Enhancement of Underwater Images Using Homomorphic Filtering and CLAHE Technique

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Abstract - Underwater images mainly suffer from absorption and scattering effects of light, which leads to poor visibility in the captured images. To enhance the degraded images for the further analysis, Homomorphic filtering and Contrast Limited Adaptive Histogram Equalization (CLAHE) techniques are used. Homomorphic filter corrects the non-uniform illumination and CLAHE enhances the contrast of an image. Also, this paper discusses the causes of underwater image degradation and methods to recover degraded image. The qualitative and quantitative analysis of enhanced underwater images show that Homomorphic and CLAHE techniques enhanced underwater images with improved contrast, sharpness in edges and better exposure of dark region.

Keywords - Underwater Image Enhancement, Image Degradation, Absorption, Scattering effects, Homomorphic Filtering, CLAHE.

1. INTRODUCTION

Underwater image processing plays an important role in oceanic scientific research. Underwater images are the photographs captured in underwater environment. This underwater environment offers many attractions like marine animals and fishes, landscape, shipwrecks, submerged cave systems etc. Underwater imaging can be used for examining the underwater infrastructures, cables, detection of man-made objects, control of underwater vehicles, marine biology research and archaeology [7]. Capturing of underwater images is quite difficult task as compared to terrestrial images due to the haze caused by light is reflected from the surface and is deflected and diverted by several water particles, and different wavelengths of light cause different degrees of attenuation resulting in color change. The images are usually captured while scuba diving, surface supplied diving, snorkeling, swimming and also from a submersible or remotely operated vehicle. The equipment used for capturing underwater images includes modern waterproof digital cameras. When the light travels from air into the water medium, it partly reflected and partly enters into the water resulting in scattering and color absorption effect. Also because of the hazes present in the water in the form of suspended particles such as sand, minerals, plankton could be the reason for the degradation of the image. The underwater degraded image is shown in Fig. 1. The first reason for degradation is light scattering which scatters the propagating energy in the form of light. When the light from the camera is incident on the objects, it gets reflected and causes change in the direction because of the particles present in the water, this phenomenon is known as light scattering. This results in poor visibility and low contrast [5]. The second reason for degraded image is color change or absorption which is due to the varying degrees of attenuation for different wavelengths. The red color has the highest wave length, hence it travels very short distance in water and is the first to be absorbed followed by orange and yellow. Blue color has shortest wavelength, therefore travels longest distance in water as shown in the Fig. 2. That is why underwater images are dominated by blue color.

In this paper, approaches to remove the haze in underwater images is proposed based on single-image based solution that increases the visibility of underwater images and enhance the contrast of the image captured. The enhancing approach consists of first correcting the non-uniform illumination by Homomorphic filtering method, then using Contrast Limited Adaptive Histogram Equalization (CLAHE) method to enhance the contrast of an image. The rest of the paper is structured as follows. The section 2 describes the Literature Survey of underwater image enhancement approaches, section 3 presents method to enhance underwater images and section 4 describes the results and discussion by presenting the comparative qualitative and quantitative assessments of enhancing approach.

Fig. 1. Underwater degraded image
2. LITERATURE SURVEY

Codruta O. Ancuti et al. [7] proposed an effective technique to enhance the images captured underwater which are degraded due to the medium scattering and absorption. It makes use of white balancing and multi-scale fusion technique which resulted in enhanced wide range of underwater images with high accuracy and also able to recover the faded features and edges. The color cannot always be fully restored and also presence of some hazes is observed in the scene regions that are far from the camera. Ritu Singh et al. [6] introduced a fusion based underwater image enhancement along with contrast stretching and auto white balance approach to improve the color and contrast of the images captured underwater and also it reduces the bluish greenish view. In this paper, removal of noise has not been addressed. Chongyi Li et al. [2] proposed a novel strategy to enhance the underwater image visibility, color and natural appearance of image based on image dehazing and contrast enhancement algorithm. The proposed method could not remove the effect of noise and also it resulted in fewer artifacts. Ahmad Shahrizan Abdul Ghani et al. [11] developed an approach to enhance the underwater images based on Integrated Color Model with Rayleigh Distribution that enhances the image contrast, reduces blue green effect and also minimizes under and over enhanced areas in output image, but produces high noise in the image outputs which gives random fluctuation of the signal intensity. Muhammad Suzuki Hitam et al. [1] derived Mixture Contrast Limited Adaptive Histogram Equalization method to improve the visual quality of an image by enhancing the contrast and produces lowest Mean Square Error (MSE) and Highest Peak Signal to Noise Ratio (PSNR) values. But in the case of complex environment and severe color loss, this method fails. John Y Chiang et al. [9] proposed a novel approach to enhance the visibility and color balance restoration in underwater images based on Wavelength Compensation and Image Dehazing method. Due to the presence of salinity and amounts of suspended particles in ocean water which vary with time, location and season, it is difficult to find out the rate of light energy loss during measurement. Zetian Mi et al. [3] proposed white balancing and multi-scale gradient-based technique to enhance the contrast and improve the vision quality of underwater images. Cosmin Ancuti et al. [8] proposed fusion based method to enhance the image with better global contrast. But the presence of bluish greenish scene could not be solved and also this method resulted in poor illumination.

3. METHOD USED

The captured underwater images are suffered with problems like non-uniform illumination, blue-green illumination, under and over enhanced areas [12]. In this section, the underwater image processing techniques that are used for the recovery of the distorted underwater images are discussed. From the previous works, it is evident that the combination of many other enhancement techniques is required to improve overall image quality. The proposed underwater image enhancement method composed of two main parts: Homomorphic filtering for correcting the non-uniform illumination and Contrast Limited Adaptive Histogram Equalization method for enhancing the contrast. The block diagram of the proposed method is shown in Fig. 3.

3.1. Homomorphic Filtering

Homomorphic filtering is basically used to remove the multiplicative noise found in an image. It normalizes the brightness and increases the contrast of an image. The non-uniform illumination effects observed in an image can be corrected using this filtering technique. Light intensity of an image at any point is the product of illumination and reflectance components which is given by Eq. (1).

\[
I(x, y) = L(x, y)R(x, y)
\]

where I represent an image, L is scene illumination and R is the reflectance of object in scene. The illumination component is resulted from light condition during image capturing process and reflectance resulted from scene object properties. While correcting the non-uniform illumination, main goal is to remove low frequency illumination component from the product as it is inseparable from high frequency reflectance component. Hence, log operation is applied as shown in Eq. (2) and (3) and gaussian high pass filter is used to reduce the significance of low frequency component.
\[ \ln(I(x, y)) = \ln(L(x, y)R(x, y)) \quad (2) \]
\[ \ln(I(x, y)) = \ln(L(x, y)) + \ln(R(x, y)) \quad (3) \]

The step of Homomorphic filtering is shown in Fig. 4.

![Homomorphic Filtering Diagram](image)

**Fig. 4. Homomorphic Filtering**

The steps involved in the process are given below.

1) Convert the gray input image to floating point type and then apply log operation to convert into linear model.
2) Compute Fourier Transform on log output.
3) High pass filter is used to enhance the reflectance part and degrade the illumination component.
4) Compute inverse Discrete Fourier Transform to reconstruct the original image.
5) Apply exponential operation to get the Homomorphic filtered image.

### 3.2. Contrast Limited Adaptive Histogram Equalization (CLAHE)

CLAHE technique is used to enhance the local contrast of the image by transforming the pixel value distribution of each region. Originally, it was developed for the enhancement of low contrast medical images [1]. To deal with the over amplification of noise problem, Adaptive Histogram Equalization (AHE) and CLAHE were proposed. In AHE method, if the processing region has relatively small intensity range then in such cases noise in that region gets more enhanced which results in artifacts in that region. To overcome and limit this problem of artifacts appearance and noise problem, AHE is modified into contrast limited AHE [10].

In this method instead of applying CLAHE on entire image, it is applied to a small region called tiles to enhance the contrast of an image. The noise amplification is restricted by clip limit by clipping the histogram in homogeneous areas in the image using uniform histogram distribution, thus the contrast of that region is limited [4]. This method thus helps in removing the light scattering and color change problem that usually is the problem occurred in the underwater images.

### 4. RESULTS AND DISCUSSIONS

The proposed method has been tested for twenty-four different underwater degraded input images with different haze levels and the work has been performed using MATLAB R2018b software. The enhanced images are validated using quantitative parameters such as Entropy, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). Also, qualitative analysis of enhanced images compared with the existing methods is discussed below.

The images used for the process, out of which some of the images has been taken from Turbid dataset [13] and Github datasets [14]. Turbid dataset consists of three different subsets of degraded images (milk, deep blue and chlorophyll). The rest of the images are taken from Github dataset which also consists of three subsets i.e., blue, green and haze sets.

#### 4.1. Qualitative Analysis

Firstly, the underwater degraded image is evaluated using Homomorphic filtering so as to correct the non-uniform illumination effect in the image. It follows certain steps as discussed in the above Fig. 4, but the output of homofiltered image contains some too dark or bright regions which can be dealt using CLAHE. By using the CLAHE method, increase in the contrast of an image and also the intensity is observed. Thus, eliminating the light scattering and color change effect that usually is the main reason for underwater image degradation. Initially testing for various filters like mean, median, average and wiener filter are used as shown in the Fig. 5 to 8 respectively, but the result of these filters did not meet the criteria of solving the degradation of underwater images. Results of homo filtered and CLAHE image in Fig. 9.

![Input and filtered output images using Mean Filter](image)
From the Fig. 9, it is evident that the homo filtered output image results in eliminating the non-uniform illumination, reduces the presence of noise by improving the appearance of grayscale image but it contains some too dark or too bright regions in the output image which can be eliminated using CLAHE technique which also enhances the contrast of an image. Fig. 10 gives the comparison of various filtered output with the proposed homomorphic filtered output, from which it is evident that the proposed method achieves good quality by removing the non-uniform illumination and also gives the detailed image structure.
Fig. 9. From (a) to (f), the first row of each contains 24 different degraded gray input images from the dataset with different subsets, second row represents the result of homomorphic filtered images, third row represents the enhanced result using CLAHE technique respectively.

Fig. 10. From (a) input gray image (b) output of Mean Filter (c) output of Median Filter (d) output of Average Filter (e) output of Wiener Filter (f) output of Homomorphic Filter

4.2. Quantitative Analysis

To justify the efficiency of the proposed work, the quantitative parameters like Entropy, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are measured. Basically, entropy it is a statistical measure of randomness in texture of an image. If the randomness in texture is high, the variation in pixel intensity will also be high. The higher the entropy, lesser is the amount of distortion in the output image. The values of MSE and PSNR are used to find out the image noise [2], MSE is defined as the sum of squared error between original and enhanced image and the PSNR measures the peak error. The higher the value of PSNR, better is quality of an image and also it reduces the number of errors. The quantitative result of the proposed method is shown in Table 1. Some of the 20 input images chosen for the evaluation are shown in the Fig. 11.

Fig. 11. Various input images selected for the quantitative analysis listed as image 1 to image 20 respectively.

From the Table 1 shown below, it is observed that the entropy values of the proposed method produce highest value as compared to the existing methods. The values from the image 6, 8, 13 and 20 represent the better entropy values 7.9400, 7.9869, 7.9287 and 7.9315 respectively amongst the other images from the table. Thus, it indicates that this method provides better entropy values and highest image details when compared to the other methods. The lower the value of MSE lowers the error and higher the PSNR gives better quality of compressed or reconstructed image. From the above table it is evident that all the images provide lower MSE in the range 1.31 to 1.65 than the existing methods. Thus, PSNR is high since the proposed work gives lower MSE than the previously proposed methods. The comparison table of the proposed work with other methods is listed in the Table 2. From the Table 2, it is clear that entropy with 7.9869, MSE 1.60 and PSNR 46.12 works better with the proposed method than the previously proposed methods. The results obtained from both qualitative and quantitative method indicates that the proposed method can be used to improve the contrast, correct the non-uniform illumination and remove the noise effectively thus improving the visual quality of underwater degraded image. The quantitative and qualitative result also shows that this method improves the visibility of underwater images, produce noise free image with lowest MSE and higher PSNR and entropy values.
Future work could be the improvement of underwater captured degraded image has been introduced. This method includes homomorphic filtering and CLAHE method. The homomorphic filtering can reduce the non-uniform illumination and minimizes the noises present in an image. But the output contains some too dark or bright regions. To overcome this problem CLAHE is used which is also used to increase the contrast and intensity and also removes the artifacts appearance in the underwater scene regions. The quantitative and qualitative result also shows that this proposed method improves the visibility of underwater images and produce low MSE, higher PSNR and entropy values when compared to other existing methods. This method can be used for wide range of underwater enhancement applications. Future work could be the enhancement of underwater captured videos and color correction to remove the bluish greenish view in the captured images and videos.

**REFERENCES**


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**Table 1. Quantitative results of measuring parameters such as entropy, MSE and PSNR**

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<th>Image No.</th>
<th>Entropy</th>
<th>MSE</th>
<th>PSNR in dB</th>
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<tr>
<td>1</td>
<td>7.8307</td>
<td>1.32</td>
<td>46.96</td>
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<tr>
<td>2</td>
<td>7.8356</td>
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<td>7.7105</td>
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<td>20</td>
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**Table 2. Quantitative Analysis comparison of proposed method parameters with existing methods**

<table>
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<th>Method</th>
<th>Entropy</th>
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<td>7.7763</td>
<td>425.68</td>
<td>21.840</td>
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<td>DCP+gamma correction</td>
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<td>508.26</td>
<td>21.069</td>
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<tr>
<td>Proposed Method</td>
<td>7.9869</td>
<td>1.60</td>
<td>46.12</td>
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5. CONCLUSION

In this paper, an approach to enhance the underwater captured degraded image has been introduced. This method includes homomorphic filtering and CLAHE method. The homomorphic filtering can reduce the non-uniform illumination and minimizes the noises present in an image. But the output contains some too dark or bright regions. To overcome this problem CLAHE is used which is also used to increase the contrast and intensity and also removes the artifacts appearance in the underwater scene regions. The quantitative and qualitative result also shows that this proposed method improves the visibility of underwater images and produce low MSE, higher PSNR and entropy values when compared to other existing methods. This method can be used for wide range of underwater enhancement applications. Future work could be the enhancement of underwater captured videos and color correction to remove the bluish greenish view in the captured images and videos.