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Automatic detection of defects in solar cells using artificial intelligence

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ABSTRACT

We define a new methodology for quantitative and timely detection of defects and failures in PV modules through image analysis in combination with the use of artificial intelligence algorithms and their correlation with module performance losses. The basis of this analysis is the use of a unique ultra-high resolution multispectral camera with UV to IR sensitivity, appropriate filters and lights setup. To achieve the project goals, a methodology for automatic identification of failure modes at the cell level will be implemented using Convolutional Neural Networks (CNNs). The results of the project will have a direct impact on future defect tracking methodology, both in research labs, manufacturing and operational environments, allowing a quantitative and measurable way to record the evolution of module performance.

Instruments and data sets

Fig 1 High res Multispectral camera

Fig 2 Test setup with UV lights

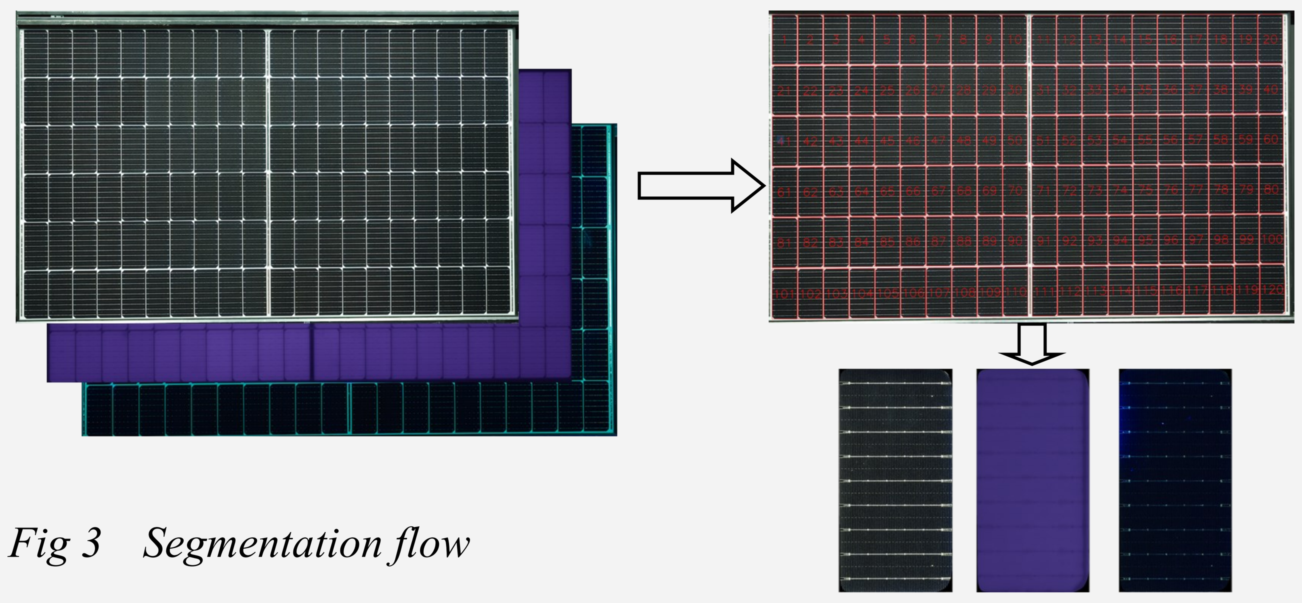


Fig 3 Segmentation flow

- Multispectral images are acquired with a Phase One iXM-MV150 camera (150 Mpx sensor, Linos 60 mm f/4 lens and manual focus).
- Three different spectral images for each module: electroluminescence, visual inspection and photoluminescence.
- Different spectral regions allow for the identification of different defects.

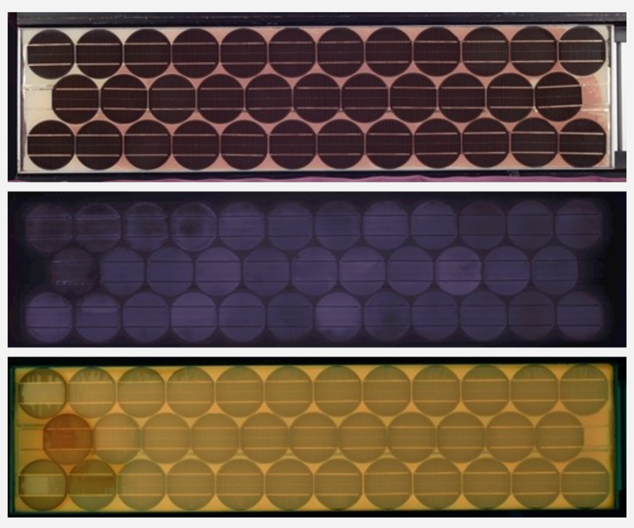


Fig 4: TISO dataset

- Dataset 1: TISO modules
  - Mono-c-Si
  - High-resolution multispectral imaging
  - 172 modules (6020 cells in total)

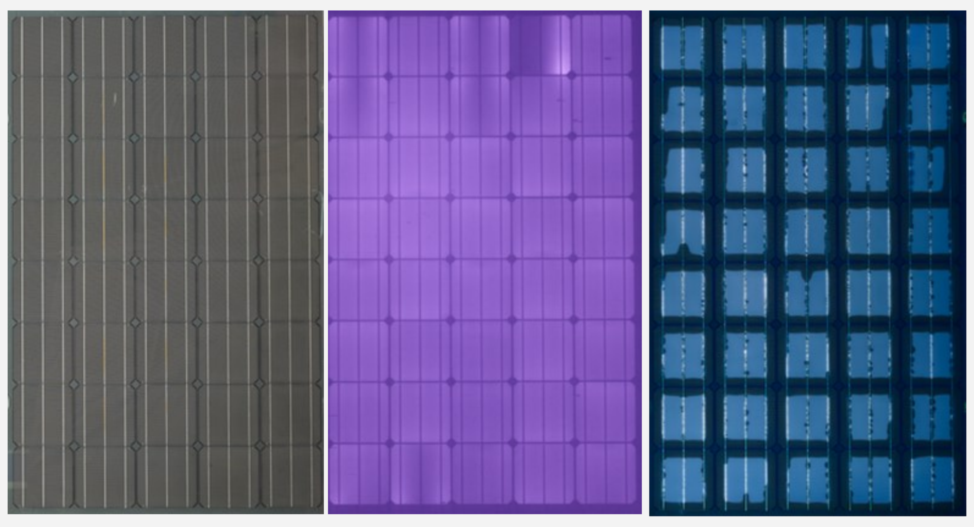
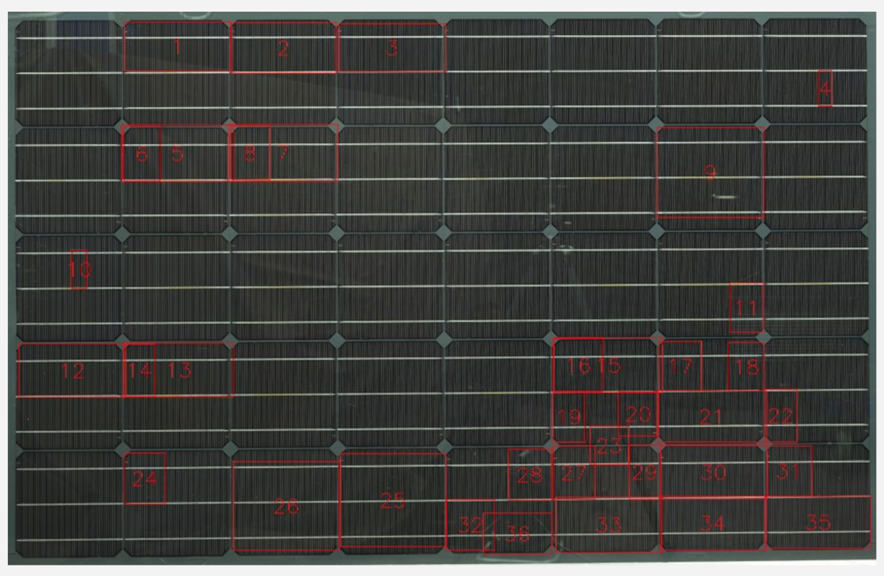


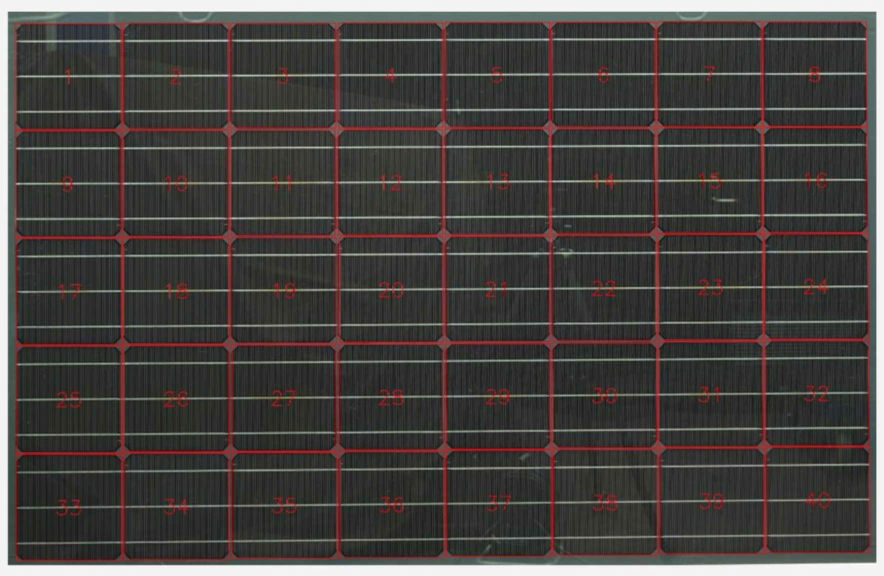
Fig 5: ACHILLES dataset

- Dataset 2: ACHILLES modules
  - Mono-c-Si, hail damaged
  - .High-resolution multispectral imaging
  - 20 modules from different technologies(4172 cells in total)

Results



Detectron2



Segment Anything

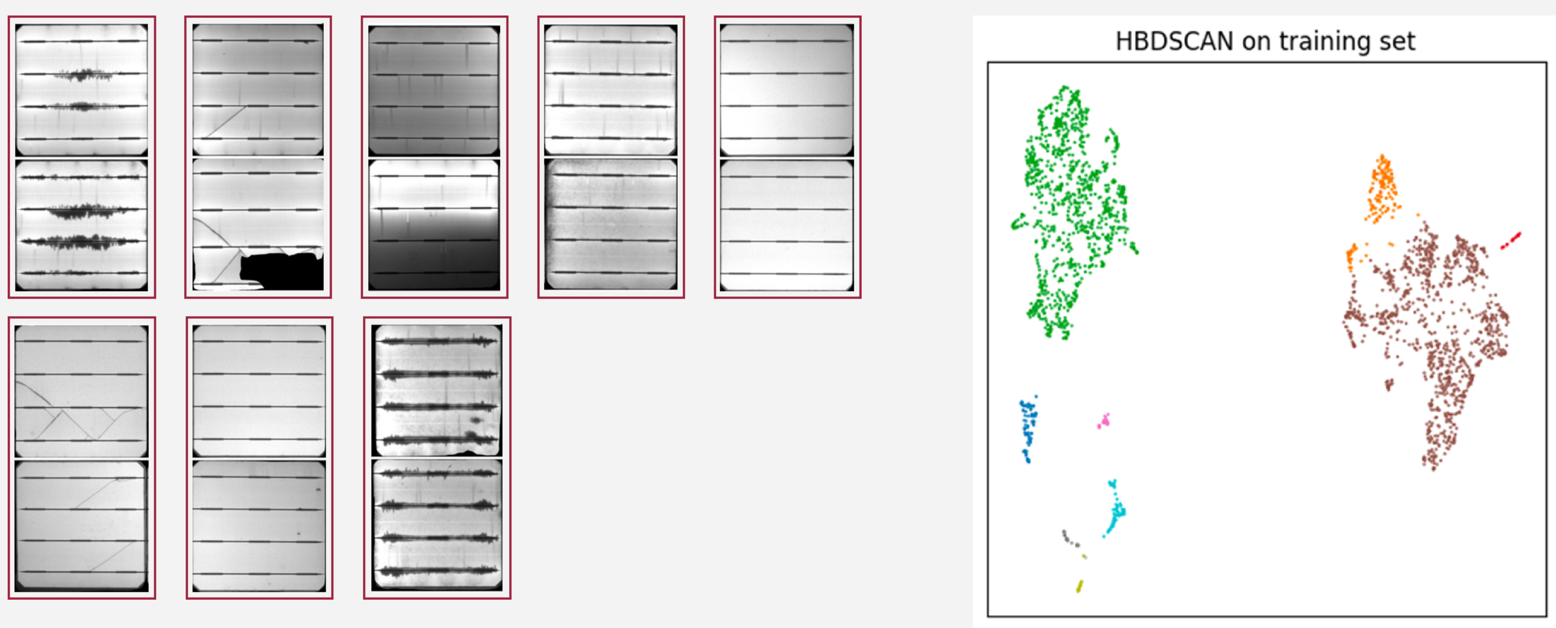


Fig 6: automatic defect classification and clustering

SEGMENTATION

- **Detectron 2** algorithm: object detection framework developed by Facebook AI Research (FAIR) in 2019.
- Segment Anything Model (SAM) model from Meta AI developed in 2023 that can segment any object, in any image.
- The algorithm „Segment Anything Model (SAM)“ has advantages over the Detectron 2, with better general results
- **Strategy:** Generally use SAM, except when a fixed positioning of the modules cannot be guaranteed.

AUTOMATIC DEFECT CLASSIFICATION

- **Scope:** reduce the initial labelling effort through a partially automatized unsupervised labelling.

- **Methodology**
  - Data scaling and feature extraction using a pre-trained network (VGG16 with ImageNet weights) + global pooling.
  - The resulting features are given to UMAP as an input, which gives 10- or 20-dimensional embeddings as an output, depending on the dataset.
  - 2-dimensional embeddings calculated for visualisation purposes.
  - Clustering of the embeddings with HDBSCAN and 2D projection.

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