A Survey on Underwater Image Restoration using Single Color Channel Prior

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Abstract - Image restoration is the process of recovering an image that has been degraded by using a priori knowledge of the degradation phenomenon. Restoration techniques involve modeling of the degradation function and applying the inverse process to recover the original image. This process is processed in two domains: spatial domain and frequency domain. Image restoration is one of the prime areas of image processing and it is very much objective .The restoration techniques are based on mathematical and statistical models of image degradation. Denoising and deblurring tasks come under this category. Its objective is to recover the images from degraded observations. The techniques involved in image restoration are oriented towards modeling the degradations and then applying an inverse procedure to obtain an approximation of the original image. Noise in an image is a very common problem. An image gets corrupted with noise during acquisition, transmission, storage and retrieval processes. Efficient suppression of noise in an image is a very important issue. Denoising finds extensive applications in many fields of image processing. Image Denoising is an important pre-processing task before further processing of image like segmentation, feature extraction, texture analysis etc.

Keywords- Image Denoising, Underwater imaging, underwater image restoration, image restoration techniques, image processing.

I. INTRODUCTION

There are numerous ways to study the underwater world. A possibility to cover large geographic areas is given by remote sensing from satellites such as Landsat and aerial photography. Both these techniques provide estimates of coral health if underwater features can be properly identified. There are advantages and disadvantages with both these techniques. It is possible to study water properties but with the expense of low spatial resolution in case of Landsat data. Hyperspectral satellite-borne sensors offer high spectral resolution at potentially lower cost than higher spectral resolution airborne sensors. However, for small scale projects, the most economical systems are off the shelf cameras. In situ measurements are sometimes used as a complementary technique for remote and airborne sensing and can provide important information about the water column, which gives a basis for quality analysis. In situ measurements require usage of camera systems when discrimination of small featured benthic habitats is needed. There are numerous methods for extracting values for water quality from spectral data measured under the water surface. These values can be used to estimate e.g. the chlorophyll or yellow substance concentrations of these waters, the latter often referred to as dissolved organic matters. Water column properties are affected by the amount of dissolved organic matters and suspended particles, which are always present.

Light, that penetrates the water body, is attenuated at a rate that depends mostly on the concentration of small particles and due to the absorption properties; light at longer wavelengths disappears first. Particles, which are smaller than a particular wavelength, will cause a regular Rayleigh scattering and larger particles will dictate in what manner light is reflected, transmitted and absorbed in a more irregular way.

The camera itself together with a reflectance standard of known reflectance can be used to estimate the coefficients. This works well for some images. However, if the bottom reflectance is very high or very low, light reflected from the bottom will have a significant impact that need to be taken into account. When that factor is added to the correction model the fraction of the images that can be corrected in a satisfactory way increases. A simplified approach to extract diffuse attenuation coefficients from the underwater images would give an easy way for scientists to study the colour information from different corals or bottoms at a resolution that is superior to satellite or airborne imagery.

Taking pictures under the water is all about light and how it interacts with the small particles that water consists of. Underwater photographers usually setup a pair of strobes on the camera as an extra light source. The drawbacks are that the photographed object may be too large for conventionally mounted strobes, or the photographer working with strobes at depth may be unable to approach the object close enough to accommodate the limited illumination range of strobe lights [20]. In either case, the result is that the object is illuminated solely by ambient light in which red and yellow wavelengths may be deficient or totally absent when deep enough.

The magnitude and spectral dependence of the solar radiation reaching the earth's surface are highly variable functions of the solar angle from the zenith (i.e. of the time of day, season and latitude) and of atmospheric conditions. In fact, the amount of light that reaches objects under the water depends strongly on the solar angle [6]. Irradiance E refers to photons incident onto a surface, where light that reaches the object under the water comes from the whole upper hemisphere and is referred to as downwelling irradiance E_d, see Figure 1.1.

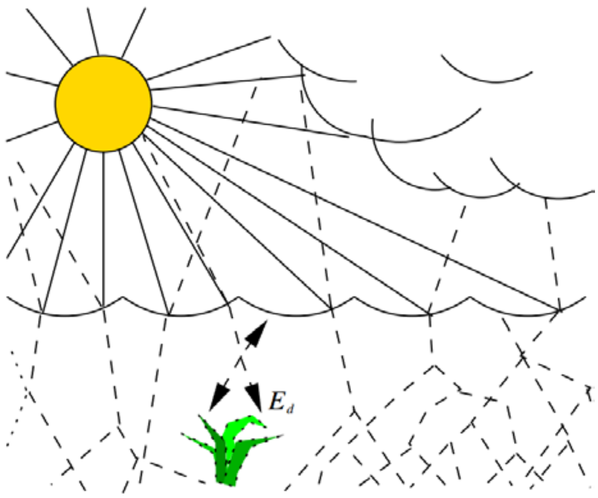

Figure 1.1 Illustration of light field under the water surface.

II. UNDER WATER IMAGE RESTORATION

In underwater images blue tones are dominant due to the optical properties of water. Most of colour balancing methods are based on subjective user supervised approaches with aid of general purpose image processing software. There are theoretical studies on how to connect spectral information from remotely sensed images to optical characteristics of water however, no algorithms are developed to apply the obtained information to correct colours underwater images. It seems feasible that image processing should be possible to use to remove or at least significantly reduce the bluishness in the imagery. A number of works have addressed this issue. E.g some authors used a de-mosaicing technique in order to estimate the value of pixels that are unknown due to lack of light under the water. However this reconstruction method gives low saturated colours in the image, which makes it unsuitable for our application. The some authors use regression models to correct colours, however to provide satisfactory results the described method requires a high number of observations. In the applications suggested in this work the divers are limited by the amount of time they can remain under water and thus cannot take a large number of images.

When a substance absorbs light of a certain wavelength (colour), it depletes the transmitted light in precisely those wavelengths that are absorbed. For this reason, a solution that appears blue to the human eye does not absorb blue light. Rather, it is blue because it absorbed orange light, and allows all other wavelengths to pass unhindered (giving a bluish colour to the transmitted light. Light of longer wavelengths will be absorbed prior to shorter wavelengths. Blue light originates from relatively short wavelengths, which are of a higher energy and thus remains longer when descending under water.

Image Enhancement Methods

The process of improving a degraded image to visibly look better is called image enhancement. Due to the effect of optical back-scatter, the images in a scattering medium have low contrast. By improving the image contrast, it is expected to increase the visibility and discern more detail. There are different definitions for measuring image contrast. There are different techniques to improve the contrast of an image. These techniques can be classified in to two approaches, hardware based and non-hardware based approach.

- Histogram Equalisation

Histogram equalisation (HE) is the most common enhancement method because of its simplicity and effectiveness. The operation of HE is to redistribute the probabilities of gray levels occurrences in such a way that the histogram of the output image to be close to the uniform distribution. Histogram equalisation does not consider the content of an image, only the gray level distribution. Different HE methods have been developed. These methods can be generally classified in to two categories, global and local. Global HE processes the histogram of the whole image. Although it is effective, but it has important limitation. Global HE stretches the contrast over the whole image, and sometimes this causes loss of information in dark regions

- Unsharp Masking

Unsharp masking (UM) is the other common image enhancement method. In this method the image is improved by emphasizing the high frequency components in the image. The UM method is derived from an earlier photographic technique and involves subtracting the blurred version of an image from the image itself. This is equivalent to adding a scaled high-pass filtered version of the image to itself. The high pass filtering is usually done with a Laplacian operator.

- Simple Contrast Loss

It is assumed that the level of the optical back-scatter is constant throughout the image. This algorithm is based on finding the minimum of a global cost function. The key feature of this method is that it does not require any segmentation as it uses a global statistic rather than the sample standard deviation of small blocks.

Contrast loss spatially varies for underwater images. This is because active illumination, i.e. a light source, is normally used for underwater imaging, since natural illumination is often not sufficient. The active light source illuminates the scene in a nonuniform way. The part in the direction of the light source is well illuminated and the other areas are less illuminated. This causes a nonuniform distribution of optical back-scatter. The other cause of spatial variation in contrast is that in an image, the objects at a greater distance from the camera have more contrast loss than closer objects.

III. RELATED WORK

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	Underwater image restoration using single color channel prior,	S. Borkar and S. V. Bonde,	2016	Developed the algorithm based on the red color channel, and obtained depth map using morphological operation
2	A Fast Single Image Haze Removal Algorithm Using Color Attenuation Prior	Q. Zhu, J. Mai and L. Shao	2015	A simple but powerful color attenuation prior for haze removal from a single input hazy image
3	A novel fast haze removal technique for single image using image pyramid	Z. Dong and B. Yong-qiang,	2015	A new technique for fast single image haze removal, which achieves a good tradeoff between the dehazing performance and the computational complexity.
4	Underwater Single Image Restoration Using Dark Channel Prior,	F. M. Codevilla, S. S. d. C. Botelho, P. Drews, N. D. Filho and J. F. d. O. Gaya,	2014	With an adaptation of the Dark Channel Prior, able to obtain a rough distance map estimative
5	Guided Image Filtering	K. He, J. Sun and X. Tang,	2013	Novel explicit image filter called guided filter.
6	Efficient Image Dehazing with Boundary Constraint and Contextual Regularization	G. Meng, Y. Wang, J. Duan, S. Xiang and C. Pan,	2013	Propose an efficient regularization method to remove hazes from a single input image
7	Underwater Image Enhancement by Wavelength Compensation and Dehazing,	J. Y. Chiang and Y. C. Chen	2012	A novel systematic approach to enhance underwater images by a dehazing algorithm

S. Borkar and S. V. Bonde,[1] Recovering dehazed image from the single underwater image has always been a challenging task. Inspired from dark channel prior, extend it further to dehaze the underwater images using a single color channel. The red color component undergoes maximum attenuation on account of the longest wavelength and dominates the dark channel prior in the underwater scenario. Developed the algorithm based on the red color channel, and obtained depth map using morphological operation. The proposed approach significantly restores the color, minimizes the effect of haze and improves the contrast. Experimental results based on qualitative and quantitative analysis exhibits that the proposed method performs efficiently as compared to existing dehazing algorithms.

Q. Zhu, J. Mai and L. Shao,[2] Single image haze removal has been a challenging problem due to its ill-posed nature. In this research work, propose a simple but powerful color attenuation prior for haze removal from a single input hazy image. By creating a linear model for modeling the scene depth of the hazy image under this novel prior and learning the parameters of the model with a supervised learning method, the depth information can be well recovered. With the depth map of the hazy image, this can easily estimate the transmission and restore the scene radiance via the atmospheric scattering model, and thus effectively remove the haze from a single image. Experimental results show that the proposed approach outperforms state-of-the-art haze removal algorithms in terms of both efficiency and the dehazing effect.

Z. Dong and B. Yong-qiang,[3] Fast single image dehazing has been a challenging problem in many fields, such as computer vision and real-time applications. Recently, many dehazing algorithms have been proposed based on the dark channel prior (DCP). However, these algorithms aim to improve the refinement of the raw transmission map, while ignore the computational complexity of DCP itself. Therefore, this research work proposes a new technique for fast single image haze removal, which achieves a good tradeoff between the dehazing performance and the computational complexity. First decompose the observed haze image into a coarse image and a detail image using Gaussian-Laplacian pyramid. Then, the coarse image is dehazed by Dark Channel Prior and Guided filter (GDCP). For the size of the coarse image is 1/4 of the original image, the computational complexity is reduced sufficiently. However, the recomposed image is blurred, since the detail image is still haze. So, employ an unsharp filter to sharpen the blurred recomposed image. Experimental results show that the proposed dehazing technique effectively removes haze, and significantly reduces the computational complexity by 69.59% on average, compared with traditional GDCP algorithm.

F. M. Codevilla, S. S. d. C. Botelho, P. Drews, N. D. Filho and J. F. d. O. Gaya,[4] The underwater vision is highly spoiled by the underwater degradation effects. As light propagates in the water or other participative mediums, it suffers from a substantial scattering effect that produces poor image quality. Based on a physical model that describes this phenomenon it is possible to recover an haze-free image. But, for this procedure to succeed, it is necessary to obtain certain parameters from the model. With an adaptation of the Dark Channel Prior, proposed by this research work, are able to obtain a rough distance map estimative. With this, and some model simplifications, to successfully obtain the restoration of the image.

K. He, J. Sun and X. Tang,[5] In this research work, propose a novel explicit image filter called guided filter. Derived from a local linear model, the guided filter computes the filtering output by considering the content of a guidance image, which can be the input image itself or another different image. The guided filter can be used as an edge-preserving smoothing operator like the popular bilateral filter [1], but it has better behaviors near edges. The guided filter is also a more generic concept beyond smoothing: It can transfer the structures of the guidance image to the filtering output, enabling new filtering applications like dehazing and guided feathering. Moreover, the guided filter naturally has a fast and nonapproximate linear time algorithm, regardless of the kernel size and the intensity range. Currently, it is one of the fastest edge-preserving filters. Experiments show that the guided filter is both effective and efficient in a great variety of computer vision and computer graphics applications, including edge-aware smoothing, detail enhancement, HDR compression, image matting/feathering, dehazing, joint upsampling, etc.

G. Meng, Y. Wang, J. Duan, S. Xiang and C. Pan,[6] Images captured in foggy weather conditions often suffer from bad visibility. In this research work, propose an efficient regularization method to remove hazes from a single input image. Our method benefits much from an exploration on the inherent boundary constraint on the transmission function. This constraint, combined with a weighted L1-norm based contextual regularization, is modeled into an optimization problem to estimate the unknown scene transmission. A quite efficient algorithm based on variable splitting is also presented to solve the problem. The proposed method requires only a few general assumptions and can restore a high-quality haze-free image with faithful colors and fine image details. Experimental results on a variety of haze images demonstrate the effectiveness and efficiency of the proposed method.

J. Y. Chiang and Y. C. Chen,[7] Light scattering and color change are two major sources of distortion for underwater photography. Light scattering is caused by light incident on objects reflected and deflected multiple times by particles present in the water before reaching the camera. This in turn lowers the visibility and contrast of the image captured. Color change 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. No existing underwater processing techniques can handle light scattering and color change distortions suffered by underwater images, and the possible presence of artificial lighting simultaneously. This research work proposes a novel systematic approach to enhance underwater images by a dehazing algorithm, to compensate the attenuation discrepancy along the propagation path, and to take the influence of the possible presence of an artifical light source into consideration. Once the depth map, i.e., distances between the objects and the camera, is estimated, the foreground and background within a scene are segmented. The light intensities of foreground and background are compared to determine whether an artificial light source is employed during the image capturing process. After compensating the effect of artifical light, the haze phenomenon and discrepancy in wavelength attenuation along the underwater propagation path to camera are corrected. Next, the water depth in the image scene is estimated according to the residual energy ratios of different color channels existing in the background light. Based on the amount of attenuation corresponding to each light wavelength, color change compensation is conducted to restore color balance. The performance of the proposed algorithm for wavelength compensation and image dehazing (WCID) is evaluated both objectively and subjectively by utilizing ground-truth color patches and video downloaded from the Youtube - ebsite. Both results demonstrate that images with significantly enhanced visibility and superior color fidelity are obtained by the WCID proposed.

IV. PROBLEM STATEMENT

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. This 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 colour variation. In the past other techniques such as sonar ranging have been used due to the limitation of visible light imaging in an underwater environment. 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. Using underwater images leads to some serious problems when compared to images from a clearer environment. Visibility in an underwater environment is poor, even when using state of the art equipment.

V. CONCLUSION

This exploration sought to determine whether suitable image processing techniques can be used to process underwater images, allowing the detection of objects within these images for use with further scientific analysis applications. With the increase in the use of underwater images comes an increase the time it takes to manually process these images. For this reason, automation is needed in the processing of underwater images. Resolution loss and contrast loss are two of main types of degradation in underwater images. There are due to the effects of small angle forward-scattered light and back-scattered light respectively. Although both of these problems degrade the image quality, the problem of contrast loss is less difficult to mitigate than that of resolution loss. The magnitudes of these two problems vary according to distance and water turbidity. A significant work has done in the field of underwater imaging this work review the challenges and techniques used for underwater image processing and restoration.

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