. Table 1 clearly shows that the resultant images obtained from our method has higher Entropy value as compared to Ancuti et al. [13] and Singh et al. [13]as desired for a good quality image.A main limitation of fusion based method is represented by the fact that the noise contribution may be amplified significantly with the depth causing undesired appearance of the distant regions. We can improve this in future. In future, the work will extend to underwater inspection and observation tasks, particularly in vision system for aquatic robot inspection and IOT.

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