iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** VIII **Month of publication:** August 2018

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VIII, August 2018- Available at www.ijraset.com

An Improved Underwater Image Enhancement Technique

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Abstract: The Most important attributes to acquire and extract more information from underwater images are color and contrast. But most of the underwater images are suffered from poor illumination due to ocean depth and color degradation. Many techniques are available to improve the perception of underwater images. Among these mostly widely used techniques are Histogram based equalization techniques. But the clarity of images are not much improved. So we proposed an approach based on slide stretching. The objective of this approach is twofold. Firstly, the contrast stretching of RGB algorithm is applied to equalize the color contrast in images. Secondly, the saturation and intensity stretching of HSI is used to increase the true color and solve the problem of lighting.
Keywords: Underwater images, Image enhancement, Histogram of color images.

I. INTRODUCTION

Underwater image processing is one of the major area in Digital image processing which is applied in various fields. Such as marine habitats monitoring. It also simplifies inspection of piping in the field of engineering. Underwater imaging is very challenging field because of the physical properties of underwater environment. Mainly related to diffusion and absorption of light.

Underwater images lose contrast and suffering from degradation mainly due to poor visibility conditions and effects such as light absorption, light reflection, bending and scaterring of light. In latest research work underwater image processing becomes an effective field of the digital image processing. The methods for underwater image enhancement are briefly discussed in the next section. The balance of the paper managed as different Histogram equalization techniques, performance analysis of different Histogram equalization techniques, experimental results respectively.

II. HISTOGRAM BASED TECHNIQUES

Underwater image enhancement by using histogram based techniques are classified in to three types as shown below

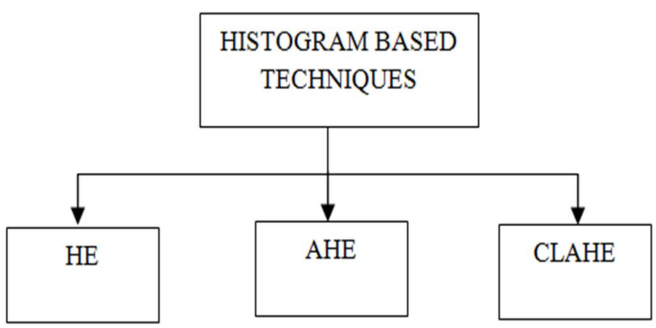


Fig.1. HISTOGRAM BASED TECHNIQUES

A. Histogram Equalization (HE)

Histogram equalization (HE) is a popular image enhancement method. HE works by stretching and equalizing the histogram through the intensity range by means of probability distribution function (PDF) and cumulative distribution function (CDF). HE is used as a basic method in the enhancement process by many researchers.

The histogram is a graph which shows the frequency of occurring of data in the whole data set. It plots the number of pixels for each tonal value. Consider an image with M total possible intensity levels. Then, the histogram of the image in [0, M-1] is defined as a discrete function:

$P(r_k) = n_k/n$

Where,

rk is the kth intensity level in the interval.

nk is the number of pixels in the image whose intensity level is rk.

n is the total number of pixels in the image.

Histogram equalization is an image enhancement technique which enhances the contrast of an image by spreading the intensity values over the entire available dynamic range. This is achieved through a transformation function T(r), which can be defined by the Cumulative Distribution Function (CDF) of a given Probability Density Function (PDF) of gray levels in an image.

1) *Continuous Case:* This is for intensity levels that are continuous quantities normalized to the range [0, 1].

Let, Pr(r) is the PDF of the intensity levels.

Then, the required transformation on the input levels to obtain the output level S is:

$$S = T(r) = \int_0^r P_r(w)\,dw \tag{1}$$

where w is a dummy variable of integration. Then, it can be shown that the PDF of the output levels is uniform, i.e.,

$$P_s = \begin{cases} 1, for\, 0 \le s \le 1 \\ 0, otherwise \end{cases} \tag{2}$$

The above transformation generates an image whose intensity levels are equally likely and also, it covers the entire range [0, 1].

This intensity level equalization process results in an image with increased dynamic range with a tendency to have higher contrast.

2) *Discrete Case:* In the case of discrete quantities, we deal with summations and hence, the equalization transformation becomes:

$$S_k = T(r_k) = \sum_{j=1}^{k} P_r(r_j) = \sum_{j=1}^{k} n_j/n \text{ , for } k = 1, 2, 3, \dots, L \tag{3}$$

where Sk is the intensity value of the output image corresponding to value rk in the input image.

B. Adaptive Histogram Equalization(ahe)

It is different from ordinary histogram equalization in the sense that it is not global and it computes many histograms corresponding to different sections of an image . So, it is possible to enhance the local contrast of an image through AHE. With AHE, the information of all intensity ranges of an image can be viewed simultaneously and thereby solving the problem of many ordinary devices which are unable to depict the full dynamic intensity range. Here, first, a contextual region is defined for every pixel in the image. The contextual region is the region centered about that particular pixel. Then, the intensity values for this region are used to find the histogram equalization mapping function. The mapping function thereby obtained is applied to the pixel being processed in the region and hence, the resultant image produced after each pixel in the image is mapping differently. This results in the local distribution of intensities and final enhancing are based on local area rather than the entire global area of the image. This is the main advantage of AHE. But, sometimes, AHE tends to over enhance the noise content that may exist in some homogeneous local block of the image by mapping a short range of pixels to a wide one.

C. Contrast Limited Adaptive Histogram Equalization(Clahe)

The major difference between Adaptive histogram equalization(AHE) and Contrast limited adaptive histogram equalization(CLAHE) is contrast limiting. The CLAHE produces clipping limit for histogram to overcome the noise amplification problem. The CLAHE method divides the image in to relative regions and applies the histogram equalization process to each region. CLAHE has two parameters clip limit(CL) and block size which are mainly control image enhancement quality. By increasing the clip limit the image brightness will be increased. Similarly by increasing block size the range becomes larger due to these the image contrast also increases. CLAHE is one of the most widely and established method for the successful enhancement of low-contrast images.

The CLAHE method consists the following 7 steps

1) Dividing the original intensity image into non-overlapping contextual regions. The total number of image tiles is equal to *MXN* , and 8X8 is a good value to preserve the image chromatic data.
2) Calculating the histogram of each contextual region according to gray levels present in the array image.
3) Calculating the contrast limited histogram of the contextual region by clipping limit value.
4) Redistribute the remain pixels until the remaining pixels have been all distributed.
5) Enhancing intensity values in each region by Rayleigh distribution.
6) Reducing abruptly changing effect
7) Calculating the new gray level assignment of pixels within a sub-matrix contextual region by using a bi-linear interpolation between four different mappings in order to eliminate boundary artifacts.

D. Histogram Stretching and Clip-Limit Process

Under- and over-contrast occur in an underwater image whereas the amount of pixels is cumulatively concentrated at low and high intensity levels. Hence, stretching and clip-limit processes are applied to the image histogram of respective regions to prevent under- and over-contrast effects. For this purpose, the histogram of a region from the previous step is generated and the LUT is built. The clip-limit visual process is shown in Fig. 2, in which the spikes in the histogram higher than the clip limit will be cut off. The excessive numbers of pixels are equally distributed to all intensity levels, thereby increasing the number of pixels at all intensity levels. In this case, a normalized value of the clip limit is set at 0.01.

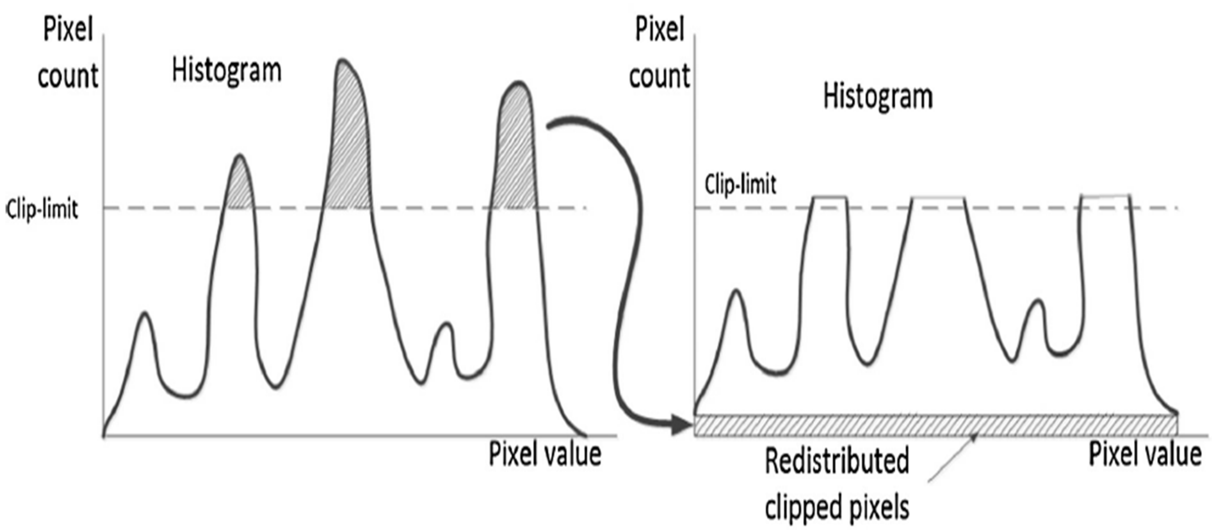


Fig. 2. Applying clip limit to the histogram of image.

E. The Proposed Approach For Underwater Image Enhancement

In order to address the issues discussed above, we propose an approach based on slide stretching. Firstly, we use contrast stretching of RGB algorithm to equalize the color contrast in the images. Secondly, we apply the saturation and intensity stretching of HSI to increase the true color and solve the problem of lighting. The proposed approach is shown in Figure 3.

The HSI model provides a wider color range by controlling the color elements of the image. The Saturation (S) and Intensity (I) are the element that generates the wider color range. In a situation when we have the blue color element in the image it is controlled by the 'S' and 'I' value in order to create the range from pale blue to deep blue, for instance. Using this technique, we can control the contrast ratio in underwater images either by decreasing or increasing the value. This is carried out by employing a histogram of the digital values for an image and redistributing the stretching value over the image variation of the maximum range of the possible values Furthermore linear stretching from 'S' value can provide stronger values to each range by looking at the less output values. Here a percentage of the saturating image can be controlled in order to perform better visual displays

The contrast stretching algorithm is used to enhance the contrast of the image. This is carried out by stretching the range of the color values to make use of all possible values.

The contrast stretching algorithm uses the linear scaling function to the pixel values. Each pixel is scaled using the following function

$Po = (Pi - c) \times (b - c) / (d - c) + a$

"Where
- Po is the normalized pixel value;
- Pi is the considered pixel value;
- a is the minimum value of the desired range;
- b is the maximum value of the desired range;
- c is the lowest pixel value currently present in the image;
- d is the highest pixel value currently present in the image "

When the contrast stretching algorithm is applied to color images, each channel is stretched using the same scaling to maintain the correct color ratio.

The first step is to balance the red and green channel to be slightly the same to the blue channel. This is done by stretching the histogram into both sides to get well-spread histogram.

In the second step we transform the RGB image into HSI, using the saturation and intensity transfer function to increase the true color and brightness of underwater images.

Using the transform function we have been able to stretch the saturation and intensity values of HSI color model.

Using the saturation parameters we can get the true color of underwater images. Brightness of the color is also considered to be important for underwater images. The HSI model also helps to solve the lighting problem using Intensity parameters.

Figure 3:Our proposed Methodology for Underwater Image Enhancement

III. EXPERIMENTAL RESULTS

The work is executed on MATLAB Software with various images. The underwater images are of size 512x512,Taken from the internet source. First the different Histogram based techniques mentioned in the previous section are applied to the images and then our proposed approach is applied. Next performance of Histogram based techniques and our approach are Analyzed.

A. Underwater Image A

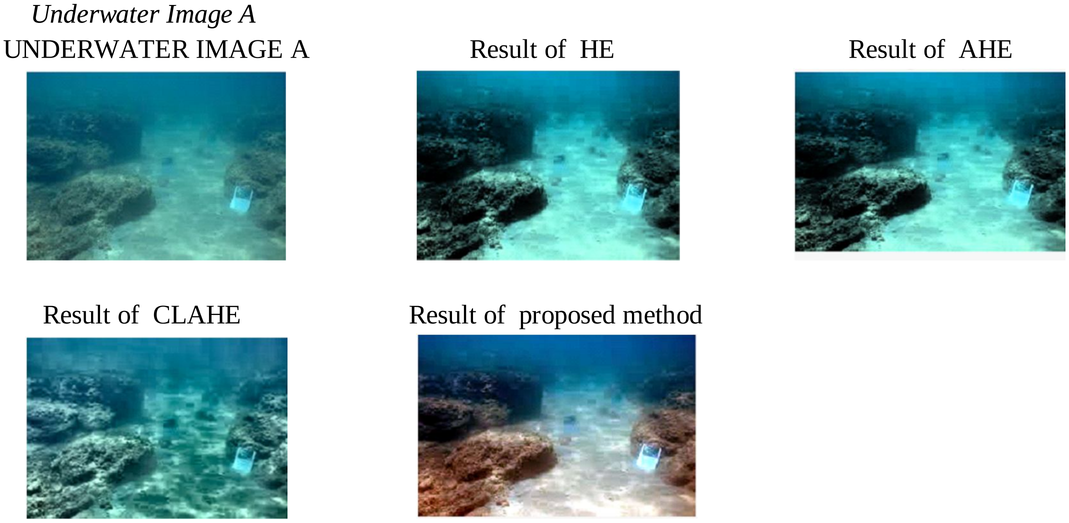
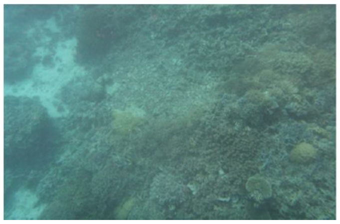


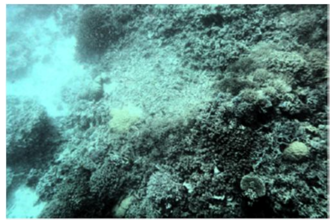
Fig4: Performance of HE, AHE, CLAHE ,Proposed method on Underwater image A

B. Underwater Image B

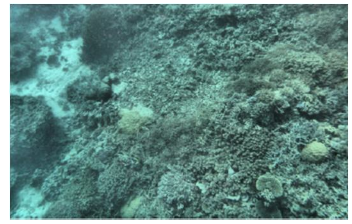
Underwater Image B



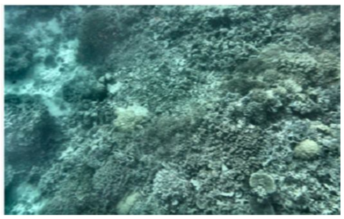
Result of HE



Result of AHE



Result of CLAHE



Result of proposed method

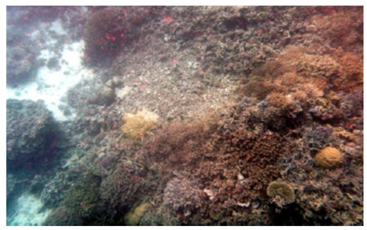


Fig.5: Performance of HE, AHE, CLAHE, Proposed method on Underwater image B

IV. CONCLUSION

In this Work Different Histogram based techniques are applied on different Underwater images. It was clearly observed that our proposed technique produce better results compare to Histogram equalization (HE), Adaptive Histogram equalization (AHE),CLAHE techniques. Future work focus on extending the algorithms by using advanced methods to improve the results.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue VIII, August 2018- Available at www.ijraset.com

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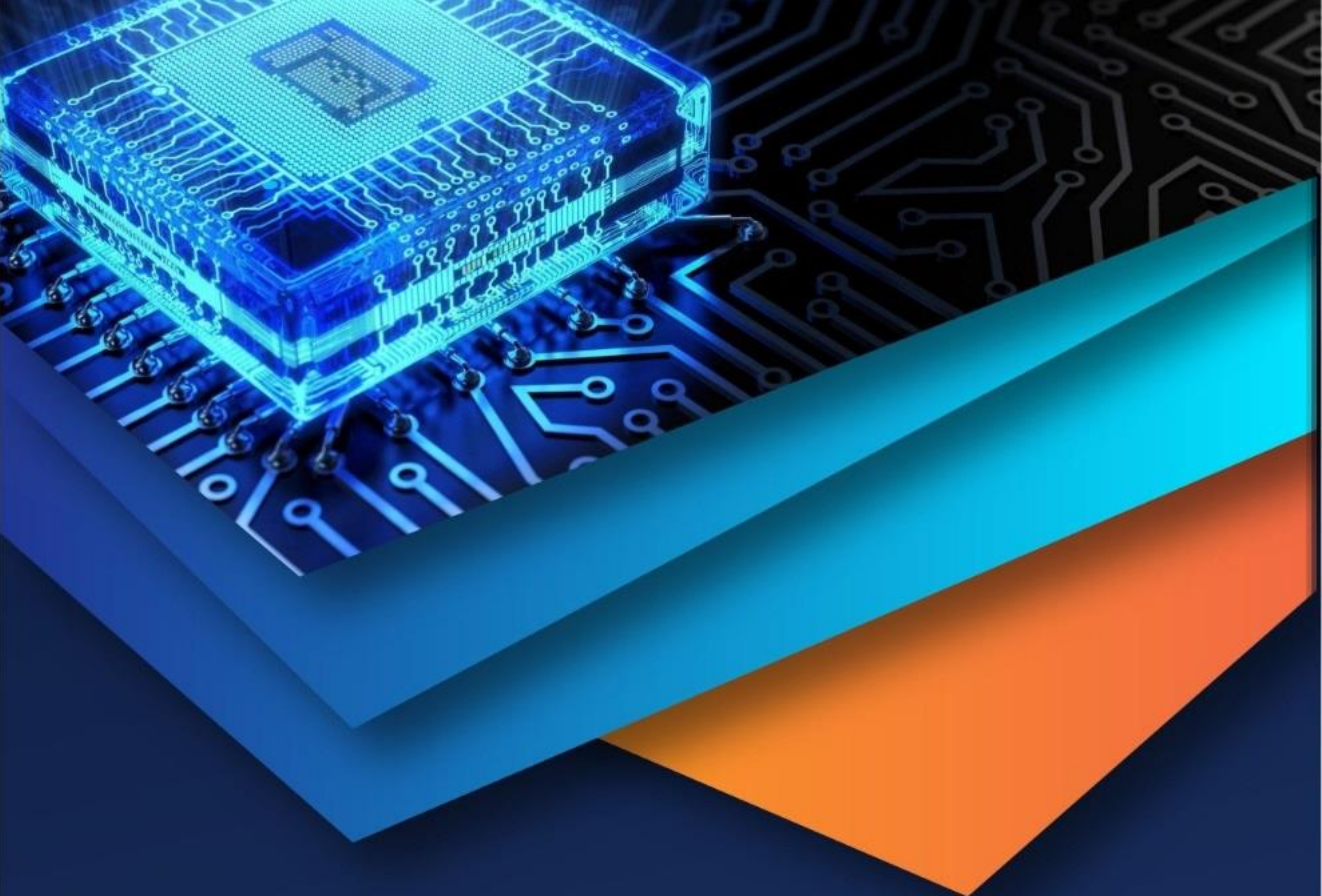

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