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AID4PV

Unmanned aerial vehicle (UAV)-based decision-making and modular approach to support photovoltaic (PV) plant diagnosis using image processing with electrical data analysis and advanced reporting and geovisualization

PV performance analytics

Mr. Georgios Tziolis
PhD Student
PV Technology Laboratory, FOSS Research Centre for Sustainable Energy,
University of Cyprus, Nicosia, Cyprus

Outline

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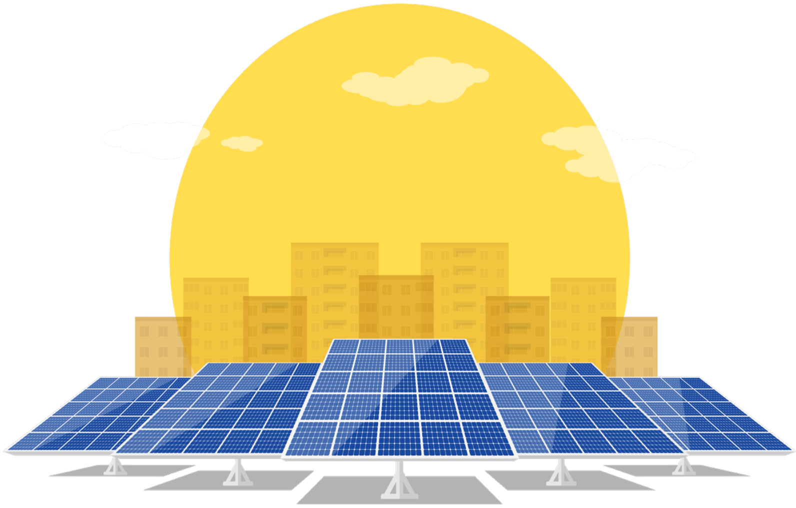

- Photovoltaic (PV) assets continue to **underperform** by up to **8%** [1]
- **Effective fault diagnosis** remains **a technical and economic challenge,** especially for large-scale PV plants
- Current practices for PV plant inspection involve electrical data analysis, image processing and visual inspection
- **More advanced** and **automated** methods and tools (e.g., drones) are required to inspect large areas with PV systems

[1] kWh Analytics, “Solar Generation Index 2022

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Background & Objective

Specific Objective: Development of an unmanned aerial vehicle (UAV) platform for decision-making and PV plant diagnostics

Advanced UAV platform performing near real-time fault detection, leading to cost-efficient PV plant diagnosis and reduced operation and maintenance (O&M) costs

Partners: TSK (coordinator), University of Cyprus (UCY) and Technical University of Crete (TUC)

TSK ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ TECHNICAL UNIVERSITY OF CRETE University of Cyprus PV Technology

Project: UAV-based decision-making and modular approach to support PV plant diagnosis using EL, RGB, IRT imagery, correlated with electrical data analysis and advanced reporting and geovisualization

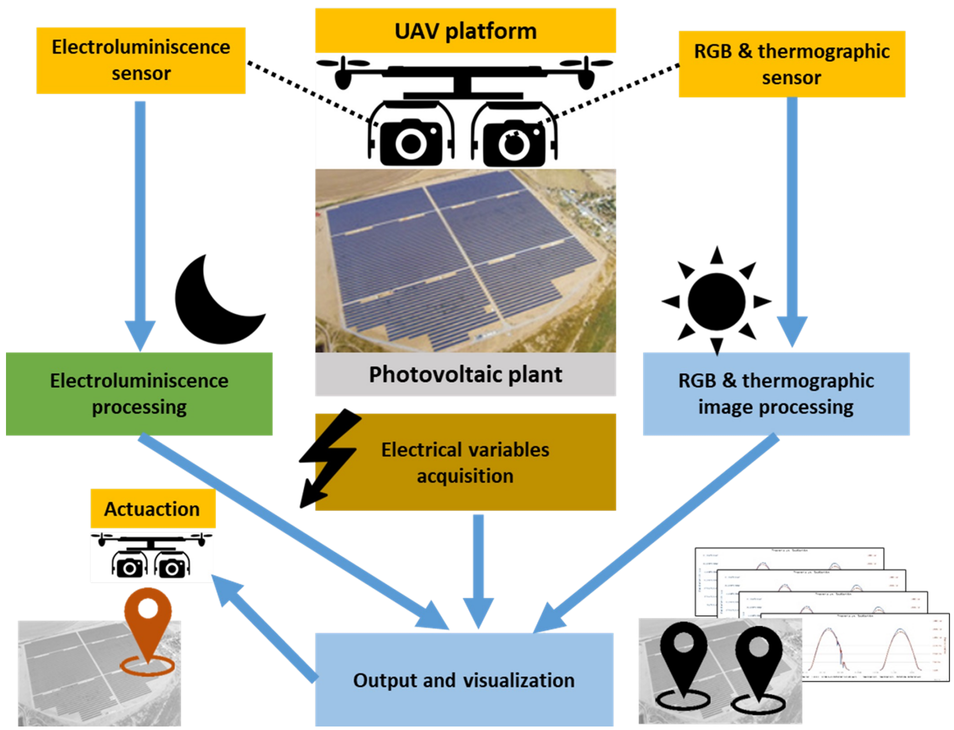
Acronym: AID4PV

Funding: SOLAR-ERA.NET

Website: https://fosscy.eu/projects/aid4pv/

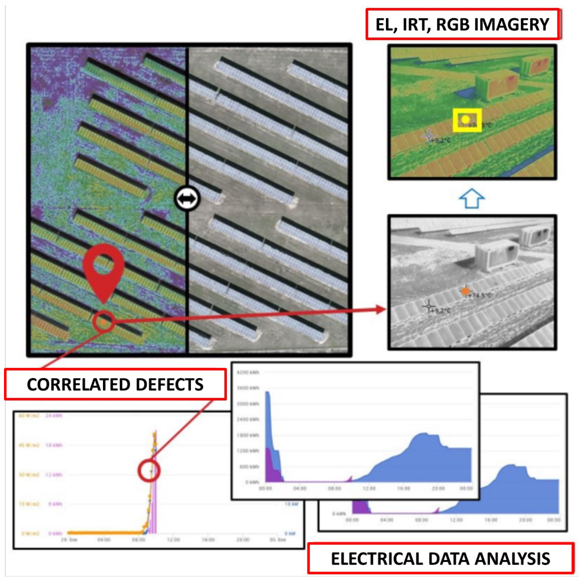
Methodology

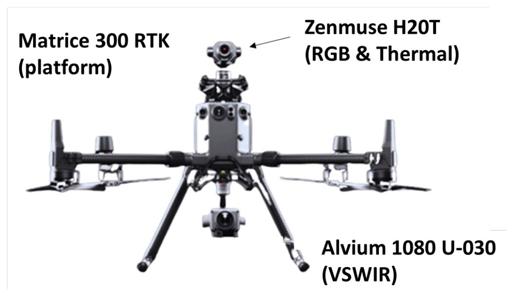
- Modular architecture that incorporates image processing and electrical data analysis algorithms for fault detection, geolocation and decision-making functionalities

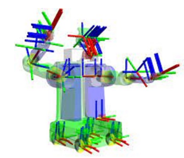


Implementation

- Combination of image processing with the electrical data analysis results
- Processing unit with Robot Operating System (ROS) software







OpenCV

ROS

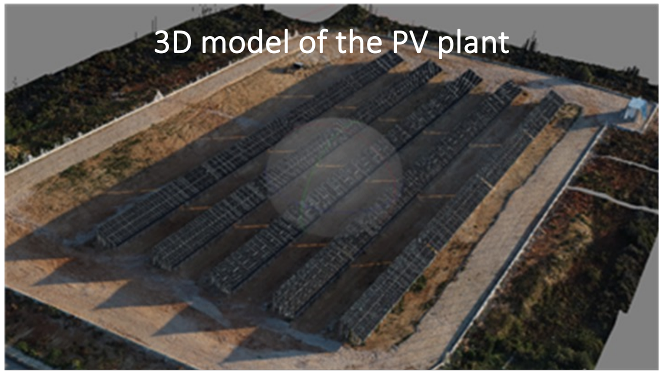
- Maximum takeoff weight of 9 kg
- Can hover for about 30 min
- Maximum speed of 17 m/s

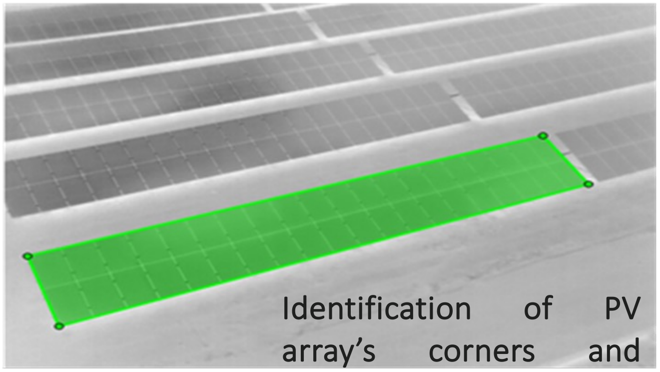
Advantages

+ **Autonomous operation**
+ **Fast detection**
+ **Large area coverage** and **noticeable time reduction**
+ **Unmanned** and **easy operations, operation** in **harsh environments**

Results - 3D modeling of PV plant

- Benchmarking at real environment





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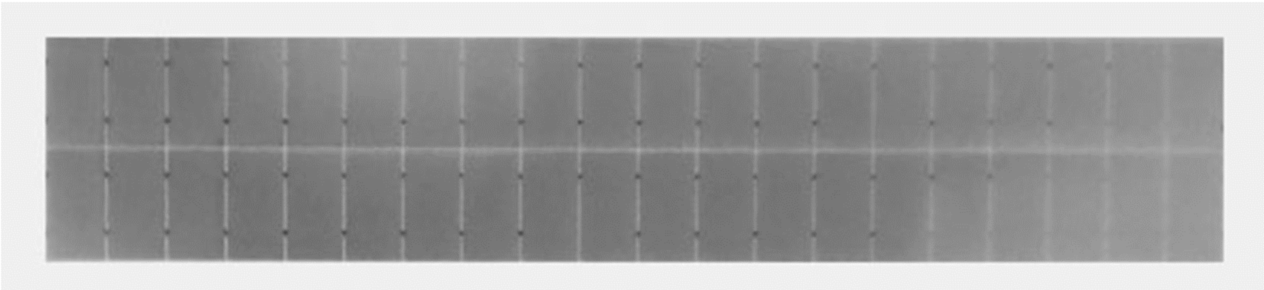
Results – 3D model and geolocation algorithms

- To ease the procedure for geolocating the defects, the algorithm applied a perspective correction

Perspective correction



- The geolocation algorithms perform sufficiently with the proposed aerial platform, achieving a 30 cm error figure in 3D space (at a distance of 15m from the panels)
- This error is mainly produced by the angular error figure of the gimbal’s yaw axis which is about ±2°

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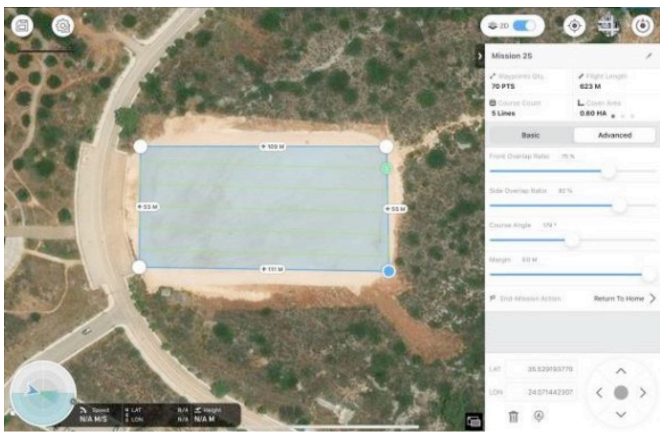
Results - Experimentation and aerial PV inspection

Flight testing

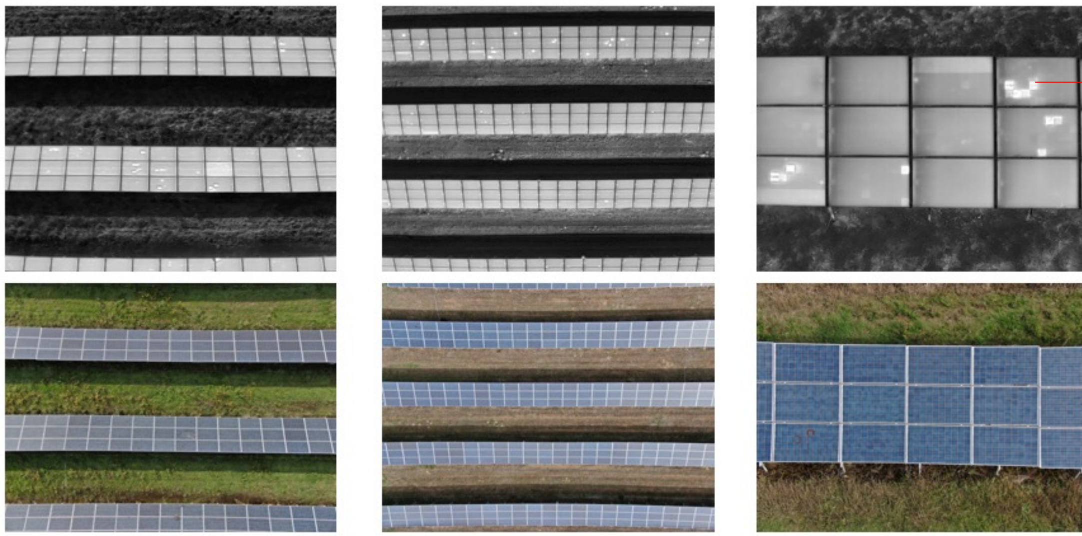
- Experiments with autonomous flight plans were conducted
- At first, a desired flight plan is designed while afterwards, the aerial platform can perform multiple flights autonomously, following the pre-defined trajectory



Results - Experimentation and aerial PV inspection

Flight testing

- Flights at different heights and taken images



Flight at 35m, -90° | *Flight at 51m, -90°* | *Flight at 15m, -60°*

Detailed captures revealing even cell defects

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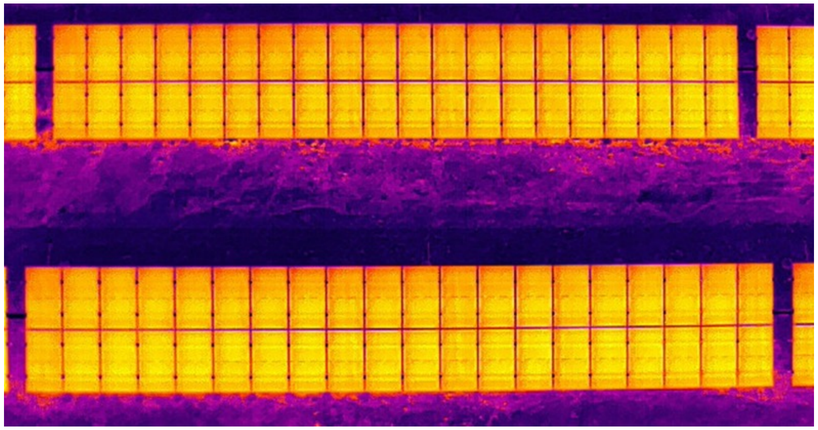
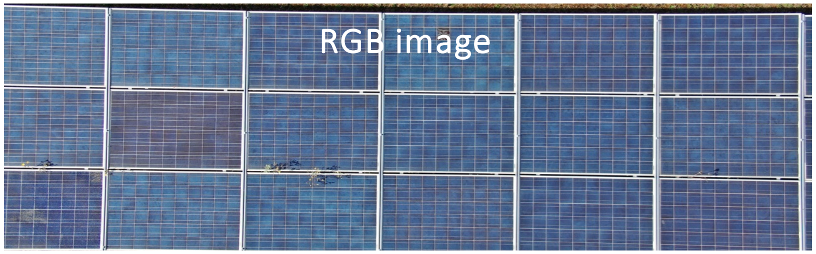
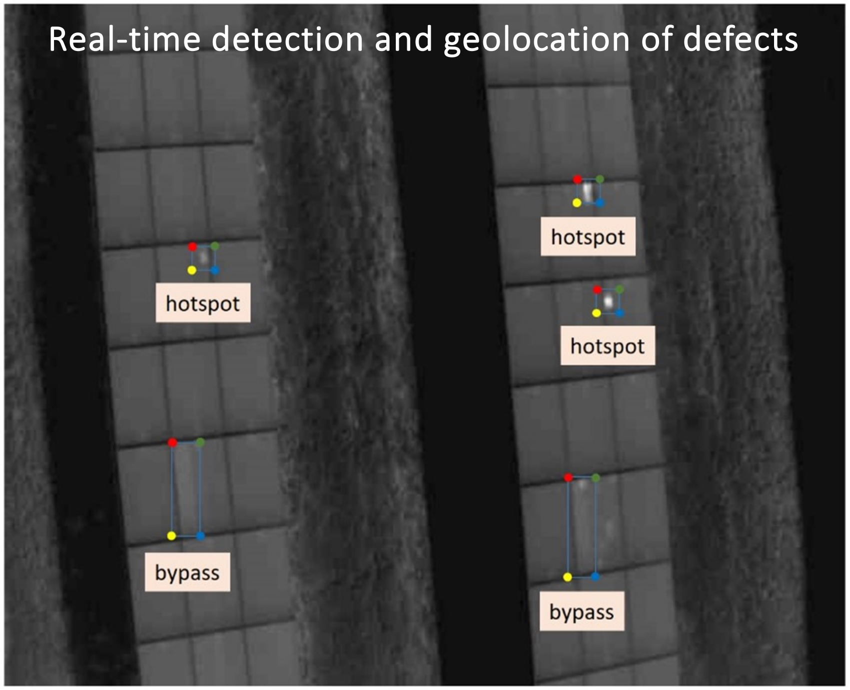
Results - Experimentation and aerial PV inspection

- Obtained images and diagnostics

Thermal image

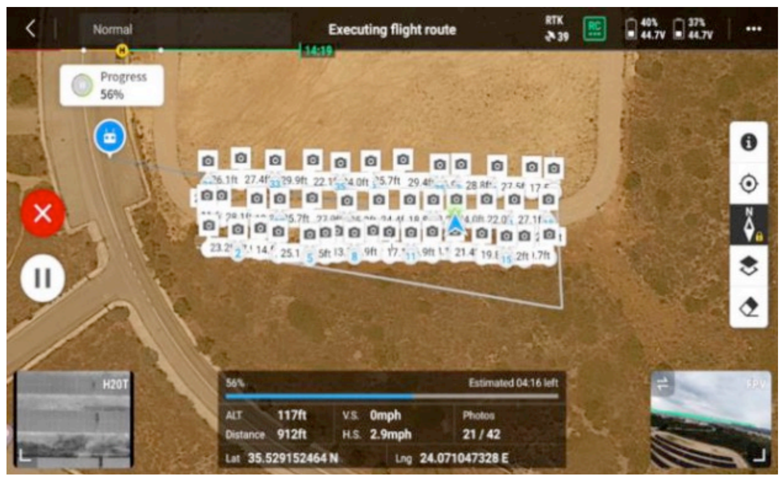






Results - Experimentation and aerial PV inspection

- In total, 122 thermal images were taken to cover the surface of the test PV plant
- 424 individual defects were detected and classified in two groups: 365 hot spot defects (not necessarily in different solar panels) and 59 bypass diode failures
- The algorithm successfully detected and located ~ 95% of the defects



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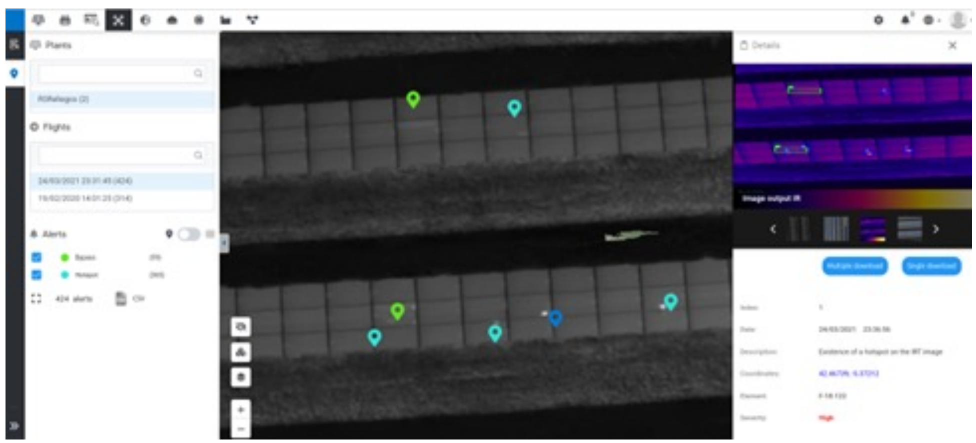
Results - Online application for geolocation of the defects

- An online application dedicated to the management of the photographed flights has been built that allows the geopositioned visualization of the defects found
- Defects can be visualized on a map or an orthophoto built with the flight images



Conclusions

- A decision-making system for online PV plant diagnostics was developed in this work
- The UAV platform was demonstrated in an operational environment
- The results showed its efficacy for near real-time fault detection, localization of faulty modules, and accurate geolocation of defects
- The proposed system can be used for improved time- and cost-efficient PV plant diagnosis, thus impacting positively the Levelized Cost of Electricity (LCOE)

Future Work

- Development and integration of EL image processing analysis algorithms
- Integration of electrical data analysis algorithms
- Correlation of image processing outcomes (using thermal, RGB and EL images) and electrical data analysis results

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University of Cyprus PV Technology

Thank you for your attention

Georgios Tziolis

FOSS Research Centre for Sustainable Energy
PV Technology Laboratory
University of Cyprus (UCY)

Email: tziolis.georgios@ucy.ac.cy

Acknowledgments

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For more info, please visit the project website
https://fosscy.eu/projects/aid4pv/

Appendix - EL image analysis

- Indoor EL images for testing image fault diagnostic algorithms for detecting bypass diode failures, cracks, PID and dead cells