Solar Panel Anomaly Classification using SARNet Model

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Abstract

This project presents a deep-learning-based system for diagnosing solar panel faults using IR and EL images. The SARNet model, combining StackNet, ResoNet, and attention mechanisms, extracts multi-scale and context-aware features. Trained and tested on IR images for binary and six-class classification, as well as on the ELPV dataset for binary fault detection, it delivered 91.7% and 91.4% in accuracy and F1 - score respectively for IR binary classification, 81.63% accuracy for IR multi - class classification, and 89.1% accuracy for the ELPV binary classification, proving its robustness across diverse fault scenarios.

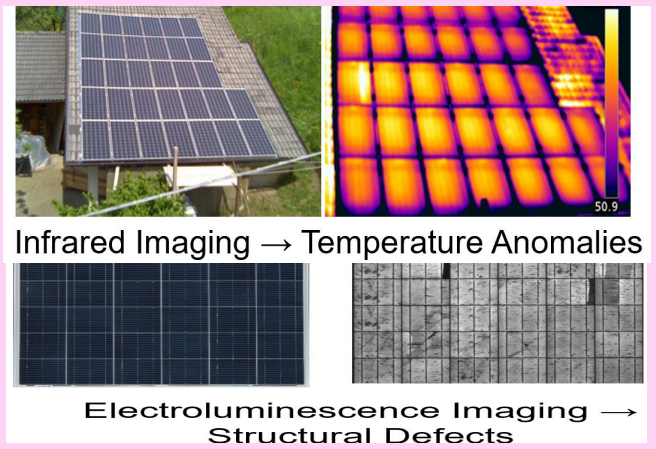

Figure 1: Infrared Image and EL Image

Dataset & Data Process

About dataset 1:

- Modality: Infrared Imaging
- Resolution: 24 x 40 pixels
- Classes: 6 (5 fault types + 1 No-Anomaly)
- Fault Types: Vegetation, Diode, Shadowing, Cell, Cracking, and Offline-Module
- Purpose: Main dataset for fault classification
- Advantage: Enables multi-class detection of solar panel issues

About dataset 2:

- Modality: EL Imaging
- Resolution: 300 × 300 pixels
- Classes: 2 classes (No Defect, Defected)
- Defects: Micro-cracks, soldering faults, disconnected cells
- Role: Supplementary dataset for generalization
- Advantage: High-resolution data reveals hidden internal defects

Data Processing:

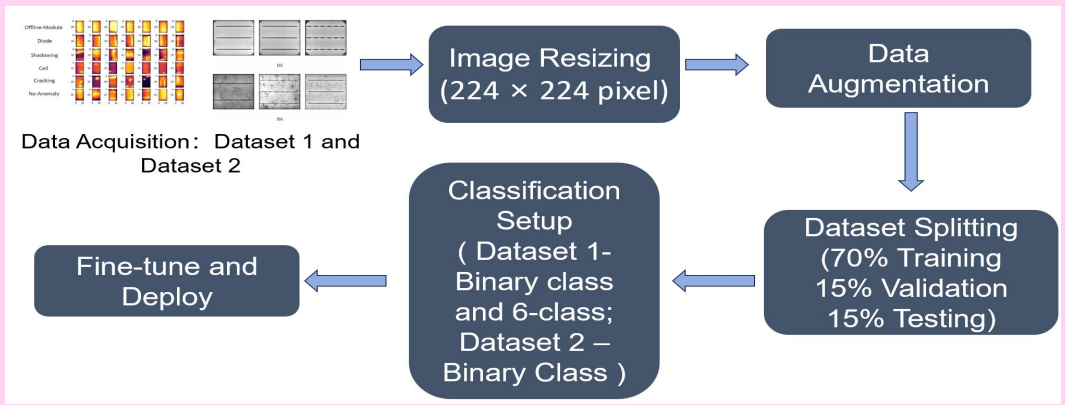

Figure 2:Data Processing Process

Deployment

Model Explainability — Grad-CAM Heatmap :

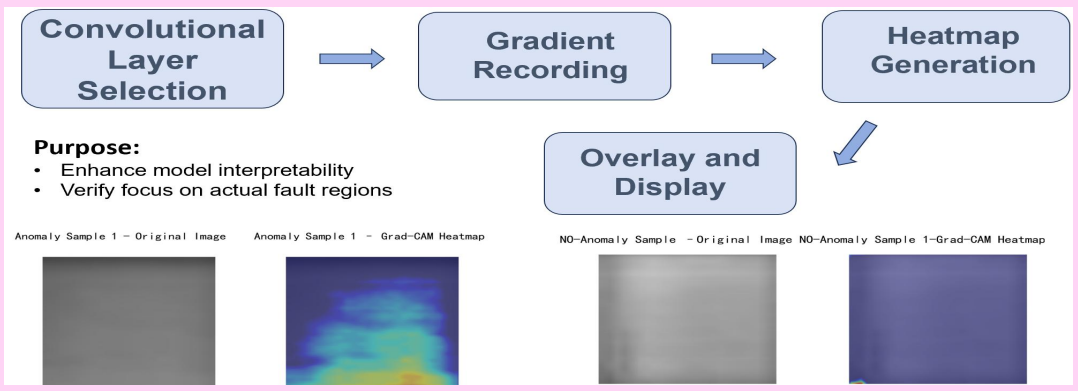

Figure 5:Model Explainability Process

GUI: In order to improve the usability and interactivity of deep learning models in actual solar panel fault detection scenarios, this project built a web-based graphical user interface (GUI) to visualize the detection results and support users to upload images for automatic recognition.

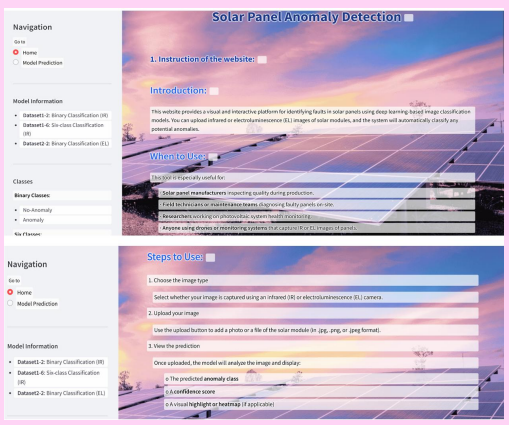

Figure 6:Deployment on Web

Implementation & Results

- The SARNet model, combining StackNet, ResoNet, and attention mechanisms, extracts multi-scale and context-aware features.
- The training is evaluated with Accuracy, Loss, Precision, Recall, Specificity, F1-Score, AUC, ROC, and the total parameters of the network.

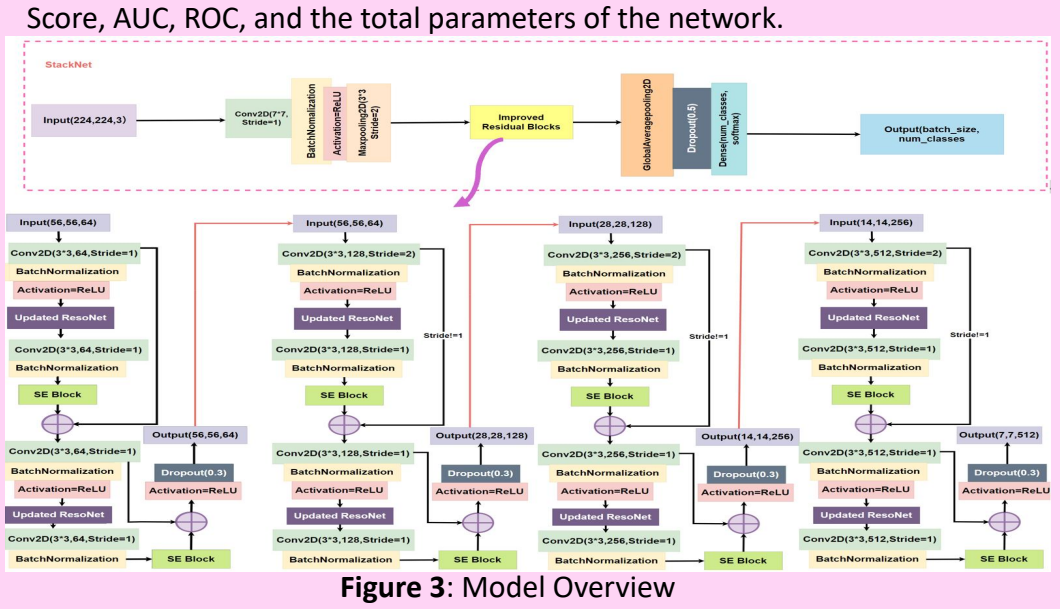

Figure 3: Model Overview

Model	Datasets	Acc (%)	Loss	Rec (%)	F1 (%)	Prec (%)	Para
SARNet	Dataset 1(2-Class)	91.70	0.2980	88.80	91.40	94.20	13,560,498
	Dataset 1(6-Class)	81.63	0.6877	82.22	81.60	81.60	
	Dataset 2(2-Class)	89.10	0.6560	85.80	87.20	84.80	

Acc =Accuracy, Rec = Recall, F1 = F1-Score, Prec = Precision, Para = Trainable Parameters

Model	Datasets	Specificity (%)	ROC-AUC (%)	PR-AUC (%)
SARNet	Dataset 1(2-Class)	94.60	97.20	97.30
	Dataset 1(6-class)	Cell:76.00 Cracking:92.00 Diode:97.00 Offline-Module:82.00 Shadowing:77.0 Vegetation:72.00	Cell:94.0 Cracking:97.0 Diode:100.0 Offline-Module:98.0 Shadowing:98.0 Vegetation:94.0	Cell:85.00 Cracking:91.0 Diode:99.0 Offline-Module:89.00 Shadowing:92.0 Vegetation:81.0
	Dataset2 (2-Class)	92.30	94.70	90.40

ROC-AUC= Receiver Operating Characteristic-Area Under Curve,
PR-AUC = Precision-Recall- Area Under Curve

Figure 4: Training Results Summary

Conclusion

- Enabled effective detection of various solar panel faults
- Improved accuracy in both binary and multi-class classification through hybrid model design
- Enabled real-time fault identification
- Deployed the model

Reference

[1] 'Infrared Solar Modules'. Accessed: Dec. 18, 2024.

[Online]. Available: https://www.kaggle.com/datasets/marcosgabriel/infrared-solar-modules

[2] 'Papers with Code - ELPV Dataset'. Accessed: Apr. 07, 2025.

[Online]. Available: https://paperswithcode.com/dataset/elpv