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Developing an Electroluminescence Image Recognition System for Monocrystalline Silicon Solar Modules Using YOLO and GAN Technologies

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Abstract: (Times new roman, font size 12) (Max. 500 words)

This project focuses on developing an electroluminescence (EL) image defect detection system suitable for half-cut solar cell modules. We utilized a DCGAN model to generate synthetic EL images, which were then used to train the YOLOv4 model. Initially, we trained the YOLOv4 model using 985 images of half-cut solar cell modules. The model achieved an average precision of 74.72% for cracks, 66.14% for breaks, 42.80% for dirt spots, and an overall mean average precision (mAP) of 61.22% when classified into three defect categories. When grouped into two defect categories (cracks and breaks), the average precision was 73.77% and 75.06%, respectively, with an average mAP of 74.42%. These results indicate that the mAP for three defect categories was lower primarily due to the lower accuracy in detecting dirt spots, which are often challenging to distinguish from breaks during manual annotation, leading to mislabeling or misjudgment. Furthermore, we generated approximately 3000 synthetic EL images using the DCGAN model and combined them with the 985 real images to train the YOLOv4 model. The average precision for cracks was 68.56%, breaks 85.24%, and the overall mAP was 76.90%, slightly higher than the results obtained using only real images for training. DCGAN's advantage lies in its ability to generate synthetic images that closely resemble real ones, effectively addressing the issue of insufficient sample sizes. However, a drawback of DCGAN is the time-consuming process of generating each synthetic image and the limited diversity in generated samples, which may not cover a wide range of different damage positions.

This study successfully developed an EL image defect detection system for solar modules based on YOLO and DCGAN models. Future work will focus on further optimizing the DCGAN model to generate more realistic synthetic images, thereby enhancing detection efficiency and ultimately improving industrial competitiveness.

Keywords: Eelectroluminescence imaging; Defects; Object detection; Deep Convolutional Generative Adversarial Network.