

UNDER WATER IMAGE ENHANCEMENT

Ch.Keerthi¹, Gella Volga Shivan², K.Sai Shruthi³, Chintala Reethika⁴, D.Sreeja⁵

1 Assistant Professor, Department Of ECE., Malla Reddy College Of Engineering For Women., Maisammaguda., Medchal., Ts, India (✉keerthureddyinchintala@gmail.com)

*2,3,4,5 B.Tech ECE, (19RG1A04D8, 19RG1A04E4, 19RG1A04D3, 19RG1A04D6),
Malla Reddy College Of Engineering For Women., Maisammaguda., Medchal., Ts, India*

Abstract

To learn more about bottom hydrothermal vents, studying underwater photographs is a great place to start. Underwater photography has significant challenges, including low contrast, color distortion, and an overall unpleasant look. Light's scattering and bending as it travels through rarer to denser substances are to blame for these issues. Light scattering weakens the distinction between colors. Water's impact on underwater photography is not limited to scattering; marine life also plays a role. Here, we provide a fusion-based technique for better underwater picture enhancement, which can successfully restore underwater photographs to their original quality. A single picture is used as input in the proposed work, which then processes it via a series of operations including white balancing, gamma correction, sharpening, and weight map manipulation. The output is obtained by performing multiscale picture fusion on the inputs. The first step in creating a realistic underwater picture is white balancing an input image that has been warped due to color distortion. The second step involves applying CLAHE to the gamma-corrected picture. CLAHE is very important for improving the brightness of underwater photos. The sharpened picture is then histogram equalized simultaneously. In order to correctly characterize the spatial pixel connection, the weight maps assess picture attributes. In the last phase, inputs and weight maps are fused using a multiscale pyramidal approach. The Pyramidal fusion method is used in this experiment. The examination of the results shows how the suggested strategy enhances underwater photographs..

Keywords: Image Enhancement; CLAHE; Histogram Equalization; Luminance; Sharpening

1. Introduction

Submarines, marine life, and the study of old shipwrecks are just a few examples of why underwater exploration is a promising

field. Due to light absorption and dispersion, the underwater pictures are difficult to make out. This results in a loss of contrast and haziness, making distant things seem hazy. Colors fade more rapidly the deeper you go in the water, making it more difficult to detect things that are more than 10 meters below the surface.

There have been several efforts made to improve the quality of these deteriorated photos. Multiplicative and additive methods often lead to unrealistic results when rendering an underwater scene[1]. Since this is not a simple process, several enhancing methods such as brightening, gamma correction, and histogram equalization have their limits. Multiple-image[2], specialized-equipment, and polarization filter[3]-based approaches are used in the literature to overcome these obstacles. Although these methods have been the subject of much study, they still have a number of drawbacks that limit their practical use. This study presents a new technique for enhancing underwater photography. The process of doing work is shown here. The first thing that happens is that the input picture is white-balanced. This picture has been gamma corrected and converted to the LAB color space after being white-balanced. The Luminance component of a picture is improved with the use of CLAHE. The original picture was converted to RGB for this reconstruction. After applying histogram equalization and unsharp masking to a white-balanced picture, the result is noticeably sharper. After processing photos, weight maps are generated. Multiscale fusion combines the weight maps and input pictures into a single cohesive whole.

The remainder of the paper is laid out as follows. The efforts in underwater image

enhancement are outlined in Section 2. The third section provides some context and theory. In Section 4, we see the suggested approach in action. Section 5 presents the findings and evaluation metrics of the suggested approach to underwater image enhancement, and Section 6 discusses the conclusion and summarizes the contributions.

Our approach differs from others in that we apply CLAHE on the luminance channel and then linearize the histogram after sharpening the picture. These two methods of histogram modification have helped marine photographers improve their work.

2. Literature Review

Several methods are proposed in the literature as potential solutions to the issue of distortion and deterioration in underwater photographs. Techniques that reject the back scattered light to increase picture quality and contrast include polarization-based, spatial, and modulation-based methods. Lidar imaging is used in the specialized procedures that need gear. Images captured in murky water may be clearly seen because to its laser technology.[4] Only the backscatter is linked to the polarization of the light in the field of vision. In these techniques, a polarizing filter is attached to the camera to take photographs of the same scene with varying degrees of polarization. To control the amplifying effect of noise on pixels, an adaptive filtering method[3] is presented. The regularization does not blur nearby objects, and the approach may be used automatically to determine the medium transmittance. Polarization filters can't be utilized for video capture, hence they're useless for taking into account moving objects. Narasimhan and Nayar[2] suggest using a monochromatic atmospheric scattering model to explain how uniform weather affects the brightness of a scene. This model holds up under a wide variety of climate conditions, including fog, haze, and hist.

The decrease of contrast in outdoor photographs was described by Tarel and Hautiere[5]. In this case, a single picture is

used to restore vision. Their suggested process includes estimating the atmospheric veil, smoothing the picture, mapping the tonal range, and restoring the image. The algorithm's strength lies in its ability to process both color and monochrome pictures.

Before being used to underwater photography, Dark Channel Prior (DCP)[6] was developed as a method for dehazing outdoor pictures.

In 2010[7], G.Padmavathi et al. examined and analyzed the efficiency of three different filters. Divers have experimented with filtering methods including homomorphic filters, average filters, and anisotropic diffusion filters to improve their underwater footage. These filters are used for preliminary processing of marine photography. The use of these filters aids in the

picture sharpness, contrast, color accuracy, and noise removal. When measuring PSNR and MSE, Wavelet denoising with an average filter produces reliable findings.

An enhancement approach is provided by Ancuti et al.[8] in which a single input picture is sharpened and its gamma corrected. Various estimated weight maps. At last, an improved underwater picture is obtained by applying multiscale fusion to the weight maps and input photos.

3. Background and Theory

Light is diminished as a result of [9] absorption and scattering. It is estimated that the density of light particles in sea water is several hundred times that in air. This causes the water at depth to progressively absorb light of varying wavelengths. Red, orange, and yellow, which have the longest wavelengths, are used to quantify colors' absorption capacities. Distances of 10–15 feet, 20–25 feet, and 35–45 feet are given as the equivalent wavelengths. According to McGlamery[10] and Jaffe[11], light separates into its direct component, forward scattering, and back scattering when it falls on an underwater picture

scene. The direct component refers to the amount of light that is immediately reflected from the object of interest onto the imaging plane. The formula for the direct component for each x-coordinate in the picture is as follows:

$$E_D(x) = J(x)e^{-\eta d(x)} = J(x)t(x)$$

where, $J(x)$ is considered as object radiance, $d(x)$ is the observer-object, distance η is the attenuation coefficient.

Particles in the undersea medium cause light scattering. Forward scattering and reverse scattering are the two types of scattering. Forward scattering refers to the random movement of a light beam after it leaves the camera lens. Particles in the water reflect the artificial light back to the sensor camera. The term "back scattering" describes this phenomenon.

Its forward scattering part EBS is a kind of light deflection. It contributes very little to the overall process of picture deterioration and may be safely disregarded. The major cause of color shift is the back scattering component. The formula for the back scattering part is

:

$$E_{BS}(x) = B_{\infty}(x)(1 - e^{-\eta d(x)})$$

where $B_{\infty}(x)$ is a color vector known as the back-scattered light. Thus the simplified underwater optical model is formed by the combination of direct component and back scattering component; ignoring the forward scattering component as,

The various phases in the proposed method are discussed as follows,

$$I(x) = J(x)e^{-\eta d(x)} + B_{\infty}(x)(1 - e^{-\eta d(x)})$$

The attenuation coefficient is very sensitive to the light's wavelength and the color of the water. The light model does not account for this. Therefore, the light model is not inverted explicitly since it does not provide satisfactory results.. (1)

4. Underwater Image Enhancement based on Multiscale Image Fusion and Histogram based techniques-Proposed Method

We provide an approach to improving the contrast of underwater photographs. The work's contribution is the sharpening of contrast. The contrast is improved using histogram-based methods. The picture is sharpened using histogram linearization and the brightness is enhanced using CLAHE. The input picture is used and its contrast is improved using this improvement. The suggested technique allows for a more nuanced level of visualization. Ancuti et al. is used as a benchmark for comparison.[8]

As can be seen in Fig.1, the suggested technique has a structural basis. The framework applies the Grey World algorithm to white-balance the supplied picture. The Gamma correction and sharpening are applied to the white-balanced picture. The two photos are sent to a processing module for improvement. Input photos have their weight maps computed. The result of Multiscale fusion is a combination of the inputs and weight maps. (2)

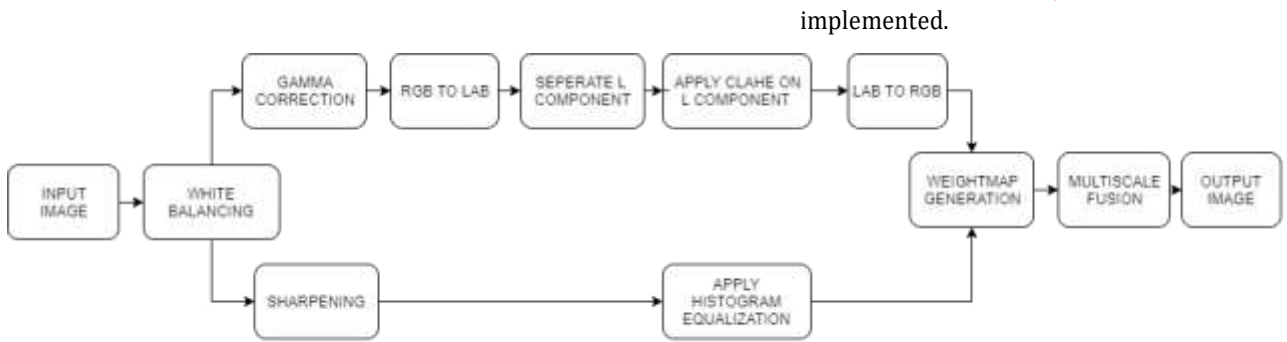


Fig. 1. Work Flow Diagram of Proposed method

4.1. Estimating White Balance

White balance refers to the technique of correcting the color shift in photographs. An image's color cast occurs when an excessive amount of one color is present at the time of capture. There are other color-correction methods, including the Robust Auto White Balance[14], Sensor Correlation[15], and the Simplest Color Balance[12]. Underwater, the depth has an effect on how easy it is to recognize and identify colors. The greenish blue coloration of underwater photographs is a major problem that has to be addressed.

To fix the color shift brought on by the selective absorption of depth hues, white balancing is performed. A color cast occurs when an excessive amount of one color is present in a picture and has a noticeable effect on the whole image.

To combat the blue cast of underwater photos, we opted for the Grey World algorithm [13], [8]. The assumption is made that the light reflected by a picture is colorless. The Grey world algorithm has a serious flaw: it produces a lot of unwanted red artifacts. certain artifacts arise because the red channel has a relatively low mean value, causing it to overcompensate in certain areas. In the Gray Universe, each channel is averaged out and then dividied up. Consistent with findings from other underwater works[16], [17], the primary objective here is to make up for the absence of a red channel. The image's white balance is then determined using the Grey World technique. are followed so that the red channel's compensation may be

implemented.

The compensated red channel [8] I_{rc} at every pixel location (x) is denoted as follows:

$$I_{rc}(x) = I_r(x) + \alpha.(\bar{I}_g - \bar{I}_r).(1 - I_r(x)).I_g(x),$$

where I_r , I_g represent the red and green color channels of image I , each channel being in the interval $[0, 1]$, after normalization by the upper limit of their dynamic range, while \bar{I}_r and \bar{I}_g denote the mean value of I_r and I_g . The blue channel may be greatly attenuated in turbid waters or in places with high plankton density due to its absorption by organic matter . Here the red channel compensation is found to be insufficient and the compensation of blue channel have to be done to reduce its attenuation.[18] This is followed by the white balancing process using Grey World algorithm.

4.2. Gamma Correction

An output is generated after white balancing, and then color compensation is applied to it. We use gamma correction on the white balanced picture to bring back the absorbed colors seen in underwater photography. Generally speaking, white-balanced photos seem overly bright, making gamma correction an essential tool for addressing this issue. However, gamma correction sometimes results in a loss of

picture information in the under/over exposed areas. A sharpening process may restore some of the lost detail..

4.3. Sharpening

In this section, the white-balanced picture is sharpened. The unsharp masking technique is used for sharpening[25]. An picture with sharper edges, corners, borders, etc. is obtained by Unsharp masking by subtracting a low pass version of the image from the original. As a result, the picture undergoes a high-pass filter. The formula for this is $S = I + (I - (G * I))$. where I is the picture to be sharpened, $G * I$ is the image after being filtered via a Gaussian kernel, and N is a parameter whose low setting does not provide enough sharpening and whose high setting causes oversaturation in the image.[8]. Therefore the unsharp masking is done as follows:

$$S = (I + N \{I - G * I\})/2,$$

where I is the image to sharpen, N is the normalization operator, $G * I$ denotes the Gaussian filtered version of I , 3×3 Gaussian filter is used in the unsharp masking.

4.4. Luminance Enhancement

In this work, improvement is carried out in tandem, in two stages. First, the gamma-corrected result is brightened using LAB color space. The second stage involves applying histogram linearization to the refined picture.

4.4.1. Luminance Enhancement using CLAHE

One of the challenging factors in an underwater image is non-uniform illumination. In order to overcome this limitation, luminance enhancement of the image is performed. The gamma-corrected output of the white balanced image is subjected to luminance enhancement in $L^*a^*b^*$ color space. The $L^*a^*b^*$ is a device-independent Color space. Here L^* denotes luminance and a^* and b^* denotes the chromaticity coordinates. The L^* component is separated and CLAHE[19],[20] is applied on it.

4.4.2. Contrast Enhancement using Histogram Linearization

The sharpened output obtained after applying unsharp masking is subjected to Histogram Linearization[26]. As a result, an output image is obtained which has a higher contrast than the input image. These two histogram manipulation procedures paved way to obtain a more enhanced output during fusion.

4.5. Weight Map Generation

To investigate the connections between deteriorated areas, a weight map must be created. Here, the object's color, saturation, and contrast are used to provide a weight to each individual pixel. Laplacian Contrast Weight, Saliency Weight, and Saturation Weight are the various weight maps used here[8]. In the following paragraphs, I will describe the steps used to produce a weight map.

4.5.1. Laplacian Contrast Weight

(5)

By calculating the absolute value of a Laplacian filter applied to each input luminance channel, Laplacian Contrast Weight(WL) provides a rough approximation of the global contrast. Since it gives significant weight to edges and texture, this map may be used for a variety of purposes, including tone mapping [21] and increasing depth of field. However, this weight is insufficient to restore the contrast for the underwater enhancement job, mostly because to its inability to discriminate between a ramp and flat sections. The issue is solved by creating a Saliency Weight map..

4.5.2. Saliency Weight

When used on an underwater scene, saliency weights (Ws) draw attention to the elements that might otherwise be lost. To do this, we use the approach developed by Achanta et al.[23]. The technique is computationally efficient since it is based on a principle from biology: the contrast between the center and the periphery. A saliency map's defining feature is its emphasis on the most prominent features. To get around this

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restriction, we develop a new weight map
predicated on the fact that highlighted areas
have lower saturation..

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4.5.3. Saturation weight

The fusion technique is able to glean chromatic information from highly saturated areas because to saturation weight (WS at). It's used to evaluate the vividness of an image's colors. The picture is given greater life by the use of vibrant colors. This estimated weight map is based on the difference between the color and brightness channels at each pixel..

4.6. Multiscale Image Fusion

Multi-scale images combine sharpened and gamma-corrected versions of an original picture with weight maps. By using a weight map, we may mitigate the flaws of these inputs and improve the picture quality to a certain degree. After that, the inputs and weight maps undergo a process of multiscale fusion..

4.6.1. The Fusion process

Here, a Laplacian Pyramid is used as the foundation for Multiscale fusion.[22].The input picture is segmented into a collection of band pass images using the Multiscale Fusion's pyramidal representation. Here, each tier of the pyramid applies a low-pass Gaussian filter G to the input picture and then uses a 2-by-2 decimation to reduce the size of the filtered image in both directions. Next, the input picture is subtracted from the upsampled lowpass image. Each source input I_k is decomposed into a Laplacian pyramid in the conventional multi-scale fusion strategy[21], while the normalized weight mappings $W_k(x)$ are decomposed into a Gaussian pyramid. At each l level, the Laplacian inputs are mixed with the normalized Gaussian weights individually.:

$$I_l(x) = \sum_{k=1}^K G_l R W_k(x) \{ I_l \} (x)$$

where l denotes the pyramid levels and k refers to the number of input images.The enhanced output is obtained by summing the fused contribution of all levels, after

appropriate upsampling. The Multiscale Fusion reduces the artifact occurred due to the sharp transition of the weight map.

5. Result Analysis

5.1. Qualitative Analysis

We have done the experiments using MATLAB in a computer with a Windows 10 Operating System, 16 GB RAM and Intel Core i7-6700CPU . The test color images of size 1037 778 are obtained from the dataset in the paper by Zhang et al.[24]

5.1.1. Result

The suggested work's intermediate steps for improving underwater images are shown in Fig. 2. In Fig:2In the top row, from left to right, the first picture is the input underwater image, which is mostly green. Red and blue channel compensation is performed before white balancing. Because the Grey World technique used for white balancing introduces a significant red artifact, the resulting picture is shown in the second image after the red and blue channels have been corrected. Images that have been white-balanced, gamma-corrected, and sharpened are shown in the second row, from left to right. There is a vague quality to the white-balanced picture. Sharpening and gamma correction are used to fix this problem. The picture is then transformed from its gamma-corrected form into LAB color space. After that, we separate the luminance information using CLAHE. The output of CLAHE, a Histogram Equalized picture, and a Multiscale fused output are shown left to right in the bottom row.

When compared to the current approach, the suggested improvement has the potential to expose far more granular features and intricate architecture. The suggested approach eliminates the color cast and produces a clean, aesthetically pleasing image. (6)

Figure 3 displays both Ancuti et al.'s and the suggested method's output pictures. The output numbers demonstrate that the suggested technique outperforms the method developed by Ancuti et al

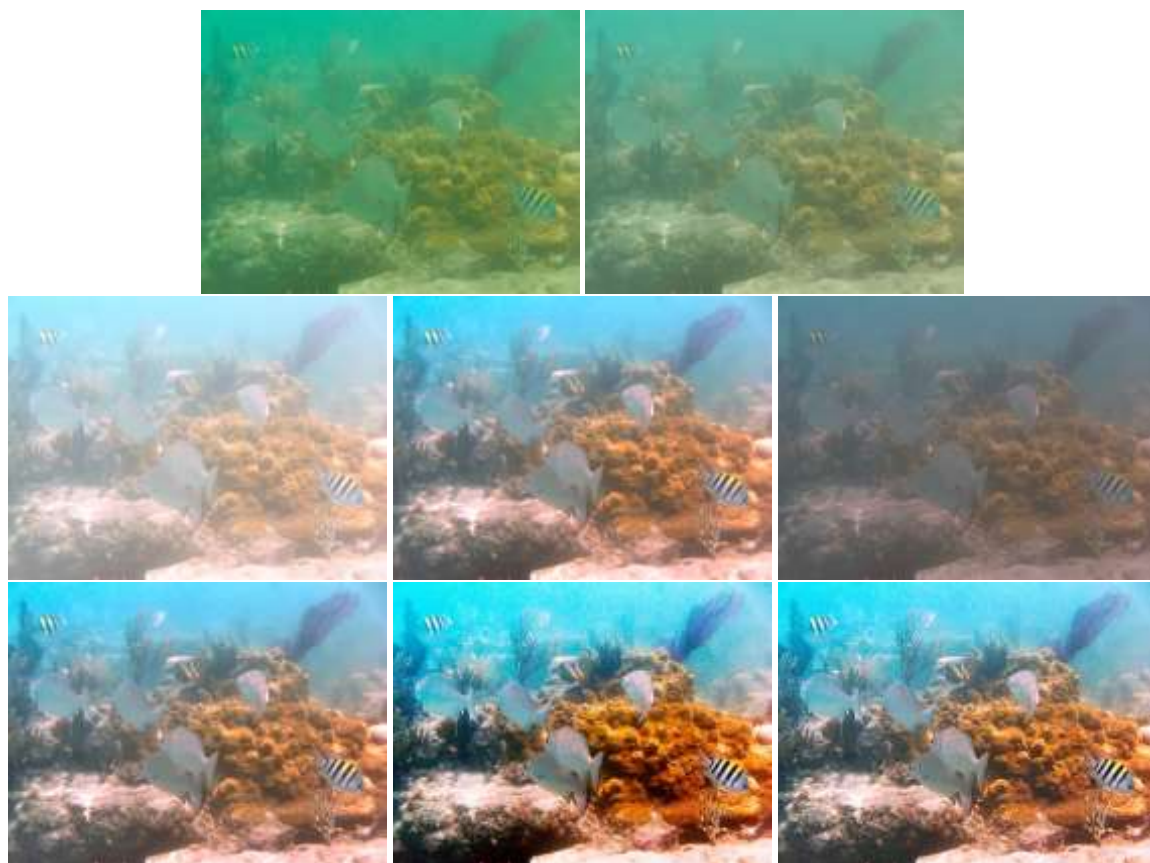


Fig. 2. Result images. Top row from left to right shows Input image and Color Compensated image. Second row from left to right shows the White balanced, Gamma corrected and Sharpened image respectively. Bottom row from left to right shows Clahe applied to gamma corrected image, Histogram equalization applied to sharpened image and Final fused output - Proposed method

5.2. Quantitative Analysis

UCIQE, BRISQUE, ENTROPY, NIQE, and PCQI are only few of the assessment methods utilized to determine the efficacy of underwater enhancement. In this case, the performance matrices UCIQE and ENTROPY are used..

5.2.1. UCIQE

UCIQE(Underwater Color Image Quality Evaluation Metric)metric, is a linear combination of saturation, chroma and contrast. It is used to measure the non-uniform color cast, low contrast and blurring that characterize and monitor underwater images.

5.2.2. ENTROPY

Measuring entropy allows one to learn about the informational density of a picture. The entropy of a picture is the number of different possible adaptations of pixel intensity. It's a staple of quantitative picture analysis and assessment. A more accurate comparison of picture features may be made using the entropy value.



Fig. 3. First column shows the output of Ancuti et al. [8] and Second column shows the output of proposed method

Images	Ancuti et al.		Proposed Method	
	UCIQE	ENTROPY	UCIQE	ENTROPY
ancuti5	2.3868	5.6481	3.5183	7.751
ancuti1	2.5018	5.9667	3.1379	7.8752
ancuti2	6.1733	5.893	6.9424	7.8531
ancuti7	1.61	5.4112	2.5828	7.6691
ancuti3	4.7776	5.7592	6.3631	7.8067
galdran1	5.0161	5.874	6.1796	7.8609
AVERAGE	3.744267	5.7587	4.78735	7.802667

Table 1. Performance Analysis of Ancuti et al. and Proposed method

Table 1 shows the performance analysis of Ancuti et al.[8] and the proposed method, from the table it is clear that the average of UCIQE and ENTROPY shows a greater value for the proposed method.

6. Conclusion

Underwater scenes provide a significant challenge for image processing due to the difficulty of determining the distance at which objects may be seen. There are a plethora of image-enhancement techniques out there, but they all have their drawbacks. The benefits of multiscale fusion and contrast enhancement methods are considered in the suggested strategy. The only thing you need is the original picture to use this technique. White balancing the input picture is a two-stage process that also includes gamma correction and sharpening. An improvement approach is applied to the results of these two procedures. The inputs' weight maps are computed. After gathering all of the necessary data, a Multi Scale fusion is performed on the inputs, and normalized weight maps are estimated to provide the final improved output. Important, but fading, features and edges may be recovered using this procedure. The results of the studies validated the effectiveness of the suggested strategy in enhancing the clarity of underwater photographs. An appropriate collection of test photos for various imaging circumstances is still needed to improve underwater image processing. More research is needed to find a solution to the problem of color restoration in underwater photographs shot at deeper depths.

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