Multispectral satellite Image Dehazing and Pollution Estimation

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***Abstract*— Since the beginning of computer vision, the difficulty of picture dehazing has existed. Due to the presence of numerous air particles, which causes hazed photos, images taken during bad weather circumstances sometimes appear to be of inferior quality. To eliminate haze from the photos, we use a static technique called dark channel before. Ground based air pollution sensors give regular readings but have limited coverage. Satellites offer broad global coverage but poor spatial resolution and insufficient data on the vertical distribution of pollutants. It is not easy to estimate the concentrations of pollutants at the surface, where they are produced. In order to address this problem, we want to offer a framework. This project focuses on providing an approach incorporating the dehazing of a multispectral satellite picture and providing a pollution range of the region by estimating the percentage of nitrogen oxides.**

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

I. INTRODUCTION

Little airborne particles (dust, smoke, and water drops) frequently generate haze, a condition that reduces the clarity of images. Pictures taken in hazy or foggy weather can suffer significantly from air particle dispersion, which lowers contrast, alters colour, and makes object characteristics challenging to distinguish by human eye. Image dehazing's purpose is to reduce the impact of environmental influences on the image in order to enhance its aesthetic effects. We use Dark Channel Prior algorithm to dehaze the images. The dehazed images are further processed to provide pollution estimation by estimating the concentrations of nitrogen oxides. The primary contributors to climate change are GHG emissions and air pollution. The environment is harmed by anthropogenic GHG emissions from the burning of fossil fuels in industrial facilities or automobiles, which also contribute to the trends in global warming. Burning fossil fuels releases chemicals like No2 and CO in addition to the main GHG and Co2 .Hence, it can be used as standards for measuring Co2 emissions.

A. Terms to be know

Multispectral image: A multi-spectral image is a compilation of several mono-chromatic pictures captured with various sensors of the same scene. A band is used to describe each image. The RGB colour image, which consists of red, green, and blue images, each captured using a sensor sensitive to a distinct wavelength, is a well-known example of a multispectral (or multiband) image.

B. Problem Definition

The Satellite images are often affected by atmospheric haze, which reduces their quality and makes it difficult to extract useful information from them. So, there is a need for effective methods to remove the haze and gain information.

We compared few models such as OpenCV, Convolutional Neural Network (CNN) and Dark Channel Prior (DCP) and we continued with DCP since it is performing well compared to methods.

The ultimate goal of this project is to develop and implement methods for dehazing and No2 detection from satellite images and air quality station and get an average value for No2 to address the issue of deviancy of concentrations using remote sensing data and image processing techniques

C . Objectives

The goal is to create a framework for dealing with a dataset that includes photos of haze and data on nitrogen oxides over the area. Dark channel prior (DCP) method is the first thing we put into practice to eliminate the haze. Then calculate the nitrogen oxide concentrations using the dehazed picture.

The Objectives of this project are:

- To have a dehazed image from a hazed image.
- To improve colour fidelity in remote-sensing images.
- To improve the accuracy of hazed image
- To find the No2 levels in the atmosphere.

II. A REVIEW OF LITERATURE

[1] This paper proposes a study on the sensitivity of No2 mapping algorithm to aerosol and surface reflectance over eastern China using the TROPOMI satellite sensor. The study highlights the importance of accounting for aerosol effects in the retrieval of No2 concentration from satellite data.

There are many strategies for dehazing the image using the multispectral behaviours that have been put forth in earlier studies. However they showed the remote sensing image dehazing.

The design or the technology involved in this state of art-work was they did the physical dehazing estimating the transmissions. The data was driven based on earlier dehazed images and also they worked on improving the image quality evolution.

[2] This paper proposes a method for dehazing satellite images using the DCP and estimating the NO_2 concentration using air quality station data. The method is shown to effectively remove the haze and accurately estimate the NO_2 concentration in the images.
[3] This paper proposes a method for improving the accuracy of NO_2 estimates from OMI satellite retrievals using multi-objective optimization. The method is shown to be effective in reducing the errors in the NO_2 concentration estimates and improving the spatial resolution of the data.
[4] This paper proposes a method for improving the estimation of NO_2 and SO_2 column densities from satellite based hyperspectral data using the optimal estimation technique. The method is shown to be effective in improving the accuracy of the estimates and reducing the errors in the data.
[5] This paper proposes a dehazing method for remote sensing images using the dark channel prior and surface reflectance constraint. The method is shown to effectively eliminate the unwanted particles and results in betterment of the visual quality of the images.
[6] This review article provides an overview of the methods for detecting nitrogen dioxide (NO_2) pollution from space using remote sensing data, including the use of satellite sensors such as OMI and TROPOMI. The article discusses the challenges and limitations of the methods and their applications in environmental monitoring.
[7] This paper demonstrate a case study on the use of satellite remote sensing data for estimating NO_2 emissions from coal fired power plants in India. The study demonstrates the potential of satellite data in providing accurate and timely information on air pollution sources and their impact on the environment.
[8] This paper proposes a dehazing method for remote sensing images based on a physically based model for atmospheric scattering. The method is shown to be effective in removing the haze and improving the visibility of the images, especially in regions with high aerosol concentration.
[9] This paper proposes a dehazing method for satellite images based on the dark channel prior and guided filter. The method is shown to effectively remove the haze and improve the visual quality of the images.
[10] For the purpose of defogging photos, it is first determined if the image is foggy or clear. As a person's vision cannot be used to make this determination, it is necessary to first understand whether the image is foggy or clear. 19 categorization approaches are used in this proposed study to determine if an image is clear or foggy. The five characteristics of area, mean, min intensity, max intensity, and standard deviation are utilised to train the classification system based on the distinctive differences between foggy and clear images.
[11] If a single picture is dehazed using a dark channel previously, the bright region may experience colour distortion (such as sky region). To get over the original algorithm's restrictions, three solutions are suggested. First, a transmission threshold was established. Next, three algorithms are able to successfully handle the sky, white object, and other situations by applying the threshold to modify the transmission map in various ways and make it adaptable to fog. Fast guider filter was used to refine the transmission map in order to simplify the computation process. The results of the experiments demonstrated that these techniques may be used to improve visibility as well as remove colour distortion from outdoor images.
[12] This paper presents a dehazing method for remote sensing images based on a physically based model for atmospheric scattering. The method is shown to be effective in removing the haze and improving the visibility of the images, especially in regions with high aerosol concentration.
[13] This paper presents a dehazing method for satellite images based on the dark channel prior and guided filter. The method is shown to effectively remove the haze and improve the visual quality of the images.
[14] Image dehazing seeks to quantify the amount of picture data lost as a result of fog, haze, and smoke in the scene at the time of capture. In image applications and consumer photography, enhancement is a necessary duty since degradation results in a loss of contrast and colour information. This paper use simulated and actual photos to show how the dehazing model impacts colour information.
[15]To eliminate haze from a single input image, this paper offer a straightforward yet efficient image prior dark channel prior in their study. A type of statistics of the haze free outdoor photographs may be found in the dark channel earlier. Its foundation is a crucial finding: most local patches in haze free outdoor photos contain some pixels with extremely low brightness in at least one colour channel. By combining this prior with the haze imaging model, they are able to directly calculate the haze's thickness and recover a clear, haze free picture. Results on a range of photographs of outdoor haze show how effective the suggested prior is.

A. Equations

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

Here I(x) is hazed image ,which can be represented as a combination of haze recovered image and haze particles.
J(x) is the image without haze particles.
t(x) is transmission map
A is atmospheric light estimation.

III. Methodology

The methodology may be broken down into two steps:
1) *Image Dehazing*
2) *Pollution Estimation*

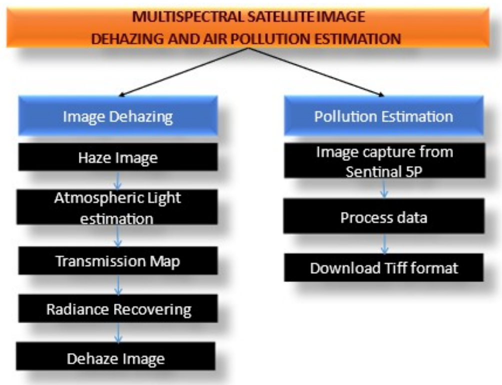

Fig 1.2: Flow of the project

3.1) Image Dehazing:

To carry out this phase, we employ a statistical procedure known as the dark-channel prior technique.

In DCP algorithm, we first calculate the atmospheric light from the haze im-age. Then, the transmission map is built after that. The constructed transmission now has to be refined, therefore it will go through this procedure to offer a refined transmission map, which will then be followed by recovering the radiance in the intermediate picture to create the dehazed image.

3.2) Pollution Estimation:

- Nitrogen dioxide (No2) pollution levels can be estimated using a variety of techniques, including air quality monitoring stations, satellite remote sensing, or modelling.

- Ground-based sensors known as air quality monitoring stations measure the amount of No2 in the air at specified sites. Although they are confined to the locations where they are deployed, they precise and dependable measurements.

- To estimate No2 levels using air quality moni stations, one can use the following steps:

1.Identify the air quality monitoring stations area of interest.

2.Obtain the No2 measurements from each stati

3.Calculate the average No2 concentration fo station over a specific time period (e.g., weekly, monthly).

Combine the station-level data to estimate the av No2 concentration for the entire area of interest.

- Pollution estimation is providec analyzing the NO2 concentration i satellite images using remote s techniques such as the Differential C Absorption Spectroscopy (DOAS) m The NO2 concentration is estimate analyzing the absorption of sunlight ... ... UV-VIS range. The estimated NO2 concentration is then compared with the ground-based air quality station data to evaluate the accuracy of the remote sensing measurements.

- The color fidelity can be improved by using image processing techniques such as image dehazing, which removes the atmospheric haze and enhances the color and contrast of the satellite images. The Dark Channel Prior (DCP) algorithm is a widely used method for image dehazing, which estimates the scene transmission and removes the haze by subtracting it from the original image.

- The NO2 level in the atmosphere can be found by extracting the NO2 concentration from the satellite images using remote sensing techniques such as the DOAS method. The estimated NO2 concentration is then converted into NO2 level in the atmosphere using the molar mass of NO2 and the vertical column density of NO2. The NO2 level in the atmosphere can be used to estimate the air quality and pollution levels in a region.

IV. PROPOSED SYSTEM

Dark-Channel-Prior

A popular image dehazing method called DCP (Dark Channel Prior) uses the statistical characteristics of the dark channel in hazy photos to its advantage.

- Effective image processing to give improved image in terms of visual quality
- It is a kind of statistics of outdoor haze free images.
- Its is based on a key observation. Usually many local patches in the images contains few pixels, which have very low intensity in minimum of one channel.

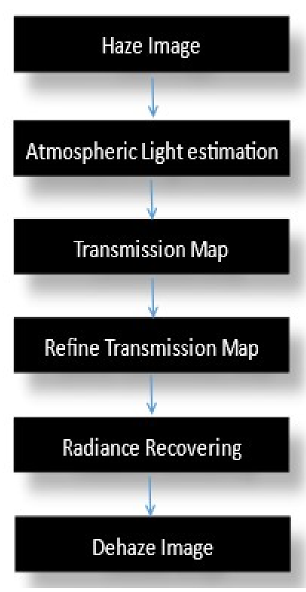

Fig1.3 Flow Chart of Image Dehazing

The steps for performing image dehazing with DCP are as follows:

- **Create the dark channel**: A 2D picture whose pixel values represent the lowest intensity in a local window around each pixel is the dark channel of an image. A box filter can be effectively used to compute this.
- **Estimate the atmospheric light**: The atmospheric light is a vector that represents the radiance of the brightest pixel in the hazy image. It can be estimated using the top 0.1% brightest pixels in the dark channel.
- **Compute the transmission**: The transmission of an image is a 2D image whose pixel values represent the amount of haze at each pixel. It can be estimated using the following equation: $t(x) = 1 - w * \min(R, G, B) / A$, where w is a weighting factor, R, G, and B are the color channels of the image, and A is the atmospheric light.
- **Perform soft matting**: Soft matting is a technique that smooths the transmission map to reduce artifacts. This can be done using a guided filter.
- **Compute the dehazed image**: The dehazed image can be computed using the following equation:

  $J(x) = (I(x) - A) / \max(t(x), t0) + A$, where $I(x)$ is the input hazy image, $t(x)$ is the estimated transmission, t0 is a small constant to avoid division by zero, and A is the estimated atmospheric light.

Dark Channel Prior (DCP) is an image enhancement technique that is widely used in computer vision and image processing. The main benefit of using DCP is that it is a simple and effective method for removing haze or fog from images. Here are some of the advantages of using DCP over other methods:

Simplicity: DCP is a relatively simple algorithm that is easy to implement. It does not require any complex mathematical operations or specialized hardware, making it an accessible method for both researchers and practitioners.

Fast processing: DCP is a fast algorithm that can process large images in real time. This makes it suitable for use in applications that require quick processing times, such as autonomous vehicles or surveillance systems.

High-quality results: DCP produces high quality results with minimal artifacts. It effectively removes haze from images while preserving important image features, such as edges and textures.

Robustness: DCP is a robust algorithm that can handle a variety of image types and conditions. It works well with both color and grayscale images and is effective in both indoor and outdoor environments.

No prior knowledge required: DCP does not require any prior knowledge of the scene or the camera parameters. It can be applied to any image without the need for calibration or manual adjustments.

Overall, the simplicity, speed, and high quality results of DCP make it a popular choice for image enhancement in a variety of applications.

Pollution Estimation:

- **Collect data:**
  - Obtain No2 raster file from Sentinel-5P satellite using Google Earth Engine and download as a TIFF file.
  - Using DCP for enhancing and sharpening the satellite images
- **Preprocess data:**
  - Load the raster file into the Python environment using the Rasterio library.
  - Extract the No2 data from the raster file.
  - Use the SNAP software to visualize the No2 data using a color spectrum to identify areas with high N2 concentrations.
  - Load the CSV file containing the latitude and longitude coordinates for Indian cities.
- **Process data:**
  - Loop through the CSV file to extract the latitude and longitude coordinates for each city.
  - Use the Rasterio library to find the corresponding row and column indices in the No2 raster file for each city.
  - Extract the No2 pixel value for each city from the raster file.
  - Calculate the No2 concentration in $\mu g/m^3$ using 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.

  Print the results for each city.
- **Validate data**:
  - Combine the calculated No2 concentrations with known No2 concentration data for the same cities.
  - Use the results of the statistical analysis to assess the accuracy of the No2 concentrations calculated using the satellite data.

V. EXPERIMENTAL RESULTS:

Dehazing results:

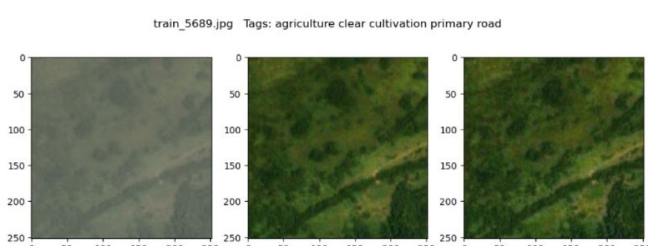

Fig.3 : Dehazing of an image containing agriculture and a primary road

(Above image shows the results generated using DCP algorithm to remove haze and other unwanted particles from the image. The first image shows the dehazed image and the last image is the corresponding dehazed image)

Estimation of Nitrogen oxide :

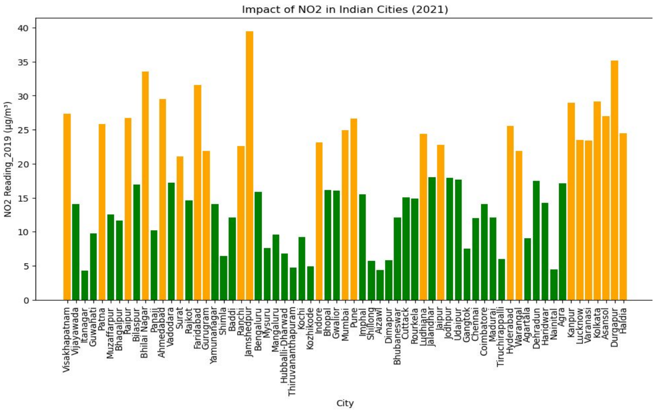

Fig.4 : Impact of No2 in Indian cities in the year 2021

(The plot depicts the nitrogen oxides levels in various cities for the year 2021.The x-coordinates represent cities and y-coordinates represent No2 reading ranging from 0 to 40 µg/m3.Green indicates its below the threshold its safe city. Yellow indicates its above the threshold and it is dangerous for the city. The Nitrogen level should be controlled by the government measures as its dangerous for the people in the city)

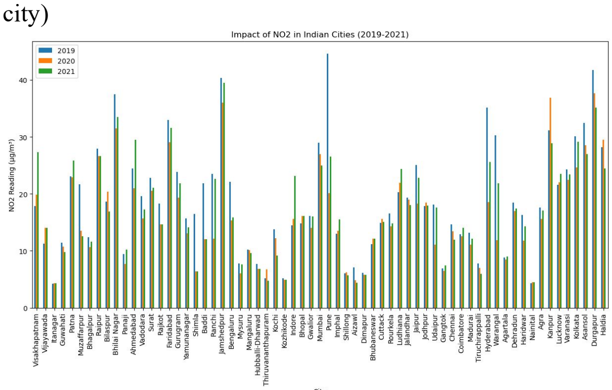

Fig 5. : Impact of No2 in Indian cities combined from the year 2019 to 2021

(The bar plot shows the concentrations of nitrogen in the different cities from the year 2019 to 2021.Pune has improved in the terms of pollution control , while the Visakhapatnam worsen over the years)

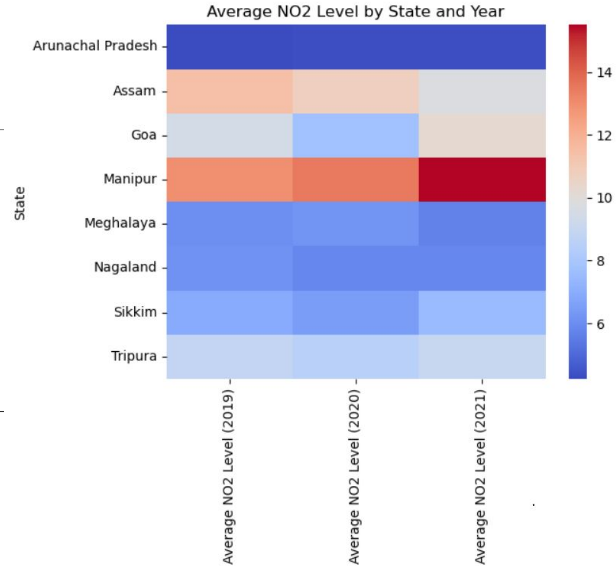

Fig.6. Average No2 level by state and year.

(Andhra Pradesh continued to be most polluted state than any other state)

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

Conclusion

In this project, we have explored the techniques for dehazing satellite images and detecting No2 using sentinel satellite images and air quality station data. We have implemented the dark channel prior method to remove the haze from the satellite images and enhance and sharpen their visual quality. We have also used spectral analysis to detect the absorption of No2 in the atmosphere and the ground level and give a whole value to its concentration in the region of India.

VII. FUTURE SCOPE

The project can be extended to include other methods for dehazing satellite images, such as multi-scale Retinex and guided filter, and compare their performance with DCP. The No2 detection can be further refined by incorporating more advanced models for atmospheric correction and accounting for the effect of other atmospheric gases.

The project can be applied to other regions and time periods to investigate the spatial and temporal variations of No2 concentration and their relation to environmental and human activities. The project can be combined with other remote sensing data, such as meteorological data and land use data, to provide a comprehensive analysis of the atmospheric and environmental conditions in the given region.

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