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Underwater Image Enhancement

Rahul R Patil[1], Rajashekar K K [1], Samarth R Patel [1], Tejas M[1], K DeepaShree[2]

[1] *UG-Student, Department of Computer Science Engineering, DSATM Bangalore*

[2] *Asst. Prof., Department of Computer Science Engineering, DSATM Bangalore*

***Abstract*- Images shot underwater are not always clear since they are taken in water and light behaves differently there. When trying to capture distant objects, underwater photographs are particularly prone to color distortion and a pronounced blue color predominance. Both light attenuation and light scattering have an impact on this. Even after restoring the image, I still need to use the histogram equalization approach to improve the colors. Depending on the working approach chosen and the resources at the designer's disposal, testing the outcomes can be done in a variety of ways. In our project, using wavelet fusion and CLAHE, we will demonstrate how to get rid of image interference and attempt to capture the precise colors of the item submerged. Because photos taken underwater are vulnerable to light dispersion and refraction, resulting in hazy images with little details, this project will assist individuals in performing object detection even if the image input is not particularly clear.**

***Index Terms*- Wavelet fusion, CLAHE, Interference, Enhanced, Attenuation, Histogram Equalization**

I. INTRODUCTION

As there is an increasing need for high-quality images in various applications, underwater image processing has developed a separate identity in the research community. It is difficult and requires specialized equipment to take a good photo in an underwater environment. Without specialist hardware, we receive a poor image that needs to be improved. Remaking a digital image involves enhancing it, and the resulting image can then be used for better display or research purposes. The fundamental goals of image improvement are to brighten visual elements like boundaries, edges, or contrasts and to lessen ringing artefacts. The quality of the image or video degrades owing to scatters when we take pictures or videos underwater. [2]. Light is diminished in an undersea environment as a result of water molecules, suspended particles, and other pollutants. As light travels deeper into the water, attenuation rises. In such a setting, less irradiance from the scene's objects reaches the camera during the picture generation process, changing the genuine colors of the objects. The range of the visible spectrum colors depends on both their wavelength and the depth of the water. Shorter wavelengths can go farther before being absorbed by water, whereas longer wavelengths do [1]. As a result, images have high absorption, poor contrast, noise, and low visibility. For some purposes, these underwater photos therefore need to be enhanced. Diverse domains, such as mine detection, underwater microscopic detection, autonomous underwater vehicles, communications cable terrain scanning, etc., have experienced an increase in the uses of underwater image processing in recent years.

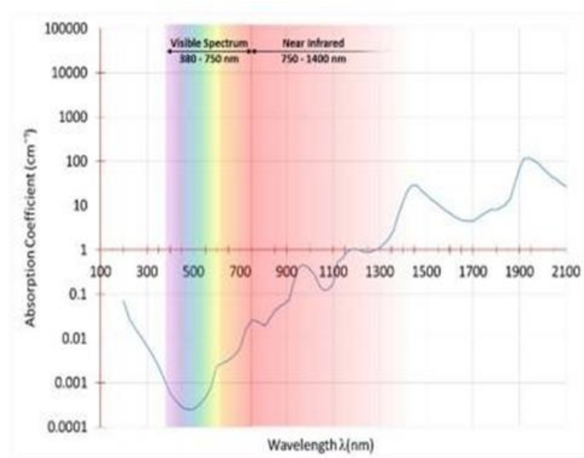

Fig: Visible light's water absorption coefficient [2].

This suggests that image enhancement could be significant. Digital image processing offers a variety of image enhancing methods, including color correction, white balancing, the dark channel before, the fusion-based method, and Histogram equalization. These methods are insufficient for a physical model of the ocean, however, hence they cannot be employed for the processing of underwater images. Consequently, numerous researchers have proposed a wide range of strategies for improving underwater image quality. [8]. An enhancement techniquebased on wavelets fusion is implemented in this project. The basic idea behind wavelet-based image fusion is to combine the wavelet decompositions of the two original images by employing fusion techniques on the details and approximations coefficients. And few other techniques such as CLAHE is alsobeing used [9].

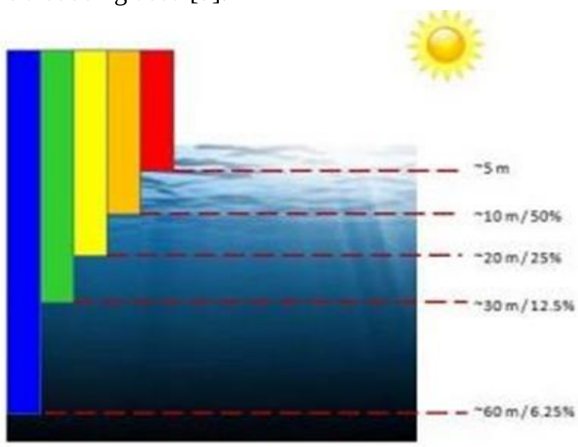

Fig: Water's Light Absorption

II. LITERATURE SURVEY

Haibin Li, Shuhuan, and Yakun Gao Wen suggested a new technique for restoring and enhancing underwater photographs that was modelled after the dark channel technique used in the field of image dehazing before. They suggested using the light channel before the underwater environment in order to restore the image. Secondly, the restoration images were equalized to rectify the color distortion using the inferred histogram equalization outcomes of the experiment demonstrated that the suggested technique might significantly improve the quality of underwater photographs. The strategy they used was to provide technologies that can improve the quality of images without taking into account the physics model. The physics model of image generation serves as the foundation for image restoration techniques. The bright tunnel before the underwater environment was their first suggestion. The final reconstruction of the underwater photographs required the use of the bright channel image, ambient light, transmittance image estimate, and enhancement. Then, in order to further rectify the color distortion, we equalized the restored photos using the histogram equalization that was calculated. As a result of this constraint, they determined that the dark channel images in underwater photographs are different from those in air. While distant or sky-filled scenes always include prominent dark channels in the air, this phenomenon does not apply to dark channels in underwater photographs. We can therefore conclude that the dark channel before did not effectively restore the underwater image. They believed that the derived histogram equalization method would be employed in the future to address the color distortion issue. This method may not be the best because it could result in one channel being over-equalized, despite the fact that this research shows how effective it is. Therefore, one should try to find a solution to the color distortion problem for future improvements. [3].

Kashif Iqbal, Rosalina Abdul Salam, Azam Osman and Abdullah Zawawi Talib proposed a development work on the techniques and methods for image enhancement. They briefly touch on a few issues, such as light absorption and the sea's innate structure, that relate to underwater photographs. Additionally, we go through how color influences pictures taken underwater. Slide stretching was the foundation of their strategy. To balance color contrast in the images, RGB algorithm contrast stretching is applied first. Secondly, to improve true color and alleviate lighting concerns, HSI saturation and intensity stretching are used. They discovered that the HSI model offers a greater color range by managing the image's color components. Intensity and saturation work together to provide a wider color range. When the "S" and "I" values govern the blue color element in the image, for example, the range of the blue color can be increased from pale blue to deep blue. By adjusting the value, one can use this technique to change the contrast ratio in underwater photographs. They discovered that the technique was limited since it had not yet achieved the necessary level of success. For instance, the movement of autonomous underwater vehicles diminishes visibility when taking images underwater with an optical camera because it produces shadows on the scene. According to a future enhancement, the advantage of employing two stretching models is that it aids in balancing the color contrast in the images and also resolves the lighting issue. The histograms provide statistical evidence of the photographs' quality. Further analysis of the suggested strategy will be part of our future study.[4]

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Anwer proposed a wavelet-based fusion technique has been developed to address color and contrast concerns in fusion and inverse composition. Here, image processing uses fusion to address a variety of issues. This technique is based on merging photos using discrete wavelet transform to improve underwater images. Their proposed approach addresses low contrast and color attenuation of hazy images. Therefore, we are applying the CLAHE and histogram stretching methodologies for contrast improvement and color correction.

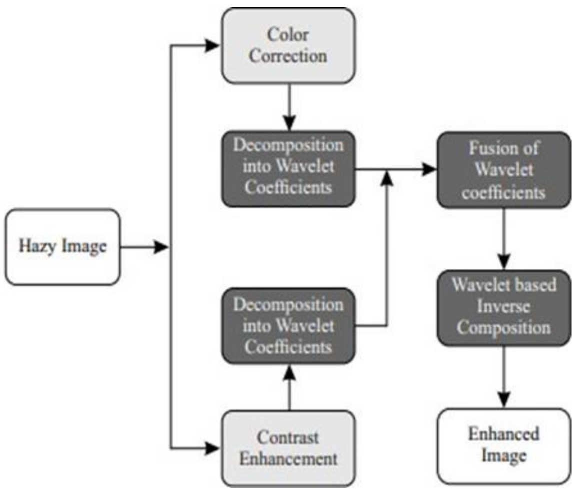

Fig: A wavelet-based fusion method for improving underwater image quality

They also found that four statistical measures, including the Root Mean Squared Error (RMSE), the Peak Signal to Noise Ratio (PSNR), the Structural Similarity Index Measure (SSIM), and the Measure of Entropy (MoE), are calculated to quantitatively evaluate the procedure. Additionally, the improved photos are qualitatively compared to contemporary image enhancing techniques. Here color and contrast enhancement are also done. Along with that decomposition, inversion and inverse composition is also done to get enhanced image. They found that this model reaches a limit when the mosaic vanishes and the color content largely decreases when the wavelet scale reaches the size of the image. Larger the scale of wavelet, more degradation. Smaller the scale of wavelet, mosaic appears. Future research will compare the proposed approach in-depth with cutting-edge quantitative analytic methods. [2]

Ezmahamrul Afreen Awalludin proposed a novel approach called Mixed Contrast Limited Adaptive Histogram Equalization (CLAHE) color models, which focuses primarily on enhancing the contrast and lowering the noise in the image. Here, a novel methodology was developed that merged two CLAHE results from applications to the two distinct color models RGB and HSV. The major objective is to significantly minimize the noise introduced by CLAHE to facilitate the following processing of underwater photos. He also investigated how CLAHE limits amplification by clipping the histogram at a user-specified threshold known as the clip limit. The histogram's noise smoothing level dictates how much the contrast should be increased based on the clipping level. Adaptive histogram clip (AHC), a version of the contrast limiting approach, can also be used. Both contrast-limited adaptive histogram equilibration (CLAHE) and adaptive histogram equilibration (AHE) were discovered to have limitations. These techniques are different from traditional histogram equalization in that they operate on discrete, tile-sized portions of the image and compute multiple histograms, each of which corresponds to a different area of the image. They then redistribute the image's brightness values using these histograms. AHE and CLAHE improve local contrast in an image by highlighting more features than does classic histogram equalization, while they still have a tendency to make the image noisier. Underwater image visibility is effectively increased by the enhancing technique. As a result, it demonstrates that the suggested strategy, particularly when visual signals are present, is promising for identifying coral reefs. Applying CLAHE to various color models and comparing the results will be the focus of future effort.[5]

Er. Charanjeet Kaur, Er. Rachna Rajput suggested a typical histogram equalization, each pixel is given the same modification derived from the image histogram. This functions well if the distribution of pixel values is uniform across the entire image. However, if the image has regions that are substantially lighter or darker than the remainder of the image, the contrast in those places won't be appropriately increased. The goal is to maintain image brightness while enhancing underwater image contrast. [6]

Dithee Dev K, Mr. S.Natrajan suggested contrast limited adaptive histogram equalization (CLAHE) approach which is recommended as effective methods for enhancing underwater images. The dark channel is calculated from the underwater input image and processed using image segmentation. then ascertain whether artificial light has had any impact on it. If so, remove it using the proper procedure before employing the CLAHE approach. By improving contrast as well as noise and artefacts, the experimental results of this technique considerably improve the visual quality of underwater photos.[7]

III. PROPOSED SYSTEM

Image fusion is the process of combining multiple images into a single image that contains information from all the original images. Wavelet-based image fusion is a widely used technique that utilizes the wavelet transform to decompose the images into different frequency bands. The low-frequency sub bands contain approximate information of the image, while the high-frequency sub bands contain detailed information. In wavelet-based image fusion, the wavelet transform is applied to both images separately, resulting in their respective wavelet decompositions. The wavelet coefficients from both decompositions are combined using different methods such as maximum selection, minimum selection, mean selection, or selection based on local variance. These methods operate on both the approximation and detail coefficients to produce a fused image that retains important information from both original images. Wavelet-based image fusion has found applications in various fields including medical imaging, remote sensing, and surveillance, and has been proven to be an effective method to enhance the quality and information content of images.

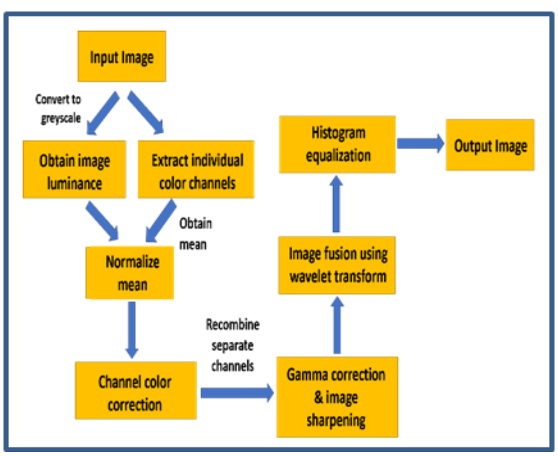

Fig: System Architecture

A. Greyscale Conversion

Greyscale images are images that have only shades of gray and no color. To convert an input image to a greyscale image, we need to transform each pixel value in the input image into a greyscale value. One common method for doing this is to take the average of the RGB values (red, green, and blue) of each pixel in the input image and use that as the greyscale value for that pixel in the greyscale image. Alternatively, we can also use other techniques like weighted averaging or luminosity method to convert input images to greyscale images. Once we have the greyscale values for all the pixels in the input image, we can construct the greyscale image by assigning these values to the corresponding pixels in the greyscale image. Greyscale images are commonly used in various image processing applications, such as image enhancement, image segmentation, and feature extraction, because they can simplify the image data while still preserving important visual information.

B. Obtain Image Luminance

In digital imaging, luminance is a measure of the perceived brightness of an image. It is often used as an indicator of image quality and can be used to enhance the visibility of important details in the image. There are different methods to obtain the luminance of an image. One common method is to convert the color image to grayscale, which results in a luminance image that contains only the brightness information. This can be done using various techniques, such as taking the average of the red, green, and blue (RGB) color channels or using a weighted sum of the RGB channels that approximates the luminance. So, from the above first step we can obtain the luminance.

C. Extraction of individual color channels

In digital imaging, an RGB image is composed of three-color channels: red, green, and blue. Each pixel in the image has a value for each of these three-color channels, which combine to produce the final color of the pixel. To extract an individual color channel from an RGB image, we can use a technique called channel splitting. This involves separating each color channel from the original image and creating a grayscale image that contains only the values of that channel. So, from conversion of greyscale we can extract individual color channels.

D. Normalize mean and Channel color correction

Normalization of the mean of an image and color correction are two separate techniques in image processing, but they can be used together to improve the visual quality of an image. Normalization of the mean involves adjusting the pixel values of an image so that the mean of the pixel values is equal to a desired value, such as zero mean or unit variance. This technique can be used to enhance the contrast and brightness of an image and to prepare it for further processing or analysis. After obtaining normalize mean, we can perform channel color correction to adjust the color balance of the image. This involves adjusting the intensities of the red, green, and blue color channels of the image to correct for color imbalances or to improve its visual quality.

E. Gamma correction and Image sharpening

Gamma correction is a technique in image processing that involves adjusting the brightness of an image by using a gamma correction factor. The gamma correction factor controls the relationship between the digital values of the pixels and the actual brightness of the image. The gamma correction factor can be used to adjust the overall brightness and contrast of an image, and to correct for gamma-related color shifts. Gamma correction can also be used to improve the visual quality of an image by enhancing its mid-tones. This is because the gamma correction factor affects the brightness of the mid-tones more than the highlights and shadows of the image. Image sharpening is a technique in image processing that involves enhancing the edges and details of an image to improve its visual quality. This can be done using various techniques, such as unsharp masking, high-pass filtering, or frequency domain filtering. Unsharp masking is a common technique for image sharpening, which involves creating a blurred copy of the image and subtracting it from the original image to enhance the edges and details. So finally, Gamma correction is used to adjust the overall brightness and contrast of an image, while image sharpening is used to enhance the edges and details of the image.

F. Image fusion using Wavelet transform

Image fusion using wavelet transform is a technique in image processing that involves combining multiple images into a single image by using wavelet transform. The wavelet transform is a mathematical technique that decomposes an image into different frequency sub-bands, which represent different levels of detail. In the very first step, the input image is divided into two sub bands. Those channels undergo all the process mentioned. And at last, we combine the selected sub-bands from each input image using a fusion rule. Reconstruct the fused image from the combined sub-bands using inverse wavelet transform. It can help to improve the visual quality and information content of the fused image by preserving the most relevant information from each input image.

G. Histogram Equalization

Histogram equalization is a technique in image processing that can be used after image fusion using wavelet transform to enhance the contrast of the fused image. After performing image fusion using wavelet transform, the resulting image may have low contrast due to the combination of multiple images with different contrast levels. Histogram equalization can be used to stretch the dynamic range of the pixel values in the fused image, which can enhance the contrast and improve the visual quality of the image. The process of histogram equalization involves computing the histogram of the pixel values in the fused image and then applying a transformation function to redistribute the pixel values to a new histogram with a more uniform distribution. This transformation function can be applied to the pixel values in each color channel of the image separately, or to the intensity values in a greyscale image. And then finally, the image is produced as output enhanced image.

IV. IMPLEMENTATION

1. Data Acquisition: Collect or obtain underwater images for processing. These images can be captured using underwater cameras or downloaded from publicly available datasets.

2. Pre-processing: Pre-process the acquired images means the image is divided into two channels by greyscale conversion. And individual channels will be extracted and undergoes further step.

3.Color Correction: Perform color correction or white balancing to remove the color cast caused by the absorption and scattering of light in water. This step aims to restore the original colors of the scene and improve visibility.

4. Contrast Enhancement: Enhance the contrast of the images to bring out details in dark or bright areas. This can be achieved using techniques such as gamma correction, histogram equalization, or adaptive contrast enhancement methods.

5. Image Dehazing: Reduce the effects of underwater haze caused by suspended particles or bubbles in the water. This can be done using dehazing algorithms.

6. Image Sharpening: Apply image sharpening techniques to enhance the details and edges in the images. Common methods include unsharp masking, high-pass filtering, or gradient-based approaches.

7. Image Fusion: Combine information from multiple images or channels to improve the overall image quality. This can be done by techniques such as wavelet or multi-scale fusion.

8. Post-processing: Perform any additional post-processing steps, such as noise reduction, image resizing, or format conversion, if needed.

9. Visualization: Display the original and enhanced images for visual comparison, and can be used for further analysis or application-specific requirements.

For the above implementation some of the built-in functions of MATLAB used are:

a. mean2(matrix): To find matrix mean

b. cat (): To concatenate matrices

c.imadjust:(image,input_range,output_range,gamma_value) : To adjust intensity values

d. imgaussfilt(image): To sharpen the image

e. wfusing (): returns fused image of img 1 & img 2

f. histeq(image): To enhance image contrast

Gamma value selection:

If gamma value is-

I) Less than 1: imadjust weights mapping toward brighter intensities

II) Greater than 1: imadjust weights mapping toward darker intensities

III) Equal to 1/3: imadjust applies unique gamma value to each color component or channel

IV) Default value: equals to 1

By using these and some other built-in functions of the MATLAB the code has been designed and implemented which gives the enhanced output image of a underwater image or hazed image.

V. RESULTS

Based on the approach mentioned above, various underwater images are captured and analyzed. The images which are given as input undergoes through all the steps and produce final images. Before producing the final output image, the image after going through the steps produces the different images in each step. The below images show the color channel extraction after the conversion of greyscale and also after white balancing. Each individual channels of RGB color combination are shown after extraction. The Separated Color Channels will go through intensities balanced and White Balanced.

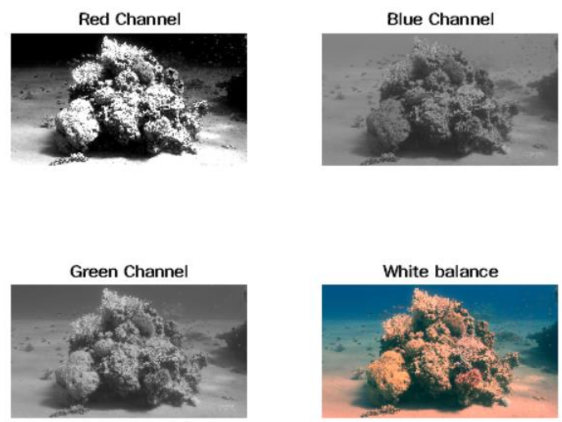

Figure: Different channels of the image

The below shown images are results of two copies of White balanced images, one of gamma corrected and another of sharpened.

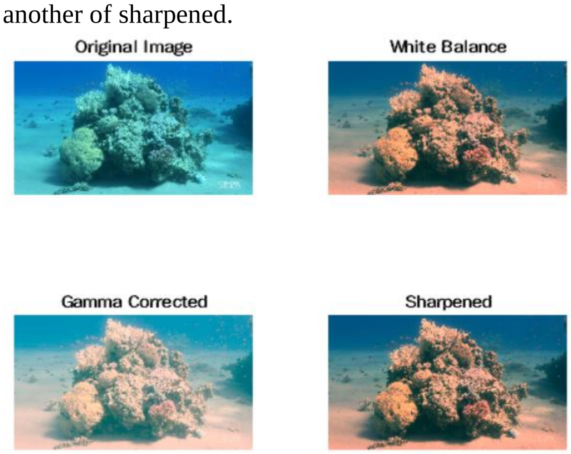

Fig: Gamma correction and Sharpening of the original image

Fig: Final enhanced image with its original image

The two obtained images after gamma correction and sharpening are fused together with wavelet fusion and undergoes histogram equalization which produces the final desired image which is used in many fields for research and other purposes. In some of the images we can see some red artifacts showing up due to high irregularities in the texture of the objects which can be considered a challenge of this method.

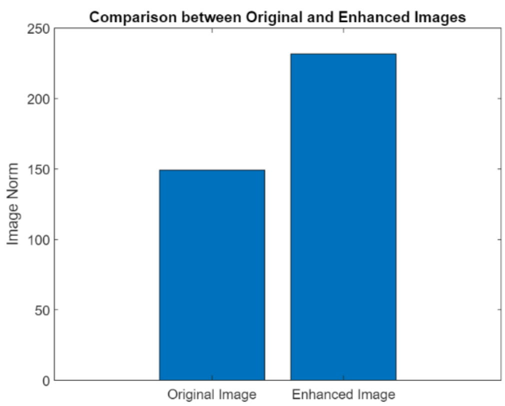

Fig: bar plot for comparison of Original and Enhanced Image

VI. CONCLUSION AND FUTURE SCOPE

Improving underwater images is a work in and of itself because there are so many distinct factors that can impact the image that is produced. The use of various image enhancement techniques like AHE, GC, BBHE, CLAHE, Wavelet fusion etc. can be applied to enhance the visual quality of the obtained photos. In order to improve an image, the technique selection is crucial. Therefore, the impacts of noise, blurring, and restricted visibility on an image can be diminished. In the future we would like to work on building an algorithm with best and suitable which helps to reconstruct images taken under other liquids, wherein the amount of wavelength absorbed by the liquid is different when compared to water. So that it helps in many ways and in many areas of research. The results indicate that the proposed system integrates the merits of histogram equalization and sharpening effectively and achieves a considerable efficiency in the enhancement of degraded underwater images.

The scope of this project extends to deployment as research tools that require image enhancement for study. The system can be developed to adaptively perform color channel correction to reduce and eliminate color artifacts in enhanced images. This system can be integrated with other components like low light image enhancement etc. to be deployed as potential image enhancer. And also, in future it can be updated and modified for best enhanced image and be integrated with underwater robot.

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