Review on Removing color & dehazing using Underwater Image enhancement.

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ABSTRACT

Typical underwater images exhibit poor visibility because of light scattering and absorption in turbid water. To resolve the ill-posed problem, a novel underwater image enhancement method based on Removing Light Source Color and Dehazing (RLSCD) is proposed. Scene depth, which his assumed strongly correlated with attenuations, is often ignored in most of the previous methods. A new scene depth estimation, which takes the attenuations of the different light conditions into account, is first presented. Additionally, the background light is estimated based on gray open operation and scene depth to avoid that the pixels in the white objects and artificial lighting regions may be wrongly estimated as the background light. With the estimated background light and transmission map, the dehazed image is achievable. Moreover, the theoretical analysis of the Lambertian Model indicates that the disturbance of the light source color in dehazed image can be estimated, this phenomenon enables us to correct color distortion and light overcompensation by removing the disturbance. Experimental results demonstrate the RLSCD method outperforms state-of-the art methods in terms of relatively genuine color, increased contrast, and brightness.

Keywords/ Index Term — Light source color, Lambertian model, underwater image enhancement, gray open.

1. INTRODUCTION

underwater images suffer from contrast degradation, mostly due to haze caused by light scattering; the bluish tone due to the color change caused by the varying degrees of light absorption for different wavelengths; and the limited range, low brightness caused by low illumination .Thus, developing an effective method to enhance such images is desirable Acquiring clear images in underwater environments play a pivotal role in exploring and investigating the underwater world, such as monitoring marine biodiversity, underwater rescue, detecting underwater pipeline leaks and so forth Subsequently, some optimized physical models are introduced. For instance, in [1], [3], Point Spread Functions (PSF) and a Modulation Transfer Function (MTF), which are derived with underwater properties, are used to reduce the blurring effects. Trucco and Olmos-Antillon [2] presented a self-tuning restoration filter based on a simplified version of the Jaffe-McGlamery image formation model. To solve the aforementioned problems, a variety of image enhancement and restoration methods have been applied in the underwater environment, such as Histogram Equalization (HE) [3] , Contrast Limited Adaptive Histogram Equalization (CLAHE) [4], Probability-based method(PB) [5] and Convex Optimization For Fast Image Dehazing (COFFID) [6].

Although the effectiveness of model-based restoration methods in removing haze, a fatal limitation of model-based restoration is that many parameters for these models are hardly obtained from underwater. In recent years, polarization-based and remarkable priors-based methods made significant breakthroughs in removing haze. The polarization-based method [7], which needs two or more images, costs a lot of time, because of its inconvenient operation. Meanwhile, based on the prior, the Dark Channel Prior (DCPrgb) [8] proposed by He et al. improves contrast by estimating the background light and the transmission map in the local regions. It is assumed that there is at least one color channel has some pixels with low intensity in the local region. However, it ignores the fact that different wavelengths have different attenuation rates, being the red light decays the fastest in the underwater environment, while the green and blue channels keep their intensity longer. In this situation, has no sense anymore: being the image degraded or not, there is almost always one color channel with low intensity (the red one), leading to erroneous depth estimation and poor visibility [5]. On the other hand, some method smainly focus on restoring color distortion according to the different attenuation of each wavelength [6]. Iqbal and Odetayo [7] presented an underwater image enhancement method based on color balance and histogram stretching (UCM). Jaulinand Bazeille [8] proposed an algorithm to enhance underwater images by suppressing noise and adjusting colors. This method is done automatically, do not need parameter adjustment, it can be used as a preliminary step of edge detection. Chambah et al. [9] proposed a color correction method based on the Automatic Color Equalization (ACE) model, an unsupervised color equalization algorithm developed by Rizzi et al. [10]. However these methods are ineffective in improving the image contrast which mainly degraded by light scattering.

Moreover, it can be invalid for the underwater images with white objects or artificial lighting. Thus, Inverse Red-channel Dark Channel Prior (DCPr0gb) [11] is proposed to avoid this problem. But the method frequently performs poorly because no work has been done with background light. Unlike DCP that calculates the transmission map with dark channel image, Peng and Cosman [12] enhanced hazy images based on Image Blurriness and Light Absorption(IBLA).This method achieves good results in low degraded images and is limited in processing underwater images with severe degradation. Although making the progress on enhancing underwater images, the above state-of-the-art methods focus solely on compensating either light scattering or color distortion, which may be invalid under the complex marine circumstances. To restore color and enhance contrast simultaneously, Chiang and Chen [12] proposed an underwater image enhancement method by combining a dehazing algorithm with a wave length compensation (WCID). The method cannot be suitable for all the underwater images because complex lighting conditions existing in underwater images make exceptions. The foreground and the background are segmented with the mean luminances to detect and remove the possible presence of the artificial light source in WCID. However, the segmentation is based on the scene depth map using DCPrgb prior, which is often ineffective in an underwater environment.

Inspired by the above successful examples, in this paper, we propose a novel underwater image enhancement methods based on Removing Light Source Color and Dehazing (RLSCD). The specific improvements are as follows:

a. Scene depth is assumed to be strongly correlated with the scattering and absorption effects [12]. Thus, it is important in accurately estimating background light and transmission map in Underwater Image Formation Model (UIFM). We estimate scene depth by incorporating the inverse red channel attenuation, and the saturation attenuation, to pick the farthest pixels;

b. Rather than calculating the brightest pixels intensity as background light directly, scene depth and gray open operation are used to estimate the background light to alleviate the disturbance of the white objects and artificial lighting;

c. In contras tto the previous methods which mainly focus on scattering effects, color distortion and light over compensation are consider edinour study. Based on Lambertian Model, the disturbance of the artificial light source color response along the propagating path can be estimated. As a result, the scene irradiance, which can be recovered by removing the disturbance of the light source color, is free of the haze, color distortion and illumination overcompensation in the meantime.

2. State of Art-Related work

In recent years, polarization-based and remarkable priors-based methods made significant breakthroughs in removing haze. The polarization-based method [12], which needs two or more images, costs a lot of time, because of its inconvenient operation. Meanwhile, based on the prior, the Dark Channel Prior (DCPrgb) [13] proposed by He et al. improves contrast by estimating the background light and the transmission map in the local regions. It is assumed that there is at least one color channel has some pixels with low intensity in the local region. However, it ignores the fact that different wavelengths have different attenuation rates, being there dlight decays the fastest in the underwater environment, while the green and blue channels keep their intensity longer. In this situation, DCPrgb has no sense anymore: being the image degraded or not, there is almost always one color channel with low intensity (thered one), leading to erroneous depth estimation and poor visibility [14]. Moreover, it can be invalid for the underwater images with white objects or artificial lighting. Thus, Inverse Red-channel Dark Channel Prior (DCPr0gb) [14] is proposed to avoid this problem. But the method frequently performs poorly because now or khasbe end one with background light. Unlike DCP that calculates the transmission map with dark channel image, Peng and Cosman [15] enhanced hazy images based on Image Blurriness and Light Absorption (IBLA). This method achieves good results in low degraded images and is limited in processing underwater images with severe degradation. On the other hand, some methods mainly focus on restoring color distortion according to the different attenuation of each wavelength [12]. Iqbal and Odetayo [13] presented an underwater image enhancement method based on color balance and histogram stretching (UCM). Jaulinand Bazeille [14] proposed an algorithm to enhance underwater images by suppressing noise and adjusting colors. This method is done automatically, do not need parameter adjustment, it can be used as a preliminary step of edge detection. Chambah et al. [14] proposed a color correction method based on the Automatic Color Equalization (ACE) model, an unsupervised color equalization algorithm developed by Rizzi et al. [15] . However these methods are ineffective in improving the image contrast which mainly degraded by light scattering.

Although making the progress on enhancing underwater images, the above state-of-the-art methods focus solely on compensating either lights cattering or color distortion, which may be invalid under the complex marine circumstances. To restore color and enhance contrast simultaneously, Chiang and Chen [15] proposed an underwater image enhancement method by combining a dehazing algorithm with a wavelength compensation (WCID). Theme thod cannot be suitable for all the underwater images because complex lighting conditions existing in underwater images make exceptions. The foreground and the background are segmented with the mean luminances to detect and remove the possible presence of the artificial lights our cein WCID. However, the segmentation is based on the scene depth map using DCPrgb prior, which is often ineffective in an underwater environment.

3. Proposed System

In this section we review the underwater image formation model and the classical dehazing method, respectively.

1. RLSCD-BASED APPROACH.

In comparison with the traditional underwater image enhancement methods, we present a new method based on Removing Light Source Color and Dehazing (RLSCD). The flowchart of the RLSCD method is shown in Fig. We first calculate two scene depths using inverse red channel attenuation and the saturation attenuation, to estimate the final scene depth. Then, we further acquire background light based on gray open operation and the estimated scene depth. Subsequently, adding a factor $\alpha 1$ $(0 \leq \alpha 1 \leq 1)$ to adjust the background light to avoid the influence of white objects and artificial lighting. The transmission map can also be estimated with the scene depth information. With the estimated background light and transmission map, the dehazed image is achievable. Next, according to the Lambertian model, the disturbance of light source color can be estimated. Finally, we can enhance the degraded underwater image by removing the light source color from the dehazed image.

A. SCENE DEPTH ESTIMATION

To our knowledge, for each meter in the water, the average light attenuations of red, green and blue channels are 18%, 5%, and 2.5%, respectively. Considering the strong correlation of scene depth with the wavelength attenuations, we propose to estimate scene depth by considering the insufficient lighting environment, as well as sufficient lighting case.

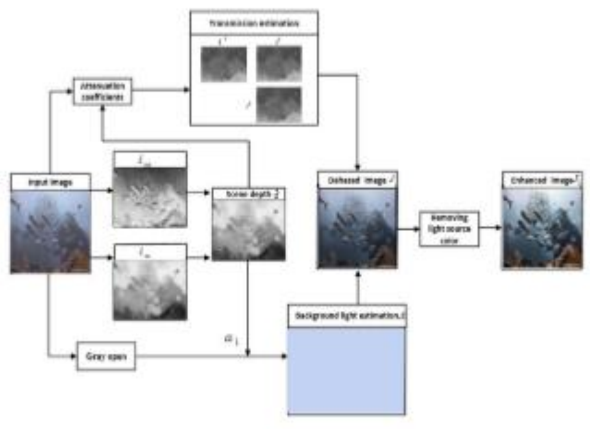

Fig 1 Flowchart of RLSCD Method

RLSCD Methods steps

Step 1 : calculate two scene depths using inverse red channel attenuation and the saturation attenuation, to estimate the final scene depth.

Step2: Acquire background light based on gray open operation and estimated scene depth.

Step 3: Add a factor to adjust background light to avoid the influence of white objects and artificial lighting as well as transmission map can also be estimated with the scene depth information.

Step 4: Using this transmission map we can achieve dehazed image.

Step5: using Lambertian model the disturbance of light source color can be estimated.

Step6: finally, we can enhance degraded underwater image by removing the light source color from the dehazed image.

Most of the previous methods neglect the different attenuations in three color channels and estimate the transmission map based on DCP prior directly, which is not always suitable to the complex underwater scenes. The transmission map is often affected by thev varied phytoplankt on concentration and light conditions. In these cases, inverse red channel attenuation can reflect the special characteristics in an underwater scene and is defined as [15] When the input image is taken under insufficient lighting, there are two conditions: one is the low-light image (mean(I) < 0.2), both the background and foreground regions are dim; another is mean(I) ≥ 0.2 and the ratio of mean intensity in red channel and the maximum ones of other two channels (ratio = mean(Ir) max (mean(Ig), mean(Ib))), is relatively small. This indicates the background light is dim, and the foreground region may be light.

$$A_{ired}(x) = \min_{x \in \Omega(x)} (1 - I^r(x^r) \quad (1)$$

The scene points with small values in the inverse red channel are assumed to be closer to the camera and are used to estimate the first depth:

$$d_{ired}(x) = Td_{ired} \quad (2)$$

where T(·) is a stretching function. However, inverse red channel attenuation cannot represent the total attenuations among three channels. Based on the fact that red light attenuates fast among three channels, and the closer scene points attenuate less than the farther scene points, MIP prior [14], [15] was first proposed by using the maximum intensity in red channel minus the maximum intensity of other two channels (1)

$$A_{sat}(x) = \min_{X^r \varepsilon \Omega(x)} (\frac{\max(I^c(x^r)) - \min(I^c(x^r))}{\max(I^c(x^r))} \quad (3)$$

It also produces inaccurate estimation in the region under sufficient lighting, whose MIP values of the closer scene may be similar to the farther points. When the image is acquired under sufficient lighting, the background light is brighter. It means that the inverse red channel also owns smaller intensity in the farther scene, in this case, dired(x) is not suitable to represent the distance. The brighter background light may becaused by natural lighting and artificial lighting. To separate the natural illuminated regions and artificially illuminated regions, we propose to estimate the second depth based on saturation attenuation. In an underwater environment, the artificial lighting region is assumed to be close to the camera. To our knowledge, artificial illumination forces a pixel to have a lower saturation value compared with the pixel under natural illumination. Thus, the scene points with small values of Asat are assumed to be closer to the camera. Typically, most underwater enhancement methods estimate Ac with the brightest pixels in the image. The brightest pixels may be derived by the foreground region, if the white object or artificially illuminated region is close to the camera. The estimations of the background light and transmission map of these methods are mainly divided into three categories:

B. BACKGROUND LIGHT ESTIMATION BASED ON GRAY OPEN AND SCENE DEPTH

The background light Ac is a key factor that determines the color and brightness of the enhanced results. As shown in Fig., the large values of Ac will lead to a bright erre covered image, while using smaller Ac values obtains an opposite result. Moreover, changing the values of the Ac only in one of the color channels will cause the color change [10]. Instead of selecting the brightest pixels from infinity, DCP rgb may calculate Ac with brightest illuminated foreground pixels, wrongly regarded as being far. To solve the illuminated lighting problem, Galdran proposed DCPr0gb by assuming that artificial illumination forces a pixel to have similar values in three channels, which indicates Ir ' Ig ' Ib. However, if a dark pixel from infinity has values near the zero in three channels, it would be wrongly judged to be the artificially illuminated pixel and further lead to inaccurate Ac estimation. DCPgb does somewhat imprecisely estimating Ac because it does not consider the red channel. In fact, anideal background light should be estimated with the bright pixels, which lies at the maximum scene depth with respect to the camera [14]. In this study, to better handle the above problems, we propose to estimate Ac based on gray open operation and scene depth, considering the effects of both white objects and artificially illuminated regions. In IFM, the recovered image Jc(x) is the total amount of incident light reflected with reflectivity ρc(x) along the distance d(x), that is Jc(x) = ρc(x) · Ac. According to Eq. (1), Ac can be calculated when ρc(x) → 0 and d(x)→∞.Then the two major steps include making the reflection coefficient close to zero and selecting the farthest points. The analysis of absorption /reflection properties shows that the image color is generated by absorbing the specific frequency light from the white light and reflecting there sidual light, and indicates that for the brighter or the darker objects, there is atleast a reflection coefficient in three color channels is very small and close to zero.

4. Conclusion

The proposed background light based on gray open operation and scene depth, which is used to all eviate the disturbance of the white objects and artificial lighting, can effectively increase contrast. Simultaneously, the transmission map can also be estimated with scene depth for removing haze more completely. With the estimated background light and transmission map, the dehazed image is achievable. In contrast to the previous methods, which mainly focus on removing scattering effects, color loss and exposed light are also consider edin our study. Then the dehazed image is applied to the Lambertian model to remove light source color attenuation to correct color distortion and light over compensation. Extensive experiments demonstrate that the RLSCD method can produce better visibility and outperforms state-of-the-art methods in terms of relatively genuine color, natural visibility and improved brightness, which can be used for unveiling more details and valuable information.

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