Underwater Image Dehazing using Dark Channel Prior and Filtering Techniques

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***Abstract*— The enhancement of underwater imaging is essential for ocean engineering research and technology. Due to the increasing number of vision applications underwater, haze reduction methods have become increasingly significant. Scientists have recently been particularly eager to investigate the strange undersea environment. Haze in an image is problematic for many computer vision and graphics applications because it reduces scene visibility and visual quality. Absorption and air light cause a haze to appear. Attenuation lessens sharpness, and air light makes the landscape seems whiter. This study examines a method for haze removal from underwater images in order to enhance them and raise their quality. The method suggested makes underwater pictures clearer, which is important for research and improvement in the underwater world.**

Keywords—underwater image dehazing, Dark Channel Prior, underwater image enhancement

I. Introduction

The tasks of marine research and underwater automated observations heavily rely on underwater vision. However, the scattering and absorption phenomena that happen during the propagation of light normally weaken the underwater images [1]. Especially in the maritime environment, underwater photographs captured in this circumstance usually exhibit haze, poor contrast, and colour distortion. The underwater object detection job is in a difficulty as a result of the poor picture quality [2]. As a result, improving the underwater photos that have been damaged is important for many vision-based functionalities in underwater situations [3].Under ideal circumstances, the wavelengths of green, blue, and red light are, respectively, 525 nm, 475 nm, and 600 nm [4]. Compared to all other signals, the red colour signal, which has the least amount of energy, is rapidly absorbed and vanishes in the water (As shown in Fig 1). The underwater images often have a blue or greenish tone as a result [5]. There is a lot of floating matter in the underwater image, which scatters and absorbs the light before it gets to the camera. This makes the picture look hazy [6].

The complexities that arise from the physical characteristics of the underwater atmosphere make underwater image analysis a particularly difficult endeavour [7]. Absorption and scattering often lead to the degradation of underwater image capture. An example of underwater optical imaging is shown in Fig. 1. In an underwater environment, a camera's light is primarily produced by three factors: a direct element, which reflects sunlight from the things, a forward dispersion element, which randomly diverts light, and a backscattering element, which reflects sunlight in the opposite direction before it reaches the entities [8]. The three components mentioned above may be superimposed linearly to create an underwater image [9]. While the backscattering component obscures the situation's specifics, the forward scatter element blurs the image. Additionally, the presence of marine snow (i.e., microscopic floating particles) amplifies scattering impacts and introduces undesired noise. When used for presentation and collecting important data for analysis, such as in marine biology and marine archaeology [10], marine ecological study, and aquatic robotic supervision [11], degraded underwater photos exhibit several limitations. So, it would be nice to have a useful technique that could make underwater photos better for presentation and analysis [12].

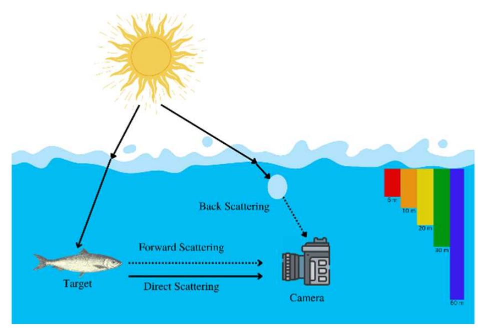


Fig 1: Effect of sunlight in the underwater *[6]*

Deep-sea species tracking and real-time navigation are two underwater activities [3] that often use underwater image enhancement methods as a pre-processing step. To repair the photographs taken in seawater, several researchers have devoted their efforts to creating underwater image improvement methods [1] [3] [6] [7] [9] [12] [13] [14]. The two major goals of underwater image improvement assignments are the reduction of colour distortion and the elimination of haze. In undersea images, colour dispersion and haze formation are linked processes that depend on the wavelength of the light and the distance it travels through the water. Both haze-line and dark channel prior (DCP) [14] [15] have had significant success with dehazing and image improvement for photographs taken from the air, and they also provide answers for situations requiring underwater image enhancement. Researchers have suggested numerous techniques to improve underwater photographs, derived from

[1] [3] [6] [7] [9] [12] [13] [14]. For underwater photos, it's still difficult to restore the image distortion and get rid of the haze.

In this paper, we have proposed a method for enhancement and dehazing of underwater images using DCP and filtering approach. Section II discusses the scope and objectives, Section III discusses the materials and methods, section IV presents the results and discussion and finally the article is concluded in section V.

II. Scope And Objectives

A. Objective

The goal of image enhancement is to modify an image such that the final result is more suited for a certain application than the original image. It draws attention to or emphasizes image elements like borders, limits, or contrasting to provide a graphic presentation more useful for study and display. The data's intrinsic information value is not increased by the augmentation. However, it widens the range of the selected traits to make them more detectable.

B. Scope

Images that are underexposed or taken underwater often have blurry details, poor contrast, uneven illumination, and decreased color. Digital image filtering is crucial for improving images. Digital image processing and interpretation are involved. Numerous causes may cause images to become noisy. As a result, de-noising the noisy images becomes critical. To get there, image refinement must be done. In order to enhance the quality of underwater digital images, this research article suggests a preprocessing approach based on the image.

III. Materials And Methods

A. Existing System

Underexposed image improvement approach based on optimally weighted multi-exposure image fusion. First, using a sequence of tone-mapping curves, we created multi-exposure image data with variously exposed copies of each underexposed image. From all of the multi-exposure image sequences, we then adaptively found the locally best-exposed parts and seamlessly combined them with a well-exposed image using certain weight values [16]. These weight values could be addressed by formulating them as an energy function so that the colors of the output image closely resemble those of photographs with high exposure while retaining characteristics from photographs with low exposure. Finally, we combined the image sequences to create a well-exposed image by integrating the best exposed areas.

B. Proposed Method

In this research, a dark channel prior (DCP)-based haze removal method and its reduction of haze are presented. The DCP is driven by the fact that certain pixels in images taken outdoors without haze often have extremely low intensity. The method is physically sound and is capable of handling far-off objects in images with significant haze. Even though a lower constraint was added to the transmission map (TM), the algorithm could still make noise louder in bright areas like the sky. The block diagram of proposed approach is shown in Fig 2.

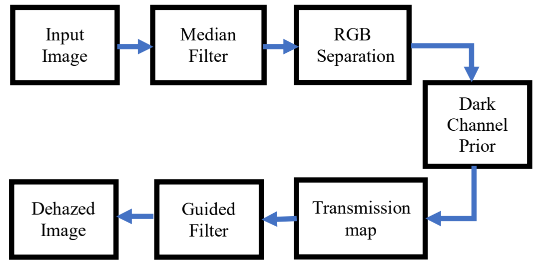


Fig 2: Proposed Methodology for Dehazing
Fig 2: Block Diagram of the Proposed Approach

Median filtering is a mathematical method for eliminating noise from images. It is often used because it successfully lowers noise while maintaining edges. To get rid of "salt and pepper" sounds, it works really well. The median filter iteratively scans the image, substituting all values with the median of its neighbors. The "window" is the neighborhood pattern, and it advances pixel by pixel over the whole image. After putting the pixel values in the window in numerical order, the median is found by substituting the pixel being looked at for the middle (median) value of the pixel. A simple and effective non-linear filter is the median filter. It is used to lessen the intensity variance between adjacent pixels. In this filter, the pixel value is swapped out for the median value [17]. To compute the median, all of the pixel values are first sorted in increasing order, and then the estimated pixel is replaced with the value of the middle pixel.

D. RGB Color Channels

Here are a few symbols that represent a photograph, including BGR, RGB, CMYK, HSV, etc [17]. But maybe there is something they all share in common. They serve as the conduits through which those image regions form an overall image. Take a look at a few explanations of channels with me. Pixels, which are combinations of the primary colors specified by a code chain, are what give rise to colored virtual snapshots. In this sense, a "channel" is a grayscale picture that has the same size as an image photo and is the result of any such amount of coloration. In single-channel grayscale photographs, each pixel contains the most basic information about the depth of light. These photos are constructed entirely of grey sunglasses frames. Grayscale photos shouldn't be compared to black-and-white photos (binary photos), which are made up of just black-and-white pixels. In binary snapshots, a pixel is either black or white. There is no difference between them. However, there are several shades of grey pixels in grayscale images. Grayscale photographs are two-channeled; RGB photographs are three-channeled.

E. UDCP Transmission

Estimating transmissions in underwater environments is done with a change to the DCP, which is a statistical prior based on features of images taken in natural outdoor settings. This approach, known as Underwater DCP (UDCP) [13], allows for a considerable advancement over previous DCP-based methodologies since it takes into account the blue and green color channels as the underwater visual source of information. This is shown by comparing it to the most up-to-date methods [17]. We also give a thorough analysis of our method that shows how it can be used and what its limits are using images from real and simulated situations.

F. Transmission Estimation

The greatest haze-opaque pixel is used to estimate ambient light A in the majority of single-image approaches [17]. For instance, the ambient light is further improved using the pixel with the greatest intensity. The brightest pixel in actual images, however, may be on a white automobile or structure. A haze image's dark channel accurately represents the haze's density. So, to enhance the assessment of ambient light, employ the dark channel. In the dark channel, we begin by selecting the top 0.1% of brightest pixels. The pixels of the given image with the greatest intensity are chosen as the atmospheric light because they are the most haze-opaque among these pixels.

A few pixels often have an extremely low intensity in at least one of the RGB channels throughout the majority of the image's areas, with the exception of the sky area [18]. Air light helps create the low-intensity pixels known as "dark pixels" in haze-distorted images. So, these dark pixels can be used to estimate how much haze is in the image [19].

A haze-free image is retrieved using this method utilizing the haze imaging model described below.

$$I(x) = J(x)t(x) + A(1 - t(x))$$

Were,

I(x) → Input hazy image
J(x) → Haze free image
t(x) → Transmission of the medium
A → Atmospheric Light

If the image is blurry, the first step is to find J_{Dark}, which is the dark channel. The following formula yields this.

$$J_{Dark} = \min_{y\in\Omega(x)}\left(\min_{c\in\{R,G,B\}} J^c(y)\right)$$

Here, $\Omega(x)$ is the local patch centered at x. We have fixed the patch size as 15×15 here for all the images.

These two min operators are responsible for the dark channel. The minimal pixel intensity in the local patch for every R, G, and B channel is provided by the one min operator, which acts on each channel individually. The minimal pixel intensity amongst every channel's lowest value is provided by the second min operator [19]. They are commutative minimum operators. We determine the values of A and t to use in this dark channel preceding J_{Dark}. By selecting the top 0.1% of sharpest pixels in the dark channel, atmospheric light A is calculated. As the ambient light changes, the pixels in the murky input image with the greatest intensity are chosen from among them [15].
The formula below is used to estimate the transmission medium.

$$t(x) = 1 - \omega_{y\in\Omega(x)}^{\min}\left(\min_c \frac{I^c(y)}{A^c}\right)$$

As in [18] [15][19], We have fixed the value of ω as 0.95.

We can recover the haze-free image using these computed values in the equation below [14].

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

As in [19] [18] [15], We have fixed the value of t_0 as 0.1.
The outcomes of the aforementioned method effectively reduce haze [18]. The "Guided Image Filter" is used to improve the halo artefacts in the image, nevertheless, indicates their existence. Using the technique described in the [18], We put this filter into practise.

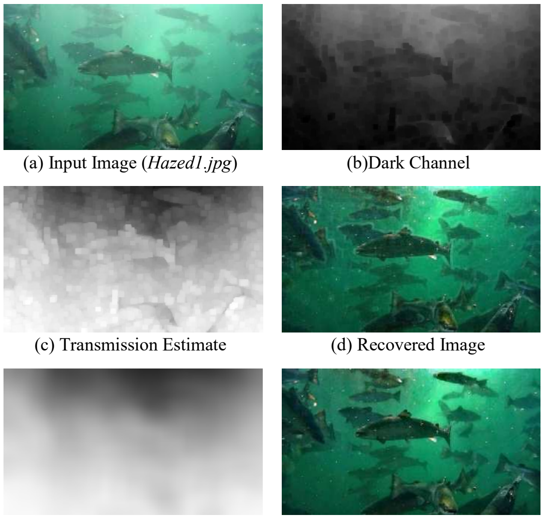
G. Transmission Refinement Using Guided Filter

The guided filter [18] [20] is used in to improve the coarser transmission map produced by the dark channel. The mating Laplacian matrix and the guided filter have a tight relationship. In the closed-form matting architecture, the input image, its *trimap* (or scribbling restrictions), and the alpha matte, respectively, perform comparable functions in the guided filter as the guiding image, the input p, and the filtering output q. It has been shown that the output of the guided filter in [5] is one Jacobi iteration for cost function optimization. Additionally, the guided filter's predicted value of the constraint weight is 2, indicating that the filter output (or the alpha matte) is only weakly bound by the input image p (or the *trimap* formatting). Since the enhanced transmission map in soft matting should be roughly bound by the coarse transmission map, as can be observed from the data term in [14], a guided filter is thus useful for transmission refinement.

IV. Results And Discussions

At the moment, impartial appraisal of underwater images remains difficult. Human observers have assessed the outputs of the majority of underwater image processing algorithms for their aesthetically pleasing qualities. Some algorithms quantify the effectiveness of the enhancement process using general image quality evaluation techniques, including PSNR, MSE, and Michelson contrast [21]. The applicability of these quality standards to underwater images is insufficient since they were not created particularly for underwater images. The histogram is another image type used to assess the quality of underwater images. However, this approach to histogram analysis only yields an analytical measurement as opposed to a quantitative one. The main drawback of these metrics is that they only directly take into account a few crucial traits, such as colour vibrancy and colour cast. Hence, in this section, the hazed test images used and its corresponding output dehazed images are depicted. Moreover, the quality metrics such as Underwater Image Quality Measurement (UIQM), Underwater Image Sharpness Measure (UISM), Underwater Image Contrast Measure (UIConM) [21] and Underwater Colour Image Quality Evaluation (UCIQE) [22] has been used for evaluating the performance of the proposed algorithm.

To limit the number of pages, the outputs of all steps are displayed for a single image, *Hazed1.jpg*, and just the original image and the hazed image are provided for the other images.



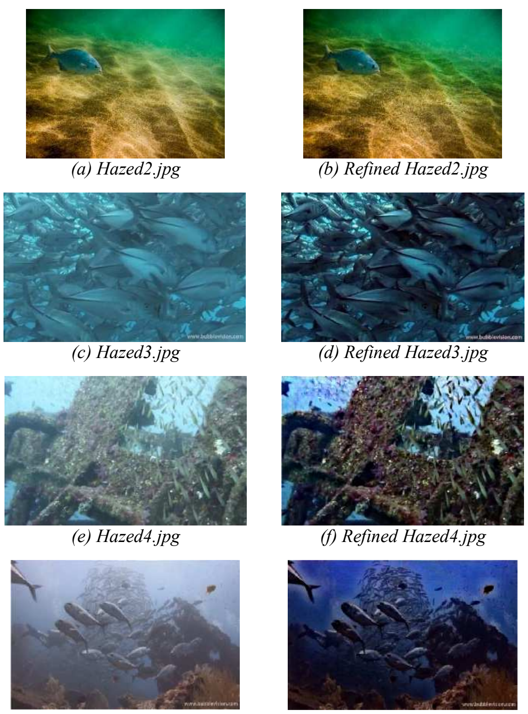
(a) Input Image (*Hazed1.jpg*) (b)Dark Channel

(c) Transmission Estimate (d) Recovered Image

(e) Refined Estimate (f) Refined Image

Fig. 3: Input and outputs of test image *Hazed1.jpg*

The Fig 3 shows the input and outputs of all the stages of the test image *Hazed1.jpg*. Fig 4 shows the inputs and final outputs of other test images. Also, the results of the metrics UIQM, UISM, UIConM and UCIQE obtained for these test images are presented in Table I.



(a) Hazed2.jpg *(b) Refined Hazed2.jpg*

(c) Hazed3.jpg *(d) Refined Hazed3.jpg*

(e) Hazed4.jpg *(f) Refined Hazed4.jpg*

(g) Hazed5.jpg *(h) Refined Hazed5.jpg*

Fig 4: Input and outputs of other test images

TABLE 1: RESULTS OBTAINED FOR ALL THE FIVE TEST IMAGES

Image	UIQM	UISM	UIConM	UCIQE
Hazed1.jpg	3.8422	7.0972	0.6233	9.8563
Hazed2.jpg	4.7904	6.8667	0.8737	11.0838
Hazed3.jpg	4.7073	6.63453	0.8923	6.0917
Hazed4.jpg	5.2427	8.0676	0.8662	11.6394
Hazed5.jpg	3.9722	6.9873	0.6444	3.8603

V. CONCLUSION

The discipline of image processing known as underwater imaging is a vibrant one. New uses and approaches for improving underwater images and videos are often reported in the creation of new products. Innovative research areas that have the ability to greatly aid designers in better examining underexposed environments include intelligence de-hazing and colour restoring techniques for underexposed images. We provide an improved method that works on underwater images, eliminates artificial illumination, and maintains image quality in order to improve underwater image dehazing. For better underwater image quality, our suggested method puts the dehazed frame into the underwater image that was sent in.

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