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Multispectral Satellite Image Dehazing

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ABSTRACT—

The challenge of picture dehazing has been around from the early days of computer vision research. Photographs shot during inclement weather can appear to be of worse quality because of the abundance of air particles that generate haze. We previously used a static approach called dark channel to remove haze from the photographs. The coverage of ground-based air pollution monitors is restricted, but they provide consistent results. Although they have a large coverage area, satellites have little data on the vertical distribution of contaminants and poor spatial resolution. Pollution concentrations at the surface, where they are generated, are difficult to determine. We wish to propose a framework to handle this issue. The goal of this research is to present a method that includes dehazing a multispectral using a satellite image and calculating the proportion of nitrogen oxides to provide a pollution range for the area.

Keywords— Multispectral images , Dehazing , Dark channel prior , Pollution sensors, Nitrogen oxides.

I. INTRODUCTION

Haze often arises from tiny airborne particles like smoke, dust, and water droplets, significantly reducing visual clarity. Air particle dispersion can severely affect photos shot in hazy or foggy conditions. This can reduce contrast, change colour, and make it difficult for the human eye to detect object characteristics. The goal of picture dehazing is to improve an image's aesthetic effects by lessening the influence of external factors. To remove haze from the photos, we apply the Dark Channel Prior algorithm. The concentrations of nitrogen oxides are estimated using additional processing on the dehazed photos to offer an estimate of pollution. The main causes of climate change are air pollution and greenhouse gas emissions. Anthropogenic greenhouse gas emissions, or GHGs, are released into the atmosphere when fossil fuels are burned in factories or in cars. These emissions further exacerbate global warming trends. In addition to the primary greenhouse gases and CO2, The combustion of fossil fuels emits compounds such as NO2 and CO, making them useful reference points for estimating CO2 emissions.

A. Key concepts to familiarize

Multispectral image: A multi-spectral image is an amalgam of multiple monochromatic photos taken of the same scene using different sensors. A band is employed in explain every picture. An established illustration of a multispectral (or multiband) image is the RGB color image, composed of separate red, green, and blue images captured using sensors responsive to distinct wavelengths.

B. Problem Definition

Atmospheric haze frequently affects satellite photos, lowering the standard of their performance and making it more challenging to extract meaningful information from them. Thus, efficient techniques to clear the fog and obtain data are required. A few models, including OpenCV, CNN, and Dark Channel Prior (DCP), were evaluated. Since DCP performs better than the other methods, we decided to stick with it.

The ultimate goal of this project entails devising and implementing tactics for dehazing and identifying NO2 from satellite imagery and air quality stations. Additionally, it aims to establish a mean value for NO2 to address concentration disparities using image processing and remote sensing information.

C. Objectives

Developing a framework for handling a dataset comprising images of haze and information on nitrogen oxide concentrations across the region is the aim. We start by using the dark channel prior (DCP) method to get rid of the haze. Next, use the dehazed image to compute the nitrogen oxide concentrations.

The aims of this project are:

• To generate a clear image from one that is obscured by haze.

• Enhancing color accuracy in remote-sensing imagery.

• To enhance the precision of images affected by haze

• To determine the concentration of NO2 in the atmosphere.

II. LITERATURE SURVEY

[1] This study proposes employing the TROPOMI satellite sensor to examine how the NO2 mapping technique responds to aerosol and surface reflectance variations across eastern China. The study emphasises how crucial it is to take aerosol effects into account when attempting to recover the No2 concentration from satellite data.

Numerous methods for dehazing multispectral images, as suggested in prior research, are available. But they displayed the dehazing of the remote sensing image.

In this condition of artwork, the design or technology was responsible for the physical dehazing and transmission estimation. The data was derived from previously dehazed pictures, and they also attempted to enhance the evolution of image quality.

[2] This work suggests a technique for utilising the DCP to dehaze satellite pictures and air quality station data to estimate the No2 content. It is demonstrated that the technique can reliably measure the NO2 content in the photos and remove the haze from them.

[3] This work suggests a multi-objective optimisation technique for raising the precision of No2 estimates obtained from OMI satellite retrievals. It is demonstrated that the technique works well for lowering estimation errors for No2 concentration and enhancing the data's spatial resolution.

[4] Employing the optimal estimation technique, this study proposes a method to improve the estimation of column densities for NO2 and SO2 using satellite-based hyperspectral data. It is demonstrated that the approach is successful in lowering data mistakes and raising estimate accuracy.

[5] This research suggests a surface reflectance limitation and dark channel prior for dehazing remote sensing photos. It has been demonstrated that using this procedure to remove undesirable particles improves the visual quality of the photographs.

[6] This paper examines a case study focusing on estimating NO2 emissions originating from coal-fired power plants in India through the analysis of satellite remote sensing data. The study shows how satellite data can be used to reliably and promptly provide information on the causes of air pollution and how it affects the ecosystem.

[7] This work presents a physically grounded model for atmospheric scattering as the basis for a dehazing technique for remote sensing photographs. It is demonstrated that the technique works well to reduce haze and enhance image vision, particularly in areas with high aerosol concentration.

[8] This study proposes a method for dehazing satellite imagery employing a guided filter and dark channel prior, showcasing its effectiveness in removing haze and improving visual clarity in the photographs.

[9] The initial step in the defogging process is assessing whether an image exhibits clarity or fog. To achieve this, the study proposes employing 19 categorization algorithms aimed at discerning the clarity status of images. These algorithms are trained using criteria such as area, mean, minimum intensity, maximum intensity, and standard deviation, enabling the system to differentiate between clear and foggy images.

[10] If a single image undergoes dehazing with a dark channel preprocessing, there's a risk of color distortion, particularly in brighter regions such as the sky. To address this issue, three alternative approaches are proposed to mitigate the limitations of the original algorithm. Initially, a transmission threshold is established, followed by three different algorithms utilizing this threshold to adjust the transmission map for fog, effectively managing scenarios involving the sky, white objects, and other elements. To streamline the computational process, the transmission map is refined using a fast guided filter. Experimentation results suggest that these methods hold promise for improving visibility and reducing color distortion in outdoor photographs.

[11] In this study, a physically grounded model for air scattering serves as the basis for a dehazing technique for remote sensing photos. It is demonstrated that the technique works well to reduce haze and enhance image vision, particularly in areas with high aerosol concentration.

[12] The dehazing technique for satellite images presented in this research uses a guided filter and dark channel prior. It is demonstrated that the technique successfully eliminates the haze and enhances the photographs' visual quality.

[13] The objective of image dehazing involves quantifying the extent of data loss in images resulting from smoke, haze, and fog during the capture process. Given that degradation leads to contrast and color information loss, enhancing image quality is crucial in various applications and consumer photography. This study illustrates the impact of the dehazing model on color information through analysis of both simulated and authentic images.

[14] In this study, a straightforward yet efficient image prior known as the dark channel prior is introduced for the purpose of haze removal from individual input images. By analyzing statistics derived from clear outdoor photographs using the dark channel prior, it is observed that in most local areas of haze-free outdoor images, there exist pixels with extremely low brightness in at least one color channel. Leveraging this observation, the thickness of haze can be estimated, and a clear, haze-free image can be generated by integrating this knowledge with the haze imaging model. Results obtained from various outdoor hazy images validate the efficacy of the proposed prior.

A. Equations

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

The hazed image, denoted as $I(x)$, can be expressed as the summation of the haze-recovered image and haze particles.

$J(x)$ represents the image devoid of haze particles.

The variable $t(x)$ denotes the transmission map.

A represents the estimation of atmospheric light.

III. METHODOLOGY

The methodology can be divided into two distinct steps:

1) Image Dehazing

2) Pollution Estimation

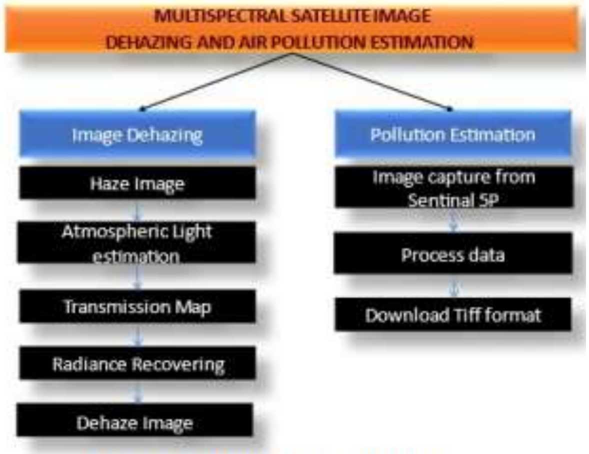

Fig 1.2: Flow of the project

3.1) Image Dehazing:

We use a statistical method called the dark-channel prior technique to complete this step.

First, we begin by extracting the atmospheric light from the hazy image within the DCP algorithm. Subsequently, the transmission map is formulated, followed by a refinement process to enhance the generated transmission. Following this, the radiance of the intermediate image is restored, resulting in the dehazed image.

3.2) Estimation of pollution levels:

• Various approaches, including the utilization of air quality monitoring stations, satellite remote sensing, or modeling techniques, can be employed to assess nitrogen dioxide (NO_2) pollution levels.

• Air quality monitoring stations, equipped with ground-based sensors, evaluate the concentration of NO_2 at specific locations. Despite being limited to the areas in which they are installed, they provide accurate and consistent measurements.

• One can utilize the subsequent methods to gauge NO_2 levels through air quality monitoring stations:

1. Locate the area of interest's air quality monitoring stations.

2. Acquire each station's No2 measurements.

3. Determine the average NO_2 concentration for every station during a given time frame, such as a day, week, or month.

Combine the data from individual stations to calculate the average concentration of NO_2 across the entire area of interest.

• Estimating pollution entails employing remote sensing methodologies, such as the Differential Optical Absorption Spectroscopy (DOAS) technique, to analyze the NO_2 levels present in satellite imagery. Examination of the UV-VIS region of sunlight absorption provides an assessment of the NO_2 content. The accuracy of the NO_2 concentration estimates is then assessed by contrasting them with data from ground-based air quality stations.

• Image processing methods like image dehazing, which eliminates air haze and improves the colour and contrast of the satellite photos, can be used to increase the colour fidelity. A popular technique for image dehazing is the Dark Channel Prior (DCP) algorithm, which calculates the scene transmission and subtracts it from the original image to eliminate haze.

• Using remote sensing methodologies such as the DOAS method to extract NO2 concentration from satellite imagery facilitates the assessment of NO2 levels in the atmosphere. The conversion of estimated NO2 concentration into atmospheric NO2 levels involves considering the molar mass and vertical column density of NO2. An area's pollution and air quality can be estimated using the amount of NO2 in the atmosphere.

IV. PROPOSED SYSTEM

Dark Channel Prior

The DCP (Dark Channel Prior) method, a popular approach for image dehazing, leverages the statistical characteristics of the dark channel observed in hazy images..

• Efficient image processing to produce a higher-quality visual image

• It is a type of statistics of photos taken outside without haze.

• It is predicated on an important finding. Many local patches in the photos often comprise a small number of pixels with very low intensity in at least one channel.

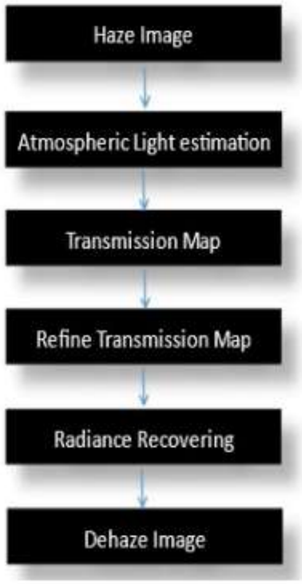

Fig1.3 Flow Chart of Image Dehazing

The procedure for conducting image dehazing using DCP can be outlined as follows:

- Create the dark channel: The dark channel of a two-dimensional image comprises pixel values indicating the minimum intensity within a local window surrounding each pixel in the picture. This can be computed efficiently with a box filter.
- Estimate the atmospheric light: The brightest pixel in the fuzzy image is represented by a vector called ambient light. The top 0.1% of brightest pixels in the dark channel can be used to estimate it.
- Compute the transmission: The quantity of haze at each pixel in a 2D image that is transmitted is represented by its pixel values. The calculation of the transmission map can be achieved using the following equation: : $t(x) = 1\text{-}w * \min(R, G, B) / A$, where A denotes the atmospheric light, R, G, and B represent the color channels of the image, and w stands for a weighting factor..
- Perform soft matting: A method called soft matting reduces artefacts by smoothing the transmission pattern. One way to do this is with a guided filter.
- Compute the dehazed image: The following formula can be used to calculate the dehazed image: With I(x) representing the input fuzzy image, t(x) representing the estimated transmission, t0 a tiny constant to prevent division by zero, and A representing the estimated ambient light, $J(x) = (I(x) - A) / \max(t(x), t0) + A$.

In computer vision and image processing, Dark Channel Prior (DCP) is a popular picture enhancing method. The primary advantage of employing DCP is that it is an easy and efficient way to eliminate haze or fog from pictures. The following are some benefits of DCP over alternative techniques:

Simplicity: DCP is an easy-to-implement, rather straightforward algorithm. Because it doesn't call for any specialised gear or intricate mathematical calculations, it's a technique that may be used by both scholars and professionals.

Rapid processing: DCP demonstrates swift algorithmic performance, capable of handle big photos instantly. This makes it appropriate for use in systems like surveillance cameras or driverless cars that need fast processing speeds.

High-quality results: DCP generates images of excellent quality with few artefacts. It successfully eliminates haze from photos while keeping key elements like textures and borders.

Sturdiness: DCP exhibits robust algorithmic capabilities, effectively adapting to diverse image types and environments. It functions effectively in both indoor and outdoor settings, and it is compatible with both colour and grayscale photos.

No prerequisite expertise needed: DCP operates without the need for prior knowledge of the scene or camera configurations. Any image can use it; no manual changes or calibration are required.

DCP is widely favored for enhancing images across various applications owing to its user-friendly interface, rapid processing speed, and superior output quality.

Pollution Estimation:

- ➢ □ Collect data:

• Utilize Google Earth Engine to acquire the raster file of nitrogen dioxide from the Sentinel-5P satellite, followed by downloading it in TIFF format.

• sharpening and improving the satellite photos using DCP.

- ➢ □ Preprocess data:

• Utilize the Rasterio library to import the raster file into the Python environment.

• Take the raster file and extract the No2 data.

• Utilise the SNAP software to detect regions with elevated N2 concentrations by visualising the No2 data as a colour spectrum.

• Open the CSV file that has the Indian cities' latitude and longitude coordinates in it.

- ➢ □ Process data:

• To retrieve the latitude and longitude coordinates for each city, iterate through the CSV file using a loop.

• For each city, identify the corresponding row and column indices in the NO2 raster file using the Rasterio library.

• From the raster file, extract the No2 pixel value for every city.

• Utilising the formula No2_concentration = (pixel_value * M) / V, where M is the molar mass of No2 in g/mol and V is the vertical column density of No2 in mol/m2, determine the No2 concentration in $\mu g/m^3$.

Display the outcomes for each city.

- ➢ □ Validate data:

• Integrate the estimated NO2 concentrations with the cities' known NO2 concentration data.

• Evaluate the accuracy of the No2 concentrations determined from the satellite data using the statistical analysis results.

V. EXPERIMENTAL RESULTS:

Dehazing results:

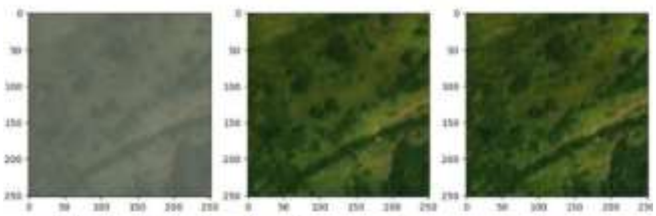

Fig.3 : Dehazing of an image containing agriculture and a primary road

(The provided image displays the outcomes obtained through the application of the DCP algorithm for haze and unwanted particle removal. The initial image showcases the dehazed result, while the final image depicts the corresponding output)

Estimation of Nitrogen oxide :

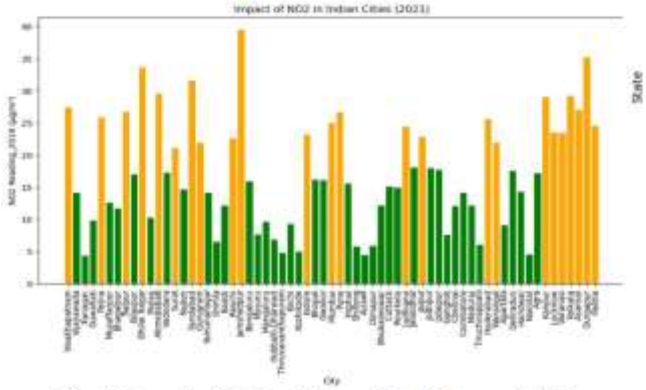

Fig.4 : Impact of No2 in Indian cities in the year 2021

(The graphic shows the amounts of nitrogen oxides for the year 2021 in different cities. Cities are represented by the x-coordinates, and No2 readings between 0 and 40 µg/m3 are represented by the y-coordinates. Green denotes a city that is safe and below the threshold. The colour yellow denotes that it is dangerous for the city and is above the threshold. Government regulations should be implemented to regulate the nitrogen level because it poses a risk to city dwellers.)

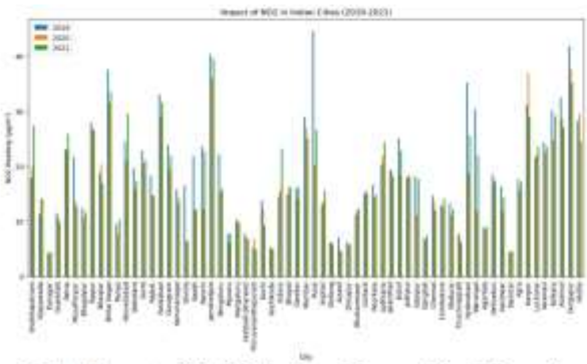

Fig 5. : Impact of No2 in Indian cities combined from the year 2019 to 2021

(The bar plot displays the nitrogen concentrations in the various cities between 2019 and 2021.Pune's pollution control has improved, but Visakhapatnam's has been worse over time.)

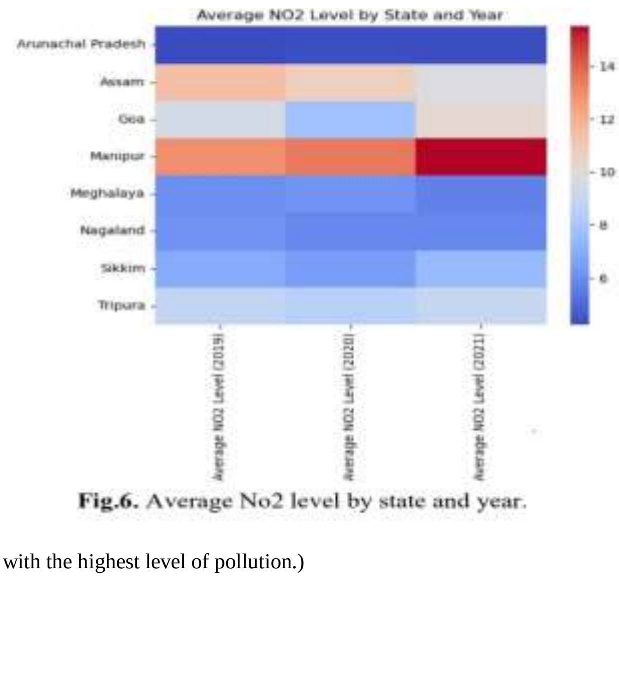

Fig.6. Average No2 level by state and year.

(Andhra Pradesh remained the state with the highest level of pollution.)

City	NO2 Reading_2019 (μg/m³)
Pune	44.59612918
Durgapur	41.76118494
Jamshedpur	40.38599279
Bhilai Nagar	37.5063499
Hyderabad	35.16364659
Faridabad	32.97632586
Asansol	32.48180214
Kanpur	31.17096637
Warangal	30.30816807
Kolkata	30.13790922

City	NO2 Reading_2021 (μg/m³)
Jamshedpur	39.50281803
Durgapur	35.18819976
Bhilai Nagar	33.52375979
Faridabad	31.60051471
Ahmedabad	29.49158315
Kolkata	29.15759123
Kanpur	28.92341746
Visakhapatnam	27.33148919
Asansol	27.00796278
Raipur	26.67608518

Fig.7: Top 10 Cities by No2 Levels in year 2019 and 2021

City	NO2 Reading_2019 (μg/m³)
Itanagar	4.238407384
Nainital	4.296494171
Kozhikode	5.13884608
Thiruvananthapuram	5.191062848
Shillong	6.009031089
Dimapur	6.125036488
Gangtok	6.880493035
Aizawl	7.122264573
Hubballi-Dharwad	7.680780325
Tiruchirappalli	7.774439923

City	NO2 Reading_2021 (μg/m³)
Agartala	9.002321986
Agra	17.11908056
Ahmedabad	29.49158315
Aizawl	4.355136823
Asansol	27.00796278
Baddi	12.05839113
Bengaluru	15.84508156
Bhagalpur	11.64886594
Bhilai Nagar	33.52375979
Bhopal	16.09614676

Fig.8: Bottom 10 Cities by No2 Levels in year 2019 and 2021

VI. CONCLUSION

In this study, we investigated methods for utilising data from air quality stations and sentinel satellite photos to identify No2 and dehaze the images. To improve and sharpen the visual clarity of the satellite photos and get rid of the haze, we used the dark channel prior approach.

To ascertain the absorption of NO2 in the atmosphere and at ground level and to derive a precise concentration estimate for the Indian subcontinent, spectral analysis techniques were also employed.

VII. FUTURE SCOPE

The research can be expanded to incorporate more dehazing techniques for satellite images, like guided filters and multi-scale Retinex, and evaluate their efficacy with DCP. By adding more sophisticated atmospheric correction models and taking other atmospheric gases into consideration, the No2 detection can be improved even more.

To investigate the variations in NO2 concentration across regions and timeframes and understand their correlation with environmental factors and human activities, the project can be expanded to encompass diverse locations and time periods. By integrating with additional remote sensing data like meteorological and land use data, a comprehensive analysis of atmospheric and environmental conditions in the specified region can be achieved.

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