A REVIEW ON SINGLE IMAGE DEHAZING FROM REPEATED AVERAGING FILTERS WITH FEED FORWARD NEURAL NETWORK

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Abstract—**We have discuss the problem of hazy image enhancement and restoration in this review. Haze image enhancement has gained widespread importance with the rapid development of modern imaging equipment. However, the contrast enhancement of single hazy image is a challenging task for scientific exploration and computational applications. Image dehazing can be classified into two categories: one is based on image enhancement and the other is on image restoration. Image restoration attempts to reconstruct or recover an image that has been degraded by using a priori knowledge of the degradation phenomenon. On the other hand, image enhancement refers to accentuation or sharpening of image features such as edges, boundaries or contrast to make a graphic display more useful for display and analysis. Image restoration and enhancement techniques are widely used in the field of computer vision, video surveillance, medical and satellite image processing etc. An averaged channel is obtained from a single image by the repeated averaging filters via integral images with feed forward neural network which provides a faster and efficient way for removing halo artifacts.**

Index Terms—Image enhancement, Image Dehazing; Averaging Filter; Feed forward Network

I. INTRODUCTION

In today's world, an image defined is considered to be a function of two real variables, for example, (x, y) with *I* as the amplitude (e.g. brightness, contrast) of the image at the coordinate position (x, y) where x and y are two coordinates in horizontally and vertically. In imaging science, image processing is a form of signal processing in which input is an image and output is either an image or characteristic or set of parameters related to image. Image processing can be further divided into analog image processing and digital image processing.

Digital image is a numerical representation of an object. It is composed of picture elements called pixels. Each pixel has a particular location and value. Pixel represents the brightness at a point in the image. All the operations in image processing are applied on these pixels. Digital image processing is the use of computer algorithms to perform image processing on digital images to get an enhanced image or to extract some useful information from it. The advantage of digital image processing is its flexibility, adaptability and data storage and transmission. Hardware modifications are not required in the digital image processing and the data within the computer can be transmitted from one place to another. The limitations of digital image processing are memory and its processing speed. For processing digital images, we have to store them on a storage device so that we can also use it in future. There are several storages devices available for storing the image data. These storage devices include optical disk, magnetic disk, and floppy disk.

Natural outdoor images and their perception is a key factor in image understanding. It is a true representation of what a human visual system is capable of and what it perceives from it. A better understanding of images makes it easier to execute visual techniques such as recognition, detection, and surveillance [1]. The hazy and foggy particles reduce the atmospheric visibility in real-world scenes. It could be in the form of haze, fog, smog, or mist. The light when strikes with these particles is scattered in different directions and thus forming images that suffer from scattered luminance, faded color, and low contrast. The camera receives irradiance from the scene point as the scene light combines with the airlight [2]. The visibility of images is reduced to a level that is harmful and causes mismanagement on the roads in case of camera-guided vehicles or autonomous vehicles and in navigation based systems.

Fig 1: Hazy images

Image dehazing has taken by storm numerous significant scientific fields of applications such as astronomy, medical sciences, remote sensing, surveillance, web mapping, land-use planning, agronomy, archaeology, and environmental studies.Haze removal/image dehazing is the basic requirement in image processing and computer vision-based applications. Once the haze removal algorithm removes the haze, then it is feasible for the computer vision algorithms to analyze them. Haze in images has become a major issue as image analysis at a low level, such as image deblurring, sharpening, and enhancement, assumes the input image is in the natural radiance. Similarly, in high-level image analysis, such as target detection, recognition, and surveillance, high-quality images are used. Haze removing techniques can also help in-depth analysis of an image [3] and can play a vital role in many image analysis related fields and applications.

Visual data is the most crucial data comprehended and analyzed by the human brain. About one-third of the cortical area in the human brain is dedicated to analysis of visual data. As a result, image clarity is of uttermost importance for numerous imaging tasks. Often, in practice the light reflected from a subject is scattered by the atmosphere before it reaches the camera.This scattering of light results from suspended particles—that is, aerosols such as mist, dust, and fumes that deflect the light from its primary course of propagation.

In vehicular systems, cameras must generate clear images even in bad weather conditions. Because mist and air particles limit the ability to recognize other vehicles, traffic signs, and pedestrians, dehazing is an indispensable requirement in the consumer devices to acquire high-quality images. Specifically in the case of remote sensing, this process results in substantial loss of contrast and color of the images. Such images often lack visual vividness and appeal, and moreover, they hinder further image-processing tasks due to poor visibility.

Image dehazing can be classified into two categories: one is based on image enhancement and the other is on image restoration [3]. Image restoration based methods establish atmospheric scattering model and further use the inversing degradation process to overcome dehazing [4]. Further Image restoration based methods can be classified into two categories: first is to consider multiple images and second on the basis of the single image [5]. Similarly, some other techniques introduced such as Retinex [6], homomorphic [7] and wavelet transform [8].

Earlier proposed techniques evaluated their haze removal experimentation on multiple images. But multiple based images techniques have faced some problems in online imaging dehazing applications which requires an extraordinary sensor. Therefore, many researches focused on single image dehazing [2], [9], [10], [11].

The process of image dehazing serves to improvise aesthetic quality, contrast, and the quality of image information in computer-vision applications and data collection. Dehazing is vital for many computer-vision algorithms such as remote sensing, intelligent vehicle control, underwater image dehazing, object recognition, and surveillance.

II. Literature Review

The earliest visibility enhancements for image dehazing have been addressed in literature [8] in which visibility improvement is carried out through dark-object subtraction to eliminate scattered light in multiple images in various weather conditions. Schechner et al. [9] introduced an onboard haze-free system. The proposed system uses a weather estimating technique to remove the haze by contrast restoration. It is based on a flat world assumption, and creating 3D geometrical information-based models is difficult in practice and makes it challenging. Tan [10] proposed a technique based on maximizing the local contrast in a homogeneous airlight improving the visibility but producing saturation and halo effect. Fattal [4] proposed a method based on optical transmission estimation, eliminating the scattering light and restoring the contrast in images with high visibility but fails in nonhomogeneous and dense hazy areas. He et al. [7] introduced a novel method that defines dark channel prior. The key idea is based on the concept that at minimum there should be one dark color channel containing pixels with very small intensity values. This information helps in estimating the depth of haze and restores a good quality dehazed image. Increased sunlight and nonhomogeneous haze in images may affect efficiency of the method. Tarel and Hautière [11] presented a technique for image dehazing based on enhanced visibility in real-time processing and less complex for both color and grey images. This algorithm is based on maximum contrast assumption and normalized airlight with preserving edges, but the depth-map restored is not smooth along the edges.

Kratz and Nishino [12] focused on the scene washout effect and density in an image by using Markov random field as two different layers. The results are promising but the algorithm creates dark artifacts at locations with high depth. Ancuti and Ancuti [13] proposed a technique based on the fusion of two hazy input images. Three important measures are considered for feature extraction that is saliency, luminance, and chromaticity. The results are pleasing; however, the image is overenhanced and natural color contrast of an image is not restored. Meng et al. [14] presented a technique which regularizes and optimizes the unknown scene transmission. The result produced high-quality images with natural colors and fine edges; however, the technique does not perform well for images with large sky areas and white areas as the resultant image is extremely enhanced to an artificial level. Tang et al. [15] gave an idea of a framework based on machine learning and extracted the combination of the best-selected features used for image dehazing. The technique focused on the dark channel features as it is the most important part of image dehazing. It restores good quality dehazed images but enhances noise, where haze depth is high. Cai et al. [16] introduced a novel technique that uses convolutional neural networks (CNNs) to estimate assumptions and priors. CNN layers are used for extracting features responsible for generating haze relevant features. This technique outperforms the state-of-the-art techniques by restoring the sky area and white patches but distorts the dark colors in the image.

Bansal et al. [17] discussed a number of a single image and multiple image dehazing algorithms for image restoration. The paper is a comparison between different state-of-the-art techniques and elaborates the advantages and disadvantages summarizing future scope as well. Salazar-Colores et al. [18] proposed a fast technique using morphological operations for restoring quality images. The performance measure is based on the peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM). This technique performs well as far as speed is concerned; however, it is unable to handle sky regions and white areas due to DCP limitations. Berman et al. [19] introduced a novel technique based on no local prior. The technique focuses on pixels in a specific cluster, and its color is represented by a few hundred different color lines. These haze lines are used to restore the haze-free image. It performs well on a variety of images but fails for parts with brighter airlight. Li et al. [20] gave a new approach called realistic single-image dehazing (RESIDE) based on a training set, with two different quality evaluations objective and subjective. The model is trained on synthetic and nonsynthetic images. The results are better than the state-of-the-art methods.

- **Overview of Image Restoration and Enhancement**

Image restoration and enhancement techniques are used to improve the appearance of the image or to extract the finer details in the degraded images. The purpose of image restoration and enhancement is to process an image so that the resulting image will be more suitable for a specific application than the original image. These techniques have a wide variety of applications such as computer vision, video surveillance, satellite and medical image processing and analysis etc. Image restoration is concerned with filtering the observed image to minimize the effect of degradations.

The images may be degraded in the form of sensor noise, random atmospheric turbulence, and so on. Images are often degraded by random noise. Noise can occur during image capture, transmission or processing, and may be dependent on or independent of image content. Noise is usually described by its probabilistic characteristics. The effectiveness of the image restoration filters depends on the extent and the accuracy of the knowledge of the degradation process as well as on the filter design criterion [Jain, 1989]. Conventional filters such as mean filter, median filter etc., are widely used for image restoration. But these conventional filters have their own disadvantages, which eventually led to the development of advanced filters such as decision-based median filters, switching median filters, wavelet filters, fuzzy filters etc [Gonzalez and Woods, 2008].

The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers or to provide better input for other automated image processing techniques [Pratt, 2001]. Image enhancement transforms images to provide better representation of the subtle details. Image contrast enhancement is one type of image enhancement operation which involves transforming one image to another so that the look and feel of an image can be improved for machine analysis or visual perception of human beings [Acharya and Ray, 2005]. It is an indispensable tool for researchers in a wide variety of fields including medical imaging, forensics, atmospheric sciences etc.

Though several fuzzy filters for image enhancement and restoration have been reported in the literature, the need for much better filtering algorithms still persists for better analysis and decision making. In order to overcome the drawbacks of the existing algorithms, three novel soft computing algorithms based on fuzzy logic has been designed and implemented, namely:

- Novel fuzzy-based decision algorithm for high density impulse noise removal.
- Novel fuzzy-based filter for additive noise removal.
- Novel fuzzy logic and histogram-based color image enhancement.

III. IMAGE RESTORATION AND ENHANCEMENT

Image dehazing can be classified into two categories: one is based on image enhancement and the other is on image restoration. Image restoration and enhancement is one of the leading research areas in the field of digital image processing. Image restoration attempts to reconstruct or recover an image that has been degraded by using a priori knowledge of the degradation phenomenon. On the other hand, image enhancement refers to accentuation or sharpening of image features such as edges, boundaries or contrast to make a graphic display more useful for display and analysis. Image restoration and enhancement techniques are widely used in the field of computer vision, video surveillance, medical and satellite image processing etc.

➢ Image Restoration

Images are often degraded by random noise which can occur during image acquisition, transmission or processing. The degradations may occur due to sensor noise, relative object-camera motion, random atmospheric turbulence, and so on. Noise may be either dependent or independent of image content, and is usually described by its probabilistic characteristics. During image transmission, noise which is usually independent of the image signal occurs. Gaussian noise is a very good approximation of noise that occurs in many practical cases. Image noise reduction has come to specifically mean a process of smoothing noise that has somehow corrupted the image. Image restoration is concerned with filtering the observed image to minimize the effect of degradations, where prior information of the degradation form is needed. The goal of image restoration is to recover an image that resembles the original image as closely as possible by reducing the noise.

Image restoration techniques are basically divided in two categories namely: Deterministic process and stochastic process. Deterministic processes are those processes in which there is a prior knowledge of degradation function or point spread function and stochastic processes are those processes in which there is no prior knowledge of degradation function or point spread function like blind de-convolution method. Deterministic methods are subsequently divided into two parts: Parametric and Nom-parametric. Linear Filters do not necessarily maintain image non-negativity or signal-dependent noise. This has led to the development of non-linear and iterative restoration algorithms. Image restoration is different from image enhancement in the way that the latter is designed to emphasize features of the image to make the image more pleasing to the observer, but not necessarily produce realistic data from a scientific point of view.

Image enhancement techniques (like contrast stretching or de-blurring by a nearest neighbor procedure) use no a priori model of the process that created the image.

Image Restoration Model

Most restoration techniques model the degradation process and attempt to apply a reverse procedure to obtain an approximation of an original image.
The process by which the original image is degraded is usually very complex and often unknown. To simplify the calculation, the degradation is often modeled as a linear function which is often referred as point spread function usually known as PSF. Image restoration technique basically employs two different models in the whole process:

- Degradation Model
- Restoration Model

Thus most of restoration techniques firstly degrade the image by passing it through image degradation model. They employ a degraded image into the restoration model to constitute the reverse process of recovering the approximation of an original image.

a) Degradation Model

In the degradation model, degradation function H consists of filters which constitute the point spread functions (PSF) to create a blurred image or degraded image. There are several types of filter which constitute the point spread function for different types of blur like Gaussian filter, motion filter, laplacian filter etc. We can also add random noise n(x, y) to a degraded image for createing a distorted image. The output of a degradation model is a blurred image with an addition of noise which is represented by g(x, y) .The block diagram of such degradation model is shown below in figure 2.
Here,
F(x,y) = Input Image
n(x,y) = Noise
G(x,y) = Degraded Image

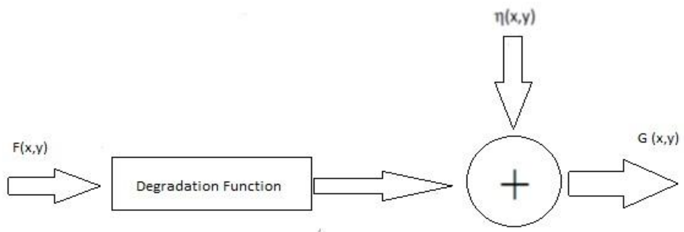

Fig 2: Architecture of Degradation Model

b) Restoration Model

In the restoration model, we apply a degraded image into the restoration function to apply the inverse process of recovering the approximation of original image. In the restoration model, the restoration function consists of different restoration method like blind de-convolution method to remove blur & noise and create a recovered image. The block diagram of original image is shown in the figure 3 below.

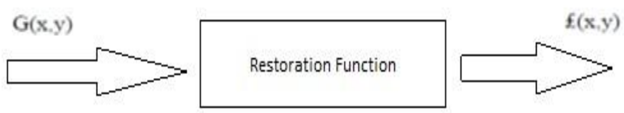

Fig 3: Architecture of Restoration Model

Where,
G(x, y) = Degraded image
£ (x, y) = Original image

- **Image Enhancement**

Image enhancement includes sharpening, contrast manipulation, filtering, interpolation and magnification, pseudo coloring, and so on. The greatest difficulty in image enhancement is quantifying the criterion for enhancement. Therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results. However, image enhancement remains very important because of its usefulness in virtually all image processing applications. Color image enhancement may require improvement of color balance or color contrast in a color image. Enhancement of color images becomes a more difficult task not only because of the added dimension of the data but also due to the added complexity of color perception [Gonzalez and Woods, 2008].

Image enhancement techniques are used to improve the appearance of the image or to extract the finer details in the degraded images. The principal objective of image enhancement is to process an image so that the result is more suitable than the original image for a specific application. A method that is quite useful for enhancing one category of images may not be necessarily be the best approach for enhancing other category of images. Color image enhancement using RGB color space is found to be inappropriate as it destroys the color composition in the original image. Due to this reason, most of the image enhancement techniques, especially contrast enhancement techniques, use HSV color space [Hanmandlu and Jha, 2006].

Image enhancement methods may be categorized into two broad classes: transform domain methods and spatial domain methods. The techniques in the first category are based on modifying the frequency transform of an image, whereas techniques in the second category directly operate on the pixels. However, computing a two dimensional (2-D) transform for a large array (image) is a very time consuming task even with fast transformation techniques and is not suitable for real time processing.

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing `better' input for other automated image processing techniques. The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer. During this process, one or more attributes of the image are modified. The choice of attributes and the way they are modified are specific to a given task.

IV. HAZE IMAGING MODEL

The haze imaging model in [4], [12] which shows a hazy image formation and widely used so far, is given as

$$I(x) = J(x)\, t(x) + A\,(1 - t(x)) \tag{1}$$

Where *I* is hazed image, *J* is the haze free image, *x* is a pixel location, *A* is the air light. *I*(*x*) and *J(x)* can be referred to as the intensities of the pixel location in *I*and *J* respectively, where *t*can be referred to as transmission coefficient which describes reflecting probability from an object not scattered and absorbed by air particles. The transmission map is given as

$$t(x) = e^{-\beta d(x)} \tag{2}$$

β is scattering coefficient and *d* is scene depth. The captured image in clear weather is $\beta \approx 0$ and hence $I \approx J$. But when has some value it results in a hazy image. In (4) the first component *J(x)t(x)* is the direct attenuation which is inversely proportional to the scene depth. The second component *A (1 − t(x))* is the air light which is directly proportional to the scene depth. Thus dehazing is all about to recover *J* from *I* after estimation of *A* and *t* from *I*.

From haze imaging (1), transmission *t* is the ratio of two line segments which can be represented mathematically as:

$$t(x) = \frac{\|A - I(x)\|}{\|A - J(x)\|} = \frac{A^c - I^c(x)}{A^c - J^c(x)} \tag{3}$$

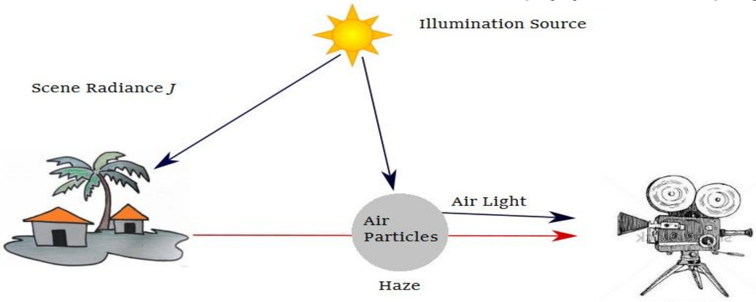

Fig 4: The Haze Imaging Model

- **Dark Channel Theory**

Dark Channel prior [2] suggests that most of the haze-free images have low pixels intensities in at least one color channel expect sky region due to three factors :1) Shadows of buildings, cars and cityscape images: 2) other objects in the image as for instance trees and plants :3) and some dark surfaces such as dark trunks of trees and stones. Noticing this phenomenon suggested that in the presence of haze, the dark pixels values altered by the air light by providing a direct contribution to its values. Therefore dark channels provide a direct clue for estimating the haze transmission. The dark channel is defined as

$$J^{dark}(x) = \min_{c\in\{r,g,b\}}\left(\min_{c\epsilon\Omega\{x\}}(J^c(y))\right) \quad (4)$$

Where Ω(x) is a local patch centering at x. J^c is a color channel of *J*. This scrutiny revealed that J^{dark} tends to low intensity such as zero, and hence J^{dark} is demonstrated as a dark channel of *J*. Summarizing our algorithm for recovering *J*, first a dark channel (J^{dark}) is derived from the hazy image, then we applied the repeated averaging filters to normalize the dark channel and estimated the better atmospheric light *A* on the basis of repeated averaging filters from the obtained dark channel. Finally got the haze free image as an output at low computational cost with high visual effects, estimated the dark channel from input image.

V. Feed-forward Neural Networks

Feedforward neural networks are artificial neural networks where the connections between units do not form a cycle. Feedforward neural networks were the first type of artificial neural network invented and are simpler than their counterpart, recurrent neural networks. They are called *feedforward* because information only travels forward in the network (no loops), first through the input nodes, then through the hidden nodes (if present), and finally through the output nodes.
Feed forward neural networks are primarily used for supervised learning in cases where the data to be learned is neither sequential nor time-dependent. That is, feedforward neural networks compute a function *f* on fixed size input *x* such that f(x) ≈ y for training pairs (x, y). On the other hand, recurrent neural networks learn sequential data, computing *g* on variable length input $X_k = \{x_1, x_2 \dots \dots .. x_k\}$such that g($X_k$) ≈ y_k for training pairs (X_n, Y_n) for the all $1 \le k \le n$.

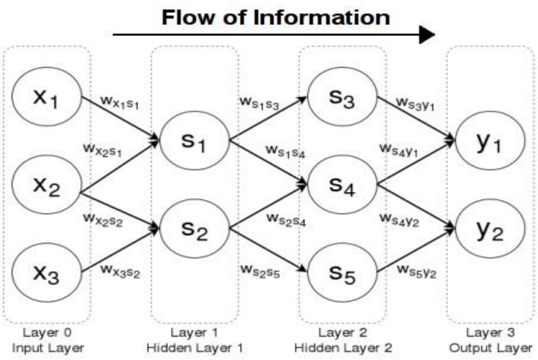

Fig 2: Feed-forward neural networks

VI. Conclusion

The basic concepts of image restoration and enhancement techniques have been used in image dehazing. Reducing the noise and recover an image that resembles the original image as closely as possible is the fundamental goal of image restoration. The extent and the accuracy of the knowledge of the degradation process makes the image restoration filters more effective. On the other hand, the goal of image enhancement is to improve the appearance of the image so that more relevant information can be extracted and utilized for a specific application.

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