Deep Learning for Automatic Defect Detection in PV Modules Using Electroluminescence Images

Abstract

Solar energy, in the form of photovoltaic (PV) panels, is important for achieving clean energy solutions. The photovoltaic health index must be monitored and improved because of the high demand for green energy. Unfortunately, defective solar cells are a significant source of performance degradation in photovoltaic (PV) systems. Experts often manually analyze electroluminescence (EL) images by visually inspecting them, which is personal, time-consuming, and requires extensive expertise. This work presents a comparative analysis of YOLOv8 and an Improved YOLOv5 for an automatic PV defect detection system in EL images in which Global Attention Module (GAM) is incorporated into the traditional YOLOv5s model for better object representation. Adaptive Feature space fusion (ASFF) was added to YOLOv5's original structure for feature fusion. The Distance Intersection over Union (Non-Maximum) Suppression (DIoUNMS)
is aggregated to produce a more accurate bounding box. The ELDDS1400C5 dataset was used to train and evaluate the proposed system. Experiments on the ELDDS1400C5 test set revealed that the Improved YOLOv5 algorithm achieved a mean Average Precision of 76.3% (mAP@0.5), which is a 2.5% improvement
over the standard YOLOv5 algorithm for detecting faults in PV modules in EL images. Furthermore, the experimental results demonstrated that Test Time Augmentation (TTA) significantly increased the mAP@0.5 to 77.7%, surpassing the YOLOv8 model, which achieved 77.5% under the same conditions.