ADVANCED IMAGING SOLUTIONS FOR AQUATIC ENVIRONMENTS

Authors Name:

[1]DOGIPARTHI SANTHOSH GUPTA, Asst. Prof. (c), Dept. of ECE, UCEN – JNTUK, Narasaraopet
[2]PADAVALA LAVANYA, Dept. of ECE, UCEN – JNTUK, Narasaraopet
[3]PALLANTLA KOMAL, Dept. of ECE, UCEN – JNTUK, Narasaraopet
[4]SHAIK HAZIYA, Dept. of ECE, UCEN – JNTUK, Narasaraopet
[5]BOMMI KARTHEEK, Dept. of ECE, UCEN – JNTUK, Narasaraopet

ABSTRACT: In recent times, extensive research has been carried out to enhance the visibility of underwater images for submarine and military operations, aiming to reveal submerged structural designs and explore the sea floor. The extended period spent engaging in deep-sea diving has presented difficulties when it comes to examining images taken beneath the water's surface. Further, other factors such as scattering resulting from presence of particles inside the water and blurring effects reduce the quality of images being captured by underwater optic camera. There are several algorithms have been introduced to improve the visual quality of deep-water images. Therefore, in this project, a novel algorithm based on bidirectional Empirical Mode Decomposition (BEMD) used to enhance the visual quality of the underwater images will be implemented and we will demonstrate the application of various traditional enhancement algorithms on datasets. And by comparing with the different quality metrics of each algorithm we can conclude which method is best to enhance the underwater images for both database images and real time images. The quality metrics of enhanced image are tested using CLAHE algorithm to achieve a good PSNR compared to other conventional enhancement algorithms.

Keywords: Bidirectional Empirical Mode Decomposition (BEMD), Contrast Limited Adaptive Histogram Equalization (CLAHE), Histogram Equalization, Intrinsic Mode Functions(IMF), Stopping Criterion, Contrast

I. INTRODUCTION

Underwater photography captures the breathtaking beauty of the ocean's diverse and colorful marine life. However, underwater images can often appear dull and lacking in clarity due to the challenging conditions of the underwater environment. In this project, we will explore various techniques and tools for enhancing underwater images to bring out their natural vibrancy and detail. Using advanced editing software and specialized filters, we will work to reveal the true beauty of underwater scenes, allowing viewers to experience the awe-inspiring underwater world in all its glory. Research and development in underwater image processing have been driven by the need to overcome the unique challenges posed by underwater environments. These challenges include the rapid

attenuation of the electromagnetic spectrum underwater, which limits the ability to capture large objects within a single frame and obtain a global perspective. Additionally, the presence of backscatter from suspended particles in the water column hinders image clarity and detail. To address these challenges, researchers and scientists have developed a range of techniques for enhancing underwater images. These techniques include image restoration algorithms that correct for distortions caused by various factors such as direct sunlight, marine snow, and the presence of organisms. Other techniques involve color correction to compensate for the loss of color due to water absorption and scattering, as well as contrast enhancement to improve the visibility of details.

II. LITERATURE SURVEY

There are several techniques which are used very frequently for processing the image to improve the visual quality. Some of them are as follows:

2.1 CONTRAST STRETCHING

Contrast stretching is a technique that brightens the brighter parts and darkens the darker parts of an image using a predefined transformation function. Underwater images usually have fewer grey values, with 0 representing black and 255 representing white out of the 256 grey values. With this method, each grey value in the image is adjusted towards 255, enhancing the image's contrast from black to white, pixel by pixel. This process improves the image quality for better visibility.

2.2 ADAPTIVE HISTOGRAM EQUALIZATION

Adaptive Histogram Equalization (AHE) is a technique used to enhance the contrast of images, particularly beneficial for correcting poor contrast resulting from skewed intensity histograms, often observed in underwater images due to light absorption and scattering. The process of AHE on underwater images involves local histogram calculation, where the image is divided into smaller patches, and histogram equalization is independently applied to each patch to enhance local contrast. Interpolation techniques are utilized to smooth out intensity transitions between neighboring patches. The adaptivity of AHE allows for variations in parameters based on image characteristics, such as using smaller patches in high variance regions and larger patches in smoother areas. To manage noise amplification, contrast limiting techniques are employed, and AHE can be applied directly to RGB channels or in a color space suitable for underwater imaging, such as the LAB color space. Overall, AHE effectively improves the visual quality of underwater images by enhancing contrast, but optimal results require careful parameter tuning and consideration of underwater-specific characteristics.

2.3 BIDIRECTIONAL EMPIRICAL MODE DECOMPOSITION

The White Balanced EMD algorithm initially removes colour effects caused by improper illumination to make the image free from photometric variations. It then extracts individual colour planes from the processed RGB image and decomposes each colour plane into intrinsic mode functions using the EMD method. These IMFs are scaled with a weight and normalized. The recovered image is constructed by considering the product of weights and the lower frequency IMFs, resulting in a visually enhanced image.

III. ALGORITHM DESCRIPTION

3.1 BIDIRECTIONAL EMPIRICAL MODE DECOMPOSITION WHITE ADJUSTED APPROACH:

The Gray World Approach, also known as the Gray World (GW) strategy, focuses on achieving color consistency independent of light. Color casts in digital images are caused by illuminants, and this approach first evaluates the color of the prevailing light and then removes unwanted color casts. The GW strategy is a widely used white balance algorithm that calculates the average of each channel in the image to determine a separate scaling value for each channel, effectively eliminating light on different channels independently. However, this method may yield poor results when applied to images with many similar colors, as it requires a wide range of colors for optimal performance.

The method of obtaining the IMFs involves utilizing a simple algorithm centered on sifting. Through this process, the original signal undergoes sifting until the resulting data series reach a stationary state. This iterative procedure can be outlined as follows:

1) To commence, the assumption is made that $input_{lk}(i, j) = I(i,j)$, with I(i,j) denoting the original image. In this case, l=1,2,3,...,L represents the total desired IMFs, and k=1,2,3,...,K indicates the iterations needed to derive a single IMF.

2) Following this, produce the upper envelope $m_1(i, j)$ and lower envelope $m_2(i, j)$ by implementing 2-D cubic spline interpolation on the complete set of 2-D local maxima and 2-D local minima points derived from the input data.

3) The mean envelope can be generated as

$$m(i,j) = \frac{(m_1(i,j) + m_2(i,j))}{2}$$

4) The difference of mean envelope m(i,j) and signal input gives rise to $h_{lk}(i,j)$

$$h_{lk}(i,j) = input_{lk}(i,j) - m(i,j)$$

5) The quantity of iterations is determined by the estimated stopping criterion (δ).

$$\delta = \frac{\sum_{i=1}^{H}\sum_{j=1}^{W}|m(i,j)|}{H \times W}$$

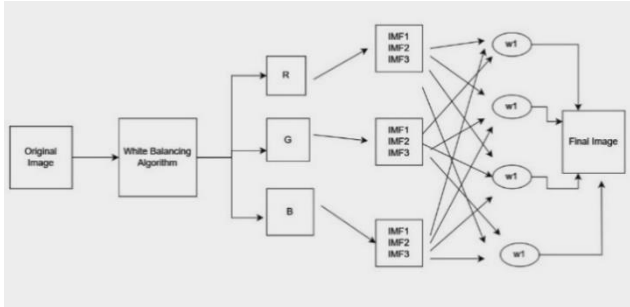
If, given the dimensions of the mean envelope m(i,j) are represented by H and W, the stopping criterion δ is less than a threshold λ for a particular k value of K, then hlk(i, j) corresponds to the lth IMF, denoted as IM Fl (i, j) = hlk(i, j). Conversely, if the stopping criterion is not met, signifying that δ is greater than λ, the next iteration starts with $input_{lk}(i, j)$ and steps 1-5 are reiterated.

6) Upon successful acquisition of the lth IMF, denoted as IMF_l, calculate the Residue signal using the following formula: $R_l(i, j) = input_{l1}(i, j) - IMF_l(i, j)$.

7) To discover the subsequent IMF, the residue Rl(i, j) serves as the input image, and steps 1-6 are reiterated. Through the method outlined above, a total of L IMFs and a concluding Residue RL(i, j) can be acquired. Hence, the resultant expression is

$$I(i,j) = R_L(i,j) + \sum_{l=1}^{L} IMF_l(i,j)$$

"The lower-order IMFs acquired provide a more detailed representation of the overall spatial structure of the image, whereas the higher-order IMFs encapsulate low-frequency features but lack spatial intricacies." These IMFs are scaled with a weight and normalized. The recovered image is constructed by considering the product of weights and the lower frequency IMFs, resulting in a visually enhanced image.The above algorithm has been picturized in Fig (1).



Fig(1): Block diagram of White balanced BEMD

3.2 CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION

When capturing underwater images, the inherent blue tint caused by sunlight's preference for blue wavelengths often leads to a visually dominant blue hue. This imbalance is further exacerbated in regular RGB images as the blue layer becomes notably stronger than the red and green layers in an underwater setting. To address this, a technique called balancing photometric variations is employed. This involves calculating the average intensity of each colour layer and then adjusting the strength of the overpowering blue layer to restore balance. This method essentially counteracts the excessive blue tint by subtly reducing its intensity while enhancing the red and green colours, resulting in a more natural-looking image. Another approach, known as the Gray World Approach, focuses on achieving colour consistency independent of the prevailing light conditions. This method involves assessing the colour of the prevailing light and subsequently removing undesirable colour casts. However, it's important to note that this approach may not yield optimal results in images with a limited range of colours. Additionally, to address issues of low contrast in images, Adaptive Histogram Equalization (AHE) is utilized to enhance details and boost contrast. Nonetheless, AHE can sometimes over-amplify certain areas, especially those with similar colours, leading to increased noise visibility. Contrast Limited Adaptive Histogram Equalization (CLAHE) presents a more refined solution by breaking down the image into smaller tiles and independently adjusting contrast within each tile. This tailored approach prevents over-amplification in areas with similar colours, reduces noise, and results in a more natural-looking contrast enhancement. Essentially, while AHE may globally increase brightness, potentially causing blotchiness, CLAHE carefully adjusts brightness in different sections of the image, enhancing colours without creating unwanted visual artifacts. Notably, CLAHE is effective for both grayscale and colour images.

3.2.1 Algorithm Explanation for White Balanced CLAHE in MATLAB

This algorithm outlines the steps for applying White Balance (WB) and Contrast Limited Adaptive Histogram Equalization (CLAHE) to an RGB image in MATLAB is well shown in Fig(2).

1. Load and Convert Image:

Load the RGB image "final.png" and convert it to double precision.
Extract the individual Red (R), Green (G), and Blue (B) channels.

2. **BEMD Technique:**

The White Balanced EMD algorithm initially removes colour effects caused by improper illumination to make the image free from photometric variations.It then extracts individual colour planes from the processed RGB image and decomposes each colour plane into intrinsic mode functions using the EMD method.These IMFs are scaled with a weight and normalized. The recovered image is constructed by considering the product of weights and the lower frequency IMFs, resulting in a visually enhanced image.

3. CLAHE Enhancement:

Read the white-balanced image and initialize an empty output image.
Apply Contrast Limited Adaptive Histogram Equalization (CLAHE) to each colour channel and store the result in the corresponding channel of the output image.

4. Display and Save Enhanced Image:

Display the original and CLAHE enhanced RGB images. Save the CLAHE enhanced image as "CLAHE_Enhanced_RGB_Image.jpg".

3.2.2 ADVANTAGES OF CLAHE ALGORITHM:

The white balanced CLAHE algorithm combines white balancing and CLAHE techniques to improve colour accuracy and enhance contrast in images. It corrects colour casts caused by different lighting conditions, particularly beneficial for underwater images, and improves local contrast to emphasize details in dark and bright areas. This combination results in more natural-looking colours and enhanced visibility of details, making it particularly useful for underwater images and those with uneven lighting. Overall, the white balanced CLAHE algorithm offers a powerful tool for enhancing images by improving colour accuracy, increasing contrast, and revealing more details in the processed image.

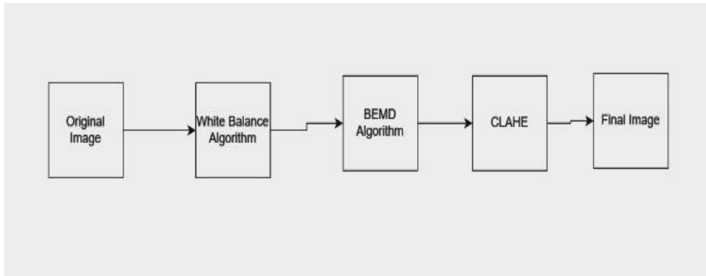
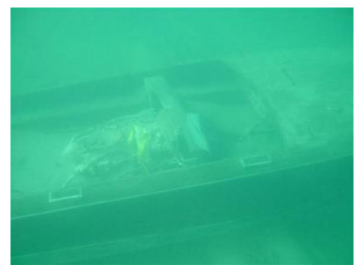


Fig (2): Block diagram of white balanced CLAHE

IV. Results and Discussion



(1) (2) (3) (4)Fig. (3) Raw Images1,2,3 & 4

Fig (3) shows the Underwater image which has poor resolution and high scattering effects of lightFig (4) : Contrast Stretching

Fig (4) shows the picture that undergone Contrast Stretching




Fig (5) : Adaptive Histogram Equalization of images 1,2,3,4

Fig (5) shows the Adaptive Histogram equalization where it increases the contrast in certain areas.

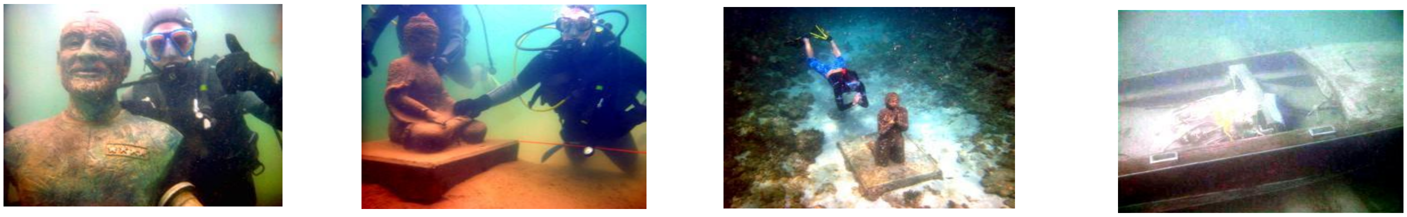
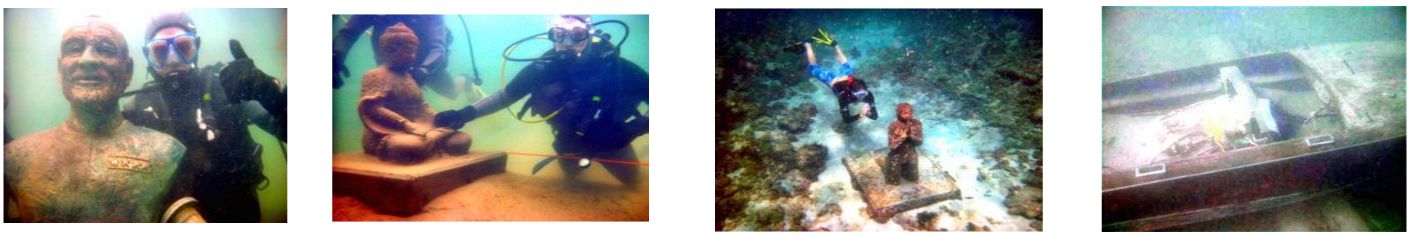


Fig (6) : BEMD Output of images 1,2,3,4

Fig(6) shows the enhanced outputs of Bidirectional Empirical Mode Decomposition.



Fig(7) : CLAHE Output for images 1,2,3,4

Below are the subjective results applied on the Fig (1) Original images to get effective results where picture gets higher psnr values and lower mse values.

Table (1) : Comparison of PSNR and MSE values of Adaptive Histogram Equalization, BEMD and CLAHE

Image Number	Quality metrics	Adaptive Histogram Equalization	White balanced BEMD	White balanced CLAHE
Image 1	PSNR	33.389933 dB	58.9919 dB	59.1943
	MSE	0.458149	0.5416	0.5170
Image 2	PSNR	33.664089 dB	57.4444 dB	57.4608
	MSE	0.430121	0.7735	0.7706
Image 3	PSNR	36.133286 dB	60.7965 dB	60.9628
	MSE	0.243597	0.3575	0.3440
Image 4	PSNR	37.098649 dB	57.9449 dB	58.2397
	MSE	0.195045	0.6893	0.6441

V. CONCLUSION

Considering all metrics, CLAHE (Contrast Limited Adaptive Histogram Equalization) emerges as the preferred choice over BEMD (Bidimensional Empirical Mode Decomposition) for image enhancement tasks. Not only does CLAHE consistently deliver superior visual quality by effectively enhancing local contrast while preserving details and controlling noise, but it also offers advantages in computational efficiency and ease of implementation. CLAHE's straightforward parameterization and lower computational demand make it more suitable for real-time applications and systems with limited processing power. Additionally, CLAHE demonstrates robustness to noise artifacts, thanks to its built-in mechanisms for limiting noise amplification during contrast enhancement. Moreover, CLAHE's adaptive nature enables it to effectively enhance contrast based on local image characteristics, making it adaptable to various scenes and lighting conditions. While BEMD offers unique capabilities in decomposing images into oscillatory modes, CLAHE's overall balance of performance, efficiency, and ease of implementation positions it as the preferred solution for many image enhancement tasks.

VI. REFERENCES

1. Ch. Jaya Lakshmi, k. prasanthi, S.Kalpana, “ Visual Enhancement Techniques For Underwater Images” 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS).
2. Ritu singh, Dr. Mantosh Biswas, “Adaptive histogram equalization based fusion Technique for hazy underwater image enhancement” IEEE international conference on computational intelligence and computing research, 2016, pp: 1-5.
3. Balvant singh, Ravi shankar mishra, Puran gour, “Analysis of contrast enhancement techniques for underwater image” International journal - of computer technology and electronics engineering (IJCTEE) Volume 1 , issue 2, pp: 190-195
4. enhancement techniques”, International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 03, June-2015, pp: 340-344.
5. Sudhansu Mallik, Salman S. Khan, Umesh C. Pati, Balanced EMD”, 8 th International Conference on Computing, Communication and Networking Technologies (ICCCNT) -2017, pp: 1-6.
6. N. E. Huang et. al, “The empirical mode decomposition and the hilbert spectrum for nonlinear and non-stationary time series analysis,” in proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, vol. 454, no. 1971. The Royal Society, 1998, pp. 903–995.
7. Jin Chen et.al “Using Empirical mode decomposition to process marine magnetotelluric data,” in Geophysical Journal International, vol. 190,Issue 1,July 2012,pg:293-309.