Machine Vision for Identifying Defects in Perovskite Thin Films

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QR CODE

Objective & Research Question:

Can automated defect detection of perovskite thin films using machine vision increase the scalability, speed, and uniformity of solar cell production?

Background:

- Perovskite solar cells are inexpensive and efficient but susceptible to production defects such as contamination, cracking, and pinholes.
- Manual inspection is labor-intensive and non-reproducible betweensamples.
- The detection of defects can be made easier and improve manufacturing by automating.
- It applies standard computer vision and deep learning methods todetect defect patterns in microscope images of perovskite thin films.

Result:

- Defects on lines, clusters, and surface voids occurred in all three sample types.
- Conditional image-specific logic assisted in capturing low-contrast or faint cracks.
- The pipeline managed to remove most of the false positives from background textures.
- Bounding boxes successfully highlight defect areas directly on the original images.

Methods:

Dataset: Images of perovskite films with various forms of defects obtained using an optical microscope.

Preprocessing:

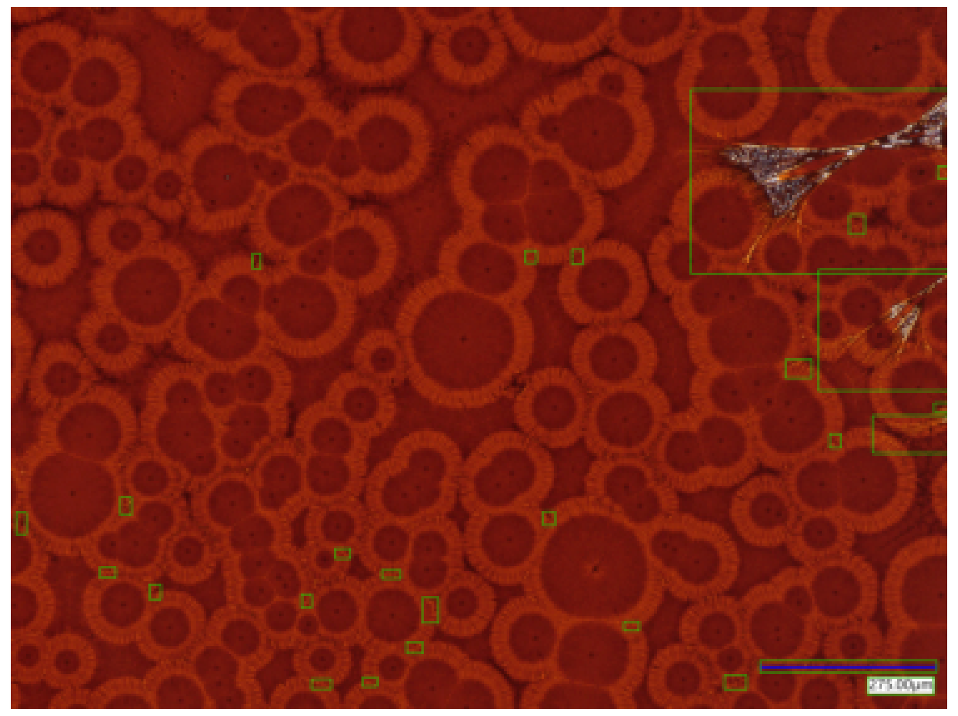
- Grayscale Conversion simplifies color complexity for edge-based processing.
- CLAHE (Contrast Limited Adaptive Histogram Equalization) was applied selectively (e.g., to the last image) to introduce contrast in low-visibility areas.
- Gaussian Blur diminishes background noise prior to edge detection.

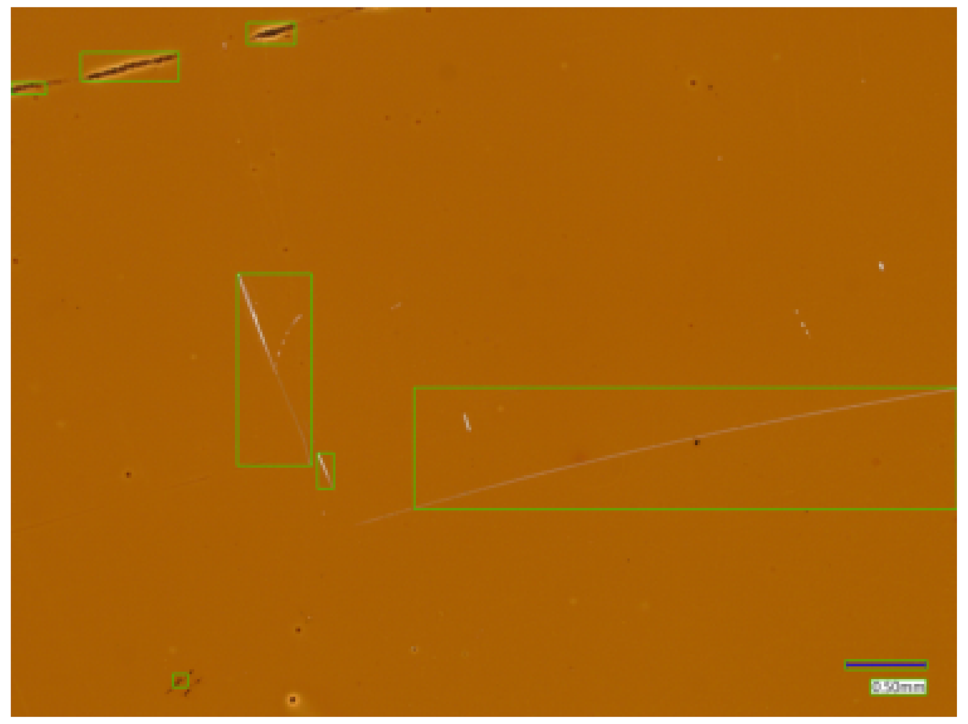
Detection Approach:

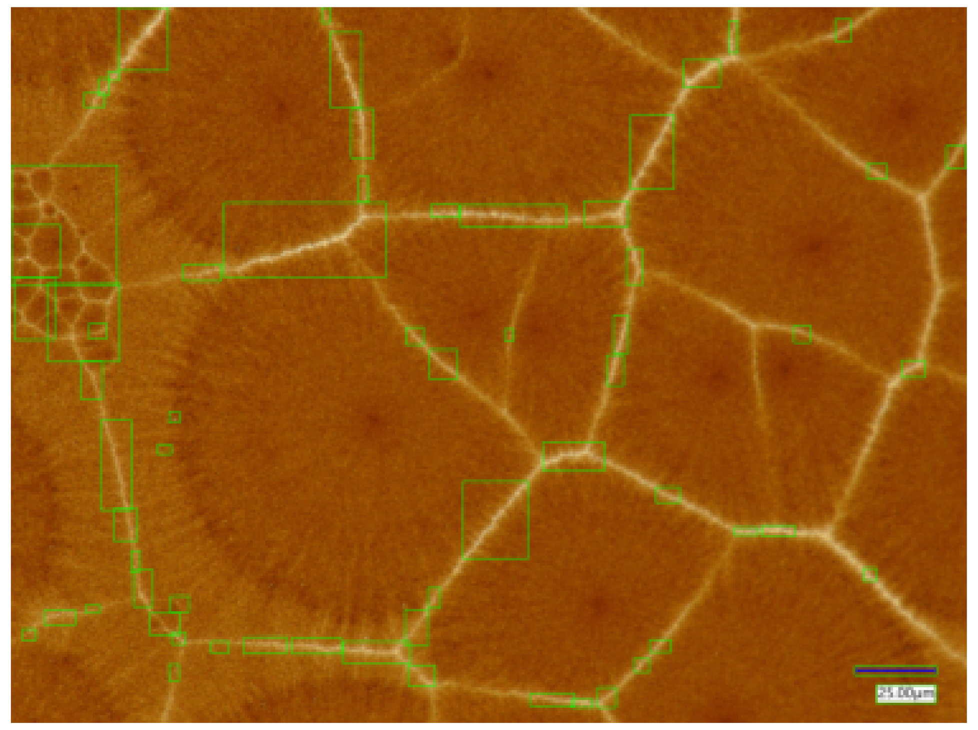
- Canny Edge Detection identifies abrupt intensity transitions typical of defect boundaries.
- Morphological Operations: Dilation expands detected edges and Closing bridges small gaps to connect fragmented or weak edge segments, making contours more complete.
- HSV Color Thresholding (Hue-Saturation-Value color space) was utilized particularly on the final sample for the revelation of faint cracks and low brightness regions, which were previously undetectable.

Contour Analysis:

- Shape- and area-based filtering was applied with individually tuned thresholds per image to deliver image-specific, adjusted sensitivity.
- Bounding boxes were only sketched if the defect met area/shape criteria to avoid false positives due to textures or artifacts.







Improvement Highlight:

The first one was that the bottom-right third image did not show up any of the identified defects due to low contrast and subtle textures. Withthe addition of CLAHE contrast enhancement and color thresholding, the enhanced pipeline can now identify many weak cracks and dark edges well, showing substantial improvement in sensitivity and overall generalization.

Next steps:

- Apply object classification to label detected defects (e.g., pinholes vs cracks).
- Quantitatively evaluate model performance on labeled datasets (F1-score, IoU).
- Test on other optical samples under different lighting or resolution conditions.
- Develop a real-time defect detection interface for lab integration.
- Talk about integration with automated feedback loops for perovskite film production.

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