A Review paper on Underwater Image Dehazing

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***Abstract*: Underwater images usually lack contrast and suffer from color distortion due to light beam scattering and attenuation. Light scattering is due to the presence of suspended particles in water in form of both organic and inorganic material which reflects and deflects the light in an unpredictable manner before it reaches the sensor and results in an image which is low in contrast. Water as a medium readily absorbs light and moreover different wavelengths of light as absorbs at different rates. In this era, underwater environment has attained more attention of scholars and scientists to observe the variation in it, due to human influence.**

***Keywords*: WCID, DWT, IDWT, AHE, Dehazing.**

1-INTRODUCTION: Similar to light traveling in the air, the underwater light propagation suffers from scattering and absorption. Nonetheless, the magnitude of absorption and scattering is enormous. While the light attenuation coefficients in the air are measured in inverse kilometers for an underwater environment it is in inverse meters. Such severe degradation of light poses serious challenges for imaging sensors to capture the information of the underwater area of interest. Unlike air, water is only transparent to the visible part of the electromagnetic spectrum and opaque to all other wavelengths. Furthermore, the constituent wavelengths of the visible spectrum are absorbed in different rates with longer wavelengths are absorbed more rapidly. The decay of light energy in water is truly remarkable. In the crystal clears waters of the middle oceans less than 1% of light energy remain by the depth of 150m. Hence the visibility degradation is such that the object is harder to see beyond the 20m range and in turbid coastal waters the visibility falls below the 5m mark. Also no natural light from sun reaches below 1km of sea. Hence, the amount of light with in water is always less than the amount of light over the surface of water. Therefore images obtained under water generally have low visual quality. The scarcity of light under water is usually because of two unavoidable facts. One, the light under water is loses its true intensity, and second the chances for scattering of light within water is quite high. The immediate impact of this insuffcient amount of light is the color distortion and illumination of the underwater scene visibility. Two of the most deteriorating effect on underwater image quality are the absorption of light energy and random path change of the light beams and at travel in water medium filled with suspended particles.

Table 1.1: Loss of light energy at 1m depth in ocean

Light Energy decay at 1m depth of ocean								
	Violet		Blue-green			Yellow	Orange	Red
λ (μm)	0.3	0.45	0.45	0.51	0.53	0.59	0.62	0.7
open seas, clearest	17%	3%	2%	3%	5%	8.5%	30%	41%
open sea, turbid waters	57%	16%	11%	10%	13%	19%	36%	55%
near coastal sea, average		64%	38%	30%	29%	31%	46%	75%

The part of light energy which enters the water is rapidly absorbed and converted into other forms of energy like heat which in returns makes the water molecules get energized and become warmer and tend to evaporate. Also some of the light energy is used up by the tiny plants based organism which uses it for photosynthesis. This absorption degrades the true color intensity of the underwater objects. As explained in the previous paragraph part of light which is not absorbed by the water molecules may not travel in straight line but follows a random Brownian motion. Presence of suspended

matter in water is responsible for this. Water, particularly the sea water contains dissolved salts and both organic and inorganic matter which reflects and deflects the light beam in new directions and it may also leave the water surface and decay back in air. Light scattering of light in water medium is further divided into two categories. The forward scattering; which is the light beam deflected after hitting the object of interest and reaching the image sensor. This type of scattering usually makes an image appear blur. The other type of scattering is the back-scattering which is the light beam hitting the image sensor without first reflecting back from the object. In a sense the light energy which is not carrying any information about the object. It just adds to degraded contrast of an image.
One way of improving the visibility underwater is by introducing the artificial light source, although it adds its own flavor to the problem. Apart from the problem mentioned above like scattering and attenuation of light, artificial light tends to illuminate the scene of interest in a non-uniform manner and usually produce a bright spotting at the center of and image with darker shades around it. In addition to this the lighting equipment is heavy and costly. Also they required constant supply of electricity either in form of batteries or wired from the surface ship.

Henceforth, the underwater imaging system not only affected with the low light conditions, severely degraded visibility, diminishing contrast, burliness, light artifacts but also restrict color range and random noise. Consequently, the standard image processing techniques which serve us well for terrestrial imaging enhancement need to be modified or abundant completely and we need to come up with new solutions. And by improving the quality of underwater images can lead to better image segmentation, an improved feature extraction and better underwater navigation algorithms to steer autonomous underwater vehicles. Also offshore drilling platforms may also benefit from the clearer imagery for assessing the structural strength of the underwater part of their rigs.

Underwater optical imaging has turn into an amassed research field in current years. However, underwater image enhancement is inspiring due to the complicated physical properties of underwater environments that lead to the visibility degradation and color distortion of underwater images A plan diagram of underwater optical imaging classical is illustrated in Fig. 1(a) where the light netted by the camera is mainly instituted by three components: a direct component (the light reflected from the object that has not been scattered), a forward scattering component (the light reflected from the object that has been scattered at small angles), and a backward scattering component (the light reflected not from the target object but from floating particles). An underwater image is regarded as a linear combination of these three components. The forward scattering component causes blurred image structures whereas the backward scattering veils image edges and details. Simultaneously, as shown in Fig. 1(b), different wavelengths of light are attenuated at different rates in water. Concretely, the red light first disappears since it has longest wavelength or minimum energy, while the blue and green lights show the opposite case. This property results in the underwater images with bluish or greenish tone [1].
Underwater object tracking is pivotal in applications, such as underwater search and rescue operations, homeland and maritime security, deep ocean exploration, underwater robot navigation, and sea life monitoring. These applications require efficient and accurate vision-based underwater sea analytics, including image enhancement, image quality assessment, and target tracking methods. On the other hand, high noise and low-light situations pose enormous challenges for marine image/video analytics understanding. Further exacerbating these issues are the inherent underwater distortions including absorption and scattering of light causing low contrast, no uniform illumination, diminished colors, and fuzz. This makes computer vision tasks for detection, recognition, and tracking in underwater environments much more challenging than in open-air environments [2].

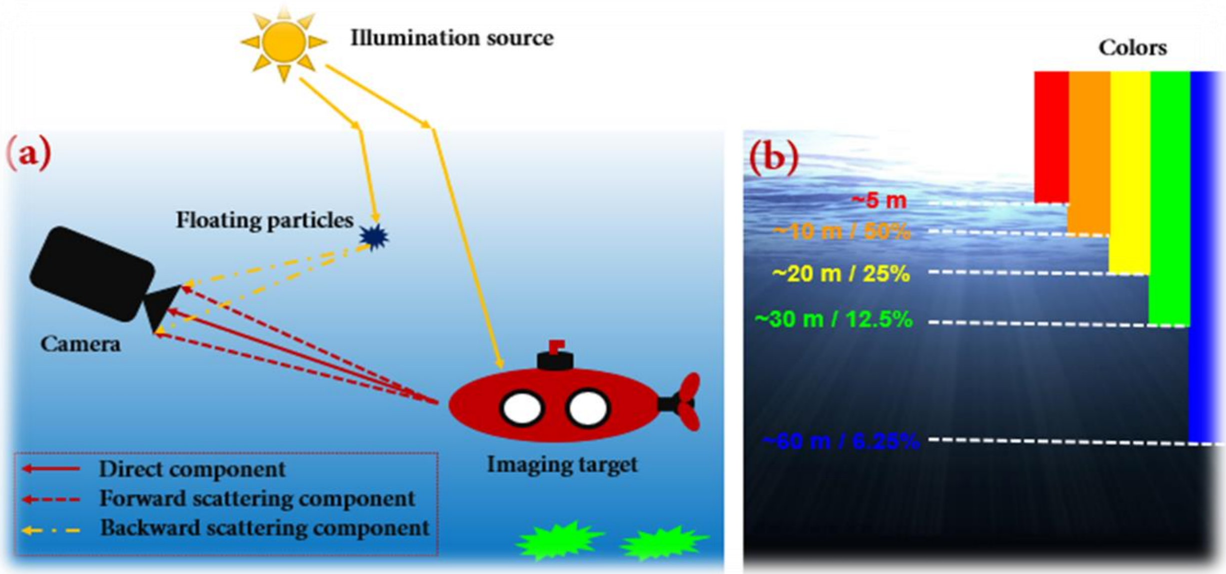

Figure 1.1 Schematic diagrams of (a) underwater imaging model and (b) light

Attenuation at different rates in water.

Studies have included identifying, detecting, analyzing objects, living organisms at the macro, and sometimes micro-levels focusing on a category of topics in recent years. It is known that dynamic light diffusion is a physical method used to determine the distribution of particles in solutions and suspensions. These non-destructive and fast methods are used to determine the particle size in the range of few nanometers to microns. It is also known that the emission wavelength of a medium in question reflects the amount of its deviation. The light emission is also overshadowed by the accumulation of the water particles. Thus, the particles can further increase the deviation of the angle and the orientation of direct motion of light in water [3].

Underwater robotics represents a fast-growing research area. Recently, great efforts are being made in developing autonomous underwater vehicles (AUVs) deployed to tackle challenging engineering problems such as underwater archaeological exploration, garbage collection, underwater rescue operations, ocean floor exploration, and military operations. Many of these applications require real-time interpretation of images/videos for the AUV to intelligently perceive the environment and take follow-up measures. Underwater images that are degraded due to the transmission of light in water could hinder the correct interpretation of the camera input, thereby inhibiting the capability of the vehicle to interact with the environment. Thus, for the above applications, the first step before any downstream task (object recognition, object classification, or object detection) is image enhancement [4].

1.2 Characteristics of Underwater Images

Unlike conventional imaging taken above sea in open air, underwater photography shows a strong dominance of bluish and greenish colors. On the other hand, the strong attenuation of light in the water with respect to the air and a greater diffusion of the incident light have the consequence of considerably reducing the visibility. Thus, objects at distant distances from the acquisition system or the observer but also at medium distances, or even relatively short in some cases, are hardly visible and poorly contrasted with respect to their environment [5].

In addition, in the presence of particles suspended in water (sand, plankton, algae, etc.), the incident light is reflected by these particles and forms a kind of inhomogeneous mist that adds to the scene observed. This turbidity of the water, most often white, also affects the visibility but also the colour dynamics of the objects contained in the image by tarnishing or veiling them. On the other hand, the formation of an underwater image is highly dependent on the nature of the water in which it was acquired. Natural waters can have very varied constitutions in terms of plants or minerals dissolved or suspended in water. The behavior of the propagation of light in such a medium is strongly governed by this factor [6].

1.2.1

1.2.2 Bio-optical Properties of Natural Waters

Natural waters and their IOPs depend on the various elements that go into their compositions. While clear waters will mostly diffuse blue light, organic-rich waters will emit a greener, sometimes even yellow. Numerous measurements have been made which have made it possible to establish a link between the optical properties of absorption and diffusion and the chemical nature of the main components of the water [7].

2-Literature review: 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 categorises and groups them in relation to their distinguishing features.

Peixian Zhuang et. al [8], developed a Bayesian retinex algorithm for enhancing single underwater image with multiorder gradient priors of reflectance and illumination. First, a simple yet effective color correction approach was adopted to remove color casts and recover naturalness. Then a maximum a posteriori formulation for underwater image enhancement was established on the color-corrected image by imposing multiorder gradient priors on reflectance and illumination. Meanwhile, a complex underwater image enhancement issue was turned into two simple denoising sub problems where their convergence analyses were mathematically provided, and their solutions was derived by an efficient optimization algorithm. Besides, the proposed model was fast implemented on pixel wise operations while not requiring additional prior knowledge about underwater imaging conditions. Final experiments demonstrated the effectiveness of the proposed method in color correction, naturalness preservation, structures and details promotion, artifacts or noise suppression.

Yecai et. al [9], proposed a new multiscale dense generative adversarial network (GAN) for enhancing underwater images. The residual multiscale dense block was presented in the generator, where the multiscale, dense concatenation and residual learning can boost the performance, render more details, and utilize previous features, respectively. And the discriminator employs computationally light spectral normalization to stabilize the training of the discriminator. Meanwhile, nonsaturating GAN loss function combining loss and gradient loss was presented to focus on image features of ground truth. Final enhanced results on synthetic and real underwater images demonstrate the superiority of the proposed method, which outperforms nondeep and deep learning methods in both qualitative and quantitative evaluations.

Jahidul et. al [10], presented a conditional generative adversarial network-based model for real-time underwater image enhancement. To supervise the adversarial training, an objective function that evaluates the perceptual image quality based on its global content, color, local texture, and style information was formulated. Author also presented EUVP, a largescale dataset of a paired and an unpaired collection of underwater images (of 'poor' and 'good' quality) that were captured using seven different cameras over various visibility conditions during oceanic explorations and human-robot collaborative experiments. In addition, author performed several qualitative and quantitative evaluations which suggested that the proposed model could learn to enhance underwater image quality from both paired and unpaired training. More importantly, the enhanced images provided improved performances of standard models for underwater object detection, human pose estimation, and saliency prediction.

XINJIE et. al [11], proposed a hybrid framework for underwater image enhancement, which unifies underwater white balance and variational contrast and saturation enhancement. In the framework, the improved underwater white balance (UWB) algorithm was integrated with histogram stretching, aiming to better compensate the attenuation difference along the propagation path and removed undesired color castings. In addition, a variational contrast and saturation enhancement (VCSE) model was developed based on the enhanced result obtained from UWB. The advantages of VCSE model lie in the improvements of contrast and saturation as well as the elimination of hazy appearance induced by scattering. Moreover, a fast Gaussian pyramid-based algorithm to speed up the solving of VCSE model was designed. The improvements achieved by proposed method included more effective in color correction, haze removal and detail clarification. Extensive qualitative and quantitative assessments demonstrated that the proposed approach obtained high quality outcomes, which outperformed several state-of-the-art methods.

2.2-THE PROCESSING OF UNDERWATER IMAGES

A large number of underwater image processing methods have been developed. Different approaches have been considered: inversion of the light propagation phenomenon, colour filtering, frequency filtering, etc. In this study, we propose to expose approaches based on colour filtering methods based on the physical model on the one hand, and colour consistency methods allowing unsupervised processing. These methods rely on an adjustment of the luminance of the pixels of the image on each of the colour channels to improve the contrast and colours of the image [12]. Existing methods of processing by the physical model require knowing one or more references allowing the establishment of the processing chain, as well as some knowledge on the conditions of acquisition. Chromatic adjustment methods are unsupervised but provide a chromatic correction that is not necessarily in keeping with reality. The goal is therefore to reconcile these two aspects: unsupervised and chromatic adjustment based on the physical model and there four methods that have particularly caught our attention because they provide good correction results [13] Several methods based on the propagation model exist. Based on an estimate of the attenuation, they use controlled acquisition conditions. These systems make it possible to estimate the spectral attenuation and diffusion coefficients necessary for the model either by having reference in the image or by using more elaborate specific systems than the simple camera. This section presents two methods corresponding respectively to each of these two categories.

2.2.1- UNDERWATER IMAGE CORRECTION BASED ON SPECTRAL DATA

This correction method, proposed by [14], is based on an estimate of the attenuation coefficient. The estimation is performed using known reflectance values of a grey reference target present in the images considered. This object, named Spectralon, consists of a plastic surface with the property of reflecting light very strongly by following a Lambertian reflection of almost perfect light [14]. On the other hand, the camera used, its properties and its position are known. Thanks to a priori knowledge about the content of the scene, the photometric behavior of the objects and the acquisition system, the luminance reaching the spectral is known as well as the value of the luminance reaching the camera for each of the three chromatic channels. In this method, the camera is placed vertically at the ocean floor. Thus, the size of the water column corresponds to the depth. The luminance can therefore be written as a function of the depth represents the luminance received By the camera. The author makes the following three hypotheses allowing correction [15]:

• The photographic seabed has a reflection following a Lambertian distribution;
• The spectral receives as much light as the surrounding environment;
• The camera has stable sensitivity curves with respect to illumination variations.

Having all these elements, it is possible to express the attenuation coefficient as a function of depth and luminance. The reflectance at a given point of an object corresponds to the ratio of the incident luminance (incoming) Lin received by the spectral and of the diffused luminance (outgoing) Lout received by the camera [12] Having measured the depth and the attenuation coefficient, Peng, Zhao, and Cosman, (2015) applied the Beer's law, for all the pixels of the image and to find the value corrected pixels. We could not reproduce the experiment, which involves an acquisition campaign with the reference object. As far as one can judge by the results given in the correction is of good quality, from a visual point of view. However, the study is limited to clear water and photographs taken in shallow waters. It is likely that high turbidity of the water causing white scattering of the incident light would distort the estimation of the attenuation coefficient and background luminance. Moreover, this method requires mastered acquisition conditions illumination, depth, position of the camera, etc.).

3-Conclusion: **-** Dehazing methods have become useful in many computer vision and image processing application like underwater imaging, video surveillance, image composting, satellite imagery etc. This paper contains an abstract view on various methods proposed in previous years for single image haze removal. Through this survey examined the different types of prior/restoration methods and the optimization approaches for the multi-scale fusion and enhancement of hazy image's quality. This paper presents few papers related to haze removal and dehazing techniques.

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