Reliable diagnostic?

EAGLE PROJECT

AI-driven Defect Detection in Solar Panels

Danuta Paraficz

University of Applied Sciences and Arts of Southern Switzerland (SUPSI)

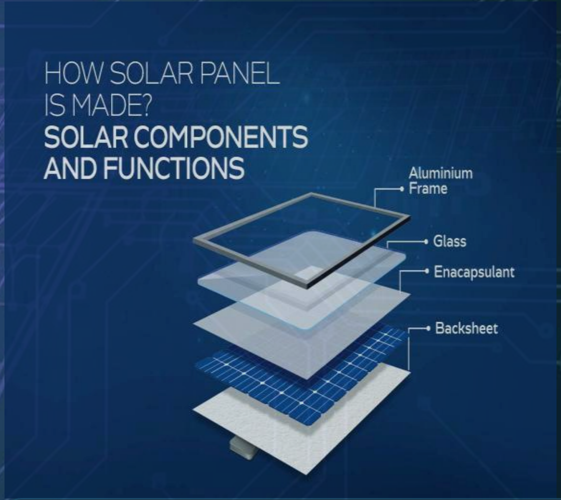
FFHS

SUPSI PVLab Team

Ebrar Özkalay

Mauro Caccivio

Multi-Spectral Imaging

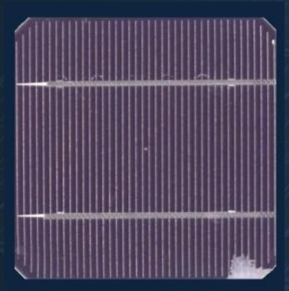


SUPSI PVLab
Ebrar Özkalay | Mauro Caccivio

Our Innovative Approach

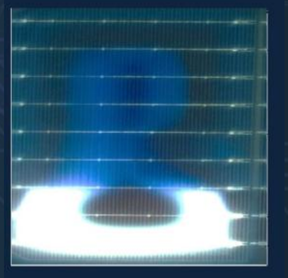
Multispectra Defect Detection

Crack • Dark Spots • Corrosion • Delamination • Discoloration



Visible (VI)

Electroluminescence (EL)

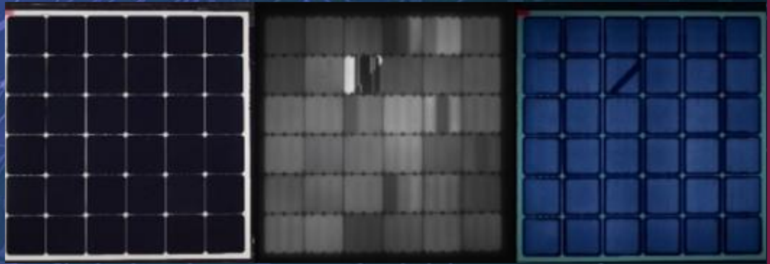


UV Fluorescence (UVf)

Our Data

TISO modules mono-c-Si

Cell Technologies:
Heterojunction, PERC, TOPCON, Back Contact

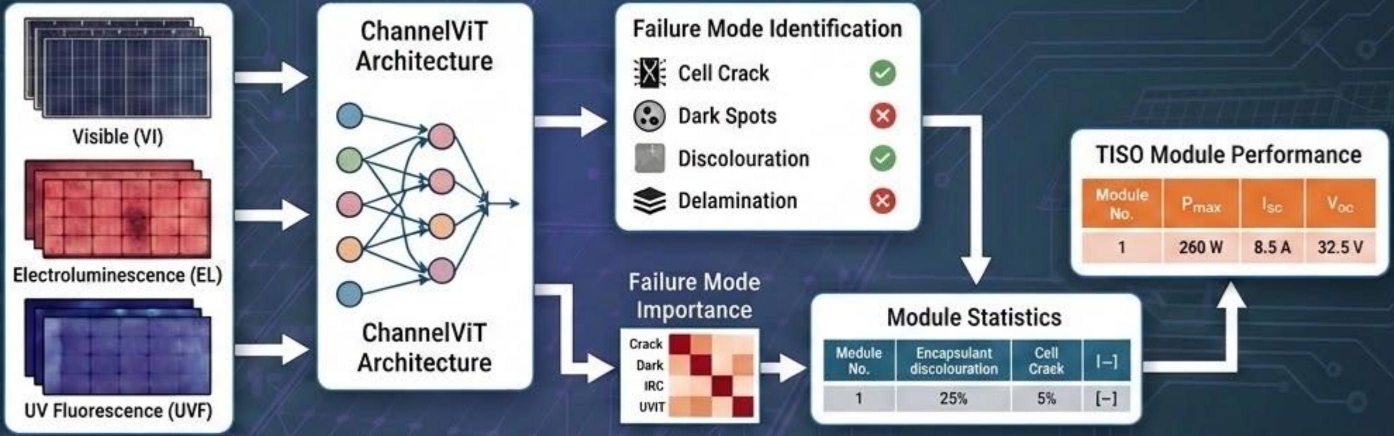


Measurement Details:
IV measurement by PVLab in SUPSI - open circuit voltage

Mission 1: Automatic identification of defects

Good Cracked Expert needed

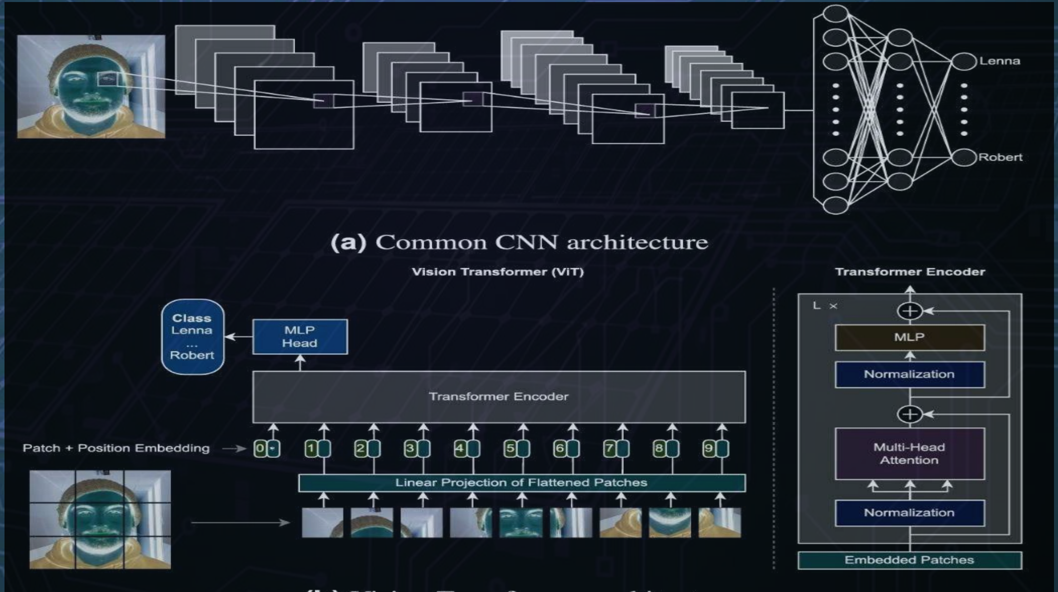
Mission 2: Correlate it with performance



- **Identify and quantify "failure modes"** (defects) across multiple visual channels.
- **Correlate defects directly** with measurable performance loss in TISO modules.

ViT vs. CNN

Comparing Architectural Paradigms



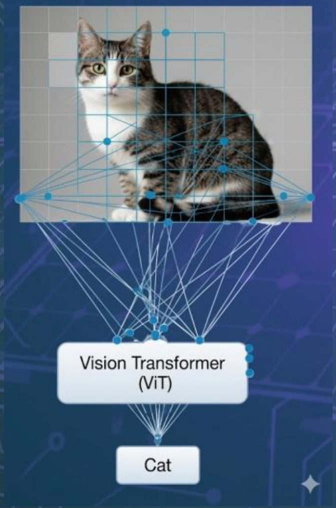
(a) Common CNN architecture

(b) Vision Transformer architecture

ViT vs. ChannelViT

Comparing Standard and Multi-Channel Architectures

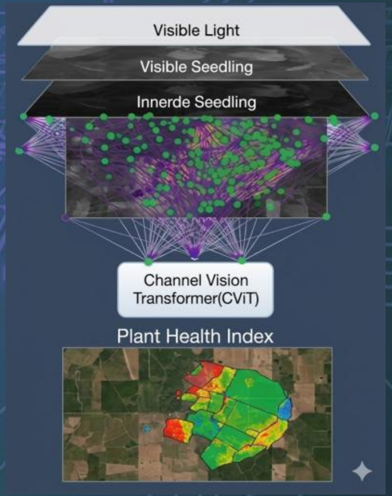
Vision Transformer (ViT)



Processes single-stream visual input

VS

Channel ViT



Integrates multi-channel (VI, EL, UVf) dependencies

Core Technology

Channel Vision Transformer (ChannelViT)

Multi-Channel Complexity

"Sees" across channels—intelligently combining and interpreting information from *all five image channels* (VI, EL, UVf).

Precise Defect Detection

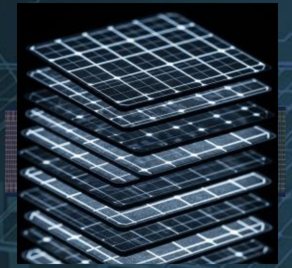
Leverages complex dependencies between channels for superior detection accuracy.

Channel Availability

Scalable framework designed for high-throughput image processing environments.

LLM-Assisted Pre-labeling

Raw Images



Thousands of images

LLM Pre-labeling
(Proposals)

LLM Analysis
Extracting patterns across images

Pre-labeled Output

Important Distinction

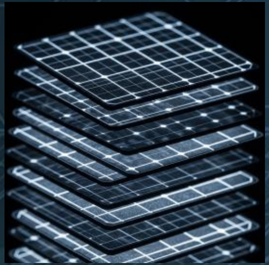
We do **NOT** use the LLM to **replace** the final model.

LLM Generalist	≠	**ChannelViT** Specialist

The LLM handles the **'grunt work'** of initial organization, but the heavy lifting of high-precision diagnostic remains with our properly trained, **domain-specific models**.

THE HUMAN-IN-THE-LOOP WORKFLOW

Raw Images



Thousands of Unlabeled Images

LLM Pre-labeling
(Proposals)

- Finger Break
- PID / Micro Crack
- Inactive Area
- Hotspot

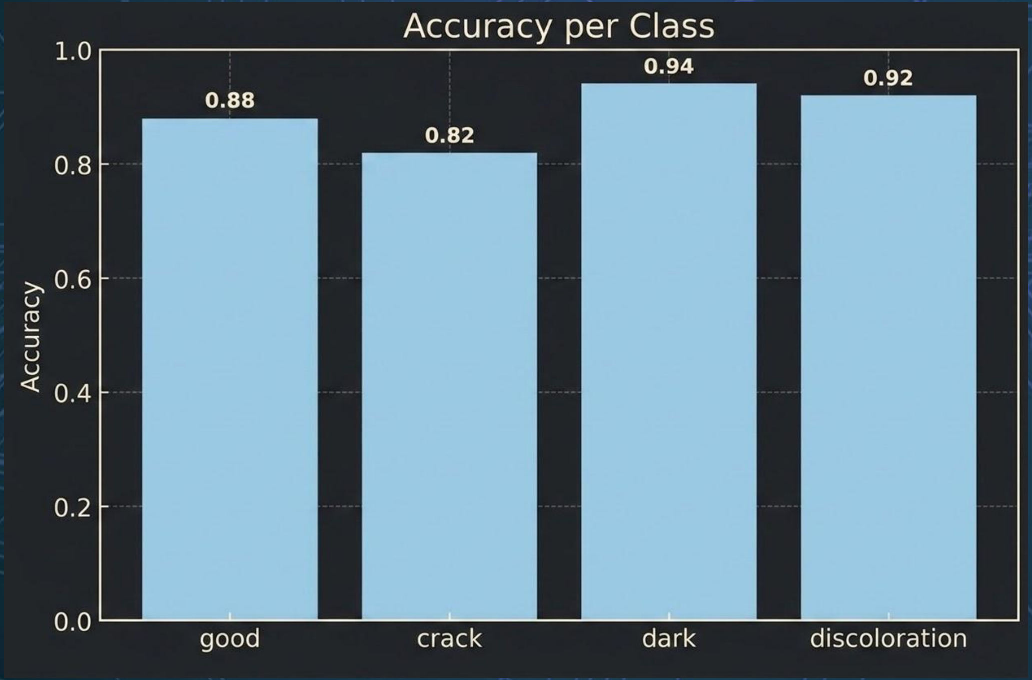
Human Expert Review
(Ground Truth)

Expert validates, corrects edge cases, and verifies complex defect overlaps.

Train Specialist Model
(EAGLE / ChannelViT)

Trained on 100% high-quality data for high-precision diagnostics.

Efficiency of the defect classification model



Key Metrics

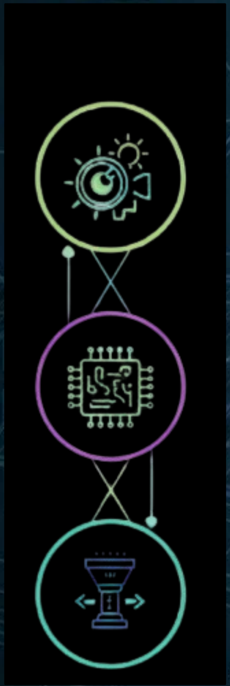
Avg. Accuracy: **89%**

Best Class: **Dark** (94%)

Lowest Class: **Crack** (82%)

The model shows high consistency across diverse defect types, with particularly strong performance in identifying dark spots.

Performance Prediction



Multispectral

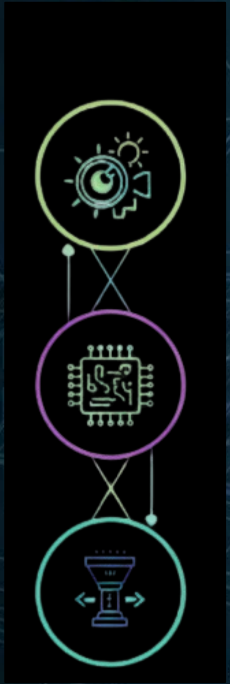
Metric	ResNet-18
MAE	4.35
MedAE	3.38
MSE	32.79
R^2 Score	0.47

Only EL

Metric	ResNet-18
MAE	5.67
MedAE	4.72
MSE	50.61
R^2 Score	0.18

A separate machine learning model predicts electrical performance metrics (Max. Power, Short-Circuit Current, Open-Circuit Voltage) directly from the multispectral images.

Performance Prediction



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FUTURE

Validating & On-site Drone Analysis

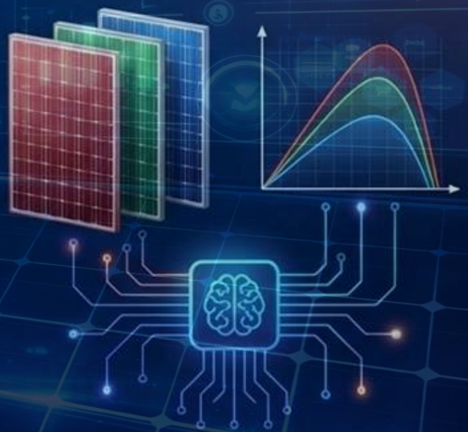
Validating in controlled environment, future - on-site drone analysis.

Advanced Measurements & Digital Twins

Other type of measurements: Thermography, Daylight electroluminescence integration.

Digital twins.

Power to Image & Colored PVs



Power to Image correlation – for colored PV panels.

Contact us!

FFHS

Danuta Paraficz

Ralf Jandl

Natasa Sarafijanovic-Djukic

SUPSI PVLab

Ebrar Özkalay

Mauro Caccivio

ebrar.oezkalay@supsi.ch

danuta.paraficz@ffhs.ch