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An Extensive Literature Review on Under Water Image Processing

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Abstract- 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.

Keywords: Deep-sea imaging, filter; image reconstruction.

I. INTRODUCTION

Light is envisioned as consisting of numerous localized packets of electromagnetic energy, called photons, which move through empty space with the speed $c = 2.998 \times 108\ m\ s^{-1}$. The photon viewpoint of light is well suited to the development of radioactive transfer theory, but the electromagnetic-field viewpoint on photons is convenient for certain types of problems, such as the scattering of light under the water surface. The photons generated by the sun stream into space in all directions away from the sun. By the principle of conservation of energy, the total energy per time unit crossing an imaginary spherical surface of radius R measured from the sun's centre is independent of R. though, since the area $4\pi R^2$ of the spherical surface increases as R^2, the energy per time unit per area unit of the sphere, which is called the irradiance, must decrease proportionally to R^{-2}. This result is known as the inverse square law for irradiance. At the mean distance of the earth from the sun, the solar irradiance from photons of all wavelengths, E_s, is near $E_s = 1367 W m^{-2}$. E_s [3] is commonly called the solar constant. The photons arriving at earth from the sun are not all equally energetic. The energy of a photon is inversely proportional to its wavelength. Furthermore, the number of photons per wavelength interval is not uniform over the electromagnetic spectrum. For measured spectral, or wavelength, distribution of the solar irradiance, $E_s(\lambda)$, over the wavelength band it is seldom necessary for optical oceanographers to concern themselves with the detailed wavelength dependence of $E_s(\lambda)$. It is sufficient to deal with $E_s(\lambda)$ values averaged over bandwidths of order $\Delta\lambda = 10\ nm$, which correspond to the bandwidths of the optical instruments routinely used in underwater measurements. Moreover, it is not the solar irradiance at the top of the atmosphere, but the sunlight that actually reaches the sea surface, that is relevant to marine optics. 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].

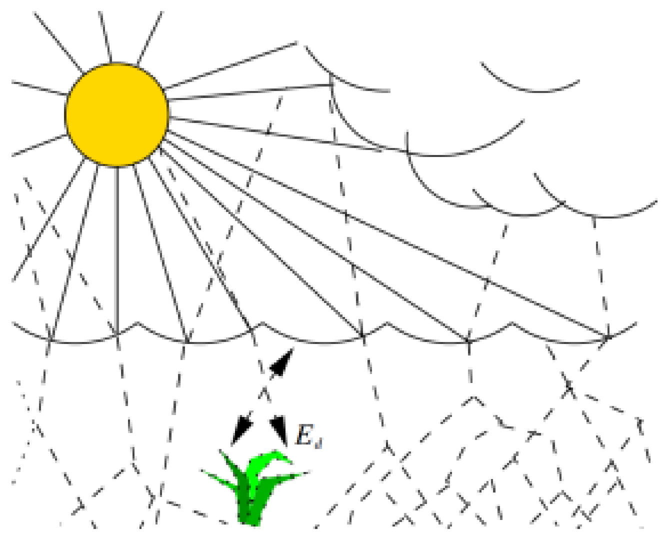

Fig 1: Illustration of light field under the water surface.

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 down welling irradiance Ed, see Fig 1.

Optical properties of water

Natural waters, both fresh and saline, are mixtures of dissolved and suspended matter. These solutes and particles are both optically significant and highly variable in kind and concentration. Consequently, the optical properties of natural waters show large temporal and spatial variations and seldom resemble those of pure water. It is the connections between the optical properties and the biological, chemical and geological constituents of natural water and the physical environment that define the critical role of optics in aquatic research.

Inherent vs apparent optical properties Inherent optical properties (IOP's) are those properties that depend only upon the medium. The two fundamental IOP's usually employed in ocean optics are the absorption coefficient and the volume scattering function, which are respectively the spectral absorbance and scattering per unit distance in the medium. For example, the total absorption coefficient a is the sum of absorption by the water itself, by various biological particles, by dissolved substances, by mineral particles, and so on. Since the composition of natural water bodies varies with location and time, so do the IOP's. Apparent optical properties (AOP's) are those properties that depend both on the medium (the IOP's) and on the geometric structure of the ambient light field, and that display enough regular features and stability to be useful descriptors of the water body. Commonly used AOP's are the irradiance reflectance, the average cosines, and the various diffuse attenuation coefficients. These properties can be measured by radiometers or can be estimated from spectral data. There are ongoing studies on monitoring water optical properties. Accurate values can be obtained from mooring stations placed in a few off shore waters around the world.

II. SYSTEM MODEL

Under typical oceanic conditions, for which the incident lighting is provided by the sun and sky, the various radiances and irradiances all decrease approximately exponentially with depth, at least when far enough below the surface and in shallow water to be free of boundary effects. It is therefore convenient to write the depth dependence of $E_d(z,\lambda)$ as:

$$E_d(z,\lambda) \;=\; E_d(0,\lambda) exp[- \int_0^z K_d(z',\lambda)dz' \;], (2.1)$$

where $K_d(z,\lambda)$ is the spectral diffuse attenuation coefficient for spectral down welling plane irradiance. Solving for $K_d(z,\lambda)$ gives:

$$K_d(z,\lambda) \;=\; -\frac{\partial \, lnE_d(z,\lambda)}{\partial \, z} \;=\; \frac{-1}{E_d(z,\lambda)} \frac{\partial E_d(z,\lambda)}{\partial \, z} \; (2.2)$$

If define $\overline{K}_d(z,\lambda)$ as the average of $K_d(z,\lambda)$ over the depth interval from 0 to z,

$$\overline{K}_d(z,\lambda) \;\equiv\; \frac{1}{z} \int_0^z K_d\,(z'\;,\lambda)\partial\, z' \qquad (2.3)$$

then it can write Eqn 2.1 as:

$$E_d(z,\lambda) \;=\; E_d(0,\lambda) exp[-\overline{K}_d\;(z',\lambda)z]. (2.4)$$

The difference between beam and diffuse attenuation coefficients is important. The beam attenuation coefficient $c(\lambda)$ is defined in terms of the radiant power lost from a single, narrow, collimated beam of photons. The down welling diffuse attenuation coefficient $K_d(z,\lambda)$ is defined in terms of the decrease with depth of the ambient down welling irradiance $E_d(z,\lambda)$, which comprises photons heading in all downward directions. $K_d(z,\lambda)$ Clearly depends on the directional structure of the ambient light field, hence its classification as an apparent optical property. In this there are confined to diffuse attenuation coefficients, since base the image restoration on estimated $K_d(z,\lambda)$:s. It need to point out the obtained values universal usefulness:

- The K_d values are defined as ratios and therefore do not require absolute radiometric measurements. • The K_d: s are strongly correlated with phytoplankton chlorophyll concentration, thus they provide a connection between biology and optics.
- About 90% of the diffusely reflected light from a water body comes from a surface layer of water of depth 1 K_d thus K_d:s has implications for remote sensing.
- Radiative transfer theory provides several useful relations between the K_d and other quantities of interest, such as the absorption and beam attenuation coefficients and other AOP's.
- Instruments are commercially available for the routine determination of the K_d: s. K_d can be calculated K_d values from estimated downwelling irradiances for each depth interval using Beer's Law, which is illustrated in Fig. 2.

Huimin Lu; Serikawa, S., [1] presented research work describes novel work for underwater scene reconstruction by using guided trigonometric bilateral filtering and wavelength conception. Scattering and color distortion are two major distortion issues for underwater optical imaging. The key contributions are proposed include a novel underwater model to compensate for the attenuation discrepancy along the propagation path and a fast guided trigonometric bilateral filtering enhancing and color correction. The enhanced images are characterized by a reduced noised level, better exposure of the dark regions, and improved global contrast where the finest details and edges are enhanced significantly. Consequently, our enhancement method achieves higher quality than other state-of-the-art methods.

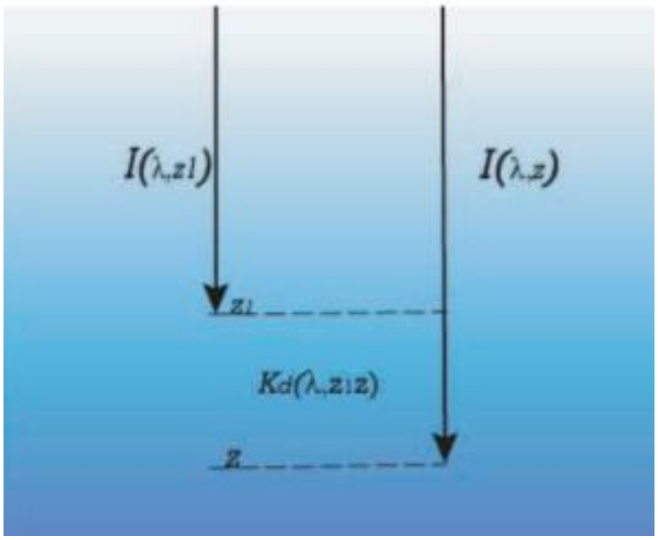

Fig. 2: Illustration of Beer's Law.

III. LITERATURE REVIEW

Ghani, A.S.A.; Isa, N.A.M., [2] Quality of underwater image is poor due to the environment of water medium. The physical property of water medium causes attenuation of light travels through the water medium, resulting in low contrast, blur, inhomogeneous lighting, and color diminishing of the underwater images. This paper extends the methods of enhancing the quality of underwater image. The proposed method consists of two stages. At the first stage, the contrast correction technique is applied to the image, where the image is applied with the modified Von Kreis hypothesis and stretching the image into two different intensity images at the average value with respects to Rayleigh distribution. At the second stage, the color correction technique is applied to the image where the image is first converted into hue-saturation-value (HSV) color model. The modification of the color component increases the image color performance. Qualitative and quantitative analyses indicate that the proposed method outperforms other state-of-the-art methods in terms of contrast, details, and noise reduction.

Shijie Zhang; Jing Zhang; Shuai Fang; Yang Cao, [3] Stereo image applications are becoming more and more prevalent. Though, there has been little research on stereo image enhancement. In this paper, address the challenging problem of underwater stereo image enhancement. A new underwater imaging model is proposed and it can better describe the degradation of underwater images including color distortion and contrast attenuation. In addition, a novel observation that the intensity of the water part within the image is mainly contributed by the scattering light is also proposed. Coupling the proposed model and prior together, the parameters of scattering light can be estimated. Then an iterative approach to process stereo matching and stereo image enhancement alternatively is presented, which can significantly improve the quality of the images and depth maps. The experimental outcomes demonstrate that the proposed method can significantly enhance the image visibility and achieve better depth perception.

Hitam, M.S.; Yussof, W.N.J.H.W.; Awalludin, E.A.; Bachok, Z [4] Within the last decades, improving the quality of an underwater image has received considerable attention due to poor visibility of the image which is caused by physical properties of the water medium. This paper presents a new method called mixture Contrast Limited Adaptive Histogram Equalization (CLAHE) color models that specifically developed for underwater image enhancement. The method operates CLAHE on RGB and HSV color models and both outcomes are combined together using Euclidean norm. The underwater images used in this study were taken from Redang Island and Bidong Island in Terengganu, Malaysia. Experimental outcomes show that the proposed approach significantly improves the visual quality of underwater images by enhancing contrast, as well as reducing noise and artifacts.

Celebi, A.T.; Erturk, S., [5] most underwater vehicles are equipped with optical cameras to capture underwater images. But underwater images acquired using optic cameras have poor visual quality due to propagation of properties of light in water. So it is useful to apply image enhancement methods to increase visual quality of the images as well as enhance interpretability and visibility. In this paper, an Empirical Mode Decomposition (EMD) based underwater image enhancement algorithm is presented for this purpose. In the proposed approach, initially each color channel (R, G, B) of an underwater image is decomposed into Intrinsic Mode Functions (IMFs) using EMD. The first IMF of each component is applied to wavelet denoising. This IMF includes all local high spatial frequency components. Then the enhanced image is constructed by combining the IMFs of spectral channels with different weights in order to obtain an enhanced image with increased visual quality. The weight estimation process is carried out automatically using a genetic algorithm that computes the weights of IMFs so as to optimize the sum of the entropy and average gradient of the reconstructed image.

Celebi, A.T.; Erturk, S., [6] Most underwater vehicles are nowadays equipped with vision sensors. Though, underwater images captured using optic cameras can be of poor quality due to lighting conditions underwater. In such cases it is necessary to apply image enhancement methods to underwater images in order to enhance visual quality as well as interpretability. In this paper, an Empirical Mode Decomposition (EMD) based image enhancement algorithm is applied to underwater images for this purpose. EMD has been shown to be particularly suitable for non-linear and non-stationary signals in the literature, and therefore provides very useful in real life applications. In the approach presented in this paper, initially each R, G and B channel of the color underwater image is separately decomposed into Intrinsic Mode Functions (IMFs) using EMD. Then, the enhanced image is constructed by combining the IMFs of each channel with different weights, so as to obtain a new image with increased visual quality. It is shown that the proposed approach provides superior outcomes compared to conventional image enhancement methods such as contrast stretching.

Nascimento, E.; Campos, M.; Barros, W., [7] presented a fully automatic methodology for underwater image restoration which is based on classical physical models of light propagation in participating media. The technique uses pairs of images acquired from distinct viewpoints under the same environmental conditions. At the kernel of the method is an iterative algorithm that is based on a contrast metric that automatically estimates all parameters of the model with good accuracy at a significantly low computational cost. Authors performed experiments with images taken from both synthesized and real scenes to verify the performance of the proposed method. Two main aspects were considered: image quality and quality of disparity maps produced by a standard stereo algorithm. Image quality was assessed by a quantitative measure of contrast, which is typically used in related literature. Authors also compare the outcomes obtained by methodology with those obtained with classic image enhancement tools. The outcomes obtained with our methodology demonstrate improvement both in scene contrast of recovered underwater images and in the accuracy of the disparity maps under different water turbidity levels.

IV. PROPOSED METHODOLOGY

The best known filter in this category is the median filter, which is an order-statistic filter. Order-statistic filters are nonlinear spatial filters whose output is based on ordering the pixels contained in the neighborhood of the filter, then replacing the centre pixel with the value determined by the ordering study. The median filter replaces the centre pixel with the median of the grey levels within the mask. Median filters can be very effective for removing particular types of random noise with less blurring than linear smoothing filters of similar size.

V. CONCLUSION

Noise Removal Noise removal, also known as image smoothing, can play an important role in image enhancement. Though, noise removal can also lead to the blurring of edges, which are extremely important in an automated system such as one required for this study. Random noise in an image will typically be sharp transitions in grey levels; therefore image smoothing is a very popular method of noise reduction. Though, a problem with using this technique is that edges are also typically defined by sharp transitions in grey levels. So using this technique to remove noise may also lead to a blurring of edges, which are extremely important in automated systems that require edge detection. Although edge detection and smoothing are regarded as two different images processing tasks, there have been some recent advances leading to methods which are able to perform both together.

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