Underwater Image Restoration and Enhancement Based on Multi Thresholding Algorithm

[1]B. Anusha, [2] DR. S. Narayana Reddy

[1]M. Tech Student, [2]Professor
Department of ECE,
S.V. University College of Engineering, Tirupati, Andhra Pradesh, India.

***Abstract*: Underwater images are susceptible to various distortions compared to images taken on land, due to the nature of the water environment. These images often suffer from diffraction, polarisation, absorption, scattering, colour loss and attenuation of light. Each part of the ocean will have its own sources of distortions, due to flickers caused by direct sunlight, marine snow, the fluorescence of biological objects, the presence of macroscopical organisms, loss of stability in divers, loss of light, artificial lighting and floating dust particles present in the water. There are numerous techniques and algorithms that may be used to restore these underwater images. A Multi threshold Segmentation method is proposed for the restoration and enhancement of underwater images. Color balance, contrast optimization and histogram stretching are carried out. To alleviate the effect of color shift in an underwater image, the scalar values of R, G, B channels are renewed so that the distributions of the three channels in histogram are similar. To verify the effectiveness of the proposed algorithm, experimental underwater images are treated.**

Index Terms: Multilevel thresholding, color balance, Reconstruct, RGB Channels etc.

I. INTRODUCTION

The research on underwater imaging is important for ocean resources exploration, marine ecological research, and marine military applications. However, underwater environment is severe, since the light is highly absorbed and scattered by medium. The light is scattered by large suspend particles reflecting into different directions, which leads to the captured image fuzzy. Moreover, the light is absorbed by water reducing the energy of light rays, which results in image under-exposure [1] and color cast. The reason of color cast is that the different wavelength of light has different absorbing rate [2]. When reaching to a certain depth, the longer wavelengths of light will disappear first. In short, underwater imaging processing will meet three main difficulties, including color cast, fuzz, and under-exposure. To make the captured images more suitable for observation, it needs to be processed to restore the relatively genuine color and natural appearance. Many approaches are proposed to enhance underwater image. At early stage, underwater image enhancement method comes from generic image enhancement methods, such as Histogram Equalization method, Generalized Unsharp Masking method and Probability-Based method. Gradually, some dehazing methods are adopted in underwater enhancement filed, since the underwater imaging has the similar foggy condition as terrestrial imaging. Fattal's SID method [3] used the fact that the surface shading and transmission functions are statistically uncorrelated in local to remove the fog. They DCP [4] method proposed the dark channel prior that haze free images have at least one color channel with a very low intensity, one can estimate the transmission map with the dark channel prior. However, the dehazing methods can't provide satisfactory color correction for the reduction in the red channel caused by the absorption, since only considering the effect of scattering. Method in [5] makes a fusion with different filters to reconstruct a clear underwater image. Fu's method [6] exploits the Retinex model to decompose the observed image into the reflectance component and illumination component. Then it makes postprocessing on reflectance and illumination components, respectively. Fu's method can get a good result, but the complexity is too high.

In the human exploration and exploitation of ocean, the underwater mission is challenging.

The acquisition and analysis of underwater information is vital to accomplish underwater missions like underwater object localization, marine life recognition, underwater archaeology, under-water environment monitoring, underwater search and salvage, underwater maintenance etc. Underwater optical image provides an important source of underwater information. However, due to the characteristic attenuation and scattering of light in water, underwater images through camera sensors are apt to degrade. Typically, the attenuation results in color shift while scattering of light makes an under-water image blurred and a decrease of contrast. Although the physical characteristics of underwater light emission have a great impact on underwater images, they are not the only phenomena that affect underwater visibility and quality of underwater images. For example, the movement of water or fish shoal can cause so-called motion blur [7].

Dissolved organisms and tiny suspended particles in waters often lead to noises in underwater images and the influence of light backscattering on underwater imaging will be amplified. Representative noises include salt-and-pepper noise, Gaussian noise and marine snow. It is noted that marine snow is a very specific but ubiquitous noise for underwater conditions, caused by biological and mineral particles, or bubbles [8]. Marine snow results in additional light backscattering which manifests in images as white blobs of various size and shape, which negatively affects underwater visibility [9], [10]. To obtain high-quality underwater images, one can resort to an advanced imaging equipment like the divergent-beam underwater Lidar imaging (UWLI) system [11] or multistate underwater laser line scan system [12]. The main obstacle for users is the expensive cost with the equipment. Another alternative to obtain high-quality underwater images is the technique of image processing. It is characterized by high efficiency and low cost. In recent years, underwater image processing has become a hot topic in underwater technology. By using histogram equalization [13] we can increase the contrast enhancement of an image. And multilevel thresholding[14][15] image segmentation is also useful for the increase quality of underwater images. Generally, underwater image processing concerns two techniques, i.e. image restoration and enhancement. Image restoration is based on a physical model about original image. The images are taken from real world underwater image enhancement RUIE images and some of the taken from the internet.

II. Literature Survey

In this subsection we are going to discuss about the works which are already carried out by the scientists or research scholars in the field of the underwater-image reconstruction.

In this paper [2], the nonlinear approximation of the reconstruction of images is explained by using the Huygens Fresnel diffraction patterns, here again the SAR images is used as a target image which can be used to make up a knowledge of a hologram for all the frequencies and angles to inspect target.

In this paper [3], describes about a method of recording by combining back-illumination of the in-line objects with an off-axis reference beam which produces the low-aberration holograms. The experiments conducted in their paper concluded by saying that the use of off-axis scheme with the normal incidence of the object beam on the holoplates which can provide the reduction of the aberrations without any additional compensation at the reconstruction stage.

In this paper [4], Reconstruction of an underwater object from a sequence of the images distorted by moving the water waves is a challenging task. Here they use the bi spectrum technique to analyse the raw images in a sequence and recover the phase information of the true object. The limitations of the paper consist of, it doesn't support on large computer memory and high computation (if dimension of image >3).

In this paper [5], presents the three-dimensional vision techniques in the field of the computer vision aims mainly for the reconstructing a scene which finds its three-dimensional geometrical information. the scene of the geometry and the pose of the camera are unknown with the problem to be addresses is very close to the problem of the computer vision and in the computer vision namely SFM (structure from Motion). The reconstruction method developed in this paper is very well extended for further to the segment of the top of the surfaces of the cuboid shaped objects which are considered as the interest at which the objects can be reconstructed using some of the reconstruction process.

In paper [6] a novel retinex-based enhancing approach is proposed to enhance single underwater image. This Paper [7] assumes that there are three independent cone systems, each starting with a set of receptors peaking, respectively, in the long-, middle-, and short-wavelength regions of the visible spectrum. Each system forms a separate image of the world in terms of lightness that shows a strong correlation with reflectance within its particular band of wavelengths. These images are not mixed, but rather are compared to generate color sensations. The problem then becomes how the lightness of areas in these separate images can be independent of flux.

[8][9] papers are dehazing techniques for the images using multiscale retinex enhancement algorithm. Paper[10] extraction of structure in an image by using relative standard deviations.[11] describes underwater image dehazing by using wavelength compensation and dehazing. Paper [12] describes the quality measures of underwater image are given better result. Paper [13] describes that the histogram equalization it is first method to enhance the image contrast by using thresholding algorithms and after that we have an extended method of histogram equalization is adaptive histogram Equalization. Paper [14] under water images are have some distractions due to light scattering in the water and different wavelength of light. To enhance the underwater image modified water wave optimization used.

III. Fundamentals of Underwater Imaging

The propagation of light differs in water and air. In the light propagation in water, there are several important factors that result in attenuation and scattering of light. The density of water is greater than air, which causes the attenuation of light. Water selectively scatters and absorbs certain wavelengths of visible light. Suspended particles in water affect the light transmission and produce scattering of light. Various types of noise occur for example marine snow that causes additional light backscattering. Temperature and salinity also cause the light scattering. To summarize, the light attenuation and scattering are more serious in water than air. As a result, underwater optical images are apt to blur along with lower contrast. The light received by an underwater camera can be divided into three components: direct component, forward scattered component and backward scattered component. The total light intensity received by the camera sensor can be expressed as:

$$E_T = E_d + E_f + E_b \quad (1)$$

Where ET represents the total light intensity; Ed the direct component; Ef the forward scattered component; Eb the backward scattered component. The three components can be calculated as follows. For direct component, it can be calculated as:

$$E_d = Je^{-cd} \quad (2)$$

where J is the reflection part from the object after receiving light from an illumination source; c is the attenuation coefficient; d is the distance between the object and the sensor. For forward scattered component, it is given by

$$E_f = E_d * g = Jt * g \quad (3)$$

where g is the point spread function (PSF) for predicting beam propagation and imaging system performance [45], [46]. t is defined as t = e −cd, As can be seen from Eq.(3), the forward scattered component Ef is the convolution of the direct component and PSF. For backward scattered component, it can be expressed as:

$$E_b = B_\infty(1 - t) \quad (4)$$

where g is the point spread function (PSF) for predicting beam propagation and imaging system performance. t is defined as t = e −cd. As can be seen from Eq(2), the forward scattered component Ef is the convolution of the direct component and PSF. For backward scattered component, it can be expressed as:

$$E_T = Jt + B_{\infty}(1 - t) \quad (5)$$

IV. PROPOSED METHOD

In proposed method, RGB colours can be separated and color balance is applied then Adaptive histogram analysis done then Mutli-thresholding image segmentation is applied to get better result. The working flow of proposed method is given in fig.3.

A. COLOR BALANCE

Images are taken from the foggy environment and underwater it looks similar. But the dehazing algorithms are applied to both the images the results were not satisfactory. Because the main reason is that the attenuation of light differs in different environments. In a foggy environment, the attenuation of light with different wavelengths is similar. In an underwater environment, the attenuation of light varies with different wavelengths. Fig. 1 displays three randomly selected foggy images and their corresponding histograms. The histogram of different channels are look like similar including peaks and width. Fig.2 presents three randomly selected underwater images and corresponding histograms. As can be seen, the color deviation of the underwater images is severe and the contrast is seriously degraded. The peaks and troughs of the different channels of the first two images are similar, except that the single channel values corresponding to the peaks and troughs are different.it is noted that the third picture is taken in the deep sea without light illumination. To relieve the effect of color shift, a color balance algorithm is proposed by which the single channel value of the histogram in each color channel of an underwater image is moved to a similar position.

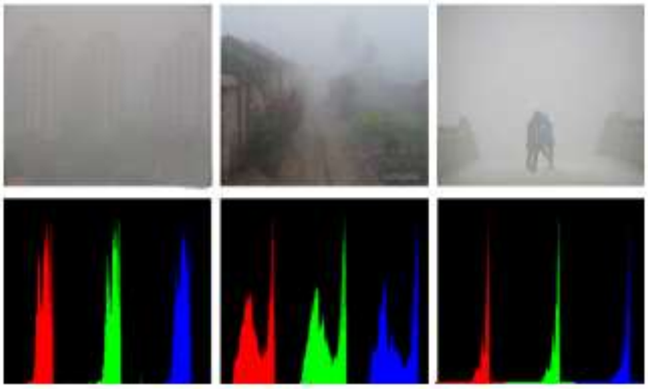


Fig. 1: Foggy images and histograms.

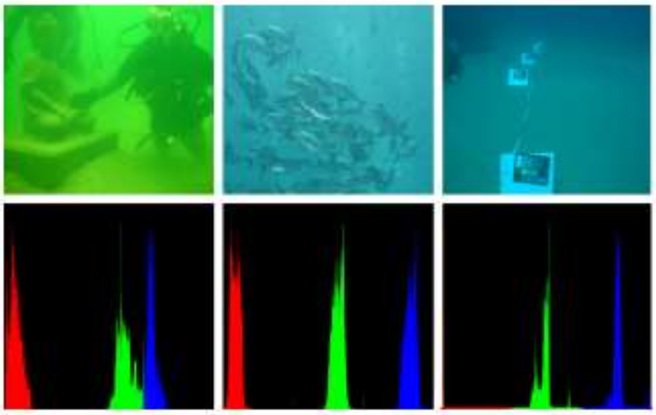


Fig. 2: Underwater images and histograms.

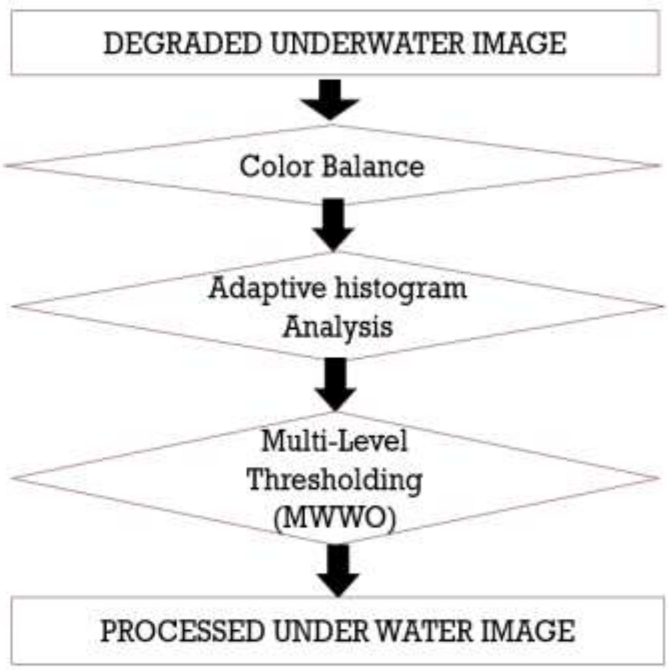


Fig. 3: Process of Enhancement of underwater Image

B. ADAPTIVE HISTOGRAM ANALYSIS

In general histogram equalization is considered for increasing the global contrast of an image. This means that the same transformation function is used to transform all the image pixels. This approach work well for most cases but when the image contains regions that are significantly lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced. some cases we want to enhance details over small areas in an image rather than whole image. This problem can be solved if we use a transformation function that is derived from the neighborhood of every pixel in the image. In adaptive histogram the image is divided into small blocks called tiles (e.g., 64tiles(8x8) is a common choice). Then each of these blocks is processed under histogram equalization [13]. Finally, we combine the all the block together.it will better contrast for the images.

C. MULTI LEVEL THRESHOLDING

The bi-level thresholding method and multilevel thresholding method occupy important positions in image segmentation. The bi-level thresholding method involves one threshold value and an image is divided into the foreground and background. That is to say, the bi-level thresholding method is effective and feasible for simple images. However, the method cannot be applied to complex images that contain multiple objects. Therefore, the multilevel thresholding method is used to segment complex images. The purpose of the optimization problem is to obtain the best values in the restricted space. Multilevel thresholding is transformed into an optimization problem that analyzes and finds the best threshold vectors by maximizing the objective function. Kapur's entropy is an important and unsupervised technique, and it has been used extensively to solve the image segmentation problem by obtaining the optimal threshold values. The entropy of a given segmented image indicates the compactness and separateness between different classes. Assuming that [t1, t2 tn] are the optimal threshold values based Kapur's entropy[14], an image is split into various classes. The formula is as follows

$$P_i = \frac{h_i}{\sum_{i=0}^{L-1} h(i)} \quad (6)$$

Where hi is the number of pixels with gray level i, N is the total number of pixels, and L is the number of levels in a given image.

$$f(t1, t2, t3 \dots \dots \dots . tn) = H_0 + H_1 + H_2 + \cdots + H_n \quad (7)$$

Where,

$$H_0 = -\sum_{i=0}^{t1-1} \frac{P_i}{\omega_0} ln \frac{P_i}{\omega_0}, \omega_0 = \sum_{i=0}^{t1-1} P_i \quad (8)$$

$$H_1 = -\sum_{i=t1}^{t2-1} \frac{P_i}{\omega_1} ln \frac{P_i}{\omega_1}, \omega_1 = \sum_{i=t1}^{t2-1} P_i \quad (9)$$

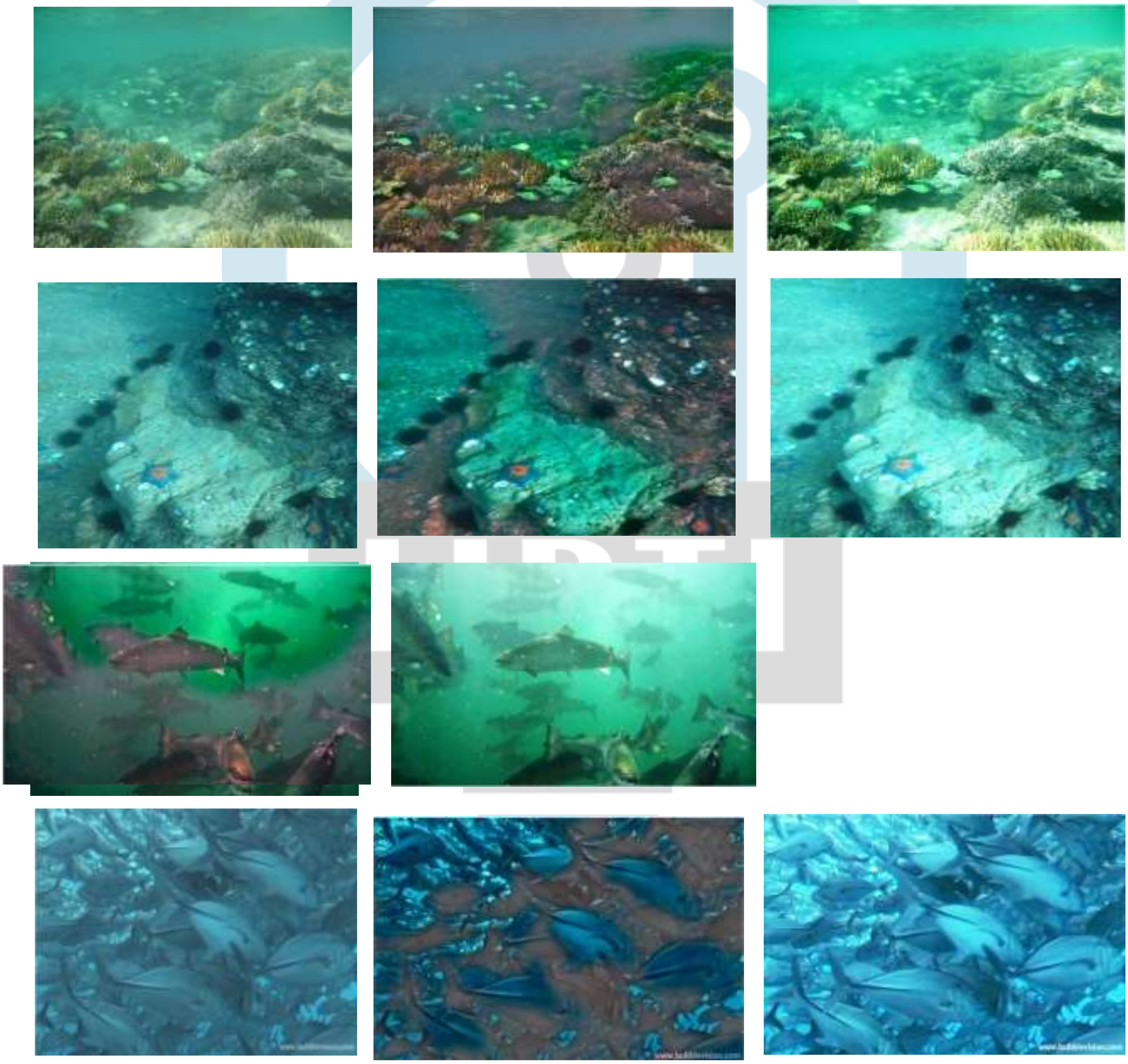
$$H_2 = -\sum_{i=t_2}^{t3-1} \frac{P_i}{\omega_2} ln \frac{P_i}{\omega_2}, \omega_2 = \sum_{i=t2}^{t3-1} P_i \quad (10)$$

$$H_n = -\sum_{i=t_n}^{L-1} \frac{P_i}{\omega_n} ln \frac{P_i}{\omega_n}, \omega_n = \sum_{i=t_n}^{L-1} P_i \quad (11)$$

H0, H1, …, Hn are the Kapur's entropies of the distinct classes, and ω0, ω1, …, ωn are the probabilities of each class
MWWO-based multilevel threshold method [14] Water waves represent search agents. Their positions represent the image segmentation thresholds, and the fitness values of the waves are determined according to the change of the position. We update the optimal wave by comparing the fitness value and the optimal position provides the optimal threshold for segmentation. Water waves represent search agents. Their positions represent the image segmentation thresholds, and the fitness values of the waves are determined according to the change of the position. We update the optimal wave by comparing the fitness value and the optimal position provides the optimal threshold for segmentation.

IV. Simulation Results

. Input images are processed using existing method and proposed method and their results are compared.



(a) (b) (c)

Fig 4: simulated results (a)Input image (b)Existing Method output (c) Proposed method output

	Existing Method			Proposed		
	MSE	PSNR(dB)	SSIM	MSE	PSNR(dB)	SSIM
No.1	0.0307	63.2563672	0.9959216	0.0095	68.3648378	0.9988062
No.2	0.0333	62.9110164	0.9957920	0.0079	69.1817955	0.9989140
No.3	0.0253	64.1005605	0.9963447	0.0068	69.8426440	0.9990604
No.4	0.0296	63.4141144	0.9957200	0.0097	68.2860455	0.9987576

TABLE 1: **Comparison Table**

V. CONCLUSION

This paper proposes a multi threshold algorithm for underwater image restoration and enhancement, in which color balance, contrast optimization and histogram stretching based on red channel are combined. Comparison results proves the advantages of the proposed algorithm over the other algorithms, both in terms of capability and robustness. Besides the visual effect evaluation, objective metrics including, PSNR and SSIM are also used to evaluate the effectiveness and merits of the proposed algorithm.

Future Scope

In future research, MWWO will be used to solve complex underwater image segmentation and high threshold color image segmentation. Meanwhile, various thresholding techniques will be applied to obtain the optimal threshold values and compare the accuracy and complexity, such as Tsallis entropy, Renyi entropy, cross entropy, fuzzy entropy, and Otsu's method. This work will further verify the segmentation performance of MWWO.

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