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Image Enhancement of Low Exposure Underwater Images using Contrast Correction

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Abstract-*Underwater image enhancement plays a crucial role in oceanic engineering. Underwater images are poor due to the properties of water and its impurities which results in many problems like low contrast, blur, color diminishing etc. There exists many techniques that enhance the quality of such images but the images produced by them are either under enhanced or over enhanced. In this paper, a hybrid technique is proposed that combines the features of RS-ESIHE and Contrast Stretching to get an enhanced image which is devoid of the limitations discussed above. Comparative analysis of the proposed technique is done with the existing techniques both quantitatively and qualitatively. For Quantitative analysis different parameters like MSE, PSNR and Entropy are calculated.*

Keywords—*Underwater Image Processing, Enhancement, stretching, histogram equalization, Mean Square Error, Peak Signal to Noise Ratio, Entropy.*

I. INTRODUCTION

Underwater image enhancement has been one of the scientific fields of investigation for the researchers. Underwater images are categorized by their poor visibility because the light travelling into the water is exponentially attenuated, thus results in images with low brightness and low contrast. The light attenuation caused by absorption and scattering, limits the visibility distance in a clear water and results in blur and hazy images[1].Therefore, processing of these images is needed to improve the quality and to retrieve the information of the interest. In the last two decades, researchers have been focusing on improving the quality of underwater images. Major work has been done in two techniques: Image Color Correction and Image Enhancement to improve the quality of image. In Image Color Correction the RGB image is transformed into other formats such as YCbCr, HSV etc. and components are extracted for overall color correction. In Image Enhancement, Histogram equalization or histogram stretching are commonly used techniques. Histogram equalization improves the overall contrast of the image by flattening the probability distribution and stretching the dynamic range of grey levels but the original image cannot be restored[2], while histogram stretching increases the difference of maximum and minimum intensity values of an image and results in original image on restoration.This work makes use of the advantages of both the fields to create a hybrid approach for better enhancement of low exposure images.

The rest of the paper is organized as follows: Section 2 describes the related work done in this field and motivation for proposed work. Section 3 presentsthe proposed algorithm and associated flow chart. In Section 4, proposed work results are presented along with the qualitative and quantitative comparison with existing results. Conclusion is done in section 5.

II. RELATED WORK

Yussof*et al*.[3], proposed a method to improve the visibility of underwater images using **CLAHE**technique that reduces over-amplification of noise and is easy to use.**Kuldeep*et al*.[4]**, proposed two recursive histogram equalization methods for underwater image enhancement. These methods are effective for the images taken in low light conditions. In the first method, the histogram is divided into under exposed and over exposed regions and successive recursive operations are applied for histogram equalization. In the second method, two exposure values were calculated and successive recursive operations on each sub histogram was applied for histogram equalization till the exposure threshold value of each sub histogram becomes less than exposure threshold value of the complete histogram.**Ghani*et al.[*5]**, proposed a method which performs contrast correction according to global and local contrast. The main goal of the method was to increase image's details and to improve the visibility by contrast correction. **Mallik*et al.[*6]** proposed a method which used haze removal algorithm followed by a ContrastLimited Adaptive Histogram Equalization (CLAHE). The method focused on underwater image enhancement for sea floor exploration, navigation and underwater environment monitoring. **AbuNaser*et al*.[7],** proposed the Swarm optimization algorithm for underwater images enhancement. A pre-processing step is introduced to reduce the absorbing and scattering effects ofwater before applying a filter based on this algorithm to enhance the image.The quality of enhanced images is quantitatively assessed by applying the framework on a dataset of underwater images. **GwanggilJeon[8]** presents a luminosity conserving and contrast enhancing histogram equalization method for color images.

III. PROPOSED TECHNIQUE

The study conducted by **Kuldeep*et al*.[4]** has a limitation that due to recursive clipping of histogram a lot of information in the image is lost. The technique proposed by **Ghani*et al*.[5]** enhances the under and over exposed area by determining the mid points of histogram but for images with more of the under exposed area, the technique performs very less enhancement. In this paper, a hybrid technique is proposed that overcomes these limitations and perform better enhancement using contrast stretching in a controllable manner.

A. Implementation of the proposed technique

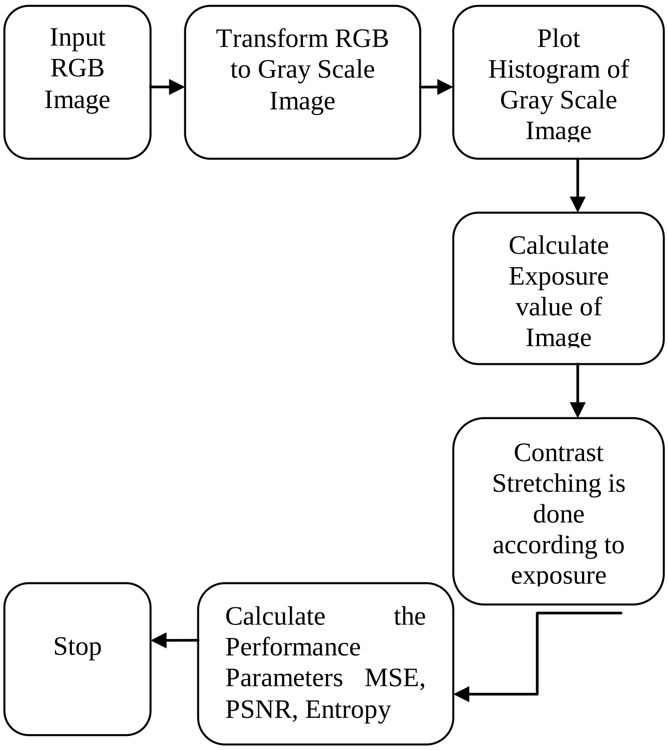


Figure 1.Flow Chart of Proposed Algorithm

The proposed technique consists of two fundamental steps:

I. Calculate Exposure Value for the image.
II. Image stretching according to exposure value.

B. Proposed Algorithm for Image Enhancement

1. Read the Color Image.
2. Transform Color image into gray scale image.
3. Plot Their Histogram.
4. Calculate the Exposure Value for the image and Gray Boundary value (Xa).
5. Use boundary value Xa to divide the histogram into two sub histograms.
6. Stretch the 10% lower region towards the high intensity level and reduce the 10% higher region towards the low Intensity level.

C. Exposure Threshold

The value of exposure threshold categorizes the images into low and high exposed images. The range of the exposure value is in the range between 0 and 1. The exposure for the images that contain the majority of the low exposure region is in between 0 to 0.5, whereas the exposure value of highly exposed images is in between 0.5 to 1. Equation (3.1) gives the Image intensity exposure value

$$Exposure\_value=\frac{\sum_{k=0}^{L-1} h(k)*k}{L\sum_{k=0}^{L-1} h(k)} \quad (3.1)$$

Where $h(k)$ represents histogram of image. Parameter Xa (as calculated in (3.2)) is the grey level boundary value that divides the image into under exposed and over exposed sub images [5].

$$Xa=G(1-Exposure\_value) \quad (3.2)$$

Here G represents the number of grey levels.

D. Histogram Stretching

Stretching or normalization is an enhancement technique that performs contrast enhancement in an image by stretching the range of pixel values to obtain a desired range of values. Unlike histogram equalization, it apply a linear scaling function on the input image which gives a more enhanced output image.
The global stretching is defined as:

$$Stretching=\frac{F(x,y)-min}{max-min}x255 \quad (3.3)$$

Here $F(x,y)$ represents input image and min and max represent the minimum and maximum pixel values.
In the proposed work, according to exposure value, the stretching is done in a controllable manner. The lower region is stretched 10% of pixels towards the high intensity level and the higher region is stretched 10% towards the low Intensity level. The final output image is taken as the average of output images from both the exposed areas.

$$\mathbf{S1}=\frac{F(x,y)-10\%}{Exposur\ e_{value}-10\%}x255$$
(3.4)

$$\mathbf{S2}=\frac{F(x,y)-0}{max-0}x245 \quad (3.5)$$

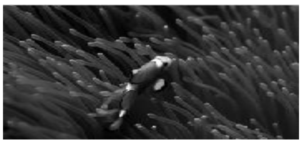
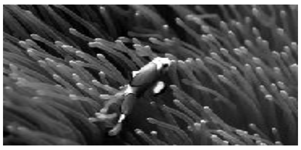
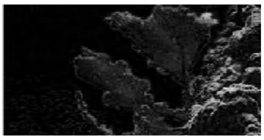
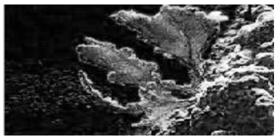
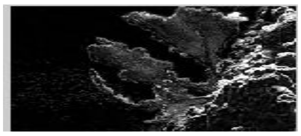
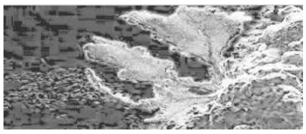
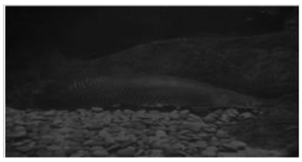
Final_output_image=(S1+S2)/2

S1 corresponds to the stretching of under exposed area and **S2** corresponds to the stretching of over exposed area.

4. RESULTS AND DISCUSSION

The techniques have been tested on a Pc runningWindow 7 operating system. Matlab 2013a has been used to evaluate the techniques and the results of 6 images have been shown. Thequantitative results are shown in Table I,II and III.Fig 4.1 shows the qualitative results.

A. Qualitative Analysis

	Original Image	**RSEHE Technique[4]**	**Contrast Stretching[5]**	**Proposed Hybrid Algorithm**
Mosque				
Fish				
Plant				
Fish 2				
A Diver				
Group				

B. Quantitative Analysis

Mean Square Error, Peak Signal to Noise Ratio and Entropy are the parameters used for quantitative analysis of the proposed technique. The two parameters (MSE and PSNR) are basically error matrices that compare the original image with the output enhanced image. The third parameter entropy measures the average information content in the enhanced image.

I. Mean Square Error

MSE measure the error between original and enhanced image.

$$\mathbf{MSE}=\frac{\mathbf{1}}{\boldsymbol{AX\,B}}\sum_{\boldsymbol{A,B}}[\boldsymbol{f1}(\boldsymbol{A},\boldsymbol{B})-\boldsymbol{f2}(\boldsymbol{A},\boldsymbol{B})]^2$$

Where $\boldsymbol{f1}(\boldsymbol{A},\boldsymbol{B})$represent the original image and $\boldsymbol{f2}(\boldsymbol{A},\boldsymbol{B})$represents the enhanced image. A X B denotes the size of the original image.

II. Peak Signal to Noise Ratio

PSNR measures the maximum noise, the signal tolerate. PSNR is given by

$$\mathbf{PSNR=10log_{10}}\,\frac{\mathbf{(2^{\boldsymbol{t}}-1)^2}}{\boldsymbol{MSE}}$$

Here, 't' represents the bits per sample i.e. 8 bits. In image processing, low MSE and high PSNR are preferred.

III. Entropy

Entropy (Average information content) measuresthe proportions of the details of the image and it is usually measured in units as bits.

$$\mathrm{E(p)}=-\sum_{i=0}^{G-1}P(i)logP(i)$$

Where $P(i)$ is probability density function of a given image at a particular intensity level and G is total number of grey levels in the image.An image having high entropy value is considered to be having high details and better quality.

TABLE I: MSE (used to assess the mean brightness of the image)

Image	**RS-ESIHE [4]**	**Contrast Stretching [5]**	**Proposed Technique**
Mosque	**7992**	**1011**	**47.62**
Fish	**5489**	**551**	**16.31**
Plant	**3058**	**539.20**	**10.41**
Fish 2	**7188**	**149.02**	**3.935**
A Diver	**1563**	**5427**	**1018**
Group	**2261**	**2171**	**258.5**

TABLE II: PSNR (used to assess the quality of the image)

Proposed Technique	**RS-ESIHE[4]**	**Contrast Stretching [5]**	**Proposed Technique**
Mosque	**9.10dB**	**18.07dB**	**31.35dB**
Fish	**10.73dB**	**20.71dB**	**36 dB**
Plant	**13.27dB**	**20.81dB**	**37.95dB**
Fish 2	**9.56dB**	**26.39dB**	**42.18dB**
A Diver	**16.18dB**	**10.78dB**	**18.05dB**
Group	**14.58dB**	**14.76dB**	**24 dB**

TABLE III: ENTROPY (used to assess quality of the image)

Image	**Original image**	**RS-ESIHE [4]**	**Contrast Stretching [5]**	**Proposed Technique**
Mosque	**6.31**	**6.28**	**6.13**	**6.18**
Fish	**6.57**	**6.50**	**6.53**	**6.55**
Plant	**5.63**	**5.57**	**5.30**	**5.36**

Fish 2	**5.18**	**5.13**	**5.14**	**5.17**
A Diver	**7.23**	**7.20**	**6.33**	**7.23**
Group	**7.09**	**6.99**	**6.71**	**7.08**

Qualitative as well as quantitative results shows that the proposed technique performs better enhancement of the image as compared to Recursive separately exposure based technique (RS-ESIHE) and contrast stretching technique when used in isolation. The images obtained now are much more natural and visually pleasing than the images obtained using the already existing techniques.

5. CONCLUSION

In this paper a hybrid technique has been proposed for better enhancement of underwater low exposure images. The proposed technique has two phases: image transformation and contrast stretching. The output image is more enhanced and clear. The quantitative and qualitative results show that the proposed technique is superior to the already existing techniques.

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