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A REVIEW ON UNDERWATER IMAGE PROCESSING

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Abstract

The field of underwater image processing has seen significant improvements during the past few decades. We examine some of the most current techniques created especially for the underwater world in this study. Marine ecology, underwater archaeology, underwater biological identification, and underwater robot vision all significantly rely on the restoration of clear and authentic underwater footage. Particles in the shallow water repeatedly reflect and deflect light before it reaches the camera. The goal of picture enhancement and restoration algorithms is to resolve blurring and background scattering, increase clarity, and restore color in order to retrieve meaningful information for underwater scenes. These are especially difficult because of the complicated underwater environment, where water turbidity and other different elements deteriorate photographs.

Keywords: Image quality, filtering, underwater image enhancement, contrast

1. INTRODUCTION

The fundamental physics of light propagation in the water medium must be taken into account before we can deal with underwater picture processing. Degradation effects that are absent from typical airborne pictures are caused by the physical characteristics of the medium. Because light is progressively attenuated as it moves through the water, underwater photographs are fundamentally characterized by low visibility, resulting in sceneries that are fuzzy and poorly contrasted [1-3]. The vision distance is limited by light attenuation to around twenty meters in clear water and five meters or less in muddy water. Both absorption and scattering contribute to the process of light attenuation.

Underwater photography has a great preponderance of bluish and greenish colors, in contrast to traditional imaging shot above sea in the open. However, vision is significantly reduced because of substantial attenuation of light in the water relative to the air and the increased dispersion of incident light. As a result, things that are far away from the acquisition system or the observer, as well as those that are medium or even reasonably close, are difficult to see and have poor contrast with their surroundings. Throughout the image restoration process, the image enhancement approach increases the information quantity and quality of the original data, as well as the noisy and fuzzy image [4-5].

Marine biology can benefit greatly from underwater picture processing. The focus of this research is on several picture enhancing approaches in underwater image processing.

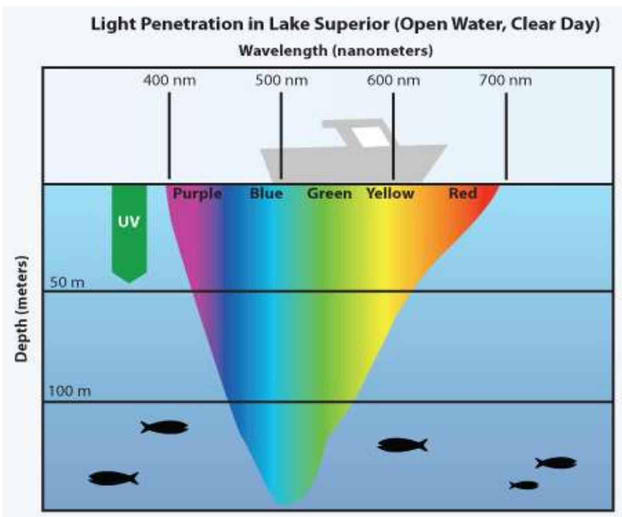

Figure 1. Deep Water level Effect of light color

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2. LITERATURE SURVEY

Underwater picture enhancement, underwater image restoration, and underwater image dehazing are some of the terms used in the literature to describe the process of increasing underwater image quality. Some literature defines "underwater image dehazing" since there are some parallels between the task we researched and the image dehazing task, such as comparable imaging principles [6]. In recent publications, this definition has been employed less frequently [7].

However, applying conventional reconstruction and restoration techniques to underwater computer vision is difficult because additional factors linked to the wavelength and range dependence of light attenuation in the water column must be taken into account. All of the scattering events within the line of sight (an imaginary line from the image sensor to the object of interest) and the water column have an impact on the light that reaches the sensor because, in the case of underwater image development, the sum of absorption and scattering yields the attenuation coefficient [8]

Shorter wavelengths are attenuated far less than the infrared spectrum, which is nearly completely lost from the surface in depths of one meter and below due to the absorption of wavelengths from the red to the blue-green band by particulate and dissolved matter. In contrast to reflectance models in air, where light propagates differently, this causes the blue or green cast seen in the majority of underwater photos [9]. Because of this, computer vision techniques frequently use color constancy approaches rather than taking wavelength and range dependency into account.

The work [10] provided a technique for improving underwater images using the retinex algorithm and adaptive feedback. The technique was improved by using guided filtering, which shortened the processing time for underwater images. Additionally, they suggested adaptive feedback stretching of saturation technique that may preserve the underwater image's structural details while enhancing its clarity; nonetheless, the global contrast improvement is insufficient. [11] created a Bayesian retinex method that uses multiorder gradient priors of light and reflectance to improve a single underwater picture. The color-corrected picture is subjected to multiorder gradient priors on reflectance and illumination in order to build a maximum a posteriori formulation for underwater image enhancement. The suggested method's efficacy in color correction and naturalness preservation is demonstrated by this algorithm.

By removing the uneven lighting and the impact of the irradiation component on the object's color, retinex theory, which is based on color constancy, produces the genuine representation of the scene. Research provided a thorough analysis of the automated color equalization (ACE) technique in the references [12], including its use in the field of underwater photographs. A multiscale retinex (MSR) enhancement technique and color enhancement retinex theory was used [13] to improve deteriorated underwater photos. Although there is some improvement, underwater photos have better visual impacts.

It is evident that there is little direct use of retinex for improving underwater images. Overexposure or too low contrasts are issues with the improved image. RGB is frequently used in conjunction with HSV and other color schemes to modify lighting and color. It can also be used in conjunction with other pretreatment or post-processing techniques, such as color correction, contrast stretching, and filtering. This may result in a noticeable improvement in appearance. The better models of this kind of approach frequently have too many parameters, which is an inevitable issue. To adapt to various undersea settings, parameters must be changed. The retinex algorithms are used for underwater images.

Author [14] used a previous estimation technique to predict transmission patterns based on attenuation differences across red channels. A triangle filter was used to adjust for the transmission, maintain the edge, eliminate noise, and expedite the computation. In order to lower the computational complexity, the color correcting approach simultaneously substitutes the convolution process for the summation operation. A quick improvement technique for underwater

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photos with uneven lighting was presented by the author in [15]. According to the gray world hypothesis, color correction is done using the area summation table approach, which lowers computing complexity and is appropriate for video improvement, based on local variations in brightness and chromaticity. They also suggested an automated multithreading technique for a real-time multithreading underwater picture enhancing system.

Using the timing features of the video along with the timing connection between frames is another way to improve underwater video. The correlations between neighboring frames will be broken if video frames are simply enhanced and connected, and the movie's overall color constancy would be lost. Moreover, the temporal complexity will be quite high. The time-bilateral filtering technique is applied to the white balance version of the video frame in the picture fusion method suggested by [16]. A bilateral filter is a non-iterative edge-preserving filter constructed on a kernel domain that combines the window's center pixel with nearby pixels to increase the smooth region's stability and sharpness.

The authors in [17] carried out stereo reconstruction and video dehazing simultaneously. Compared to conventional stereo or fog removal techniques, the depth cues from stereo matching and fog information complement one another. The light consistency term is initially enhanced in order to replicate the appearance shift brought about by the scattering effect. The sequence coherence between the scene depth and the fog propagation of nearby points is strengthened by the a priori matting Laplace constraint of fog propagation, which applies a smoothing requirement to maintain scene depth features. In addition to the auxiliary variables for iterative optimization, these limitations were added to the built MRF framework. The technique uses the scene depth to determine each pixel's fog transmission. This guarantees consistent stereo reconstruction and defogging outcomes.

3. DATASET

Datasets comprising photos and films taken in freshwater and marine settings are known as underwater picture datasets. For underwater applications like image enhancement, object detection, image restoration, marine species classification, coral reef monitoring, underwater robotics, and autonomous underwater vehicles (AUVs), these datasets are extensively utilized for the development and assessment of computer vision and deep learning algorithms.

1. UIEB (Underwater Image Enhancement Benchmark)

The Underwater Image Enhancement Benchmark (UIEB) provides a standard benchmark for evaluating underwater image enhancement algorithms. It contains 950 real underwater images captured under various underwater conditions, including different lighting, depths, and water types. Among these, 890 images are accompanied by high-quality reference images, which were selected through a human evaluation process to represent the best possible enhanced versions. The remaining images are considered challenging cases without satisfactory reference images. UIEB is one of the most widely used datasets for training and testing deep learning models for underwater image enhancement.

2. EUVP (Enhancing Underwater Visual Perception)

The Enhancing Underwater Visual Perception (EUVP) dataset was introduced in 2020 to support the development of deep learning techniques for underwater image enhancement and restoration. It contains more than 20,000 underwater image pairs, making it one of the largest publicly available underwater datasets. The dataset includes both paired and unpaired images, allowing researchers to train supervised and unsupervised learning models such as Generative Adversarial Networks (GANs). Images were collected from diverse underwater environments, including oceans, lakes, and swimming pools, representing various lighting conditions, water depths, and color distortions. EUVP is widely used for tasks such as underwater image enhancement, image restoration, color correction, and domain adaptation.

3. RUIE (Real-world Underwater Image Enhancement)

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The Real-world Underwater Image Enhancement (RUIE) dataset was developed specifically to evaluate underwater image enhancement methods under real-world conditions. It contains 4,224 underwater images captured in different aquatic environments exhibiting varying levels of turbidity, illumination, and color degradation. Unlike datasets with reference images, RUIE focuses on evaluating enhancement algorithms in practical scenarios where ground-truth images are unavailable. The dataset is divided into three subsets: the Underwater Image Quality Set (UIQS) for visibility enhancement, the Underwater Color Cast Set (UCCS) for color correction, and the Underwater Higher-level Task-driven Set (UHTS) for evaluating object detection performance after enhancement.

4. SUIM (Segmented Underwater Image Dataset)
The Segmented Underwater Image (SUIM) dataset was introduced in 2020 to facilitate research in underwater semantic segmentation. It contains 1,525 underwater images with detailed pixel-level annotations, enabling precise segmentation of underwater scenes. The dataset includes various underwater objects such as fish, coral reefs, sea plants, robots, human divers, and the sea floor, covering a wide range of natural and artificial underwater environments. SUIM supports the development and evaluation of deep learning models for semantic segmentation, underwater scene understanding, autonomous underwater vehicle (AUV) navigation, and marine ecosystem monitoring. Due to its comprehensive annotations and diverse image content, SUIM has become a standard benchmark for underwater image segmentation tasks.

4. METHODOLOGY

The rising need for precise underwater exploration, marine biodiversity monitoring, offshore infrastructure inspection, underwater archaeology, and autonomous underwater vehicle (AUV) navigation has made the development of underwater image processing systems crucial. The physical characteristics of water, such as light absorption, scattering, suspended particles, color attenuation, low contrast, and uneven lighting, provide special difficulties for underwater imaging systems in contrast to terrestrial imaging systems. These elements considerably deteriorate image quality and lower the effectiveness of traditional computer vision algorithms.
Several interrelated steps make up a typical underwater image processing system, which converts unprocessed underwater photos into useful data. Image acquisition is the first step in the process, when underwater cameras, autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), or underwater drones take pictures in various environmental settings. The following step is picture preprocessing to enhance image quality because the obtained photos frequently contain noise, haze, color distortion, and poor visibility. Denoising, color correction, white balance modification, histogram equalization, contrast enhancement, and picture restoration procedures are examples of preprocessing techniques.
Image capture, preprocessing, enhancement, quality evaluation, and application-specific analysis are all integrated into a single workflow by the underwater image enhancement system. Modern enhancement systems greatly improve underwater image quality and enable dependable performance in scientific research, marine exploration, environmental monitoring, and autonomous underwater operations by fusing traditional image processing methods with cutting-edge deep learning models. Numerous cutting-edge underwater vision systems reported in recent literature are based on this technique.

5. CONCLUSION

This work provides various underwater image processing techniques for image enhancement. Underwater image processing has become a fast-developing field of study due to its important significance in marine exploration, environmental monitoring, underwater robotics, archeology, and oceanographic studies. The main advancements in underwater picture improvement and restoration have been reviewed here, along with the advantages and disadvantages of both conventional image processing methods and cutting-edge deep learning strategies.

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Recent developments in deep learning have greatly enhanced and restored underwater images. The capacity to restore picture color, contrast, texture, and structural elements while maintaining natural scene information has been demonstrated via Convolution Neural Networks (CNNs), Generative Adversarial Networks (GANs), Transformer-based architectures, and diffusion models.

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