Underwater Image/Video Enhancement Using Wavelet Based Color Correction (WBCC) Method

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***Abstract*—In this paper, a wavelet based color correction approach for the enhancement of underwater image/video is proposed. Firstly, the discrete wavelet transform is applied on input image to get its approximation and detailed coefficients. The detailed coefficients of these images are kept intact to preserve their structure whereas the approximation coefficients are utilized for color correction. Thereafter, the color correction factor (CCF) corresponding to the specific color cast is estimated, followed by the evaluation of gain values for each RGB component. Input image pixels are adjusted by multiplying the obtained gain values with corresponding RGB components. Finally, the enhanced image/video is achieved by applying inverse wavelet transform on these processed approximation and the detailed coefficients. The performance of the proposed method is validated by using PSNR and SSIM index quality metrics. Superior values of these metrics in comparison to some existing enhancement approaches demonstrate the efficacy of the proposed method.**

Keywords*— *Image enhancement; discrete wavelet transform (DWT); color correction; peak signal-to-noise ratio (PSNR); structural similarity measure (SSIM).

I. INTRODUCTION

In water the absorption and scattering process of light influence the overall performance of underwater imaging system. Scattering changes the direction of the light path, leads to multiple reflections from suspended particles. Forward scattering leads to blurring of underwater images whereas the backward scattering limits the contrast of underwater images.Absorption and scattering effects are not only due to water properties but also other components like floating particles or dissolved organic matter. Floating particles called marine snow, increases the absorption and scattering effects. Moving deeper in water causes deterioration of different colors on the basis of their wavelengths. Hence, main challenges associated with underwater imaging are limited range visibility, low contrast, non-uniform lighting, color waive off, noise versus snow particles, etc.[1-3].

Various underwater image enhancement methods exist in the literature [4-7]. Celebi et al. [8] proposed an Empirical Mode Decomposition (EMD) based underwater image enhancement method. In this, an underwater image is decomposed into Intrinsic Mode Functions (IMFs) using EMD followed by combining its spectral channels with different weights. This method partially resolved low contrast problem of underwater images. Hitamet al. [9] proposed mixture contrast limited adaptive histogram equalization (M-CLAHE) algorithm. This approach is used for classifying coral reefs when visual cues are visible. Most of these enhancement methods are based on contrast stretching, histogram equalization, image filtering, etc. Despite the improved contrast enhancement, above mentioned approaches are inefficient for getting true colors of an image and equalizing the colors presented in the underwater image.

II. PROPOSED METHOD

For good quality image/video the distribution of its RGB components should be uniform but this may not be possible in case of underwater image/video wherein 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 pre-processed by means of some enhancement techniques. Iqbal et al. [10] have introduced the Integrated Image Enhancement method for biometric security. Inspired from their work, we have proposed an improvement to this approach so that it can be utilized in underwater environment. The detailed procedure of the proposed Wavelet Based Color Correction (WBCC) method is described in Fig.1. Firstly, discrete wavelet transform is applied on the input image/video frame to get its approximation and detailed coefficients. These obtained approximation coefficients are then processed for color enhancement as per the procedure given by [10].

1. Calculat the color casting factor (CCF) for each color as follows:

$$\text{if}\left(R_{awsf} > G_{awsf} \&\& R_{awsf} > B_{awsf}\right) \text{ then}$$
$$G_{fac} = \frac{G_{mwsf}}{R_{mwsf}} \; ; \; B_{fac} = \frac{B_{mwsf}}{R_{mwsf}} \; ;$$
$$CCF = (G_{fac} + B_{fac})/2 \tag{1}$$

$$\text{if}\left(G_{awsf} > R_{awsf} \&\& G_{awsf} > B_{awsf}\right) \text{ then}$$
$$R_{fac} = \frac{R_{mwsf}}{G_{mwsf}} \; ; \; B_{fac} = \frac{B_{mwsf}}{G_{mwsf}} \; ;$$
$$CCF = (R_{fac} + B_{fac})/2 \tag{2}$$

$$\text{if}\left(B_{awsf} > G_{awsf} \&\& B_{awsf} > R_{awsf}\right) \text{ then}$$
$$R_{fac} = \frac{R_{mwsf}}{B_{mwsf}} \; ; \; G_{fac} = \frac{G_{mwsf}}{B_{mwsf}} \; ;$$
$$CCF = (R_{fac} + G_{fac})/2 \tag{3}$$

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2. Calculate gain factor for individual RGB components as

$$R_{gf} = CCF * R_{awsf} * R_{mwsf}$$
$$G_{gf} = CCF * G_{awsf} * G_{mwsf}$$
$$B_{gf} = CCF * B_{awsf} * B_{mwsf} \tag{4}$$

3. Adjust the image pixels as

$$R' = R_{gf} * R \;;$$
$$G' = G_{gf} * G \;;$$
$$B' = B_{gf} * B \tag{5}$$

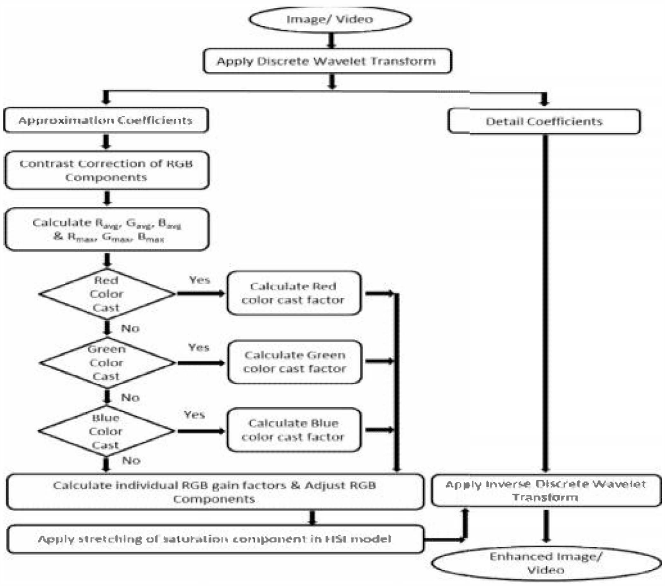


Fig.1. Flow chart describing procedure of the proposed method

The proposed method evaluates a relative color cast factor (CCF) in presence of any excessive color which is then employed to estimate the precise value of each RGB component.The quality of the output image/video is assessed by using the peak signal-to-noise(PSNR) and the structure similarity measure (SSIM). SSIM attempts to measures the change in luminance, contrast and structure in an image. Hence, it is observed as a better quality metric than PSNR to address various image degradations [11].

III. EXPERIMENTS AND RESULTS

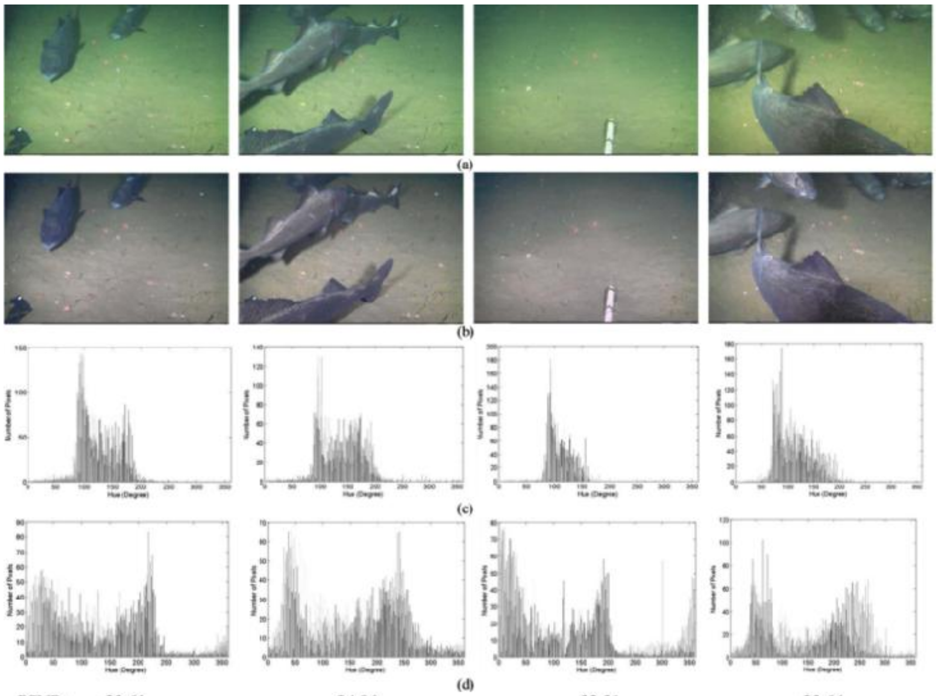
In this section, we analyse the performance of the proposed method on a variety of underwater images and videos. The underwater videos were obtained from the Ocean Networks Canada Data Archive [12] and the dataset used in this work consists of different videos of length between 25-300 seconds with frame size 704×480. These videos were captured using "BC Mideast POD3 ROS HD Inspector camera" located on Barkley Canyon, North-East Pacific Ocean off British Canada Columbia, Canada, at a depth of 981 meters. All the experiments are performed in MATLAB.

Fig. 2 (a)-(b) shows the original video frames selected from three different videos from the Mideast dataset and the corresponding output frames obtained after applying the proposed WBCC method. The color distribution of an image/frame is usually depicted by its hue component. So, in order to analyse the effectiveness of the proposed method in terms of color enhancement, histograms of hue components of the original frames and the output frames are also shown Fig. 2 (c)-(d). From the obtained results, it is observed that most of the pixels in original videos are concentrated between 100 to 200 degrees in hue circle belonging to greenish color band which is also visible in the video frames presented in Fig. 2 (a). The proposed WBCC method significantly removes the green color cast by casing full color range as shown by the histograms of output frames. The main strength of the proposed method is that it sustains the structure of the image/video by preserving its detailed coefficients in addition to improving its color cast. Higher values of SSIM index and PSNR demonstrate the superior quality of obtained image/videos.

The performance of the proposed method is also analysed on some underwater images obtained from Iqbal et al. [4] and Bazeille et al [6]. The obtained results are shown in Fig. 3 (a-d) for some of the images from this set. These underwater images are also dominated by green/blue color and their corresponding histograms for hue component are precisely narrow, i.e. not spread over the full color map. The proposed WBCC method is able to estimate the actual color cast factor of input image/video and it accordingly sets the gain factor of individual RGB components. Therefore, the obtained results for these underwater images exhibits higher color cast (as a result of covering maximum color wheel), better PSNR and SSIM index values along with visually enhanced images.

Performance of the proposed WBCC method is also compared with some existing underwater image enhancement methods such as Color Balance (CB), CLAHE and Unsupervised Color Correction Method (UCM) [6]. The results obtained from this experiment are shown in Fig. 4. From the obtained results it is noticed that the performance of the proposed method is superior as compared to these existing techniques. It efficiently removes the effect of dominant green or blue colors from these underwater images/frames that is not possible through the existing techniques.

The averaged PSNR and SSIM index values for all the video frames are evaluated to test the quality of full videos. The obtained averaged quality test scores of some sample full videos are presented in Table 1. Although, on some of the videos the PSNR value of CLAHE method is higher as compared to the proposed WBCC method but in all of the experiments corresponding SSIM index value is far better than these approaches, demonstrating superior quality of the output videos. PSNR is not able to properly correlate the perceived quality measurement. Conversely, SSIM index computes the local statistics and provides spatially varying quality map of the image which delivers more information about the image quality degradation [11].



PSNR:	22.61	24.06	22.31	23.66
SSIM:	0.9769	0.9807	0.9788	0.9799

Fig.2. a) Original b) Output video frames c) Hue histogram of original and d) Hue histogram of output video frames

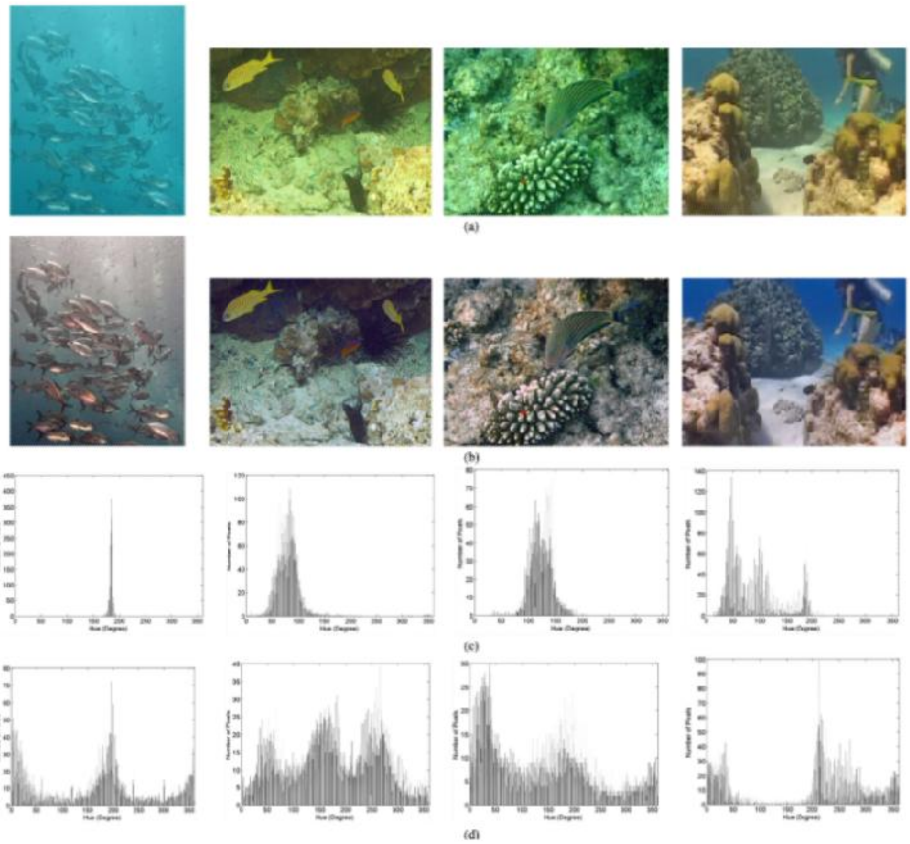


Fig.3. a) Original b) Output images c) Hue histogram of original and d) Hue histogram of output images

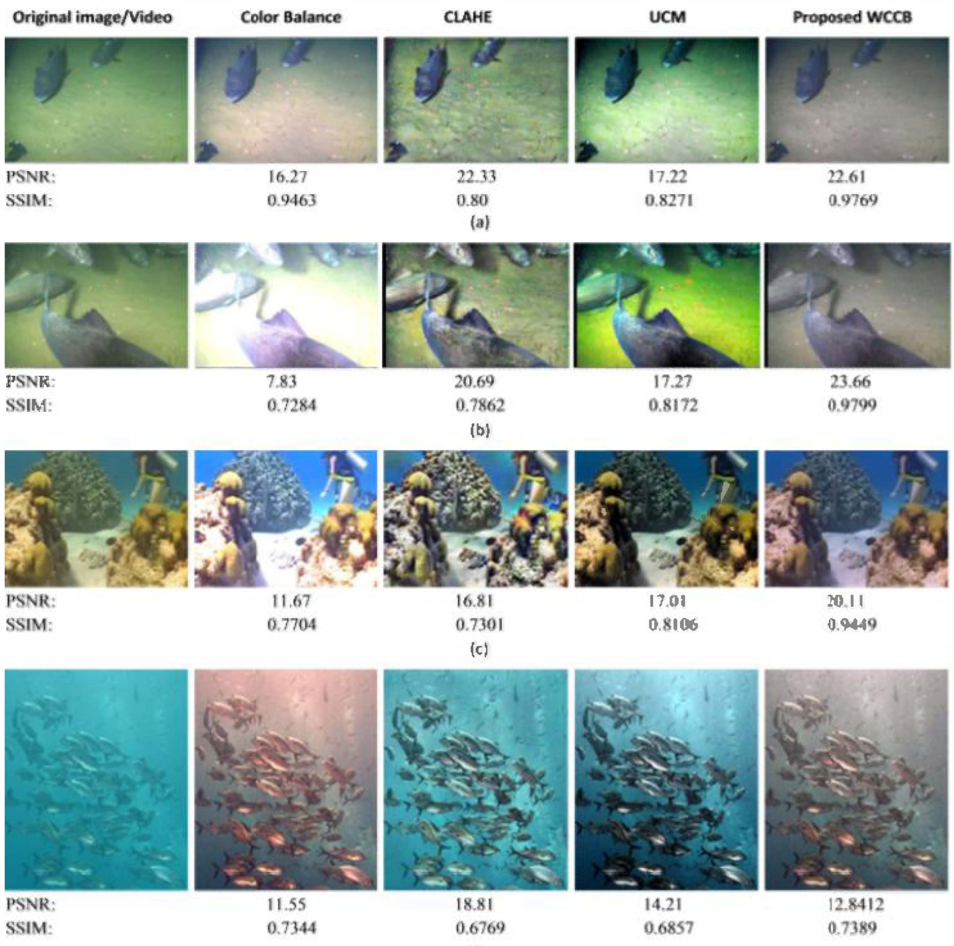


Fig.4. Results for color balance, CLAHE, UCM and WCCB method on (a-b) Sample video frames and (c-d) underwater images

TABLE 1. QUALITYSCORE (AVERAGE) ON SOME SAMPLE VIDEOS

Sample Videos	Qualitymetric	CB	CLAHE	UCM	WCCM
Video1	PSNR	9.49	**24.36**	18.31	22.27
	SSIM Index	0.80	0.82	0.83	**0.97**
Video2	PSNR	13.48	**27.01**	16.12	22.78
	SSIM Index	0.88	0.86	0.75	**0.98**
Video3	PSNR	17.71	21.84	18.42	**25.69**
	SSIM Index	0.94	0.78	0.79	**0.98**
Video4	PSNR	17.82	21.29	18.45	**24.17**
	SSIM Index	0.94	0.76	0.79	**0.97**
Video5	PSNR	7.35	**22.88**	17.64	21.40
	SSIM Index	0.72	0.77	0.79	**0.97**
Video6	PSNR	13.96	**23.20**	17.73	21.87
	SSIM Index	0.89	0.78	0.83	**0.97**

IV. CONCLUSION

This work presents wavelet based color correction method for the enhancement of underwater image/video. The colors are improved using the approximation coefficients of the input image/video whereas detailed coefficients are preserved in order to retain their original structure. It significantly improves the color content in an underwater image and removes green/blue color cast. Main application of the proposed method is in improving the visual quality of underwater image/video that is significantly useful in human-computer interaction and realization of underwater environment. It may also be useful in applications where efficient manipulation and communication of underwater image/video frames, captured from diverse environment, is required. In future, improvements to this approach may be achieved by applying certain optimal ways to utilize the detailed coefficients of underwater image/video.

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