REGRESSION MODEL FOR HAZE REMOVAL OF AN IMAGE

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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ENGINEERING

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(UGC AUTONOMOUS)
(*Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC*)
Sangivalasa, Bheemili mandal, Visakhapatnam dist. (A.P)
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CERTIFICATE

This is to certify that the project report entitled **"REGRESSION MODEL FOR HAZE REMOVAL OF AN IMAGE"** submitted by **V. Yugandhar (319126512186), D. Sowjanya (319126512140), B. Upendra (319126512135), A. Revanth (319126512132)** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics & Communication Engineering** of Anil Neerukonda Institute of technology and Sciences(A), Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.
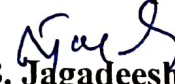
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ABSTRACT

Haze refers to a phenomenon where the atmosphere appears to be hazy or foggy due to the existence of fragments such as dirt, smoke, and other pollutants, which reduce visibility and create a blurred or obscured view. Haze can be caused by natural sources, such as wildfires or volcanic eruptions, as well as human activities, including industrial emissions, vehicle exhaust, and agricultural burning. Dehazing, is important and required in both outdoor photography and computer vision applications. In this project an efficient dehazing method is implemented. This method consists of two phases Training and Dehazing. Seven features which represent image quality are extracted and evaluated. Atmospheric light and Transmission map and are key components in image dehazing. A regression model is developed using Extreme Learning Machine (ELM), in Training phase to estimate transmission map. The experimental results are visually appealing, even for the most demanding photos. Better dehazing outcomes are generated by introducing this method, which reduces computing complexity.

Keywords: Extreme Learning Machine (ELM), Dehazing, Dynamic atmospheric light, image restoration.

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ABBREVATIONS

DIP	**Digital Image Processing**
FT	**Fourier Transform**
DCT	**Discrete Cosine Transform**
UV	**Ultra Violate**
LED	**Light Emitting diode**
CCD	**Charged Coupled Device**
CMOS	**Complementary Metal Oxide Conductor**
ALU	**Arithmetic Logic Unit**
MSE	**Mean Square Error**
ELM	**Extreme Learning Machine**
DCP	**Dark Channel Prior**
IDE	**Integrated Development Environment**
LINPACK	**Linear Equations software Package**
EISPACK	**Eigen System Package Subroutine Computing Faculty**

CHAPTER 1: Introduction

1.1. Digital Image Processing

WHAT IS MEANT BY DIGITAL IMAGE PROCESSING?

Digital image processing involves modifying digital photographs using a computer. It is a branch of signals and systems with a strong emphasis on pictures. DIP focuses on creating a computer system that can be utilized to run applications for processing digital pictures. A digital image is used as the system's input, which is processed by the system utilizing effectivealgorithms to produce an image. The most typical illustration is Adobe Photoshop. Basically, image processing involves the following three steps:

1. Importing the photo using picture capture software.
2. Examining and modifying the picture.
3. A report or updated image that was the consequence of the output from the image analysis.

ORIGIN OF DIGITAL IMAGE PROCESSING:

Digital images were initially used in the newspaper industry when they were transported by underwater cable from London to New York. In 1921, the cable picture transmission made it possible to send a picture across the Atlantic in less than 3 hours instead of taking more than aweek. Pictures were encoded for cable transmission using specialized printing equipment, andthe image was decoded at the receiving end.

FIELDS WHICH USE DIGITAL IMAGE PROCESSING:

Nuclear medicine and court medicine both employ gamma-ray imaging. Both diagnosis andprevention can be accomplished with this strategy. Gamma-ray imaging can be used for a variety of purposes, including:

- Cancer imaging
- Imaging of infections

- Bone scanning

- Imaging of the thyroid

IMAGING WITH X-RAYS:

Digital radiography is another name for digital x-rays. Medical technology can make extensiveuse of digital x-rays. An instantaneous digital radiographic image is created using digital radiography (DR), an enhanced method of x-ray inspection. With this method, data is recordedwhile an object is being examined using x-ray sensitive plates, and it is then instantly transferred to a computer without the necessity of a middle cassette.

IMAGING IN ULTRAVIOLET BAND:

UV imaging begins by passing a UV-emitting LED, bulb, or diode or by observing a subject that has been lighted by UV light that has been reflected from the object being inspected. The camera then records the UV light that was reflected. In this technique, the UV light's wavelength is not altered or shifted.

RADIO BAND IMAGING:

The process of using radio waves to create a visual image of an item. It is used to see items that are situated in optically opaque mediums and to analyze the interior structure of objects that are opaque to optical waves. Since millimeter and centimeter band radio waves are typically used in radio imaging, very fine details of an object's structure can be seen in the resulting optical image.

The main purpose of radio imaging is to gather data and display it as a visible image. This is done using specialized equipment known as radio age gadget is one example.

1.2.Fundamentals Of Digital Image Processing

1.2.1. Image Capture:

The first of DIP's essential processes is image acquisition. At this point, a digital image is provided. Typically, pre-processing like scaling is carried out at this stage.

1.2.2. Image Improvement:

The simplest and most appealing aspect of DIP is image enhancement. Details that are

unknown or, as might say, intriguing aspects of an image are highlighted at this stage. such as contrast, brightness, etc.

1.2.3. Restoring the image:

The process of enhancing an image's appearance is known as image restoration.

1.2.4. Image color processing:

A well-known use of color image processing is the rise in the use of digital photographs on a website. This involves digital processing, color modeling and other related techniques.

1.2.5. Wavelets and Multi-Resolution Processing:

An image is displayed in this stage in varying degrees of resolution. The pyramidal representation and data compression require smaller portions of the image.

1.2.6. Compression:

The approach for minimizing the amount of storage needed for an image is compression. It is a crucial stage because data compression is essential for internet use.

1.2.7. Morphological Processing:

This stage deals with tools which are used for extracting the components of the image, which is useful in the representation and description of shape.

1.2.8. Segmentation:

In this stage, an image is a partitioned into its objects. Segmentation is the most difficult tasks in DIP. It is a process which takes a lot of time for the successful solution of imaging problems which requires objects to identify individually.

1.2.9. Representation and Description:

Representation and description follow the output of the segmentation stage. The output is a raw pixel data which has all points of the region itself. To transform the raw data, representation is the only solution. Whereas description is used for extracting information's to differentiate one class of objects from another.

1.2.10. Object recognition:

In this stage, the label is assigned to the object, which is based on descriptors.

1.2.11. Knowledge Base:

Knowledge is the last stage in DIP. In this stage, important information of the image is located, which limits the searching processes. The knowledge base is very complex when the image database has a high-resolution satellite.
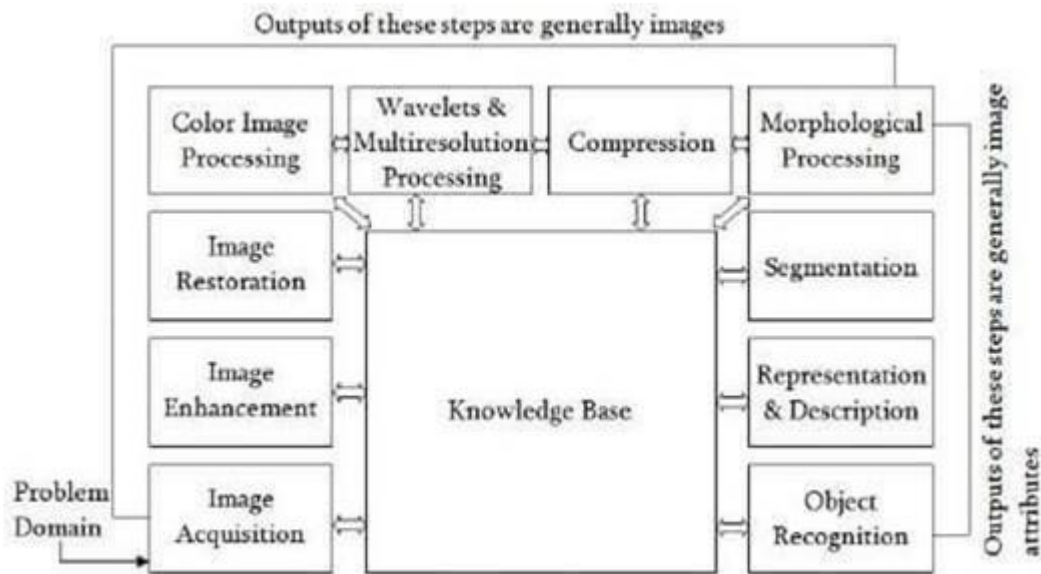
Figure 1: Knowledge Base

1.3. Image Transformation:

An image is obtained in spatial coordinates (x, y) or (x, y, z). There are many advantages if the spatial domain image is transformed into another domain. In which solution of any problem can be found easily.

Following are two types of transformations:

1.3.1. Fourier Transform:

Image processing is the major application of the Fourier transform. The intensity of the image is translated into a frequency variation and subsequently into the frequency domain during the Fourier transform. It is utilized for slow, variable intensity images, such passport-size photos, where the edges and background can both be represented by high- and low-frequency components. Filters in the FT domain can be used to eliminate low-frequency components. Only the edges of the image are present in an image that has been

filtered in the FT domain. Additionally, if reverse the FT domain to the spatial domain, only edges remain in the image. The easiest method for fine-tuning an image's edges is the Fourier transform.

Two-Dimensional Fourier Transform:
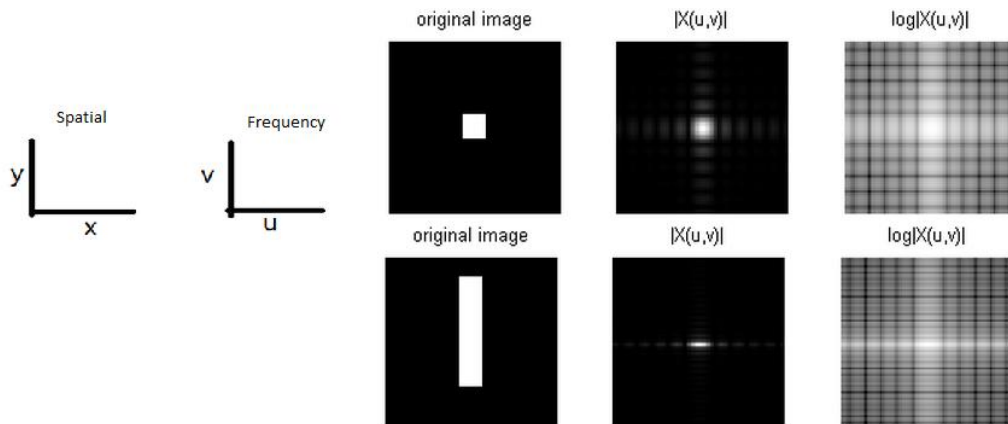
Figure 2: 2-D Fourier Transform

Matrix Notation:

$$V = FUF \Leftrightarrow U = F^*VF^*$$

$$F = \left\{ \left(\frac{1}{\sqrt{N}} \right) W_N^{kn} \right\}^{N-1}$$

Example:
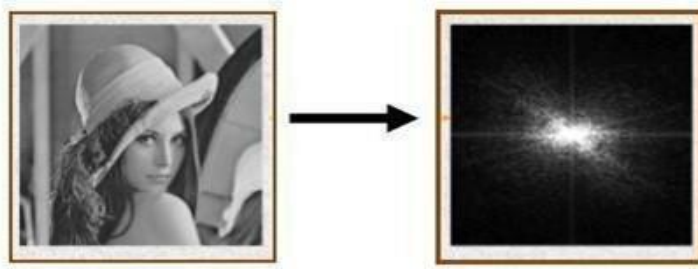
Figure 3: Example
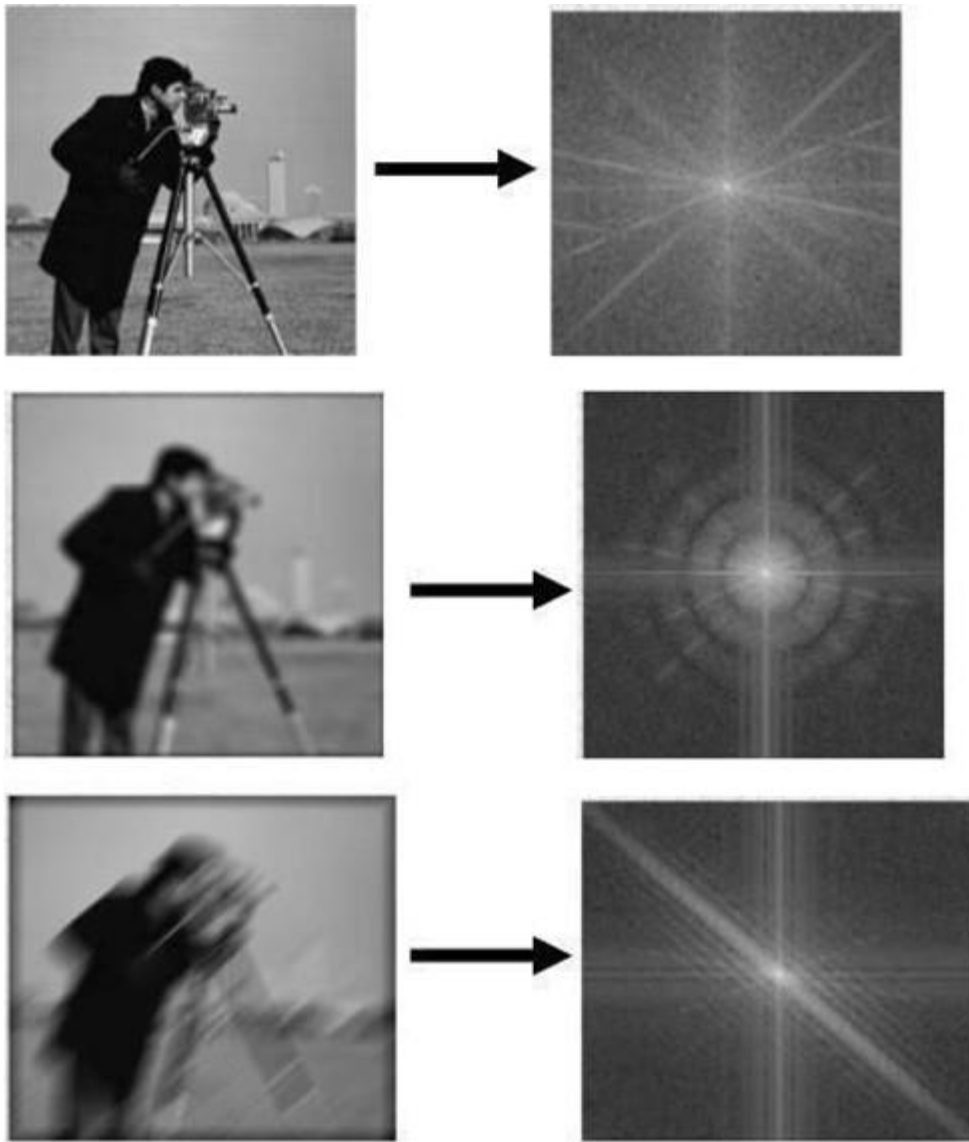
Figure 4: Example of Blurred image and its Fourier transformation

Discrete Cosine Transformation (DCT):

In Discrete Cosine Transformation, coefficients carry information about the pixels of the image. Also, much information is contained using very few coefficients, and the remaining coefficient contains minimal information. These coefficients can be removed without losing information. By doing this, the file size is reduced in the DCT domain. DCT is used

for lossy compression.

One Dimension Discrete cosine transformation:

Figure 5: One Dimension Discrete cosine transformation

Two Dimension Discrete cosine transformations:

$$-A = A^* = C$$

Example:
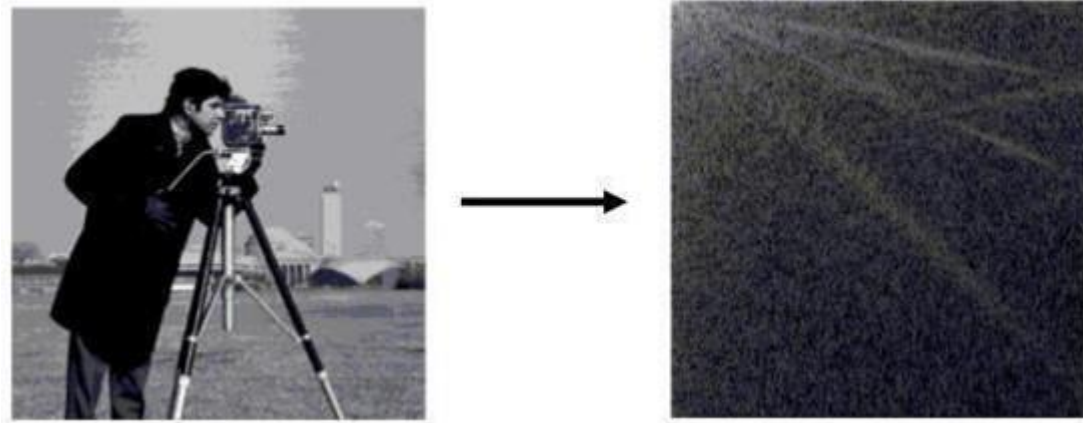
Figure 6: Two Dimension Discrete cosine transformations example

1.4. Components Of Digital Image Processing

The basic components comprising a typical general-purpose system used for digital image processing are:

Image Sensors:

- It refers to sensing.

- Incoming light is captured by the image sensor, which then transforms it into an electrical signal, measures it, and outputs the result to supporting electronics.
- A 2D array of light-sensitive components that transform photons into electrons makes up an image sensor.
- In image-capturing equipment like digital cameras, CCD (Charged Coupled Device) and CMOS (Complementary Metal Oxide Conductor) image sensors are frequently utilized.
- To capture digital images, image sensors need to contain two components.
- The first is a physical apparatus (sensor) that is responsive to the energy emitted by the item that want to turn into an image of.
- The second is a digitizer, which transforms a physical sensing device's output into digital form.

Specialized Image Processing Hardware:

- It consists of the digitizer and hardware that performs primitive operations, such as an Arithmetic Logic Unit (ALU), which performs arithmetic and logical operations in parallel on entire images.
- Computer:
- The computer in an image processing system is a general-purpose computer and can range from a PC to a supercomputer.
- Image Processing Software:
- Software for image processing consists of specialized modules that perform specific tasks.
- A well-designed package also includes the capability for the user to write code.

Mass Storage:

- Mass storage refers to the storage of a large amount of data in persisting and machine-readable fashion.
- The mass storage capability is a must in image processing applications.

Image Displays:

- Image display is the final link in the digital image processing chain.
- Image displays are mainly colored TV monitors. Hardcopy Devices:
- Various devices for recording images are Laser printers, film cameras, heat-sensitive devices, and digital units, such as optical and CD-ROM disks.

Networking:

- It is a required component to transmit image information over a networked computer.
- Because of the large amount of data inherent in image processing applications, the key consideration in image transmission is bandwidth.

1.5. Histogram Processing:

An example of a histogram that visualizes the tonal distribution in a digital image is an image histogram. [1] Each tonal value's number of pixels is plotted. A viewer will be able to quickly assess the complete tonal distribution of an image by taking a quick look at the histogram for that particular image.

Modern digital cameras frequently provide image histograms. They can be used by photographers as a tool to indicate the distribution of tones captured and whether image detail has been lost due to overexposed or underexposed highlights or shadows. When using a raw picture format, this is less helpful because the dynamic range of the displayed image might only be roughly equivalent to that of the raw file.

The graph's vertical axis shows the total number of pixels in that particular tone, while the graph's horizontal axis represents tonal variations. Dark areas are represented by the left side of the horizontal axis, mid-tone values are represented by the center, and light areas are represented by the right side. The area (total number of pixels) that is photographed in each of these zones is represented by the vertical axis.

1.6. Histogram Equalization:

Histogram Equalization is a computer image processing technique used to improve contrast in images. It accomplishes this by effectively spreading out the most frequent intensity

values, i.e., stretching out the intensity range of the image.

This method usually increases the global contrast of images when its usable data is represented by close contrast values. This allows for areas of lower local contrast to gain a higher contrast. A color histogram of an image represents the number of pixels in each type of color component.

Histogram equalization cannot be applied separately to the red, green and blue components of the image as it leads to dramatic changes in the image's color balance. However, if the image is first converted to another color space, like HSL/HSV color space, then the algorithm can be applied to the luminance or value channel without resulting in changes to the hue and saturation of the image.

1.7. Local Enhancement:

Local enhancement techniques can enhance overall contrast more effectively. In local enhancement, a small window slides through every pixel of the input image sequentially and only those blocks of pixels are enhanced that fall in this window. Then gray level mapping is done only for the center pixel of that window.

Local Enhancement essentially takes into consideration the local properties of the image by moving a window/mask throughout. The image from pixel to pixel. The histogram of the points in the window is calculated and then a histogram.

Local contrast enhancement attempts to increase the appearance of large-scale light-dark transitions, like how sharpening with an "unsharp mask" increases the appearance of small-scale edges.

CHAPTER 2: Image Dehazing

2.1.Introduction:

Image Dehazing is the process of removing the atmospheric haze or fog from an image to improve its visibility and clarity. The haze in an image is caused by the scattering of light by   particles in the atmosphere, which reduces the contrast and sharpness of the image. The air light and attenuation are two main phenomena responsible for haze formation. The air light enhances the whiteness in the scene and contrast gets reduced by attenuation. Haze comes   both smoky and oily. Smoky haze caused by zillions of particles much smaller than the wavelengths of light, smears the light over all areas equally.

2.2.Importance of Dehazing:

Some of the key reasons why image dehazing is important include:

- Enhancing image quality: Haze and fog can greatly reduce the visibility of objects in   images, making them appear blurred or distorted. By removing the haze, image dehazing helps to enhance the visual quality and clarity of images, making them more appealing and informative.

- Improving accuracy: In applications where image analysis and processing are required, such as in medical imaging, remote sensing, and surveillance, the accuracy of the analysis depends on the clarity of the images. Image dehazing helps to remove the distortions caused by haze, thereby improving the accuracy of image analysis.

- Enhancing visual perception: Hazy images can lead to visual fatigue, which can make it difficult to interpret and analyze the images. By removing the haze, image dehazing enhances the visual perception of the images, making them easier to interpret and analyze.

- Improving safety: In applications such as autonomous driving, aviation, and maritime navigation, clear and accurate images are crucial for ensuring safety. Image dehazing helps to improve the visibility of objects in images, thereby

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enhancing safety in these applications.

Image dehazing is an important task in image processing that has several practical applications in various fields. It helps to improve the visual quality and clarity of images, enhance accuracy, and improve safety in applications where clear and accurate images are essential.

2.3. Applications of Dehazing:

Image dehazing is a crucial task in various fields, and its applications include:

- Aviation and Maritime Navigation: In these fields, image dehazing can be used to enhance the clarity of images captured by radar or other sensors. This can help pilots and ship captains to navigate safely in low-visibility conditions caused by haze or fog.

- Outdoor Surveillance: Image dehazing is used in surveillance systems to improve the visibility of objects in outdoor environments. This can be particularly important in security applications where the identification of objects or individuals is crucial.

- Agriculture and Forestry: In agriculture and forestry, image dehazing can be used to improve the visibility of crops, trees, and other vegetation. This can help farmers and forest managers to monitor the growth and health of their plants, as well as to identify any issues that may arise.

- Medical Imaging: Image dehazing is used in medical imaging to improve the visibility of internal organs and other structures. This can help doctors to make more accurate diagnoses and to plan more effective treatments.

- Autonomous Vehicles: Image dehazing can be used in autonomous vehicle applications to improve the visibility of objects in low-visibility conditions, such as fog or haze. This is essential for ensuring the safety of passengers and other vehicles on the road.

- Photography and Film: Image dehazing is used in photography and film to enhance the visual quality of images captured in hazy or foggy conditions. This can help photographers and filmmakers to achieve clearer and more vivid images.
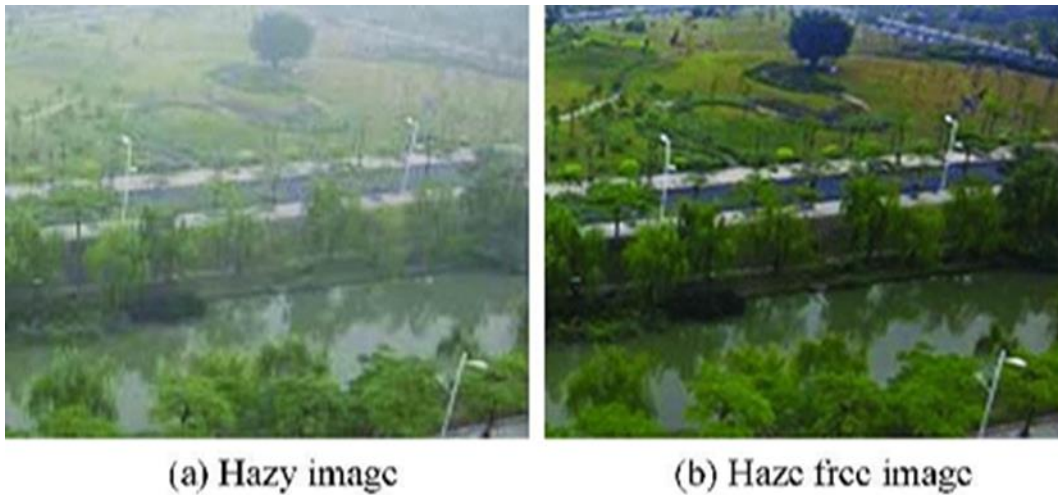
Figure 7: Haze and Haze-free image

2.4. Dehazing Methods:

There are various methods for dehazing an image, including:

- Dark channel prior: This method is based on the observation that the dark channel in a hazy image tends to have low intensities in the areas where the haze is present. By estimating the dark channel and using it to remove the haze, the image can be dehazed.

- Color attenuation prior: This method is based on the fact that the color of an object in a hazy image becomes more saturated as the distance from the camera increases. By estimating the amount of color attenuation in the image, the haze can be removed.

- Depth-based methods: These methods use depth information to estimate the amount of haze in the image. By estimating the depth map and using it to remove the haze, the image can be dehazed.

- Machine learning-based methods: These methods use machine learning algorithms to learn the relationship between hazy and dehazed images. By training a model on a dataset of hazy and dehazed images, the model can be used to dehaze new images.

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                    ┌─────────────────────┐
                    │  Dehazing Methods   │
                    └──────────┬──────────┘
            ┌──────────────────┴──────────────────┐
┌───────────────────────┐            ┌───────────────────────────┐
│ Dehazing using Multiple│            │ Dehazing using Single Images│
└───────────────────────┘            └───────────────────────────┘

┌───────────────────────┐            ┌───────────────────────────┐
│Polarisation Filtering Method│      │    Dark Channel Prior      │
└───────────────────────┘            └───────────────────────────┘

┌───────────────────────┐            ┌───────────────────────────┐
│Contrast Restoration Method│        │    Dehazing by Fusion      │
└───────────────────────┘            └───────────────────────────┘

                                     ┌───────────────────────────┐
                                     │       Dehazing by         │
                                     │    Learning Framework      │
                                     └───────────────────────────┘

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                                     │     Dehazing based on     │
                                     │     Neural Networks        │
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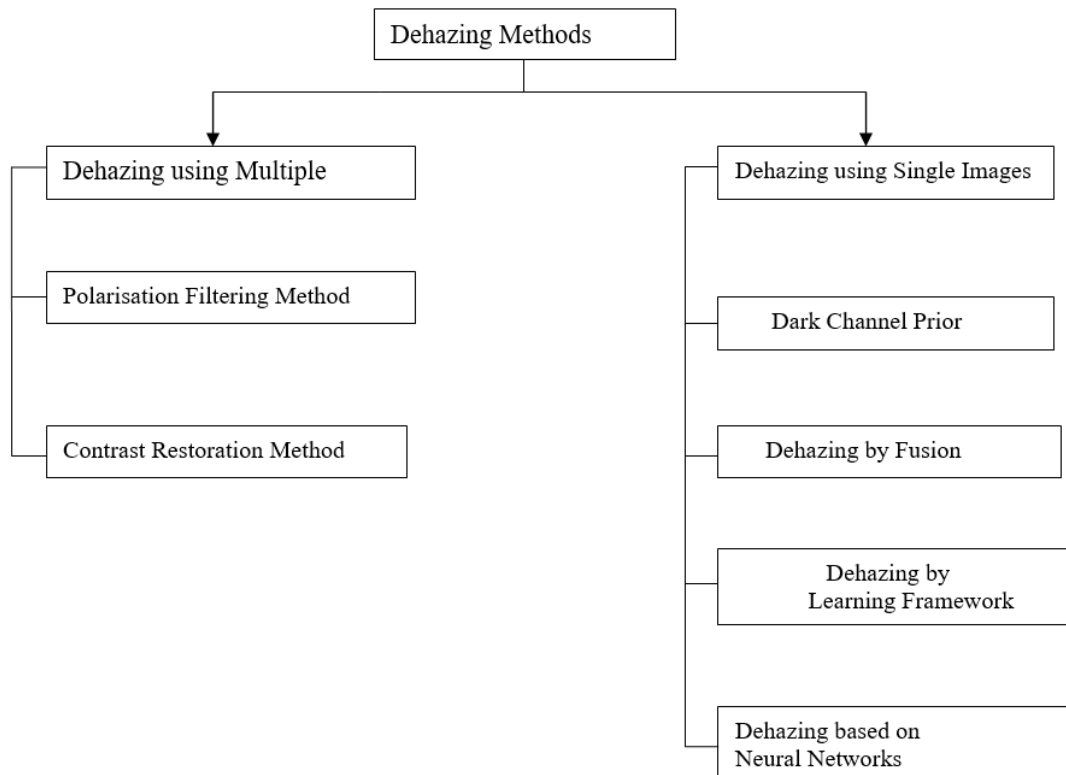
Figure 8: Dehazing Methods

2.4.1. Dehazing of Images using Polarization:

Airlight scattered by atmospheric particles is partially polarized. Polarization filtering alone cannot remove the haze effects, except in restricted situations. This method works under a wide range of atmospheric and viewing conditions. It analyzes the image formation process, taking into account polarization effects of atmospheric scattering. Then invert the process to enable the removal of haze from images. The method can be used with as few as two images taken through a polarizer at different orientations. Obtain a great improvement of scene contrast and correction of color. As a byproduct, the method also yields a range (depth) map of the scene, and information about properties of the atmospheric particles.

Airlight Polarization:

One of the causes for image degradation associated with atmospheric scattering is airlight. In this process, light coming from the illumination sources (e.g., the sun) is scattered towards theviewer. Consider the figure, airlight increases with the distance z from the object:
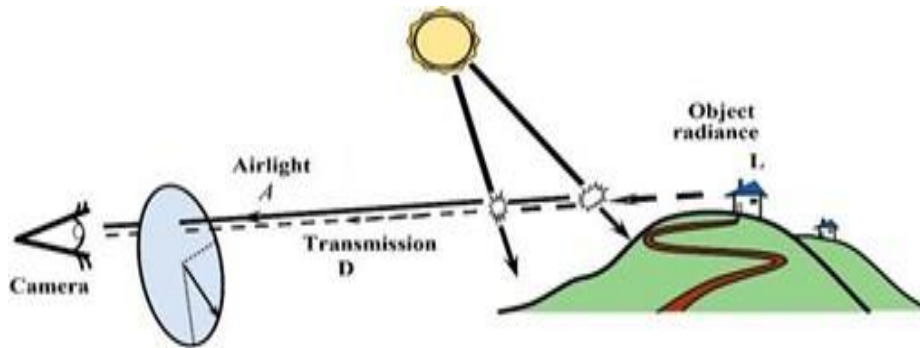
Figure 9: Airlight Polarization

$$A = A_\infty (1 - e^{-\beta z})$$

where β is the scattering coefficient. Here $A\infty$ is the airlight corresponding to an object at an infinite distance, which may take as the horizon. Assume for a moment that the illumination of any scattering particle comes from one direction (one illumination source). The light ray from the source to a scatterer and the line of sight from the camera to the scatterer define a plane of incidence. Then divide the airlight intensity into two components1, that are parallel and perpendicular to this plane, $A\|$and$A\perp$, respectively. The scattered light is partially linearly polarized perpendicular to this plane. The airlight degree of polarization is

$$P = \frac{A^\perp - A^\|}{A}$$

Where $A = A^\perp + A^\|$

is the total airlight intensity given in Eq. (1). The degree of polarization greatly varies as a function of the size of the scattering particles, their density, and the viewing direction.

Direct Transmission Polarization:

In addition to the presence of airlight, scattering degrades images by attenuating the light emanating from scene objects. Let the scene radiance be R in the absence of haze (scattering) between the scene and the viewer. When haze is present, as a ray of light progresses towards the viewer, part of its energy is scattered to other directions. Thus, the light energy that reaches the viewer is an attenuated fraction of R, called the direct transmission. As a function of the distance z and scattering coefficient β, the direct transmission is

$$T = Re^{-\beta z}$$

The scattering of the directly transmitted light does not change the polarization state of the incident light2, although the overall intensity is attenuated. Therefore, the degree of polarization and the polarization direction of the transmitted light do not change along the line of sight. The assumption that make in this paper is that light emanating from scene objects has insignificant polarization. It follows that the polarization of the direct transmission is also insignificant. This assumption is invalid for specular surfaces. Nevertheless, the polarization associated with specular objects becomes negligible when they are far enough. The reason is that the direct transmission decreases while airlight increases with distance. Thus, the polarization of the airlight dominates the measured light. Hence, the model becomes more accurate where it is needed most - for distant objects that are most affected by haze. Note that airlight is just the aggregation of light scattered by particles at various distances along the line of sight. Since the degree of polarization of this light does not change along the line of sight, P does not depend on the distance.

2.4.2. Image Dehazing Using Dark Channel Prior:

The dark channel prior is a kind of statistics of the haze-free outdoor images. It is based on a key observation - most local patches in haze-free outdoor images contain some

pixels which have very low intensities in at least one color channel. Using this prior with the haze imaging model, directly estimate the thickness of the haze and recover a high-quality haze-free image. A high-quality depth map can also be obtained as a by-product of haze removal.

DEGRADATION MODEL:

$$I(X) = J(X)e^{-\beta d(x)} + A(1-e^{-\beta d(x)})$$

Airlight : A(1-t(x))
Direct attenuation : J(x)t(x)
Scattering
Camera (I)
Object (J)
Distance (d)
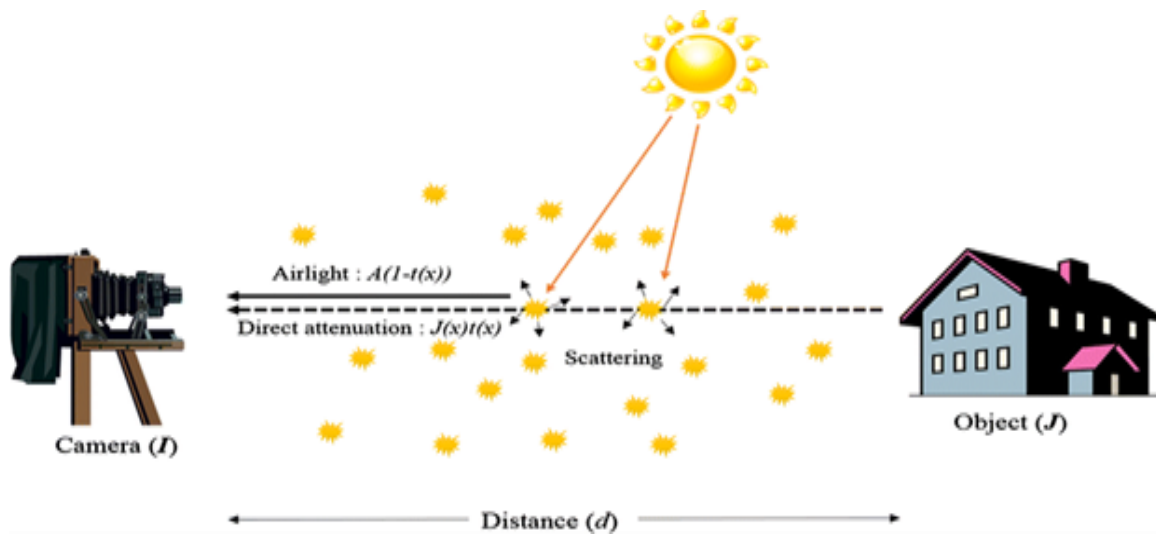
Figure 10: Degradation Model

where x represents the image coordinates, I is the observed hazy image, J is the haze-free image, A is the global atmospheric light, β is the scattering coefficient of the atmosphere, and d is the scene depth. Here, $e^{-\beta d}$ is often represented as the transmission map and is given by

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

In clear weather conditions, $\beta \approx 0$, and thus $I \approx J$. However, β becomes non-negligible for hazy images. The first term of, J(x)t(x) (the direct attenuation), decreases as the scene depth

increases. In contrast, the second term of A $(1 - t(x))$ (the airlight), increases as the scene depth increases. Since the goal of image dehazing is to recover J from I, once A and t are estimated from I, J can be arithmetically obtained as

$$J(x) = \frac{I(x) - A(x)}{t(x)} + A(x)$$

However, the estimation of A and t is non-trivial. In particular, since t varies spatially according to the scene depth, the number of unknowns is equivalent to the number of image pixels. Thus, a direct estimation of t from I is prohibitive without any prior knowledge or assumptions.

Dark channel prior (DCP):

On performing an empirical investigation on the characteristics of haze-free outdoor images. They found that there are dark pixels whose intensity values are very close to zero for at least one color channel within an image patch.

The low intensities in the dark channel are due to the following three main features: (i) shadows, e.g., shadows from cars and buildings in an urban scene or shadows from trees, leaves, and rocks in a landscape; (ii) colorful objects or surfaces, e.g., red or yellow flowers and leaves and (iii) dark objects or surfaces, e.g., dark tree trunks and stones. The pixel value at the dark channel can be approximated as follows:

$$J^{dark} \approx 0$$

This approximation to zero for the pixel value of the dark channel is called the DCP.

Global atmospheric light tends to be achromatic and bright, and a mixture of airlight and direct attenuation significantly increases the minimum value of the three color channels in the local patch. This implies that the pixel values of the dark channel can serve as an important clue to estimate the haze density.

2.4.3. Dehazing Algorithm Based on Learning Framework:

Remote Sensing Multispectral Image Dehazing Based on a Learning Framework:

In this model the influence of the light reflected by the atmosphere is divided into two parts: direct attenuation and veiling light. The formation of a hazy image can be described as

$$I(p) = J(p)t(p) + A(p)(1 - t(p)) \tag{1}$$
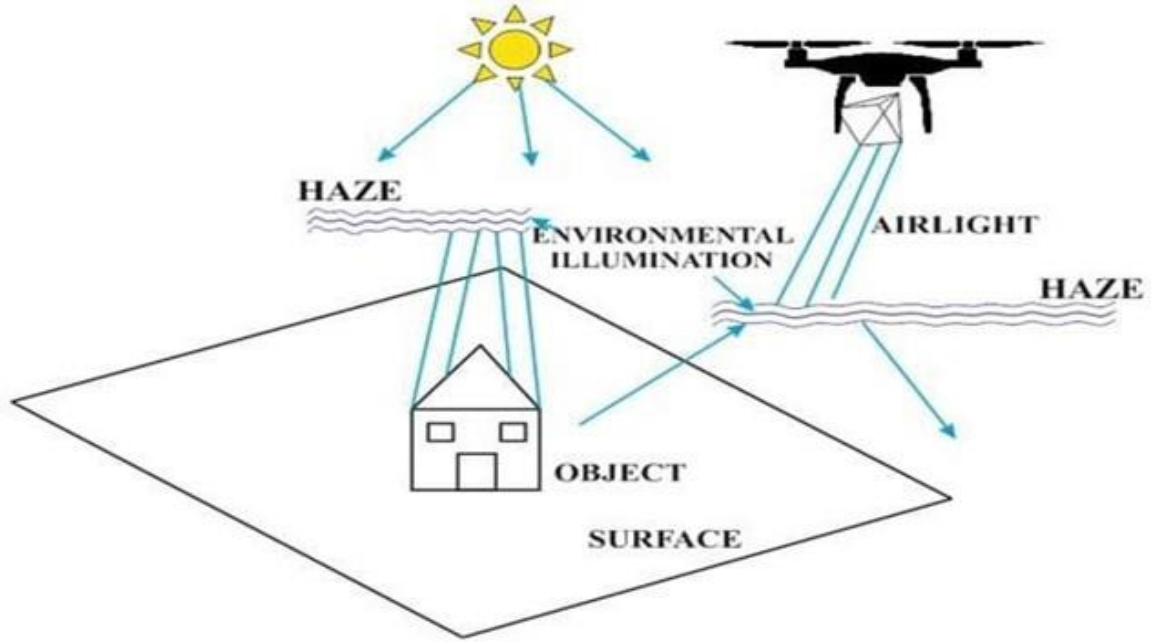
Figure 11: Imaging

where x represents the position of the pixel in the image, I(p) is the observed hazy image, J(p) is the scene radiance, A is the global atmospheric light usually assumed to be constant, and t(p)is the medium transmission, which describes the radio of the light that is not scattered and gets to the camera. The medium transmission can be expressed as

$$t(p) = e^{\beta(p)}$$

where d(x) is the scene depth and β is the scattering coefficient of the atmosphere. The goal of dehazing is to estimate the J(p); obtain the real scene J(p) since having an estimate of A and t(x) by

$$J(p) = \frac{I(p) - A(p)}{t(p)} + A(p) \tag{2}$$

Estimation of atmospheric light: This method reduces the influence of highlight areas on the atmospheric light acquisition.it is required to take the minimum channel map of the degraded remote sensing images.

Based on the weighted quad-tree search method, the minimum channel map of the hazy image is divided into four average areas by location and then the score of each region is obtained:

$$score_i = \overline{M_\iota} - \delta^2, \qquad i = 1,2,3,4$$

where i is the index of each region, is the score of region represents the mean value of the region$i$, M_i represents mean value of the region i and $\delta2$ represents variance in the region i. Then take the region with the highest score as the candidate iterative region, and it is further divided into four smaller regions. This process continues to iterate until the size of the candidate region is smaller than the present size threshold. The average of each channel in the last candidate region is selected as the result of A.

Transmission Estimation: The luminance componentI_L, the saliency componentSa, and the saturation component I_S have a strong relationship with the distribution of haze. The concentration of haze F(x, y) is described as follows:

$$F(x,y) = \theta_0 + \theta_1 I_L(x,y) + \theta_2 I_s(x,y) + \theta_3 S_a(x,y)$$

Where $\theta_i, i \in (0,1,,2,3)$, represents the nonnegative coefficients of the linear regression model with multiple variables in above equation. As a result of transmission is inversely proportional to the haze density, a linear model between transmission and the haze concentration feature was developed as follows:

t$(x,y) = 1 - \beta(x,y)$

Where β is a nonnegative coefficient.

Training Data Preparation: A random depth map with equal size is generated for each unblemished image, and the pixel values in the synthetic depth map were extracted from the standard uniform distribution in the open interval (0, 1). Then generated random atmospheric light A (m, m, m), where m is between 0.8 and 1. Obtain the hazy image I by utilizing the random depth map d and the random atmospheric light A. For transmission to

be revealed better, randomly collect 600 haze-free remote sensing images from the Google Earth for generating the training data. These coefficients ultimately represent the common characteristics of remote sensing hazy images. Through a large number of experiments on the real remote sensing hazy images, found that these coefficients can be applied for a single remote sensing image.

Scene Radiance Restoration: Since the transmission map and the atmospheric light were known, the scene radiance can be recovered according to. However, the direct attenuation term can be very close to zero when the transmission is close to zero. That will bring a lot noise. The scene radiance restoration can be expressed as

$$J(x) = \frac{I(x) - A}{\min\{\max\{t(x), 0.1\}, 0.9\}} + A$$

2.4.4. Dehazing Algorithm Based on Negative Correction:

The concept of negative correction inspired by the practical application of photographic developing and a fast image dehazing algorithm is accordingly proposed. Based on the observation of the photographic developing, find that the contrast of images can be enlarged, and their saturation can also be increased when their negative images (or reverse image) are rectified. Thus, instead of estimating the transmission map, the correction factor of negative is estimated, and it is used to rectify the corresponding haze images. In order to suppress halos, a modified maximum-filter is proposed to limit the larger value of correction factor of local region.
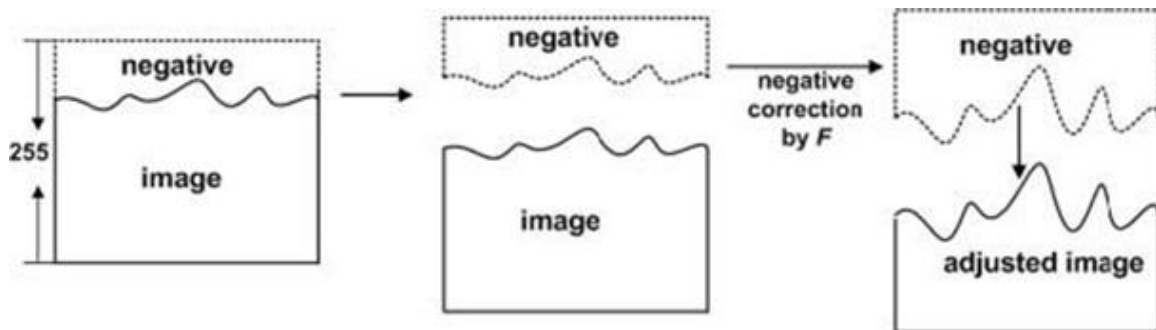
Figure 12: Negative Correction image

2.4.5. Dehazing By Multiscale Fusion:

Fusion enhancement technique estimates for each pixel the desirable perceptual base qualities (called weight maps) that control the contribution of each input to the final result. In fusion framework the derived inputs are weighted by three normalized weight maps (luminance, chromatic and saliency) that aim to preserve the regions with good visibility. To minimize artifacts introduced by the weight maps, the approach is designed in a multi-scale fashion, using a Laplacian pyramid representation of the inputs combined with Gaussian pyramids of normalized weights.

The fusion technique that employs only the inputs and weights derived from the original hazy image. The fundamental idea is to combine several input images (guided by the weights maps) into one, by keeping only the most significant features of them.

Inputs:

The algorithm generates from the original image only two inputs that recover color and visibility of the entire image. The first one better depicts the haze-free regions while the second derived input increases visible details of the hazy regions. The first input I_1 is obtained by white balancing the original hazy image. By this step, aim a natural rendition of images, by eliminating chromatic casts that are caused by the atmospheric color.

Weight Maps:

Weight maps are designed in a per-pixel fashion to better define the spatial relations of degraded regions. These maps balance the contribution of each input and ensure that regions with high contrast or more saliency from a derived input, receive higher values.

The luminance weight map measures the visibility of each pixel and assigns high values to regions with good visibility and small values to the rest. Since hazy images present low saturation, an effective way to measure this property is to evaluate the loss of colorfulness. This weight is processed based on the RGB color channel information. This weight map is simply computed (for each input I_k, with k indexes the derived inputs) as the deviation (for

every pixel location) between the R, G and B color channels and the luminance L from the input:

$$W_L^k = \sqrt{1/3[(R^k - L^k)^2 + (G^k - L^k)^2 + (B^k - L^k)^2]}$$

Since the luminance L is computed by averaging the RGB channels, this disparity yields higher values for the saturated pixels which are assumed to be part of the initial haze- free regions. The luminance weight acts as an identifier of the degradation induced in I_2 in the haze-free regions, ensuring a seamless transition between the derived inputs I_1, I_2. On the other hand this map also tends to reduce the global contrast and colorfulness.

The chromatic weight map controls the saturation gain in the output image. This weight map is motivated by the fact that in general humans prefer images characterized by a high level of saturation. Since the color is an inherent indicator of the image quality, often similar color enhancement strategies are also performed in tone mapping. To obtain this map, for each pixel the distance between its saturation value S and the maximum of the saturation range is computed.

Therefore, small values are assigned to pixels with reduced saturation while the most saturated pixels get high values. As a result, this map ensures that the initial saturated regions will be better depicted in the final result.

The saliency weight map identifies the degree of conspicuousness with respect to the neighborhood regions. This perceptual quality measure assesses that a certain object/person stands out from the rest of the image, or from nearby regions. Saliency referred to as visual attention estimate the contrast of image regions relative to their surroundings (based on different image features such as intensity, color or orientation).

In the fusion process, the inputs are weighted by specific computed maps. Each pixel x of the output F is computed by summing the inputs I_k weighted by corresponding normalized weight maps.

The normalization of the weights ensures that the intensity scale of the result is maintained in relatively the same scale as the inputs (since the sum of each pixel equals 1).

In this case, each input I_k, is decomposed into a pyramid by applying Laplacian operator at different scales. Similarly, for each normalized weight map W_k, a Gaussian pyramid is computed. Considering that both the Gaussian and Laplacian pyramids have the same number of levels, the mixing between the Laplacian inputs and Gaussian normalized weights is performed at each level independently, yielding the fused pyramid.

2.4.6. Dehazing based on Multi Scale Neural Networks:

Multiscale networks have been shown to be effective in a wide range of computer vision tasks, including image classification, object detection, and segmentation.
To perform dehazing using multiscale neural networks, the input image is first divided into multiple scales or resolutions. Each scale is then processed using a separate processing module, which may consist of one or more convolutional layers. The outputs of the modules are then combined to produce a final dehazed image.

There are several advantages to using multiscale neural networks for dehazing. First, they allow the network to process images at different levels of detail, which can be useful for removing haze from both large-scale and small-scale features in the image. Second, they can be more computationally efficient than processing the entire image at a single scale, since smaller scales require less computation. Finally, multiscale networks can be trained end-to-end using backpropagation, which makes them easy to optimize for the dehazing task.
Overall, dehazing based on multiscale neural networks is a promising approach for improving the quality of images affected by haze or fog.

2.4.7. Dehazing By Contrast Restoration Method:

Contrast restoration method is a technique used in image dehazing to improve the visibility and clarity of images captured in hazy or foggy environments. The contrast restoration method in image dehazing works by enhancing the contrast of the image through a process

of local image enhancement. This involves dividing the hazy image into smaller regions and processing each region separately to enhance its contrast. One popular technique used for contrast restoration in image dehazing is the Dark Channel Prior (DCP) method. The DCP method works by identifying the dark pixels in the image and using them to estimate the transmission map, which represents the degree of haze present in each pixel. By using the transmission map, the method can then estimate the true colors and contrast of the image and enhance it accordingly.

Other techniques used for contrast restoration in image dehazing include Retinex-based algorithms, guided image filtering, and histogram equalization methods. These methods all aim to enhance the contrast of the image to improve its visibility and make it easier to perceive details and features that were previously obscured by haze or fog.

CHAPTER 3: Methodology

3.1.Basic Haze modelling:

In this method the hazy image deterioration is depicted using the 'atmospheric scattering model'. The light pass in the imaging equipment is divided into two components, atmospheric and damped scene radiance, as a result of atmospheric scattering.
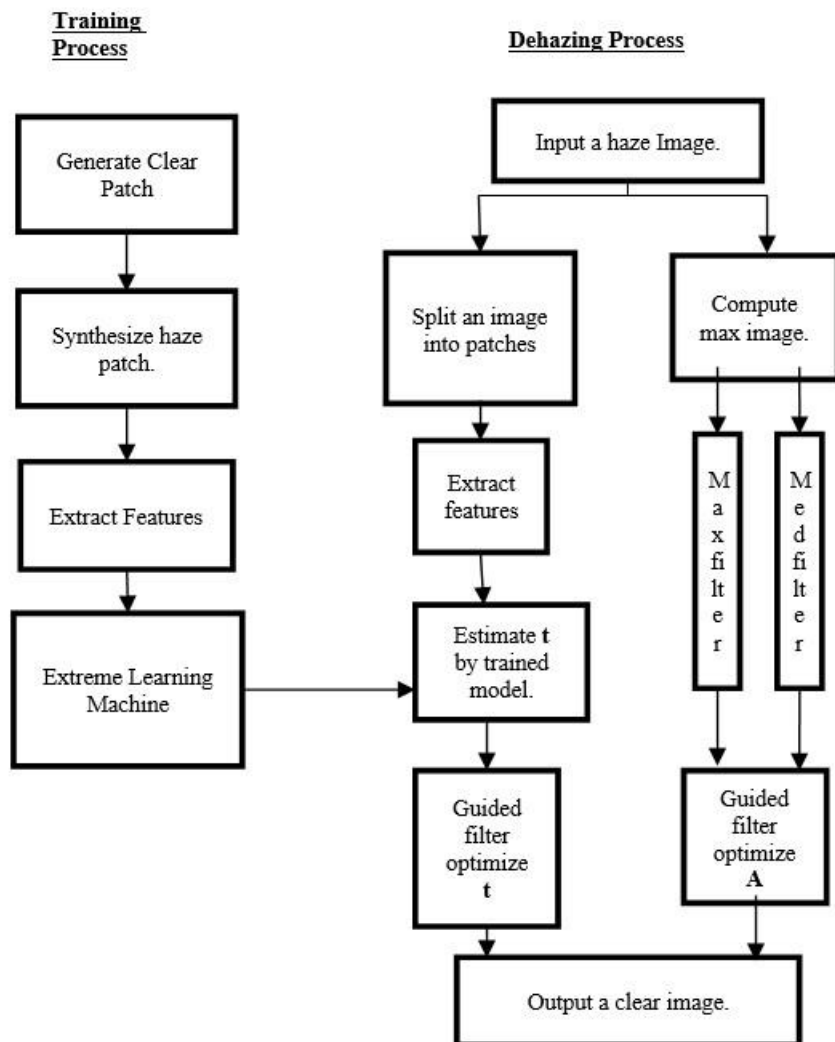
Figure 13: The algorithms flow chart

$$I(p) = J(p)t(p) + A(p)(1 - t(p)) \tag{3.1}$$

Here   I(p)=haze image at pixel position p

     J(p)=haze free output image at pixel position p

     t(p)=medium of transmission at pixel position p

     A(p)=atmospheric light at pixel position p

J value from I can be obtained by estimation of A and t accurate.

$$J(p) = \frac{I(p) - A(p)}{t(p)} + A(p) \tag{3.2}$$

3.2. Atmospheric Light Evaluation(A)

The atmospheric light A in the hazy picture degradation model stands in for the scene's illumination. First estimate the illumination map and edge map to evaluate the A value. For estimating the illumination map, determine the maximum image. It can be obtained by the equation (3.3).

$$I_m(p) = \max_{c \in \{r,g,b\}} I^C(p) \tag{3.3}$$

Maximum image is applied to the maximum filter of mask size 21x21 to get the illumination map. It can be obtained by the equation (3.4).

$$A_{ill}(p) = \max_{x \in \Omega(p)} (I_m(x)) \tag{3.4}$$

Where $\Omega(p)$ is a local patch centered at position p

For estimating the edge map, a median filter of mask size 15x15 is applied to the gray scale image to obtain the edge of A_{ill}. It can be obtained from equation (3.5).

$$A_{edge}(p) = \underset{x \in \Omega(p)}{\mathrm{med}} (gray(I(x))) \tag{3.5}$$

gray () is an operation that converts a color image into grayscale image

A guided filter is used to make the illumination map A_{ill} nearer to the edge map A_{edge}.

Finally 'A' value can be obtained by the following equation (3.6).

$$A = GF_{A_{edge}}(A_{ill}) \tag{3.6}$$

Where GF_I denotes the guided filter.

3.3. Generation of training data

A random algorithm is applied to create high-saturated fog-free arrays and haze-free patches, while also containing random colors and textures.

There are four main steps:

1. Make a irregular 24 x 24 color picture fix where each color channel of the pixel within the irregular fix could be a irregular esteem between and 1, as appeared in Figure 2.
2. The irregular patches are obscured utilizing normal channels with distinctive window sizes to create diverse surfaces, as appeared in Figure 2.
3. Alter the greatest and least channel of fluffy fix to extend its contrast and immersion to make a clear fix p_j as appeared in fig 2.
4. Repeat the over steps to produce huge number of clear patches.
5. Finally the physics model is used to synthesize a training patches p_i as shown in fig 3.

$$p_i = tp_j + (1 - t)A$$

6. Where A is fixed to 1 and set t= 0.1,0.2,0.3, ……0.9,1 to replicate various amounts of haziness.

(a) random patch   (b) fuzzy patch   (c) clear patch
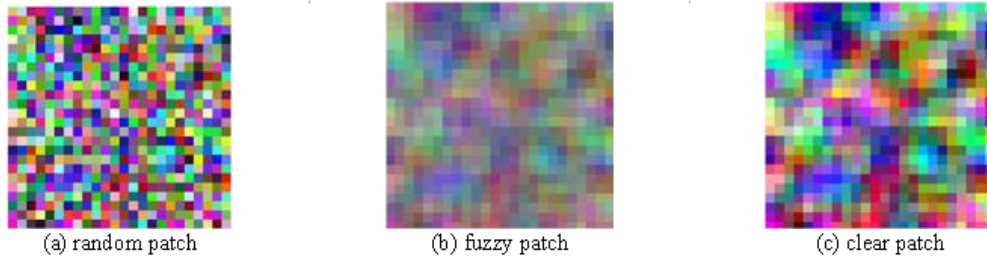
Figure 14: Process of generating clear patch
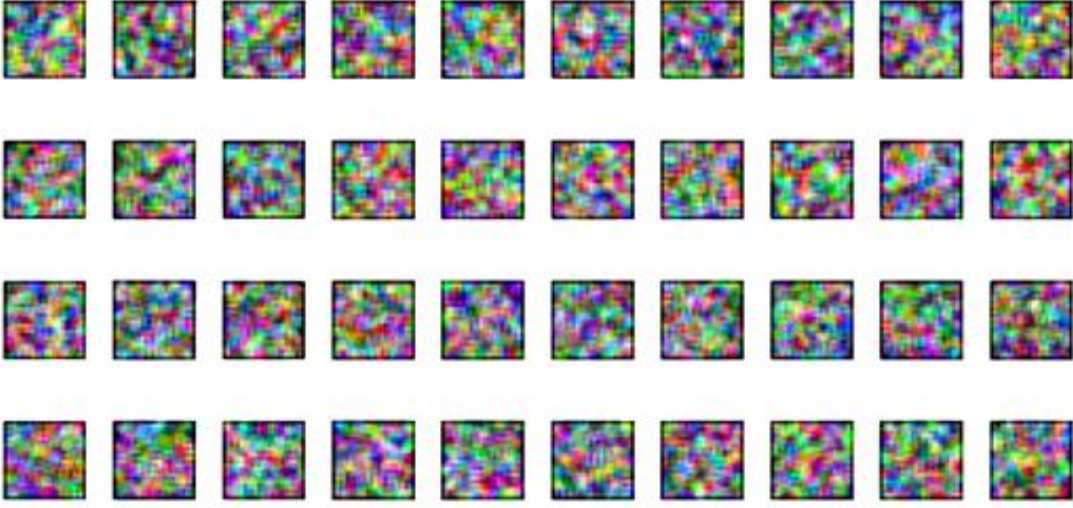
Figure 15: some of the generated clear patches

3.4. Feature Extraction

The clear patches generated by the algorithm is 7000. The full number of the preparing patches is 70,000 after including 10 artificial haze patches with t = [1,0.9, 0.8, ….. 0.1] for each clear patch as shown in fig 2. These patches are sorted in descending order of t before feature values are obtained and the training information is used to extract seven features.

3.4.1. Mean Squared Error (M.S.E):

The mean squared error (M.S.E) is used to assess image quality. It represents the cumulative squared error between the compressed and the original image. The lower the value of MSE, the lower the error. It is determined by considering the average, particularly the mean, of errors squared from data as it relates to a function. It is measured by equation (3.7).

$$F_{MSE} = \sum_{c\epsilon\{r,g,b\}} \sum_{p=1}^{N} \frac{(I_c(p) - \bar{I}_c)^2}{N}$$

(3.7)

Where $I_c(p)$ is refer to the value of pixel at position p in a color channel c of the patch, $\bar{I}_c$ is the average pixel value of channel c of the patch.
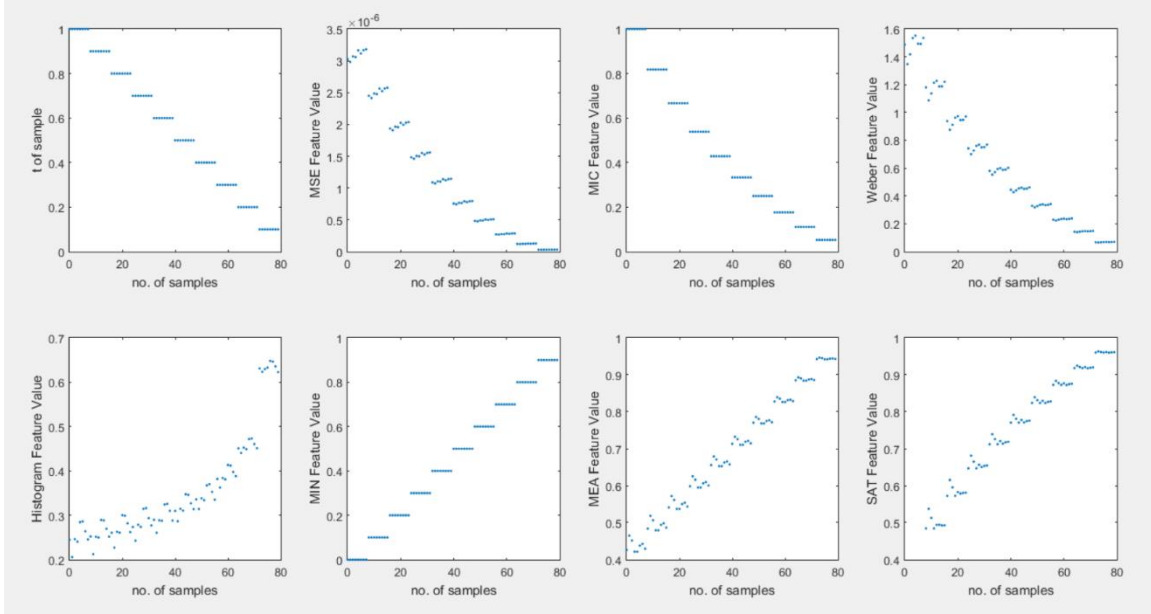
Figure 16: The relationship between each feature and the actual value; (a) the ground truth or actual values (b) MSE feature(c) MIC feature (d) WEB feature (e) HIS feature (f) MIN feature (g) MEA feature (h) SAT feature

3.4.2. Michelson Contrast Feature:

The Michelson contrast FMIC can be defined as the fraction of the variation between the peak and least intensities in an image to the sum of the maximum and minimum intensity values. The Michelson contrast is used to assess the visibility and quality of an image. The Michelson contrast can also be used as a feature for image classification, segmentation, and other image processing tasks. It is measured by equation (3.8).

$$F_{MIC} = \sum_{c\epsilon\{r,g,b\}} \frac{I_{c,MAX} - I_{c,MIN}}{I_{c,MAX} + I_{c,MIN}} \tag{3.8}$$

Where $I_{c,MAX}$ and $I_{c,MIN}$ are the most extreme and the least pixel esteem in channel 'c' of the patch.

3.4.3. Weber Contrast Feature:

The weber contrast feature[3.9] FWEB can be described as the standardized disparity between object and background colors. Here object color is each pixel value of patch and background color indicates the mean pixel values. It is measured by equation (3.9).

$$F_{WEB} = \sum_{c\epsilon\{r,g,b\}} \sum_{p=1}^{N} \frac{|I_c(p) - \bar{I_c}|}{N\bar{I_c}} \tag{3.9}$$

3.4.4. Histogram Feature:

The histogram could be a prevalent graphing instrument. It is utilized to summarize discrete or persistent information that are measured on an interval scale. It is frequently utilized to demonstrate the major highlights of the conveyance of the information in a helpful frame. It is additionally valuable when managing with huge information sets (greater than 100 perceptions). It can offer assistance distinguish any abnormal perceptions (exceptions) or any crevices within the information.

A histogram isolates up the extend of conceivable values in a information set into classes or bunches. For each gather, a rectangle is developed with a base length break even with to the extend of values in that particular bunch and a length break even with to the number of perceptions falling into that bunch. It is measured by equation (3.10).

$$F_{HIS} = \sum_{c\epsilon\{r,g,b\}} \sqrt{\sum_{p=0}^{2^M-1} \left(\frac{1}{2^M - 1} - \frac{N_{c,p}}{N}\right)^2} \tag{3.10}$$

Here M=width of the bit of pixel (normally 8)

$N_{c,p}$ = total count of pixels that equals value p in color channel c.

3.4.5. Minimum Channel Mean Feature:

Mean value is the sum of pixel values divided by the total number of pixel values Each of the pixels that represents an image stored inside a computer has a pixel value which describes how bright that pixel is, and/or what color it should be. In the simplest case of binary images, the pixel value is a 1- bit number indicating either foreground or background. Mean is most basic of all statistical measure. Means are often used in geometry and analysis; a wide range of means have been developed for thesepurposes. In contest of image processing filtering using mean is classified as spatial filtering and used for noise reduction. It is measured by equation (3.11).

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$$F_{MIN} = \text{mean} \left(\min_{c \epsilon \{r,g,b\}} (I_c) \right) \qquad\qquad (3.11)$$

3.4.6. Mean Value Feature:

Mean value is the sum of pixel values divided by the total number of pixel values Each of the pixels that represents an image stored inside a computer has a pixel value which describes how bright that pixel is, and/or what color it should be. In the simplest case of binary images, the pixel value is a 1- bit number indicating either foreground or background. Mean is most basic of all statistical measure. Means are often used in geometry and analysis; a wide range of means have been developed for thesepurposes. In contest of image processing filtering using mean is classified as spatial filtering and used for noise reduction.

$$F_{MEA} = \text{mean}_{c \epsilon \{r,g,b\}} (mean(I_c)) \qquad\qquad (3.12)$$

3.4.7. Saturation Feature

In image processing, saturation refers to the amount of color in an image and is a feature that can be used to describe an image. Saturation is often used in color correction and color balance tasks.

Saturation is a dimension of color that is orthogonal to hue and brightness. A fully saturated color is vivid and has a pure hue, whereas a color with low saturation is closer to a shade of gray.

$$F_{SAT} = \sum_{p=1}^{N} \left(\frac{\min_{c \epsilon \{r,g,b\}} (I_{c,p})}{\max_{c \epsilon \{r,g,b\}} (I_{c,p})} \right) \qquad\qquad (3.13)$$

Each sample has all characteristics extracted from it. Figure 17 depicts the association among the feature value and the real t of models, with FMSE, FMIC, and FWEB all being proportional to the real t. Although these results show strong correlations for samples with the same t, the samples' random-texture and random-color make their feature values very variable.

The unpredictability of texture and color has a little impact on FMIN (Fig. 17(f)), FMEA (Fig. 17(g)), and FSAT (Fig. 17(h)), which are all inversely proportional to the real t with strong correlation. Although some articles employed the uniformity of the histogram value FHIS to assess picture quality and specify the cost function, it should be highlighted that FHIS (Fig. 17(e)) has the weakest association with the true t and is significantly impacted by texture and color. As a result, do not suggest utilizing FHIS as a sole source for haze related characteristics.

3.5. Extreme Learning Machine(ELM)

Extreme Learning Machine (ELM) is a type of machine learning algorithm that belongs to the family of neural networks. It was first introduced by Huang et al. in 2006 as an alternative to traditional training methods in neural networks, such as backpropagation.

Unlike traditional neural networks, which require a time-consuming iterative training process, ELM uses a one-pass learning algorithm. This means that it can learn from the training data in a single iteration, making it much faster than traditional methods.

The key idea behind ELM is to randomly initialize the weights of the hidden layer neurons and then solve the linear system of equations that maps the input data to the output. The hidden layer neurons are activated by a nonlinear activation function, such as the sigmoid or the radial basis function.

ELM is particularly useful for solving regression and classification problems with large datasets, as it can handle a large number of features and samples efficiently. It has been successfully applied in a variety of fields, such as image recognition, speech recognition, and financial forecasting.

One of the main advantages of ELM is its simplicity and ease of implementation. It requires no tuning of hyperparameters and has no local minima, making it less prone to overfitting

than traditional neural networks. ELM also has a high generalization ability, which means it can perform well on unseen data.

It is a brand-new learning technique for feedforward neural networks with a single hidden layer is called the extreme learning machine (ELM). It addresses the issues of sluggish training speed and over-fitting as compared to the traditional neural network learning technique. ELM's learning method only requires one iteration and is based on empirical risk minimization theory. Many rounds and local reduction are avoided by the approach. As it has superior generalization capabilities, is more resilient, is more controllable, andhas a rapid learning rate, it has been connected in a assortment of disciplines and applications. A quick and reliable machine learning algorithm is ELM. The generalized single-layer feed-forward neural network was simply referred to as that. The ELM theory is in favor of the assumption that learning models can be fed by randomness in the selection of input weights without any distribution- specific adjustment.

However, ELM also has some limitations. It may not perform as well as traditional neural networks on some complex tasks, such as natural language processing or image segmentation. Additionally, ELM does not provide a mechanism for fine-tuning the weights of the hidden layer neurons, which can limit its flexibility in some applications.

ELM doesn't require gradient-based backpropagation to work. It uses More-Penrose generalizedinverse to set its weights.

First, look at standard SLFN (Single hidden Layer Feedforward Neural network):
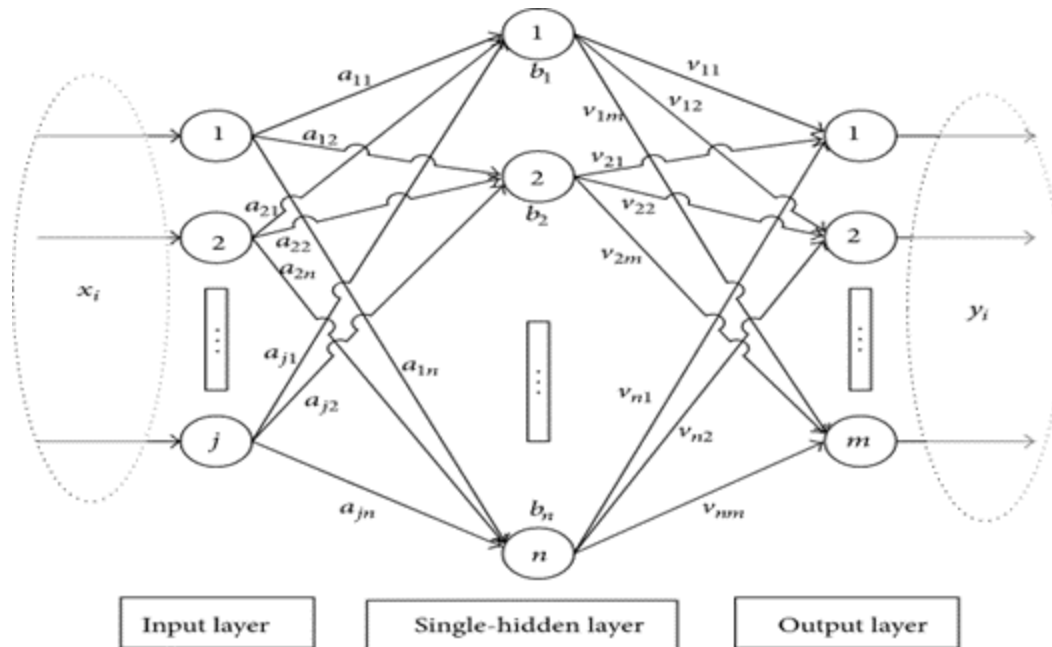
Figure 17: Structure of ELM

Single hidden Layer Feedforward Neural network.

It's straightforward:

1. multiply inputs by weights
2. add bias
3. apply the activation function
4. repeat steps 1–3 number of layers times
5. calculate output
6. backpropagate
7. repeat everything

How ELM Output Is Calculated:

$$f_L(x) = \sum_{i=1}^{L} \beta_i g_i(x) = \sum_{i=1}^{L} \beta_i g(w_i * x_j + b_i), j = 1, ..., N$$

Where:

L is a number of hidden units

N is a number of training samples

is weight vector between the hidden layer and output

w is a weight vector between input and hidden layer

g is an activation function

b is a vias vector

x in an input vector

It is quite similar to what's going one in standard NN with backpropagation but if you look closely you can see that we're naming weight between hidden layer and output as Beta. This Beta matrix is aspecial matrix because that is the pseudo-inverse. So shorten the equation and write it as:

$$T = H\beta$$

Where:

$$H = \begin{bmatrix} g(w_1 * x_1 + b_1) & \cdots & g(w_L * x_1 + b_L) \\ \vdots & \cdots & \vdots \\ g(w_1 * x_N + b_1) & \cdots & g(w_L * x_N + b_L) \end{bmatrix}_{N \times L}$$

$$\beta = \begin{bmatrix} \beta_1^T \\ \vdots \\ \beta_L^T \end{bmatrix}_{L \times m} \quad T = \begin{bmatrix} t_1^T \\ \vdots \\ t_N^T \end{bmatrix}_{N \times m}$$

Where:

m is a number of outputs

H is called Hidden Layer Output Matrix

T is a training data target matrix.

CHPATER 4: Software Description

4.1. Introduction

The implementation of this project is done using MATLAB. MATLAB (short for "matrix laboratory") is a numerical computing environment and programming language that is widely used in engineering, science, and mathematics. It is a high-level programming language that allows you to easily perform numerical computations, data analysis, and visualization. MATLAB includes a large library of built-in functions and toolboxes for various areas such as signal processing, control systems, image processing, and optimization, among others. The language is interactive and provides an integrated development environment (IDE) with a debugger and profiler for troubleshooting and performance analysis. MATLAB can be used for a wide range of applications, including modeling and simulation, algorithm development, data analysis, and machine learning.

4.1.1. Typical uses of MATLAB:

MATLAB is a versatile tool that can be used in a variety of applications. Here are some common uses of MATLAB:

- Data analysis: MATLAB is commonly used for data analysis, including signal processing, image processing, and statistics. It provides built-in functions for common data analysis tasks, and it also supports the use of external libraries and toolboxes.

- Modeling and simulation: MATLAB is often used for modeling and simulation of systems in engineering, physics, and other fields. It supports the creation of complex models and simulations, and it can be used to simulate the behavior of systems under different conditions.

- Algorithm development: MATLAB is used for algorithm development in a wide range of applications, including control systems, image processing, and machine learning. It provides a rich set of built-in functions and libraries for developing and testing algorithms, and it supports the use of external libraries and toolboxes.

- Numerical computation: MATLAB provides a powerful set of tools for numerical computation, including matrix operations, numerical optimization, and differential

- equation solvers. It can be used to solve a wide range of numerical problems, including those in engineering, physics, and finance.

- Visualization: MATLAB provides powerful tools for creating high-quality visualizations of data, including 2D and 3D plots, animations, and interactive graphics. It supports a variety of visualization types and styles, and it can be used to create custom visualizations.

- Overall, MATLAB is a powerful tool that can be used in a wide range of applications, from data   analysis to algorithm development to numerical computation and visualization. Its rich set of built-in functions, toolboxes, and libraries make it a popular choice for researchers, engineers, and scientists across many fields.

MATLAB can be used as a standalone application or integrated with other programming languages such as C/C++, Java, and Python. It supports a wide range of file formats and can interface with hardware devices such as cameras, microcontrollers, and data acquisition systems.

A simple data element in the interactive system MATLAB is an array that doesn't need to be dimensioned. In comparison to the time it would take to build a programme in a scalar non-interactive language like C or Fortran, this enables you to solve a variety of technical computing problems, particularly those using matrix and vector formulations.

The LINPACK and EISPACK projects, which together constitute the state-of-the-art in software for matrix computation, were the inspiration for the creation of MATLAB, which was designed to make it simple to access their matrix software. With the help of numerous users, MATLAB has developed over time. It is the typical teaching tool for introductory and advanced courses in science, engineering, and mathematics in university settings.

For high-productivity research, development, and analysis in business, MATLAB is the go-to tool. MATLAB provides a comprehensive set of tools and functions for numerical calculations, linear algebra, signal processing, image processing, optimization, statistics, and more. It also has built-in graphics capabilities for creating 2D and 3D plots, animations,

and interactive applications. Toolboxes are essential for the majority of MATLAB users since they let you study and use specific technologies.

MATLAB is developed and maintained by MathWorks, and is available on Windows, macOS, and Linux platforms.

4.2. MATLAB System

The five main parts of the MATLAB system are**:**

4.2.1. MATLAB Language

This is the programming language used in MATLAB. It is a high-level language that allows users to write scripts and functions for data analysis, numerical computations, and algorithm development. In MATLAB, variables are created dynamically and can be of different data types such as integers, floating-point numbers, complex numbers, strings, and logical values.

Object-oriented programming, control flow statements, functions, data structures, input/output facilities, and an advanced matrix/array language are all included in this language. Both "programming in the small" and "programming in the large" are made possible by it, enabling the quick creation of throw-away programmers as well as the full development of extensive application systems.

4.2.2. MATLAB Environment

The MATLAB environment is a comprehensive development environment that provides a variety of tools and features for programming, data analysis, and visualization. The MATLAB environment includes the following components:

- MATLAB desktop: This is the main interface of the MATLAB environment. It includes the Command Window, which is used for interactive programming and executing commands, and the Workspace, which displays the variables and data used in the current session.

- Editor: This is a text editor that is used to create and edit MATLAB code files. It includes features such as syntax highlighting, debugging tools, and code folding.
- Debugger: The MATLAB debugger is a powerful tool for debugging and analyzing MATLAB code. It includes features such as breakpoints, step-by-step execution, and variable inspection.
- Profiler: The MATLAB profiler is used to analyze the performance of MATLAB code. It identifies the time and memory usage of each line of code, allowing users to optimize their programs for better performance.
- Help browser: The MATLAB help browser provides extensive documentation and reference materials for the MATLAB language and its functions. It includes examples, tutorials, and user-contributed content.
- Toolboxes: MATLAB offers a wide range of toolboxes that provide specialized functions for specific areas of application. Examples include the Signal Processing Toolbox, the Image Processing Toolbox, and the Control System Toolbox.

4.2.3. MATLAB Graphics

MATLAB is a powerful tool for creating and manipulating graphics, including 2D and 3D plots, animations, and interactive visualizations. Here are some basic concepts and commands related to MATLAB graphics:

- Plotting a function: To plot a function, you can use the plot function.
- Customizing plots: You can customize your plot by changing the axis labels, colors, line styles, and more. You can also add a title and axis labels by using the title, xlabel, and ylabel functions.
- 3D plots: MATLAB also supports 3D plots. To plot a 3D function, you can use the surf function.
- Animations: MATLAB can also create animations. You can use the animated line function to create a line that updates with each iteration of a loop.

4.2.4. MATLAB Libraries:

MATLAB comes with a variety of libraries that provide functions and tools for specific tasks such as signal processing, optimization, and machine learning.

- Signal Processing Toolbox - This toolbox provides functions and apps for analyzing, processing, and synthesizing signals.
- Image Processing Toolbox - This toolbox provides functions and apps for processing, analyzing, and visualizing 2D and 3D images.
- Optimization Toolbox - This toolbox provides functions and apps for solving optimization problems.
- Statistics and Machine Learning Toolbox - This toolbox provides functions and apps for statistical analysis, machine learning, and data mining.
- Simulink - This is a graphical programming environment for modeling, simulating, and analyzing dynamic systems.

4.2.5. MATLAB Apps:

MATLAB includes several built-in apps that provide interactive tools and interfaces for specific tasks. Examples include the Curve Fitting app, the Control System Designer app, and the Image Labeler app.

- Signal Analyzer - A signal processing app that lets you analyze and visualize signals in time and frequency domains.
- Control System Designer - An app for designing and analyzing control systems. It includes tools for modeling, simulating, and optimizing control systems.
- Curve Fitting Toolbox - An app for fitting curves to data. It includes a wide range of regression models, and you can customize your own models as well.
- Image labeler app - The image labeling app provides an easy-to-use interface for annotating images, with tools to draw and edit annotations, and to view the annotations in real-time.

4.3. Computational Mathematics in MATLAB

MATLAB is a powerful tool for computational mathematics that has revolutionized the way engineers, scientists, and mathematicians approach complex problems. It provides a flexible environment for numerical analysis, data visualization, and algorithm development. The following are some mathematical operations where it is most frequently used:

- Linear Algebra
- Algebraic Equations
- Non-linear Functions
- Statistics
- Data Analysis
- Calculus and Differential Equations
- Numerical Calculations
- Integration
- Transforms
- Curve Fitting
- Dealing with Matrices and Arrays
- 2-D and 3-D Plotting and graphics

4.4. MATLAB Features

Here are some features of MATLAB:

- Matrix manipulation: MATLAB is built around the concept of matrices, which makes it easy to perform mathematical operations on data.
- Interactive environment: MATLAB provides an interactive environment for exploring, analyzing and visualizing data.
- Programming language: MATLAB is a programming language that supports procedural, object-oriented and functional programming paradigms.
- Visualization: MATLAB has powerful built-in tools for creating high-quality 2D and 3D visualizations, such as plots, charts, and graphs.

- Toolboxes: MATLAB has many specialized toolboxes that extend its functionality, such as for signal processing, image processing, optimization, control systems, and more.
- Interoperability: MATLAB can interact with other programming languages and software, such as Python, C/C++, and Excel.
- Parallel computing: MATLAB provides support for parallel computing, which can speed up computation time for certain tasks.
- Support community: MATLAB has a large user community and extensive documentation and support resources available online.
- The MATLAB environment functions like an incredibly complicated calculator. The command prompt allows you to type commands.
- The MATLAB environment is interpretive. Hence, when you give MATLAB a command, it immediately carries it out.

4.5. Applications of MATLAB

MATLAB is a versatile software tool that has a wide range of applications in various fields, including:

- Engineering: MATLAB is extensively used in engineering for tasks such as data analysis, system modeling, and simulation, control system design, and signal processing.
- Science: MATLAB is commonly used in scientific research for data analysis, image processing, and statistical analysis.
- Finance: MATLAB is used in finance for tasks such as risk management, portfolio optimization, and financial modeling.
- Education: MATLAB is widely used in education for teaching and learning mathematics, programming, and data analysis.
- Medical research: MATLAB is used in medical research for tasks such as medical imaging analysis, signal processing, and statistical analysis.

- Machine learning: MATLAB has a comprehensive set of tools for machine learning, including deep learning, and is used extensively in the field of artificial intelligence.
- Aerospace and defense: MATLAB is used for modeling and simulation of complex systems, such as aircraft and missile guidance systems.
- Automotive: MATLAB is used for designing and simulating complex automotive systems, such as engines and powertrains.
- Renewable energy: MATLAB is used for modeling and simulation of renewable energy systems, such as wind turbines and solar panels.
- Overall, MATLAB is a powerful and flexible tool that can be applied to a wide range of fields and applications, making it a valuable asset for researchers, engineers, scientists, and students.

4.6. Implementation Of ELM in MATLAB

To implement an ELM in MATLAB, you can follow these steps:

1. Load the dataset: First, load the dataset that you want to use for training and testing the ELM. You can use the "load" command to load data from a file.
2. Prepare the dataset: Next, prepare the dataset by dividing it into training and testing sets. You can use the "cvpartition" function to create a partition object for cross-validation.
3. Define the ELM model: In MATLAB, you can define an ELM model using the "fitelm" function. This function takes as input the training data and the number of hidden neurons to be used in the network.
4. Train the ELM model: Once you have defined the ELM model, you can train it using the "train" function. This function takes as input the ELM model and the training data.
5. Test the ELM model: After training the ELM model, you can test its performance using the testing data. You can use the "predict" function to obtain the predicted output for the testing data.

6. Evaluate the ELM model: Finally, you can evaluate the performance of the ELM model by comparing the predicted output with the actual output. You can use various evaluation metrics such as mean squared error (MSE) or correlation coefficient.

CHAPTER 5: Results

In this chapter, in order to verify the effectiveness of the method, multiple hazy visible images data were tested. To evaluate the performance of the algorithm, compare the approach with two priori-based methods: kim[1], Tarel[7] and a dehazing algorithm based on a boundary constraint and contextual regularization meng[19].

5.1. Performance of different Features

In Chapter 3, there are seven features to learn a regression model. To determine whether these features are redundant, test different combinations of these features. Table 1 shows the accuracy of these trained model, where f1 to f7 denotes MSE, MIC, WEB, HIS, MIN, MEA, SAT, respectively. Observe that color-related features (e.g., the SAT feature) perform better than contrast-related features (e.g., the MSE feature). Although some of these features do not perform well by themselves, the model based on the combination of all seven features performs the best.

Contained features	Accuracy
f1	51.8271
f2	10.0029
f3	8.8800
f4	82.3343
f5	80.0086
f6	93.2471
f7	94.0271
f1, f5	80.0057
f1, f2, f3	10.0456
f5, f6, f7	99.7686
f1 ~f7	99.8843

Table 1: The accuracy of testing results by different combinations of features

5.2. Time Complexity

All algorithms are tested on a personal computer with an AMD Ryzen 5 3500U 2.1 GHz processor, 8 GB RAM, and 64-bit Windows 11 operating system. All the source codes are implemented with MATLAB 2022 version and ELM 2.1.0.

To provide a comprehensive efficiency comparison of different algorithms, images were tested with different resolutions. It can be observed from Table 2, the proposed method has advantages in speed and there is a linear relationship between the image resolution and the running time. Note that, considering the high computation complexity of soft matting in He et al. [4], so replace it with the guided filter [17], which has similar results, but is more efficient.

Image Resolution	Kim[1]	Meng[19]	Tarel[7]	This Method
510 × 510	0.60	4.00	2.35	0.59
576 × 768	1.00	4.64	8.96	0.87
1024 × 768	1.96	5.03	28.73	1.29
2048 × 1280	6.06	7.66	367.98	4.20

Table 2: Running times per image (second) of comparison methods at different resolutions

5.3. Result Analysis

It is essential to observe and analyze some representative images. So, the Algorithms are evaluated without adding any postprocessing or additional constraints. Each algorithm processes all test images with constant parameters and no manual adjustment.

(a) Input   **(b) Kim[1]**   **(c) Meng[19]**   **(d) Tarel[7]**   **(e) This Method**

Figure 18: wall image

Observing the figure 19, Meng[19] got the satisfied output image. The remaining two algorithms are failed to achieve better results. Kim[1]'s algorithm still has some haze in particular areas like windows. Tarel[7]'s algorithm couldn't able dehaze the foreground object i.e., on the branches of the tree.

(a) Input   (b) Kim[1]   (c) Meng[19]   (d) Tarel[7]   (e) This Method

Figure 19: China rocks image

Observing the figure 20, the visibilty of figure 20 (e) is more clear to human eye than other images and it resembles best input image. Tarel[7]'s algorithm couldn't dehaze appropriately, still there is haze between the two persons. In Kim's algorithm[1], the walls become more darker.

(a)Input   (b)Kim[1]   (c)Meng[19]

(d)Tarel[7]   (e)This Method

Figure 20: Horses image

(a)Input   (b)Kim[1]   (c)Meng[19]

(d)Tarel[7]   (e)This Method

Figure 21: School bus image

(a)Input   (b)Kim[1]   (c)Meng[19]

(d)Tarel[7]   (e)This Method

Figure 22: Traffic image

Fig. 21(a), Fig.22(a), Fig. 23(a) are some of the haze pictures, applied to the mentioned algorithms and compared with the current approach. To sum up, current method achieves better results with reduced complexity.

CONCLUSION AND FUTURE SCOPE

In conclusion, haze removal using a regression model is a promising approach for improving image quality in hazy conditions. By training a regression model using a dataset of randomly generated colored images, it can calculate the required t of a foggy image and apply it to remove the haze and restore the image's clarity. This approach has the potential to be faster and more accurate than traditional methods of haze removal and can be applied to a variety of applications, including surveillance, remote sensing, and photography. However, further research is needed to improve the accuracy and robustness of regression models for haze removal and to develop methods that can handle complex lighting conditions and scenes with multiple layers of haze.

The current model works offline and processes one image at a time. In the future, this project could be extended to perform real-time image processing, making it possible to remove haze from live video feeds, drone footage, or other applications where rapid processing is essential. Furthermore, the current project only focuses on removing haze from images. However, there are many other image enhancement techniques that could be incorporated, such as image denoising, color correction, or contrast adjustment. Combining these techniques could produce even better results.

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