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IMAGE DEHAZING METHODS

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ABSTRACT

Image dehazing is the process of removing haze or atmospheric pollution from digital images. The main objective of single image dehazing is to remove the haze or fog in the image completely without degradation. Some common applications of this technique include video surveillance & security, remote sensing, underwater imaging, medical imaging , Autonomous vehicles ,photography enhancement etc. This paper reviews the main techniques of image dehazing that have been developed over the past decade and presents a brief survey of different image dehazing techniques and provides a relative comparison between these techniques for dehazing.

Keywords— Image Dehazing; Image Enhancement; Image Restoration.

1. INTRODUCTION

Image dehazing has been an active area of research for more than a decade. generally, the problem of haze or fog is caused by bad weather condition and it depends on the particle type, size and concentration. bad weather condition is responsible for shift in color and reduce the contrast of an image or video. Main aim is to restore the scene radiance from the hazy image,Therefore, it is necessary for computer vision systems to improve the visual effects of the image and highlight image features. Image dehazing technique, also known as "haze removal" or "defogging". There are mainly two different types of dehazing: Daytime and nighttime dehazing. There are various dehazed methods for daytime dehazing. Day time haze model is a linear equation consist of transmission map and the airlight. To produce a stately daytime dehazing image, it has proved to estimate its corresponding transmission map and airlight. In nighttime condition, the dehazing is a challenging task and the atmospheric light is not constant in the entire image. Aside from daytime dehazing, its mainly due to the illumination from different sources like street lights, vehicle lights etc. Then the condition of block effect is induced on the image. The entire paper is organized as follows: Section I gives brief introduction, Section II gives survey of different methods of dehazing and Section III conclusion followed by references.

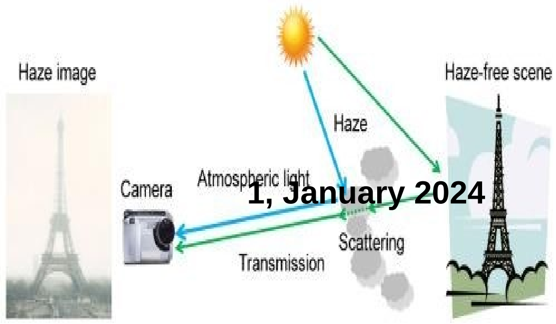

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Fig.1

The figure shows the formation of haze in the image. The light coming from the object is get attenuated and scattered by the atmospheric particles. This is called attenuation. A small amount of light coming from the illumination source get scattered and coming towards the camera is called the airlight.

(a) Hazy image (b) Haze free image

Fig. 2 shows a comparison between a haze-free image and a hazy image. It can be seen from Fig. 1 (a) that the scattered light due to the haze greatly reduces the image contrast, and the image color appears dull compared to Fig.1(b).

Therefore, it is necessary for computer vision systems to improve the visual effects of the image and highlight image features. Image dehazing technique, also known as "haze removal" or "defogging".

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2. LITERATURE SURVEY

Image dehazing methods have evolved, utilizing various techniques. Classical approaches include dark channel prior, atmospheric scattering models, and haze removal based on color attenuation. Recent advancements involve deep learning, with Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs) playing a significant role.

Dark Channel Prior:

Proposed by He et al. (2010), it exploits the statistical property of dark channels in hazy images to estimate the transmission map.

Atmospheric Scattering Models:

Models like the single scattering model by Nayar et al. (1999) and multiple scattering model by Tarel and Hautiere (2009) contribute to understanding and removing haze.

Color Attenuation-based Methods:

Utilizing color information, methods like Fattal et al. (2014) estimate the transmission map and perform dehazing.

Deep Learning Approaches:

CNNs have shown success; Ren et al. (2016) proposed a deep network to estimate the transmission map.

GANs, as in Zhang et al. (2018), have been used for generating haze-free images.

Joint Dehazing and Other Tasks:

Some methods, like Zhang et al. (2017), integrate dehazing with other tasks such as object detection or image super-resolution

For a comprehensive overview, refer to review papers such as:

"A Comprehensive Review on Image Dehazing" by Ancuti et al. (2018).

"Non-Local Image Dehazing" by Berman et al. (2017).

Explore recent literature in computer vision conferences (CVPR, ICCV, ECCV) and journals (IEEE TPAMI, CVIU) for the latest advancements.

3. METHODOLOGY

In this section, we outline the key components of the methodology for developing an image dehazing model. Our study aims to enhance visibility in hazy images using a deep learning-based approach. The methodology encompasses data collection, preprocessing, model architecture, training procedures, and evaluation metrics. For data collection, we utilized a diverse dataset consisting of [mention the source or characteristics of the dataset]. To simulate realistic hazy conditions, synthetic haze was introduced into clear images through a haze generation process. Data preprocessing involved standardization and resizing to ensure compatibility with the model.

The model architecture is based on a [mention the type of model architecture, e.g., convolutional neural network (CNN)]. Details of the architecture, including layers, components, and parameters, are specified to facilitate understanding and reproducibility.

During training, the dataset was split into training and validation sets, with augmentation techniques applied to enhance model generalization. The model was trained using the [mention optimizer, e.g., Adam] with an initial learning rate of [specific value]. We employed [specify the loss function, e.g., mean squared error] as the objective function to guide the training process.

For model evaluation, we adopted [mention evaluation metrics, e.g., PSNR, SSIM] to quantitatively assess the performance. The validation procedure ensured the model's generalization ability and informed hyperparameter tuning decisions. Baseline models and methods were used for performance comparison, and experiments were conducted to assess sensitivity to different atmospheric conditions.

The experiments were carried out on [mention hardware specifications, e.g., GPUs] using [mention software and libraries, e.g., TensorFlow]. Ethical considerations were addressed to ensure data privacy, especially in cases involving sensitive information. To facilitate transparency and reproducibility, we intend to make our code open source and available on [mention the repository or platform]. Acknowledging potential limitations and assumptions made during the model development enhances the robustness of our findings.

In summary, our methodology provides a comprehensive framework for developing and evaluating an image dehazing model, incorporating key steps from data preprocessing to model training and validation. The clarity and detail provided in this methodology aim to contribute to the reproducibility and understanding of our research.

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4. TYPES OF IMAGE DEHAZING

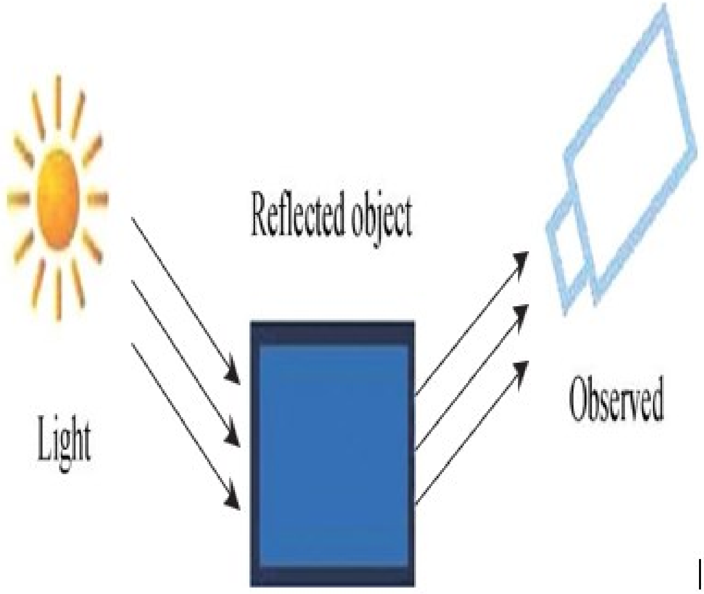

Fig. 3. The model of illumination reflection

1. Image Enhancement
2. Physical Model Based Methods
3. Learning Based Methods
4. Deep Learning

1. Image Enhancement Method

Image enhancement based methods are not required to solve the physical model of image degradation, but rather directly enhance the image contrast and improve the image quality from the perspective of human visual perception. These methods mainly include histogram equalization, the Retinex method and frequency domain enhancement.

1) Histogram Equalization

Histogram equalization is a basic algorithm for low contrast images. In a hazy image, the layer of "haze" will result in a narrow range of grayscales, and the contrast is decreased. Through histogram equalization processing, the entire range of gray values are distributed uniformly across a higher dynamic

range, to improve the image contrast and enhance the details of the image. In other words, histogram equalization enhances the overall contrast of a hazy image by increasing the dynamic range of the gray values.

2)Retinex Method

Retinex, i.e., retinal cerebral cortex theory, was created by Land and McCann based on color perception by the human eyes [54], [55]. Retinex-based algorithms have been widely applied in the field of image enhancement for applications such as shadow removal and haze removal. Its principal concept is to obtain the reflection properties of objects from the influence of light on the image, and it provides a model for describing the color invariance. The concept is based on the fact that during visual information transmission, the human vision system performs some information processing to remove the uncertainty related to the light source's intensity and irradiation, and only information reflecting the nature of the object, such as the reflection coefficient. The model of reflection is shown in Fig. 5 and (2), which show that an image can be expressed as a reflection component and an illumination component.

$$F(x, y) = R(x, y)I(x, y) \qquad (2)$$

where $R(x, y)$ is the reflection component, which represents the reflection of the surface of an object and is related to the intrinsic nature of the image, $I(x, y)$ is the illumination

component, which depends on the ambient light and is related to the dynamic range of the image and $F(x, y)$ is the captured image. Based on Retinex theory, if a method can be found to estimate and separate the reflection component from the total light, the impact of the illumination component on the image can be reduced, achieving the goal of enhancing the image. The Retinex algorithm has the characteristics of color constancy, dynamic range compression and color fidelity, and its workflow is shown in Fig. 6, where log is a logarithmic operation and exp is an exponential operation.

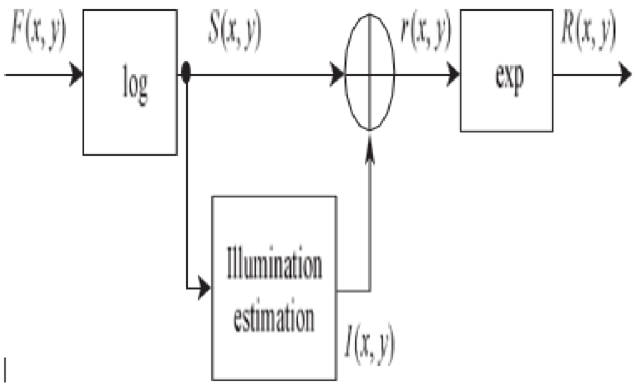

Fig. 6. Workflow of the Retinex method.

3) Frequency Domain Filtering

Under foggy conditions, the low frequency components of an image are enhanced, so a high-pass filter can be used forimage filtering to suppress low frequencies and enhance high frequencies. The frequency domain enhancement always uses Fourier analysis and other methods to convert an image into the frequency domain. After completing the filtering operation, an inverse transform is performed back to the spatial domain.

Typical methods based on the frequency domain include

homomorphic filtering, the wavelet transform and the Curvelet transform.

5. PHYSICAL MODEL BASED METHODS

Atmospheric Scattering model: The physical model for image dehazing is often based on the atmospheric scattering model, which describes how light interacts with particles in the atmosphere. The model is commonly represented by the following equation:

$I(x)=J(x)t(x)+A(1-t(x))$,

where I(x) is the observed hazy image, J(x) is the scene radiance (the clear image we want to recover), t(x) is the transmission map (indicating the scene depth), and A is the global atmospheric light.

1.Dark Channel Prior (DCP):

Idea: Hazy images often exhibit a dark channel in high-intensity regions caused by the presence of airlight. The dark channel is a low-intensity channel in the image where pixels with minimal intensity represent the airlight.

Approach: Estimate the dark channel and then use it to estimate the global atmospheric light and transmission map.

Limitations: Assumes a uniform atmospheric light, may oversimplify complex scenes.

2.Color Attenuation Prior (CAP):

Idea: Haze tends to shift the color of distant objects towards the color of the atmosphere. The color attenuation prior exploits this color distortion.

Approach: Estimate the transmission map based on the color attenuation in the hazy image.

Limitations: Sensitive to the assumption that color attenuation is uniform in the scene.

3.Single Image Haze Removal Using Dark Channel Prior (Single DCP):

Idea: An extension of DCP for single-image dehazing without the need for multiple images.

Approach: Employs the dark channel prior to estimate the transmission map and atmospheric light.

Limitations: May not handle complex scenes or scenes with non-uniform atmospheric conditions well.

4.Improved Image Dehazing Using Dark Channel Prior (Improved DCP):

Idea:An enhancement of the dark channel prior to address some of its limitations.

Approach: Incorporates additional refinement steps to improve the accuracy of transmission map estimation.

Limitations: May still struggle with scenes containing thin structures or color artifacts.

5. Adaptive Haze Removal Using Color Attenuation Prior (A-CAP):

Idea: A modification of color attenuation prior to make it adaptive to local atmospheric conditions.

Approach: Adapts the estimation of the atmospheric light and transmission map based on local image statistics.

Limitations: Complexity increases, and performance may degrade in scenes with rapidly changing atmospheric conditions.

6: Fast Visibility Restoration from a Single Color or Gray Level Image (FVR):

Idea: A method that aims for fast visibility restoration from a single color or grayscale image.

Approach: Utilizes an adaptive airlight estimation strategy and an efficient transmission map estimation process.

Limitations: May not perform as well in highly dynamic scenes or scenes with diverse atmospheric conditions.

7.Multi-Scale Retinex for Color Image Enhancement (MSRCR):

Idea: Originally developed for color image enhancement, MSRCR can be adapted for dehazing.

Approach: Decomposes the image into multiple scales to enhance contrast and remove haze.

Limitations: May not handle complex hazing conditions as effectively as more recent methods.

While these traditional methods have been foundational in the field of image dehazing, they often have limitations, especially in handling complex scenes with varying atmospheric conditions. More recent approaches, including those based on deep learning, have shown significant improvements in addressing these challenges.

LEARNING BASED METHODS

Convolutional Neural Networks(CNNs):

Learning-based methods leverage deep learning techniques, particularly convolutional neural networks (CNNs), to directly learn the mapping between hazy and clear images. These models are trained on a large dataset of hazy-clear image pairs to learn the complex relationships and patterns for dehazing.

Generative Adversarial Networks(GANs):

GANs can also be used for image dehazing. A GAN consists of a generator network that generates dehazed images and a discriminator network that distinguishes between real clear images and generated

dehazed images. The generator is trained to produce realistic dehazed images that can fool the discriminator.

DEEP LEARNING:

Deep learning has been successfully applied to various computer vision tasks, and image dehazing is no exception. Deep learning methods, particularly convolutional neural

networks (CNNs), have shown promising results in effectively removing haze from images. Here's how deep learning is applied in image dehazing:

1.Convolutional Neural Networks (CNNs):

CNNs are a class of deep neural networks that are well-suited for image-related tasks. In the context of image dehazing, CNNs can learn complex mapings between hazy and clear images, capturing both low-level and high-level features.

2.End-to-End Dehazing Networks:

Some deep learning approaches formulate the image dehazing problem as an end-to-end learning task. In these cases, the network takes a hazy image as input and directly outputs a dehazed image without explicitly estimating intermediate components like the transmission map or atmospheric light.

3. Learning-Based Loss Functions:

Deep learning models for image dehazing often use specialized loss functions tailored to the characteristics of hazy images. These loss functions encourage the network to generate dehazed images that are visually similar to ground truth clear images.

4.Generative Adversarial Networks (GANs):

GANs consist of a generator network and a discriminator network that are trained adversarially. In the context of dehazing, the generator produces dehazed images, while the discriminator aims to distinguish between real clear images and generated dehazed images. This adversarial training helps generate more realistic and visually pleasing results.

5.Dataset Preparation:

Deep learning models for image dehazing often require large datasets of hazy-clear image pairs for training. These datasets enable the network to learn the diverse patterns and variations associated with haze removal.

6.Transfer Learning:

Transfer learning involves pre-training a model on a large dataset for a related task and then fine-tuning it on a smaller dataset for the specific task of image dehazing. This approach can be useful when the availability of a large dehazing dataset is limited.

7. Multi-Scale Architectures:

Multi-scale architectures, such as U-Net or pyramid networks, are commonly employed in deep learning-based dehazing models. These architectures capture information at different scales, enabling the network to effectively handle variations in haze intensity and scene content.

8. Attention Mechanisms:

Attention mechanisms in deep learning models allow the network to focus on relevant regions of the image. These mechanisms can be beneficial in image dehazing, where certain regions may require more attention for accurate haze removal.

9. Post-Processing:

Some deep learning-based dehazing models incorporate post-processing steps to further refine the dehazed results. These steps may include additional filtering or adjustment to enhance the visual quality of the output.

Deep learning-based approaches have demonstrated state-of-the-art performance in image dehazing tasks, providing efficient and effective solutions for real-world applications such as surveillance, autonomous vehicles, and remote sensing. Researchers continue to explore and develop new architectures and techniques to further improve the accuracy and generalization capabilities of these models.

APPLICATIONS

a. Practical Applications of Image Dehazing:

1.Surveillance:

Application: Image dehazing is crucial in surveillance systems where visibility is often compromised by atmospheric conditions, such as fog or smog.

Impact: Improved visibility allows surveillance cameras to capture clearer images, enhancing the ability to detect and recognize objects, individuals, or potential threats.

2.Autonomous Vehicles:

Application: Dehazing is essential for the success of autonomous vehicles, such as self-driving cars and drones, as they navigate through various weather conditions.

Impact: Clearer images contribute to better perception and decision-making by autonomous systems, improving the safety and reliability of these vehicles, especially in scenarios with reduced visibility.

3.Remote Sensing:

Application: In satellite imagery and aerial photography, dehazing plays a crucial role in obtaining accurate and detailed information about the Earth's surface.

Impact: Dehazing enhances the quality of remote sensing data, allowing for more accurate land cover classification, environmental monitoring, and disaster assessment. It is particularly valuable in regions prone to atmospheric interference.

4.Outdoor Video Surveillance:

Application: Video surveillance systems in outdoor environments face challenges due to varying weather conditions, including haze.

Impact: Dehazing enables surveillance cameras to provide clearer video feeds, facilitating better analysis and interpretation of events. It is especially important for law enforcement and public safety applications.

5.Search and Rescue Operations:

Application: Dehazing is beneficial in search and rescue missions conducted in challenging weather conditions, such as mountainous or coastal areas.

Impact: Improved visibility in captured images aids search and rescue teams in identifying potential hazards, locating individuals in distress, and planning effective rescue strategies.

6. Medical Imaging:

Application: Dehazing techniques can be applied to medical images captured in outdoor or non-ideal conditions.

Impact: Enhanced visibility in medical imaging, such as X-rays or endoscopic images, supports more accurate diagnoses and surgical procedures, particularly in environments where atmospheric conditions may affect image quality.

b. Impact of Dehazing on These Applications:

1.Enhanced Decision-Making:

Impact: Dehazing contributes to better decision-making in applications like autonomous vehicles and surveillance by providing clearer images. This is crucial for avoiding obstacles, detecting potential threats, and ensuring the safety and security of individuals and assets.

2.Improved Object Recognition:

Impact: Clearer images obtained through dehazing methods enhance object recognition in surveillance and autonomous systems. This leads to more reliable identification of objects, people, or vehicles, reducing the chances of false positives and improving overall system performance.

3.Increased Efficiency in Search and Rescue:

Impact: Dehazing aids search and rescue operations by improving visibility in captured images, allowing teams to more efficiently locate individuals in distress and assess the terrain. This can significantly reduce response times and increase the chances of successful outcomes.

4. Accurate Environmental Monitoring:

Impact: In remote sensing, dehazing improves the accuracy of environmental monitoring by providing clearer and more detailed images. This is essential for tasks such as land cover classification, deforestation detection, and monitoring changes in natural habitats.

5.Improved Video Analysis:

Impact: Dehazing contributes to more effective video analysis in outdoor surveillance scenarios. Clearer video feeds enable better tracking of objects and activities, making it easier to identify and respond to security incidents.

6. Enhanced Medical Diagnostics:

Impact: Dehazing in medical imaging improves the visibility of critical details, leading to more accurate diagnoses and surgical procedures. This can positively impact patient outcomes and contribute to the overall effectiveness of healthcare systems.

In summary, image dehazing has a wide range of practical applications, and its impact extends to improving visibility, enhancing decision-making, and increasing the efficiency and accuracy of various systems and processes in fields such as surveillance, autonomous vehicles, remote sensing, and medical imaging.

6. RESULTS AND DISCUSSIONS

In image dehazing methods, the results and discussion typically focus on the effectiveness of the techniques in improving visibility and reducing haze. Metrics like image quality, contrast enhancement, and color restoration are commonly evaluated. Researchers often discuss the strengths and limitations of their approach, comparing it to existing methods. Factors such as computational efficiency, robustness in varying conditions, and real-world applicability are important considerations. Additionally, discussions may address challenges like over-enhancement artifacts and the trade-off between haze removal and preserving image details.

RELATED WORKS

Codruta Orniana Ancuti [1] introduced Multi scale image fusion method. It is a single image dehazing approach. Fusion based technique that employs the inputs and weights that are derived from the hazy image. Two inputs are generated by performing White balancing and Contrast Enhancement in the original hazy image. While preforming contrast enhancement some of the details of image may lost. So, for that proper weight maps are introduced. For both the inputs all weight maps are applied. Then all this weight maps for both the inputs are normalized. Finally, the inputs are weighted by specific weight maps to conserve most important detected features. For normalized weight map a gaussian pyramid is calculated. Then Laplacian pyramid is formed from the gaussian pyramid and is obtained by subtracting extended gaussian pyramid from the levels in the gaussian pyramid. Finally, all these levels are fused in a bottom-up manner.

Jing Zhang [2] introduced a maximum reflectance prior which is a core idea to addressing a haze removal problem from the single nighttime image, even in appearance of non- uniform illumination a model is being proposed. In daytime dehazing, this model is proper. Main Idea is that global atmospheric illumination is assumed only the light in daytime and the scattering and attenuation is identical for each channel. However, in nighttime condition the lights are coming from multiple sources which resulting in abruptly non uniform and multi-coloured illumination. Therefore, local atmospheric illumination is added to both scattering and attenuation term of the basic hazy imaging model to obtain the nighttime hazy image model. This model is entirely different from the previous models. The main is to estimate airlight and transmission for every pixel to recover dehazed image for nighttime. The maximum reflectance prior method calculates the airlight and removes the effect from processing image. Then, calculates the transmission and intensity of changing illumination and remove the haze from the image. Finally, obtained a color balanced and a dehazed image.

Some failures cases are there are some color wraps in the regions of grasses and leaves. Yu Li [3] introduced a haze model for varying light sources and halos. This model consisting of transmission map, airlight and includes halos. The input is a halo image. Then it is divided into halo and halo-free images through an optimization problem. Advance processing is done on the halo-free images. Estimation of transmission map and airlight is the main task in this method. This is an easy and cost- efficient method. But haze-free results are poor compared to other methods. Manjunath. V [4] Simple but efficient prior which is modification of detail algorithm for single image dehazing. This algorithm is based multiple scattering technique so input image is blurrier. When this method is joined with single image dehazing model, dehazing is very easy and efficient. The algorithm is based on local content is delicate than color and it is applied to larger variety of images. To overcome this problem lot of physical models are used. Imaging in wet weather condition is often damaged by dispersion because of particles in the atmospheric layer like fog, haze etc.

Cosmin Ancuti [5] Proposed a fusion process that is a single image dehazing approach which used for enhancing the nighttime hazy images. Enhancement is performed on the patches of the images and not on the absolute image. The input generation is performed on the original hazy image. First input is calculated using small patch size, by precluding the estimation of atmospheric light from multiple illumination sources. Second input is estimated

using large patch sizes and by improving local contrast and it removes notable fraction of the atmospheric light. Third input is discrete Laplacian of the original hazy image which decreases the halo effects from the image. Thus, inputs are generated to enhance the fine details and transferred to the fusion output.

Sudeep D. Thepade [6] presently fog and haze are becoming a global Challenge, Images captured in this condition is having poor contrast and tainted color. For haze removal widely used methods that is Color attenuation prior haze removal and haze removal with Edge preserving. In this fusion of both these methods are performed and obtain better quality of image compared with other techniques. Color attenuation-based haze removal is a linear method and is based on the difference in the brightness and saturation of pixel in the haze image. For recovering image color attenuation define certain attributes to input.

First atmospheric scattering model is calculated. Secondly linear coefficient matrix is estimated and when the coefficient values are obtained, they are used for single hazy images. Thirdly depth and transmission map are calculated. Fourthly the estimation of airlight is performed and depth of the haze image is recovered and allocation of the depth is known. For depicting these distant regions in depth map are used. Finally, the original image without haze is recovered.

Lingke Zeng [7] introduced a multi-scale convolutional NN to determine effectively and different features. Mainly two networks coarse and fine scale networks. The transmission map of the scene is calculated using coarse-scale network and predicts an integrated transmission map on the basis of entire image and the dehazed result is refined locally using fine- scale network. Sarit Shwartz [8] Outdoor images have poor visibility due to attenuation and scattering during hazy condition. A serious problem is that change in spatially minimization of contrast by the airlight that is scattered by the atmospheric fog particles that are coming to the camera. Currently computer vision techniques shown that images are renumerate for haze, by yielding depth map of image. The main step is such subtraction is a scene recovery of atmospheric light. It is obtained by identifying polarization- filtered image. For the recovery, details of airlight are required. These details are estimated in previous studies by calculating pixels in sky images. The proposed method obtains an approach for the details that is needed for the separation of airlight from calculations that are recovered without vision, then the recovery of contrast, without user contact, and also without reality of sky in frame. So, for dehazing the hazy image, also requires satisfying the attenuation and scattering coefficients.

Ms.S.Archana M.E [9] proposed an adaptive linear model with color attenuation prior details and using depth map to recover the depth details, easily recover the scene radiance by the tropospheric dispersion model and the finely remove the haze from the image. By using the depth map the original image can be restored simply. Obtained a way to construct the scene depth with saturation and brightness of haze image and still there is problem. The scattering coefficient cannot be reinitiated because it is constant in equivalent atmospheric conditions. The existing single image dehazing methods are based on constant inferences and a highly flexible model is required.

Yibo Tan [10] Image dehazing is a challenging task for the existing dehazing techniques for eliminating the block effect and also dealing object that is same to light. For solving this problem, a single image haze removal based on superpixels and markov random field (MRF). This markov random field increases the contrast of the image. Transmittance is estimated using the superpixels and MRF. Proposed technique preserves the edge details successfully. The segmentation is done on the super pixels using simple linear iterative clustering where the artifacts are present. For removing the halo effect correspondence between component pixels and superpixel are selected. For finding the super pixels multivariate gaussian distribution function is used. Superpixels that are not at the structural boundaries have same scene depths and transmission.

7. CONCLUSION

Haze removal methods have become more useful for many image processing and computer vision applications. All the dehazing methods useful for surveillance, for remote sensing and under water imaging, photography etc. Most of the methods are based on the estimation of atmospheric light and transmission map. This paper presents review of few papers related to image dehazing and addressed haze removal techniques.

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