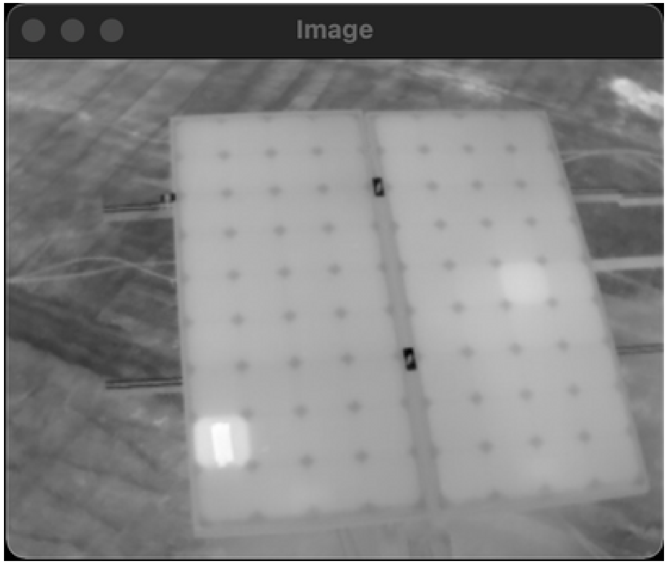
Automatic Failure Detection in Photovoltaic Solar Panel

mhilmiasyrofi@gmail.com
Muhammad Hilmi Asyrofi

mhilmiasyrofi@gmail.com
Muhammad Hilmi Asyrofi

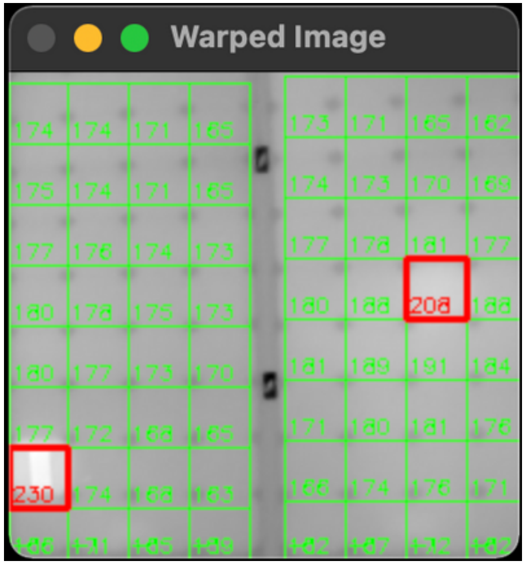
Failure Detection

Input



The input image of Photovoltaic (PV) Solar Panel is obtained from Kaggle [1]. Each PV contains 4x9 cells on the left and 4x9 cells on the right. The white color of a cell that differs from the other cells indicates the particular cell has failure

Output



Warped Image of the object interest, i.e. PV. The number inside the box (PV cell) informs the pixel intensity. The red box shows that the algorithm discovers failure in the PV cell, i.e. the pixel intensity of the red box is significantly higher than the pixel intensity of the surrounding PV cells

[1] https://www.kaggle.com/saurabhshahane/photo-voltaic-cell-images

Pipeline

1. Image Binarization
2. Filter with Flann Matching Algorithm
3. Detect Minimum Enclosing Quadrilateral
4. Warp with Perspective Transformation
5. Localize PV Grid
6. Detect Failure

Muhammad Hilmi Asyrofi
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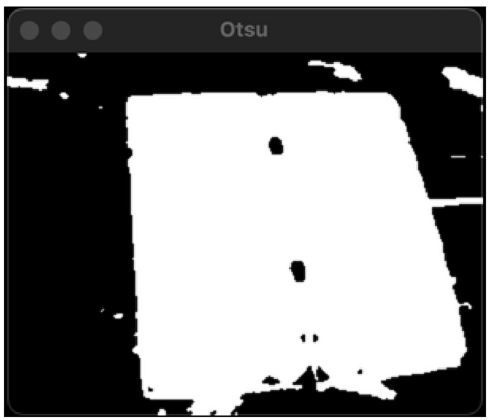
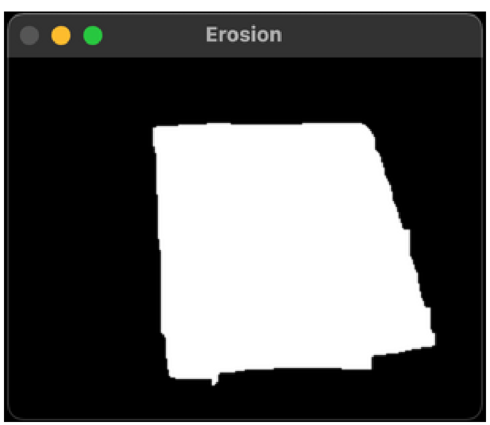
1 IMAGE BINARIZATION

- utilize Otsu binarization to get a binary image containing the PV area
- take advantage of morphological transformations, specifically by closing, eroding, and dilating each contour (white color) in the binary image, to reduce the noise in the binary image

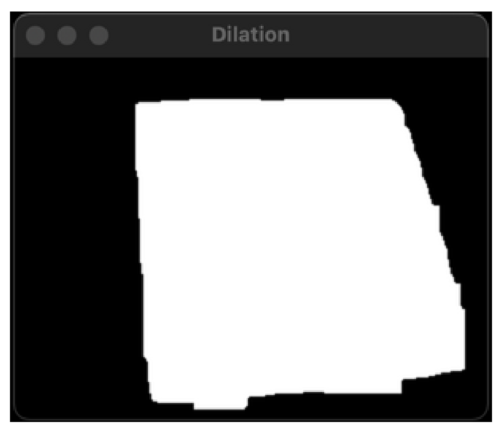


Otsu

Closing



Eroding



Dilating

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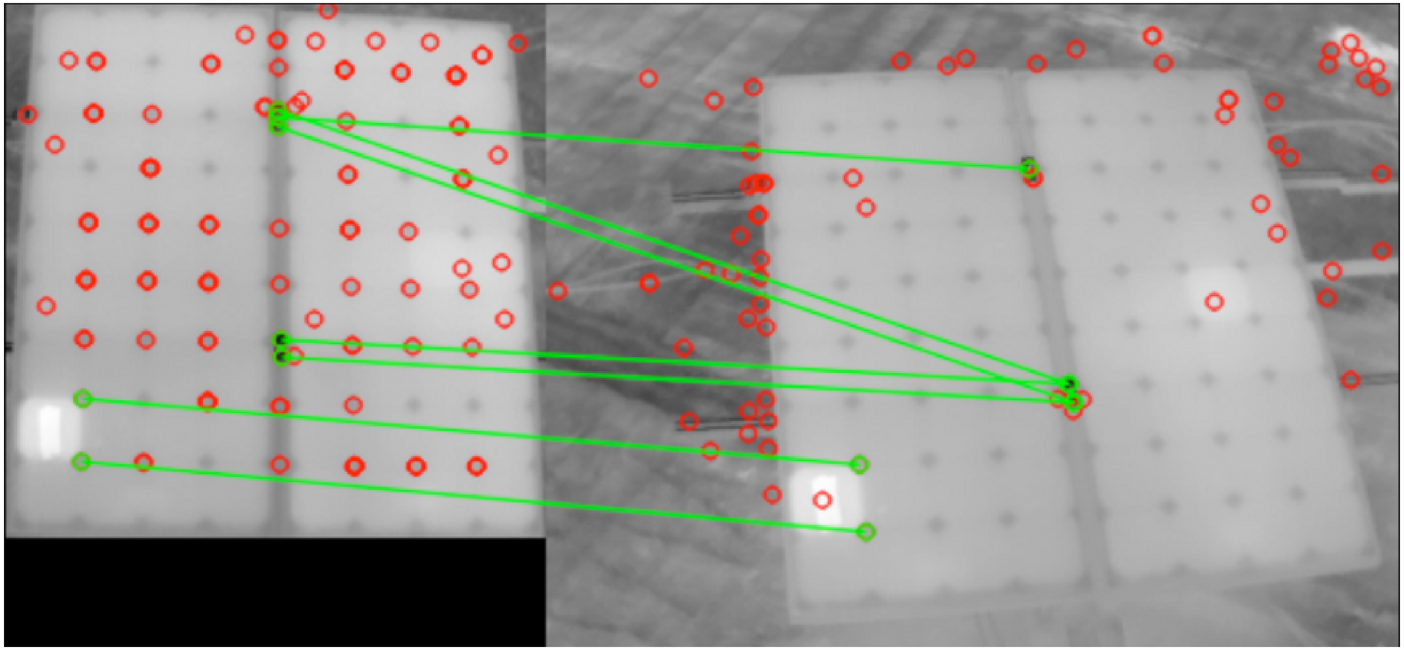
2 FLANN MATCHER

- develop a Flann matcher to filter the correct contour.
- the Flann matcher detects key points in the target image (right) by using a reference image of a PV (left).
- Iterate over contours found in the previous step, then get the contour where the majority of key points are located inside the particular contour



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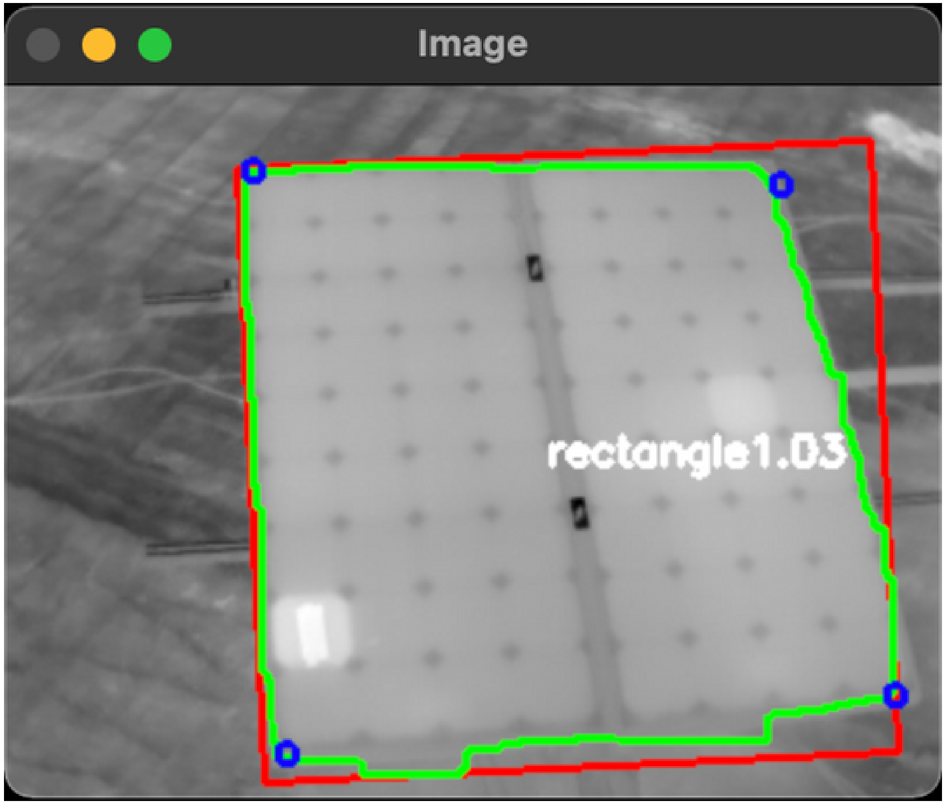
3 ENCLOSING QUADRILATERAL

- detect minimum enclosing rectangle (red line) for the contour (green line)
- identify the vertex of the quadrilateral contour by finding the 4 points (blue points) on the contour (green line) where each point has the minimum distance to each vertex of the rectangle (red line)



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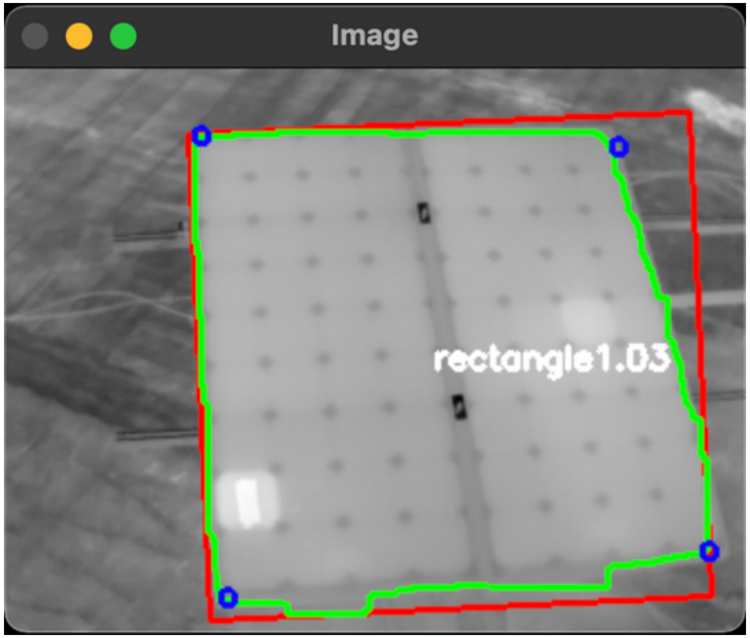
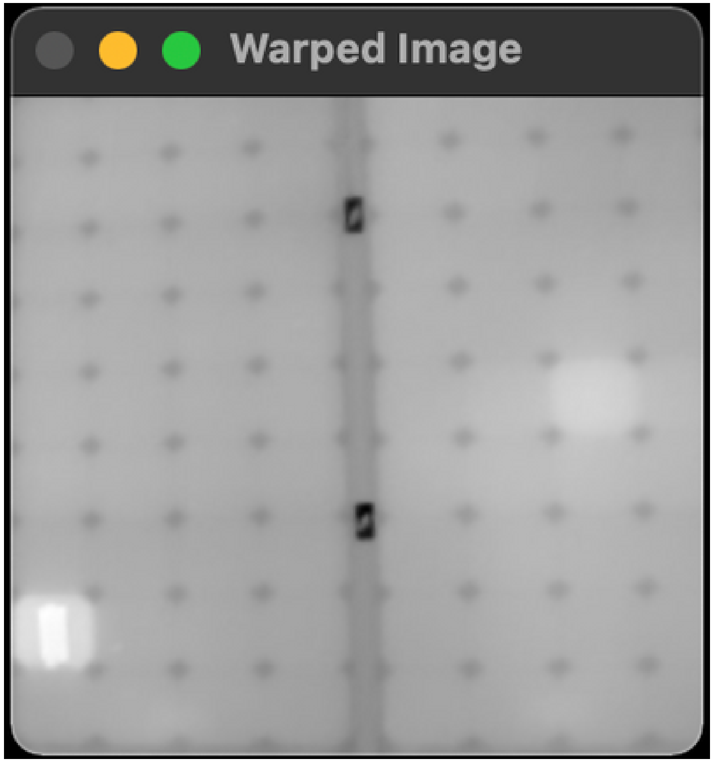
4 IMAGE WARPING

- warping means reshaping the contour that corresponds to the PV
- warp the quadrilateral contour into a rectangle with a perspective transformation





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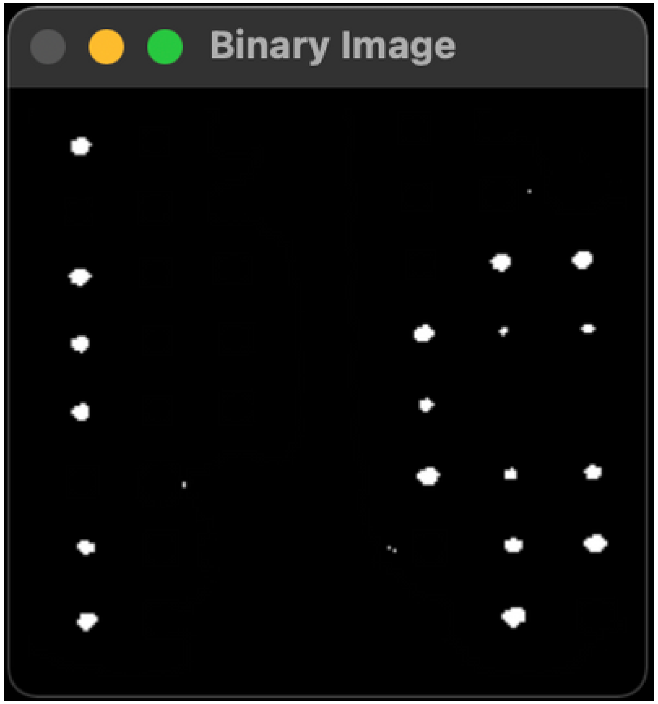
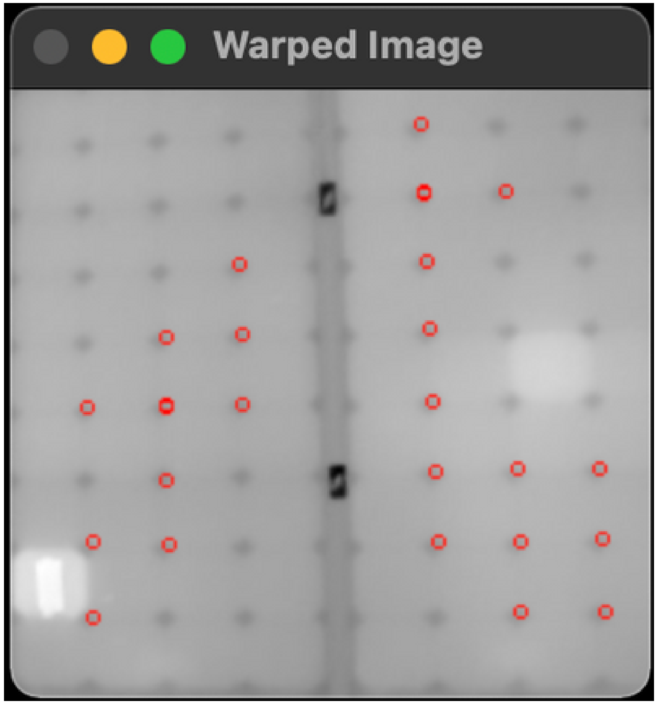
5 LOCALIZE PV GRID

- The PV has a special characteristic: it has a regular dots pattern. We can use this information to detect each 4x9 PV grid
- utilize otsu and morphology operator to detect some dots (left).
  **note that some dots might be imperceptible due to the size
- detect dots where they lie on a parallel line and they have a consistent distance each other. It can be horizontally parallel or vertically parallel





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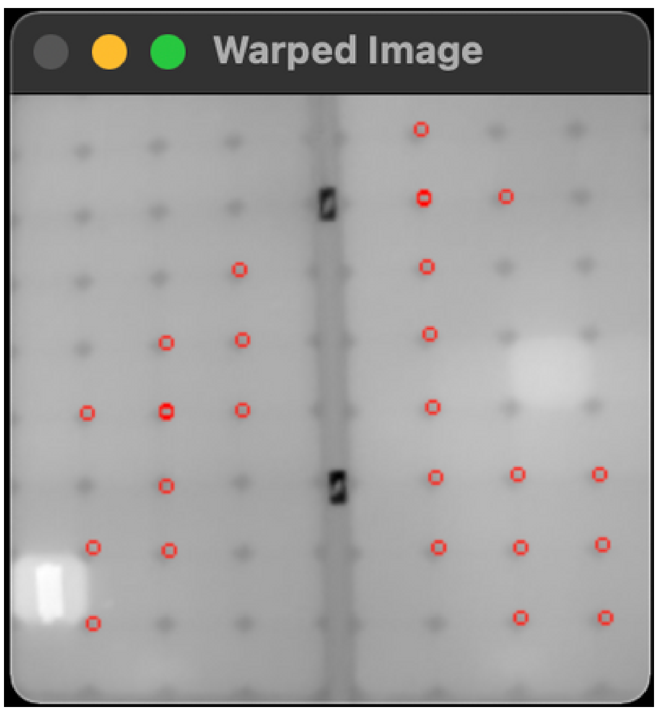
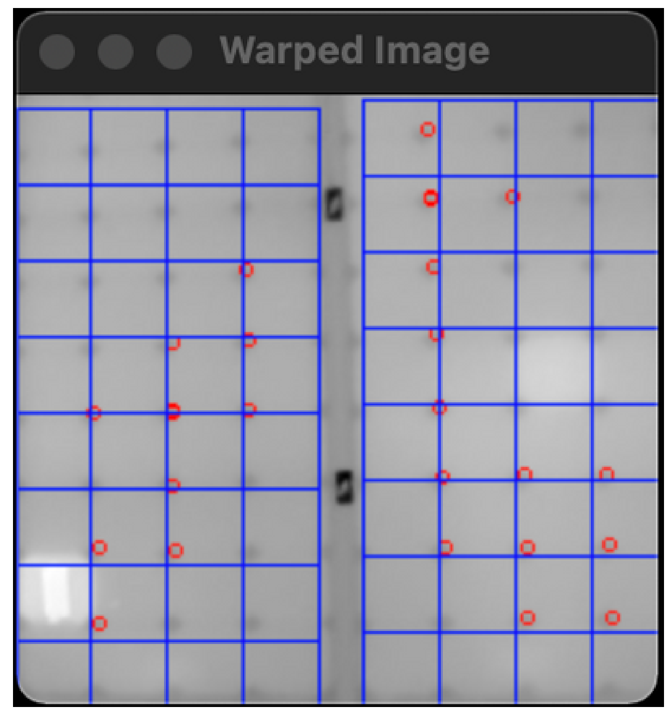
5 LOCALIZE PV GRID

- Define the PV cell size by calculating the median distance between two neighboring dots.
- Create several imaginary 4x9 grids by varying the grid location.
- Perform a sliding window to get the fittest grid, i.e., the grid that has the lowest error score when the red dots are stretched on the grid





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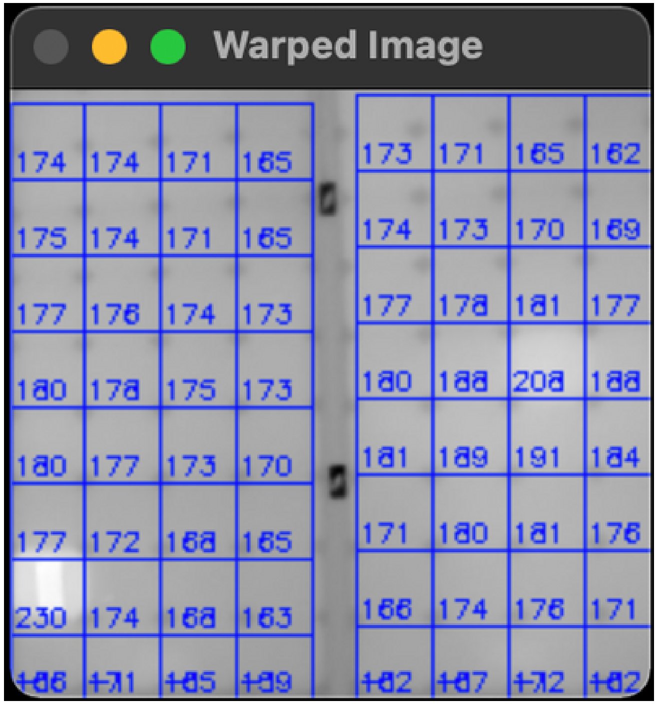
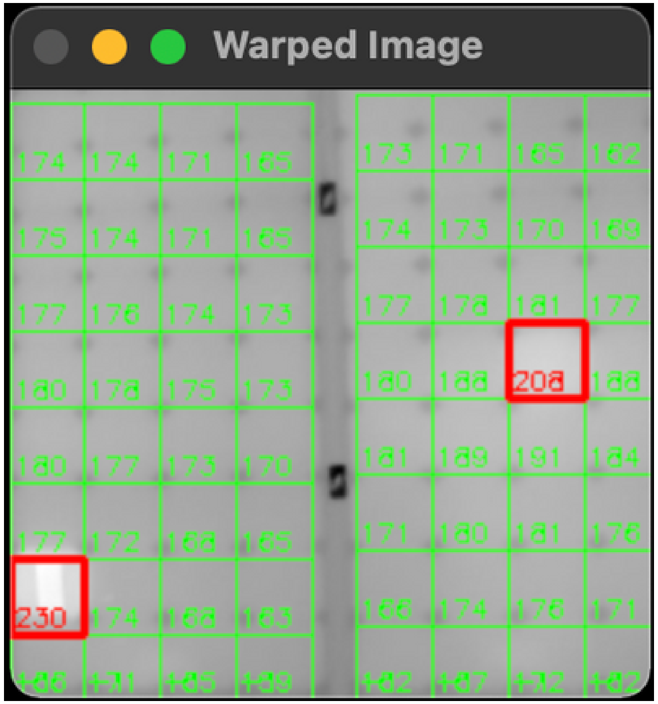
6 DETECT FAILURE

- Measure the average pixel intensity for each cell in the grid
- Detect failure when the average pixel intensity of the particular cell has significant differences with the surrounding cells
- The red cell informs that there is a failure with the cell





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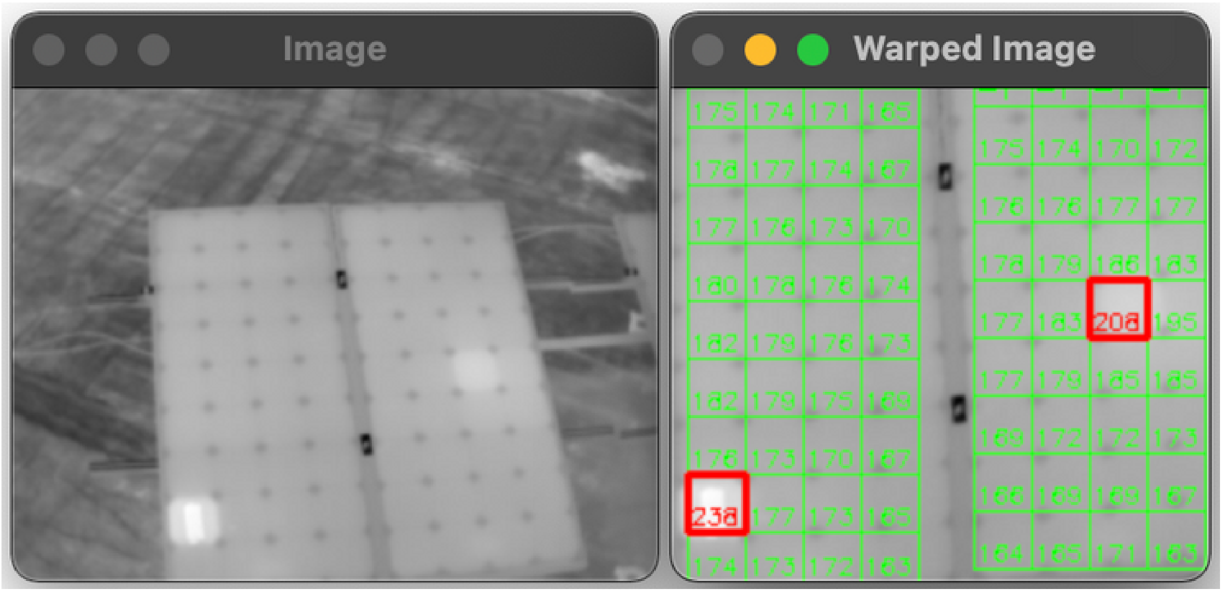
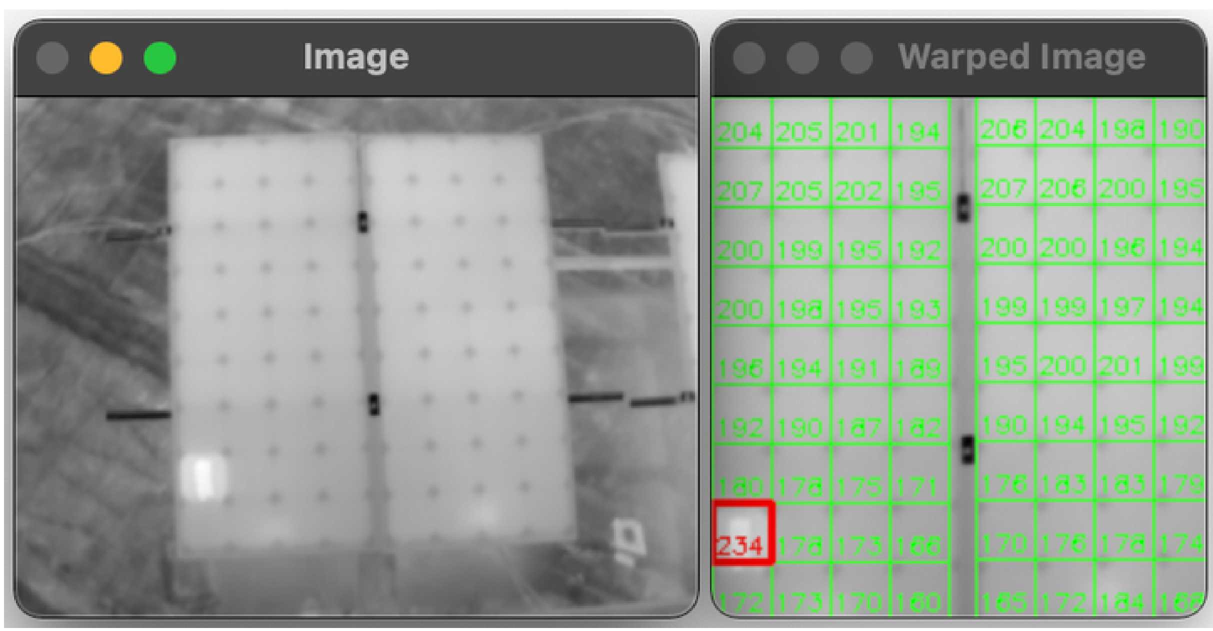
ROBUSTNESS TEST





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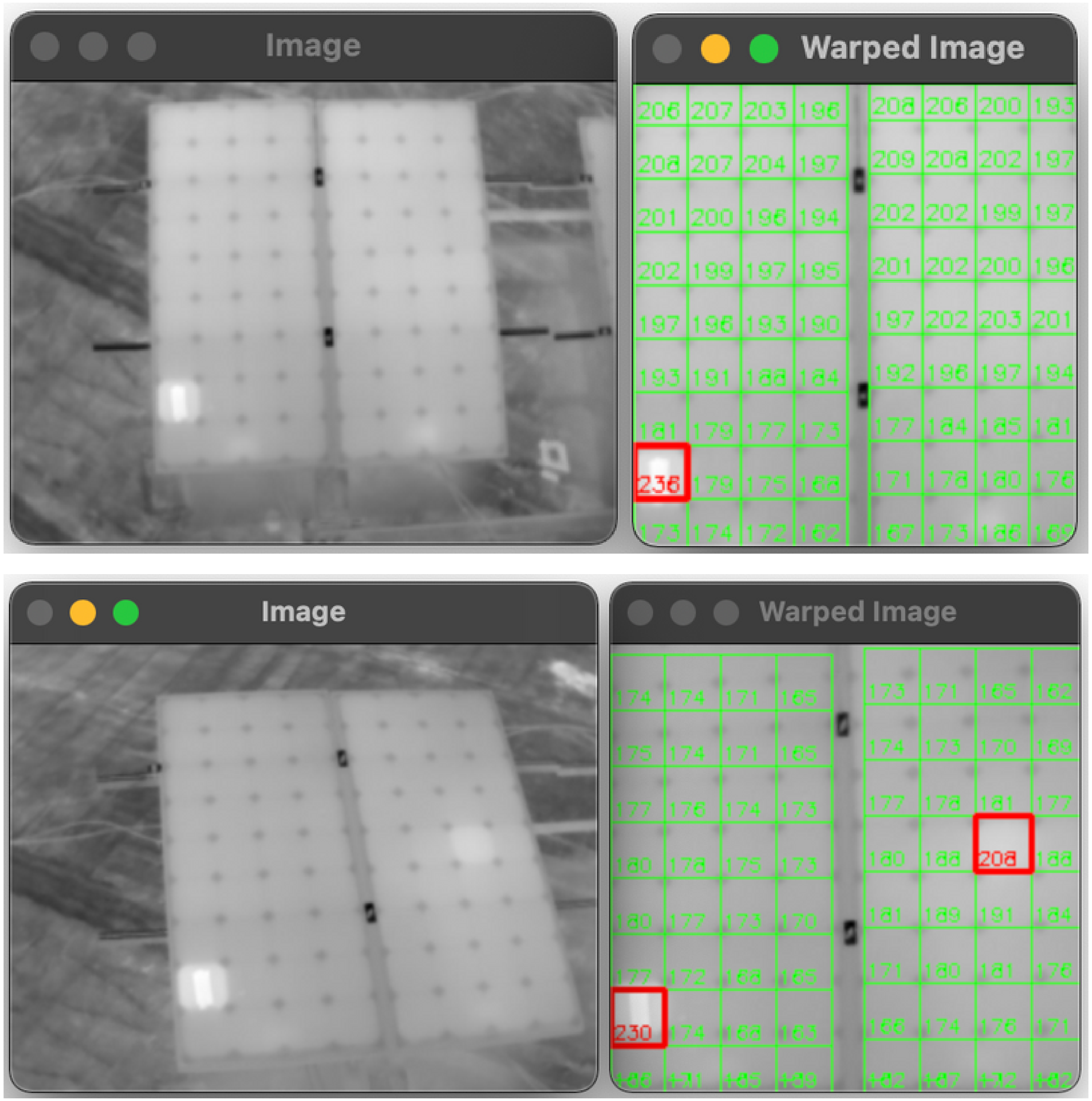

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Potential Works for Collaboration

PV Segmentation

The current approach to obtain the PV area using Otsu binarization is fast but it might not be accurate enough. There are some deep learning approaches for image segmentation proposed in the CV community, such as FastFCN, Gated-SCNN, and Facebook's Mask R-CNN. The future work might try adapting these DL architectures for this task.

PV Grid Localization

Currently, the algorithm relies on regular dots to localize the PV grid. A different version of PV might not have this feature. The future work should try a general approach to localize the grid, e.g. perform a sliding window to measure the intensity of a small area of the grid and analyze the pixel intensity distribution using histogram