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Solar Hotspot Analysis using Image Processing in MATLAB

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Abstract: ***Solar energy has proven to be an undisputed frontrunner among renewable energy sources: it is clean, environmentally responsible, and cost-effective. The utilization of solar energy as a sustainable and renewable source of power has gained significant attention in recent years. The rapid growth of solar farms and solar roofs of residential buildings has led to an increase in demand for solar modules in the global market. Therefore, the maintenance and monitoring of solar modules must rely on an effective technique for predicting and evaluating future performance. Solar hotspots, also known as solar irradiance anomalies, are areas on solar photovoltaic (PV) panels or arrays that experience excessive heating, resulting in decreased energy output and potential damage to the PV cells.***
Detecting and analyzing these hotspots is crucial for optimizing the performance and lifespan of solar power systems.
Keywords: Hotspot, Image Processing, MATLAB, Image segmentation, Image enhancement, Photovoltaic cell.

I. INTRODUCTION

Solar energy is a rapidly growing renewable energy source that has the potential to address the world's energy challenges. To harness solar energy efficiently, it is crucial to understand the spatial
distribution and intensity of solar radiation. One key aspect of this understanding is the identification and analysis of solar hotspots. Hotspots in photovoltaic cells are localized areas of high temperature that can occur when a cell is
shaded or when there is a defect in the cell. When a photovoltaic cell is partially shaded, some areas of the cell receive less sunlight than others, resulting in a non-uniform distribution of current. This can cause the shaded areas to become hotspots, as they absorb more heat than the rest of the cell. Hotspots can cause a decrease in the efficiency of a photovoltaic cell, as they can lead to reduced output and potential damage to the cell. Traditionally, solar hotspot analysis has been performed using ground-based instruments and satellite imagery. However, these are often expensive, time-consuming, and may lack the necessary spatial resolution.
Image processing techniques offer a promising alternative for solar hotspot analysis by leveraging the abundance of high-resolution aerial or satellite images. In recent years, MATLAB has emerged as a powerful tool for image processing due to its extensive library of functions and algorithms specifically designed for image analysis. This research paper aims to explore the application of image processing techniques in MATLAB for solar hotspot analysis.



II. METHODOLOGY/EXPERIMENTAL

A. Visual Assessment

Visual assessment of solar panels refers to the process of visually inspecting solar panels to identify any visible defects, damage, or issues that may affect their performance. It is an essential part of regular maintenance and quality control in solar panel installations. During a visual assessment, trained professionals or technicians visually inspect the solar panels and their components, such as the photovoltaic modules, support structures, electrical connections, and wiring. They look for various signs of potential problems.

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B. Thermographic Assessment

Thermographic assessment, also known as thermal imaging, is a technique used to evaluate performance and identify potential issues in solar panels by analyzing their thermal patterns. It involves using an infrared camera to capture images that depict the temperature distribution across the surface of the solar panels.

C. New Method

By using this toolkit for image processing in MATLAB, the condition of solar panels' health can be determined. Filtering, binary pictures, and three-dimensional (3-D) images are all used in the thermal image processing of solar panels. Determining the thermal image's degradation pattern can be done with the use of image processing. On PV modules, it also aids in identifying unhealthy and faulty cells. The image must first be changed from RGB to grayscale. This will improve the image's color and resolution to aid in diagnosis. The image must then be filtered to get rid of the noise and lessen the sharpness. The noise and other unused features in the IR image are removed using Gaussian filters. However, flaws like hot spots and cracks can also impact the photovoltaic modules' ability to maintain a consistent temperature.

D. Hotspot Detection

Individual hotspots can be identified and assigned unique labels or identifiers by performing region labeling. This allows for the localization and analysis of each hotspot separately. It also facilitates subsequent processing steps, such as calculating statistics or applying specific operations to each labeled region.

E. Region Labeling

It is possible to count the number of spots or hotspots in an image using region labeling. Each labeled region represents a distinct hotspot in the image once the regions have been labeled using a region labeling algorithm. The total number of spots or hotspots can be calculated by counting the distinct labels or regions.

F. Area Calculation

After labeling the connected components in the binary image using bwlabel() the regionprops() function is used to calculate the area of each connected component.



Fig 1: The UAV performs a visible light image of the aerial photography.

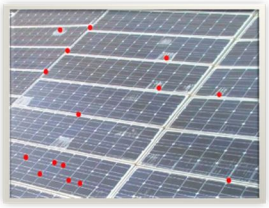
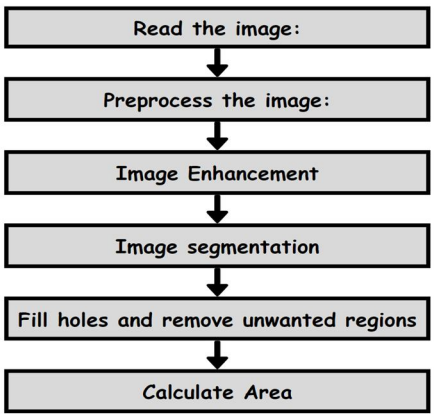
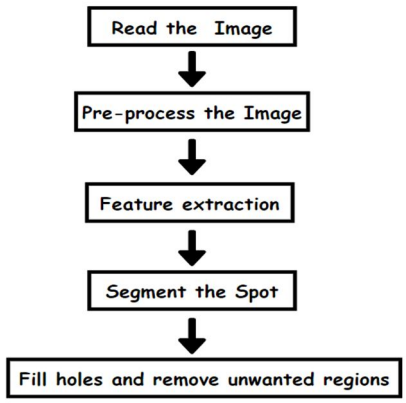


Fig 2: The highlight of thermal imaging is the hot spot caused by abnormally high temperatures.





Flowchart 1: To calculate the area of a particular "Hotspot" using image processing in MATLAB:

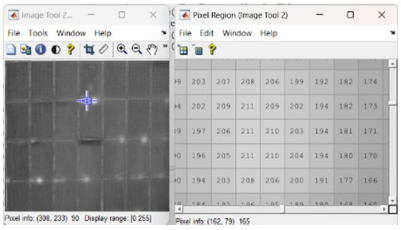


Figure 3: Used Pixel region tool on Normal image.

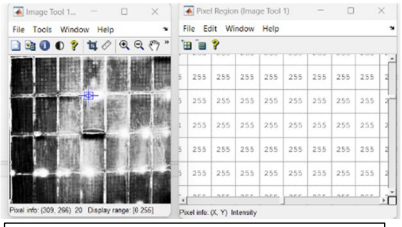


Figure 4: Uniformity in Pixel intensity values after Image Enhancement.

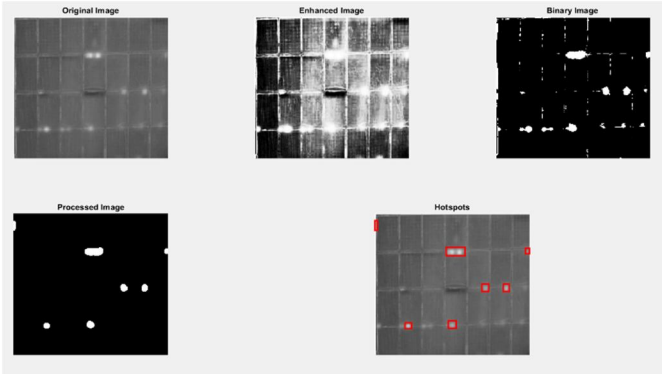


Figure 5: MATLAB subplot showing result at each step: Original image, Enhanced, Image , Binary Image , Processed Image, Hotspot detection.

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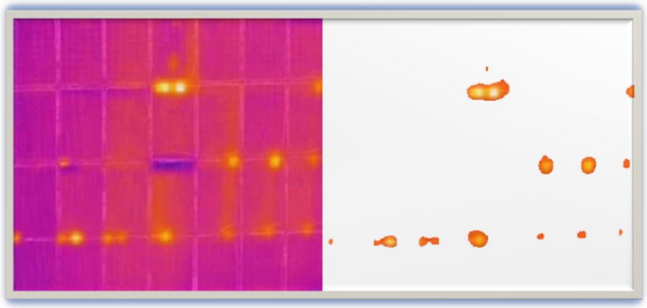


Figure 6: Original RGB image of Solar Hotspot vs Hotspot Detected

III. RESULTS AND DISCUSSIONS

The research conducted using image processing techniques in MATLAB for solar hotspot analysis yielded valuable insights into the spatial distribution and intensity of solar radiation. The results provide a comprehensive understanding of solar hotspots and their potential for solar energy generation.

Firstly, the aerial or satellite images used in the study were successfully preprocessed using MATLAB's image processing toolbox. The preprocessing steps involved enhancing the image quality, removing noise, and correcting geometric distortions. These preprocessing techniques ensured that the subsequent analysis was performed on accurate and reliable data.

IV. CONCLUSION

Image processing of hotspots on solar cells can help in analyzing damage by providing a way to detect and locate hotspots on the cells.

This can help in identifying and addressing any issues that may be affecting the efficiency of the solar cells. This can help in identifying and addressing any issues that may be affecting the efficiency of the solar cells.

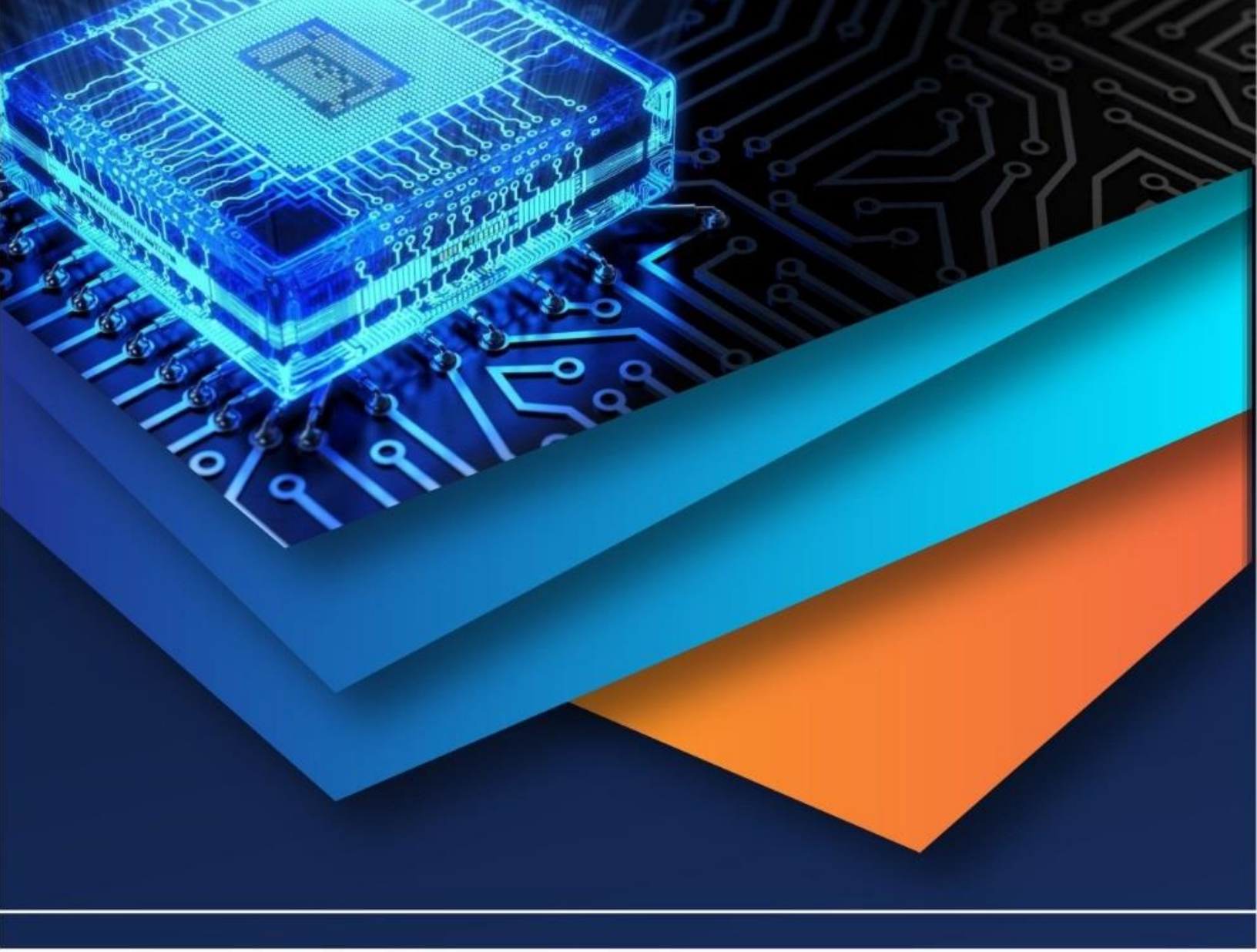
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