# Illuminance Estimation in Underwater using Color Constancy

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***Abstract***

Underwater image is not clear in visible because of light scattering and color change in their environment. Haze effect is caused by light scattering which the image is viewed by lower visibility and color change. The water particles in underwater causes the light reflected from objects is absorbed or scattered multiple times. Color changing is caused by different wavelength in underwater environment. The red light possesses longer wavelength and lower frequency, thereby attenuating faster than blue light. This results in the blueness of most underwater images. The scattering and color changing problem such as bluish effect in underwater can be solved by Wavelength Compensation and Image Dehazing algorithm (WCID).The initial step is the distance between object and camera has been estimated and image matting is performed. If any artificial light source is employed that should be removed because it causes various effects in images. After that, the haze effects from color scatter is removed by the image dehazing algorithm. According to different wavelength the attenuation of each wavelength taken into consideration the reverse compensation can be employed to restore the original color. This paper proposes color constancy algorithm that causes the spectral distribution of light source is uniform across the image. However the luminance effects from the artificial light has been removed efficiently and provides the superior quality of the image.

***Keywords***— Wavelength Compensation and Image Dehazing algorithm (WCID), Haze effect, Bluish effect, color constancy, Underwater image, Image dehazing.

## 1.0 Introduction

Underwater imaging is most important for scientific fields of investigation for researchers. Water is the denser substance which is greater than 800 times than air. As soon as light enters the water, it interacts with the water molecules and suspended particles to cause loss of light, color changes, diffusion, loss of contrast and other effects. A photo taken under water at one meter distance is not unlike a telephoto above water at 800 meter distance, both looking bluish while lacking contrast. The way light changes under water is responsible for the typical under water 'atmosphere' and it offers creative possibilities not found on land [1]. Due to concern about the current state of the world's oceans, several large scale scientific projects have begun to investigate the condition of our oceans.

These projects are making use of underwater images to monitor marine species. When the light is enter into water it interacts with water molecules and particles such as phytoplankton cells and it leads to the problem of using visible light imaging in an underwater environment. Underwater vision is plagued by poor visibility conditions producing images with poor contrast and color variation. In the other techniques such as sonar ranging have been used due to the limitation of visible light imaging in an underwater environment. When taking photos in underwater environment it is not like a normal photo looking like more bluish and lacking contrast such as blurred image which is called as haze or Marine snow to get clear image there is the need to dehaze the underwater image. Scientists are now starting to use visible imaging for close range studies due to the fact that alternative techniques produce low resolution images that are difficult to interpret.

Underwater vision plays a important role in Navy applications involving mine detection, diver visibility, and search and rescue. The ability to see better clarity and farther object has always been a central goal of underwater imaging projects. Unlike in the atmosphere, where visibility can be on the order of miles, the visual range in the underwater environment is rather limited, at best on the order of tens of meters, even in the clearest waters. This is the result of combined attenuation effects from both absorption, where photons disappear into water molecules, phytoplankton cells, and detritus, and scattering, where photons bounce away from the original path into different travelling directions. It is mostly the effects of scattering by water and particulates that make the water look dirty or less transparent, resulting in a blurred image recorded by cameras [4]. In underwater environment there is the need to get the better quality of the image.

This paper focus to compensate the light scattering and color changing by using the algorithm Wavelength compensation and image dehazing algorithm (WCID) [5] also provides the haze removing by using dark channel prior[7].In the processing of WCID, it effectively performs the recovery of problems in underwater. However due to artificial light source, it introduce the spherically radiating light different to surface light sources generally used in underwater photography so that the value of luminance is also difficult to estimate accurately. By using the Color Constancy algorithm the luminance is effectively performed [6]. The main concept of the paper is to estimate the luminance in the processed WCID image so that the lacking of the problem due to artificial light source can be solved efficiently.

### *1.0 Problems In Underwater*

The Sun light is the major sources of illumination in underwater photography. The reflection of the light varies greatly depending on the structure of the sea. The amount of light that enters the water also starts reducing as we start going deeper in the sea. In the same way, the water molecules also absorb certain amount of light as a result the underwater images are getting darker and darker as the depth increases [3]. Fig. 1 shows the water surface effects [3]. Here the incident light that enters into the sea causes varying effect the arrow marks indicates that the entering sunlight that causes reflections, diffusions, and directly enter into the water surface. Due to the penetration of light that produces the more blue light effects in underwater that makes more blue color effect in the image. Fig. 2 shows that the red light possesses longer wavelength and lower frequency, thereby attenuating faster than blue light. Here the blue is strongest and red is weakest. This results in the blueness of most underwater images [3]. It illustrates that at the depth of 0m all the colors will appear and it starts reducing when the depth increases. Different wavelengths of light are attenuated at different rates in water. The blue color travels the longest in the water due to its shortest wavelength.

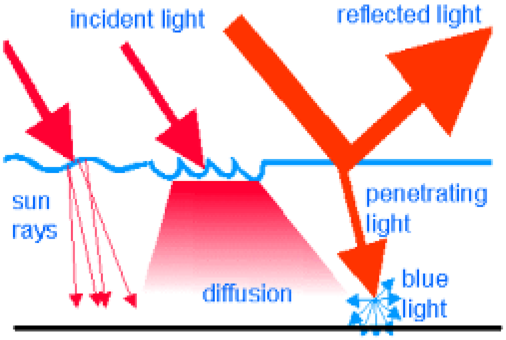



Fig. 1 Water surface effects

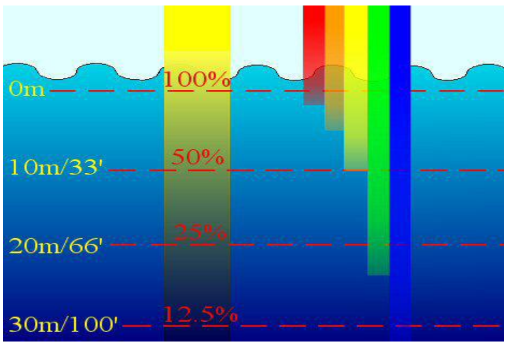



Fig. 2 Color appearance in underwater

***1.1 Related Works***

In general the goal of processing underwater image is to resolve the haze effect as well as to solve the scattering and color changing problem. In this section, the discussion is about related works to enhance the underwater image.

### *A. Dark Channel Prior*

The Dark channel prior is used to remove the haze in underwater images. This image contains very low intensity at some pixels. The minimum intensity in such patch should have very low value. The dark prior image is formulated by:

$$J^{dark}(x) = \min(\min((J^c(y)))$$

(1)

Where $J^c$ is a color channel of J and Ω(x) is a local patch. For the underwater region, the intensity of $J^{dark}$ is low and tends to be zero, if J is a haze-free underwater image and $J^{dark}$ dark channel of J [7].

The low intensities in the dark channel are mainly due to three factors:

- Shadows, for example, shadows of creatures, planktons, plants or rocks in sea bed images.
- Colorful objects or surfaces, for example, green plants, red or yellow sands, and colorful rocks/minerals lacking color in any color channel will result in low values in the dark channel.
- Dark objects or surfaces, for example, dark creatures and stone.

These are the three major things [8] that can cause the low intensity in underwater images. Here the atmospheric light A has been assumed at first. The local patch Ω(x) is a constant. By taking minimum operation in the local patch and the small amount of haze for the distant objects by introducing a constant parameter $\omega(0 < \omega < 1)$ on the haze image equation (1) is

$$\tilde{t}(x) = 1 - \omega \min_{c}\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right) \quad (2)$$

Where the value of $\omega$ is application based [7]. Here the value is taken as 0.65. The soft matting is performed by sparse linear system and it can be given as,

$$(L + \lambda U)t = \lambda \tilde{t}$$

(3)

Where U is an identity matrix and $\lambda$ is taken as $10^{-4}$.

$$I_\lambda(x) = J_\lambda(x) \cdot t_\lambda(x) + (1 - t_\lambda) \cdot B_\lambda,\ \lambda \in \{R, G, B\} \quad (5)$$

where is a point in the underwater scene, $I_\lambda(x)$ is the image captured by the camera, $J_\lambda(x)$ is the scene radiance at point, x,$t_{\lambda(x)}$ is the residual energy ratio of $J_\lambda(x)$ after reflecting from point in the underwater scene and reaching the camera, $B_\lambda$ is the homogeneous background light, and $\lambda$ is the light wavelength. The residual energy ratio $(x)$ can be represented alternatively as the energy of a light beam with wavelength $(x)$ before $d(x)$ and after traveling distance within the water $E_\lambda^{initial}(x)$ and $E_\lambda^{residual}(x)$ respectively formulated as

$$t_\lambda(x) = \frac{E_\lambda^{residual}(x)}{E_\lambda^{initial}(x)} = Nrer(\lambda)^{d(x)} \quad (6)$$

Where the normalized residual energy ratio $Nrer(\lambda)$ corresponds to the ratio of residual to initial energy for every unit of distance propagates and β(λ) is the medium extinction coefficient. The normalized residual energy ratio Nrer depends on the light wavelength transmitted.

The fig 3 shows that the processing procedure for haze free and color corrected image by performing dark channel prior the haze has been removed. Here the image matting is performed to estimate the foreground and background image.

The oceanic water is classified into three categories. Type-I water represent extremely clear oceanic water. Most clear coastal water with a higher level of attenuation belongs to the Type-II class. Turbid upwelling coastal water is listed as Type III. Water types I, II, and III roughly correspond to oligo-, meso-, and eutrophic waters [9].Based on the water type considered, the normalized residual energy ratio

can be adjusted based on that of Ocean Type I, is given by,

$$Nrer(\lambda) = \begin{cases} 0.8\sim0.85\ if\ \lambda = 650\sim750\mu m(red) \\ 0.93\sim0.97\ if\ \lambda = 490\sim550\mu m(green) \\ 0.8\sim0.99\ if\ \lambda = 400\sim490\mu m(blue) \end{cases} \quad (7)$$

During the course of propagation, light with different wavelengths is subjected to varying degrees of attenuation. The colour change of ambient lighting makes the underwater environment turned with a bluish hue. When the airlight incident from air to the water and reaches the underwater scene point with D(X).

The underwater background is brighter point of the image. The foreground and background have been separated during the enhancement processing of the image. This segmentation of foreground and background that depends on the depth map derived [5].

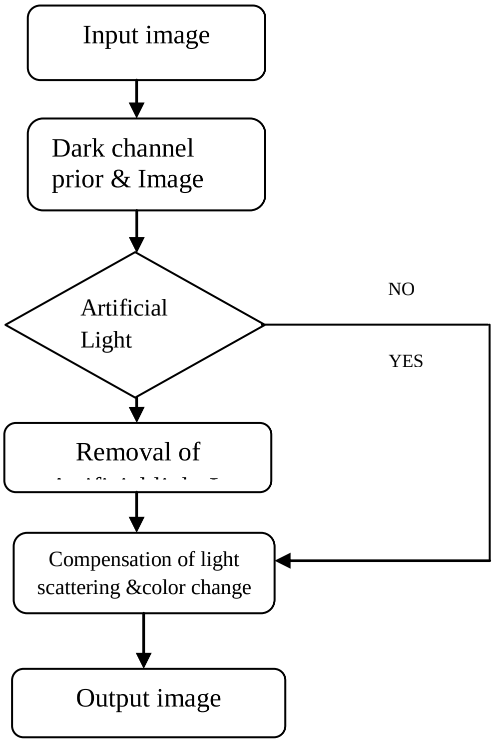



Fig. 5 Processing of WCID

The overall algorithm is used to restore the clarity of the image. The enhancement procedure of WCID is given as follows:

1) Initialize parameters to expected values for chosen water conditions.
2) Converting the image into gray image.
3) Calculating dark channel prior image [7] and atmospheric light estimation [5].
4) Image matting is performed to get the haze free WCID underwater image.

Since there is no other algorithms that solves the light scattering and color change problems effectively also the haze has been removed. The WCID can be possible to use the natural outdoor images.

## 1.0 Proposed scheme

*A. Underwater Color Constancy*

This paper proposes the color constancy algorithms in underwater image to resolve the luminance problem due to the artificial light source used to capture the image. The color constancy algorithm that causes the spectral distribution of light source is uniform across image. However the clarity of the scene is violated due to the multiple light sources present in underwater to capture the scene. It is the patch based illuminate estimation and correction is applied to the modified diagonal model.

There are number of color constancy proposed [10], [11], [12] for reviews. The light source that has the significant influence on object colors in the image [11].The major goal of color constancy is the color has been corrected and defective light source has been removed. The luminance is given by the following equation,

$$L(x, y) = I(x, y) \times R(x, y) \qquad (8)$$

Where the luminance (observed image intensity) is equal to the multiplication of illumination (incident light) and reflectance (percent reflected).

The retinex is the first color constancy method [14]. The retinex process each receptor class independently. The objective is to calculate illuminant-independent lightness values and the lightness values represent perceived color. The retinex is too dependent on composition of surfaces in image and the higher-order processes influence color.

There are two major goals of color constancy [6] that is given by,

- Estimation of chromaticity of light source.
- Correction image to canonical illumination using diagonal model.

The color image consists of RGB and the values of image is $I= (I_R, I_G, I_B)^T$. The value of I that depends on the color of light source $L(\lambda)$, the surface reflectance $R(x, \lambda)$ and the camera sensitivity function $\rho(\lambda)= (\rho_R(\lambda), \rho_G(\lambda), \rho_B(\lambda))^T$.The Lambertian surface at location x can be given as,

$$S_C(x) = m_{obj}(x)\int_{\omega} L(\lambda)\,\rho_C(\lambda)R(x,\lambda)d\lambda \qquad (9)$$

Where $C\in\{R, G, B\}$, ω is the visible spectrum, $m_{obj}$ is the object reflectance and it is the scaling factor which contribute the light reflectance at location x. The observed color light source is OC and it depends on light source $L(\lambda)$ and camera sensitivity function $\rho(\lambda)$. The OC is given by,

$$OC = \begin{pmatrix} OC_R \\ OC_G \\ OC_B \end{pmatrix} = \int_{\omega} L(\lambda)\rho(\lambda)d\lambda \qquad (10)$$

The color constancy that provides uniform lighting across the image. The illuminant estimation is based on white patch algorithm [13] and Grey world algorithm [14]. The white patch algorithm the maximum response of color channels that cause the perfect reflectance. The color channel is the RGB channel. It having the maximum response of separate colors [12] and it is given by,

$$\max_x S_C(x) = k \times oc \qquad (11)$$

The White-Patch and the Grey-World algorithms are shown to be special instantiations of the more general Minkowski framework [16]. The frame work is given as,

$$L_C(p) = \left(\int S_C^{p}(x)dx\right)^{\frac{1}{P}} \qquad (12)$$

Similarly the second order derivative [12] is used to perform the global estimation of light source and third derivative is the Gaussian filter with the scaling parameter. The Methodology design criteria in underwater image for the artificial light source that is based on the scenes containing multiple light sources, work on single image and no prior knowledge or restrictions on spectral distribution of light source.

The color constancy is used to provide the better image enhancement and the procedure for color constancy as follows. Initially the sampling is performed that is based on Grid based, key-point based and segmentation based sampling. After that luminance estimation and combination is performed. Finally the color correction has been done to get the superior quality of the underwater image.

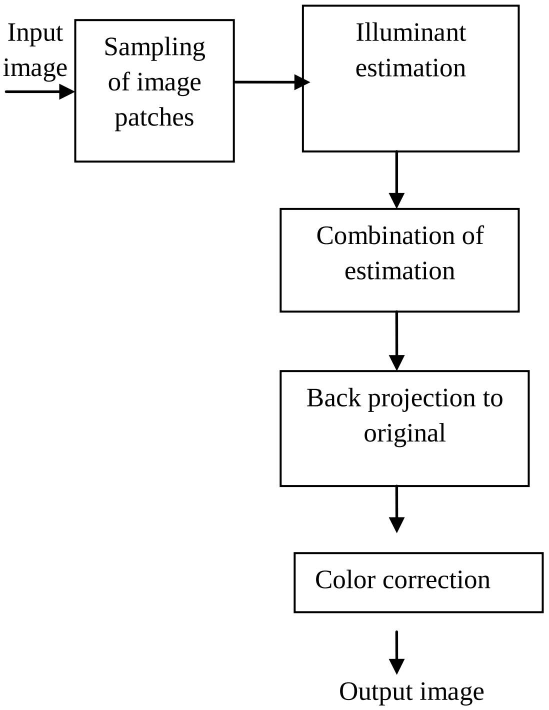



Fig. 9 Block diagram for color constancy algorithm.

The color correction is done by the diagonal model otherwise called as von Kries Model [10]. The equation for diagonal model is given as follows,

$$I^{C} = \Lambda^{u,c} I^{u} \quad (13)$$

Where $I^C$ is the transformed image captured under the canonical illuminant, $I^u$ is the image that is captured due to the unknown artificial light source and $\Lambda^{u,c}$ is the diagonal matrix.

The proposed color constancy method is illustrated in fig. 9. During sampling, the limited patch size is used for sampling to give the accurate estimation [10].

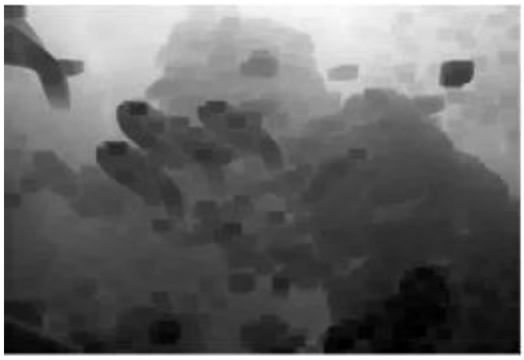
The color of each light source is uniform in all patches. There are three types of sampling methods are used segmentation based, key point based and grid based sampling. Segmentation sampling produces result image between boundary and sample. The grid based sampling each patch containing the different amount of information and the segmentation is based on similar patch size [17]. The key point based sampling [16] that specifies the edges and junctions by using Harris detector. The illuminant estimation is done by patch by patch. Here the local illuminant can be estimated by traditional color constancy algorithm.

After the estimation the chromaticities are grouped by using clustering algorithm and this can be back projected into the image. The estimated light source is used to identify the location of the image. After that each pixel has been illumination has been obtained. Final stage is color correction. While Transforming the input image it appears to be taken under a white light source is an instantiation of chromatic adaptation.

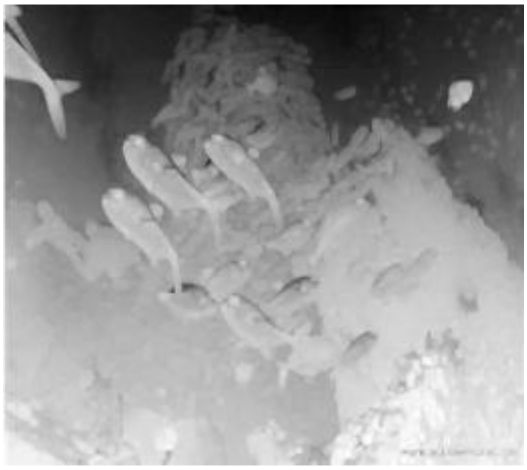
### B. *Implementation of Color constancy*

In this experiment the constant values are given as patch size is 15, Window w is 0.95, Width of the window is 3, Epsilon is given as $10^{-8}$, Wavelength lambda is $10^{-4}$, and t0 value is 0.1. In this paper the MATLAB is used to estimate the haze and resolve the problems in underwater.

a. Haze in underwater image



b. Patch estimation of dark prior image



c. Matted transmitted image from the haze image

d. Red channel reflectivity

e. Green channel reflectivity

f. Blue channel reflectivity

g. Haze free image

The fig 5(a) shows that the underwater image is affected by heavy haze which the image is not clear. Fig 5(b) shows that the gray conversion of the input image. In case of color image the estimation of low intensity in image is complexity. Fig 5(c) and 5(d) shows that the patch estimation and matted transmitted image. Fig (e), (f), (g) is the red, green, blue channel reflectivity and the haze free result is shown in fig 5(h).

The major goal of the dark channel prior in underwater is to estimate the haze on each patch there by removing haze to get the haze free image. The patch estimation is done by gray image and increase the complexity for the estimation of color image. The matted transmitted image is used for transmission finally haze free image has been obtained.

## 2.0 Conclusions

This paper proposes the color constancy algorithm for enhancing the underwater image and performs the illuminant estimation due to the presence of the artificial light source. The WCID algorithm that effectively performs the better clarity of the image the hazy effect causes in presence of scattering and color changing. Illuminance estimation is combined into more robust estimates and local corrections. These corrections are performed in diagonal model. This proposed methodology is used to estimate the illuminant estimation that is done by pixel by pixel there by getting the more clarity vision of underwater image.

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