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Underwater Image Enchancement using CNN based Learning Methods

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Abstract: Underwater images find application in various fields, like marine research, inspection of aquatic habitat, underwater surveillance, identification of minerals, and more. However, underwater shots are affected a lot during the acquisition process due to the absorption and scattering of light. As depth increases, longer wavelengths get absorbed by water; therefore, the images appear predominantly bluish-green, and red gets absorbed due to higher wavelength. These phenomenon's result in significant degradation of images due to which images have low contrast, colour distortion, and low visibility. Hence, underwater images need enhancement to improve the quality of images to be used for various applications while preserving the valuable information contained in them.

Keywords: Histogram Equalization Technique, White Balance Technique, DCT Technique.

1. Introduction

The earth is an aquatic planet with about 70% of its surface is covered by water, and as the river, sea, lakes, and oceans contain many valuable resources inside them the scientists and researchers have shown great interest in capturing underwater aquatic life. The underwater environment presents unique challenges for capturing images accurately. These challenges can significantly degrade the quality of underwater images, impacting various applications like marine biology research, underwater exploration, and underwater photography. The researchers concluded that the effect of scattering and absorption of light in water are the major causes of this distortion. Since water is about approx. 800 times denser than air, so when the light enters from the air into the water, it encounters a rejection phenomenon on the surface due to which only a partial amount of light enters into water. So, the light suffers a dispersion, scattering effect when it strikes particles of sand and minerals dissolved in water. Scattering deflects light in different directions reducing the amount of light falling on the object captured. Underwater images have also been an important source of interest in various branches of technology and scientific research. Hence, we perform underwater image enhancement. The goal of the underwater image enhancement project is to develop techniques and algorithms to improve the quality and visibility of underwater images, thereby enhancing their usability and visual appeal. These techniques are widely used in numerous applications, such as the inspection of submarine infrastructure and cables, the detection of artificial objects, the control of underwater vehicles, research in marine biology and archaeology, object detection, consumer electronics, external surveillance, etc.

Image enhancement is to bring more visibility to the image and make it more appropriate to the required application. Image enhancement intensifies the information content of the image by emphasizing the deep underwater image edges and changes the visual influence of the observer. The sharpness and contrast of the images captured in under water suffer from poor colour contrast and poor visibility. Moreover, the quality of underwater images deteriorates due to the physical properties of the aquatic medium, light scattering, reflection, and becomes more and less visible as water depth increases. The haziness is caused by suspended particles such as sand, minerals, and plankton that exist in lakes, oceans, and rivers. As the light reflected from the objects advances towards the camera, a part of the light meets these suspended particles, which absorb and disperse the light. Capturing clear images underwater is a challenge, mainly due to the turbidity caused by the dispersion of the colour, in addition to the colour emitted by the attenuation of the variable light at different wavelengths. Colour dispersion and colour emission produce blurred subjects and low-intensity contrast in underwater images. The light consists of the combination of 7"VIBGYOR" colours, each of which has a specific associated wavelength. When light enters the

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water, the red colour corresponding to the maximum wavelength i s absorbed first at a depth of 5m.The blue colour has the lowest wavelength and, therefore, travels maximum depth that reaches the level of the deep sea. Thus, the photographs captured in the depths of the water are greenish and bluish. Because of the fog, there are problems in many graphic applications for machine vision, as this degrades the visibility of the scene. The fog is formed due to the two main elements, one is the light of the air, and another is the attenuation. In the scene, white light increases white, and darkening decreases the contrast of the scene. Using haze removal techniques, we can recover the colour and contrast of the scene in underwater images.

2. Literature Survey

This chapter presents a comprehensive review of literature focusing on various techniques that are used to enhance under water image and restore visibility and quality of the image. There is a wide variety of technologies as well as techniques used for underwater image restoration and therefore the following discussion categorizes and groups them in relation to their distinguishing features.

Adagale –Vairagar.S, Gupta.P, "Quality Enhancement for Underwater Images usi ng Various Image Processing Techniques", 2023. With the wide application of underwater vision in different scientific research fields, underwater image enhancement can play an increasingly significant role in the process of image processing in underwater research and underwater archaeology. Most of the target images of the current algorithms are shallow water images. When the artificial light source is added to deep water images, the raw images will face more diverse noises, an d image enhancement will face more challenges. As a result, this study investigates the numerous existing systems used for quality enhancement of underwater mages using various image processing techniques. The purpose of this paper is to improve the accuracy in terms of reducing MSE and enhancing PSNR using CNN-based in-deep learning approaches which helps to improve underwater low-resolution photos and improve contrast and colour deviation compared to other algorithms.

Dachang zhu, "Underwater Image Enhancement Based on the Improved Algorith m of Dark Channel", 2023. An improved image fusion and enhancement algorithm based on a prior dark channel is proposed in this paper based on graph theory. Image edge feature sharpening, and dark detail enhancement by homomorphism filtering in CIE Lab colour space are realized. In the RGB colour space, the multi-scale retinal with colour restoration (MSRCR) algorithm is used to improve colour deviation and enhance colour saturation. The contrast limited adaptive histogram equalization (CLAHE) algorithm defogs and enhances image contrast. Finally, according to the dark channel images of the three processing results, the final enhanced image is obtained by the linear fusion of multiple images and channels. Experimental results demonstrate the effectiveness and practicality of the proposed method on various data sets.

Vaithiyanathan Dhandapani, Manigandan Muniraj, "Underwater image enhancem ent by modified colour correction and adaptive Look-Up-Table with edge-preserving f ilter", 2023. This paper proposes an underwater image enhancement method that improve the visibility, contrast and colour cast in the underwater images. The proposed method includes a modified colour correction, an adaptive Look-Up-Table (LUT) and an edge- preserving filter. First, a colour correction is performed on individual LAB colour space components. The improvement of the luminance (L) component is processed with a sequence of steps such as CLAHE, sharpening, gamma, and colour correction. In addition, the chrominance (A and B) components are modified by further colour correction. Second, the contrast of the colour-corrected image is enhanced using the adaptive LUT based on probability threshold. This probability threshold increases the image contrast by limiting the pixel intensity values in each RGB channel. In addition, the probability threshold controls the halo effects and artifacts. Finally, the underwater image is enhanced with a fast local Laplacian filter (FLLF) to preserve the edge details with texture smoothing. The denoised image is adjusted with histogram normalization for a further colour balancing. The experimental results obtained from the proposed method on different underwater image datasets shows a supremacy over colour casts, visibility, halo effects, free of artifacts and edge- preserving in the underwater images compared to the existing methods.

Weidong Zhang, Peixian Zhuang, Haihan Sun, Guohou Li, Sam Kwong, and Chon gyi Li, "Underwater Image Enhancement via Minimal Colour Loss and Locally Adapt ive Contrast Enhancement", 2022. To deal with these degradation issues, this paper proposes an efficient and robust underwater image enhancement method, called MLLE. Specifically, they first locally adjust the colour and details of an input image according to a minimum colour loss principle and a maximum attenuation map-guided fusion strategy. Afterward, they employ the integral and squared integral maps to compute the mean and variance of local image blocks, which are used to adaptively adjust the contrast of the input image. Meanwhile, a colour balance strategy is introduced to balance the colour differences between channel a and channel b in the CIELAB colour space. The enhanced results are characterized by vivid colour, improved contrast, and enhanced details. Extensive experiments on three

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underwater image enhancement datasets demonstrate that our method outperforms the state-of-the-art methods.

These papers proposes a hybrid framework for underwater image enhancement, which unifies underwater white balance and variation contrast and saturation enhancement. In our framework, the improved underwater white balance (UWB) algorithm m is integrated with histogram stretching, aiming to better compensate the attenuation difference along the propagation path and remove undesired colour castings. In this paper, an underwater image sharpness enhancement algorithm based on light field imaging is proposed. According to Retinex theory, the underwater scattering imaging model is established, and the image enhancement effect of the scattering imaging model is optimised by using the multi perspective characteristics of light field, which further improve the quality of underwater image.

3. Implementation of Proposed Method

Underwater imaging is vital for various applications, including marine research, underwater archaeology, and underwater surveillance. However, underwater images often suffer from colour distortion, low contrast, and poor visibility due to light absorption and scattering in water. Enhancing these images is crucial for extracting meaningful information and improving visual quality.

The histogram of a digital image, with intensity levels between 0 and (L-1), is a function $h(r_k) = n_k$, where r_k is the kth intensity level and n_k is the number of pixels in the image having that intensity level. We can also normalize the histogram by dividing it by the total number of pixels in the image. For an N x N image, we have the following definition of a normalized histogram function:

$$p(r_k) = n_k/N^2$$

This $p(r_k)$ function is the probability of the occurrence of a pixel with the intensity level r_k. Clearly,

$$\sum p(r_k) = 1$$

The histogram of an image, as shown in the figure, consists of the x-axis representing the intensity levels r_k and the y-axis denoting the $h(r_k)$ or the $p(r_k)$ functions. The histogram Type equation here. Of an image gives important information about the grayscale and contrast of the image. If the entire histogram of an image is centered towards the left end of the x-axis, then it implies a dark image. If the histogram is more inclined towards the right end, it signifies a white or bright image. A narrow-width histogram plot at the center of the intensity axis shows a low-contrast image, as it has a few levels of grayscale. On the other hand, an evenly distributed histogram over the entire x-axis gives a high-contrast effect to the image.

In image processing, there frequently arises the need to improve the contrast of the image. In such cases, we use an intensity transformation technique known as histogram equalization. Histogram equalization is the process of uniformly distributing the image histogram over the entire intensity axis by choosing a proper intensity transformation function. Hence, histogram equalization is an intensity transformation process.

The choice of the ideal transformation function for uniform distribution of the image histogram is mathematically explained below.

Let us consider that the intensity levels of the image r is continuous, unlike the discrete case in digital images. We limit the values that r can take between 0 and L-1, that is, $0 \le r \le L-1$. $r = 0$ represents black and $r = L-1$ represents white. Let us consider an arbitrary transformation function:

$$s = T(r)$$

Where s denotes the intensity levels of the resultant image. We have certain constraints on T(r). T(r) must be a strictly increasing function. This makes it an injective function.

$0 \le T(r) \le L-1$. This makes T(r) surjective.

The above two conditions make T(r) a bijective function. We know that such functions are invertible. So we can get back r values from s. We can have a function such that $r = T^{-1}(s)$. Let us now say that the probability density function (pdf) of r is $p_r(x)$ and the cumulative distribution function (CDF) of r is $F_r(x)$. Now the CDF of s will be :

$$F_S(x) = p(s \le x) = p(T(r) \le x) = p(r \le T-1(r)) = F_r(T-1(x))$$

We put the first condition of T(r) precisely to make the above step hold true. The second condition is needed as s is the intensity value for the output image and so must be between o and (L-1).

So, a pdf of s can be obtained by differentiating $F_S(x)$ with respect to x. We get the following relation:

$$P_s(s)=p_r(r)\frac{dr}{ds}$$

Now, if we define the transformation function as follows:

$$s = T(r)\ (L-1)\int_0 p_r(x)dx$$

Then using this function gives us a uniform pdf for s.

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The above step used Leibnitz's integral rule. Using the above derivative, we get:

Now, we extend the above continuous case to the discrete case. The natural replacement of the integral sign is the summation. Hence, we are left with the following histogram equalization transformation function.

4. Software Requirements/Procedure/Design

Compensating for color degradation involves adding a fraction of the green channel to the red and blue channels using specific formulas derived from histogram analysis. This step aims to restore the original color balance and reduce color distortion in the images.

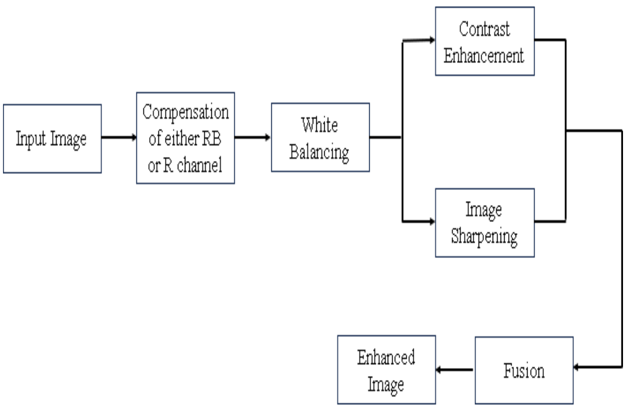

Fig 4.1: Block Diagram.

In image processing that ensures accurate color representation by eliminating unrealistic color casts. The Gray World algorithm is applied for white balancing to correct color distortions further. By adjusting the color temperature of the images, this step improves overall color accuracy and enhances visual quality. Poor illumination, limited dynamic range in imaging sensors, or incorrect lens aperture settings during image acquisition can result in low contrast. Global Histogram Equalization is employed to enhance the contrast of color-corrected images. By redistributing pixel intensities, this technique improves the visibility of details and enhances image clarity. Image sharpening is an essential technique in image processing that enhances the clarity and definition of edges within an image. When applied, it makes the edges more distinguishable and gives the image a sharper appearance.

Image fusion is a crucial technique in image processing that combines information from multiple images to create a more informative and accurate composite image. Two fusion techniques, averaging-based fusion and PCA-based fusion are employed to integrate contrast-enhanced and sharpened images. Averaging-based fusion computes the average intensity of corresponding pixels from both input images, while PCA-based fusion utilizes eigenvectors and eigenvalues to combine images effectively.

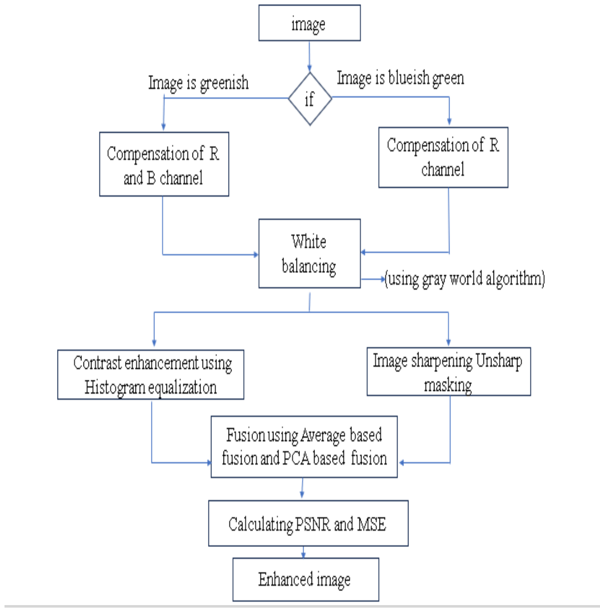

Fig 4.2: Circuit Diagram

The algorithms used in underwater image enhancement are discussed below

The Gray World Algorithm is a method used for color constancy, which aims to correct color variations caused by different lighting conditions in digital images. Let's delve into the details: Color Constancy**:** Color constancy is a mechanism that detects colors independently of the light source. It helps compensate for color shifts introduced by varying illumination conditions. When we capture digital images, the light source can introduce color casts. Color constancy methods aim to estimate the prevailing light color and then remove it from the image. Gray World Assumption**:** The Gray World Assumption is a white balance technique that assumes the average reflectance of surfaces in the scene is **achromatic** (neutral gray).This assumption holds when we have a good distribution of colors in the scene. If the scene's colors are well-balanced, the average reflected color is assumed to be the color of the light. The Gray World Algorithm produces an estimate of the illumination by computing the mean of each channel (red, green, and blue) in the image. Here's how it works: Compute the mean value for each channel (R, G, B).Normalize each pixel's color value by dividing it by the corresponding channel mean. This normalization process helps remove the color cast caused by the light source. Essentially, the algorithm assumes that the average scene color is gray, and any deviation from gray indicates a color cast.

5. Results and Discussion

From the fig:5.1, we observed that the image, the red and blue channel concentrated on the left side of the histogram as the red, blue color gets absorbed due to a higher wavelength. hence compensated for the degradation of the R and B channel and in cases where images have a

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greenish appearance shown in fig:5.2

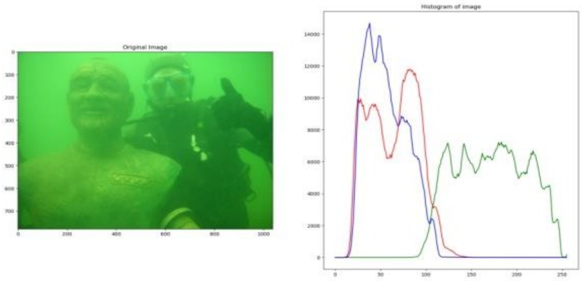

Fig 5.1 plotting histogram of input image

Fig 5.2 RB Compensated Image of Input Image

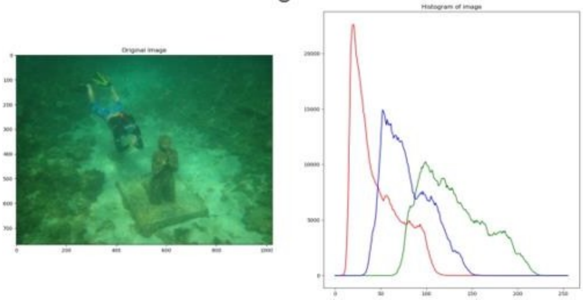

Fig 5.3: plotting histogram of input image

Fig 5.3: plotting histogram of input image concentrated on the left side of the histogram as the red, blue color gets absorbed due to a higher wavelength. Hence compensated for the degradation of the R and B channel and in cases where images have a greenish appearance shown in fig:5.4.

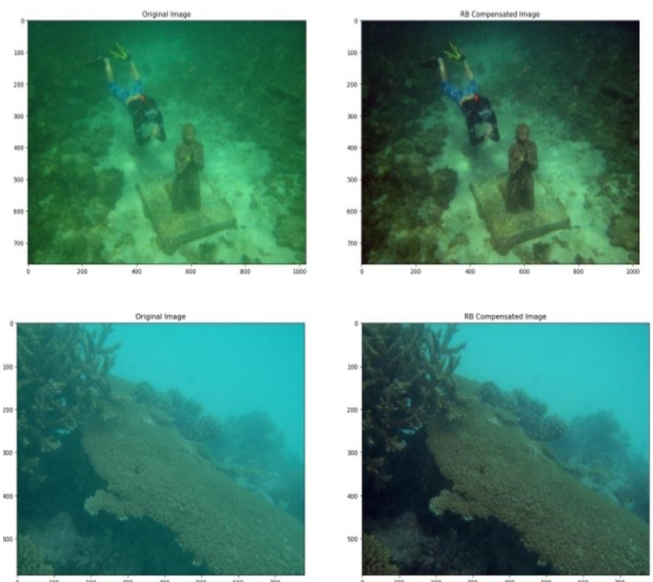

Fig 5.4 RB Compensated Image of Input Image

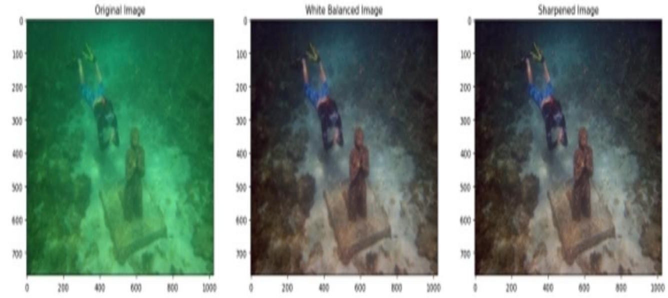

Fig 5.5 : average based fusion output

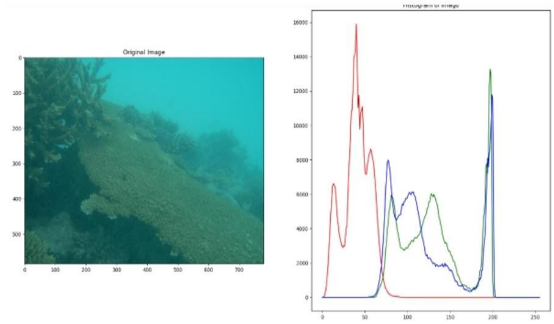

Fig 5.6 plotting histogram of input image

From the fig:5.6, we observed that the image, the red channel concentrated on the left side of the histogram as the red, blue color gets absorbed due to a higher wavelength.

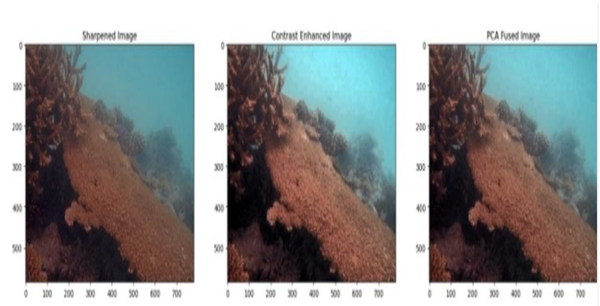

Fig 5.7 RB Compensated Image of Input Image

Hence compensated for the degradation of the R channel and in cases where images have a greenish appearance shown in fig: 5.7.

```
MSE & PSNR of PCA fused image
Reference vs Original- MSE:  330.55965811965814 PSNR: 22.93830510195926
Reference vs Fused    - MSE:  301.161023449485 PSNR: 23.342815965136793

MSE & PSNR of Average fused image
Reference vs Original- MSE:  330.55965811965814 PSNR: 22.93830510195926
Reference vs Fused    - MSE:  298.3462064431295 PSNR: 23.383598408305453
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Fig 5.8 : PCA based fusion output.

Fig 5.8 : MSE & PSNR values for average based fusion and PCA based fusion with respect to reference image

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6. Conclusion And Future Scope

Underwater imaging is vital for various applications, including marine research, underwater archaeology, and underwater surveillance. However, underwater images often suffer from color distortion, low contrast, and poor visibility due to light absorption and scattering in water. Enhancing these images is crucial for extracting meaningful information and improving visual quality.

By applying color correction, contrast enhancement, image sharpening, and fusion techniques, we can reveal the hidden beauty of the aquatic world. Whether you're a marine biologist studying coral reefs or an underwater photographer capturing mesmerizing scenes, these methods empower us to appreciate the depths and mysteries of our oceans.

Successfully able to enhance the underwater images. We also measured the quality of images obtained from the method using metrics namely, MSE and PSNR. The method used above has a downfall that sometimes it produces blue artifacts on whitish parts of images, particularly in the underwater images when water bubbles are there. So, it's not robust for all types of images. Also, if the image is noisy then firstly image noise should be removed by applying Gaussian smoothing.

Now the enhancement process is not automated, we have to decide what type of compensation we need like we have to provide a variable flag in the algorithm which takes values 0 and 1, where 0 represents that it is a greenish image and we need to compensate R and B channels while 1 represents that it is a bluish image and we need to compensate only R channel as B is not much degraded. To automate this process, we can employ a deep learning-based model but it would require a large dataset to provide efficient results. Improve the robustness of the whole process which could eliminate the downfall mentioned above that it produces bluish artifacts. So, that it works for all possible images.

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