Review on Enhancement Techniques for Underwater Images

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***Abstract*: In Ocean engineering, getting clear images and recordings in underwater conditions is critical. Because of the differences in physical attributes, underwater image and video restoration and enhancement are difficult tasks. Scattering and absorption are major aspects in the underwater climate that generates hazy photos and recordings, as well as color distortion, low contrast, and a reduction in visual range. Underwater images offer many rare attractions but capturing such a picture is challenging because of the exceptional properties of the underwater environment that is several hundred times denser than the normal atmosphere. This paper talks about several underwater image enhancement techniques like Contrast enhancement, Histogram Equalization, Contrast Stretching, Homomorphic Filtering, etc.**

***Keywords*: Underwater Image Enhancement, Underwater ecosystem, Restoration, Histogram Equalization, CLAHE**

I. INTRODUCTION

The underwater image enhancement has drawn a great deal of consideration in the processing and perception of images. Underwater Image Enhancement is a challenge because the underwater environment and lighting conditions are complicated. The wave length-based absorption and dispersion, including forwarding dispersion and reverse dispersion, typically deteriorate an underwater picture. Also, marine snow creates noise and also increases the effects of dispersion. The natural light is absorbed quickly by subsea water. That decreases contrast and sharpness. Underwater photographers faced a remarkable loss of color/naturalness when deeper they dive that is why underwater image enhancement is necessary. These negative effects reduced visibility, decreased contrast, the practical applications of marine biology as well as marine ecological underwater images & videos is also affected. To solve this problem, earlier methods used multiple underwater images or filters, whereas recent algorithms solve this problem using only single-image content.

Improving images requires computer image processing system that transforms visual photographs. Modification of the picture involves changing the contrast and color, sharpening or vibration, etc. This technique is important to increase contrast since the human eyes are more prone to luminance than the image chrominance/color. Contrast improvement theory is to enhance the image's visibility while adding unnecessary effects and objects. Diverse images including medical images, satellite images, and real-life pictures can be prone to noise or bad contrast because of inadequate illumination during shot image capture or the incorrect change of the camera's aperture size or shutter speed. The area of use extends from scientific imaging to images in everyday life. Improving contrast is an important & problematic field in the production of images.

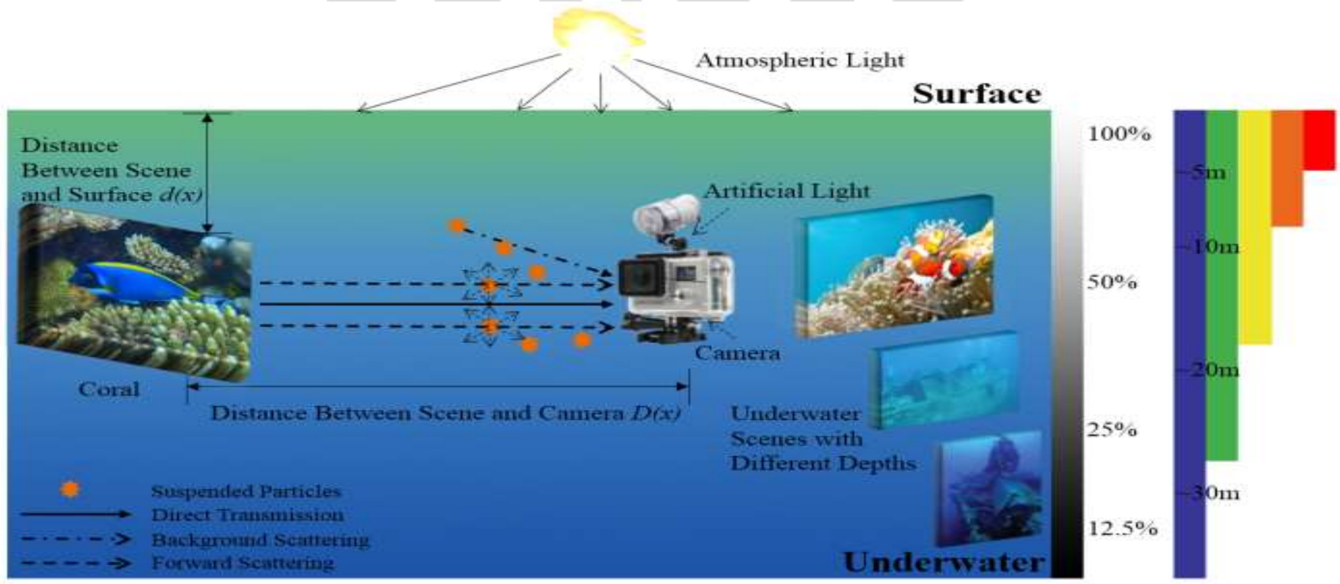

Fig.1. An illustration of Underwater Optical Imaging.

Understanding the Underwater optical imaging (UOI) model may helping the advancement of more robust and efficient enhancing solutions. The UOI process and particular light weakening are portrayed in Figure.1, which was portrayed and refreshed by Huang et al. model [2]. To the right half of Figure.1, the particular attenuation characteristics were represented. Since red light has a longer wavelength, it tends to absorb quicker than the green and blue wavelength, when travelling through water. As a result, underwater photographs feature somewhat green-bluish tones.

The interaction of light, transmission medium, camera, and scene is illustrated in Figure 1. In the line of sight (LOS), three forms of light energies are established by the camera: direct transmission: light energy reflected from the scene captured; forward scattering: light energy scattered by little suspended particles but still arriving at the camera, and background scattering: light energy reflected by suspended particles.

II. PROBLEMS WITH UNDERWATER IMAGE PROCESSING

Light is associated with the water medium in an underwater environment through two processes: absorption, which refers to the loss of power based on its index of refraction, as light travels through the medium, and scattering, which refers to the deflection of light from a straight-line propagation path. Deflection can occur when the particulate matter has a refraction index that differs from that of water which can either cause refraction or diffraction. Processing underwater images present several challenges and suffer from- Strong absorption, Scattering, Color distortion, Noise, Image blur, Haziness, Bluish or greenish tone, Poor illumination etc.

III. UNDERWATER IMAGE ENHANCEMENT

Underwater image enhancement is a set of computer techniques that are applied to degraded photographs to improve image quality, contrast, and detail information acceptable for human and machine interpretation. Image Enhancement can be broadly categorized into the following two methods as shown in figure 2. Spatial Domain Methods and Frequency Domain Methods.

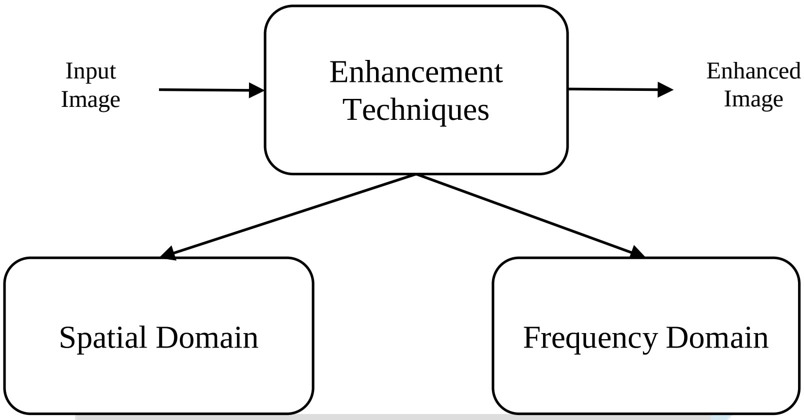

Fig .2. Image Enhancement Techniques

Spatial Domain

The techniques that perform manipulation operations on individual pixels of a given image are referred to as spatial domain improvement techniques. For pixel processing, it contains point arithmetic operations and neighbourhood enhancement methods. Mathematical representation of spatial domain enhancement-

$$g(x, y) = T[f(x, y)] \qquad (1)$$

where,
$f(x, y)$: the Input image.
$g(x, y)$: The Enhanced image.
T: an operator on f, defined over some neighbourhood of (x, y).

Frequency Domain

The Fourier Transform (FT) of a picture is carried out in the frequency domain, and the output is then multiplied by a filter. To get the original enhanced image, use the Inverse FT. Low-pass, high-pass, and homomorphic filtering are all part of the frequency domain enhancement methods. Mathematical representation of frequency domain enhancement-

$$g(x, y) = h(x, y) * f(x, y) \qquad (2)$$
$$G(u, v) = H(u, v)F(u, v) \qquad (3)$$

where,
$f(x, y)$: the Input image.
$g(x, y)$: the Enhanced image.
$h(x, y)$: the Filter functions.
$F(u, v), H(u, v), G(u, v)$: are the Fourier transforms of $f(x, y),\ h(x, y),\ g(x, y)$ respectively.

IV. RELATED WORK

Underwater image processing is a significant subject in scholastics. Numerous techniques and calculations for underwater picture enhancement have been created by numerous researchers. GuojiaHou et al.[3] developed an underwater image synthesis algorithm (UISA) through which synthetic underwater images can be generated from an outdoor ground-truth image built on real-world underwater images. They create a new large-scale benchmark based on this method that includes ground-truth photos and synthetic UI of the same landscape, dubbed the synthetic underwater image dataset (SUID). The SUID is based on the UI formation model (IFM) and underwater optical propagation properties, and it has a high level of dependability and practicability. The suggested SUID allows for an FR assessment of current UI enhancement and restoration technologies shown by rigorous experimentation and measurable studies.

Sharma et al.[4] focuses on a distinctive underwater image enhancement technique, which is implemented in 3 steps. They also investigated the discrete cosine transformation to balance picture illumination and the tri-threshold intensification technique for underwater image enhancement. The method followed and compared with three existing strategies to test the efficacy of their method's competency and found that the approach proposed produces better performance.

Y. Li et al.[5] introduced a super-goal renovation technique to resolve the underwater degraded image problem. Gamma correction is utilized to recover the sensitivity of the enhanced image. The researchers fused the network with Retinex Algorithm. This synthesis of multiple methods provided better results than methods from BI and SRCNN.

The turbid aquatic climate presents major obstacles for vision processing implementations. The dynamic noise propagation of the underwater images is one of the main challenges owing to the extreme scattering and absorption. To reduce this issue, Xin Sun et.al.[6] introduced an encoding-decoding method to improve the underwater image by creating a profound network model of pixels to pixels. This encodes the sound buffer using convergence layers, while the layers of deconvolution are used to decode the lost details and optimize the pixel-by-pixel audio frame.

Iman Abaspur et al.[7] provides a quick and reliable underwater picture mosaicking system that is based on key-point extraction (2D)2-PCA and A-KAZE, as well as optimal seam-line approaches. As a pre-processing phase in the system, image enhancement is employed to improve quality and allow for better key frame extraction and matching performance, resulting in higher-quality mosaicking.

The authors' primary application emphasis is underwater imaging, which proves the proposed system's capability for advanced underwater reconstructions. The outcomes suggested that the introduced approach is capable of dealing with noise, mismatching, and quality difficulties that are common in underwater image collections. The outcomes uncover that the proposed technique is scale-invariant and that it beats existing techniques in the context of processed speed and robust systems.

V. TECHNIQUES OF UNDERWATER IMAGE ENHANCEMENT

In this fragment, we have examined many image enhancement strategies which come under spatial domain and frequency domain enhancement methods, which can enhance UI.

Table 1 Various Approaches Used For Underwater Images

Technique	Advantage
Depth estimation Method [8]	Underwater photos are enhanced and recovered, as well as precisely determine the depth of an underwater scene.
Dark Channel Prior Method [9]	Enhances outstanding color fidelity and visibility of underwater pictures, as well as reduces computing complexity and increasing dehazing affect efficacy.
Red Channel Method [10]	When compared to other best-in-class techniques, it gracefully manages artificially illuminated zones and accomplishes natural color correction and similar or higher visibility growth.
Histogram Method [11]	Auto level for the underwater image is improved
Particle Swarm Optimization [12]	Reduces the number of particles and the greatest number of iterations, while likewise working on the quality and speed of the underwater image.
WCID Algorithm (Wavelength compensation and image dehazing) [13]	Eliminates artificial lighting and picture quality is maintained
CLAHE [14]	The contrast and intensity of underwater photos are enhanced.

Histogram Equalization (HE)

HE is a common picture enhancement technique that improves image contrast and attractiveness. Imagine we have a predominantly darker tone image. The visible contents are squeezed into the dark end of the histogram, which is tilted towards the greyscale's lower end. Stretch out the grey levels towards the dark end of the image to create a more evenly spread histogram. By determining a greyscale transformation function, histogram equalization produces an image with a consistent histogram.

Brightness Preserving Bi-Histogram Equalization (BBHE)

The BBHE technique is used to keep an image's brightness. The preservation of brightness is one of the most significant features of an image. The histogram of an image is partitioned into two equalized sections using this method. As a result, the intensities are also evenly distributed. The brightness of a particular image has been modified as a result of histogram equalization's flattening property. As a result histogram equalization is rarely used in consumer electronics applications. To avoid unnecessary visual Corrosion, it may be required to preserve the original brightness of televisions and other devices[15].

Adaptive Histogram Equalization (AHE)

It is a technique for enhancing image contrast. It varies from Histogram Equalization in a way to calculate many histograms, each corresponding to a distinct part of the image, using an adaptive technique. Histogram Equalization will not sufficiently boost the contrast region of a picture. AHE improves this by using a transformation function drawn from a neighbourhood region to transform each pixel. It's used to get around some of the drawbacks of the global linear minimax windowing method. As a result, the amount of noise in some areas of the image is reduced. Additionally, AHE can improve grayscale and color image contrast [16].

Contrast Limited Adaptive Histogram Equalization (CLAHE)

It's a method of boosting grayscale image contrast. Rather than synthesizing the entire image, this method focuses on small sections of the image known as tiles. Each tile's contrast is enhanced, and the output region's histogram roughly follows the histogram indicated by the distribution parameter. To eliminate synthetically produced barriers, the neighbouring tiles are eventually blended using bilinear interpolation. The visual contrast might be limited, especially in homogeneous areas, to avoid exaggerating any noise.

Contrast Enhancement (CE)

Image enhancement techniques are useful in a variety of digital image processing applications where image quality in terms of contrast and visual appearance is critical for human interpretation. Contrast is a key consideration in any subjective assessment of digital image quality. The brightness difference reflected from two neighbouring surface is used to create the feature contrast. To put it another way, contrast is the distinction in graphic highlights or properties that recognizes an object from different objects and backgrounds.

The distinction in brightness, color, and the relationship of the object to other things determines visual perception contrast. Because the human graphic system is touchier to contrast than absolute luminance, humans can interpret the environment in the same way regardless of significant changes in lighting conditions.

The majority of contrast enhancement algorithms have been proposed and developed, and they are used to solve difficulties in image processing. This method automatically boosts the brightness of digital photographs that appear dark and blurry. To improve quality and clarity, use appropriate tone correction. For the most part, this approach is used in medical applications.

Contrast Stretching (CS)

It is a simple process of enhancing images and is used to improve the image contrast by 'stretching' intensity values series. The contrast of a picture is a measure of the range of the picture or the "broaden" histogram of the image. Full-spectrum of intensity values within the image, or more simply, the minimal differentiation by the maximum pixel value is considered as the dynamic picture range [17].

This is an image enhancement method used by stretching the varying color values to improve the values of the gray levels present in the processed picture. A pixel value of each picture is changed at the same time to improve the visualization of arrangement both in the dark and light regions of the image. A contrast of picture is variance among maximum and minimum pixel intensity. Like the equalization of the histogram, this handles a uniform scale function of picture pixel values.

Homomorphic Filtering (HE)

This filtering operates with a high-pass filter in the frequency domain (FD) to reduce the importance of low-incidence components. It is one of the essential ways to improve the digital picture, particularly if there are poor lighting conditions in the input image. In many imaging applications, including biometric, medical as well as robot vision, this filtering technique has been used [18].

Naturalness Preserved Image Enhancement (NPEA)

The NPEA model is used in preserving the natural nature of an image while improving its accuracy. In general, the following three main contributions are made through this study. First, it is introduced to provide objective access to natural preservation through the lightness-order-error method. Second, a bright-pass filter is suggested to break down an image into reflection or illumination that decides specifics or naturalness of the image respectively.

In the NPEA algorithm, two limitations are suggested. The first constraint concerns the specifics, requiring a range of [0, 1] specular reflection taking in explanation property of reflection[19].

The next limitation is naturalness, as the relative order of illumination in various local areas must not be dramatically modified. NPEA's most important aim is to preserve the naturalness of the image by enhancing non-uniform illumination of the picture elements.

NPEA is designed to restore the local image variance while preserving the overall intensity at the same time. The lightness order error (LOE) is computed for NP to evaluate the enhanced image.

Table 2 Comparison Of Various Enhancement Method

Methods	Advantages	Disadvantages
HE	It is effective for Gray-scale images.	With color images, increases the contrast of background noise while decreasing the signals.
BBHE	Preserves brightness and enhances the contrast.	Fails with no symmetric images.
AHE	It has a lot of low contrast and darker sections.	This does not work effectively.
CLAHE	It enhances contrast and minimizes noise and distortions in images, considerably improving their visual quality.	It is computationally intensive and operates on small data sections rather than the complete image.
CE	Improves visibility of object by adjusting brightness and darkness	It does not preserve the brightness of the image
CS	The graphic presentation of the actual scene is excellent.	Due to saturation and cutting, certain details may be lost.
HF	Multiplicative noise is removed. Gray-level range reduction and contrast augmentation in real-time.	Bleaching of the image is a problem.
NPEA	By improving the non-uniform illumination of the picture elements, the image's naturalness is preserved.	Some areas were not be modified.

VI. CONCLUSION

The field of image processing known as underwater picture enhancement is a fast-growing industry. Obtaining item visibility in underwater sceneries, whether at a short or long distance is a difficult issue. This review paper looked at the many approaches used in underwater image processing and describes how image quality can be improved. The resulting enhanced photos are superior in terms of image quality, contrast, uniform dynamic brightness range, edge and corner preservation, and so on, thanks to these enhancement approaches. The work could be expanded in the future by putting the methodologies under consideration to use concurrently and then comparing results with the proper estimation techniques.

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