A Hybrid Approach to Enhance Underwater Images

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Abstract. Underwater pictures are barely visible due to effects of dispersion and absorption. Due to poor visibility it is very difficult to study underwater environment. Many Techniques have been used to increase the quality of degraded underwater images. This research paper follows the approach which has two major steps. First step is color correction based on grey world hypothesis. The second step is dehazing technique which is used to eradicate camera haziness. The approach suggested is ideal for use in real time application.

1. Introduction

The method of taking photographs underwater is called underwater photography. Image is captured during underwater diving, swimming, from a camera which can be operated from a remote location or from lowered surface automated camera. These Underwater images are used in many researches these images can be used to study underwater environment. Researchers can study aquatic plants and animals using these images. Many ships which are found either breached on the land or sunken to the bottom of a body of water can be studied and identified using these images, but the primary obstacle faced by underwater photographers or the primary obstacle in studying from these underwater images is the loss of color and contrast. The image which is taken underwater gets degraded and is not clear this is because of light absorption and dispersion. Due to the inadequate lighting and interference of the propagated light, the underwater images degrade more than a regular image that has poor visibility. The light typically decreases exponentially with the length and depth due to the light being scattered and absorbed. The direction of light will be influenced which will eventually blur the picture. In a particular direction, the attenuation of light is not defined. It varies instantly according to external conditions. Such light attenuation creates a muddled appearance while the scattered light vitiates the contrast. Because their wavelengths are affected, the objects in the sea water that are more
than 10 meters are almost hazy with fading colors. Ultimately, all of these variables contribute to a low contrast picture that appears blurred and hazy.

The degraded image can be restored by various techniques that are not very effective. To tackle these issues and to enhance underwater image standard, numerous methods of picture reconstruction & enhancement have been suggested. The goal in enhancing the picture is to get the image back by explicitly modelling the degradation process. E.g., Many haze reduction algorithms have been introduced to fix contrast distortions. Many of these concentrate on modelling the dark channel.

In this paper, we suggest an easy but efficient hybrid enhancement technique that allows only a single underwater picture to be enhanced. Every steps handles one of the two key problems of color saturation & poor contrast. For this issue of color distortion, we suggest a technique for colour correction based on a of piecewise linear transformation. Similar to different colour correction techniques, the suggested algorithm is highly effective when coping with differing color distortion in underwater setting. Even after color correcting the image the contrast will still be a problem so to overcome that Image dehazing technique has been used to remove the haziness of the image.

Figure 1. (a) Represents degraded image (b) Represents enhanced image.
2. Literature Review

2.1. Two-Step Approach for Single Underwater Image Enhancement.

In this paper [1], they proposed a simple but efficient strategy that has only 2 steps and only requires the improvement of the single underwater picture. The two key issues like color saturation and poor contrast are discussed in each step. For the first step they proposed a color correction technique which depends on a partly linear transformation for the problem of color distortions. The proposed algorithm is better to address the various degrees of colour distortion in underground environment than other color corrective algorithms. They used an optimal contrast technique for low contrast of the underwater picture, this technique is used as it is very efficient and reduce artifacts. Other techniques like Equalizing histograms (HE) and CLAHE (Contrast Limited) histograms are easy to implement, but have unwanted artifacts because of their blackbox deployment.

2.1.1. Color Correction:
As the colors are hard to recreate in underwater pictures conventional algorithms for color correction may fail to recover colors due to light absorption [9]. Scenes in the meantime the poor illumination conditions cause underwater images to seem dim. They used a color adjustment approach depends on a linear transition. Inspired by the Gray-World Hypothesis[9]. According to this hypothesis the average colour on a picture is achromatic[9]. In other respects, the average of an 8-bit picture is supposed to be 128.

The color correlation approach proposed is a linear transformation in part based on this gray-world hypothesis. Stretch the average value of the picture up to 128. The medium is used as a criterion for determining the direction to be taken. As in particular, the scaling above will induce over-correction by unnecessary straightening, for example underwaters, where the red channel width is extremely low due to rapid absorption of the red wave length they used a different approach there.

2.1.2. Optimal Contrast:
Once color correction is completed, underwater pictures will still look hazy because the condition underwater resembles a hazy environment[10,11,12]. Therefore, contrast to highlight objects and details should be improved. An improved imagen between the normal image and an output image is the fundamental idea of our contrast approach. In addition, a weight restriction can be included to the target function to avoid unusual pictures[13]. This prevents overimproved result by smoothing the improved picture so that sudden changes are avoided without affecting the contrast increase.

Figure 2. Two Step approach.

2.2. Single Image Haze Removal using Dark Channel Prior
A simple but effective technique of removing Haze from the picture using the dark channel Prior has been used in certain researches[14, 15]. The dark channel before is a sort of outdoor image statistics. This is focused on a crucial finding that most local patches include pixels with very low intensities on at least one color channel in haze free exterior images. This will help us measure the haze thickness and provide a high-quality haze-free image utilizing the haze imaging device beforehand. Results on a variety of images from outdoor haze show the power of the previous one. In addition, the product for haze removal may also obtain a high-quality depth map. First of all, eliminating hazel will significantly improve the scene's brightness and correct the airlight's color change. The hazel-free picture is generally has high gratifying visually. Secondly, Most machine view algorithms typically presume that the picture data has the lighting of a scene from low image processing to high level object recognition after radiometric calibration. These algorithms performance (e.g., characteristics detection, filtering & photographic analysis) will inevitably undermine the prejudicial, low contrast luster. Lastly, The removal of the hazel can generate depth data and many views and advanced picture editing algorithms benefit [16]. Blur or Fog may be a valuable glimpse into the nature of the environment. The image of the wrong haze can be used well. At least one light channel has a strong contrast of certain pixels of most non-sky regions: the dark channel previous is based on an observation of hazard-free images from outside. In other words, the total size should be very small in such a patch. Normally for a picture \( J \) they defined as

\[
f_{\text{dark}}(x) = \min(\min(f_c^e(y)))
\]  

Where in equation(1), \( c \in \{r, g, b\} \), \( y \in \Omega(x) \) and \( J_c \) is color channel of \( J \) & \( \Omega(x) \) is a local patch centered at \( x \).

There are three factors to the poor intensities in the dark channel. For instance, the shadows of cars, buildings, and windows on the inside of images of the townscape, or the shadows of the picture of pictures of the leaves, trees and rocks; For example, an object lacking in color in any color channel will leads in low dark- channel value, \( c \) dark surfaces or objects. For eg, the stone and dark tree trunk. The dark channels of such pictures are extremely dark, as the natural outdoor images usually are full of shadows and colors.

2.2. Underwater Image Enhancement using fusion

An effective strategy for optimizing underwater images on the basis of a single image [4]. This technique is straightforward and can be carried out relatively quickly on any equipment. This method is focused on fusion. The magnificence of this method lies in the need for a single image. This approach does not require multiple images, only one image is sufficient to be processed through multiple enhancement techniques. Such methods consist only of the distorted image deriving inputs and weights. Such methods consist only of the distorted object deriving inputs and weights. Current improvement methods such as white balance, color adjustment, Equalization of histogram many drawbacks, only the one combined use of these strategies provides the good results. The result of the fusion method relies on the type of inputs and ultimately on the weights that we are applying on these inputs to obtain better enhanced images which are captured underwater. From originally restored version, the undesired noise is removed. With several weight charts, their solution strengthens the photos. Their algorithm's weight maps gage the several object attributes that determine the relationships between spatial pixels. Such weights allocate higher values to pixels to increase the image quality. This is a method of multi-resolution that is stable to objects.

Single image-based approach [4] have used a built on fusion principle. This is a quick and simple solution that can improve the exposure of underwater objects. While advanced optical systems are not used, the called weights and defined inputs have been carefully taken to address the weakness of such settings. Using two sources, the original image is extracted. The photo is filtered first and white balance methodology is applied after that weights added to these images and the resultant weighted
images are fused. The second input processes the image in the same way. The two resulting images will be further merged and the improved picture will be collected.

2.2.1. Inputs:
To get the Clear image from the degraded image using fusion, proper application of inputs and weights involved. They used the fastest and easiest fusion system methods, so we're using derived inputs to tackle this method. Because of the various wavelengths of light, such as the penetration of light and dispersion, this induces some with less Wavelength dispersion, remainder of light of different duration.

The channel will be divided by wavelength. This will inevitably result in the light difference. At the same moment, light absorption can decrease the light intensity. Thus, they used an output approach to tackle this problem called the process of white balancing. To restore the natural light, this white balance is used [5] [6]. Thus global contrast enhancement is another output technique that is used because after light attenuation global contrast method of picture is stronger. then add output to the main picture which was white balanced, then they derived a picture let’s say P1 and then another reference picture (P2) by using the global contrast enhancement technique.

2.2.2. Weights:
They are proposing maps of weight because the original image can be recreated. Mainly every picture is linked to color display and as a consequence, observable values like salient characteristics, local contrast, global contrast and saturation are hard to accommodate by blending naively per pixel, left out the possibility of adding artifacts. Thus, they needed higher weight values in order to achieve final and transparent image. In addition, the RGB system is not good to describe the color of the human sight. Thus, they follow the color object because it describes the Saturation, color, contrast and in this method, they used weight maps such as the luminance weight to quantify and search clues from the source picture [7][8]. Then they can get more accurate results combined into one picture. In this approach they have used three weights which are Chromatic weight, Luminance Weight Map and Saliency weight.

2.2.3. Image Fusion:
In the last step the different images derived after putting weights gets fused to get the desired result. Image fusion is a technique where exact computed maps weigh the inputs to preserve the most important perceived characteristics. So, they fuse all the 3 weighted images which are derived from input I1 and same for images of input I2. After that fuse both image to get the derived output image.

![Flow Chart of their work.](image_url)
3. The Proposed Approach

![Figure 4. Proposed Approach for this paper.](image)

In the proposed model the underwater image will undergo two steps.

3.1. Color Correction

Color correction is the technique of changing raw image data so that the resulting image looks realistic. In other word it a image processing technique that transforms a camera dependent RGB space to standard space. Color correction is a process in the lighting of a stage, photography, television, film and other disciplines that use gels or filters for changing the overall color of light. A scene can have a mixture of different colors, without colored gels. Conceptually, the color correction can be broken down into three facets: brightness, contrast, and color balance. Brightness & contrast can be seen as tonal changes combined. Because underwater image colors are hard to recover due to absorption of light, traditional color correction algorithms can fail to retrieve colors. While, underwater picture scenes appear dark because of bad lighting conditions. Inspired by the gray-world hypothesis [9], we are using a linear transformation-based approach to correct color.

The theory in the gray-world suggests the mean colour in a picture is achromatic [9]. Achromatic means that every bit for an 8-bit image has value 1 or in other words, in an 8-bit image, the average value of the picture equals 128.

The suggested color correction approach, depends on this gray-world hypothesis, which is depends on a piecewise linear transformation to extend the average value of the picture towards 128. As the grey world hypothesis suggest that every image should have mean equals to 128 so we are stretching the mean value to get the color corrected image. Defining I as the input image, the steps are: First, the RGB channels of I measure the mean, average, and minimum. The Basic formula which is used in color correction using grey world hypothesis is:

\[
I_{cCR}^c =  \begin{cases} 
(I^c - I_{c \text{mean}}^c) \frac{I_{c \text{min}}^c - 128}{I_{c \text{min}}^c - I_{c \text{mean}}^c} + 128, & I_{c \text{mean}}^c \leq 128, \\
(I^c - I_{c \text{mean}}^c) \frac{I_{c \text{max}}^c - 128}{I_{c \text{max}}^c - I_{c \text{mean}}^c} + 128, & I_{c \text{mean}}^c > 128,
\end{cases}
\]  

(2)

Where in equation (6), c ∈ {R, G, B}. \(I_{c \text{mean}}^c\), \(I_{c \text{max}}^c\), and \(I_{c \text{min}}^c\), are the values in the ‘c’ channel, respectively, and \(I_{cCR}^c\) is the colour corrected picture. The average is used as a measure for the calculation of which path to apply. In special conditions such as an underwater picture in which the red channel width is extremely low due to rapid absorption of wavelength of red color, following the above scaling may result in extreme stretching over-correction. So, for that another formula is there which is slightly the improved version of the above formula.
Where in equation (3), \( \lambda \) denotes the positive parameter for monitoring spectrum of shifts and \( P \) denotes the probability of pixel values below or equal to 40. That can accommodate overcorrection effectively.

3.2. Dehazing
Underwater pictures will still appear hazy after color correction, since the underwater state is close to a hazy world. Haziness should therefore be removed by image dehazing method using dark channel prior. The dark channel prior is based on the following observation of haze-free outdoor images: at least one-color channel at some pixels in most non-sky patches has very low intensity. In other words, the minimum size will have a very limited value in such a patch.

In the dark channel the small intensities are mainly due to three factors [2]: a) shadows; b) decorative items or surfaces. For eg, any entity missing in color on any color channel would result in low dark channel values; c) points or places of darkness; For example, the dark bark and stone of the tree. A haze picture is lighter than its version of haze free, due to the additive air light. So, in regions of denser haze the dark channel of the haze picture will have higher intensity.

The model of a hazy image can be defined as

\[
I(x) = J(x)t(x) + A(1 - t(x))
\]

Where in equation (4), \( I(x) \) denotes intensity at pixel, \( J(x) \) denotes the original picture intensity (haze free), \( A \) means the atmospheric light for the whole pixel picture, \( t(x) \) means medium transmission which is regarded as a kind of blending element for mixing atmospheric light and the original object colour.

The \( t(x) \) transmission typically reduced as the object and camera’s distance increases. By identifying \( A \) and \( t(x) \) at increasing location, the dehazing is to preserve the initial picture color \( J(x) \).

The tentative expectation of the dark channel is that at least one of the colour channels values (RGB) in certain artifacts always near to zero in a haze-free setting.

Pictures which are in dark channel are defined as

\[
J^{dark}(x) = \min(\min(I^c(y)))
\]

Where in equation (5), \( c \in \{r, g, b\} \), \( y \in \Omega(x) \), \( I^c \) channel represents a color image, \( \Omega(x) \) expressed in pixel \( X \) as the center of a window. In the formula first, the minimum value of the RGB components of each pixel is obtained and the same is retained in the original picture size of a gray scale and then on the minimal gray scale. The dark J channel is believed to be 0. The transmission is then calculated as:

\[
t(x) = 1 - \min(\min(I^c(y), \frac{I^c(y)}{A^c}))
\]

Where in equation (6), \( y \in \Omega(x), c \in (R, G, B) \), The \( J(x) \) can be restored with an appropriate estimation of \( A \).

\[
I^c_{\text{ER}} = \begin{cases} 
I^c - \lambda (I^c_{\text{mean}} - 128), & P^c > 0.7, \\
(I^c - I^c_{\text{mean}}) \frac{I^c_{\text{min}} - I^c_{\text{mean}}}{I^c_{\text{min}} - I^c} + 128, & I^c_{\text{mean}} \leq 128, \\
(I^c - I^c_{\text{mean}}) \frac{I^c_{\text{max}} - I^c_{\text{mean}}}{I^c_{\text{max}} - I^c} + 128, & I^c_{\text{mean}} > 128, 
\end{cases}
\]

\((3)\)
4. Results and Discussion

![Figure 5](image)

**Figure 5.** Color Corrected image from equation (2) and (3).

After the color correction, the image with corrected colors is obtained. But this image is still hazy. To remove this haziness, the paper [1] has used the optimal contrast methodology. Our Approach was straightforward which is to remove the haziness we used dehazing algorithm.

![Figure 6](image)

**Figure 6.** Result after applying Dehazing Technique

The image after applying Dehazing A haze picture is lighter than its haze-free version due to the additive air light. So, in regions of denser haze the dark channel of the haze picture will have higher intensity.

We have used different Images to see the result in every cases.
We also compared our method with another technique used in paper named Two step approach, the output we are getting is taking more time than the two-step approach but our final output is much clearer than that.

As we can see the output after color correction and Optimal contrast is not very clear as compared to our model.

The processing time taken to enhance every pictures is directly linked to the picture scale. The Computational time to enhance a single image in Two step approach is about 9 seconds, our approach is talking almost 20 seconds, but the enhanced image through dehazing is much better than through optimal contrast.
5. Conclusion
In this Paper an effective two step hybrid approach is used to enhance the underwater Images. The proposed method solves these issues separately by concentrating on the 2 main problems in underwater photos — color shift & poor contrast. First, to cope with color saturation, an efficient color correction technique is implemented based on linear transformation. Then, a novel dehazing method is used to remove haziness.

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