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Satellite Imagery System for Pruning Vegetation Interference in Power Transmission Lines

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Abstract: *Vegetation encroachment in power transmission lines can cause outages, which may result in severe impact on electricity board as well as the consumer. Vegetation detection and monitoring along the power lines are implemented to protect power transmission lines from vegetation interference. There were various methods used to monitor the vegetation interference with power transmission lines, however, most of them were too expensive and time consuming. Satellite images can play a pivotal role in vegetation monitoring, because it can cover high spatial area with relatively low cost. The current methods depend usually on setting manually threshold values and parameters which make the detection process very static. Machine Learning (ML) and deep learning (DL) algorithms can provide a very high accuracy with flexibility in the detection process. Hence the potential of using Deep Learning based algorithms are also included. The input data were derived from satellite images, UAV images and other aerial images. This work is significant because it shows how satellite images that are already commercially available can be used for the large-scale assessment of vegetation encroachment on transmission lines.*

Keywords: DeepForest, Hough Transforms, Vegetation interference with transmission lines

I. INTRODUCTION

In modern power transmission systems, maintaining the transmission lines is important for ensuring reliable electricity supply. One of the critical challenges faced by the Electricity board is the management of vegetation interference along transmission lines. Vegetation encroachment poses a significant risk to power infrastructure, leading to outages, safety hazards, and environmental concerns. By leveraging the capabilities of satellite imagery and deep learning, a satellite imagery system for pruning vegetation interference in power transmission lines offers a proactive rather than reactive and data-driven approach to vegetation management.

Problem Statement

Vegetation encroachment poses a critical challenge to power transmission systems, leading to outages, safety hazards, and environmental concerns. Traditional methods for monitoring vegetation interference along transmission lines are costly and time-consuming, often resulting in reactive rather than proactive maintenance. To address this issue, a proactive and data-driven approach utilizing satellite imagery and deep learning techniques has been proposed. However, existing methods rely on manual threshold setting and lack flexibility in detection processes. Therefore, there is a need for an automated system that can accurately detect and monitor vegetation encroachment along power transmission lines using satellite imagery and deep learning algorithms while offering real-time monitoring capabilities.

Scope

The scope of this project encompasses several key components aimed at addressing the challenge of vegetation interference along power transmission lines through the utilization of satellite imagery and deep learning techniques. A robust vegetation detection algorithm will be developed, leveraging deep learning methodologies, to accurately identify and delineate vegetation encroachment along the transmission lines. Complementing this, a power-line identification module will be implemented to contextualize the detected vegetation by identifying the power infrastructure within the satellite imagery. Integration of these modules will enable comprehensive analysis to assess the extent of vegetation interference and prioritize maintenance efforts accordingly. A user-friendly web interface will be designed to visualize the analysis results, facilitating interactive exploration and decision-making.

Purpose

The purpose of the system is to provide a proactive and data-driven approach to vegetation management along power transmission lines, aiming to mitigate the risks associated with vegetation encroachment. By leveraging satellite imagery and deep learning techniques, the system seeks to accurately detect and monitor vegetation interference, thereby reducing the likelihood of outages, safety hazards, and environmental concerns. Through automated analysis and visualization of the detected vegetation and power-line infrastructure, the system enables electricity board to make informed decisions regarding maintenance prioritization. Additionally, the system aims to enhance efficiency by replacing traditional, costly, and time-consuming monitoring methods with a more scalable and cost-effective solution. Ultimately, the purpose of the system is to ensure the reliable operation of power transmission infrastructure while minimizing disruptions and ensuring safety for both the electricity board and consumers.

Deep learning

Deep learning, a subset of artificial intelligence, has emerged as a powerful tool for solving complex problems by enabling machines to learn from data. Making use of the rapid expansion of Earth observation data from various sources like satellite imagery, UAV imagery, deep learning has been effectively applied to various applications in remote sensing and environmental monitoring, including **land cover classification, scene classification, object detection, change detection, multimodal fusion, segmentation, and object-based image analysis.** Deep learning has been used in this system for predicting the vegetation growth that can potentially harm the transmission lines.

Deep Forest Algorithm

DeepForest is a python package for training and predicting tree crowns and birds in aerial imagery. We extended the tree crown detection model by annotating and training our custom model. DeepForest uses deep learning object detection networks to predict bounding boxes corresponding to individual trees in RGB imagery. DeepForest is built onthe object detection module from the torch vision package and it is the first open source implementation of a deep learning model for crown detection. Deep learning has made enormous strides in a range of computer vision tasks but requires significant amounts of training data. By including a trained model, we hope to simplify the process of retraining deep learning models.

Hough Transform

Hough transform is a feature extraction method used in image analysis. Hough transform can be used to isolate features of any regular curve like lines, circles, ellipses, etc. Hough transform in its simplest from can be used to detect straight lines in an image. Thus it can be used in our system for extracting the power transmission lines. We are using this algorithm in our system where simple analytic description of features is not possible.

Hough Transforms Algorithm:

A straight line is the simplest boundary we can recognize in an image. Multiple straight lines can form a much complex boundary. We transform the image space into Hough space. By doing this we convert a line in image space to a point on Hough space.

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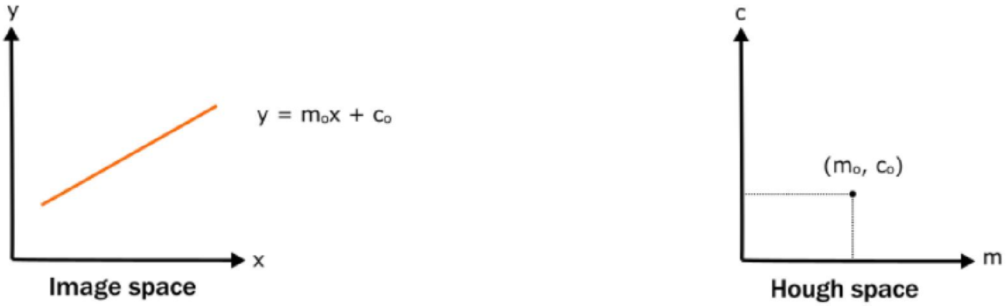

Fig 1.1 Image Space and Hough space of a point in Cartesian coordinate

The equation of the line in the image space is of the form y = mx + c where m is the slope and c is the y-intercept of the line. This line will be transformed to a point of the form (m, c) in the hough space. But in this representation m goes to infinity for vertical lines. So in the polar coordinates the transformation will be as follows.

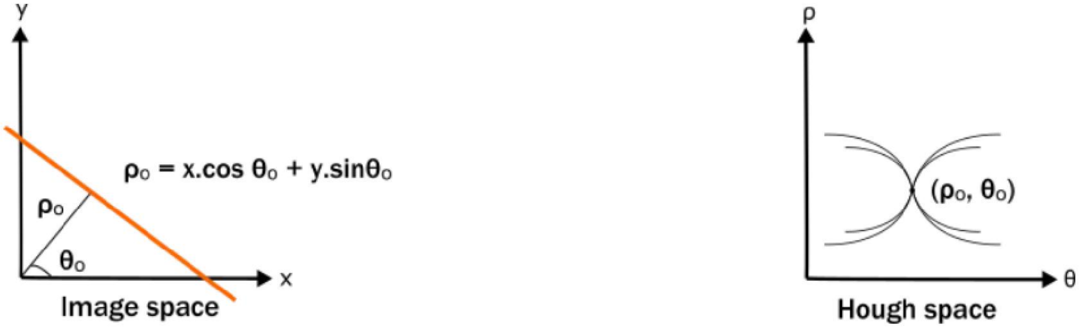

Fig 1.2 Image Space and Hough space of a point in Polar coordinate

The line is represented by the length of that segment ρ, and the angle θ it makes with the x-axis. This line will be transformed to a point of the form (ρ,θ) in the hough space. The Hough transform constructs a histogram array representing the parameter space (i.e., an M x N matrix, for M different values of the radius ρ and N different values of angle θ). For each parameter combination, ρ and θ we then find the number of non-zero pixels in the input image that would fall close to the corresponding line, and increment the array at position (ρ,θ) appropriately.

II. LITERATURE REVIEW

Vegetation monitoring and management along power line corridors is a critical aspect of ensuring reliable electricity transmission infrastructure. Over the years, the application of satellite imagery has played a significant role in this domain, offering a wide range of spatial resolutions and observation frequencies [1]. Satellite data, with its varying spatial resolutions and coverage, provides valuable insights into vegetation encroachment on power lines [8], [11]. Additionally, advancements in cloud-computing services have facilitated the processing of large volumes of satellite data, further enhancing the utility of these resources. In recent years, unmanned aerial vehicles (UAVs) or drones have emerged as a complementary tool for vegetation monitoring in power line corridors [5]. Despite facing operational limitations such as flight autonomy and payload capacity, UAVs offer high spatial resolution data acquisition capabilities [8]. The integration of UAV-based hyper-spectral sensors enables detailed characterization of vegetation properties, enhancing the accuracy of vegetation interference detection [11].Moreover, the integration of machine learning techniques with remote sensing data has provided novel approaches for vegetation encroachment monitoring [12]. Machine learning algorithms trained on multi-source data, including satellite imagery and LiDAR data, offer efficient tools for detecting vegetation encroachments along power transmission lines [13].Recent research also explores innovative methods for vegetation monitoring, such as utilizing single 2D cameras mounted on transmission poles[15]. These cameras, when integrated into wireless networks, enable automated and real-time monitoring of vegetation encroachments, thereby enhancing the efficiency of vegetation management practices along power line corridors. In summary, the integration of satellite imagery, UAV technology, hyper-spectral sensors, and machine learning or deep learning techniques offers a comprehensive approach to vegetation monitoring and management along power transmission lines, contributing to the reliability and resilience of the electrical grid infrastructure.

III. SYSTEM ARCHITECTURE

In Fig 2 the general system architecture is depicted which shows the overall structure and workflow of the entire system. There are in general two people who interact with this system. One is Administrator who has the function of training and testing the two modules: DeepForest and Hough Transforms module. Then the other is the user or the TNEB professionals who interact with the frontend of the system. The TNEB professionals upload the image of the area to be predicted and the user interface then transfers the request to the DeepForest module and the Hough Transform module. The results obtained from these are integrated and then the response is sent back to the UI. The User interface then displays the results back to the user.

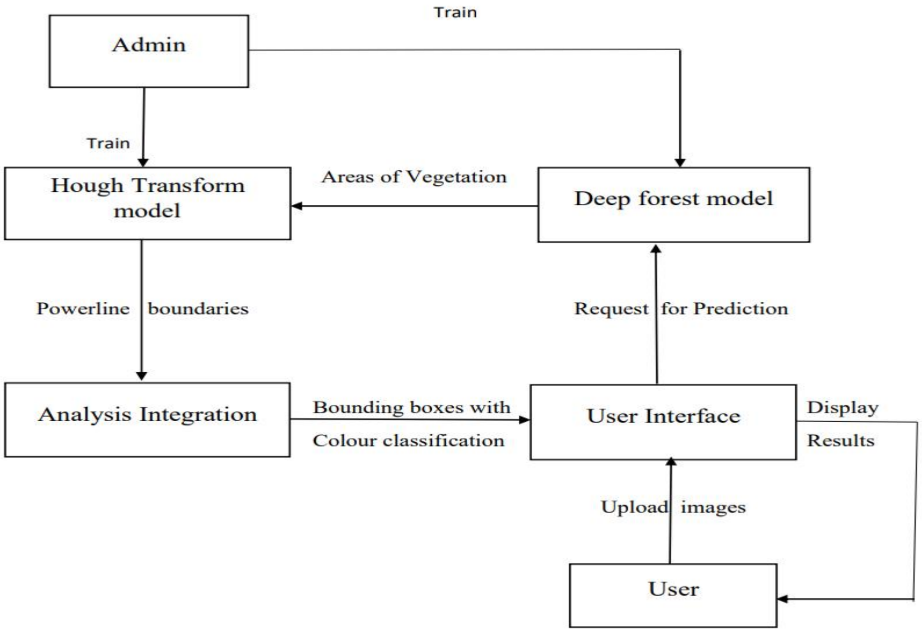

Figure 2: System Architecture

IV. FLOWCHART

A flowchart is a graphical representation of a process or system that uses symbols, arrows, and text to depict the various steps or stages of the process. Fig 3 shows the flowchart for the overall system. The process starts with the data acquisition. The acquired data is pre-processed and used to train the model. After the model has been trained it is tested and validated. The user can now use the trained model to check if the vegetation has grown beyond a certain threshold. If the growth is beyond threshold the model predicts the areas of vulnerabilities inthe present and the future. If the growth is less than the threshold the model predicts the areas of vulnerabilities in the future.

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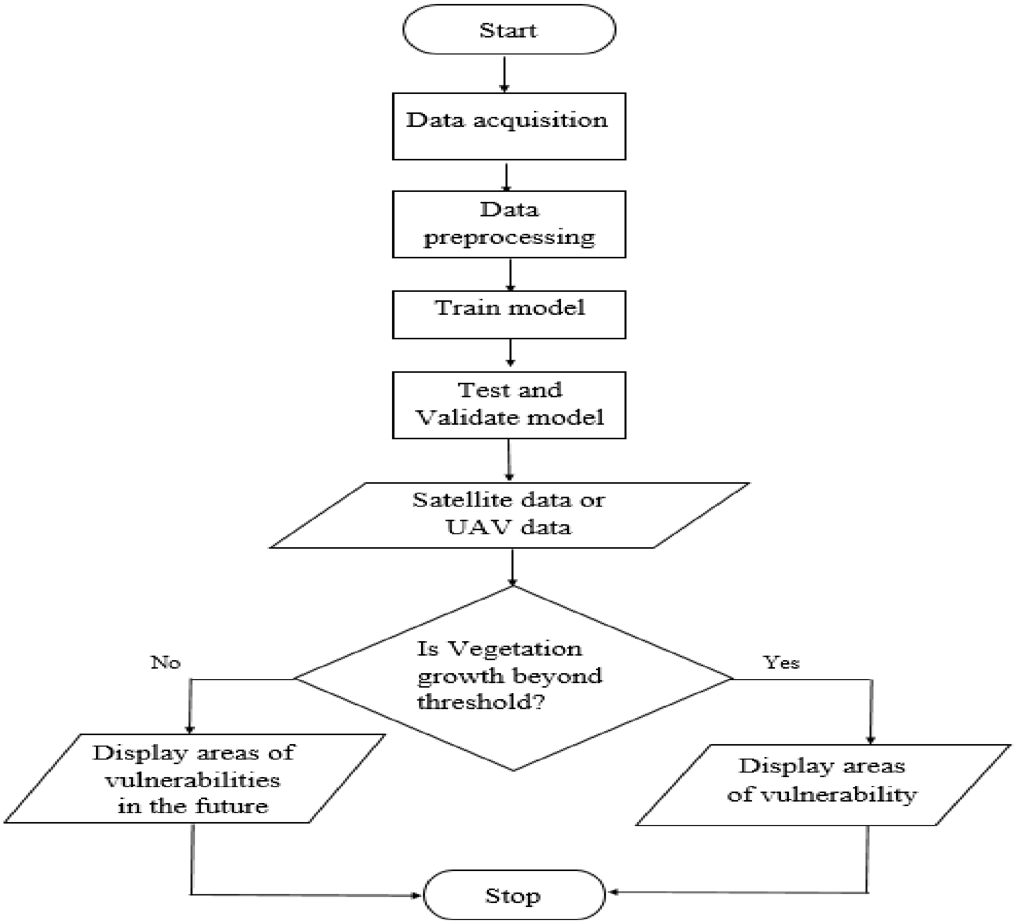
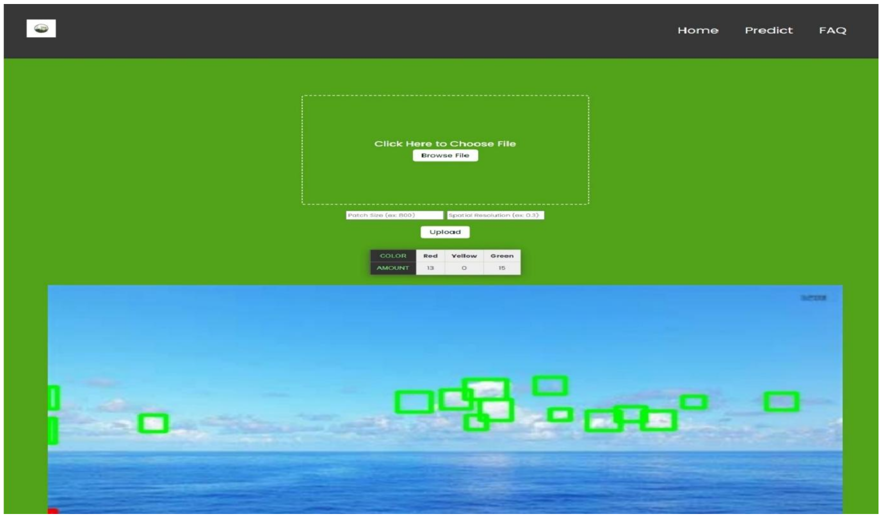


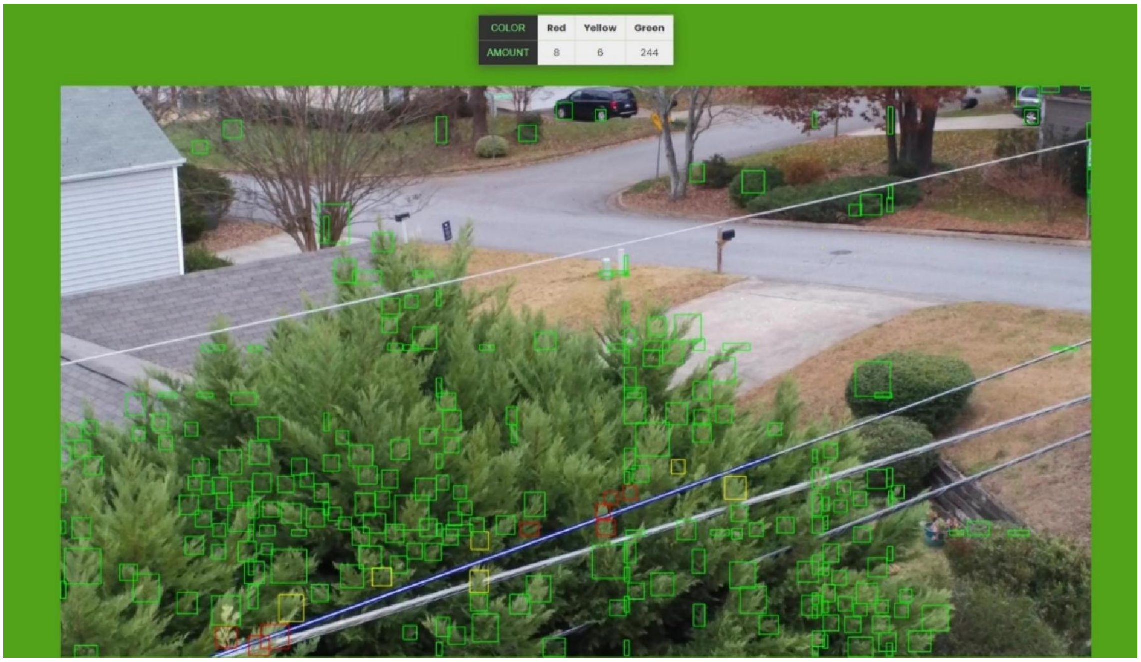
Figure 3: Flowchart

V. IMPLEMENTATION



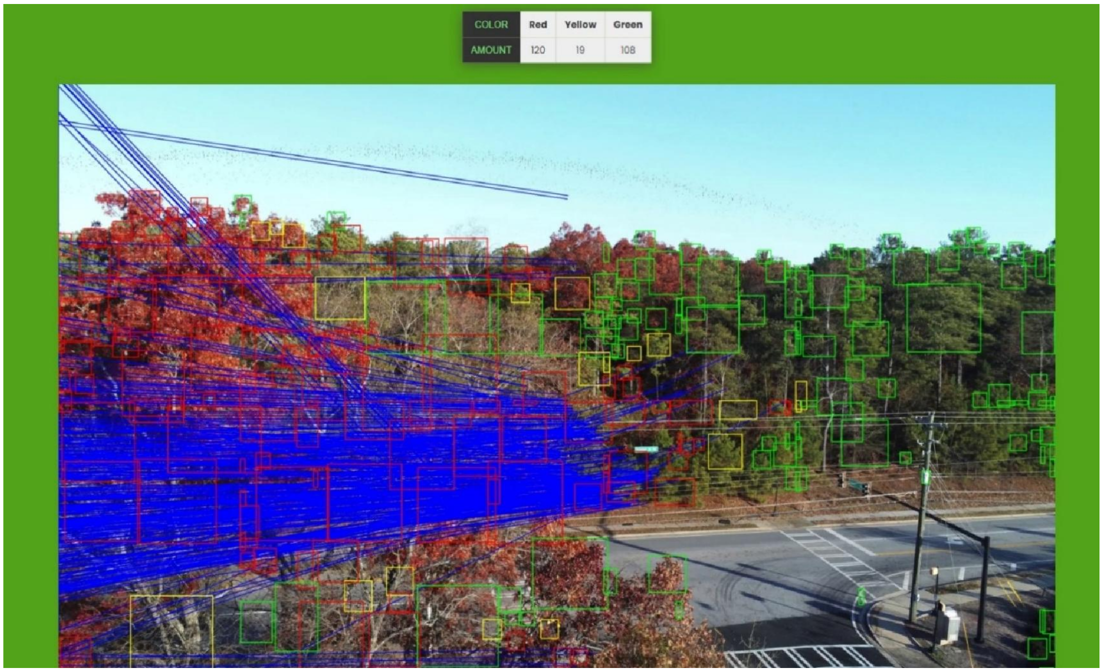
COLOR	Red	Yellow	Green
AMOUNT	13	0	15

Figure 4: Output for an image with no vegetation and no transmission lines



COLOR	Red	Yellow	Green
AMOUNT	8	6	244

Figure 5: Output for an image with vegetation and transmission lines



COLOR	Red	Yellow	Green
AMOUNT	120	19	108

Figure 6: Output for an image with vegetation and transmission lines

VI. CONCLUSION AND FUTURE ENHANCEMENT

Implementing real-time monitoring capabilities would enable the system to continuously analyze incoming imagery and provide instant alerts in case of detected vegetation interference with transmission lines. This could involve deploying cloud-based solutions to process data in real-time and trigger notifications to utility companies or infrastructure managers. By providing timely alerts, the system can facilitate proactive maintenance and mitigation efforts to prevent potential disruptions to the power grid.

Improving the user interface of the client website and enhancing visualization tools can enhance the usability and accessibility of the system. Future enhancements could also include interactive maps with overlaying vegetation and transmission line boundaries and customizable alert settings for users. Integrating the system with existing GIS platforms used by utility companies and infrastructure managers can streamline data exchange and enhance interoperability. This could involve developing plugins or APIs to facilitate seamless integration with popular GIS software such as ArcGIS or QGIS. By leveraging GIS data layers and spatial analysis capabilities, the system can provide additional context and insights into vegetation encroachment patterns, facilitating more informed decision-making processes.

Incorporating machine learning-based predictive analytics can enable the system to forecast future vegetation growth trends and anticipate potential risks to transmission lines. By analyzing historical data on vegetation encroachment, weather patterns, and environmental factors, the system can identify spatial and temporal trends to predict areas at higher risk of vegetation interference. This proactive approach can help utility companies prioritize maintenance activities and allocate resources more effectively to prevent disruptions to the power grid.

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