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SINGLE IMAGE DEHAZING METHOD BASED ON CURRENT STRATEGIES

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ABSTRACT

Recently the most role and wide application fields have seen in computer vision and graphics, Computer vision applications are largely impaired when weather is unfavorable, which typically causes reduced visibility in capturing clear images. In image processing context, haze is a surrounding condition that affects scene objects clarity attributed to the influence of moisture in the atmosphere. Haze worsens clarity of scene objects, which consequently impact computer vision and graphic applications negatively. Here the role of the dehazing method still it is very important in computer vision applications, it can make images more clear by taking off haze from them, thus the scene vision will increment. From earlier up to now, many methods have been proposed for improving images. The single image dehazing method is one of them and recently the researchers are more interested in this method. The primary contributions of this review study focus on explaining the cause of haze formation for images, general historical overview of single image dehazing methods, explain the most equation used in the dehazing process those help to contribute the new methods to remove haze and clarify the hazy image, and clarify the pros and cons of haze removal methods.

Keywords: Hazy Image, *Dehazing Methods, Haze Removal Techniques, Single Image Dehazing, Multiple Image Dehazing, Outdoor Image, Image Restoration, Image Enhancement, Image Fusion Based, Dark Channel, Deep Learning-Based.*

1. INTRODUCTION

Polluted air medium impact photographs quality adversely as essential data is lost when light is transmitted from scene objects to the camera. Polluted air medium comprises of water mist and pollutant particles drifting freely in the atmosphere. Under such atmospheric conditions, data may only be collected insufficiently, which is inadequate for use in the coming decade computer vision applications [1]. Bad weather leads to reduced visibility in photographs taken for work of art, affecting the detection of objects in numerous computer vision applications [2], as well as adversely impacting the quality of surveillance videos [3], so those cause to formation the haze on image and all vision applications. Images would also be adversely affected by poor lighting. Such images would be unfit to be processed in computer vision applications, such as assistive lane navigation, radar detection, and weather forecast.

Haze lowers outdoor scenes visibility attributed to distorted moisture in the atmosphere. It is responsible for negatively impacting scenes' clarity in graphics processing systems. Haze is composed of suspended gaseous particles, which is present in heavy concentrations from sources encompassing, sea salt, products of combustion, exudation by plants, and ashes from volcanoes [4]. Formations of fog and haze are attributed to release, sucking, and scattering activities that take place between the atmosphere and light. Their formations degrade visibility, which is commonplace. In literature, fog and mist, along with haze, and clouds are characteristically described as particles exhibiting aerosol behavior in the atmosphere. These aerosols decrease the contrast property of photographs taken linearly with growing distance. This is attributed to two primary factors: 1) Attenuation of reflected light from an object as a result of scattered aerosols, and 2) Scattering of light emitted to the lens of the camera [5]. Fog and haze are differentiated by their particles' types and dimensions [6], [7]. Hazes primarily influence computer vision applications, in terms of air-light (spikes whiteness points) and attenuation (degrades disparity points). The following equation expresses the creation of haze-laden images [8], [9]

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

where, $I(x)$ is the attitude of identified density for xth pixel; $J(x)$ is the radiation sight (i.e. genuine color that needs to be retrieved); A is the light of the universal atmosphere, and t is the transmission medium depicting a section of the light that is beamed and traveling towards the camera.

In image processing context, haze is a surrounding condition that affects scene objects clarity attributed to the influence of moisture in the atmosphere. Haze worsens the clarity of scene objects, which consequently impact computer vision and graphics applications negatively. Two primary effects of haze include impairment of air-light (spiked whiteness intensity) and attenuation (low disparity). For reference, Figure 1 depicts the formation of images impacted by haze.

In such conditions, individual pixel brightness of any images relies solely on individual point scene brightness. Current applications of algorithms in vision processing can analyze and process such images effectively. Despite this, an intelligent vision system that is dependable and operable under poor visibility is also needed for outdoor use. For instance, poor visibility due to snow, hail, rain, smog, and haze must be handled by systems operating computer vision applications [10].

Due to this, there is a greater need to remove haze from images captured under fuzzy visibility, so, as to uplift computer vision [2]. Besides, systems implementing full automation with the computer vision component would produce defective outcomes if input images contain substandard quality [1]. With the development of computer technology, the video and image dehazing algorithms have received much attention and are widely applied in civil and military fields, such as remote sensing, target detection, and traffic surveillance. Thus, haze removal mechanisms implemented on processed images could significantly uplift the capability of computer vision, such as in the areas of capturing aerial images [11], classifying images [12]–[15], retrieving videos/images [16]–[18], sensing reconnaissance [19]–[21], and recognizing and analyzing videos [22]–[24].

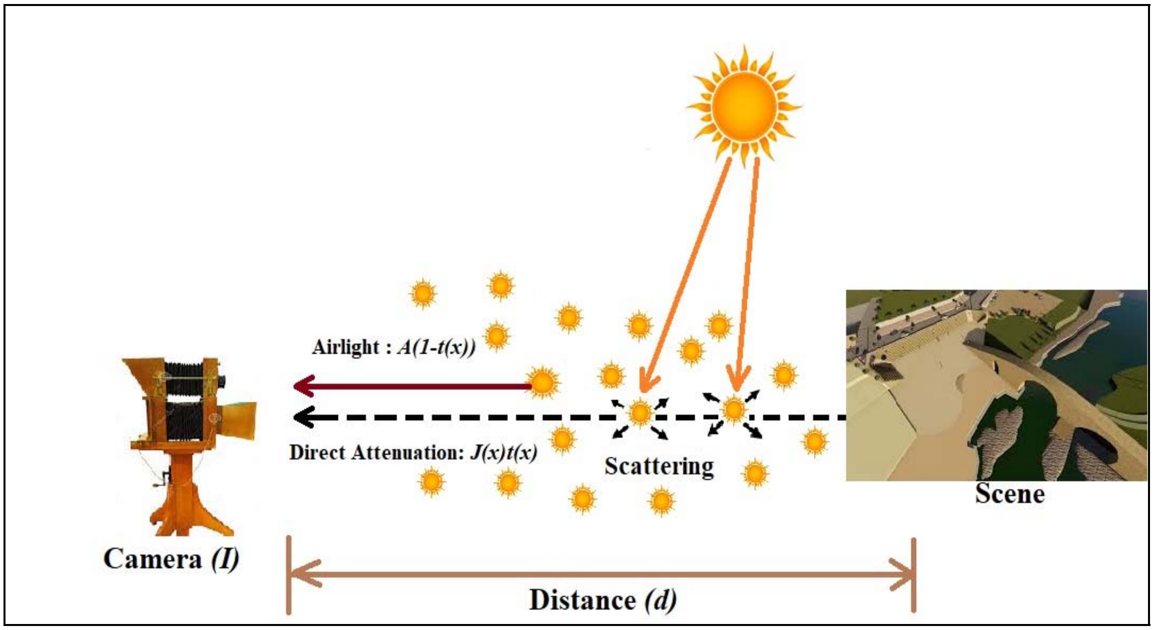

Figure 1: Image impacted by Haze

The uplifting effort should not merely cover clearing images from fuzziness, but should also retrieve as much information of scenes as possible. Thus, the mechanisms should ideally incorporate flexibility to allow adaptations considering environment conditions to be taken by visual applications [25].

Recent computer vision processing techniques tried to improve the contrast and color of scene objects impacted by haze in images captured by consumer devices, object detection applications, as well as outdoor surveillance equipment. Such techniques are also termed as de-hazing that operates by the physical degradation model with the presumption that a problem's solution is non-reversal [26]. Existing de-hazing techniques utilize; either manual input from users to manipulate atmospheric light or hard threshold presumptions.

Most de-hazing techniques ignored the consideration of artificial lighting. Scene objects with artificial lighting including street lamps and car lights, typically, possess numerous pixel points with high brightness. De-hazing quality could be severely influenced by inaccurate approximation of atmospheric light [27]. Image de-hazing techniques have been broadly divided into two categories in the past, including the physical recovery model and image enhancement model [28]. Formerly, de-hazing techniques were detailed out from the aspects of, a common field of application, time expense, and fundamental principles. Briefly, there are three main types of de-hazing techniques, namely; improvement of images, a fusion of images, and restoration of images. The main aims among scholars include removing haze as well as improving image clarity. In single image processing, there are three parameters considered for removing haze: 1) approximation of transmission map, 2) approximation of atmospheric light at global, and 3) restoration of clear image. For reference, Figure 2 depicts imaging in two weather conditions.

We letter that there are numerous review papers on image dehazing or defogging [26], [28]–[31]. In [26] categorize all the methods by the four steps of image dehazing and then perform analysis through steps sequence. In [28] categorized the several image dehazing approaches into two comprehensive categories i.e. image enhancement and physical model restoration. Referring to [29] the image enhancement method, restoration works on improving the contrast of the image, and other several fields, including the alteration of medical, underwater, and de-hazing imageries. In [30], several restorations based defogging methods are investigated. In [31], haze removal algorithms present an analysis of the local histogram equalization. Besides, the paper [32] attentions on mathematical models of dehazing methods along with their implementation sides.

As we touched in our study, our paper also reviewed specialized methods to remove haze, explain the most mathematical models used in the dehazing process and identifies the pros and cons of those methods. This review is expected to confirm researchers' efforts towards improving the main haze removal methods.

The rest of the paper is organized as follows. In Section 2, the literature review discussed. Section 3 discusses the study and comparison between methods. And section 4 concludes the paper.

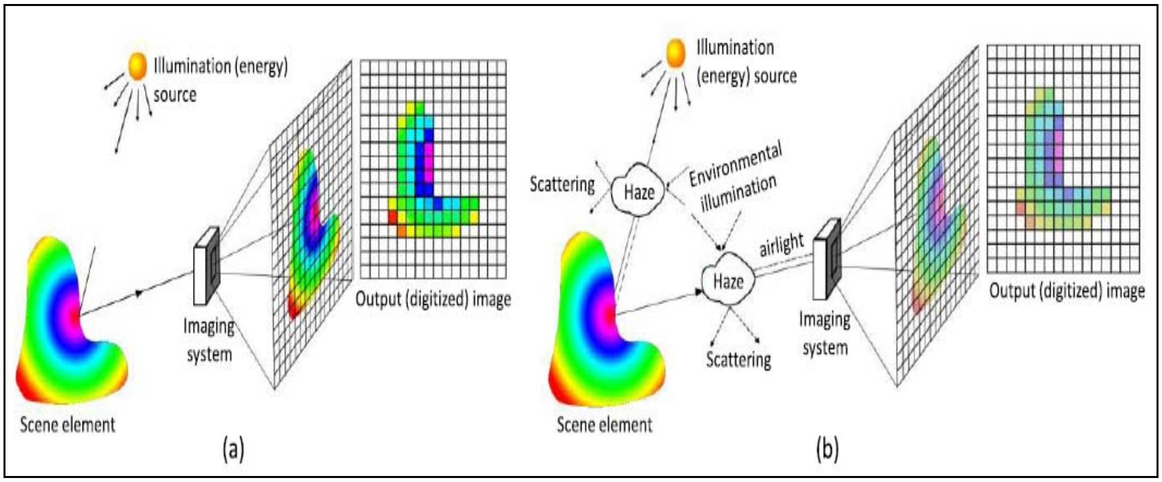

Figure 2: Imaging processes in distinct weather surroundings. (a) Sunny weather imaging; (b) Hazy weather imaging. (Adopted from [1]).

2. LITERATURE REVIEW

This section will illustrate dehazing methods with the basic strategy that works and depend upon.

2.1 Dehazing Methods

Haze can transform a colored picture into a white-and-ashy, one, causing lost picture details and the decrease in disparity. Likewise haze trouble numerous applications, including targeted direct monitoring and indirect confession, tracking, and measurements. Image dehazing can take off haze from the pictures, increment the scene vision, and enhance the general impact visual [33].

The great challenge that rests with mathematical ambiguity is the removal of haze. The goal of haze elimination is to enhance the contemplated light (i.e., the scene colors) from the mix mild. Though, dehazing images are very important in computer vision applications. Consequently, most of the researcher strives to attitude these challenging tasks and suggested a variety of dehazing algorithm.

In past years, some institutions have researched image dehazing and obtained good results. In America, the Langley Research Center (LRC) of National Aeronautics and Space Administration (NASA) has studied the image enhancement and dehazing algorithm since 1995, and their research has made a great contribution to the field of image enhancement based on the Retinex theory. Their algorithms can greatly enhance the visibility of an image acquired under bad weather conditions, such as smoke, haze, underwater, night, or low illumination conditions [34]–[38].

On the DSP microprocessor, their algorithms can reach a speed of 30 frames per second with an image size of 256*256 [33]. The French Central Laboratory of Roads and Bridges made significant progress in enhancing the visibility of the vehicle visual system in foggy weather [34]–[36].

Dehazing methods can be collected into three categories as mentioned above, which are image enhancement, image fusion, and image restoration. Each one of them has specific classes, so in turn image restoration single has two categories single image haze removal which required only single image as input and multiple image haze removal which are take multi images two, three, or more of the same sight. Both methods come under many categories are described as a diagram follows in Figure 3.

2.1.1 Image Enhancement

Referring to the image enhancement method, restoration works solely focus on improving the contrast of the image and altering images based on human visual assessment, whereby, the physical model is not required. This method is used in several fields, including the alteration of medical, underwater, and de-hazing imageries. Among the methods that implement image enhancement treatments include 1) Histogram Equalization, concerns with altering images' contrast. Through this method, the detected haze layer would yield a steep grayscale range, consequently, leading to the implementation of the reduction in contrast [10], [31], [37]–[42]. 2) Retinex method, which was constructed based on the understanding of the working of the retinal cerebral cortex, whereby, the method closely mimics the human eye's observation of colors [43]–[45], [46]–[50]. And 3) Frequency Transform Domain Enhancement, it dissects images into frequency representation either; through Fourier analysis, or other comparable approaches. Inversed image is transformed into the spatial domain upon completion of the clarifying process [39], [51]–[59].

2.1.2 Image Fusion

Single image haze removal could be achieved via a multiscale depth fusion technique [60]. The outcomes generated from filtering on multiscale are merged using probabilistic means into a fused depth map. This fusion raises the reduction of energy challenge integrating Markov dependence. The strategy allows the map's depth to be estimated reliably, which also subsequently allows edge preservation to be undertaken, yielding sharper and high clarity images.

The work in [60] introduced a promising strategy to estimate the transmission map utilizing directed fusion. Reliability directed fusion at channel's pixel-point and block-point allow transmission map with heightened quality to be assessed. Haloes and dark channel's likelihood of prior failures are greatly reduced when the mask dimension is enlarged, which consequently assist in refining images' edges. Meanwhile, dark channel prior failures in the atmosphere could be mitigated through suppressing contrast intensity on exteriors exhibiting skies' properties. This ensures skies illumination to be preserved.

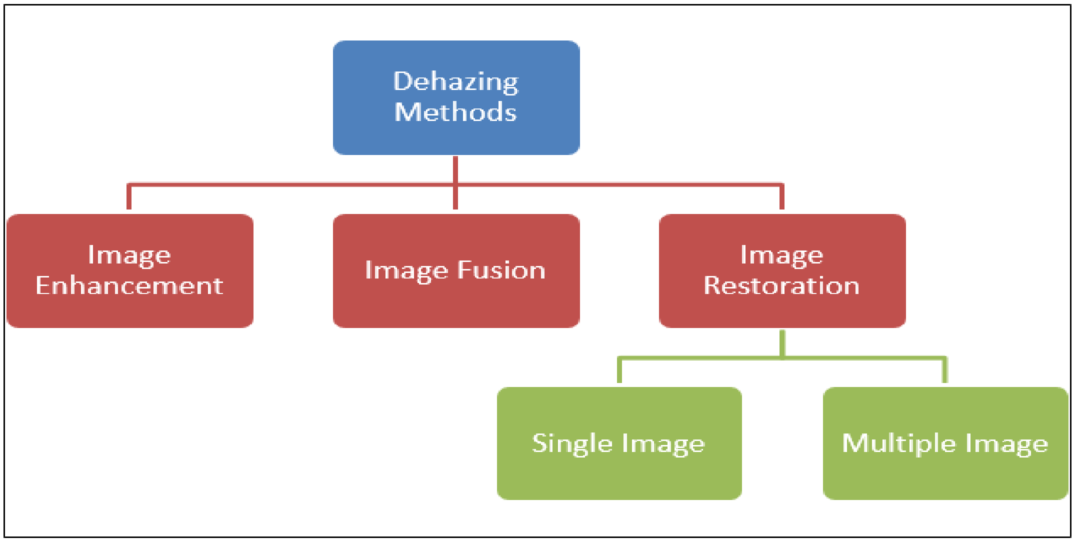

Figure 3: De-hazing Methods Diagram.

Meanwhile, the work in [11] proposed a fusion approach in dealing with haze on images. Fusion occurs in the merging of linear transform output with directed image filtering. The algorithm operates firstly by obtaining a fusion process input image utilizing a linear transformation. Secondly, the second input image is obtained utilizing directed image filtering. Next, the two input images are fused. Finally, the fused image would yield a haze-free output image by rudimentary white balancing procedures. The approach is highly efficient as well as performs with superior performance in refining clarity of images affected by outdoor climates.

2.1.3 Image Restoration

The physical model capturing attenuation in the atmosphere was introduced by [58]. The model was built upon the understanding of the Mie scattering theory. The physical model is composed of the air-light model and the direct transmission model. In the direct transmission model, the light for imaging will be attenuated by atmospheric scattering, which leads to the degradation of edge details and object textures of the image. In the air-light model, some sunlight will also be scattered by the atmosphere and transmitted to the camera, and these lights are not the scene lights and can be considered as the haze component of the image whose influence is similar to that of a veil to hide the objects in the image. For a clear image, the direct transmission model makes up a large proportion of the imaging model. With an increase in the concentration of the haze, the proportion of the direct transmission model will decrease while the proportion of the air-light model will increase and visibility of the image will decrease. In other words, the air-light model is the main reason that leads to an image acquired under hazy conditions being a fuzzy image with low contrast and visibility [30].

Contrary to the model, Narasimhan and Nayar [6], [8] claimed that the coefficient for scattering is inappropriate for application in atmospheric homogeneity. Subsequently, the model was streamlined to reflect the restructured refinement of images.

$$I(x)= I_{\infty}\, p(x)\, e^{-\beta d(x)} + I_{\infty}\, (1- e^{-\beta d(x)}), \qquad (2)$$

where, $I1$ is the brightness of the sky; $p(x)$ is the normalized radiance of a scene point x; β is the atmosphere scattering coefficient, and $d(x)$ is the distance between the object point x and the camera. On the right side of Eq. (2), the first item signifies the direct transmission model, while the second item indicates the air-light model. Eq. (2) also indicates that the proportion of the direct model declines linearly with a growing distance. This justifies fuzzy images formation; even under fine outdoor weather conditions.

[61] further stream Eq. (2) further, like the following:

$$I(x)= J(x)t(x)+ A_{\infty}\, (1- t(x)), \qquad (3)$$

where, J is the clear image; t is the transmission; and $A1$ is the atmospheric light value relative to an object at a distance, which is commonly assessed based on the sky extent.

There are only two unknown parameters in Eq. (3). If we can obtain transmission t and atmospheric light value $A1$, then restored image J will be obtained.

Further, image restoration based methods for dehazing are studied to explore the reasons for the image degradation and analyze the imaging mechanism, then recover the scene by an inverse transformation. In this method, the physical model of the degraded images is the basis, and many researchers have used the following general model for image restoration.

1) **Degradation Model:** Figure 4 depicts *f(x)* as the input image; *d(x)* as the degradation function; *n(x)* as the noise; *g(x)* as the degraded image; *d'(x)* as the restoration function; and *f'(x)* as the restored image. Thus, a linear time-invariant system could be defined as the following:

$$g(x) = f(x) * d(x) + n(x) \qquad (4)$$

2) **Physical Models** Based on Atmospheric Scattering: In 1998, [5] started to use the Mie atmospheric scattering law to undertake some research work on images taken in bad weather conditions. The model-based dehazing method is now a research hotspot in the image processing field. In the last decade, some researchers have performed a deep analysis of the degradation mechanism and foggy image modeling based on atmospheric scattering theory, and have made great progress and proposed some image processing methods to enhance image clearness.

Previously, restored images have utilized physical model reference, comprising of two restoration types; including multiple-image restoration and single-image restoration [30], [58], [62]. Figure 5 illustrates a diagram for most image restoration dehazing methods.

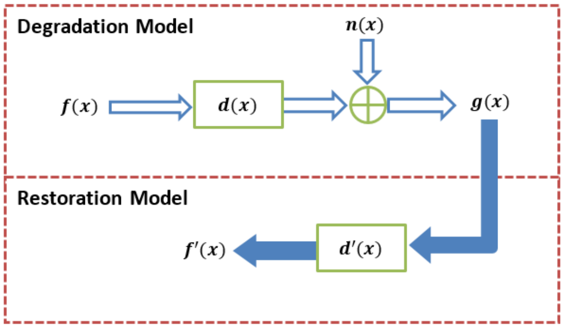

Figure 4: Degradation and Restoration Model Diagram

2.1.3.1 Multiple Image Restoration

Multiple images could be used to approximate detailed information or depth. Strategies that could be utilized to assist recovery to depend on 1) condition of a polarizing filter and 2) condition of weather [58]. Figure 5 shows further categories of image de-hazing. The first type utilizes several images captured under identical weather. The second type utilizes several images captured under non-identical weather. The final type utilizes a constructed 3D scene and a single scene image [16], [18], [20], [63].

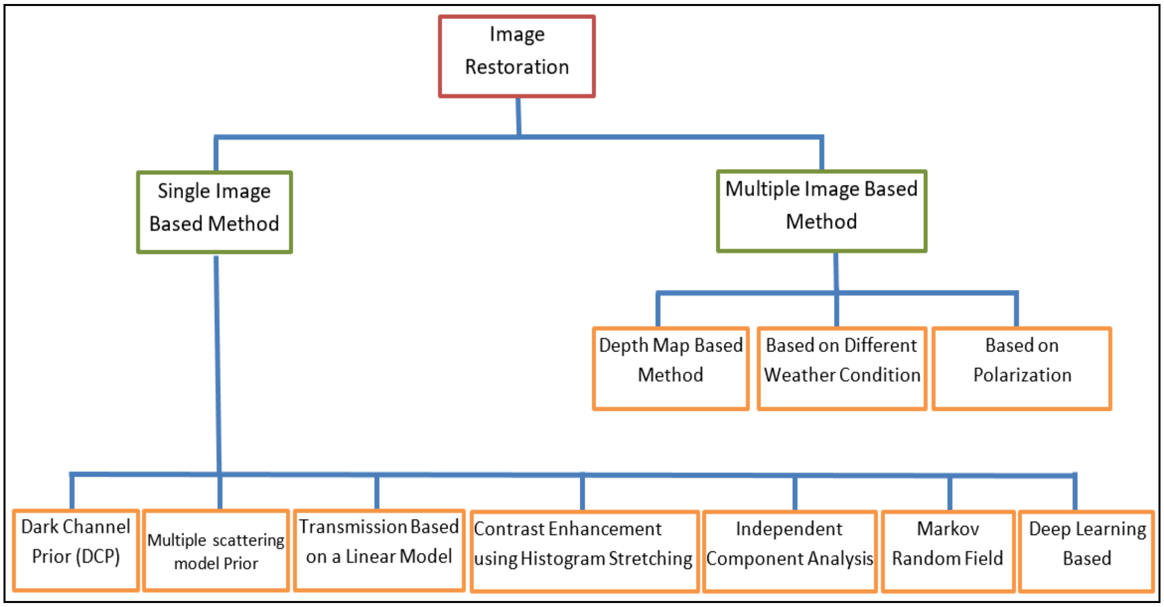

Figure 5: Image Restoration De-hazing Methods Diagram

A. Based on polarizing conditions

A light polarized study conducted by [64] discovered that upon the scattering of light, skylight possesses polarization properties. Further, the study also concluded that a target's light reflection does not indicate polarization properties. Exploiting the properties of the skylight, the study managed to refine haze affected images through computing polarization degrees by retrieving several images of a scene point on the distinct angle of polarization.

Treibitz et al. compared the image restoration effect with either one or two polarization images and demonstrated that using two polarization images reduces the noise for image restoration [65]. The polarization images with different brightnesses of the same circumstance of the scene are obtained by using a polarization filter with different orientations. Such a method requires minimally a pair of images of an identical scene before restoring image through physical model inversely.

Schechner et al. first discussed an image restoration algorithm by using two polarization images [66]. The two polarization images are captured through parallel and perpendicular orientations, respectively.

B. Based on Different Weather Conditions

Haze removal algorithm which required only a single image as input can classify the single image into three major types: 1) Algorithms based on priors or hypotheses. This type of methods takes off the fog from the image during valuing parameters of the model fog imaging, which can fulfill satisfying outcomes, examples Fattal, and He et al. 2) Enhancement image based on image processing, Meanwhile, images captured under variant weather conditions were pursued in the study conducted by [7], [60], [6], [67]. The study introduced a physical dichromatic atmospheric scattering model upon investigating the properties of weather via visual assessment. Through the model, a geometric blueprint was established in identifying haze-laden images and constructed 3D representation as well as scene coloration from minimally a pair of haze effected images [7]. However, the proposed scattering model would fail to restore images if haze coloration is not differentiable from the scene. A variant of this strategy was proposed, utilizing monochromic instead of a dichromic scattering model [60], [68]. Through this variant, an efficient two-step haze removal computation was achieved. Initially, under variant weather conditions, a structural component of scene and discontinuity depth would be determined based on the assessment of intensity change between identical scene images. Next, the structural component would be exploited to uplift contrast. The work reported excellent performance in restoring the quality of surveillance video by removing the haze effect [42].

C. Depth Map Based Method

Depth map-based method concerns with the information of depth through assumptions that the scene's constructed 3D representation and single image [60], [69] are indexed by Google as well as assuming ready availability of scene's texture (terrestrial imagery). The depth of the scene is established based on the haze-laden image's alignment with its 3D representation [35], using manual interactivity from users. The work yielded outcomes with great accuracy, discounting the need for additional tooling. However, the method is highly dependent on user intervention in performing haze removal by estimating parameters in image restoration. Additionally, the method is challenging to be executed due to the scarcity of further information that could be obtained.

2.1.3.2 Single Image Restoration

Image enhancement; reliant on scenes instead of a physical model would yield poor restoration results in the face varying scenes. For instance, Retinex and histogram equalization are two strategies that rely on scenes information. In the work of Ancuti et al., the fusion approach was utilized in enhancing image through extracting information from the original image, computed on luminance, chromatic and salience maps. The computations of the maps were mixed in a multiscale arrangement to execute the removal of haze[67].

Previously, researchers were drawn further into this strategy, which can be classified into the following:

A. Dark Channel Prior (DCP)

Dark Channel Prior (DCP) aims to perform efficient yet operational haze removal. DCP exploits dark pixels in the scene point, which possesses low single monochromatic color channel density, discounting sky region [61].

Such algorithms depend upon the dark channel before the hypothesis towards the air light the estimation of which offers itself as an urgent parameter towards dehazing. The approach of the dark channel towards the image haze removal based on the surveillance that in parts other than in the sky there is at least one color channel with associated pixels of very low density, sometimes terminate to zero. Intuitively, the intensity calculated within these zero approach parts. This connotation is exemplified mathematically in the equation below [70].

$$J^{dark}(x) = \min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}}(J^c(y))\right) \quad (5)$$

In the above equation, J^c denotes the channel color of *J* while *Ω (x)* signifies the native patch which is center around *x*. The hypothesis of the dark channel before recommends that rejecting sky patches, the intensity of J^{dark} expressively low and in most cases preserve the value of zero. This condition holds if *J* is an open-air picture not affect upon by fog. With all the fulfillment of conditions, Jdark is alluded to as the dark channel which relates to the fog-free outside picture, *J*.

The [71] proposed paradigm takes into account both, chromatic and colorless features of the picture to characterize the dark channel. When improving the sky area from haze by classical dark channel before the returned image did not dispose of noise so improved dark channel algorithm addresses this issue, IDCP which locates sky region in haze-laden pictures through combining aerial light and dark channel diversity value with incline threshold [72]. Researchers have investigated other threshold variations, including basic segmentation and OTSU segmentation. Through such threshold strategy, images are separated into the sky and non-sky components.

B. Multiple Scattering Model with Superpixel Algorithm

Previous work has utilized single scattering of light in restoring clarity to images affected by the haze. Multiple scattering of light has also been recently considered. Multiple scattering model (MSM) is a strategy used to remove haze on a single image utilizing DCP information (denoted by point spread function, SPF).

A variant of MSM, a global Gaussian assumption was undertaken in performing the estimation of SPF in the transmission map of an image in the work of [73]. This strategy considers numerical and visual correctness of haze removal. Thus, this strategy is comprehensive as it assesses the visual appearance of an image (qualitative) as well as its numerical structure (quantitative), which consequently yields promising results in comparison to existing strategies.

In addition, the superpixel algorithm has been utilized in the past to assess non-sky and sky regions. This algorithm effectively eliminates halo effect surrounding scene objects as well as reduce suppression on dark sky area. Establishment of the refined image through the removal of haze, eliminating halo effect, as well as sharpening small details could be finally achieved utilizing learning, such as self-adaption learning [73] on haze-laden images.

C. Transmission Function Based on a Linear Model

Numerous strategies have been introduced previously to remove haze, consequently leading to overall improvement for computer vision applications. Airlight condition may be best represented utilizing quadtree in searching for haze areas with efficiency. The quadtree is useful particularly in the presence of sunrays as the algorithm then combines spatial requirements and topical inclination and brightness, leading to superior results in sky region identification [74].

So based on Eq. (1), the light attenuation function t(x) can be expressed as follows:

$$t(x) = (A - I(x)) / (A - J(x)) \quad (6)$$

Since sunlight is scattered by particles in the atmosphere, it results in the near-identical atmospheric colors of light in hazy conditions. Hence; Eq. (6) could be further expressed, by taking the minimum value of the three color bands as following:

$$t(x) = (A0 - I^*(x)) / (A0 - J^*(x)) \ , \quad (7)$$

where, $I*(x) = \min[Ir(x), Ig(x), Ib(x)]$ and $Jcm(x) = \min[Jr(x), Jg(x), Jb(x)]$. Under haze influence, the minimum color component of the three channels is proportionate to the conveyance rate. The minimum of I(x) can be approached with a linear function of J(x) as following:

$$I^*(x)=aJ^*(x) + b \ , \quad (8)$$

where a and b are fixed. From the aforementioned equations, the following equation is subsequently expressed:

$$J^*(x) = \delta((I^*(x) - p) / (q - p) I^*(x)) \ , \quad (9)$$

where, q and p give the range of $I*$, and δ ($\delta \leq 1$) is a factor scale. Hence, t(x) can be calculated by combining Eqs. (17) and (19) as follows:

$$t(x)=(A0-I^*(x)) / (A0-\delta((I^*(x)-p)/(q-p))I^*(x) \quad (10)$$

D. Contrast Enhancement using Histogram Stretching

Airlight makes the genuine picture be crumbled and original differentiate moves radically. Histogram extending before dehazing will convey picture pixels over the whole brilliance go qualities to fill the whole shine run guaranteeing high complexity picture. The RGB standardized picture was changed over to HSV, histogram extending was additionally connected to the S and V channel before changing over it back to RGB.

Robert T. Tan [75], proposed to maximize the regional contrast of the hazy picture during the variance enhancement technique. The major thought that this method depends on to appreciation air-light from the brightest pixels in the hazy picture by expanding the regional contrast and the color with chromaticity division of air-light. Utilizing algorithm represented as:

$$\mathrm{Contrast}(\hat{R}(x)) = \sum^{S}{}_{x,c} \left| \nabla \hat{R}_{c(x)} \right|, \qquad (11)$$

Where S is the size of the window set to 5x5.

The specific problem that selected this method is the connection and the contrast is rounded which can be cast into Markov Random Field. The method proficient to handles haze depth and mechanism well for both color and gray images.

E. Independent Component Analysis

Independent component analysis (ICA) and Markov random field (MRF) models have been used in the estimation of surface shading in the work of Fattal [72]. The strategy assumes that surface grayscales and transmission maps are unconnected at the local level. The strategy is capable of yielding superior results despite poor performance in heavy haze conditions. The strategy also allows transmission and shading to be statistically assessed, which could invite optimization opportunities. In more recent work, [76] considered color lines. The work draws the assumption whereby image regions exhibit consistent colored surface with consistent depth, only differentiable by shading. Hazy images are best described as following:

$$I(x) = l(x)J(x) + (1 - t)\, A \qquad (12)$$

where $l(x)$ is the shading.

In order to obtain image transmission, the strategy performs scanning on pixel points, retrieving patches, and quantifying intersections. Certain patches yield inaccurate intersection, despite this, in the case where a majority of patches yield intersection, estimation would consequently yield greater accuracy. Patches displaying in a different color to sky color would fail to produce intersection. The strategy utilizes Gaussian Markov Random Field to perform interpolating calculations.

F. Based on Markov Random Field (MRF)

Markov Random Field (MRF) has been used to uplift the degree of brightness in images as reported in the work of Robert T. Tan [75]. The strategy employs joint probability distribution, represented by the undirected graph with random variables denoted as nodes. The method produced two deductions. Firstly, the contrast is worse in poor weather than in fine weather. Secondly, airtight magnitude is dependent on the distance of the scene point from the camera.

G. Deep Learning-Based

In literature, various deep learning algorithms have been introduced to handle restorative work on haze images. Deep neural networks, also well known as deep learning or feature learning, are more powerful than shallow learning algorithms [77]. Many researchers use deep learning to perform high-level computer vision tasks and significantly improve performance, such as image classification [78], [79]. A pre-trained convolutional neural network (CNN) was proposed by [80] in tracking moving objects. On the other hand, CNN was utilized in the training of end-to-end mapping among high-pixel and low-pixel pictures in the work of [81]. While researches also have applied utilized CNNs in estimating haze-laden pictures' transmission map [82], [25], [77], [83], [84]. Despite the numerous applications, deep learning strategies are challenging to be performed on a single image, attributed to challenges in retrieving poor weather images that could be associated with poor weather images of an identical scene. The absence of poor weather images of identical scenes renders deep learning to produce poor results.

2. COMPARISON AND DISCUSSION

In the field of computer vision and image processing, the use of the haze creation model assumes a broad position. This model in most cases used for the development of the image in the existence of bad atmospheric situations. Though Haze removal method or alleged dehazing images is very important in computer vision applications, provided many benefits to computer vision application. According to that, in this literature review, we discussed the prior methods that remove haze from a single image or multiple images. There are three categories for the dehazing method which are image enhancement, image fusion, and image restoration. However, this research focuses broadly on the hazes removal method for the single image which applied image restoration. Many previous researchers struggled to resolve the problem of haze removal in terms of haze isolation or haze thickness. Even though the problem can be reduced, but it still has the remaining limitation which is to handle haze level and abrupt changes in depth discontinuity. Hence, an enhancement to improve the remaining problem will be proposed to produce a better result.

TABLE 1: COMPARISON OF SINGLE IMAGE DE-HAZING METHOD BASED ON STRATIGIES.

Method	Technic	Author	Year	Strategy	Base equation	pros	cons
Dark Chanel Prior (DCP)	DCP	He et al.	2011	Exploits dark pixel in scene point, and discounting sky region	$J^{dark}(x) = \min_{y\in\Omega(x)} (\min_{c\in\{r,g,b\}} (J^c(y)))$	- Effective in preserving natural image characterizations.	- It would be less effective in hollow transmission estimation that has a radial length lesser than a patch. - The initial transmission map needs to be recast under an additional boundary prior.
	Improved DCP	Ullah et al.	2013	Depend on DCP to theorize chromatic as well as chromatic sides of the image to define the dark channel	$t(x) = 1 - \min_{y\in\Omega(x)} (\min_{c\in\{r,g,b\}} \frac{I^c(y)}{A^c})$	- Improved quality of restored haze-free images with the new definition of the dark channel. - The improved considerable disparity of the restored images.	- lose the tools that involve quantitative measures identification to describe the perfection in the color vibrancy
	Dark Channel Prior and Energy Minimization	Zhu et al.	2017	The energy function reduced combining piecewise smoothness with a DCP.	$E(t) = \sum_x \sum_{y\in N(x)} K(x,y) + \sum_x B(x)$	- The method is shown as an outstanding performance. - Remove the unwanted artifacts, while traditional DCP did not.	- It has no ability to estimate the largest possible number of hollow transmissions smaller than the patch radius
Multiple Scattering Model	atmosphere point spread function (APSF)	Wang et al.	2016	remove haze on single image utilizing DCP	$L_m = L_s * APSF$	- Estimating conveyance on regions of sky and non-sky. - Relieve the artifact corona around sharp rims. - Reduce color deformation in the sky area.	- Need more learning adaptability to strike a balance between the efficiency and effect for natural recovery
Transmission Function Based on a Linear Model	based on a linear model	Wencheng Wang et al.	2016	Based Quadtree to search for a preferable area that the appear the scatter of air-light, and computation of the efficiency	$A_0 = \bar{Q}_n^*$	- Significant improvement inefficiency could be extra than thirty-doubling exactly when the image is in moderate and large size.	- Lose to research the effects of modifying user-specified parameters and select suitable values automatically by identifying a workable way. - It fetches problems to realize the impact of inhomogeneous haze intensity across the domain of vision.
Contrast Enhancement	Markov Random Field (MRF)	Tan	2008	Enhanced visibility and air-light	$E(\{A_x\}\|P_x) = \frac{C_{edges}\left(\left[D_{\gamma'}\right]_x^*\right)}{m} + 1 - \frac{\|A_x - A_y\|}{\sum_c L_{\infty c}}$	- Solve many problems of the previous methods difficult to be fulfilled, which has various degrees of polarization or different aerial states. - Applicable for both color and gray images	- First is the auras at deepness cutout. Several small auras are fencing the image. - The optimized data cost function does not know the existing values the outputs tend to have larger saturation amounts

	Color-Lines based Markov Random Field	Fattal	2014	Eliminating the scattered light based on estimating the optical transmission to raise scene visibility and recover haze-free scene disparities	$J(x) = l(x)\bar{R}\ , x \in \omega$	- Describes color-lines in hazy images and recovers scene transmission reliant on the lines' offset. - Advantage of a generic regularity in natural images in which pixels of small image patches typically exhibit 1D distributions in RGB color space, known as color-lines	- Poor brightness. - Grey images could not be refined. - Fail to resolve monochromatic images where color-lines are indifferent. - This list is not sufficient to guarantee a correct classification
Independent Component Analysis (ICA)	estimating the optical transmission	Fattal	2008	Based on estimating the optical transmission to raise scene visibility and eliminating the scattered light	$t = e\left(-\int_0^d \beta(\boldsymbol{r}(s))\,ds)\right)$	- Formulate a refined image formation model that accounts for surface shading in addition to the transmission function	- Cannot remove dense fog or haze. - It cannot remove the halo artifact efficiently.
Deep Neural Network	DehazeNet based on CNN	Cai et al.	2016	Proposed DehazeNet trainable end-to-end system for estimating transmission medium to realize a haze-free image	$L_5 = \min(t_{max}, \max(t_{min}, W_5 * L_4 + B_5))$	- Achieves dramatically high efficiency and outstanding dehazing effects. - It works as a suitable platform to be used to perform learning on atmospheric scattering model	- Light at the atmosphere would not be considered as a global constant. - Learning would take place in addition to the medium transmission through one network
	(Ranking-CNN)	Song et al.	2017	Proposed a novel Ranking Convolutional Neural Network (Ranking-CNN) that is a trainable end-to-end system, which obtains effective features.	$\lambda = \log\left(\frac{\sum_x I^l(x)}{\sum_x J^l(x)}\right) + 1$	- Powerful haze-relevant features can be automatically learned from massive hazy image patches. - It can learn haze-relevant features automatically. - Achieves satisfactory results. - Aims to recover the clear image solely	- It may be insufficient to fully capture the intrinsic attributes of hazy images. - It has poor capability in processing images in image retrieval applications. - Rendering it as a weak solution in enhancing hazy images. - It lacks an efficient enhancement process
	DNN	Huang et al.	2017	Proposed dehazing based deep neural network, to restore the hazy image.	$D(y, y^*) = \frac{1}{2n}\sum_{i=1}^{n}\left(\log y_i - \log y_i^* + \alpha(y, y^*)\right)^2$	- The method works better than the others in reducing the Halo effect. - It does well to restore the color of an input image. - Finally, the process faster. - Do good in color restoration and dehzing	- Poor weather conditions negatively affect contrast quality. - Attributed to a poor understanding of how hazy images are formed. - The proposed technique would ignore critical information. - Sometimes, the MSE is bigger than some comparable method
	multi-channel multi-scale convolutional neural network (C2MSNet)	Dudhane et al.	2018	Proposed dehazing McMs-CNN based on Cardinal color fusion, and DCP for estimates the scene transmission map.	$C_w C_i = \Cap\{\Psi_i^R, \Psi_i^G, \Psi_i^B\}$	- Eliminate the need for customizing haze treatment features.	- The final image output suffers color distortion when the initial scene image is captured in gloomy (poor illumination) surroundings.

4. Conclusion

The role of dehazing methods is very bright in recent years because one of the most important fields appears to be more valuable for many vision applications, so there are many applications available concerning the field of computer vision and graphics depend on these methods. It can dislocation haze from the pictures, increment the scene vision. Several dehazing methods have been used from beginning up to now to remove the haze and improve images, and recently become most filed the researchers concerned. So, the dehazing technique has a major role to solve these kinds of problems. This survey contributes to explain the cause of haze formation, the summary introduction to image enhancement and restoration algorithms and their associated methods, and learning about hazy image's characteristics and many problems whereas catching an image. But each algorithm has certain details and characteristics that distinguish it from other algorithms.

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