New Approach to Underwater Image Dehazing using Dark Channel Prior

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ABSTRACT. Images captured in dense, hazy, foggy atmospheric conditions or in a surrounding filled with impurities, are exposed to deterioration of the captured image which lowers the contrast, color changes, and the object features observed are difficult to recognise by normal human vision and also by some outdoor computer vision systems. This paper analyses the enhancement in the visibility of a single degraded image. The single image is processed to give two or more images of different characteristics and features. The information from these images is used to generate a solitary image with more accurate information of the scene than the original images. To maintain the important features and information of the image for good visibility regions, various parameters are used as filters using dark channel prior technique. The resultant images are then combined and weighed to reduce the unwanted attributes. The resultant image eventually is improved as compared to the resource images.

Introduction

Images which are of inferior quality or have deteriorated due to bad atmospheric conditions are very difficult for human as well computer vision and processing. Images may lose their quality due to bad atmospheric conditions, foggy weather or haziness. Haze is a phenomenon in which dust, smoke, and other dry particulates obscure the clarity of the sky. Almost the impurities in air ranges below 1000m. Haziness constitutes of “Airlight” and “Direct Attenuation”. Images which are captured outside or under the influence of sunlight in poor atmospheric conditions are prone to unwanted radiance. This unwanted radiance in addition to the unwanted light coming from all directions is call Airlight. This adds unwanted whiteness to the image. Direct Attenuation is the gradual loss of intensity in the image which causes decay in the color of the image. Haze leads to failure of many computer vision/graphics applications as it diminishes the scene visibility, however, many automated systems mostly based on the definition of the input images, fail to work efficiently due to degradation of images. To improvethese images and correct the inconsistencies of the image, Image Dehazing is used.

Removing the haze layer from the input hazy image can significantly increase the visibility of the scene. The dehaze image is also pleasing to view. Image Dehazing also plays a dominant role in many image processing applications. Image Dehazing is mainly of two types, i.e. Single Image Dehazing and Multiple Image Dehazing.
In Single Image Dehazing, a Single Image of the scene is taken while in Multiple Image Dehazing two or more Images of a scene are taken. Here, Single Image Dehazing is explored.

Here we explore a single image based strategy that is capable to precisely dehaze images using only the unique degraded information in MATLAB R2018b. MATLAB is an amazing software for image processing and dehazing owing to its ease of use and amazing functionalities.

## Background

### A. Atmospheric fog formation

Acquisition of digital images is a process, where a capturing device as an observer is immersed in a transparent medium. The image observed by the device is created by light rays that are reflected from the objects in the scene and travel through the medium to the device's sensor. This means that the brightness of pixels in the resulting image depends exclusively on the brightness of the scene objects [3].

However, in practice the characteristics of light captured by the observer are altered by a spectrum of different factors determined by the propagation of light from its source, reflection of light from the objects and the interaction between the light and the transparent medium. The transparent medium in the scene can affect the acquired images significantly, and its influence can vary greatly depending on the current conditions of the environment where the image is captured. In most cases the medium is the Earth’s atmosphere consisting of air. The effects caused by the interaction of light and the atmosphere, which can be identified as the weather, are studied by atmospheric optics [3].

The literature on the topic of atmospheric optics presents models that are relevant to computer vision, describing possible weather conditions such as haze, fog or rain. Haze, fog or smoke can be described as a situation when small solid or liquid particles are suspended in the medium where light is propagating. The light traveling through such environment interferes with these particles and is subsequently absorbed or scattered by them. This interaction alters the light captured in the camera and results in images that are different than the real radiance of the scene.

Visual effects caused by interaction of light with the particles present in the atmosphere can be divided into three categories: scattering, absorption, and emission. A ray of light hitting a particle transfers its energy to it. While a portion of the light’s energy is absorbed by the particle, the rest of the energy is non-uniformly scattered into different directions in respect to the direction of incoming light.
In addition, the light scattered back to the environment further interferes with the scene. Complex interactions between particles concentrated in the atmosphere therefore result in blurring, attenuation of the light along the line of sight, lack of contrast, and color distortion. The result of the interaction between light and a particle depends on the material, shape, and size of the particle.

Since the particles present in the atmosphere are mostly miniature water droplets, their shape and material is generally the same in different conditions. Varying size of the particles, however, dramatically changes the way the light is scattered by the particles. It has been observed that the scattering function of a particle is directly related to its size in respect to the wavelength of incident light [3]. If the size of particles is less than the wavelength of the light, the scattering is more equally distributed in both forward and backward direction of the incoming light.

On the other hand, the particles of size equal or greater than the wavelength of the light tend to scatter the light entirely in the forward direction, while absorbing most of the light’s energy. Since the scattered light is propagating further to the environment, each particle can also be considered a point light source emitting light into different directions according to its specific scattering function. Scattering of all particles in the atmosphere collectively creates an ambient light reflected into the scene called atmospheric light or airlight, which is the source of blur and color shifts in observed images.

Different weather conditions are observed based on the type, size, and concentration of the particles present in the atmosphere. Every weather condition has specific effect on the general appearance of the scene and may appear in different intensities.

- **Haze** Haze is created by aerosol — a mixture of microscopic liquid particles suspended in gas — or very small solid particles such as dust, pollen or sea salt. Its effect gradually increases with higher humidity when the particles are enlarged by condensed water. Haze usually shifts colors in image to gray or blue hues.

- **Fog** When the humidity in air approaches saturation, haze droplets grow in size due to water condensation creating fog. Greater particle size in fog decreases visibility in the scene much more than haze, which means that fog becomes visible at shorter distance than haze.

- **Smoke** Although smoke is not a weather condition, it affects atmosphere similarly. It consists of small solid and liquid particles dispersed in air, typically emitted by a process of burning. Smoke can be very thick, obscuring objects in the scene completely. Different sources of smoke may result in shifting the image’s colors to different hues.

Distortion created in images by weather conditions also increases with the distance of the visible objects. The further the light travels from the source to the camera, the greater is the effect of particles interfering with the light. Because of this, milder conditions such as haze may only be visible from long distances while more intensive conditions like fog are visible immediately [2].

![Figure 3. Image Formation Model](image-url)
B. **Image Dehazing Methods**

The simplified image formation model shows that the dehaze image $J(x)$ which is calculated from the hazy image, $I(x)$ is used to identify the transmittance of the scene $t(x)$ and the atmospheric light $A$ which are given by:

$$J(x) = (I(x) - A / t(x)) + A.$$  

In practice, the complex physical conditions in the scene are not known, so the problem of dehazing is solved by finding a way to compute the transmittance and airlight in the image. Some methods use additional information about the scene or special input to estimate the haze effects. Mimages of the same scene in different weather conditions are used here. By comparing the same scene with different degrees of distortion by the weather they estimate the properties of environment and use it to restore the image. Another approach utilizes partially polarized light created by the hazy environment.

Polarization filters applied to the input image in different orientations make it possible to estimate the effects of atmosphere and remove the haze affecting the scene. Schechner et al. [5] presented a method using two or more images acquired with different orientations of polarization filter.
Literature Review:

3.1 Underwater Dehazing Techniques

The complication in underwater photographs is distributed images, uneven diffusion and absorption of light. The humidity is causing the atmosphere and it is calculated by using Haze model particle suspended techniques. This method is applied for muddy and populated areas which are used to find degraded the quality of imaged. Schechner et al gives polarization and atmospheric light are the two major factors to reduce the image quality. The above method is effectively removing the haze points and polarizes the image filters [5].

Bin Xie et al, to improve image quality image dehazing algorithm is used with dark channel priority scheme. Multi-Scale Retinex method is applied for intensity calculation in YCbCr space. The combination of dark channel prior and haze image model is applied for finding high quality image factor. So, the above method have the advantage of faster comparative result [7].
Hue et al, dark channel method is single input processing method and it is haze removal calculation for finding image restoration values. So, this method provided better result in atmospheric in which no haze in images are found. The local region values are estimated using thickness factor and edges [8].

Yin et al, the dark channel method can be applied for single image. The pixel values are calculated using Haze points and low intensity values are marked. The estimation of each position can be obtained from image formation table values. This effect may cause total image quality. This method provides the advantage of image estimation result and carried out transmission map results also. The disadvantage is to predict haze image and hallo effect of resultant images are reduced the image quality.

Bingquan Huo et al, specifies improved dark channel prior method is applied and improves the soft matting results. Bilateral filter is applied for blending and smoothing the image texture. This method avoids the error caused by brightness pixel level. So, the above method gives higher efficiency, less computation time and enhanced quality images. The disadvantage is halo effect in all regions should be mapped so couldn’t map accurate results [6].

To enhance the persistence of underwater photography an unsupervised colour correction method is applied. This method improves the image quality and aerial light values calculated. The low intensity values are eliminated using dark channel method and verify the due factor such as tint, tone, hue, saturation, dark and light objects. Soft matting algorithm is applied for removing black effect and restores the image quality.

The iteration process is involved for high dimensional image process and smoothing. Chiang et al, a wavelength based dark channel is applied for de-hazing process to remove blur and darkness. In this method image sampling and histogram process are involved to handle de-hazing process. The result causes color distortions and attenuation. Fattal et al, color line algorithms is suggested for veiling light process and it removes hazy objects. But, in high turbulence photography means it is tedious process to remove scatters.

In 2018, Sun et al, Deep pixel-to-pixel network model is used for under water image enhancement [10]. Here, the underwater images are supervised and apply encoding-decoding process. The converted images are configured and applied dark channel prior process. The convolution and de-convolution process are applied for reduce noise and attenuation factor.

Each pixel are evaluated and added in deep network model. The low-level feature images are removed and applied image enhancement process. It is else adaptive driven process, so each pixel applied in deep network process and achieve image quality.
Chongyi et al, Underwater de-hazing and underwater image contrast both methods are proposed to reduce external noise and improve quality [11]. The de-hazing algorithm have set of rules which is indented process image restore, visibility, colour images and degradation process. The main contribution of this method is distributing each histogram values to all the deep networks so we can improve the brightness and contrast of underwater image. There are two categories of enhanced images as-

1. Natural appearance images and
2. Relatively suitable display images. For both two categories specifies image quality, brightness, lighting, contrast and saturation factors.

### 3.2 Image Color enhancement

The general phenomena are water absorbs the light source and travel in long distance. Some artificial lighting is used to taking underwater images. But problem is artificial lighting is produced more brightness so the originality may be changed. The light sources are reflected objects and change the quality.

The balancing unwanted colour effect and contrast both can be obtained from while balancing method. The histogram stretching is applied to find haze region and degraded values. The luminance, chromaticity and saturation are calculated, and it is important factor degradation. The above factor values are set by different pixel representation. Each pixel can vary depends on lighting, brightness and colour models. Sometimes encoding-decoding methods are also important for image enhancement. Based on this also image quality is affected.

Amjad Khan et al introduced wavelet based fusion underwater image enhancement method for finding low contrast colour images. The hazy degraded images are processed parallel and find apply wavelet transform. This method improves the image quality and enhances the result. The wavelet fusion process consists of low and high pass filter mechanism, so it is fill the values and generated histogram. The contrast adaptive histogram equalization method is process for clipping and visible surface identification. The limitation is normalization and clipping the images in the method [13].

Yan-Tsung Peng et al, depth estimation method is used for restoring under water images based on blur and absorption. The image formation model is used to enhancement and restoration. In this method restored underwater images properly because depth is important factor to measure colour channel values. The underwater images are properly handled and find the depth. The blurry levels are selected from underwater images. Then depth factor is applied for calculating scene radiance [4].

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**Objectives.**

1. To improve the image quality and visual significance of the image material using DarkChannel Prior.
2. To perform the dehazing approach in presence of non uniform artificial illumination and selective absorption of colors.
3. To perform underwater image reconstruction and image enhancement.

**Methodology - Dark Channel prior Algorithm:**
A. Underwater Image dehaze:

Figure 7. Underwater Image Formation

Imaging through haze is shown in Figure 8. The apparent luminance \( I \) of an object placed at distance \( d \) is controlled by two processes that occur concurrently: the transmitted light denoted by \( t \), which emanates from the object and it is attenuated by scattering and absorption along the line of sight. The airlight \( A \), which comes from a light source (i.e., Sun) and scattered by the haze particles toward the observer before reaching the object, and absorption. It is denoted by \( t \). The airlight \( A \) coming from a light source (i.e., Sun) and it is scattered by the haze particles toward the observer all along the line of sight.

Figure 8. Imaging through haze

B. Dark Channel Prior:

The Dark Channel Prior (DCP) was first introduced by He et al. [8][12][13][14]. It was inspired from an earlier haze removal method known as dark object subtraction technique [2]. Based on the observations provided in the paper, the intensity of one of the channels in a typical color image pixel is low and tends to be zero (5000 outdoor and daytime images have been chosen from flickr.com, they cut out the sky region, they calculated the dark channel prior: 75% of the pixels in the dark channel have zero values, and the intensity of 90% of the pixels is below 25). This technique has been used to remove spatially homogeneous haze. This is done by subtracting a constant value corresponding to the darkest object in the scene.
**Step 1. Dark channel restoration**

It relies on the assumption that, for a given pixel in a color image of a natural scene, one channel (red, green or blue) is usually very dark, except for the sky. The airlight tends to brighten these dark pixels, and therefore it is estimated from the darkest pixels in the scene. This observation is inspired from [2], and it is known as dark channel prior. For a hazy image \( J(x) \), the dark channel \( J_{\text{dark}}(x) \) is given by

\[
J_{\text{dark}}(x) = \min_{c \in \{r, g, b\}} \min_{y \in (x)} J_c(y)
\]

\( J_c \) is a color channel of \( J \) and \( (x) \) is a local patch centered at \( x \).

**Step 2. Atmospheric light estimation**

The brightest pixels in the hazy image are the most haze-transparent, only if the weather is overcast, and the sunlight denoted by \( S \) is ignored and only the atmospheric light \( A_{1} \) is considered. Thus, the brightest pixel can be brighter than the atmospheric light.

To resolve this problem, the dark channel is used: here the top 0.1% brightest pixels in the dark channel is considered. Then, from these pixels, pixels which are having greater intensity in the input image \( I \) are considered and selected for the atmospheric light.
Step 3. Transmission estimation

After estimating atmospheric light, here transmission in local patch is assumed to constant and represented by ‘t(x)’.

Step 4. Transmission refinement:

In order to refine the transmission map, soft matting Laplacian is applied to smooth artifacts along edges. However, it increases dramatically the computational time.

Step 5. Scene radiance recovery

- DCP fails to estimate the transmission when the objects are inherently similar to the atmospheric light and not covered by shadows. It fails to restore the image with a large sky area or a large white area, as well.
- Since DCP is a physics-based method, it fails when the haze model is physically not valid.
- DCP fails to recover the image under non-homogeneous haze.
- The soft matting used for transmission map refinement is time consuming. Thus, it is not suitable for real time applications.
- The color distortion phenomenon will occur when the transmission is not accurately estimated, and it is different among three color channels.
- Like any other color-based dehazing methods, DCP fails when the fog is dense
C. Haze Removal using DCP:

In the table 1 shown below image dehazing using DCP is shown along with all parameters [2].

Table 1. Dark channel prior Mathematical Analysis

| Sr.No. | Component | Equation |
|--------|-----------|----------|
| 1      | imaging process of fogging image: | \( I(x) = J(x) \cdot t(x) + A(1 - t(x)) \) |
| 2      | Depth of information Scene | \( t(x) = e - \beta(\lambda) d(x) \) |
| 3      | Local Dark channel Values | \( J_{\text{dark}}(x) = \min c \subset \{r,g,b\} \{ \min y \Omega(x) (Jc(y)) \} \) |
| 4      | Idark | \( Idark = A(1 - t(x)) \cdot \) |
| 5      | Depth Information | \( t(x) = 1 - Idark/A \) |
| 6      | Defogging imager model | \( J(x) = (I(x) - A/t(x)) + A \) |
| 7      | FogFree Image | \( J(x) = (I(x) - A/\max (t(x), t0)) + A. \) |
| 8      | Final Defogging effect | \( J(x) = (I(x) - A/\max ((1 - w(\text{Idark}/A)), t0)) + A \) |
| 9      | Color Channel RGB | \( Jc(x) = (Jc(x) - A/\max ((1 - w(\text{Idark}/A)), t0)) + A \) |
| 10     | Threshold Mechanism | \( t_{\text{after}} = \min (\max \{ k \cdot \max ( \{ t_{\text{before}}(x), t0 \} \}) \) |
| 11     | T after let constant = 50 in | \( x \) located at light color areas |
| 12     | Restored Image | \( k = \max (\Delta(x))/Jc(x) - A \) |
| 13     | Optimise Transmittance | \( t_{\text{after}} = \min (\max (\Delta(x)))/Jc(x) - A, 1) \cdot \max (t_{\text{before}}, t0), 1) \) |
| 14     | Threshold value | \( \Delta_{\text{mean}} \leq \Delta_{\text{thread}} \), countlower mean/counthigher mean > 1 |
| 15     | Weight Calculation | \( \Delta_{\text{star}}(x) = \Delta(x) \cdot ((\Delta(x) - \Delta_{\text{min}})/(\Delta_{\text{max}} - \Delta(x))) \) |
| 16     | Combining the primary maximum value \( \max(\Delta(x)) \) and linear stretch maximum \( \max(\Delta_{\text{star}}(x)) \). | \( \max f(\Delta(x)) = \max(\Delta_{\text{star}}(x)) + \max(\Delta(x))/2 \) |
Based on this information, a final \( \max(\Delta(x)) \) could be calculated again by using the stretch difference value \( \Delta^* \) and the original difference value \( \Delta \). Further, the weight coefficient \( k \) could be gotten by formula (13) and formula (17).

**Experimental Results**

Genuine submerged photos are explored from different picture taker assortment caught utilizing optical camera are considered for various atmospheric conditions. (Hp CORE i3, CPU @ 1.70 GHz, Windows 7-64 piece) gadget used to run the framework utilizing MATLAB R2018a.

1. **Result Analysis I**: Input Images are considered for three different atmospheric conditions as
   - Smoke image
   - Fog Image
   - Underwater Image

   **Table 2. Input Image**

   | Input Image-1 | Input Image-2 | Input Image-3 |
   |---------------|---------------|---------------|
   | ![Image-1](image1.png) | ![Image-2](image2.png) | ![Image-3](image3.png) |

2. **Result Analysis II: Weight Parameter ‘t’**

   Transmission map of the image, which reflects the depth information of the scene is being calculated using weight parameter ‘t’. we observed that transmission map is found to be good quality image.

   **Table 3. Observed Weight Parameter ‘t’**

   | Image-1 | Image-2 | Image-3 |
   |---------|---------|---------|
   | ![Image-1](image4.png) | ![Image-2](image5.png) | ![Image-3](image6.png) |

3. **Result Analysis III: After Filtered ‘t’ Image**

   Due to the fact that dark channel values of the fogging image are always close to zero in fog weather, the dark
channel values obtain certain brightness at the process of imaging. Here we have observed image brightness after using filtered ‘t’.

**Table 4.** Observed After Filtered ‘t’ Image

| Image-1 | Image-2 | Image-3 |
|---------|---------|---------|
| ![Image-1](image1.png) | ![Image-2](image2.png) | ![Image-3](image3.png) |

4. **Result Analysis IV: Weight ‘J’**

Colored picture is observer properly using this weight, these dark channel values always exist in object shadow, dark object, and object with bright colors.

**Table 5.** Observed Weight ‘J’ Image

| Image-1 | Image-2 | Image-3 |
|---------|---------|---------|
| ![Image-1](image1.png) | ![Image-2](image2.png) | ![Image-3](image3.png) |

5. **Result Analysis V- Min rgb-dep algorithm:**

Transmission map (x) is calculated and found to be very clear image brightness.

**Table 6.** Observed Min rgb-dep’ Image
6. Result Analysis of all weights VI:

All weights and its values are evaluated as shown in Table 6.5 Here Five different images from the dataset are considered for evaluation of these parameters.

Table 7. Result of Weighted Parameters:

| 'File Name/Parameter' | 'KemRatio' | 'MinAtomsLight' | 'A' | 'R' | 'w' | 'x' | 'y' |
|-----------------------|------------|------------------|-----|-----|-----|-----|-----|
| 'Ancuti1'             | 0.01       | 240              | 109 | 16  | 404 | 404 | 303 |
| 'Ancuti2'             | 0.01       | 240              | 87  | 40  | 1037| 1037| 778 |
| 'Ancuti3'             | 0.01       | 240              | 123 | 20  | 512 | 512 | 384 |
| 'Eustice4'            | 0.01       | 240              | 176 | 24  | 690 | 690 | 560 |
| 'Galdran_Im1'         | 0.01       | 240              | 198 | 16  | 473 | 473 | 353 |
| 'fish'                | 0.01       | 240              | 161 | 20  | 512 | 512 | 384 |

7. Result Analysis VII - Final filtered image

Table 8. Filtered image

In final Output we have clearly observed the image which are considered as smoke, fog and haze effect in underwater now is removed and image is very clear as per visibility is considered.

8. Result Analysis VII: All weighted parameters are considered for DCP with six different underwater images and results are shown in Table-6.8.
### Table 9. All weighted parameters with observed image output

| Sr. No | SRC | Min rgb | After Min rgb | Filter ‘t’ | Weight ‘t’ | Weight ‘J’ | Output |
|--------|-----|---------|---------------|------------|------------|------------|--------|
| 1      |     |         |               |            |            |            |        |
| 2      |     |         |               |            |            |            |        |
| 3      |     |         |               |            |            |            |        |
| 4      |     |         |               |            |            |            |        |
| 5      |     |         |               |            |            |            |        |
| 6      |     |         |               |            |            |            |        |

**Conclusion**

We have successfully shown that images deteriorated due to haziness and cloudy atmosphere or fog or due to underwater haziness can be successfully improved and enriched to a great extent using new approach to dark channel prior technique. These images have considerably enriched visibility and distinct features. They can now be efficiently used in many computer vision systems. Image dehazing has an extensive use in the field of satellite imagery. It has also proved helpful in enriching images of various geographical terrains which have undergone extensive deterioration due to haze.

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