An underwater image enhancement by reducing speckle noise using modified anisotropic diffusion filter

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ABSTRACT

Underwater images are usually suffering from the issues of quality degradation, such as low contrast due to blurring details, color deviations, non-uniform lighting, and noise. Since last few decades, many researches are undergoing for restoration and enhancement for degraded underwater images. In this paper, we proposed a novel algorithm using modified anisotropic diffusion filter with dynamic color balancing strategy. This proposed algorithm performs based on an employing effective noise reduction as well as edge preserving technique with dynamic color correction to make uniform lighting and minimize the speckle noise. Furthermore, reanalyze the contributions and limitations of existing underwater image restoration and enhancement methods. Finally, in this research provided the detailed objective evaluations and compared with the various underwater scenarios for above said challenges also made subjective studies, which shows that our proposed method will improve the quality of the image and significantly enhanced the image.

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1. INTRODUCTION

Since last few decades, huge research is undergoing for the development of color images-based application in various fields like medical, and security application in defense. It has in the urge of exposure of effective tools and algorithms for color image processing. Even though variety of researches is focusing about image processing, the research in underwater image is not in considerable amount of attention given. The environment of underwater is very complex and as source of light in underwater environment is non-uniform or some places, the presence of light is absence, due to these various complex difficulties, underwater imaging systems have to require on the light to provide illumination artificially [1]. Figure 1 explains an illustration of underwater image capturing system.

The enormous researches are show that underwater images have various challenges and forces significant problems due to reflection, absorption bending and scattering, poor visibility [2]. In this research, a proposed method for restoration and enhancement of underwater images is proposed. In this proposed approach, considerable improvement of image restoration and enhancement is using edge preserving technique with the help of gamma correction and dynamic color correction techniques. The rest of this paper organized as follows. In section 2, the existing and related works of underwater image processing techniques are discussed; section 3 details the motivation of the proposed method and section 4 shows the results of qualitative and quantitative comparison of the proposed method with state-of-the arts methods. Finally, summarizes the conclusion and discussed the further work of the study.

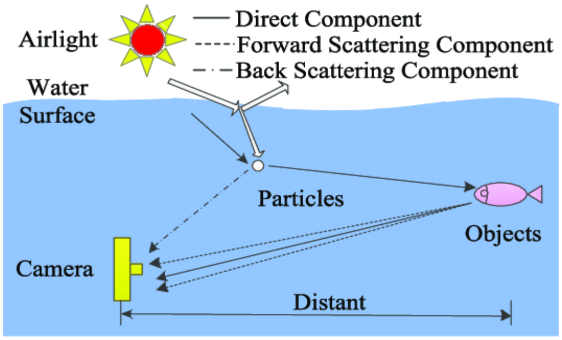

Figure 1. Illustration of underwater image capturing system

2. RELATED WORK

Last few years, enormous research has been going on for image restoration and enhancement. Image restoration is dealt with in an objective manner and it is related to feature extraction from the imperfect image and the function of image enhancement is kind of subjective [3]. It could not be precisely represented by mathematical function and also it is manipulated the degraded image, improves the contrast of the image and visual appearance could be improved. In this paper, various existing image restoration and enhancement methods are compared with the proposed method. Han *et al.* [4] proposed the simplest and most efficient prior, called dark channel prior (DCP), for the application of single image haze removal. This algorithmic depends on the statistical modeling of the outdoor images and while implementing this prior into the haze imaging model, it is observed that removal of single image haze becomes more effective and simpler. In this method, at the first estimating the transmission map, then applied the soft matting algorithm for the purpose to refine the transmission. Hou *et al.* [5] presented an underwater color image enhancement approach named wavelet-domain filtering and constrained histogram stretching algorithms (WDF–CHS) based on H preserving.

Fu *et al.* [6] presented and addressed mainly two challenges to enhance underwater image quality. Initially, to address the color distortion based on piece-wise linear transformation, they were introduced an effective color correcting strategy. Also, they were proposed a novel optimal contrast improvement method to address the low contrast, it is efficient and may reduce artifacts. In this paper, authors were addressed color shift and low contrast as ed issues by two-step image enhancement procedure for single underwater images. Also, the authors show proved that the proposed method was well suitable for real-time applications.

To restore and enhance underwater images, with aid of image formation model (IFM), Peng *et al.* [7] proposed a depth estimation method for underwater scenes based on image blurriness and light absorption. Previous IFM-based image restoration methods are estimated the scene depth based on the DCP or the maximum intensity prior (MIP). It leads to poor restoration results. Based on both image blurriness and light absorption method, Balaji *et al.* [8] proposed a new restoration method, in this proposed method, efficient BL and depth estimation were provided. The Authors proved that their proposed method was produce better restoration output by both the subjective and objective experimental.

Ancuti *et al.* [9] described a novel method for underwater videos and image enhancement. Using the fusion principles, this method obtained by the weight measures from the degraded version of the image. To retrieve underwater images, Schettini and Corchs [10] proposed a red channel method, in this, the colors combined with short wavelengths are recovered, as it is expected for underwater images, and leads to a recover the lost contrast. This method was used for retrieve the images which degraded by the atmosphere mostly affected by haze. Nuclei segmentation and optimized classification with deep learning approach features classification of the forecasted nucleus for reach accuracy [11]. Image retrieval approach that applies locality-sensitive hashing with convolutional neural networks to extract several feature types. This approach concentrates on both the high-level and low-level, which offers visual content of the images [12]. The artificial neural network is utilized to precisely notice the mass lesions in the mammogram images in a short time [13]. The object-based classification method demonstrates how the object-based method can be employed in the available data to precisely realize vegetation that can be sub-categorized to receive region under tree canopy [14].

3. PROPOSED METHOD

In this research, the proposed method is used to restore and enhance the visibility and quality of the underwater image. The block diagram for the proposed method is shown in Figure 2. Since the underwater image is generally degraded due to particles present in the medium and it is lead to non-uniform illumination of light and it will affect the quality and visibility of the images causing poor contrast and color retention. Initially, the underwater input image is pre-processed by converting red, green, and blue (RGB) into gray images then color compensation and color corrected algorithm, then it is followed by gamma correction and white balancing. This filtered output image is enhancing the contrast with high-frequency components due to non-uniform illumination in RGB underwater input image using speckle reducing anisotropic diffusion (SRAD) filter. SRAD filtered output is again processed with a color compensation and white balancing for getting a better pleasant visual effect. The system model for the proposed algorithm is shown in Figure 2. It describes the complete flow of the proposed algorithm. The following section is discussed the preprocessing stages of color correction and white balancing process. After the preprocessing step, modified speckle reduction anisotropic diffusion (MSRAD) filter is used to reduce the speckle noise after that image.

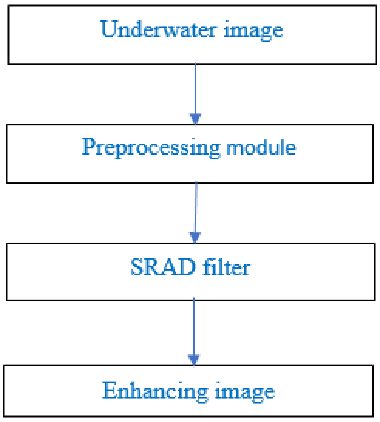

Figure 2. System model of the proposed work

3.1. Evaluation of pre-processing image

In this stage, before applying denoising algorithm, need to pre-process input image by using color compensation, gamma corrections and white balancing.

a. Color compensation

Color compensation is used as initial pre-processing step. In this step, the mean of each channel and gray mean value are determined and then calculate individual value of each channel is calculated by using the mean value of gray image and its own channel mean value and then color correction is done for red and blue channel by adjusting the α value from 0 to 1 (considered as 0.3). Determining individual color channel value then make all channels have same mean color correction made for red and blue channel.

$$I_r = I_r - 0.3 * m(I_{mg}) - m(I_{mr}) * I_g * (1 - I_r) \quad (1)$$

$$I_b = I_b + 0.3 * m(I_{mg}) - m(I_{mb}) * I_g * (1 - I_b) \quad (2)$$

Where, I_r is red channel of the input image, I_b is blue channel of the input image, I_g is green channel of the input image, I_{mb} is mean value of the blue channel, I_{mr} is mean value of the red channel, and I_{mg} is mean value of the green channel

b. Gamma correction

Gamma correction or gamma is a nonlinear operation and it is used to encode and decode luminance in video or still image systems. Using power law, it is given by (3),

$$V_{out} = AV_{in}^{\gamma} \quad (3)$$

where the positive real input value V_{in} is maximized to the power γ and multiplied by the constant A to get the output value V_{out}. If A=1, inputs and outputs values are lies between in the range 0–1. If gamma (γ) is less than 1, then is denoted as an encoding gamma, and the process of encoding with this compressive power-law nonlinearity is called gamma compression; if gamma (γ) is greater than 1, than it is denoted as a decoding gamma, and the application of the expansive power-law nonlinearity is called gamma expansion.

c. White balancing

The color casting may be introduced in the captured images. A method for identifying an independent color of light is called color constancy. To solve this particular issue, the existing light will be taken out and its component colors estimated. In general, gray-world and Max-RGB algorithms estimate the color of the light The gray-world algorithm, a white balance technique used in this study, assumes that the input image is typically neutral grey. Using this process, one can estimate the lighting color cast by looking at the average color and comparing it to grey. By calculating the mean of each image channel, the Grey World method generates an estimate of lighting. To normalize the underwater image of channel i, the pixel value of the image is scaled by (4),

$$S_1 = \frac{avg}{avg_i} \tag{4}$$

where, avg_i is the channel mean and avg is the illumination estimate.

3.2. Anisotropic diffusion filter to reduction speckle noise

By using a partial differential equation (PDE) technique, incorporated in the SRAD filter, it is possible to eliminate the speckle noise present in an image. Even the most basic anisotropic diffusion filters can perform edge sensitive diffusion for anisotropic diffusion, developed by Rahman *et al.* [15], is thought to be the edge-sensitive extension of the average filter, as opposed to SRAD, which is thought to be the edge-sensitive extension of the adaptive speckle filter. The SRAD filter uses a diffusion technique based on the minimum mean square error (MMSE). Since Lee filter and Frost filter also employ this strategy, their results are comparable. Compared to traditional anisotropic diffusion, anisotropic diffusion in SRAD filters is unique and advantageous. Even though it operates in the typical manner at the edge's center, it nonetheless affects negative edge diffusion on both sides of the edge. As a result, the edge's contour is sharper, resulting in darker and brighter than usual sides of the edge [16].

$$\begin{cases} \frac{\partial I}{\partial t} = div[c(q).\nabla I] \\ I(t=0) = I_0. \end{cases} \tag{5}$$

By applying Jacobi iterative method over the (3) and (6) obtain:

$$I_{i,j}^{n+1} = I_{i,j}^{n} + \left(\frac{\Delta t}{4}\right) d_{i,j}^{n}. \tag{6}$$

here, the definition of diffusion coefficient $c(q)$ is:

$$c(q) = exp\left\{-\frac{[q^2-q_0^2]}{[q_0^2(1+q_0^2)]}\right\} \tag{7}$$

$$q = \sqrt{\frac{\left(\frac{1}{4}\right)\left(\frac{|\nabla I|}{I}\right)^2 - \left(\frac{1}{4^2}\right)\left(\frac{|\nabla^2 I|}{I}\right)^2}{\left[1+\left(\frac{1}{4}\right)\left(\frac{|\nabla^2 I|}{I}\right)\right]^2}} \tag{8}$$

4. RESULTS AND DISCUSSION

Full reference-based quality measurements result in unsuitable subjective evaluation because the peak signal to noise ratio (PSNR) is always lower in underwater image scenes due to general scene distortion. Consequently, in this study, a no-reference based quantitative evaluation measure of distorted underwater image scenes was taken into consideration [17]. In this research, considered six of the following parameters such as average gradient, entropy, edge intensity, patch-based contrast quality index (PCQI), underwater image and quality measure (UIQM) and underwater color image quality evaluation metric (UCIQE) are used to demonstrate the performance and advantages attained by our proposed method [18]. The UIQM and UCIQE are no-reference parameters and PCQI is with reference parameter.

The proposed method is compared with the state-of-the-art work via above mentioned metrics for the images shown in Figures 3 to 5 and corresponding comparison data values are shown in Table 1 to 3. In this proposed work, the underwater image enhance benchmark (UIEB) images [19] are taken for quantitative experimental analysis. In this research considered five UIEB images and all these images are enhanced with our proposed method and then compared their performances with various existing methods [20]–[24] using above mentioned performance metrics.

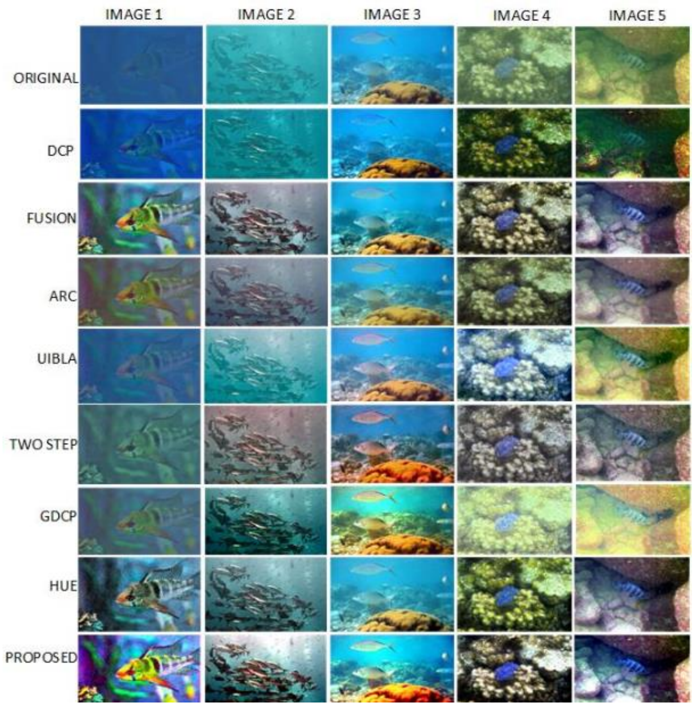

Figure 3. UIEB images for quantitative experimental analysis comparison of our proposed method with state-of-the-art work

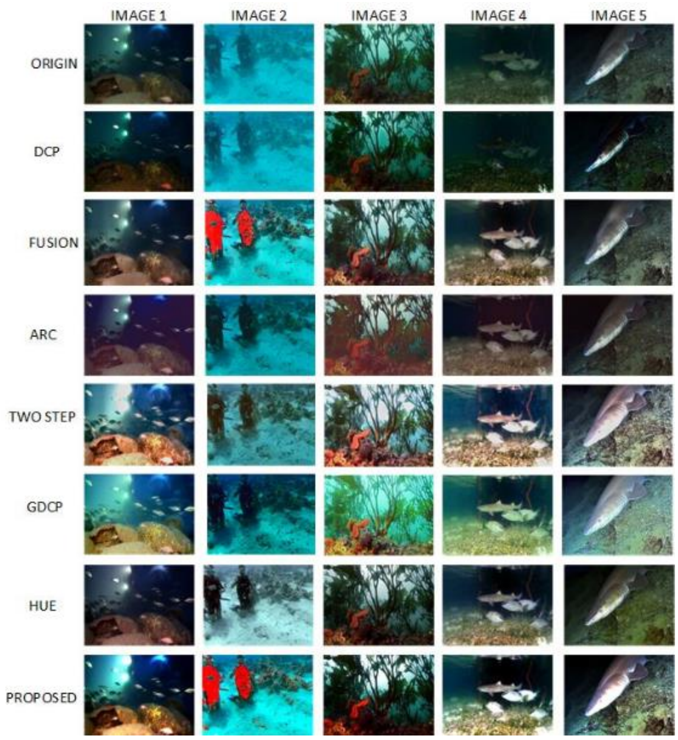

Figure 4. UIEBC images for quantitative experimental analysis comparison of proposed method with state-of-the-art work

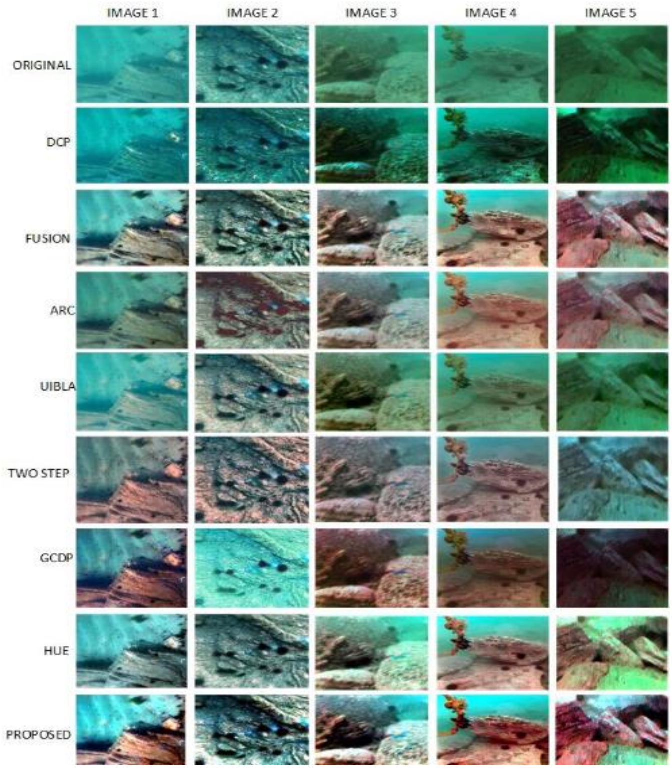

Figure 5. RUIE images for quantitative experimental analysis comparison of our proposed method with state-of-the-art work

Table 1 describes the average values of the proposed and existing algorithms for various performance metrics like UIQM, UCIQE, PCQI, average gradient, edge intensity and entropy for UIEB images of proposed and existing algorithm [25], [26]. From this table, it is observed that, proposed method being produce better performance in all metric except PCQI values. In this work, used no-reference data, due to this getting UIQM and UCIQE are good enough values and PCQI has poor response.

Table 1. Average value of UIEB dataset

	UIQM	UCIQE	PCQI	Average Gradient	Edge Intensity	Entropy
DCP	1.21518	0.531764	0.971588	3.4552224	36.04665252	7.159062
FUSION	1.251124	0.580736	1.125603	4.7669431	50.04985942	7.635385
ARC	1.031423	0.516431	1.070736	3.1056281	32.59000628	7.230595
UIBLA	1.049677	0.5058	1.137428	3.7888624	39.71627794	7.526755
TWO STEP	1.1847	0.497278	1.182411	4.2883913	44.85363493	7.114091
GDCP	1.111356	0.499796	1.056433	4.1448251	43.33681959	7.169811
HUE	1.246339	0.602754	0.962365	4.3597861	45.30746406	7.702979
PROPOSED	1.303056	0.661121	1.029761	4.8443004	52.69452947	7.652017
Rank	1	1	6	1	1	2

Figure 4 shows that underwater image enhancement benchmark challenged (UIEBC) image dataset for subjective analysis of proposed method with existing algorithm. The objective values for proposed and existing methods are given in the Table 2. From the table, it is observed that the proposed method gives better performance than that of DCP, Fusion, ARC and UIBLA methods. In this research, challenged - No reference images are used for analysis, due to this, the objective values of Average gradients, entropy of the proposed method value is lesser than the existing method.

Figure 5 shows that real-world underwater image enhanced (RUIE) image dataset for the subjective analysis of proposed method with existing algorithm. The objective values for proposed and existing methods are given in the Table 3. The Table 3 have the average values of various performance metrics like UIQM, UCIQE, PCQI, Average gradient, edge intensity and entropy for RUIE images of proposed and existing algorithms. From this table, it is observed that the proposed method gives better performance except PCQI values. Rank for all existing and proposed method is given for all performance metrics for quick observation. It is observed that, the entropy of UIEB and RUIE dataset is higher than the other methods. But, in UIEBC, it ranks 5, due to the usage of challenges - No reference images.

Table 2. Average value of UIEBC dataset

	UIQM	UCIQE	PCQI	Average Gradient	Edge Intensity	Entropy
DCP	1.108635	0.506508	0.908895	1.998555	21.15608	6.220873
FUSION	1.136368	0.594616	0.992773	3.684717	38.70833	7.224158
ARC	0.975017	0.521074	0.921482	2.098793	22.31972	6.585772
UIBLA	1.209401	0.61141	1.003758	3.740324	39.73055	7.098359
TWO STEP	1.145304	0.584047	1.040184	4.597862	48.86106	7.449934
GDCP	1.184508	0.599683	0.981126	4.147914	43.92099	7.251545
HUE	1.200059	0.585642	0.884571	3.14661	32.86251	7.269209
PROPOSED	1.183254	0.663582	0.969419	3.949454	42.99054	7.077169
Rank	4	1	4	3	3	5

Table 3. Average value based on RUIE dataset

	UIQM	UCIQE	PCQI	Average gradient	Edge intensity	Entropy
DCP	1.165308	0.518504	0.996152	2.407795	26.17732	7.159754
FUSION	1.163584	0.598194	1.173877	4.244993	46.24449	7.710271
ARC	0.959382	0.54227	1.084915	2.752395	29.96073	7.330692
UIBLA	0.928843	0.49605	1.104862	2.596007	28.20542	7.353155
TWO STEP	1.082002	0.521306	1.215046	3.825236	41.58739	7.222659
GDCP	1.184953	0.541974	1.057842	3.179214	34.48807	7.205088
HUE	1.108178	0.597427	0.991549	3.701663	40.28211	7.752023
PROPOSED	1.289912	0.68392	1.119634	4.685068	51.5409	7.817841
Rank	1	1	3	1	1	1

5. CONSLUSION

In this proposed method, the enhancement of underwater image is improved by employing the MSRAD filter. In this proposed method, the captured image is pre-processed with various stages like white balancing, and color correction, for improvement of underwater images visual effect. The pre-processed image is still enhanced with MSRAD filter. In this research, UIEB, UIBC and RUIE image data set are used for the purpose of subjective analysis. In UIEB and RUIE proposed methods performance are better than the Hue and Fusion method, the performance are same only in UIEBC because we used challenged-No-reference images. This proposed method performance is compared with various existing method like DCP, Fusion, ARC, UIBL, two step algorithm and GDCP algorithm. From the performance metric values, it is observed that, our proposed method will enhance the hazy underwater images better than existing methods. Further, this work can be extended using convolutional neural network for better underwater image enhancement.

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