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Underwater Image Enhancement by Color Balance, Fusion and Contrast Limited AHE

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ABSTRACT*:* Image capturing process consists of various steps like collecting the analog signal from source, conversion to digital signal, and application of algorithm to properly store and transmit high quality images. All this objectives can be fulfilled with high standards only when the collection of primary analog signal is achieved of high quality and distinct properties. Image capturing underwater is more challenging then general atmosphere, it's because of degradation due to medium scattering and absorption. A pre-defined method is used in a single image approach avoiding customized equipment's and rigorous sensors. First a degraded image is obtained with general camera and color balance and white balance is performed acting as the initial process of de-hazing. This image is further segmented into two parts by performing gamma correction and sharpening and its individual weight maps are been derived. Further multi-scale fusion is been performed to provide the transfer of edges and proper color contrast to the de-hazed enhanced image. The next process is been proposed to increase the structural details of the image by performing contrast limited adaptive histogram equalization. Further step has provided better quantitative details of the image to achieve better recognition of dark region, improving global contrast and sharpness. This all-over method is been developed as the base to support the further objective to perform textural details enhancement and it will help to obtain a more color enhanced image providing a better color quality de-hazed underwater image.

KEYWORDS*:* Underwater image enhancement, colour balance, white balance, gamma correction, sharpening, multi-scale fusion, weight maps, normalized weight, contrast limited adaptive histogram equalization.

I. INTRODUCTION

Thecurrent world is the digital because the major amount of device being used in day-today life are working in digital format, every data are been stored in digital format but around all natural signals are analog. The primary process to retrieve the signal for storage is to use a method to obtain the high quality analog signals and to use a transducer to convert it into a digital format and it can be stored in various devices. The analog signal used to extract the information of any object is mostly the light and its frequency and intensity is an important factor to consider in capturing any image. While in general atmosphere the medium is less dense so the light wave doesn't gets deviated due to medium scattering. In the case of underwater as the medium is much denser than the general atmosphere the traveling light wave in the water does get scattered due to medium and even get absorbed due to medium particles. In general atmosphere the distance of the object from the camera doesn't impact the illumination factor of the traveling light rays, but in underwater the distance between the object and camera does create an issue. In underwater environment like in sea the object beyond 10 meters are almost unappreciable [1]. The color get faded because of low light intensity and it is depends on the depth of the sea as well as the angle of incidence of the sun light rays with respect to water surface. If the sun rays is incidence in 90^0 degree then the light intensity will be more in the general depth and if the angle of incidence is something different then the intensity varies mostly in reduced direction as the depth in general [2]. Many Methods were been introduced to perform the enhancement of the image obtained in underwater [3], [15], [5]. But most of this method suffers due to low light availability due to which the color components get reduced. But in [1] they introduced the method to perform there steps to enhance the image even in low light intensity and providing a better quality score. Further this proposed method helped to obtain better image score.

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This method is implemented as shown in the Fig. 1, first white balance is been performed on the image and then two individual steps of gamma correction and sharpening is been performed which is further used to obtain the individual weight maps and this are been used in multi-scale fusion. After multi-scale fusion the proposed CLAHE method is been implemented and a better quality image is been obtained. Further the individual score relations are been denoted as a result of this implementation. In this work the next section describes the overview of the implemented method of underwater image enhancement

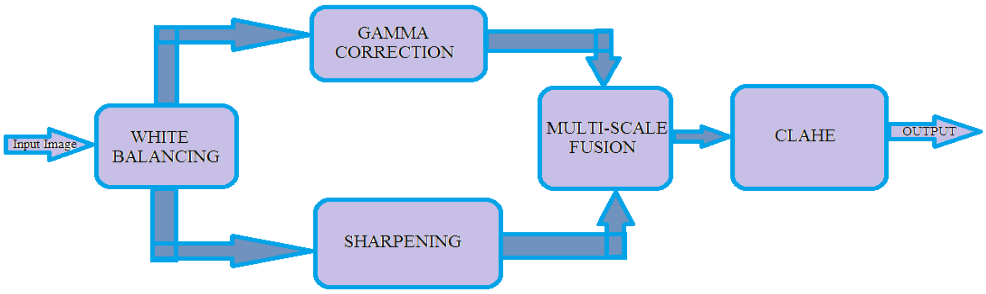

Fig. 1 – General Method Overview.

II. UNDERWATER IMAGE ENHANCEMENT

A. Overview of the Method

The Fig. 2 have represented the properly described method which is been implemented in the proposed method for underwater image enhancement.

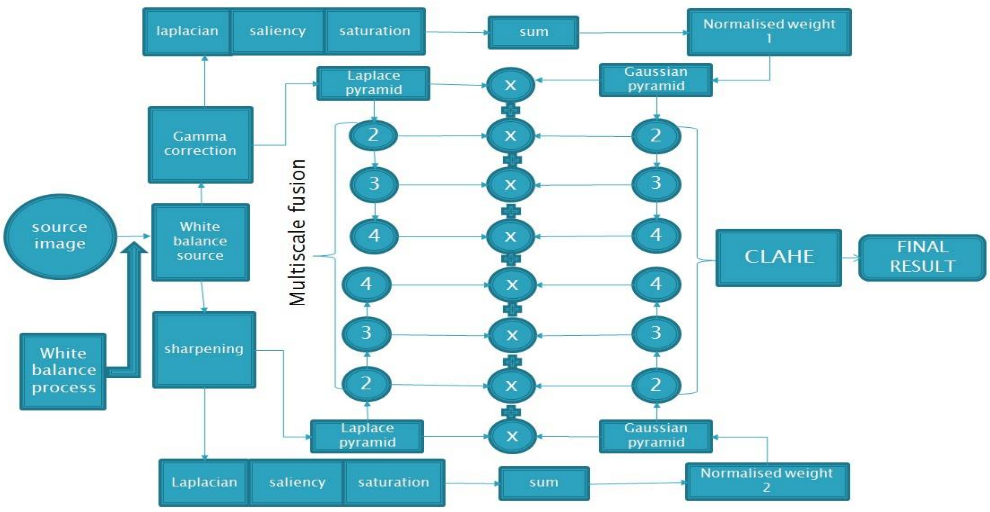

Fig. 2 –Implemented Underwater Image enhancement procedure.

B. White Balance

The first step of the enhancement process is to remove the colour cast caused due to various level of illumination which is depend upon the depth of the water. As the depth varies the amount of light reaching the point will degrade in exponential form. Generally, for digital recording the RGB value of light source is been recorded and in the case of

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underwater the high wavelength colour component gets diffracted easily and couldn't reach the further depth of the sea. So, the red colour component couldn't reach till extreme depth, due to this reason the natural picture obtained by the help of general camera is green-bluish type image output. This phenomenon defines the selective colour component removal or inefficiency to travel deep into the sea. So, to consider the process of white balance a large spectrum of colour component is needed to be consider. While considering [9], [10], [11] and [12] they have estimated the colour of the light source and then by dividing each colour channel a normalized light intensity value to balance all the colour illumination intensity to obtain an image with reduced colour artefacts due to scattering and absorption.

The best algorithm is Gray world algorithm in which the normalized intensity estimation is done by averaging each channel independently and then removing with unwanted colour cast. The Gray world algorithm even provides good visual performance in extreme distorted underwater environment. While performing the computation due to less illumination of red channel the averaging and adding the mean to each luminance channel does provide red effect as shown in Fig. 3, to avoid it the compensation of red channel loss is been performed and then the white balance algorithm is been performed. Mathematically the red effect compensation is represented as shown below in Equation 1.

$$I_{RC}(x) = I_R(x) + a. (I_{GM} - I_{RM}). (1\text{-}I_R(x)).I_G(x) \qquad (1)$$

Here I_R, I_G represent the red and green channel of the image I and each channel is been normalized with this value to compensate the red channel effect on the image. After this the Gray world algorithm is been performed and the required white balance objective is been achieved. The relative image can be seen in Fig. 3

Fig. 3 – The original image (right), the image without red channel compensation (middle) and the image with red compensation & white-baanced (left).

C. Gamma Correction

The gamma correction is a method implemented to enhance the shaded region of the image. It mostly defines the relationship between a pixel's numerical values and its actual luminance. As to store the image digitally it's necessary for the light to be brighter but in the low luminance environment the darker region get saturated. To enhance that region gamma correction is been performed. Its basic mathematical equation is shown in Equation 2.

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$$Vout = A*Vin^{G} \qquad (2)$$

These G is the gamma value and the equation denote that it's a non-linear operation. In this operation mostly the A value is 1 and the input value is raised to the power G (Gamma). Mostly the range of the output remains within 0 to 1. When the gamma value increases in the operation the dark channel luminance decreases and the details of the image gets darker and when the gamma value is less or decreasing the darker regions get luminance value and the pixels luminance increases by which the darker part is reduced, and the hidden details gets enlighten. In underwater imaging this operation helps to obtain the hidden details as shown in the Fig. 4.

Fig. 4 – Image with gamma value high (right), image with gamma value 1(center) and Image with gamma value 0.5 (right).

D. Sharpening

Sharpening is used to increase the texture emphasise of the image and increases the focus point of the image. In underwater environment due to high density and medium scattering the focus on the texture of the image decreases due to which the edge difference quality decreases during image abstraction in underwater environment. To remove the blur part of the image the sharpening process in been implemented. This method doesn't reconstruct the image, it only able to create the appearance of the edge more recognizable. To perform this operation generally un-sharp mask is been performed, it does means that a blurred negative image is been created from the source and is been subtracted from the source image by which the blurred value gets removed and the textural part of the image remains as sharpened image. Mathematical representation is been provided in equation 3 below.

$$Sharpened\ Image = Original\ Image + (original - blurred) * Amount \qquad (3)$$

With the equation 3 we can understand the sharpening is been performed by removing the blurred part and even by multiplying the amount of luminance to be consider while removing the blur part by which the colour loss of the image doesn't gets implemented with this process. The Fig. 5, represents the sharpening on a general image below.

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Fig. 5 – Source image (left) and Sharpened image (right).

III. MULTI-SCALE FUSION

The white balance was only been used to remove the colour cast due to unwanted illumination mostly arise due to scattering and absorptions. But to enhance the image it does means to make the image brighter and to enhance the texture of the image. Gamma correction does perform the brightness of the darker region and sharpness does enhance the textural part of the image, but to combine the both property of the image the fusion of these multiple image is does necessary. For the fusion of both characteristics of the image Multi-scale Fusion is been performed it has two stages.

A. *Weight of Fusion Process*

Since the both stage of gamma correction and sharpening perform it's processing from the white-balance image, its leads to Gaussian version of filtered image passed through high pass filter. These leads to magnification of high frequency noise and will leads to artefacts. To avoid these artefacts multi-scale fusion process is been performed with the derivation of individual weights, these weights are been derived as a filter to remove the high frequency components amplitude. In these method three weight maps are been derived from the gamma corrected image and sharpened image and the respective weight maps are been determined.

1) Laplacian Contrast Weight (W_L) – These Laplacian weights is been obtained by computing the absolute value of a Laplace filter applied to every luminance channel. By which some of the high noise of higher frequency creating artefacts. But as Laplace can't distinguish between a ramp and flat regions so some of the noise still persists. To remove that further weights are been derived. The Fig. 6, shows a Laplace filter channel of both Gamma corrected image and sharpened image.

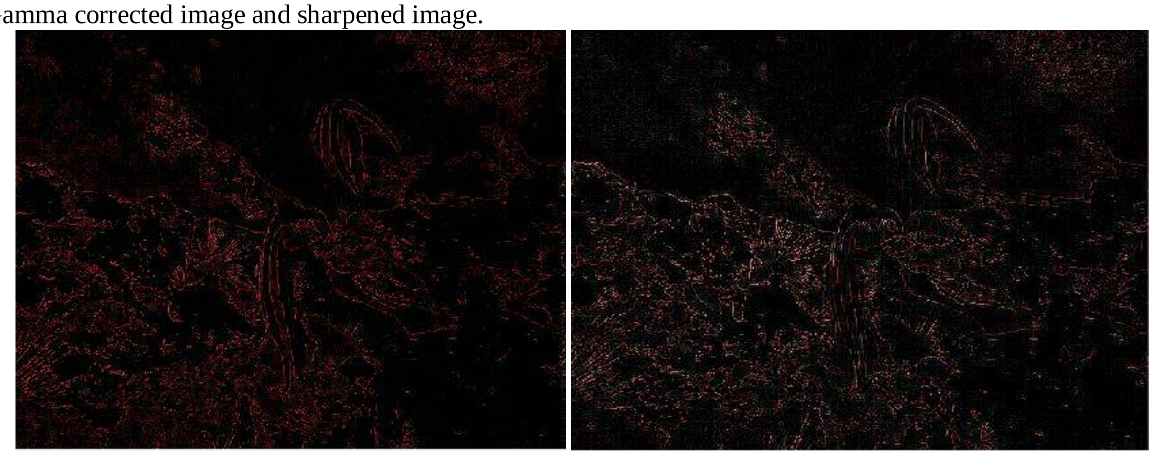

Fig. 6 – Laplace Weight of gamma corrected image (left) and Sharpened image (right)

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2) Saliency Weight (W_S) – This weight map is introduced to help the low luminance or salient objects of the image. The implementation of filters to remove the artefacts will further reduce the illumination of these object, so to increase the individual value of the salient objects of the source these weight is been derived by simply masking the high luminance channel from every channel by which only the low luminance value will be remained and by further the individual residual channel intensity is been increased to obtain the saliency weight. The Fig. 7, shown the individual saliency weight of the gamma corrected and sharpened weight.

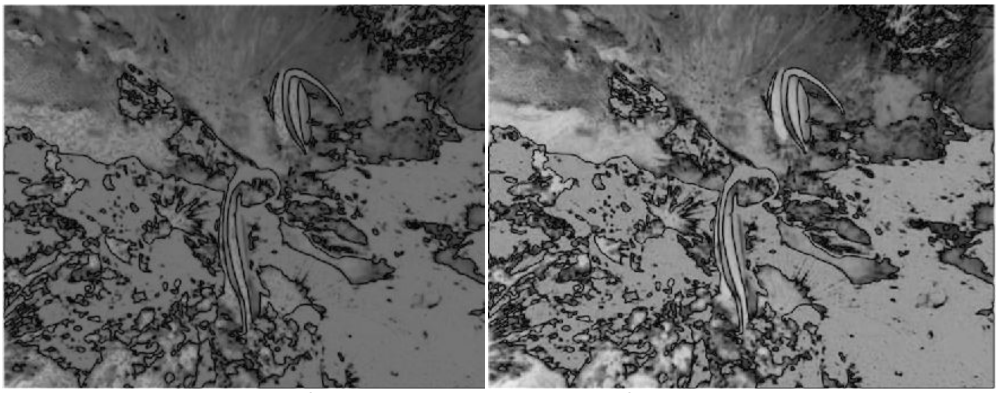

Fig. 7- Saliency weight of Gamma Corrected image (left) and Sharpened Image (right)

3) Saturation Weight (W_{SAT}) – These weight map helps to obtain the chromatic information of the highly saturation region of the image. It is been simply computed by implementing the square root on the average of the difference between the Red, Green and Blue channel and the luminance of the input for every channel of the image. The saturation weight of gamma corrected image and the sharpened image is shown in Fig. 8.

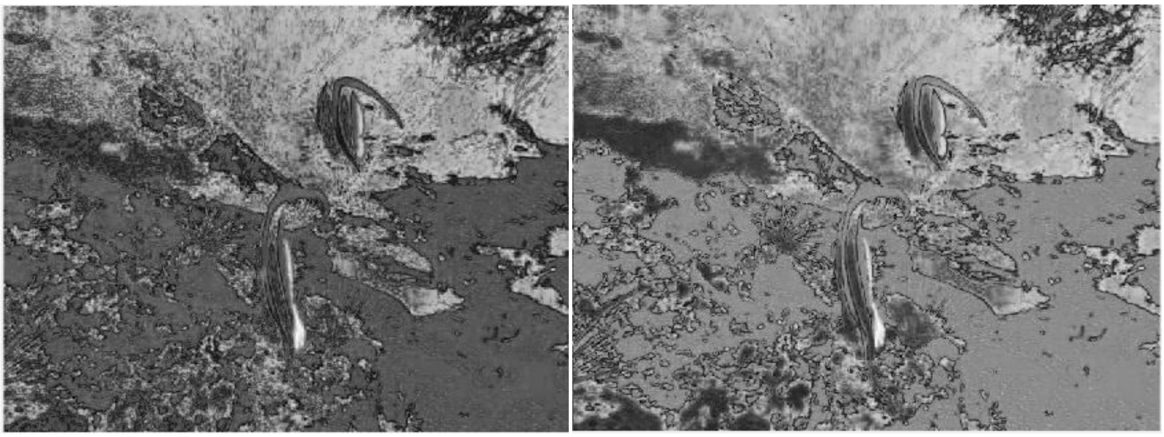

Fig. 8 – Saturation Weight of gamma corrected image (left) and sharpened image (right)

B. *Multi-level Fusion Process*

To obtain a single image if all the individual weights are been summed to obtain a normalized weight of the gamma corrected and sharpened image respectively and further been added together in general manner to every pixel's channel then there will be an undesirable halo, and un-distinguish image will be obtained. To avoid these halos further computation process for fusion is been performed as shown in Fig. 2, First the gamma corrected image and sharpened image is been provided to the Laplace pyramid which will individually perform Laplace filter operation and sequentially in every step will degrade the image and will provide it for the merger with the normalized weight map supplied to the Gaussian pyramid in which in each sequential step the low pass gauss filet operation is been performed. After the merger of the Laplace pyramid steps output to the respective Gaussian pyramid step output the

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obtained factor is been factorised by 2 in both direction and again the further step is been performed. These individual steps will add the pixel's value of the channel by removing the unwanted halos and finally uptilt N steps mostly N=5 individual pyramid steps the final output is been added to obtain a multi-level fusion processed single image containing every property implemented in these processes.

IV. Proposed Further method implementation

The above process provides a proper enhanced image of underwater environment with a very high-quality output. But the white balance, gamma correction and sharpening does remove the colour of the image. To further process the image to provide a base to perform colour enhancement the texture of the image has to be increased. As a base step for colour enhancement in the operation, I proposed the CLAHE method to further remove the noise in the image and to enhance the texture. For the proof of the benefit we did perform the quality assessment by a non-reference matrix and got a better score.

A. CLACHE Method

As given in the [30], [31] and [32] contrast limited adaptive histogram equalization does helps to increase the contrast further of the image where colour reduction took place and mask the difficulty of texture enhancement. The [30], [31] is mostly used for medical images. I here tried to implement in enhancement of underwater image enhancement. To understand the working of the method, I need to consider the three methods.

1) Histogram Equalization

The histogram equalization performs the operation to obtain the grey levels of the image and equalizes them to an average point b which the grey level is equally likely to occur in every level. This operation does increases brightness and illuminates the dark and low contrast areas of the image. With this method the invisible part of the image is made visible.

2) Adaptive Histogram Equalization

The above process can only be used when the distribution of the pixels is similar thought the image. But by considering the underwater environment the pixels value will not be similar all-over the image so contrast of those locations can't be performed. To solve this issue the adaptive mode is been performed in which the transformation of each pixels is been performed from a function derived from neighbourhood regions. When the pixels are homogeneous the histogram will have strong peak value. But when these operationsare been performed in narrow range of pixels value then it will make the image blur and expand the small amount of noise to spread all over pixels of the image. To avoid these effects the further operation is been performed.

3) *Contrast Limited Adaptive Histogram Equalization*

To limit the spread of the noise the further process was considered to first increase the contrast of the image and to convey more details. To methodically implement these concepts first the image, need to be padded properly to avoid zero-pixel values. Then the grey level mapping is been performed for each pixel and the histograms are been prepared. To avoid the noise spread and to enhance the contrast a clip limit of the histogram is been considered above which the value will be discarded. These limitsis been applied to every transformation function obtained through the neighbour pixels and then the average equalization is been performed to obtained a high contrast, illuminated lossy texture of the image. The cumulative representation of channel histogram is been represented in the Fig. 9.

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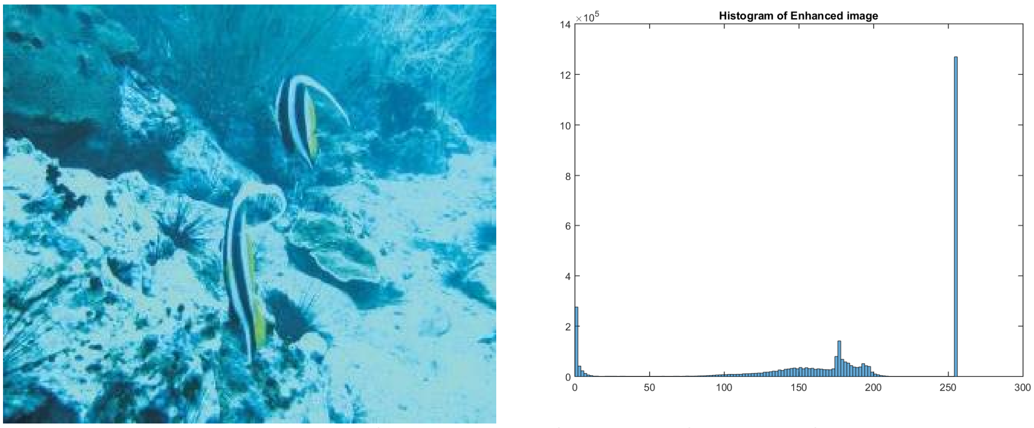

Fig. 9 – The histogram representation of RGB channel of individual frequency of the image (right), the source image (left)

This implementation of further step in underwater image enhancement increased the quality of the image and theoretically this work can be a base for any image enhancement procedure for underwater image. The further implementation can be colour enhancement of the images.

V. RESULT AND DISCUSSION

The method is implemented to obtain a better quantitative and qualitative image, when the CLAHE is been implemented it increases the textural value of the image. As there is no perfect image source so performing the referential analysis will provide the reverse quantity estimation. So, to obtain the quality of the image non-referential image analysis is to be performed. So, the all over process of underwater image enhancement is been implemented in MATLAB and a pre-defined image quality evaluation is been applied to determine the quality of the images. The function used is Brisque Score (Blind/Reference less Image Spatial Quality Evaluator) a smallest score indicates better perceptual quality. The implantation of the process and the enhancement percentage is been obtained and shown in Table 1 & Table 2 below.

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TABLE I

HISTOGRAM REPRESENTATION

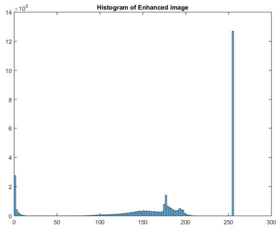
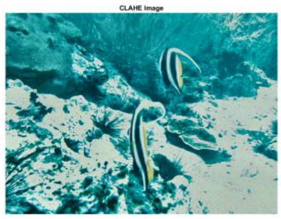
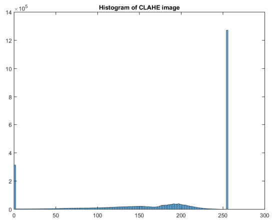
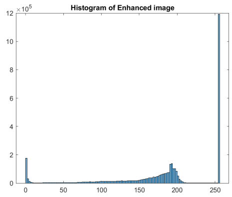
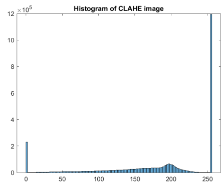
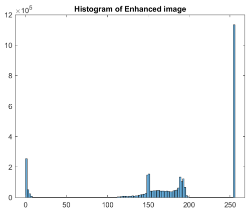
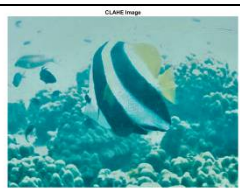
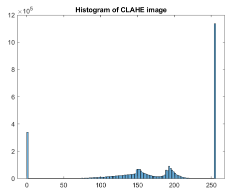
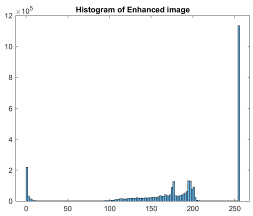
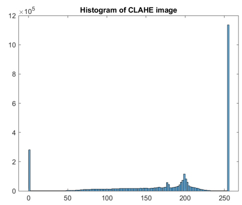
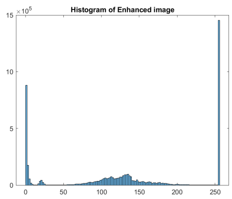
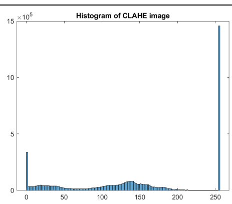
UNDERWATER ENHANCED IMAGE	UNDERWATER ENHANCED IMAGE HISTOGRAM	CLAHE IMAGE	CLAHE IMAGE HISTOGRAM
			
			
			
			
			

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TABLE II
IMAGE QUALITY ASSESSMENT (BRISQUE)

UNDERWATER ENHANCED IMAGE	BRISQUE SCORE OF UNDERWATER ENHANCED IMAGE	FURTHER PROPOSED CLAHE METHOD IMPLEMENTATION	BRISQUE SCORE OF CLAHE IMAGE	PERCENTAGE QUALITY CHANGE
TEST IMAGE - 1	30.3484	29.4495	18.5868	61.244%
TEST IMAGE – 2	23.0230	22.5820	20.5742	89.3636%
TEST IMAGE- 3	51.9094	41.8188	37.5055	72.2518%
TEST IMAGE- 4	42.7543	33.7960	32.5210	80.7427%
TEST IMAGE- 5	43.3616	33.2230	31.5181	72.6866%

As shown in the Table 1 the percentage change in quality is positive which denoted that the further proposed CLAHE method does increases the quality of the image and according to the theory this quality is been enhanced due to the textural enhancement of the image. To notify the important point these complete methods doesn't re-create any image, it only performs removal of noise and some unnecessary signals and increase some important details signals of the image to get a better recognizable image.

VI. CONCLUSIONS

The Underwater image enhancement procedure is a computational rigorous method to obtain an underwater de-hazed image with both sharpness and illuminated with removal of noise type image. This work can be further upgraded by implementing the color enhancement procedure. It will help for underwater robots, can be used to determine the underwater ecosystem, it can be used to determine any damage of sea cable. Vision is the equipment to recognize an object and this algorithm is develop to machine support the visual objective.

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