# Using Drones to Detect Solar Panel Malfunctions

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## Background and Motivation

### Background

- In 2009, the **American Recovery and Reinvestment Act (ARRA)** directed $31 billion to clean renewable energy projects [6].
- As a result, numerous solar arrays were installed worldwide at U.S. Navy installations, but no budget was provided for their maintenance [5].
- Solar panels provide a way to harness **solar energy**, one of the cheapest and most abundant renewable energy sources available.
- A group of solar panels is called a **solar array**.

Photo from [AleSpa]

- Since solar arrays have no moving parts, a main focus of maintenance is to keep panels clear of dust, foliage, snow and other debris.
- Maintaining **roof-mounted arrays** can be difficult, dangerous and expensive because the steeper and more complex the roof is, the more training and safety equipment is needed [4].
- Thermal imaging can be used to detect **hotspots** on solar arrays.
- Hotspots are generally indicative of solar panel failure [3].
- An **Unmanned Aerial System (UAS)** consists of three parts: an autonomous control system (e.g. human), an unmanned aerial vehicle (commonly referred to as a "drone") and a communication system to link the two.

Photo from [1]

### Project and Motivation

- **What?** Provide the U.S. Navy with a tool that aids in solar array inspection
- **How?** Using python's computer vision library to develop scripts
- **Why?** To help the U.S. Navy increase efficiency, decrease spending and contribute to environmental health

## Goal

To develop a collection of python scripts that will allow for a UAS to engage in real-time inspection of solar arrays by

- Detecting the solar arrays and individual panels
- Finding hotspots and returning pertinent information about them

## Tools

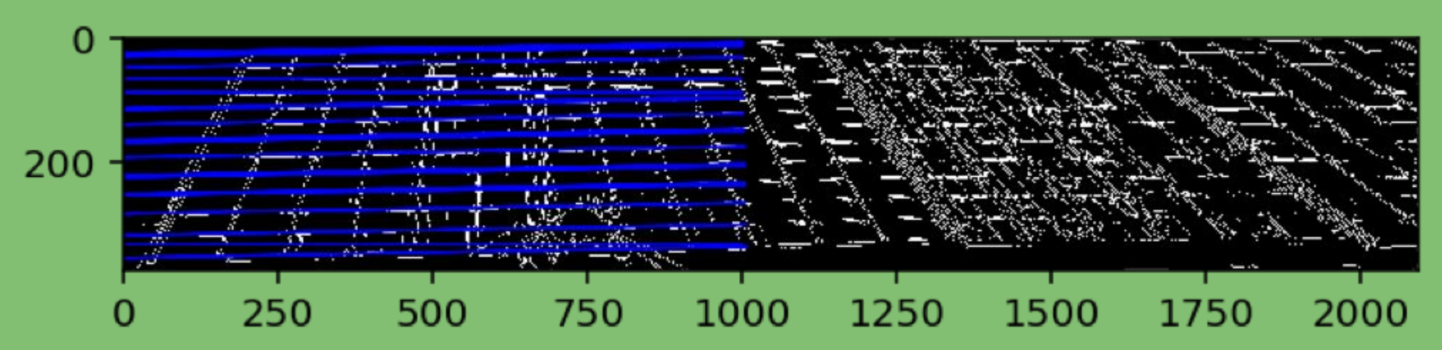
For our project, we use the python programming language to develop the scripts. To manipulate images and get information from them, we use the NumPy and OpenCV python libraries (see their online documentation for more information). We also use CoCalc, an online computing environment that allows us to share code and data with others without using our own computer's storage or processors.

*For more information about CoCalc, please visit cocalc.com*

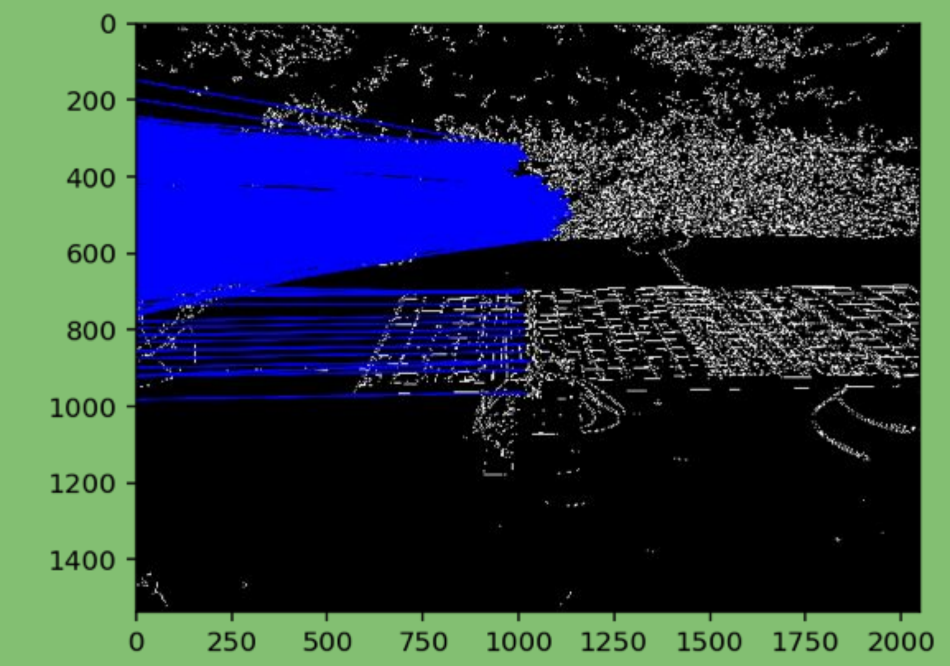
## Results and Discussion

### Using Lines to Detect Solar Panels

I originally wanted to find a method of image detection that would be able to distinguish between solar panels and background images. Initially, I started with a technique called the Hough-Line transform. Some initial results of applying this technique are pictured below.

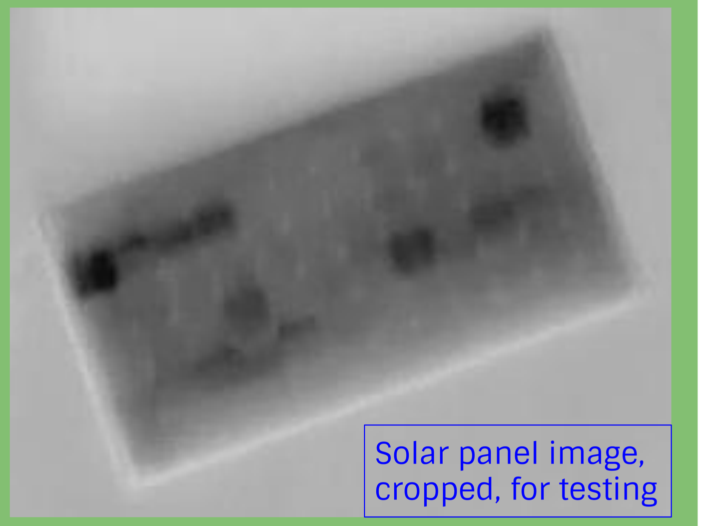



The Hough Line transform seemed to only isolate one particular property of a solar array. Because our images have objects with multiple properties, I needed a set of techniques that would be able to identify solar arrays in a wide range of environments. This led me to research into machine learning techniques that could aggregate properties of the solar array to identify the object in different images. Further, I hope to use these techniques to be able to identify solar panels in video feed to provide drone operators with real-time identification of broken solar panels. Another example of a Hough Line transform is shown below.

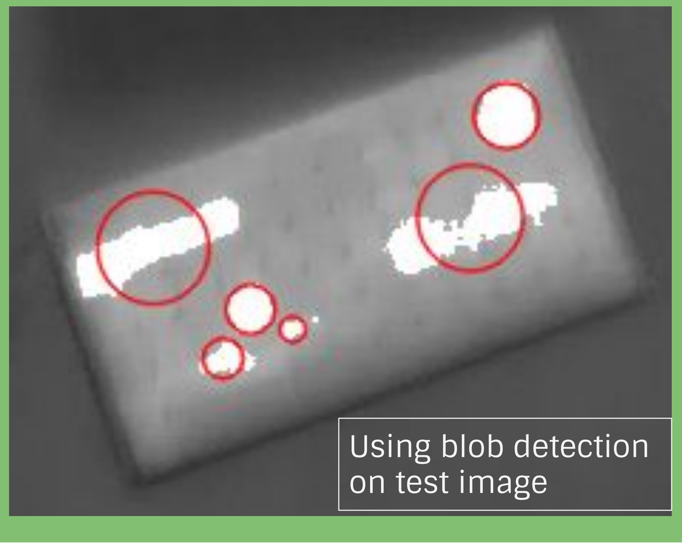



### Hotspot Detection

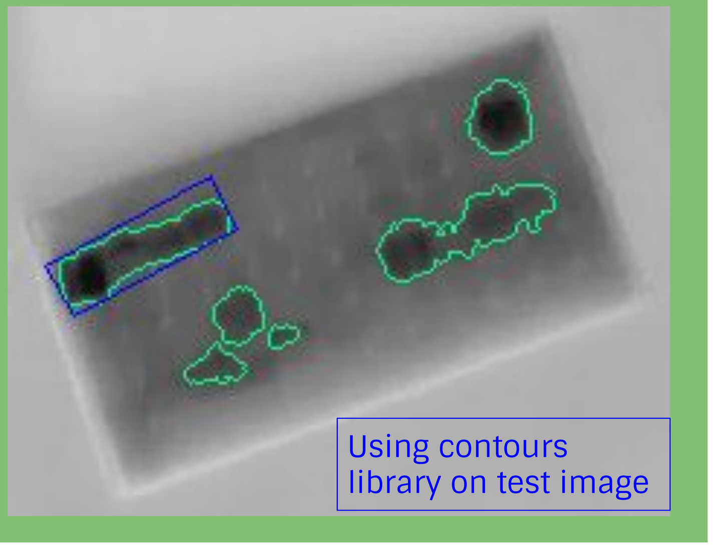
I began with an image of a solar panel that I knew had hotspots. First, I tried the blob detection algorithm in OpenCV (seen below, left). Although I was able to draw circles in areas with hotspots, I couldn't get good information about the hotspots because some just weren't circle-shaped. So, I turned to OpenCv's contours library (see below, right). This enabled me to draw a closer outline around each hotspot, or "contour", and retrieve attributes, or information, about each one. For example, I can return the bounding rectangle coordinates, moment, area and perimeter.



Solar panel image, cropped, for testing

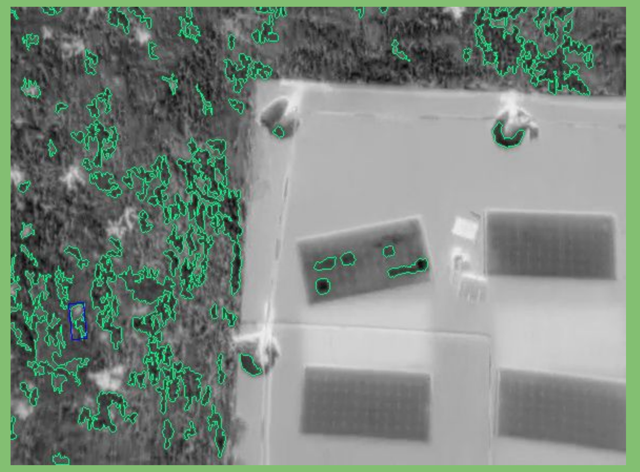


Using blob detection on test image



Using contours library on test image

## Results and Discussion Continued




In the image above (left), you can see the result of finding the contours on an uncropped image of a solar panel. Although the script identifies the hotspots on the solar panel, it also identifies various other contours in the image. This is because the contours library finds its contours based on the intensity of pixels in an image. In the other image above (right), you see the result of finding the contours on an RGB thermal image. Again, the hotspots are identified on the solar panel, but other parts of the image are incorrectly taken to be "hotspots."

## Future Work

We are interested in how we could apply **deep learning** to our project to improve our results. Deep learning is a type of machine learning that uses a **convolutional neural network (CNN)** algorithm. A CNN takes an input image and breaks it down into layers to find objects by examining the different features of the image (such as edges, texture, shape and color). Listed below are some areas left for exploration.

- Distinguishing solar panels from other objects in an image
- Detecting hotspots on solar panels without detecting other objects
- Returning the probability that a detected hotspot is actually a hotspot
- Establishing the real-life dimensions of the hotspots and solar panels based on two-dimensional images

Since solar arrays can be thousands of feet long, we'll need to be able to "stitch" the images together to give the user a complete image of the solar array and faulty solar panels. Dr. Adrian Rosebrock created a script to stitch two images together. Using his script as a basis, we can create a script that will stitch multiple images together.

## GitHub

**Contours, thresholding, & panorama stitching** - https://tinyurl.com/yd4j267e

## Selected References

[1] Abel Insurance, 2019. Retrieved from https://abelins.com/drone-insurance-coverage/
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[5] Richards, Luke. Personal Communication, 12-05-2018.
[6] US Department of Energy, Successes of the Recovery Act, 2012, Retrieved from https://www.energy.gov/sites/prod/files/RecoveryActSuccess Jan2012final.pdf.

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