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Enhancement of Underwater Images based on PCA Fusion

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Abstract

In Oceanic Environment, removal of hazy scenes due to the effects of scattering and absorption in underwater images plays an important issue. It is important to enhance the visual appearance of such images. In this paper a fusion based approach to enhance the underwater images is proposed. In this work, the input RGB image is subjected to Gaussian Filter and CLAHE. The RGB components applied to CLAHE are smoothened by means of median filter. The filtered RGB components are then fused using Principal Component Analysis (PCA) fusion technique. The final enhanced underwater images are subjected to both qualitative and quantitative analysis. The performance measures such as SSIM, Entropy and AMBE reveals the validation of the proposed findings.

Keyword: Underwater image enhancement, Gaussian filter, CLAHE, Image fusion, Median filter.

INTRODUCTION

This Underwater images is affected by the color cast, poor visibility, foggy appearance and misty. Underwater images are usually degraded due to the effects of 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. While capturing a image of an underwater object from outside of the water, waves on the surface cause blurred. If series of images are captured at various times, different distortions will be seen in each picture. The image seen by the camera is blurred by refraction as a function of both the angle of the water surface and the amplitude of the water waves.

V.Vembuselvi, T.Murugan, [1] have discussed a new method developed for enhancing the underwater images. The input image is pre-processed and convert the RGB to LAB color space. Finally, LAB color space is convert into the RGB color space. Ritu Singh, Dr.Mantosh Biswas, have discussed a new method developed for enhancing the underwater images. In this paper, the fusion technique based on hazy image to improve the quality of degraded underwater images [2]. The contrast limited adaptive histogram equalization (CLAHE) technique is used to enhance the underwater image by Dithee Dev K, Mr. S.Natrajan [3]. Ashish Gupta, J Sandesh.et al have discussed a new image enhancement method is developed for better visual quality. In this paper, the input RGB image is converted into HSV format. Then split the individual H, S and V component. And apply Histogram Equalization method for Saturation component. The histogram of a digital image gives conclusive proof about the quality of the image. After the Histogram Equalization technique, concatenated the H, equalization method and V component. Then convert these HSV component into RGB component. Finally, the output image is better than the input image [4]. R. Priyadharsini,T. Sree Sharmila et al have worked in Stationary Wavelet Transform (SWT) with laplacian filter. The Laplacian filter is applied on LL component and subtracting the LL component with the filtered image we get one mask image[5]. Ansar MK, Vimal Krishnan VR research has been carried out in underwater image enhancement by using PCA fusion is proposed by [11]. Jasneet kaur Babool, Satbir Singh have discussed a contrast limited adaptive histogram equalization color models for enhancing the underwater images[12]. Joost van de Weijer, Theo Gevers et al researcher work is based on color constancy. Color constancy is the ability to measure the colors of the light source [13]. Codruta O. Ancuti , Cosmin Ancuti, in this paper, Adaptive Histogram Equalization based Fusion Methods are developed to enhance the underwater images [14]. Yafei Wang, Xueyan Ding et al , the proposed fusion process involves two inputs which are represented as color corrected and contrast enhanced images extracted from original underwater image [15].

PROPOSED METHOD

The presence of uniform RGB components in natural images improve its visual quality. But it is not possible to maintain uniformity of RGB components in underwater images. So, in order to remove the effects of color loss and low contrast from underwater images, some enhancement technique has to be proposed. In this work, an underwater image enhancement algorithm based on principal component analysis fusion method is introduced. Also, to overcome the problem of diminished underwater visibility an artificial lighting source is used.

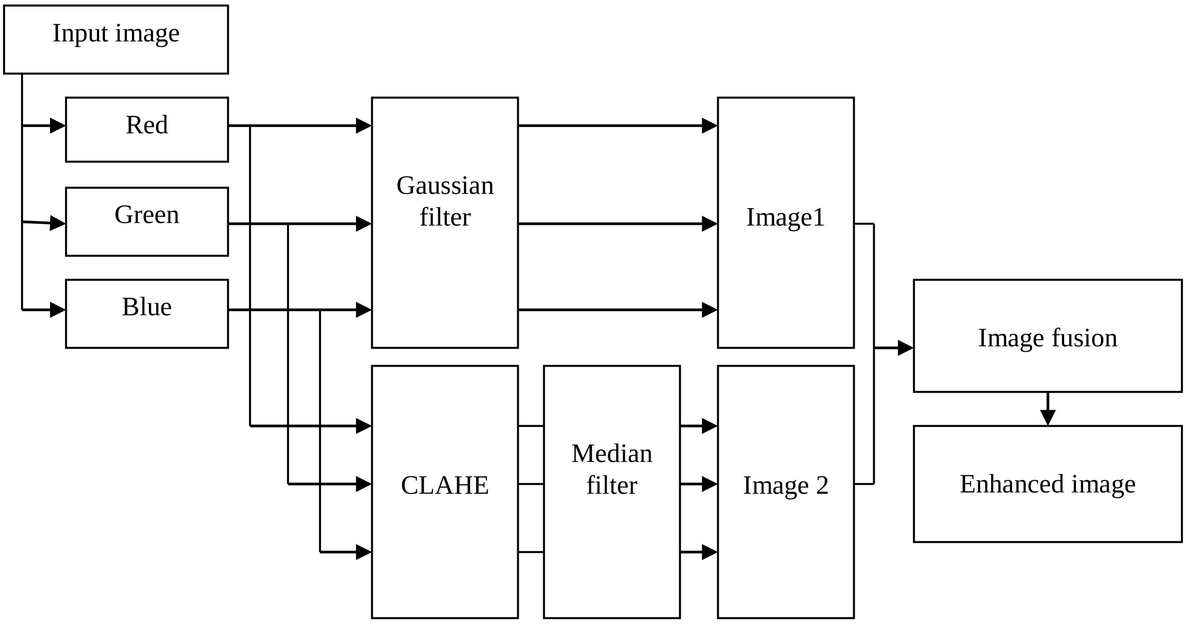

Figure 1. Flowchart of proposed method

A. Gaussian Filter

Gaussian filter is a non-uniform low pass filter that is used to blur the images and remove the noise. It is more effective at smoothing images. In our approach, Gaussian filter is applied to the input underwater image. Here, a low pass Gaussian filter is designed from which the high pass filter equivalent is obtained. The gaussian function is given as:

$$G(x,y)=\frac{1}{2\pi\sigma^2}e^{-\left(\frac{x^2+y^2}{2\sigma^2}\right)} \qquad (1)$$

where σ is the standard deviation of the distribution and *(x,y)* is the pixel coordinate position.

B. Contrast Limited Adaptive Histogram Equalization

Contrast Limited Adaptive Histogram Equalization (CLAHE) is an improved version of Adaptive Histogram Equalization (AHE) which overcomes the noise problem in AHE. CLAHE is applied to the input underwater image which reduces the noise by enhancing image contrast especially in homogenous area. The process of image contrast enhancement takes place by changing the intensity value in the image. Here, the RGB component image is divided into 8x8 tiles with a cliplimit of 0.001. An uniform distribution is applied as the histogram shape for the image tiles. Thus CLAHE has reduced noise and prevent brightness saturation as in histogram equalization.

C. Median Filter

In CLAHE technique on account of its inherent structure results in over enhancement at some pixels and also introduces image noise. To overcome this problem, a median filter is used to smoothen the image. Median filter is one of the non-linear digital filter. It is used to remove the noise and smoothing the images. Median filter is a sliding-window spatial filter. It replaces the value of the center pixel with the median of the intensity values in the neighborhood of that pixel. For every pixel, a 3x3 neighborhood with the pixel as center is considered. In median filtering, the value of the pixel is replaced by the median of the pixel values in the 3x3 neighborhood and is given by the function.

$$y[m,n] = median\{x(i,j),(i,j) \in w\} \qquad (2)$$

Where w represents a neighborhood centered around *[m,n]* defined by the user.

D. Image Fusion

Image fusion is the process of combining particular information from two or more images into a single image. The resulting image will be more informative than any of the input images. Some well-known image fusion methods are:High pass filtering technique,IHS transform based image fusion, PCA based image fusion,Wavelet transform image fusion, Pair-wise spatial frequency matching. In this work, PCA based image fusion is used to fuse the two images obtained from Gaussian filter and CLAHE to get the output image.

1) PCA based image fusion: PCA transform is a statistical technique that transform a multivariate dataset of correlated variables into a dataset of uncorrelated combination of the original variables.

The following steps are used for two column vector to 2D free spaces:

Step 1: The data is arranged into column wise vectors, to generating a matrix Z of 2xN size.

Step 2: Empirical mean vector M_e of size 1x2 is generated.

Step 3: Empirical mean vector M_e is subtracted from matrix obtained in step 1. This results in matrix X of 2xN dimension.

Step 4: Covariance matrix C is obtained using expression C = XXT.

Step 5: Eigen vector V and eigen value D is computed for covariance matrix C.

Step 6: Eigen vector V and eigen value D are then arranged in descending eigen value. Where dimension of V and D is 2x2.
Step 7: By using primary column of V, it corresponds to the larger eigen value, and obtains A1 and A2.

$$A_1 = \frac{V(1)}{\sum V} \text{ and } A_2 = \frac{V(2)}{\sum V} \quad (3)$$

Step 8: The fused image $I_f(x, y)$ is then obtained by using the following expressions,

$$I_f(x,y) = A_1 I_1(x,y) + A_2 I_2(x,y) \quad (4)$$

where $I_1(x,y)$ and $I_2(x,y)$ are the two fused input image.

The PCA based fusion method does not required number of bands.

PERFORMANCE ESTIMATION

The effect of image noise reduction may estimated by either subjective visual method or objective estimation method. In this work, three performance measures such as Structural Similarity Index, Entropy and Absolute Mean Brightness Error are calculated.

A. Structural Similarity Index

Structural similarity (SSIM) index is a method for measuring similarity between the Input and Output images. The SSIM index can be viewed as a quality measure of one of the images being compared, provided the other image is regarded as perfect quality.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (5)$$

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

B. Entropy

The image enhancement is based on detailed information of an image, larger entropy value in the image has some higher information contained in the output image. whereas lower entropy value in the image has lower information contained in the output image. The entropy for the whole image can be defined by

$$H(k) = -\sum_{i=0}^{255} \rho_i \log_2 \rho_i \quad (6)$$

Where ρ_i is the probability of intensity *i* at a pixel in output image.

C. Absolute Mean Brightness Error

AMBE is used to obtain the degree of brightness preservation and is used to calculate the difference in mean brightness between two images.

$$AMBE(x,y) = \left| Mean_x - Mean_y \right| \quad (7)$$

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

RESULTS AND DISCUSSION

The performance measure plays an different role in the images. In the case of underwater image enhancement field, the original images are difficult by the absence of poor visibility, foggy appearance. Therefore, to evaluate the performance of the proposed algorithm we have used the some set of underwater images. The proposed method is compared with Adaptive Histogram Equalization. The results are shown in Qualitative and Quantitative Assessments.

1) *Qualitative Assessments:* The underwater images are obtained by applying our method is characterized by enhanced contrast, visibility and a natural appearance. The results of different underwater images are shown in Fig.4.1

The enhanced image exposes the hidden information in the input image. Therefore, the output image is better than the input image.

Images	Input Images	Output Images
Image 1		
Image 2		
Image 3		
Image 4		
Image 5		

Figure 1. Input and Output images of proposed method

2) *Quantitative Assessments:* The Performance is measured on different underwater images. Three measurements are calculated such as, Structural Similarity Index, Entropy and Absolute Mean Brightness Error for 100 different images. The individual performance measures of some sample underwater images are obtained in Table I.

Table I. Performance measure of some underwater images

Images	SSIM	Entropy	AMBE
Image1	0.8844	7.6441	0.0971
Image2	0.8461	7.7374	0.9004
Image3	0.8255	7.7474	1.5105
Image4	0.8816	6.7188	1.0237
Image5	0.8955	6.6722	0.0014

The Average Values of SSIM, Entropy and AMBE for 100 different underwater images are obtained in Table II.

Table II. Average values of SSIM, Entropy and AMBE for 100 different images

Method	SSIM	Entropy	AMBE
Proposed	0.8942	7.6602	1.4302
AHE	0.8044	7.0089	5.8100

The Proposed method perform best performance when compared with previous techniques of Adaptive histogram equalization (AHE) methods. In terms of better contrast verified by improving Structural Similarity Index, Entropy and less value of Absolute mean brightness error (AMBE). If AMBE value is lower that indicates that the brightness is better preserved, thus a small AMBE value is desired and a zero AMBE value is the best result.

CONCLUSION

In this paper, an Image enhancement algorithm for restoring the visibility and color contrast appearance of underwater images with less computational complexity is proposed. The novelty of the proposed method lies in the PCA image fusion method to obtain an enhanced underwater images. The proposed technique offers an improved SSIM for better contrast, improved entropy for high information content and reduced AMBE for better enhancement. The experimental results were illustrates the overall superiority of the proposed scheme over the other methods.

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