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Solar Cell Surface Defect Detection Based on Optimized YOLOv5

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ABSTRACT

Traditional vision methods for solar cell defect detection have problems such as low accuracy and few types of detection, so this project proposes an optimized YOLOv5 model for more accurate and comprehensive identification of defects in solar cells. The model firstly integrates five data enhancement methods, namely Mosaic, Mixup, hsv transform, scale transform and flip, to expand the existing data set to improve the feature training accuracy and enhance the robustness of the model; secondly, CA attention mechanism is introduced to improve the feature extraction ability of the model; to address the problems of different target defect classification and localization concerns, the detection head in the original model is replaced with a decoupling head, which significantly improve the detection accuracy of the model without affecting the convergence speed of the mode

I. INTRODUCTION

At the present stage, under the dual pressure of environmental pollution and the increasingly prominent traditional energy crisis, people have turned their attention to the development and utilization of new energy sources. Due to the advantages of a wide range of applications, low cost, safety, and reliability, solar energy has become one of the mainstream new energy sources with high-speed development. Solar panels are important components of photovoltaic power generation, silicon crystal plates are fragile and fragile, and defects are easily produced by improper operation in production and installation, these defects cannot only affect the efficiency of solar cell power generation but also seriously threaten people’s life and property safety. Therefore, the study of solar cell defect detection methods is of great significance.

II. OBJECTIVES

- The primary goal is to create an advanced solar cell defect detection system using YOLOv5.
- To apply four distinct image enhancement techniques, including Mosaic, Mix-up, HSV transformation, scaling, and flipping, to improve image clarity and defect identification.
- To enhance feature extraction and defect classification by introducing a Channel Attention (CA) model while replacing the detection head to enhance accuracy without affecting convergence speed.
- To conduct a comparative evaluation of the proposed Optimized YOLOv5 with the existing Faster RCNN algorithm, assessing performance using accuracy, precision, recall, F1 score, Confusion Matrix, and Mean Absolute Precision (MAP).

III. EXISTING SYSTEM

Solar cell defect detection relies on traditional methods like manual visual inspection, where human operators subjectively identify defects based on their expertise, and machine vision techniques that use automated systems to analyze solar cells for anomalies. These methods have limitations in accuracy and comprehensiveness, underscoring the need for more advanced defect detection solutions in solar cell manufacturing.

IV. PROPOSED SYSTEM

The proposed system introduces an optimized YOLOv5 model with data enhancement techniques, a Channel Attention mechanism, and a decoupling head to improve solar cell defect detection. These innovations enhance accuracy, comprehensiveness, and real-time capabilities, providing a modern and efficient approach to defect identification. The proposed system significantly enhances defect detection accuracy, reducing errors. It identifies a wider range of defect types, ensuring more comprehensive quality control. The system operates in real-time, reducing the need for labor-intensive inspections and increasing production efficiency. Integration of advanced mechanisms boosts the system's resilience in varying conditions, ensuring consistent defect detection. As an extension to the project, the incorporation of the YOLOv6 model further amplifies the system's prowess.

V. LITERATURE SURVEY

The proposed system improves upon existing methods by efficiently combining region proposal and object detection networks, reducing computational demands and achieving real-time performance while maintaining high accuracy. It also streamlines the overall architecture and provides effective object localization, making it a practical choice for various applications.

VI. SYSTEM ARCHITECTURE

A system architecture for solar cell surface defect detection using an optimized YOLOv5 model typically involves image acquisition, pre-processing, model training and deployment, and post-processing for defect classification. The core of the system is the YOLOv5 model, which is modified to enhance its ability to detect various types of solar cell defects.

1. Image Acquisition:

- Solar cell images are captured using cameras or other image acquisition systems.
- These images are often taken in a controlled environment to ensure consistent illumination and focus.

2. Pre-processing:

- **Data Augmentation:**

Techniques like rotation, scaling, flipping, and color adjustments are used to increase the diversity of the training dataset, improving the model's robustness.

- **Noise Reduction:**

Image noise can be reduced using techniques like Gaussian blurring or median filtering.

- **Image Enhancement:**

Techniques like contrast adjustment or histogram equalization can enhance the visibility of defects.

3. Model Training and Optimization:

- **YOLOv5 Model:**

The core of the system is the YOLOv5 object detection model. This model is trained on a dataset of solar cell images labeled with different types of defects.

- **Optimization Techniques:**

Various techniques are used to optimize the YOLOv5 model for solar cell defect detection, including:

    - **Deformable Convolution:** Used to enhance the model's ability to capture defects of varying shapes and sizes.
    - **Attention Mechanisms:** Like ECA-Net, are used to focus on the relevant features of the image.

4. Model Deployment:

- The trained YOLOv5 model is deployed on a device capable of real-time processing, such as a GPU or a specialized hardware accelerator.
- The model is used to process new images and identify defects in real-time.

5. Post-processing and Defect Classification:

- **Defect Classification:**

The YOLOv5 model outputs bounding boxes around detected defects and their corresponding class labels.

- **Non-Maximum Suppression (NMS):**

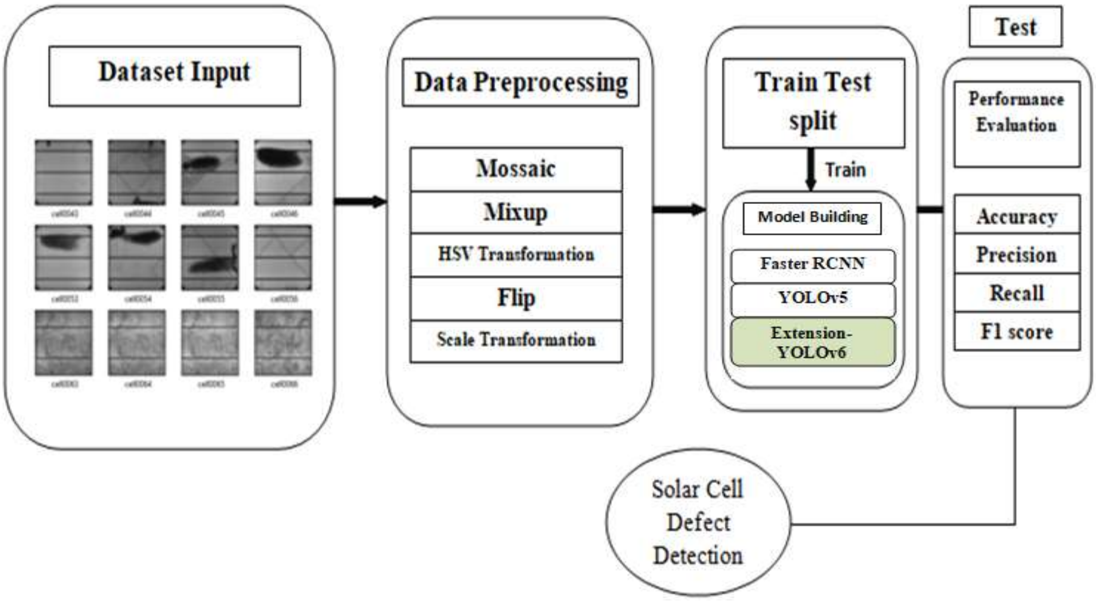
This technique removes redundant bounding boxes, ensuring that each defect is identified only once.

- **Defect Severity Assessment:**

Additional processing can be applied to assess the severity of detected defects.

6. System Integration:

- The entire system can be integrated into a larger manufacturing or quality control process.
- The detected defects can be used to automatically reject defective solar cells or to guide repair or rework processes.



VII. RESULT

The results show that the optimized model achieves an mAP of 96.1% on the publicly available dichotomous ELPV dataset, and can identify and locate a variety of common defects in the PVEL-AD dataset, while the mAP can reach 87.4%, an improvement of 10.38% compared with the original YOLOv5 model, which enables the model .

VIII. CONCLUSION

- In this project , an optimized YOLOv5 solar cell surface defect detection model is proposed for solar cell defects.
- That are difficult to collect, difficult to distinguish, easy to mis-detect and miss detection, etc.
- The model achieves defect detection at different scales by introducing a CA attention mechanism and replacing the decoupling head to enhance the feature extraction capability.

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