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Implementation of Edge Preserving Decomposition Based Single Image Haze Removal in Raspberry Pi3

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Abstract: Single image haze removal is under-obliged, in light of the fact that the quantity of opportunities is bigger than the quantity of perceptions. A novel edge-preserving decomposition-based method is introduced to estimate transmission map for a haze image in order to design a single image haze removal algorithm from the Koschmiedars law without using any prior. Weighted guided image filter (WGIF) is adopted to decompose simplified dark channel of the haze image into a base layer and a detail layer. The transmission map is estimated from the base layer, and it is used to restore the haze-free image. The trial comes about on various sorts of pictures, including hazy images, underwater images, and normal image without haze, demonstrate the execution of the proposed algorithm.

Keywords: Single image haze removal, edge-preserving smoothing, weighted guided image filtering, minimal color channel.

I. INTRODUCTION

The primary point of image processing is to comprehend, perceive, and decipher the information from the image pattern. Now and again image might be undermined by dampness less particles, for example, clean, smoke, snow, murkiness, and mist. These poor climate conditions lessen the clearness of the pictures. While expanding the separation amongst question and the camera, clarity of the image consequently lessens.

Visibility restoration refers to various strategies that intend to decrease or evacuate the deterioration or degradation that have happened while the advanced image was being acquired. The deterioration may be due to different elements like relative object-camera motion, blur due to camera misfocus, relative atmospheric violent features and others. Here it is talking about the degradations due to bad weather such as fog, hazy image.

Outdoors pictures taken in horrendous atmosphere conditions lost shading and separation. Horrendous atmosphere conditions, for instance, duskiness, haze and murkiness degenerate the idea of pictures in light of the way that such conditions changes the shading and many-sided quality of pictures which is a troublesome issue to picture takers. It is a hazard to numerous photo getting ready applications. Poor environment conditions furthermore decrease the idea of satellite and submerged pictures.

Pictures of outdoor scenes regularly experience the ill effects of awful climate conditions, for example, fog, mist, smoke and so on. The light is scattered and absorbed by the aerosols in the atmosphere, and it is also mixed with air-light reflected from different directions. This process blurs the color and reduces the contrast of captured objects, and the degraded images often lack visual vividness. Haze removal can significantly increase both local and global contrast of the scene, correct the color distortion caused by the air-light, and produce depth information. As such, the dehazed picture is typically more outwardly pleasuring. The performance of computer vision algorithms and advanced image editing algorithms can also be improved. Therefore, haze removal is highly demanded in image processing, computational photography and computer vision applications.

By utilization of haze removal algorithms, we can improve the consistent quality and robustness of the tangible framework. Removal of haze could be a tough thing as a result of fog depends upon the unknown scene depth data. Haze impact is outlined as event of distance between camera and object.

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Here, a novel edge-preserving decomposition-based technique is introduced to estimate transmission map for a haze image in order to design a single image haze removal algorithm from the Koschmiedars law without using any earlier. Weighted guided image filter is adopted to decompose simplified dark channel of the haze image into a base layer and a detail layer. The transmission map is estimated from the base layer, and it is applied to reproduce the haze-free image. The experimental results come about on various kinds of pictures, including cloudiness pictures, submerged pictures, and ordinary pictures without haze, demonstrate the execution of the proposed calculation.

II. Theoretical Background

This section depicts the different atmospheric model those describe the degradation level

A. Atmosphere and vision

Basically, all the research in vision is based on the very fact that observer is in the clear medium (air). It has been assumed that light rays mirrored by scene objects reach the observer with no attenuation or alteration. With this supposition, the brightness of a pixel of image depends entirely on the brightness of one single point in the scene.

Existing vision sensors and algorithms are created solely to perform on clear days. A good vision system but should consider the entire cases of atmospheric condition which can contain haze, fog, rain, snow.

Haze is ingrained of aerosol that could be spreader little particles of gas. Haze includes a various set of sources together with volcanic ashes, foliage exudations, combustion merchandise, and ocean salt. The particles made by these sources respond quickly to changes in humidity. These particles can act as a centre of water droplets in a high humid weather. Air molecules are larger than haze particles. Fog droplets are smaller than haze particles. A gray hue caused by haze particles causes' poor visibility.

Atmospheric scattering attributes are illustrated by attenuation and air light.

B .Attenuation Model

How light gets weakened while venturing out from scene point to the camera, is described by the attenuation model [7].

In the atmospherically scattering, some of the light is detached from the incident ray. The unscattered light reaches a camera. This light is called direct transmission. The attenuated irradiance received at the observer is given by

$$E\ d\ t(d, \lambda) = E\infty(\lambda)\ r(\lambda)\ e-\ \beta(\lambda)d/\ d2 \qquad (1)$$

d= depth of the scene point from the observer, λ= wavelength, (λ)= scattering coefficient of the atmosphere, *E*∞= horizon brightness, *r*= function describes the reflectance properties.

C. Air light Model

This model illustrates about the atmosphere's acting as a supply to replicate the environmental illuminations towards the observer. The mirrored light travels the whole path length d, the gap from the scene purpose to the observer or the camera. The irradiance due to the air light is given by

$$E\ a\ (d, \lambda) = E\infty\ (\lambda)\ (1-\ e-\beta\ (\lambda)\ d) \qquad (2)$$

D. Haze Formation Model

While capturing the outdoor pictures during bad weather condition, the radiance got by the camera from the scene is attenuated along the line of sight. The incoming light is mixed with the light coming from all other directions called the Air light. It adds whiteness in the image. And the second component Attenuation is the gradual loss in intensity. Because of this there is significant decay in the color. Amount of scattering depends on the distance between the scene points and the camera. So the degradation is spatially variable. In a machine vision the most widely used model for the formation of hazy pictures is given as [8]

$$I(x) = t(x)*J(x) + (1 - t(x))*A \qquad (3)$$

Where x indicates the position of the picture element, I is that the determined hazy image, J is that the scene radiance which is haze free image, A is the atmospheric, t is the medium of transmission describing the portion of the light that's not scattered and reaches the camera. The transmission features a scalar worth ranges from zero to one for every picture element and therefore the worth indicates the depth of the data of the scene objects directly. For the same medium the transmission will be expressed as $t(x) = e-\beta(\lambda)d$ where β is that the scattering constant of the medium. Scene radiance is weakened exponentially with the scene depth. Primarily the image received by the observer is that the combination of the attenuated scene radiance with haze layer, haze color is represented by atmospheric light. The ultimate goal of the haze removal is to get the scene radiance J, A and t from the determined hazy image.

Haze removal is used to get the haze free image from the observed hazy image. But while doing the dehazing for a image, the transmission co-efficient t is unknown, the air light A, the scene radiance J (or the haze free image) is unknown. Hence if the air light and also the transmission co-efficient are recognized then the scene radiance will simply be recovered.

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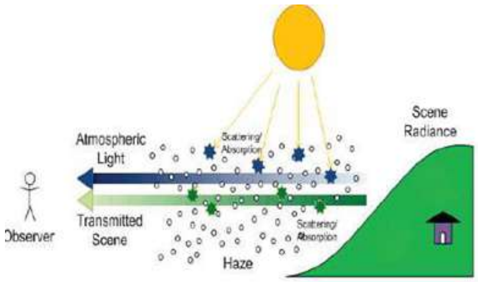

Fig.1. Haze model

Fig.1. shows a Haze formation model [8].

D. Dehazing

Dehazing is highly required in consumer photography and computer vision applications. Because many computer vision applications are suffer from low- contrast scene radiance.

(a) (b)

Fig.2.(a). Hazy image and (b) Dehazed image

Fig.2.(a) shows a Hazy image and Fig.2. (b) Shows a dehazed image.

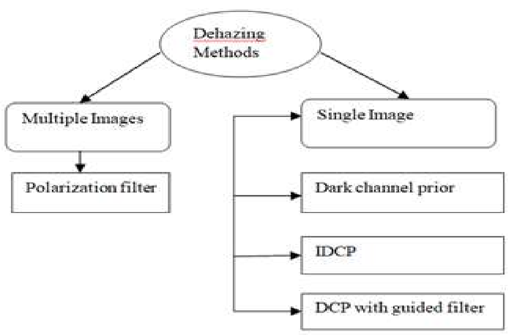

Fig.3. Different Dehazing strategies

Fig.3. describes different about dehazing strategies. Dehazing methods can be subdivided in to multiple images and single image methods. Polarization filter is an example for multiple images method and single image method consist of Dark channel prior (DCP), IDCP, Dark channel prior with guided filter.

III. Related Works

This section presents survey on various haze removal methods. Haze causes problems in various computer vision and image processing based applications as it reduces the visibility of image.

Wang, et al. [1] has investigated that the haze removal from the picture relies upon the unknown depth information. This calculation is based on the atmospheric scattering physics-based model. In this on chosen region, a dark channel prior is used to get a novel estimation of atmospheric light.

Yu, et al. [2] has proposed a novel quick defogging strategy from a single image based on the scattering model. A white balancing is utilized prior to the scattering model applied for visibility restoration. Then an edge-preserving smoothing approach based on weighted least squares (WLS) optimization framework to smooth the edges of picture. Finally inverse scene is applied for recovery process. This technique does not require earlier data.

Shuai, et al. [3] discussed issues regards the dark channel prior of color distortion problem for some light white bright area in image. An algorithm to assess the media function in the use of median filtering based on the dark channel was proposed.

Cheng, et al. [4] has proposed a lowest channel earlier for picture haze expulsion. This algorithm is streamlined from dark channel prior. It depends on a key truth that fog-free intensity in a color image is usually a least value of trichromatic channels.

Xu, et al. [5] has prescribed in a model based on the physical process of imaging in foggy weather. In this model a quick fog expulsion algorithm which depends on a fast trilateral filtering with dark colours prior is explained.

Sahu, et al. [6] has proposed an algorithm of haze expulsion from the color image and also useful in hue preserving contrast improvement of color images. In this method firstly, the original image is changed over from RGB to YCbCr (a way of encoding RGB information). Y′ is the luma component and CB and CR are the blue-difference and red-difference chroma components. Furthermore, the intensity component of the converted image and the key.

Snehal O. Mundhada et al. [7] has presented image improvement is the task of applying certain alterations to an input image like as to obtain a more visually pleasing image.

Ms Munira A Jiwani* et al.[8] has presented that the visibility in bad weather condition is severely decreased by scattering of light due to suspended particles in the atmosphere such as haze and fog. In this paper, authors have

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proposed defogging strategy from a single image based on depth estimation using blur.

Khitish Kumar Gadnayak et al. [9] said one of the essential issues in the area of image processing is the restoration of the images those are corrupted due to several degradations. Images of outdoor scenes caught in a poor weather conditions contain atmospheric degradation such as haze, fog, smoke occurred by the particles in the atmospheric medium absorbing and scattering as the light travels from the scene point to the observer.

SreekuttyK et al. [10] it utilizes a color attenuation prior model for haze expulsion. A direct model is build for modeling the depth of the scene and using depth map we can easily estimate transmission map and outlook radiance, thus effectively removing haze from single image. In the haze free image some private data like time at which images are taken and temperature of the place from where the images are taken can be made hidden and this secret message can be recovered whenever necessary.

Prashant Rajaram Sawant et al. [11] presented transmission of visual information in the form of digital image is becoming a major method of communication in the modern age but still the image received after transmission is corrupted with some noise, so the received image requires processing before it can be utilized in application. Our aim is to expel the noise from noisy laser image because it includes several types of noises like random noise, speckle noise, gaussian noise, salt and pepper noise, brownian noise etc. Image denoising is involved manipulation of image data to produce a visually high quality image. Proposed method in this paper is used to enhance the quality of image by improving its features. The laser image processing area has received sufficient considerable attention in the recent decades. Utilizing some special type of filter it is possible to denoise the image. The filter we will utilize is homomoprphic & Gaussian low pass filter for smoothing the image. Image denoising is required for various researchers in laser community for their research activity. Thus laser image denoising is very important factor for various domains like medical & engineering applications. There are different methods or algorithms are available for denoising of image like spatial domain filtering, nonlinear filtering, wavelet domain, etc. In all of these wavelet transform have some advantages like.

a) Wavelet offers a synchronous localization in time and frequency domain.

b) It is computationally very quick.

c) One of the most important advantages of wavelet transform is that it isolates the fine details in a signal, very small wavelet can be used to separate very fine details in a signal while very large wavelet can identify course details.

Angitha P V et al. [12] has introduced that dehazing plays a dominant role in many image processing applications. The visibility of outdoor images is often degraded due to the presence of haze, fog, sandstorms etc. Poor visibility occured by atmospheric phenomena causes failure in image processing applications. Haze leads to failure of many computer vision or graphics applications as it decreases the visibility of the scene. Haze is formed due to the two fundamental phenomena that are attenuation and air light. Haze removal also known as dehazing refers to different techniques that aim to reduce or remove the image corruption that occurred while the digital image was being obtained during inclement weather conditions. This paper gives a brief idea about different image dehazing techniques and also provides an idea about advanced color attenuation prior based dehazing technique. Colour attenuation earlier based dehazing provides a better dehazing results and improves the contrast of the image very well in comparison to other earlier based dehazing techniques and this dehazing technique can be enhanced by adding a edge attenuation operation so a better dehazing result can be achieved.

Lakshmi Raj et al. [13] said image haze removal has become an important research direction in the field of computer vision. Outdoor images that are captured in poor weather are corrupted due to factors like noise and haze. These factors seriously affect the visibility of the picture. Images may contain impulse noise which is produced by the sensor and circuitry of image-capturing devices like cameras. Images may also contain haze, which is the combination of two fundamental phenomena namely: attenuation and airlight. Attenuation decreases the image contrast and air light enhances the whiteness in the image, thereby making the images hazy. This work presents a combined approach for denoising and dehazing a single noisy and hazy image. First, the input image is passed through an adaptive median filter to remove the impulse noise. Then the resultant image is dehazed using simple color attenuation prior. The experimental results showed that the visual quality of the output images is much better than the original input images, which proves the efficiency of this method.

Surabhi Deshpande et al. [14] concentrated on executing image processing for human understanding in low visibility using different image processing techniques, high-speed processors, employing the BBB board in designing embedded systems and rules with their comparative study. They have proposed a framework called as “image processing for human understanding in low visibility". The reason of this application is to overcome the issue of low-visibility conditions for Navigation of vehicles, driving at night, in blizzards, in sand storms or in fog form an obvious set of challenging conditions. The fundamental thought is to solve the problem of low visibility by advanced image processing technique purpose to improve the perceptual quality of images that lack the contrast or color depth perceived by the human visual system. This paper gives the utilization of high-speed infrared cameras and improved image processing techniques to deal with the problem of low visibility.

IV. Methodology

A. Modelling Of Haze Images

According to the Koschmiedars law, a haze image is generally modelled by [10],

$$X_c(p) = Z_c(p)t(p) + A_c(1 - t(p)) \quad (4)$$

Where $c = \{r, g, b\}$ is a color channel index, X_c is a haze image, Z_c is a haze-free image, A_c is the global atmospheric light, and t is the transmission medium describing the portion of the light that is not scattered and reaches the camera. The first term $Z_c(p)t(p)$ is called direct attenuation and it describes the scene radiance and its decay in the medium. The second term $A_c(1 - t(p))$ is called air-light. Air-light results from previous scattered light and leads to the shift of the scene color. When the atmosphere is homogenous, the transmission t (p) can be expressed as: t (p) = e−ad (p).Where α is the scattering coefficient of the atmosphere. It indicates that the scene radiance is attenuated exponentially with the scene depth d (p). The value of α is a monotonically increasing function of the haze degree.

B. Decomposition of Simplified Dark Channel of a Haze Image

A new haze image model is derived by using the simplified dark channels of the haze image *X* and the haze-free image *Z*. Let A_m, $X_m(p)$ and $Z_m(p)$ be defined as

$$A_m = \min\{A_r, A_g, A_b\} \quad (5)$$

$$X_m(p) = \min\{X_r(p), X_g(p), X_b(p)\} \quad (6)$$

$$Z_m(p) = \min\{Z_r(p), Z_g(p), Z_b(p)\} \quad (7)$$

The relationship between the minimal color components X_m and Z_m is given as

$$A_m - X_m(p) = (A_m - Z_m(p))t(p). \quad (8)$$

$$A_m - J\,X_d(p) = (A_m - J\,Z_d(p))\,t(p) \quad (9)$$

Equation (9) forms two layers, $(A_m - J\,Z_d(p))$ forms detail layer and t (p) forms base layer.

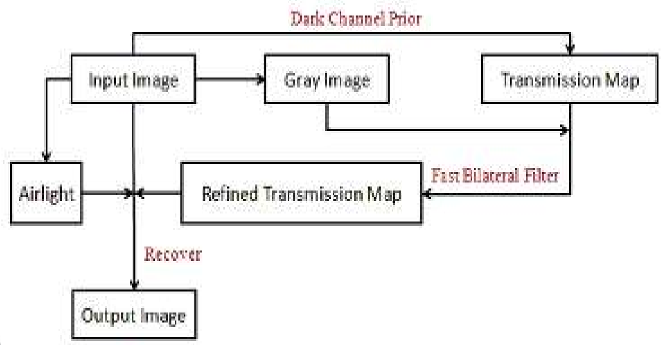

Fig.4. Flow chart of haze removal algorithm

Fig.4. shows a flowchart of a haze removal algorithm [4].

V. Single Image Haze Removal Via Edge-Preserving Decomposition

In this section, a simple single image haze removal algorithm is introduced by using the new decomposition model proposed in the previous section. The global atmospheric light $A_c(c = \{r, g, b\})$ is first empirically determined by using a hierarchical searching method based on the quad tree subdivision. The WGIF is then adopted to decompose the simplified dark channel of a haze image derived in equation (9) into two layers and the value of t (p) is then obtained. Finally, the scene radiance Z (p) is recovered by using the haze image model.

A. Empirical Estimation of the Global Atmospheric Light

The global atmospheric light *Ac* is usually estimated as the brightest color in a hazed image, since a large amount of haze causes a bright color. However, objects, which are brighter than the atmospheric light, could lead to undesirable selection of the atmospheric light. Based on the observations that the variance values of pixels are generally small while the intensity values are large in bright regions, the values of Ac are obtained by a hierarchical searching method on basis of the quad-tree Subdivision.

The input image is firstly divided into four rectangular regions. Each region is assigned a value which is computed as the average pixel value subtracted by the standard deviation of the pixel values within the region. The region with the highest value is then selected and it is furthered divided into four smaller rectangular regions. The process is repeated until the size of the selected region is smaller than a pre-defined threshold which is selected as 32×32 if it is not specified. In the finally selected region, the pixel which minimizes the difference $(X_r(p), X_g(p), X_b(p)) - (255, 255, 255)$ is chosen and it is used to determine the global atmospheric light.

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B. Estimation of transmission map

Once the values of Ac(c = {r, g, b}) are obtained, the value of Am can be computed via Equation (5). The decomposition model in Equation (9) is available. The WGIF is applied to decompose the dark channel of haze image into two layers base layer and detail layer. t (p) is then obtained.

V. SOFTWARE & HARDWARE USED

A .OpenCV-Python (Software)

OpenCV-Python is a library of Python ties intended to take care of PC vision issues.

Python is a broadly useful programming dialect created by Guido van Rossum that turned out to be exceptionally prevalent rapidly, essentially due to its effortlessness and code lucidness. It empowers the software engineer to express thoughts in less lines of code without diminishing meaningfulness.

Compared to languages like C/C++, Python is slower. All things considered, Python can be effortlessly stretched out with C/C++, which enables us to compose computationally intensive code in C/C++ and make Python wrappers that can be utilized as Python modules. This gives us two favorable circumstances: to begin with, the code is as quick as the first C/C++ code (since it is the genuine C++ code working in foundation) and second, it less demanding to code in Python than C/C++. OpenCV-Python is a Python wrapper for the first OpenCV C++ implementation.

OpenCV-Python makes utilization of Numpy, which is an exceptionally improved library which is utilized for numerical tasks with MATLAB-style syntax. All the OpenCV exhibit structures are changed over to and from Numpy arrays. This likewise makes it simpler to incorporate with different libraries that utilization Numpy, for example, SciPy and Matplotlib.

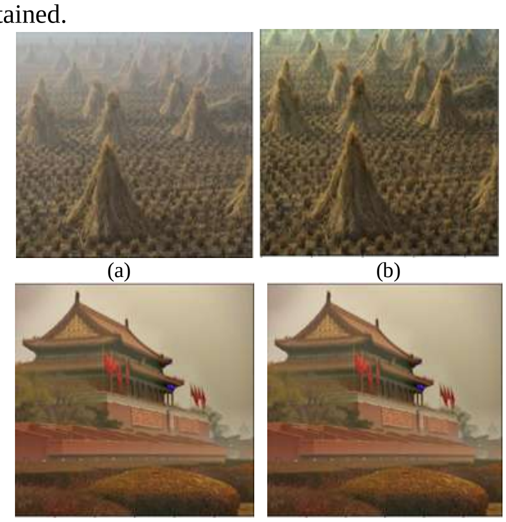
B.E.Raspberry Pi 3 Model B (Hardware)

Technical specifications

- Broadcom BCM2837 64bit Quad Core Processor powered Single Board Computer running at 1.2GHz.
- 1GB RAM
- 40pin GPIO
- 4 USB 2 ports
- 4 pole Stereo output and video port
- Full size HDMI
- CSI camera port
- DSI display port
- Micro SD port

VI. RESULTS AND DISCUSSIONS

The proposed method is applied to the hazy images and dehazed image is obtained. Software used here is Open-CV Python platform. This method is implemented in hardware using Raspberry pi3 model B and successfully got the results. Fig.5. shows the results obtained from the haze image and haze is removed successfully. The algorithm is repeated for more number of pictures and the result is obtained.



(a) (b) (c) (d)

Fig.5. (a) and (b) shows the hazy image and dehazed image of one image and (c) and (d) shows another image.

VII. HAZE REMOVAL APPLICATIONS

- Remote sensing system
- Capturing under water image.
- .Consumer photography
- Computer vision applications.
- Surveillance systems.

VIII. CONCLUSION

A simple single image haze removal algorithm has been presented here by using an edge-preserving decomposition strategy to estimate transmission map for a haze image. Experimental results describes that the proposed algorithm is applicable to haze images, underwater images, and normal images without haze. This algorithm is a new framework for single image haze removal which is from the Koschmiedars law without using any earlier. It also introduces a new application for existing edge-preserving smoothing techniques.

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