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A Review on Underwater Image Enhancement

Zhiqiang Liu

School of Shanghai Maritime University, Shanghai 201306, China.

Abstract

The light propagation under water is affected by absorption and scattering. The absorption of light by water and the scattering of suspended particles result in poor clarity and lack of edge detail in underwater images. Besides, the water's selective absorption of light at different wavelengths results in the blue-green appearance of the underwater image. These problems bring great challenges to underwater image collection and processing. Underwater image enhancement is not only an important means to improve the quality of underwater image, but also an important precondition for subsequent image technology such as image recognition. Many underwater image enhancement algorithms have been proposed to solve the problems of color bias, blur and missing details in underwater image. These methods are systematically classified and introduced in detail in order to help readers better understand underwater image enhancement and promote the development of advanced algorithms.

Keywords

Image Processing; Underwater Image; Image Enhancement.

1. Introduction

With the rapid development of economy and society, resources on land has been unable to meet the needs of rapid development of human beings. Therefore, people turn their eyes to the ocean, and underwater technology has been rapidly developed. Thanks to the development of machine vision and imaging equipment, underwater image has become an important means to obtain ocean information, and is widely used in underwater exploration, underwater robot control, environmental monitoring and other fields[1,2,3].

Compared with the land environment, the underwater imaging environment is very complex, and there are various problems in the underwater image, such as blue-green appearance, blur, edge information loss and so on.There are two main reasons for the degradation of underwater image quality: light absorption by water and light scattering by underwater suspended particles.

First of all, in the underwater environment, water, as the propagation medium of light, has a strong attenuation effect on light waves.And the larger the wavelength of light, the more water will absorb it.The longer wavelengths of red light are always the most decayed, typically at five meters under water, and it is the first wave to disappear.The wavelengths of blue-green light are shorter and decay more slowly than red light.Underwater images therefore always have a turquoise appearance, with an extremely distinct color bias

Secondly, in the underwater environment, there are many impurities such as plankton and suspended particles in the water.These impurities greatly reduces the visibility in the water, and let the light reflected on the surface of the target scattering happened: the reflected light before is captured by the imaging device has changed direction, it reduces the reflected light into the imaging equipment, but also make a lot of stray light into the imaging device, interfere with the imaging quality of imaging equipment.Under the influence of scattering, the background of the underwater image is blurred, the

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clarity and contrast are greatly reduced, and the edge details are missing, which makes it impossible to present the scene and extract information well.

In addition, because of the water's absorption of light, there is a problem of insufficient light in deeper waters.Sometimes, in order to improve the illumination under water, artificial light will be added in the imaging, which will make the image uneven illumination and some white spots appear.In addition, the light from artificial light sources will also be absorbed and scattered, which may interfere with the imaging equipment.

Under the influence of light propagation in water, underwater images have some problems, such as color bias, lack of clarity and lack of edge details.To solve these problems, many image enhancement methods have been proposed to better extract information from underwater images. These enhancement methods can be roughly divided into two categories: one is model-based underwater image enhancement algorithm;Second, non-model underwater image enhancement algorithm.

2. Model-based Enhancement Algorithm

Through the analysis of the underwater environment or underwater images, get some credible model, theories or assumptions, and on these models or assumptions derived underwater image enhancement algorithms, or put some water method and combining with underwater light propagation model, to a certain extent, the transformed into new underwater image enhancement algorithm, these methods are called model-based underwater image enhancement algorithm. Among these methods, the method based on DCP is a representative one.

He et al. [4] proposed the DCP (dark channel prior) algorithm in the 2009 CVPR (IEEE Conference on Computer Vision and Pattern Recognition) Conference.In the underwater environment, ignoring the influence of backscattering, the optical model can be expressed as:

$$I(x) = J(x)t(x) + A(1 - t(x)) \tag{1}$$

Where $I(x)$ is the initial image, which is the image that our imaging equipment gets; $J(x)$ represents the image that we need to recover; $t(x)$ is the tranmission map, which is influenced by scence depth; A is atmospheric light.

DCP is based on the dark channel priori theory: the dark channel of normal image is tend to 0, but the dark channel of a foggy image does not. Dark channel can be expressed as:

$$I_{(x)}^{dark} = \min_{y \in \Omega(x)} \left(\min_{c \in \{r,g,b\}} I_{(y)}^{c} \right) \tag{2}$$

Where, $I_{(y)}^{c}$ represents any color channel of the image, $\Omega(x)$ refers to a window area centered on the x pixel point.

Using minimum filtering and Equation (1), (2), we can get $t(x)$:

$$t(x) = 1 - \omega \min_{y \in \boldsymbol{\Omega}(x)} \left(\min_{c \in \{r,g,b\}} \frac{I^c(y)}{A^c} \right) \tag{3}$$

In order to retain some of the haze on the far side to preserve the depth of the image, $\omega = 0.95$. Finally, the defogging image can be expressed as:

$$J(x) = \frac{I(x) - A}{max(t(x), t_0)} + A \tag{4}$$

In order to remove some over-bright spots or blocks in the restored image, $t_0 = 0.1$.

Underwater images have low red channel values (tend to 0) because of the absorption of light by water. Because DCP uses the minimum filtering function, the dark channel of the underwater image is always small, Furthermore, it affects the acquisition of the transmission image and fails to achieve the enhanced effect. Figure 1 shows this problem.

Due to problems with the DCP, many underwater methods have improved the DCP. Drews Jr et al. [5] proposed an adaptive Underwater dark channel prior (UDCP) by further analyzing Underwater

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environment and considering that blue-green light is the main Underwater visual information source, and using DCP to estimate Underwater transmission characteristics.This method improves the effectiveness of traditional DCP, but it still has some limitations. Li and Yang et al. [6] proposed a new brightness adjustment algorithm to solve the problem that the enhancement based on the dark channel prior method would make the brightness of the underwater image too low, which improved the overall contrast of the image and enhanced the processing effect of DCP in the underwater image. Yang and Chen et al. [7] proposed a new background light estimation method combined with the deep learning method, which effectively improved the blur and chromatic aberration of underwater images. Zhou et al. [8] used the fog line model to improve the dark channel prior algorithm. Combined with the characteristics of underwater images, a new method is introduced to obtain the red channel information.

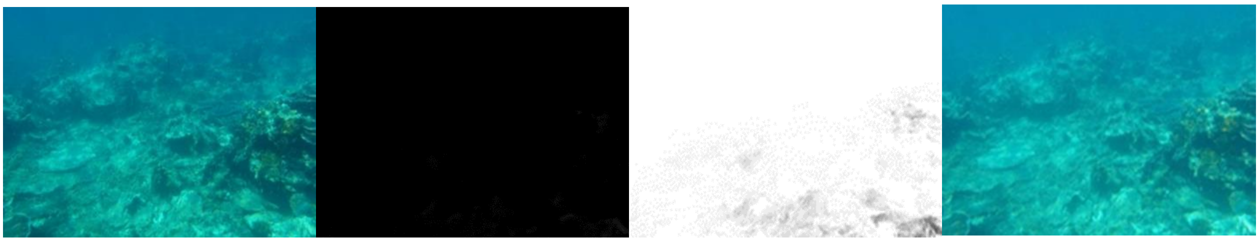

Figure 1. DCP method. From the left to the right: initial image, dark channel, transmission map, result

There are also some underwater image enhancement methods [9,10,11] based on other assumptions or prior knowledge, which also accomplish the enhancement task well.

These algorithms are based on the model, through the analysis of the model to determine the underwater image degradation process. Through the analysis of the process of image degradation, some unknown parameters in the model are solved. Combined with the model or assumed known conditions, the underwater image is enhanced accordingly. Because these methods all use some models or assumptions, the enhancement effect will be very good for the images that conform to the model or assumptions, but for some images that do not conform to the model or assumptions, it will be difficult to achieve the ideal effect.

3. Non-model Enhancement Algorithms

Non-model image enhancement methods do not pay attention to optical propagation under water, but focus on the relationship between pixels or the features of images in the spatial and frequency domains, and achieve the purpose of image enhancement by adjusting pixel values. The spatial domain method and the frequency domain method are the two main methods of non-model method.

The spatial domain method can enhance the image by directly adjusting the value of the pixel, and the spatial domain method is widely used in water. Combined with the research of underwater environment, many methods of underwater airspace enhancement have been proposed. Fu et al. [12] proposed a comprehensive underwater image enhancement framework. First, a color skew correction algorithm is used for underwater images. After correcting the color skew, they proposed an algorithm to separate the reflected light and direct light, and then enhanced the reflected light and direct light respectively through different enhancement methods to achieve the purpose of enhancing the image contrast. Ji et al. [13] proposed an underwater image enhancement method based on structure decomposition. It is mainly used for contrast restoration of underwater images. In general, although the spatial method has a good effect in removing color bias or improving contrast, it is also prone to problems such as noise amplification and artifact introduction.

Different from the spatial domain method, the frequency domain method mainly converts the image to the frequency domain through some special transformations, and then modifies the frequency

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domain parameters of the image through some features. Finally, the enhanced image is obtained through the inverse transformation. Common frequency-domain methods include underwater image enhancement based on wavelet transform [14,15] and other frequency-domain transformation methods [16,17]. The frequency-domain methods are robust to the image noise, but not to the image color bias and other visual effects.

Non-model image enhancement algorithms do not use models to determine the degradation process of underwater images. Therefore, these methods are effective for most images. That is, the non-model approach has a wider range of use than the model-based approach, but the enhancement effect is not as good as the model-based approach for images that conform to the model.

4. Conclusion

In this paper, firstly, the causes of underwater image degradation are analyzed. Many enhancement algorithms have been proposed to solve the problems of color bias, low resolution and rare edges of underwater images. These algorithms are classified into two categories and introduced. The two kinds of algorithms are further analyzed, and the development of the two kinds of algorithms and their advantages and disadvantages are illustrated. This provides a good foundation for the subsequent development of advanced algorithms.

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