ENEA
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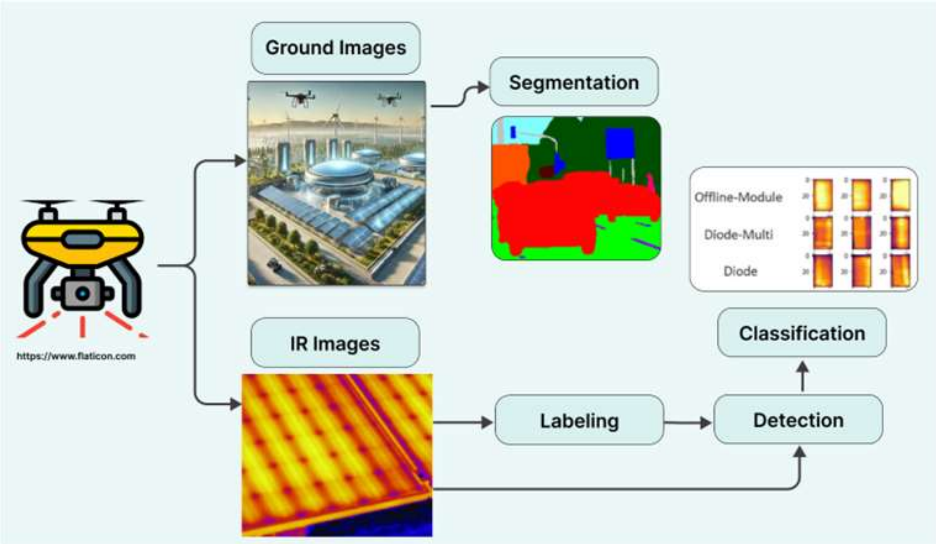
Anomaly Detection in Photovoltaic PV Plants

ABSTRACT



This study explores the application of Machine Learning (ML) models for anomaly detection in photovoltaic (PV) plants, leveraging infrared (IR) imaging to improve fault identification. Existing research has demonstrated promising accuracy, but challenges remain in ***model generalization*** and ***real-time detection***. This work aims to develop a ***scalable solution*** by evaluating different ML models and ***addressing dataset biases*** and ***privacy concerns***.

The expected outcome is a robust, generalized model that enhances ***predictive maintenance***, ***reduces maintenance costs***, and supports the global transition to renewable energy.

INTRODUCTION

Photovoltaic (PV) plants require continuous maintenance, but these operations are expensive and labor-intensive, making them

Slow ***Error-prone*** ***Expensive*** ***Non-scalable***

A solution is the ***automation of anomaly detection*** using Machine Learning (ML) models, that can ensure:

Reliability ***Efficiency*** ***Scalability***
Reduced maintenance costs

Additionally, predictive capabilities can help in ***forecasting potential failures***, further ***optimizing maintenance schedules*** and ***improving overall sustainability*** of PV plants.

Research questions

I. Which ML models are the most accurate?
II. How can a ML model be developed to generalize effectively?

Hypothesis

When a PV module develops faults or degradation, its electrical and thermal properties change, so ***Infrared imaging (IR)*** can capture these thermal variations, and by combining these images with 'normal' images of the PV modules, a combination of two Machine Learning models trained on this data will be able to ***detect*** and ***classify*** anomalies ***faster*** than manual inspection.

LITERATURE REVIEW

Recent studies on anomaly detection in PV plants have shown promising results in terms of **accuracy**.
However:

I. many studies rely on data from specific PV systems, creating ***difficulties in generalizing models***.
II. real-time detection has not been extensively analysed.

Addressing these challenges could ***enhance adoption of ML models*** promoting wider integration in the field.

RESEARCH METHODOLOGY

Machine Learning models needed for:

1. ***Segmentation***: using normal PV plants images;
2. ***Labeling***: using IR images;
3. ***Detection:*** applied to IR images + labels;
4. ***Classification:*** to classify the state of solar panels

Preliminary accuracy results:

I. ***Segmentation***: *U-Net*, Train [76.67%], Validation [75.68%]
II. ***Classification***: *CNN*: 79.25%

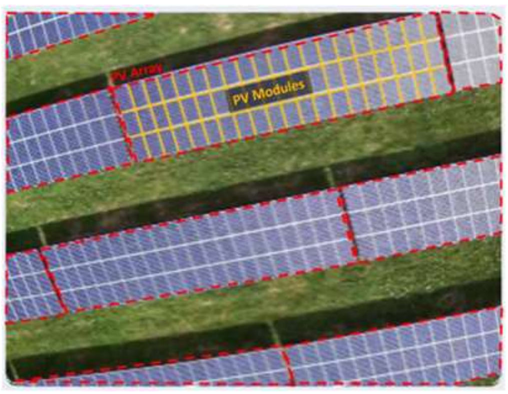


Fig. 2: *Segmentation using normal images*

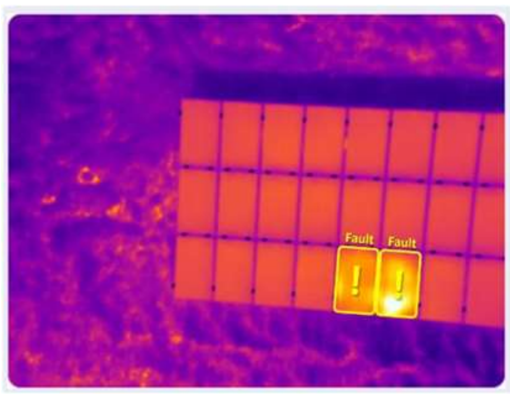


Fig. 3: *Labeling using IR images*

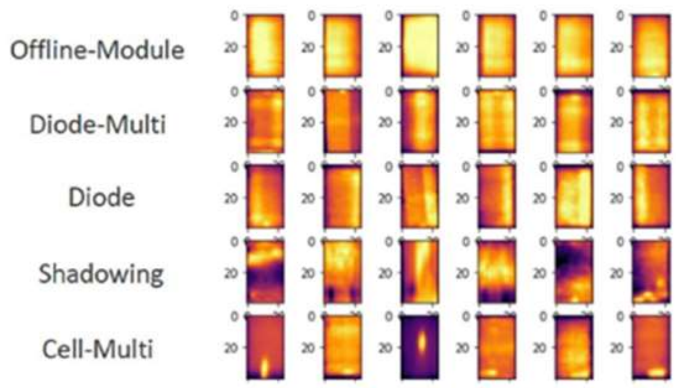


Fig. 4: *Classification of solar panels (IR images)*

PRELIMINARY CONSIDERATIONS

Human-centered aspects considered to ensure ethical and fair use:

- **Privacy**: ensure that images used in the analysis that contain people, logos, or other elements are properly ***blurred***.
- **Bias:** Differences in PV module quality affect fault occurrence rates leading to a ***distortion in the model's performance***

CONCLUSIONS

The advantages of applying ML models go beyond ***improved accuracy*** in fault detection, enabling ***proactive maintenance***, ***real-time forecasting***, and ***scalability*** across various PV systems, ***reducing maintenance costs***.

This, in turn, supports the global transition to renewable energy.

References.
[1] "**Machine Learning for Anomaly Detection: A Systematic Review**", IEEE document 9439459

Acknowledgements. The HCAIM (the Human-Centred AI Master's Programme) Project is Co-Financed by the Connecting Europe Facility of the European Union Under Grant №CEF-TC-2020-1 Digital Skills 2020-EU-IA-0068. This poster was created as part of the Blended Intensive Programme organized under the Erasmus + Programme of the European Union