An Approach for Shallow Underwater Images Visibility and Color Improvement

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Abstract

It has been observed that characteristics of underwater images are similar to day hazy images under poor lighting situation. So the problem of image visibility and color cast for underwater scenes is still challenging and demands more research attempts in this direction. This paper proposes an approach for shallow underwater visibility improvement which utilizes a combination of histogram equalization, gamma correction, and dark channel prior with morphological operation, in order to achieve effective haze subtraction and avoid halo effects in a single image with a complex structure. Our methodology, also consider the effect of an adaptive gamma correction technique for further refinement of transmission map. The outcomes show better peak signal to noise ratio and contrast noise ratio values over existing state-of-the-art methods based on dark channel prior. Results show that our proposed approach in turn can be utilized in various underwater applications such as forensic image recognition, telecommunication cables recognition etc.

Keywords: Gamma, Haze, Histogram, Morphological, Underwater, Visibility

1. Introduction

The haze removal is very vital in the field of image processing because the diverse computer vision algorithm assumes the input image as the original scene radiance. But in most outdoor processing the images are despoiled due to haze. If the haze can be detached then the scene has proper brightness, contrast and the information contents. The haze removal process is very difficult because the mist depends upon the unknown deepness of the object in the sight. It has been observed that characteristics of underwater image are similar to day hazy image under poor lighting condition. Reduced visibility in under water is a key problem for oceanic applications of computer vision. This is mainly due to the existence of the significant number of the suspended particles with considerable size and density in the medium.

As far as single image approaches are newly arose, in1,2 proposed a novel method called Dark Channel Prior (DCP). Their method is based on the interpretation that fog-free images have at least single color channel in the Red, Green and Blue (RGB) band with small intensity value. More newly, the DCP methodology has also been functional in underwater image restoration6,7,10,11. However, those approaches do not deal with some of the important DCP limitations and the required modification in the assumptions for underwater imaging system. Thus, the major input of the present work is the alteration of the Dark Channel Prior in order to prevail over its boundaries for applications in submerged imaging system.

In the literature, few approaches have been proposed to enhance the underwater image: using specific hardware23, multiple images under diversesituation24, stereo images25,26 and polarization filters27. Despite the fine results, the methods that rely on particular hardware are costly and complex. Besides, they are tough to apply when more automatic attainment is requisite. In the stereo systems methods, the correspondence difficulty becomes even difficult due to the strapping effects forced by the participating medium. Approaches based on multiple images need quite a lot of images of the similar scene taken in dissimilar environment situation, which makes it of complex application in real circumstances. So, in spite

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of the new advances that have already been attained, the problem of image renovation for underwater scenes still demands much research attempts.

2. Underwater Image Formation Model

According to \(^1\), the formation of a haze image is:

\[
\text{img}(p) = jrd(p) \cdot \text{tmap}(p) + B(1 - \text{tmap}(p))
\]  

(1)

Where, \(jrd\) is the scene radiance, \(\text{img}\) is the observed intensity, \(B\) is the global atmospheric light, and \(\text{tmap}(p)\) is the transmission map. Underwater image improvement in 6–8 is done using this model. Because both day and underwater images are despoiled by the turbid medium, an underwater image is similar to a day haze image and the intensity is being composed of two components: The indirect transmission due to scattering by the medium dirt particles and the direct transmission of light from the scene.

Because of dissimilarity in attenuation between water and atmospheric environment, one cannot equate the underwater imaging model to its atmospheric version. The model for underwater images \(^8\) can be described mathematically after considering both the effect of absorption and scattering on light attenuation as:

The airlight constant \(B\) is predictable by finding the brightest pixel in the underwater dark channel. The value of local patch is defined as \(\Omega(p) = 15 
\times 15\) and the transmission \(\text{tmap}(p)\) is calculated as:

\[
\text{tmap}_\beta(p) = 1 - \text{tmap}_\alpha(p) = 1 - \min_{y \in \Omega(p)} \left( \frac{\text{img}_c(y)}{B} \right)
\]  

(2)

Where, \(\text{img}\) is the observed intensity, \(c\) is a color channel (red, green or blue), \(B\) is the scattering light called as background light, \(\text{tmap}_\alpha\) is the scattering rate and \(\text{tmap}_\beta\) is the transmission (Portion of the scene radiance reaching the camera).

3. Underwater Images Visibility and Color Improvement Algorithm

- Firstly acquire the sample degraded underwater input RGB images.
- Identify whether the acquired image is clear or have haze appearance.

If (Mean > \(\sigma\)) Then
  i. Print “Image is Haze”
  ii. Execute the step 3 to step 12.
Else
  i. Print “Image is Clear”.
- Apply histogram equalization technique for visibility improvement.
- Apply gamma correction adjusting dynamic range for color rectification.
- Apply the dark channel prior on pre-processed above input image.
- Apply morphological operation to circumvent halo effect from image.
- Estimate the background light using brightest pixel in dark channel.
- Estimate the improve transmission map using improve dark channel prior.
- Recover the scene radiance using morphological improved transmission.
- Refine the transmission map using soft matting and recover scene radiance.
- Enhance the transmission map using adaptive gamma correction technique.
- Recover the output scene radiance using above enhanced transmission map.

4. Proposed Method Modules

The model proposes a visibility improvement and color rectification method that uses a combination of four major modules:

4.1 Haze Detection and Split Module

After the acquisition of underwater image, the intensity of image is calculated and is compared with the threshold value obtained after averaging the mean intensities of several clear and hazy images. If the intensity is greater than the set threshold the image is considered to be hazy otherwise clear image. The image is then split into separate Red, Green and Blue (RGB) channels and group into red-green, green-blue and blue-red component image for better analysis of visibility and quality of image.

4.2 Image Preprocessing Module

When the Red, Green, and Blue channels of an image are not correctly balanced the problem of color cast occurs. The color cast can be across the complete range of pixel...
values or can bound itself to the highlight, shade of the image. Our proposed method has solved this problem by applying visibility improvement and contrast correction method.

This is processed out by elongating the range of intensity values in order to extent the preferred range of values. prior to performing contrast alteration a step is made for the higher and lower limits of the image for contrast rectification of each band. Usually, the range of values in 8 bit color channel is 0-255. Our proposed approach has use a common normalization scheme to find the least and most pixel values in the histogram and elongate them between the particular ranges using histogram equalization which in turn improve the visibility of image and gamma correction technique to improve the contrast of an image.

4.3 Scene Radiance Recovery Module

The visibility of underwater image is spoil due to presence of haze. The dark channel prior provides a method by which to estimate better transmission in an underwater image. Here the dark channel of image is identified first and then estimate the background light B in the underwater image. In our approach the brightest 0.1 percent of pixels will chosen from within the dark channel prior. The pixels with the highest intensity are determined to be the background light B. The value of local patch is defined as Ω(p) =15∗15.

The dark channel obtain by old dark channel prior technique contain lot more halo effect which lead to blocky transmission map estimation and blocky scene radiance recovery. For this reason, our approach proposed a improve transmission procedure which uses a morphological technique to reduce generation of halo effects.

4.4 Image Post processing Module

The Dark Channel Prior (DCP)\(^1\) depends on minimum value of the RGB channel and always produces an insufficient transmission map for images captured during underwater conditions. This is because the intensity value will be lower for at least one RGB channel in underwater images. In order to achieve optimum haze removal results and to estimate efficient transmission map, our proposed approach has apply an adaptive gamma correction technique\(^{14}\) to adjust the intensity of the transmission map during this procedure. Adaptive gamma correction technique redistribute within the dynamic range of the histogram by using a varying adaptive parameter.

\[
t_{\text{new}}(p) = \left( \frac{p_{\text{max}}}{p_{\text{max}}} \right)^{\gamma}(3)
\]

5. Experimental Observations

The proposed algorithm is implemented in MATLAB running on Windows XP operating system. Refer to Table 1. Sample input images. The peak to signal ratio (PSNR) and contrast to noise ratio (CNR) has been calculated for different output images of different authors using matlab code. Refer to Table 2. PSNR and CNR values for first output image. Refer to Table 3. PSNR and CNR values for second output image.

6. Discussion and Conclusion

Our propose approach have try to improve shallow underwater images visibility through image enhancement

| S.No | Image Name | Image | Original CNR |
|------|------------|-------|--------------|
| 1    | Input1.jpg | ![Input1.jpg](image1.jpg) | 252.064 |
| 2    | Input2.jpg | ![Input2.jpg](image2.jpg) | 287.168 |
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Table 2. PSNR and CNR values for first output image

| S.No | Output Image | Proposed Output | PSNR | CNR  |
|------|--------------|----------------|------|------|
| 1    | Output 1     |                | 13.956 | 318.673 |
| 2    | Output 2     |                | 14.252 | 301.698 |
| 3    | Output 3     |                | 14.336 | 302.560 |

Table 3. PSNR and CNR values for second output image

| S.No | Output Image | Proposed Output | PSNR | CNR  |
|------|--------------|----------------|------|------|
| 1    | Output 1     |                | 21.629 | 291.831 |
| 2    | Output 2     |                | 23.139 | 285.115 |
| 3    | Output 3     |                | 23.128 | 284.717 |

and color correction techniques such as dark channel prior, histogram equalization, gamma correction.

Our approach have also apply morphological operation, soft matting and adaptive gamma correction technique for improving the image visual quality such as, avoiding halo effect, improve and refine transmission estimation, enhancing image contrast as well as reducing noise and artifacts from output image which enables a significant enhancement over existing state-of-the-art methods based on DCP.

The outcome also presented that proposed method output 3 has better Peak Signal to Noise Ratio (PSNR) values from all other outputs while output 1 has better Contrast to Noise Ratio (CNR) values from all other outputs, while output 2 had shown both good PSNR and CNR values for all above inputs as well as had shown significant enhancement over existing state-of-the-art methods based on dark channel prior. Refer to Table 4. PSNR and CNR based comparison of different methods.

Table 4. PSNR and CNR based comparison of different methods

| S. No | Image | Graph/Chart |
|------|-------|-------------|
| 1    | PSNR and CNR Based Comparison (RGB Input Image 1) |
| 2    | PSNR and CNR Based Comparison (RGB Input Image 2) |

The above graphs showed that proposed method produced better PSNR values from all other authors like He, Xiao, Seiichi, Lu except the result of Fattal as well as better CNR values from Fattal, He, and nearby to all other authors for first input image.

The above graphs showed that proposed method produced better PSNR values from all other authors like Fattal, He except the result of Hung as well as better CNR values from all other authors for second input image.
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