# UNDERWATER IMAGE ENHANCEMENT VIA MINIMAL COLOR LOSS AND LOCALLY ADAPTIVE CONTRAST ENHANCEMENT

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**ABSTRACT**

Underwater images typically suffer from color deviations and low visibility due to the wavelength-dependent light absorption and scattering. To deal with these degradation issues, we propose an efficient and robust underwater image enhancement method, called MLLE. Specifically, we first locally adjust the color and details of an input image according to a minimum color loss principle and a maximum attenuation map-guided fusion strategy. Afterward, we employ the integral and squared integral maps to compute the mean andvariance of local image blocks, which are used to adaptively adjust the contrastof theinputimage. Meanwhile,a color balance strategy is introduced to balance the color differences between channel a and channel b in theCIELAB color space. Our enhanced results are characterized by vivid color, improved contrast, and enhanceddetails.Extensiveexperimentsonaunderwaterimageenhancementdatasetdemonstratethatourmethodoutperforms the state-of-the-art methods. Our method is also appealing in its fast processing speed within 1s forprocessing an image of size 1024×1024×3 on a single CPU. Experiments further suggest that our method caneffectively improvetheperformanceofunderwaterimagesegmentation,key pointdetection, and saliencydetection displays.

## 1. INTRODUCTION

With the fast advance of technologies and the prevalence of imaging devices, billions of digital images are being created every day. Due to undesirable light source, unfavorable weather or failure of the imaging device itself, the contrast and tone of the captured image may not always be satisfactory. In fact, image enhancement algorithms have already been widely applied in imaging devices for tone mapping. For example, in a typical digital camera, the CCD (Charge Coupled Device) or CMOS (Complementary Metal Oxide Semiconductor) array receives the photons passing through lens and then the charge levels are transformed to the original image. Usually, the original image is stored in raw format, with a bit length too big for normal displays.

In this project the image enhancement approach adopts a two step strategy,

- White-balancing
- Image fusion

Combining white-balancing and image fusion, to improve underwater image without restoring. In this approach white-balancing aims at compensating for color cast caused by the selective absorption of colors with depth and image fusion is considered to enhance the edges of the image. Here, we aim for a simple and fast approach that is able to increase the scene visibility in a wide range of underwater images.

**White-Balancing**

Because of the undesirable illuminance or the physical limitations of inexpensive imaging sensors, the captured image may carry obvious color bias. To calibrate the color bias of image, we need to estimate the value of light source, the problem of which called color constancy. Using a suitable physical imaging model, one can get an approximated illuminance, and then a linear transform can be applied to map the original image into an ideal one.

White balance determines color rendition of digital photography's, here it is a typical example for the effect of different white balance settings show in the below Figure 1.3.1. White-balance is an aspect of photography that many digital camera owners don't understand, so for those of you have been avoiding white balancing.

**Adjustment of White Balancing**

Different digital cameras have different ways of adjusting white balance. Many digital cameras have automatic and semi-automatic modes to help you make the adjustments. White balance basically means color balance. It is a function which gives the camera a reference to "true white". It tells the camera what the color white looks like, so the camera will record it correctly.

**Image Fusion**

Image fusion is a procedure of fusing two or more images of same scene to form single fused image which displays vital information in the fused image. Image fusion technique is used for removing noise from images. The advantages of image fusion includes image sharpening and feature enhancement.

## 2. EXISTING SYSTEM

- **Image Enhancement**
- **Histogram**

### 2.1 Basic Steps of Image Enhancement

The basic steps of image enhancement, if we are taking the any input image, the image is then specify application pre-processing method will be performed on those image after this method the image quality is increased.

**Input Image:** In this first an image will be taken as an input. These images can be medical images, blur images, remote sensing images machine vision, the military applications etc.

**Perform Pre-processing on the Image:**

Images that will be taken as input can be blur image or noisy image so the various pre-processing methods will be performed on those images before applying enhancement technique.

**Applying Domain Techniques:** After applying pre-processing method on input images then image quality will be enhanced by using Image enhancement domain techniques such as spatial or transformation.

**Output Enhanced Image:** In this the output image will be get which is an enhanced image.

## 3. PROPOSED SYSTEM

Underwater environment offers many rare attractions such as marine animals and fishes, Different from common images, underwater images suffer from poor visibility resulting from the attenuation of the propagated light, mainly due to absorption and scattering effects. The absorption substantially reduces the light energy, while the scattering causes changes in the light propagation direction. They result in foggy appearance and contrast degradation making distant objects misty. Practically, in common sea water images, the objects at a distance of more than 10 meters are almost unperceivable, and the colors are faded because their composing wavelengths are cut according to the water depth.There have been several attempts to restore and enhance the visibility of such degraded images. Since the deterioration of underwater scenes results from the combination of multiplicative and additive processes traditional enhancing techniques such as gamma correction, histogram equalization appear to be strongly limited for such a task. Works that are the problem has been tackled by tailored acquisition strategies

$$I(x)=J(x)e^{-\eta d(x)}+B_{\infty}(x)(1-e^{-\eta d(x)}) \;.....(2)$$

using multiple images, specialized hardware or polarization filters. In contrast, this paper introduces a novel approach to remove the haze in underwater images based on a single image captured with a conventional camera.

**3.1 Light Propagation in Underwater**

For an ideal transmission medium they received light is influenced mainly by the properties of the target objects and the camera lens characteristics. This is not the case underwater. First, the amount of light available under water, depends on several factors. The interaction between the sun light and the sea surface is affected by the time of the day (which influences the light incidence angle), and by the shape of the interface between air and water (rough vs. calm sea). The diving location also directly impacts the available light, due to a location-specific color cast: deeper seas and oceans induce green and blue casts; tropical waters appear cyan, while protected reefs are characterized by high visibility. In addition to the variable amount of light available under water, the density of particles that the light has to go through is several hundreds of times denser in seawater than in normal atmosphere.

As a consequence, sub-sea water absorbs gradually different wavelengths of light. The direct component is the component of light reflected directly by the target object onto the image plane. At each image coordinate $x$ the direct component is expressed as

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

Where J($x$) is the radiance of the object, $d(x)$ is the distance between the observer and the object, and $\eta$ is the attenuation coefficient. The exponential term $e^{-\eta d(x)}$) is also known as the transmission $t(x)$ through the underwater medium.

superimposed on the object. Mathematically, it is often expressed as shown below in Eq.2 and Eq.3.

$$E_{BS}(x)= B_{\infty}(x)(1- e^{-\eta d(x)}) \;.........(3)$$

**3.2 Gaussiandifference**

The Second input will be applied as input to the sharpening using Gaussian operation. Inan underwater image, all pixels will not be exposed. Pixels are commonly better exposed whenthey have normalised values close to the average value of 0.5. This weight avoids an over orunderexposedlookbyconstrainingtheresulttomatchtheaverageluminance.asimilarweightinthe context of tone mapping. The exposedness weight map is expressed as a Gaussian-modelleddistance to the average normalised range value (0.5). One of the main challenges in underwaterimageenhancementisthattheobjectswithintheimagelosetheirvisibilityandhencediscriminationoftheobjectsfromthebackgroundscenebecomesdifficult.Thequalitythatmakesthe object distinctive relative to its neighbours is known as saliency. It is based on the concept ofcentre-surroundcontrastwhereinasaliencymapisdeveloped

**3.3. Underwater White Balance**

In our approach, white balancing aims at compensating for the color cast caused by the selective absorption of colors with depth, while image fusion is considered to enhance the edges and details of the scene, to mitigate the loss of contrast resulting from back-scattering. We now focus on the white-balancing stage.White-balancing aims at improving the image aspect, primarily by removing the undesired color castings due to various illumination or medium attenuation properties. In underwater, the perception of color is highly correlated with the depth, and an important problem is the green-bluish appearance that needs to be rectified. Since the scattering attenuates more the long wavelengths than the short ones, the color perception is affected as we go down in deeper water.In practice, the attenuation and the loss of color also depends on the total distance between the observer and the scene. To compensate for the loss of red channel, we build on the four following observations/principles:The green channel is relatively well preserved under water, compared to the red and blue ones. Light with a long wavelength, i.e. the red light, is indeed lost first when travelling in clear water. The green channel is the one that contains opponent color information compared to the red channel, and it is thus especially important to compensate for the stronger attenuation induced on red, compared to green. Therefore, we compensate the red attenuation by adding a fraction of the green channel to red. We had initially tried to add both a fraction of green and blue to the red but, using only the information of the green channel allows to better recover the entire color spectrum while maintaining a natural appearance of the background (water regions).

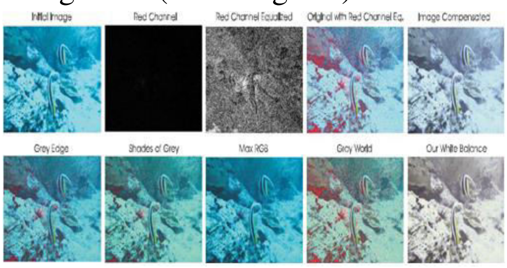


**Fig4.1.** Underwater White-Balancing

The compensation should be proportional to the difference between the mean green and the mean red values because, under the Gray world assumption (all channels have the same mean value before attenuation), this difference reflects the disparity/unbalance between red and green attenuation.To avoid saturation of the red channel during the Gray World step that follows the red loss compensation, the enhancement of red should primarily affect the pixels with small red channel values, and should not change pixels that already include a significant red component.

In other words, the green channel information should not be transferred in regions where the information of the red channel is still significant. Basically, the compensation of the red channel has to be performed only in those regions that are highly attenuated telling that if a pixel has a significant value for the three channels, this is because it lies in a location near the observer, or in an artificially illuminated area, and does not need to be restored.Mathematically, to account for the above observations, we propose to express the compensated red channel $I_{rc}$ at every pixel location $(x)$ as follows

$$Irc(x) = Ir(x) + \alpha.(\bar{I}g-\bar{I}r).(1-Ir(x)).Ig(x) \quad \text{...(Eq.4)}$$

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 $I_r$ and $I_g$ denote the mean value of $I_r$ and $I_g$ .each factor in the second term directly results from one of the above observations, and $\alpha$ denotes a constant parameter. In practice, our tests have revealed that a value of $\alpha$= 1 is appropriate for various illumination conditions and acquisition settings. To complete our discussion about the severe and color-dependent attenuation of light under water, it is worth noting the works in, which reveal and exploit the fact that, in turbid waters or in places with high concentration of plankton, the blue channel may be significantly attenuated due to absorption by organic matter. To address those cases, when blue is strongly attenuated and the compensation of the red channel appears to be insufficient, we propose to also compensate for the blue channel attenuation, i.e. we compute

$$Ibc(x) = Ib(x) + \alpha.(Ig - Ib).(1-Ib(x)).Ig(x) \quad \textbf{...(Eq.5)}$$

Our white-balancing approach reduces the quantization artifacts introduced by domain stretching (the red regions in the different outputs). The reddish appearance of high intensity regions is also well corrected since the red channel is better balanced, our approach shows the highest robustness compared to the other well-known white-balancing techniques. In particular, whilst being conceptually simplest, in cases for which the red channel of the underwater image is highly attenuated, it outperforms the white balancing strategy introduced in our conference version of our fusion-based underwater dehazing method.

### 3.2. Multi-Scale Fusion

**Inputs of Multi Fusion**

Since the color correction is critical in underwater, we first apply our white balancing technique to the original image. This step aims at enhancing the image appearance by discarding unwanted color casts caused by various illuminants. In water deeper than 30 ft, white balancing suffers from noticeable effects since the absorbed colors are difficult to be recovered. As a result, to obtain our ***first input*** we perform a gamma correction of the white balanced image version. Gamma correction aims at correcting the global contrast and is relevant since; in general, white balanced underwater images tend to appear too bright.

To compensate for this loss, we derive a ***second input*** that corresponds to a sharpened version of the white balanced image. Therefore, we follow the unsharp masking principle, in the sense that we blend a blurred or unsharp (here Gaussian filtered) version of the image with the image to sharpen.

The typical formula for unsharp masking defines the sharpened image $S$ as $S=I+\beta\ (I - G*I)$, where $I$ is the image to sharpen (in our case the white balanced image), $G*I$ denotes the Gaussian filtered version of $I$, and $\beta$ is a parameter. In practice, the selection of $\beta$ is not trivial. A small $\beta$ fails to sharpen $I$, but a too large $\beta$ results in over-saturated regions, with brighter highlights and darker shadows. To circumvent this problem, we define the sharpened image $S$ as follows:

$$S = (I + N\{I - G * I\}) / 2, \quad \textbf{\textit{...(Eq.6)}}$$

With $N\ \{.\}$ denoting the linear normalization operator, also named histogram stretching in the literature. This operator shifts and scales all the color pixel intensities of an image with a unique shifting and scaling factor defined so that the set of transformed pixel values cover the entire available dynamic range.

### 3.4 Multi-Scale Fusion Process

The pyramid representation decomposes an image into a sum of band pass images. In practice, each level of the pyramid does filter the input image using a low-pass Gaussian kernel $G$, and decimates the filtered image by a factor of 2 in both directions. It then subtracts from the input an up-sampled version of the low-pass image, thereby approximating the (inverse of the) Laplacian, and uses the decimated low-pass image as the input for the subsequent level of the pyramid. In this equation, $L_l$ and $G_l$ represent the $l^{th}$ level of the Laplacian and Gaussian pyramid, respectively. To write the equation, all those images have been up-sampled to the original image dimension. However, in an efficient implementation, each level $l$ of the pyramid is manipulated at native sub sampled resolution. Following the traditional multi-scale fusion strategy, each source input $I_k$ is decomposed into a Laplacian pyramid while the normalized weight maps $W_k$ are decomposed using a Gaussian pyramid. Both pyramids have the same number of levels, and the mixing of the Laplacian inputs with the Gaussian normalized weights is performed independently at each level.

## 4. BLOCK DIAGRAM

In this project, two images are derived from a white-balanced version of the single input and are merged based on a multi-scale fusion algorithm. Block diagram is shown in the Figure 2.

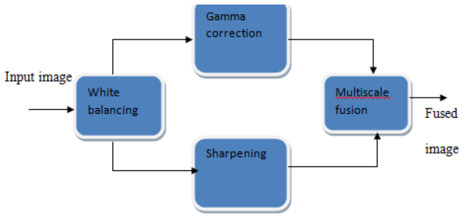


**Fig 4.1.**.Block Diagram of Project

### 4.1 . DESIGN AN IMPLEMENTATION

In this paper our white-balancing aim at compensating for the color cast caused by selective absorption of color with depth. Primarily by removing the undesired color casting due to various illumination or medium attenuation properties. Image fusion is to improve underwater images without restoring. Here the results are executed in MATLAB software .Image processing toolbox is used to perform analysis and algorithm development which perform image segmentation, image enhancement and noise reduction.

### 4.2 SYSTEM ARCHITECTURE:

In this paper a single image is given as input image and our white-balancing approach derived into two images one is the input 1 and input 2 as shown in the Figure using gamma correction and edge sharpening and the two input images are used as inputs of the fusion process. Multi-scale fusion approach is here to examine with three levels by weight maps calculation.

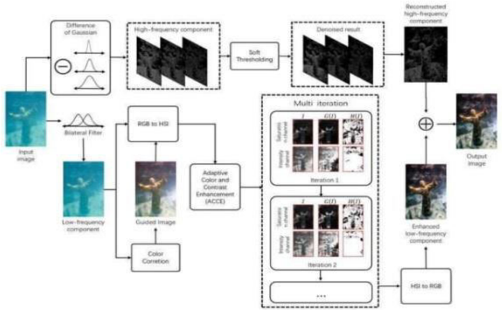

**Fig 4.2.** System Architecture Diagram

The weight maps tends to amplify some artifacts such as ramp edges of our second input and to reduce the benefits derived from the gamma corrected image in terms of image contrast. This second input corresponds to a sharpened version of the white balanced image. Second input primarily helps in reducing the degradation caused by scattering. The weight maps are used during blending in such a way that pixels with high weight value are more represented in the final image.

## 5. OUTPUT SCREENS

**Fig.5.1:** Input Image

**Fig.5.2:**Fused Image

As shown in the Figure 5.Fused image builds on the set of inputs and weight maps derived from single image. This fused image is defined based on number of local image quality. In this Figure we can see the difference between the input image and fused image as the fused image is clear with color and quality of the image. Finally we calculate and get the values of MSE and psnr to know the quality of the image.

| METOD | ENTROPY | MSE | PSNR |
|---|---|---|---|
| HE | 5.974 | 0.46 | 11.80 |
| CLAHE | 7.622 | 0.14 | 14.80 |
| PROPOSED | 7.746 | 0.12 | 18.90 |

TABLE: COMPARSION OF TE METODS

Underwater images are captured in three different dataset to evaluate the proposed method. Different images with different environments, objects, and backgrounds are tested and evaluated using the proposed method. in terms of details and noise, the proposed technique is compared with these two methods in terms of entropy, MSE, and PSNR.

The overall results of the HE indicate that the image is over-saturated and become reddish, and thus image details arereduced. Even the resultant images produced by the displays excellent MSE and PSNR.

## 6. CONCLUSION

In this paper, we have presented an alternative approach to enhance underwater images. Our strategy builds on the fusion principle and does not require additional information than the single original image. We have shown in our experiments that our approach is able to enhance a wide range of underwater images (e.g. different cameras, depths, light conditions) with high accuracy, being able to recover important faded features and edges. Moreover, for the first time, we demonstrate the utility and relevance of the proposed image enhancement technique for several challenging underwater computer vision applications.

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