Robust Algorithm for Finding NIF Mask Features

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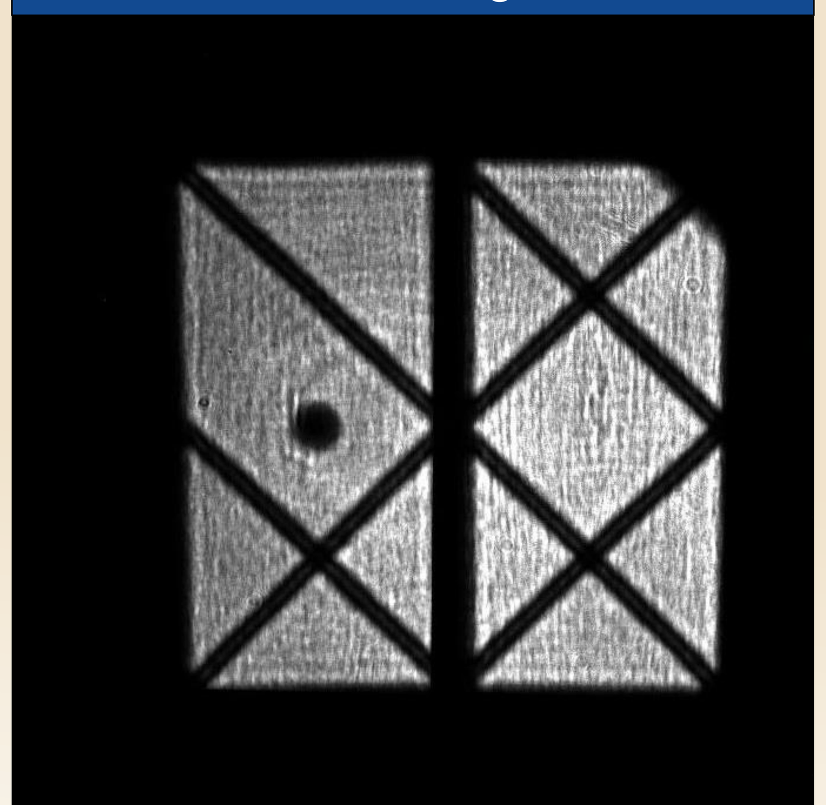
***Abstract:** Creating a robust algorithm for finding NIF Mask features is an exploratory project into image analysis. The objective of the project is to create a program that automatically detects features on images of the mask to better understand image analysis techniques. The program itself may be used to measure the quality of the image. Through this project, various image analysis techniques were used such as filtering, smoothing, edge detection, and Radon/Hough Transform. The program robustly handles imperfect images and accurately detects the features such as the circle, lines, and intersections.*

Introduction

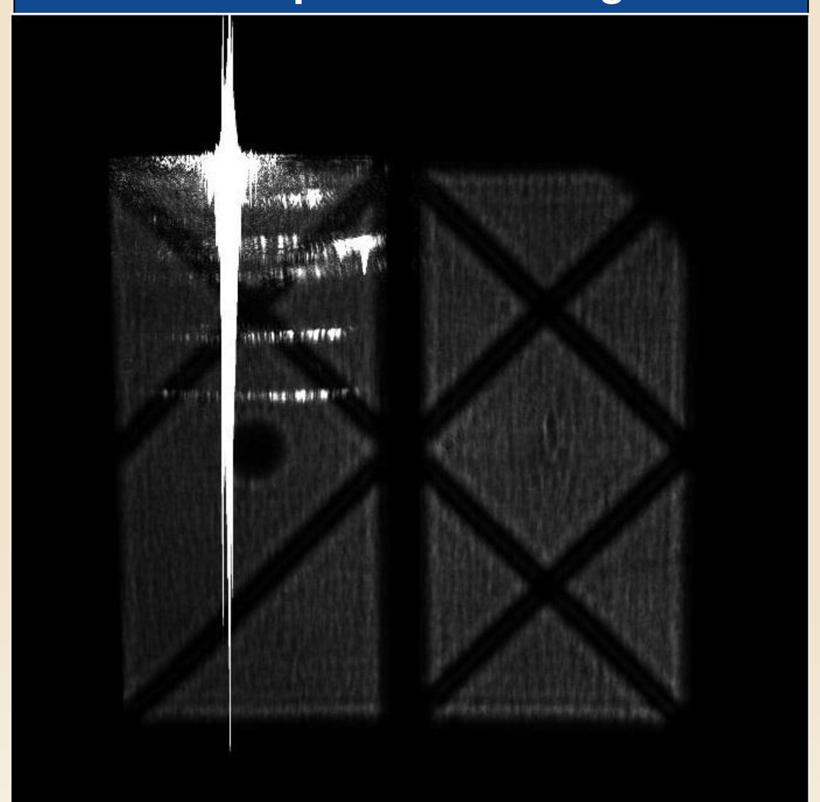
NIF laser beams require a coordinate system for various purposes including laser alignment and precise blocking of certain locations on optics. A mask with features (created with photolithography and placed in the front-end of the laser) is used to develop a coordinate system. To verify the masks, we look for features on images(whether good or corrupted) taken of the mask. These features can then be qualitatively identified using image analysis methods and techniques such as the Radon Transform and using a models based approach.

Mask Image



An example of a good ARC mask image.

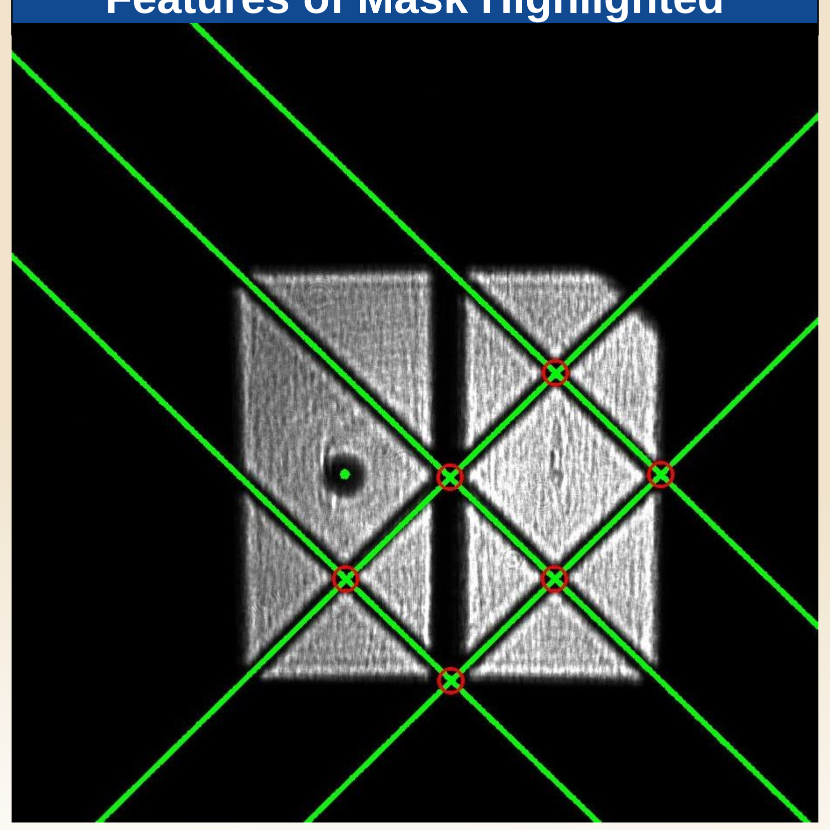
Corrupted Mask Image



An example of an image corrupted by an external light source.

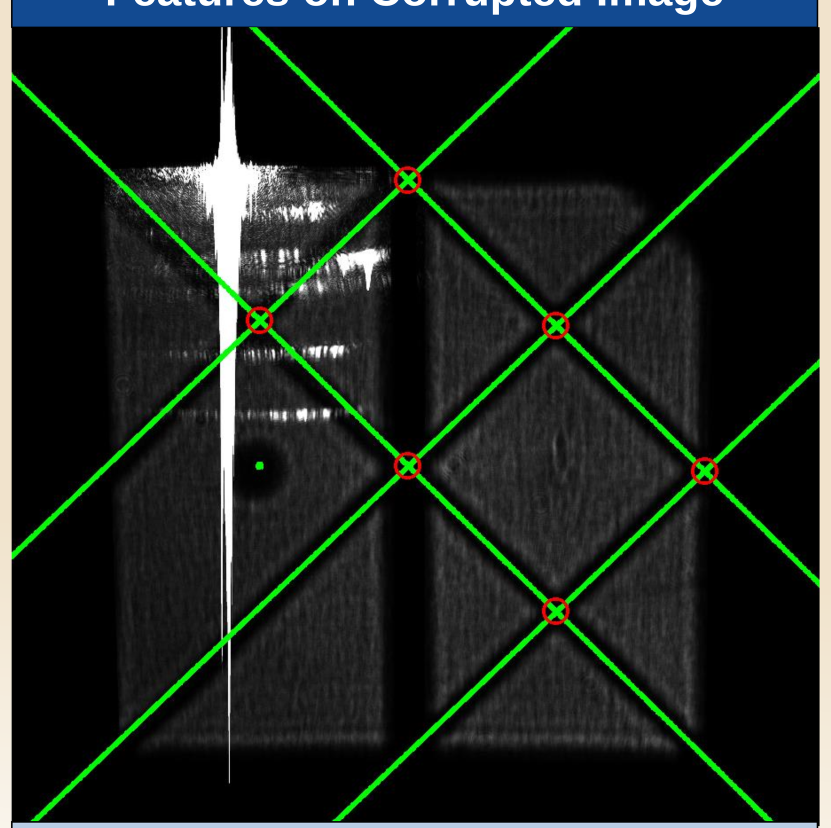
Results

Features of Mask Highlighted



The red and green circles and lines highlight the mask features.

Features on Corrupted Image

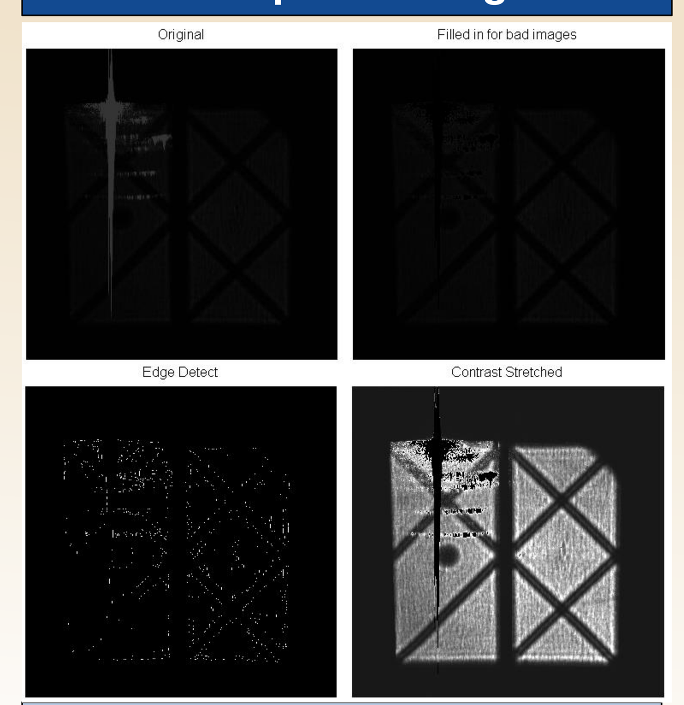


Same features being shown on a corrupted image.

Methods

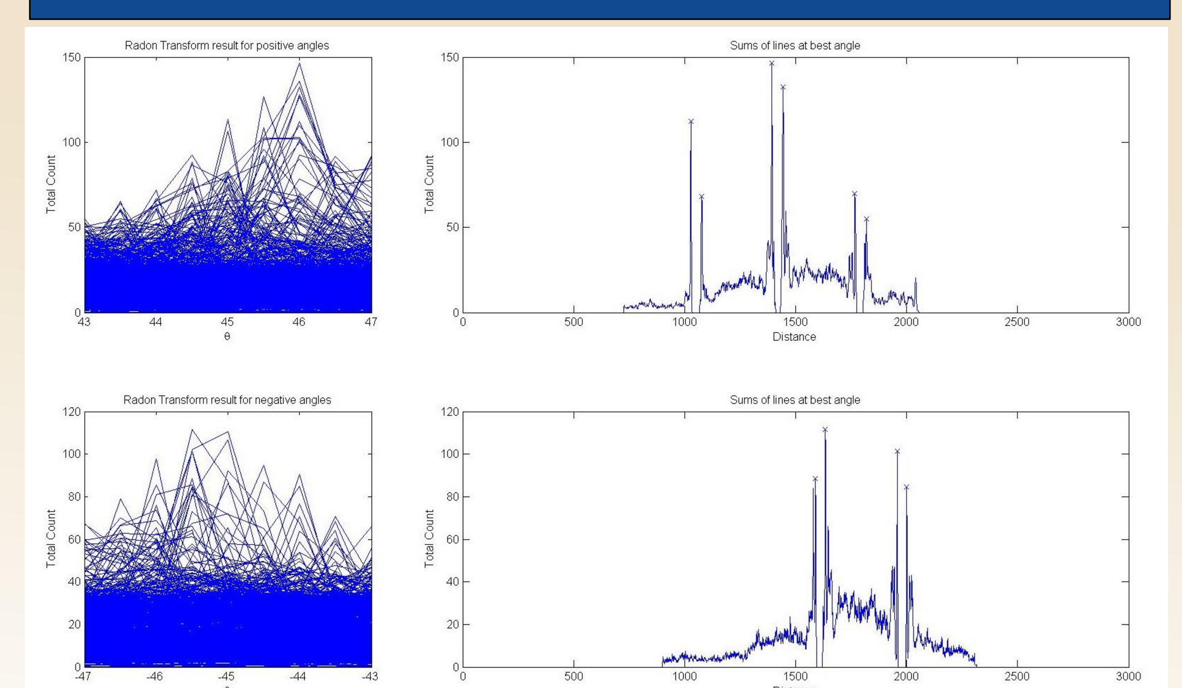
- We begin by obtaining (from a look-up table) the orientation of the mask, defined *a priori*, per beamline. This defines the range of angles and positions to be used for line and circle identification and enables integrity checks.
- Using MATLAB, we preprocess the images by shrinking, smoothing and filtering. To allow for the case of corrupted or off normal images, we also removed saturated areas of intensities.
- We employed a Canny edge detector to find strong edges. Detection of the edges is necessary for the Radon transform to identify the lines. Since we know that lines of interest are either 45° or -45°, we can limit the search for lines that are within a tolerance of those angles.
- A form of integrity check is line counting. If we know the orientation, then we know that some lines must be positively sloped and the other lines must be negatively sloped. We can correct any lines that the Radon Transform did not accurately detect by comparing the detected lines to the template.
- To find the coordinates of the circle feature, we can either use the circle Hough transform or use the intersections of the lines to calculate the coordinate of the circle. This is possible as we precise specifications of the mask, as designed.
- The intersections also serve as another form of integrity check. The distance between each intersection should be similar. If they are not, then the program will throw an error.

Pre-processing



Various stages of preprocessing before feature detection.

Radon Transform



Plots of Radon Transform results and finding best fit lines

Conclusion

Moving forward, we may examine other image analysis and processing techniques. Given more time, we would implement template matching, better preprocessing for finding the circle, and include more integrity checks and corrections to increase the robustness.

The project itself served its purpose of being exploratory and as a learning tool for basic image analysis. From this project, I learned common image analysis techniques such as edge detection, the radon transform, and smoothing and filtering. There were other methods that I learned and experimented with. These methods included: skeletonization, dilation, erosion, the hough transform and other edge detection algorithms.

The algorithm described here demonstrates a method to meet initial requirements while still allowing me to explore and learn about image analysis.

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