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Survey on Visibility Restoration of Underwater Optical Images and Enhancement Techniques

Aditi Mehrolia, Prof. Aditya Patel

M. Tech. Scholar, Department of Computer Science and Engineering, LNCT, Bhopal, India

Assistant Professor, Department of Computer Science and Engineering, LNCT, Bhopal, India

ABSTRACT: We have investigated the problem of underwater hazy image enhancement and restoration in this paper studied. Underwater image processing has several applications in the field of oceanic research work and scientific applications such as archaeology, geology, underwater environmental assessment, laying of long distance gas pipelines and communication links across the continents which demand geo-referential surveying of the oceanic bed and prospection of ancient shipwreck. There are many difficulties for undersea optical imaging. The submerging of a camera underwater requires adequate housing. The maneuvering of the camera with the help from remote place or in person at the site is likewise a complex task. However, the major challenge is imposed by underwater medium properties. Underwater haze image enhancement has gained widespread importance with the rapid development of modern imaging equipment. However, the contrast enhancement of single underwater hazy image is a challenging task for scientific exploration and computational applications. At greater depths, due to attenuation in light propagation, the underwater images are prone to inferior visibility.

KEYWORDS: Multi-unit Fusion, Biometic System, Iris Images

I. INTRODUCTION

A large part of our planet's surface is covered by oceans and the health of our planet is governed by these water resources. The study of underwater flora and fauna is just an indispensable part of oceanic research work [1]. Underwater surveys feature in scientific applications such as archaeology [2], geology [3], underwater environmental assessment [4], and laying of long distance gas pipelines and communication links across the continents, demand geo-referential surveying [5] of the oceanic bed. Oceanic exploration is also concerned with prospection of ancient shipwreck [6]. So underwater optical imaging science has become critical and moreover a challenging area of research. In the past, Sonar based equipment had been widely used by marine researchers to locate shallow water fish, wrecks etc. The images that are generated from Sonar imaging system suffer from clarity issues and prevalent noise, which demand selective filtering [7] [8] [9]. Though it offers long distance visibility and efficient target detection, the resolution aspect for short-range is limited [10]. The noisy environment, especially in the sonar sub-band, added its own complications. But certain imaging applications demand high resolutions at shorter distances, so optical imaging devices have started finding a foothold. However, in spite of high resolution, the optical imaging too has its own shortcomings on account of the image formation and degradation process in the underwater scenario.

Capturing underwater images is more difficult than acquiring conventional outdoor scene images. The first underwater picture was taken by W. Thompson in 1856 in England [11]. The photographer lowered a camera in housing in Weymouth Bay and the shutter was operated from an anchored boat. The exposure time used was 10 minutes. This experiment resulted in flooding of the camera, however the film was salvaged. Today, such underwater photography is performed using advanced cameras with scuba diving. There are many difficulties for undersea optical imaging. The submerging of a camera underwater requires adequate housing. The maneuvering of camera with the help from remote place or in person at the site is likewise a complex task. However, the major challenge is imposed by underwater medium properties. The two foremost underwater phenomenon affecting the outcome and visual aspect is light attenuation and scattering [12]. As the distance between camera and object increases, the scattered light renders lower screen contrast in underwater images. As evident, scattered light component does not carry any scene information and thus underwater optical imaging becomes tedious. Research has been carried out to gauge the wideband attenuation coefficients per color channel in underwater images. However, these findings are relatively limited, as the parameters become sensitive to the original color and the distance between object and camera [13].

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The parameters of scattering play a vital role in recovering the dehazed image. but, it has implications as these values tend to vary for the same type of water body at different places on account of turbidity, temperature, salinity and turbulence to name a few, which further demands precise calibration. For clean shallow water bodies, ambient light is sufficient to capture quality images. But, for deep sea underwater imaging, an artificial source of lighting is must to capture images. This source of light results in two problems. The first is a color cast of illumination source formed on the captured image, which requires a suitable whitebalancing approach to address the problem. Second, this artificial source of lighting tends to create non-uniform illumination, with a bright spot at the center which radially decreases from the center of the image. Underwater optical imaging suffers from light attenuation, which results on account of light absorption by water which increases exponentially with the depth and affects all the wavelengths to varying degrees [14]. The effect of wavelength dependency for gradual color attenuation is as shown in Figure 1.

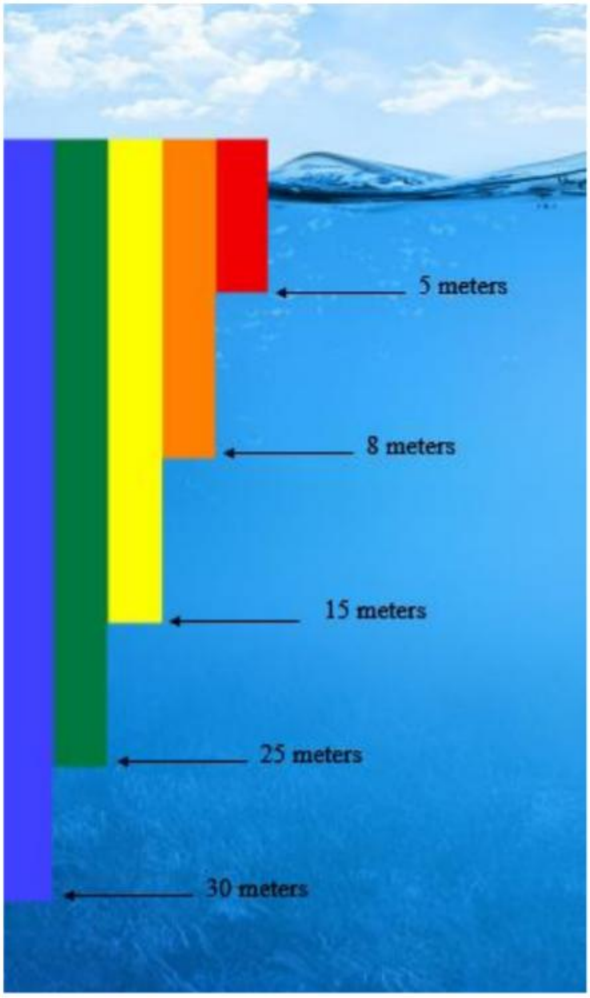

Figure 1: Illustration of the color attenuation for different wavelength at varying depths in underwater

II. LITERATURE REVIEW

RajniSethi et al. [1],proposed YUV color space based turbid underwater image enhancement using filtering approach in the frequency domain. The YUV color model is defined in terms of one luma (Y) and two chrominance (UV) components. The technique is comprised of numerous independent algorithms. In the first step repetitive wave patterns are removed using filtering based on spectral analysis. The problem of non-uniform lighting is corrected using homomorphic filtering followed with wavelet noise reduction. The resultant image requires smoothing yet preserving the edge information. This is performed by applying anisotropic filtering. Further, the image intensity is enhanced by contrast stretching. The image is subsequently transformed back to RGB color space followed with color normalization. However, the resulting image exhibits distorted output in terms of color fidelity.

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H. Wang et al. [2],presented an ICM model wherein the underwater image is dynamically stretched for entire range in RGB color space followed with contrast stretching of the resultant image for I and S component in hue intensity saturation (HIS) color space. This method is simple and effective and is ideally suited for underwater images with minimal haze component. Color cast issue was addressed by modifying red and green channels in RGB color space using von Kries hypothesis followed by contrast correction in Unsupervised Color Model (UCM) algorithm.

Y. Wang et al. [3],presented a PDSCC technique for underwater image contrast enhancement based on a 3D rotational technique to shift underlying image pixel distribution. This technique extends the 3D rotational matrix method. Basically it is a color correction method wherein the authors employ a shifting process on the pixel distribution of a color image to correct its white reference point and ensure the white reference point is achromatic. However, the method fails to improve the overall contrast significantly. Another drawback of this system is that it relies on conventional color estimation processes such as Gray World and White Patch algorithms. Though, not specifically designed for underwater scenario, but authors in their research article have implemented the algorithms for some underwater images.

C. O. Ancuti et al. [4], proposed yet another algorithm based on DIRS method to overcome the limitations of ICM and UCM, by using two-step algorithm viz., contrast correction and color correction by adopting modified Von Kries theory followed with global stretching of the histogram. The stretched histogram is then decomposed into two parts and histogram stretching is applied based on Rayleigh distribution. The two images are then combined back using an averaging rule. The resultant image is further processed in the hue saturation value (HSV) color model.

C. Ancuti et al. [5], proposed underwater image and video enhancement using fusion to combine different weighted images using saliency, luminance, and chrominance via filtering. This was the first recorded work for the enhancement of underwater images using fusion approach based on Laplacian pyramid. The authors specifically validated the selection of white balancing algorithm for underwater images. Although the contrast of the output images appears increased, the problem associated with it is, as reflected in the results section, the processed images are non-uniformly enhanced and does not appear natural.

T. Çelebi et al. [6], proposed a simple but effective image prior, a dark channel prior (DCP) to remove haze from a single input image. The dark channel prior is a kind of statistics of outdoor haze-free images. It is based on a key observation that most local patches in outdoor haze-free images contain some pixels whose intensity is very low in at least one color channel. Using this prior with the haze imaging model, one can directly estimate the thickness of the haze and recover a haze-free image. As the authors have pointed out, this model can fail if the haze imaging model itself is not physically valid. But for any other situation, transmission for involved channels may be not common so different approach needs to be implemented for such situations. This method has been adopted by various researchers for underwater image enhancement for estimating a rough distance map, novel priors, blurriness, adaptive restoration etc.

L. Chao et al. [7],presented his studies on variable attenuation amongst different color channels. As light is transmitted from subject to observer it is absorbed and scattered by the medium it passes through. In mediums with large suspended particles, such as fog or turbid water, the effect of scattering can drastically decrease the quality of images. The authors proposed an algorithm for removing the effects of light scattering, referred to as dehazing in underwater images. The key contribution is to propose a prior that exploits the strong difference in attenuation between the three image color channels. But the prior proposed has difficulty determining the depth of the large solid objects similar in color to hazy veil. The authors have also outlined additional method to compensate for attenuation in addition to scattering. The resultant image however suffers in case of dense haze.

J. Y. Chiang et al. [8],described a strategy to enhance underwater videos and images. It takes a low computation time and delivers a high-quality result as documented. The authors use the contrast stretching in the proposed method to improve the contrast of an image and perform color correction to equalize the means of each color channel. The color of underwater image is rarely balanced correctly, and prominent blue or green color can be suppressed by this step without taking into account the absorption phenomena. In order, to overwrite the limitations of the underwater medium, authors define that two inputs represent the contrast stretched and clip limited adaptive histogram equalization.

Duarte, F. et al. [9], described a novel method to enhance underwater images by image dehazing. As discussed earlier, scattering and color change are two major problems of distortion for underwater imaging. Scattering is caused by large suspended particles, such as turbid water which contains abundant particles sometimes known as marine snow. Color change or color distortion corresponds to the varying degrees of attenuation encountered by light traveling in the water with different wavelengths, rendering ambient underwater environments dominated by a bluish tone. The key contributions proposed being, new underwater model to compensate for the attenuation discrepancy along the propagation path, and proposal of a fast joint trigonometric filtering dehazing algorithm.

A. Galdran et al. [10],adopted and extended work of DCP which is primarily meant for atmospheric haze removal by recovering the dehazed image using the red channel of RGB color space, as the red color channel is the most attenuated and contributes maximum to formation of dark channel image in DCP. Authors proposed a technique to locate the portion of the image affected with artificial illumination within the scene. The major issue with this algorithm is the prior assumption of red color being the most affected channel. Contrary, if we obtain the mean intensity of the underwater images for the varied set, we find that in some cases the blue color wavelength is the most attenuated channel. So this can be considered upon as a major shortcoming of this work.

Table 1: Summary of Literature Review

Title	Author	Methodology	Conclusion
Fusion of Underwater Image Enhancement and Restoration	RajniSethi	Underwater image using enhancement and restoration	Simple and computationally less intensive
Low-rank matrix recovery via smooth rank function and its application in image restoration	H. Wang, R. Zhao, Y. Cen, L. Liang, Q. He, F. Zhang and M. Zeng	Image restoration using low-rank matrix	Higher approximation performance
A deep CNN method for underwater image enhancement	Y. Wang, J. Zhang, Y. Cao and Z. Wang	Image underwater using CNN	Lees computation time
Color balance and fusion for underwater image enhancement	C. O. Ancuti, C. Ancuti, C. D. Vleeschouwer and P. Bekaert,	Underwater image enhancement using image fusion	Less entropy of the system
Enhancing underwater images and videos by fusion	C. Ancuti, C. O. Ancuti, T. Haber and P. Bekaert	Underwater images using enhancing	Improved global contrast
Visual enhancement of underwater images using empirical mode decomposition	T. Çelebi and S. Ertürk	Underwater images using empirical mode	Entropy and average gradient
Removal of water scattering	L. Chao and M. Wang	underwater images using scattering	original clarity of images

III. IMAGE FUSION

Image processing is one kind of signal processing for this image acts as input, it may be either photo or video frame and the outcome of image processing may be either an image or a set of characteristics related to the image. Most of the image-processing techniques, image of two-dimensional signal is treated as input and standard signal-processing techniques are applied to it. Image and video compression is an active application area in image processing. In the field of Image processing, image fusion has received a significant attention for remote sensing, medical imaging, machine vision and the military applications. A hierarchical idea of image fusion has been proposed for combining significant information from several images into one image.

The aim of image fusion is to achieve improved situation assessment and/or more fast and accurate completion of a pre-defined task than would be possible using any of the sensors individually. Mainly image fusion requires precise techniques and also good understanding of input data.

A solution to this problem is provided by the double-density complex DWT, which combines the characteristics of the double-density DWT and the dual-tree DWT. The double-density complex DWT is based on two scaling functions and four distinct wavelets, each of which is specifically designed such that the two wavelets of the first pair are offset from one other by one half, and the other pair of wavelets form an approximate Hilbert transform pair. By ensuring these two properties, the double-density complex DWT possesses improved directional selectivity and can be used to implement complex and directional wavelet transforms in multiple dimensions.

The requirement for the successful image fusion is that images have to be correctly aligned on a pixel-by-pixel basis. In this project, the images to be combined are assumed to be already perfectly registered. The Figure 1 shows the top-level block diagram of image fusion using wavelet transform. The two input images image 1 and image 2 that are captured from visible and infrared camera respectively are taken as inputs.

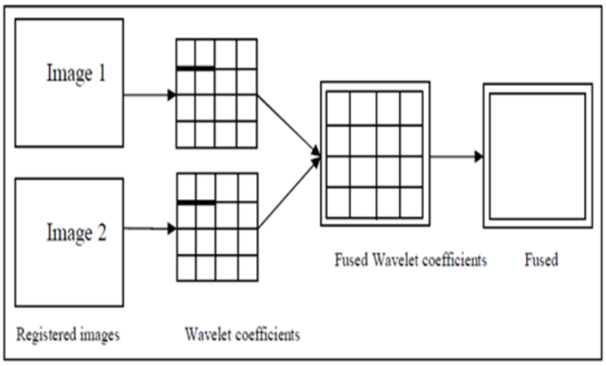

Figure 2: Block diagram of DWT based image fusion

IV. METHODOLOGY

It is the image background part that contributes to haze as seen. So separating the two regions, has a tendency to enhance the image in a better way. As we have discussed earlier, the image is subdivided into the foreground and background parts and dehazing is applied individually to each of the parts and then combined at the final stage. In this chapter, we propose segmentation of the underwater image into foreground and background component based on k-means clustering using intensity profile. It is widely used techniques for the segmentation of a data range into k groups.

The k-means algorithm works well in underwater oceanic images if the nonhomogeneous haze is distinct or well separated from each other. The term nonhomogeneous haze refers to the condition where in haze quantity is not equally distributed across the entire image. Rather, in realistic scenario we can observe that some portion of the image is laden with more haze content and in certain areas the amount of haze is minimal. So this clustering approach work efficiently if the haze coverage portion is distinct and which can be visually distinguishable so as to decide the number of clusters to be formed. The only shortcoming of this algorithm is that it requires apriori specification about the number of clusters, and as such at the same time the number of such clusters for image segmentation possible should be few for efficient implementation. In our case, we have partitioned the image into two parts. The partitioning of an image and dehazing process is as shown for one underwater image in Figure 3.

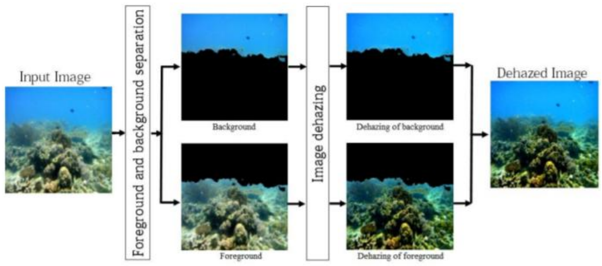

Figure 3: Segmentation of underwater image and dehazing.

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V. CONCLUSION

The main challenges in the field of underwater image restoration are the attenuation of color profiles and scattering on account of suspended particles otherwise known as marine snow. We have attempted to address the underwater vision restoration and enhancement issues. Underwater image processing is a comparatively new area of research and lots of things are yet to be explored. Regarding the course of future work, there are numerous problems to be tackled which will help ocean engineering science in a big way. Understanding the profile of turbidity still remains the major task. It is a challenge to develop an underwater image formation model taking into consideration a turbidity effect, which will be a complex topic to be solved.

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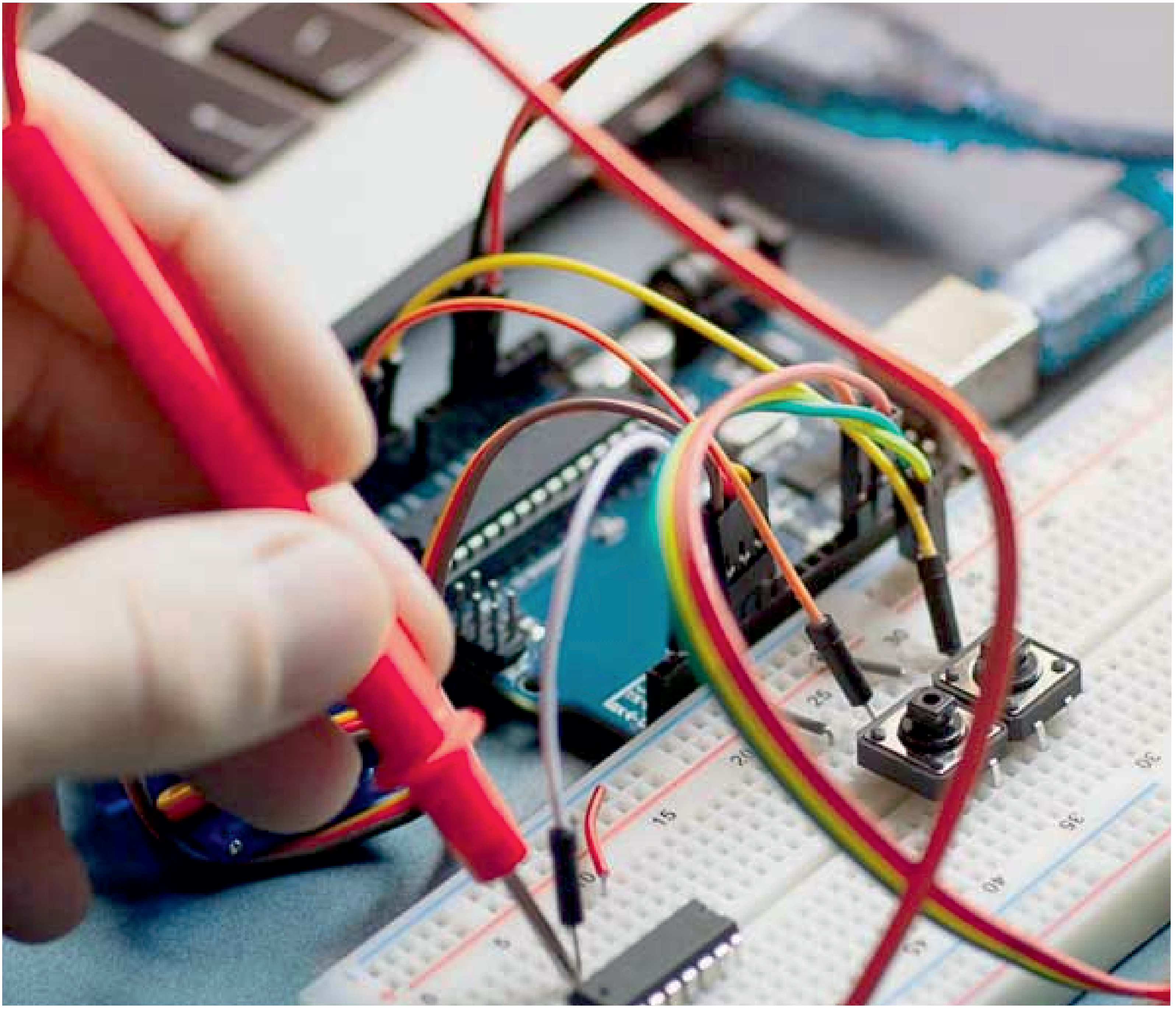

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