

# Team 14: Design of a Vehicle Hail Damage Detection System

ME 470 Senior Design Project



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# Project Overview

# Project Sponsor

- One of the largest banks by assets in US
- Largest car finance company by volume
- Insures lots for automotive dealerships



# Problem Statement

- Hundreds of millions of dollars worth of hail damage to vehicles annually
  - Cars in dealership lots are particularly susceptible
- Develop test stand to automate inspection process
- Develop image processing algorithm to detect, count, and sort dents
- Categorize into coin sizes
  - Accurately and efficiently



# Previous Prototype

## How it works

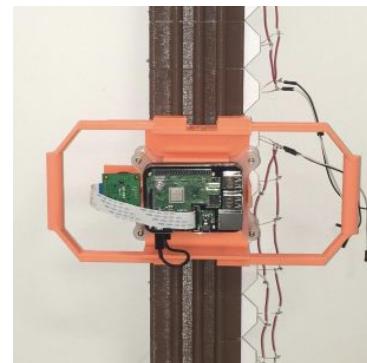
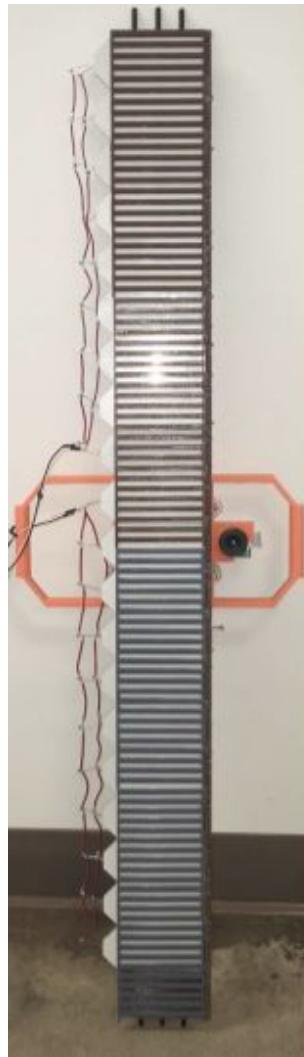
- Manually hold it
- Camera automatically takes pictures

## Advantages

- Column matrix makes dents much more visible
- Camera is controlled remotely

## Shortcomings

- Only works on dark and flat surface
- Manual operation produces poor image stitching



# Improved Design

1. Designed and built rail rig to mount light source and camera
  - a. Smooth stitching
  - b. Scan entire car without panel removal
2. Use shape extraction method instead of fourier transform
3. Using Raspberry PI and picamera
4. Software implementation in Python instead of MATLAB

# Image Acquisition

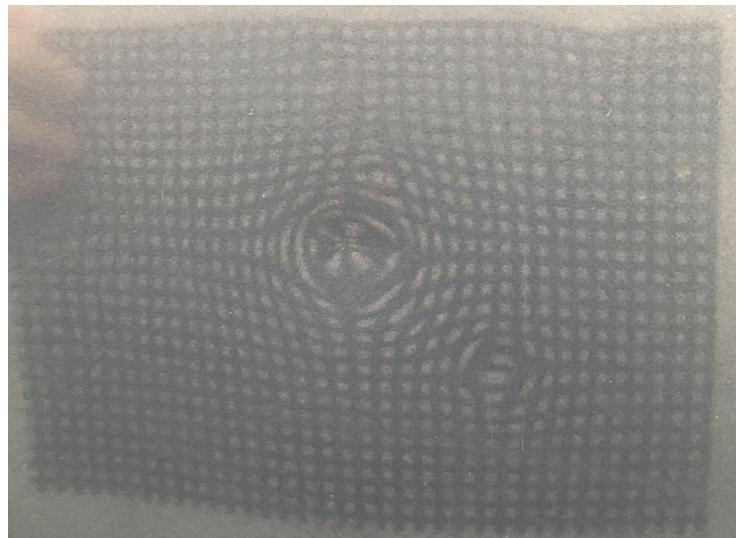
# Obtaining Samples

- Hail damaged car panels are not easily available
- Golf balls were used to simulate hail damage

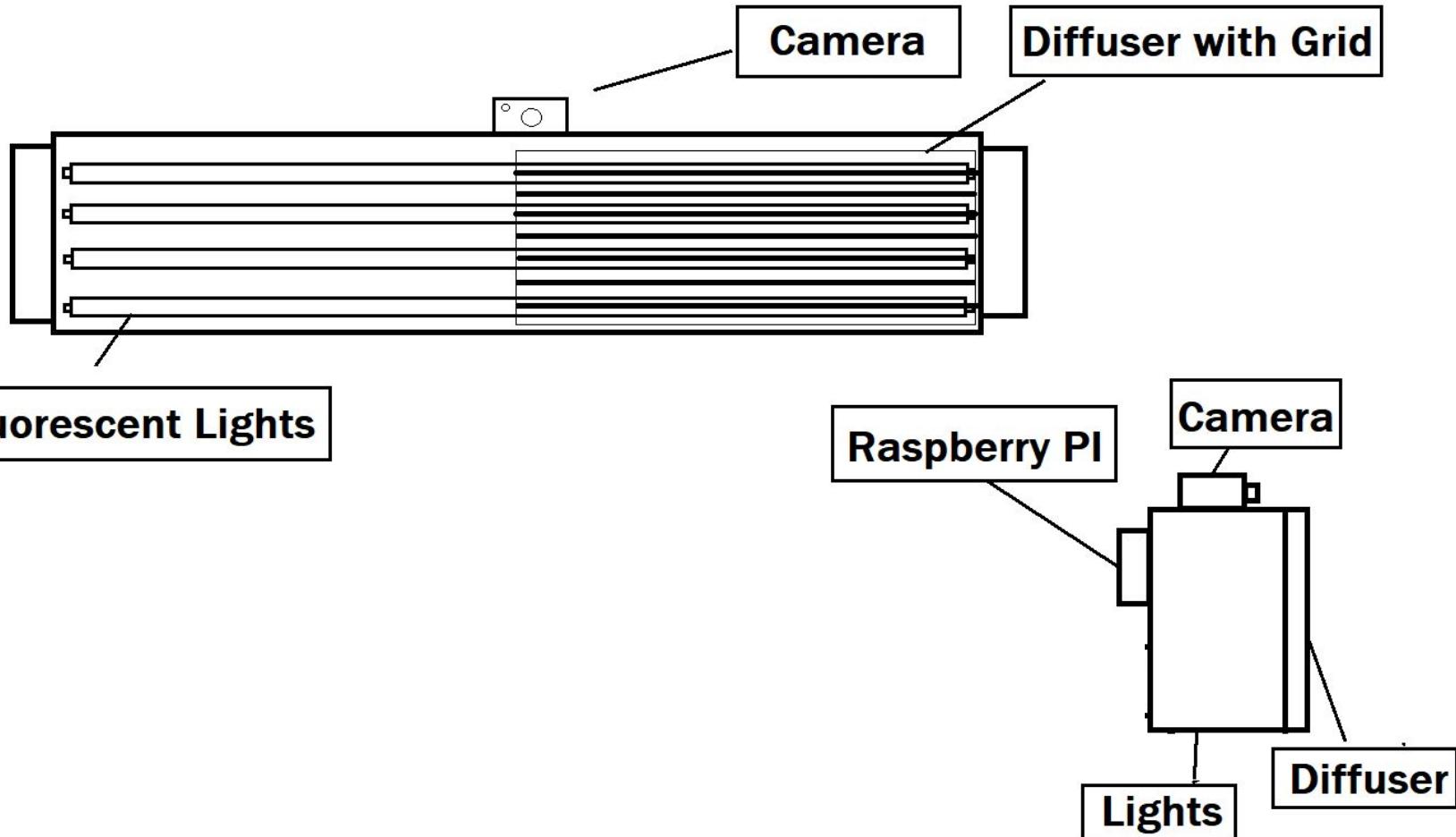


# Distortion Imaging

- Project or reflect predetermined pattern on a panel
- Pattern gets distorted due to the presence of dents
- Tested multiple methods of pattern creation
  - Projection
  - Reflection
- Tested Multiple Patterns
  - Stripes
  - Dots
  - Checkerboard



# Lighting and Imaging Apparatus



# Fluorescent Light Panel

- Can cover the length of the panel
- Very bright, with high contrast
- Economical



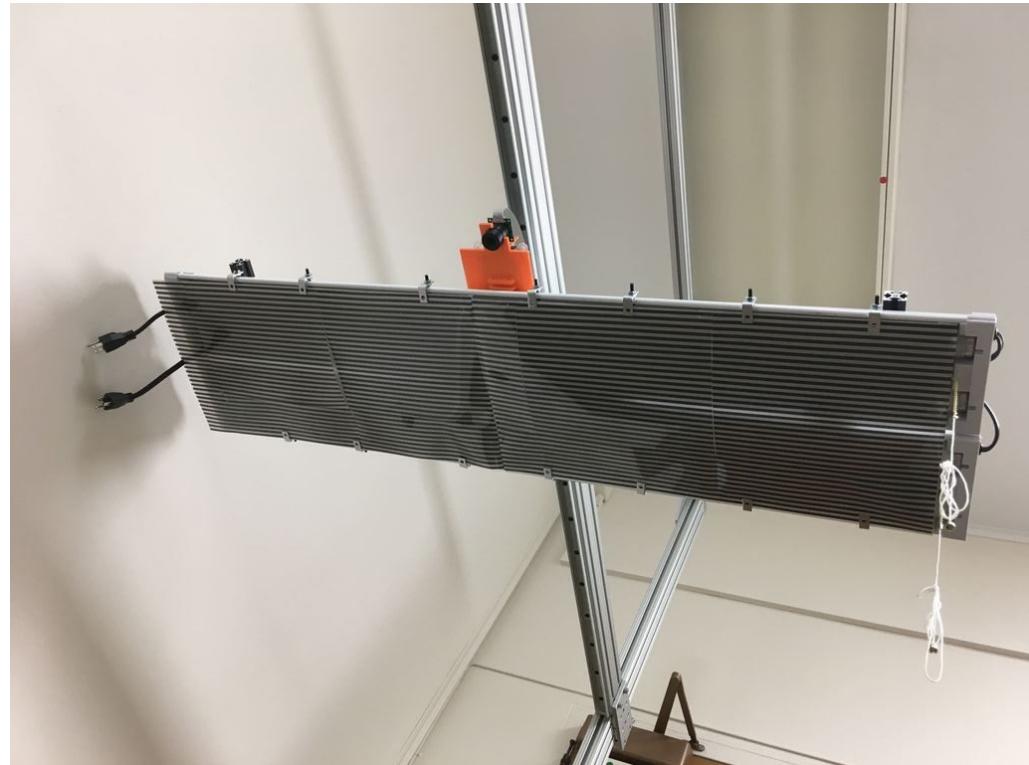
# Fluorescent Light Panel

- Can cover the length of the panel
- Very bright, with high contrast
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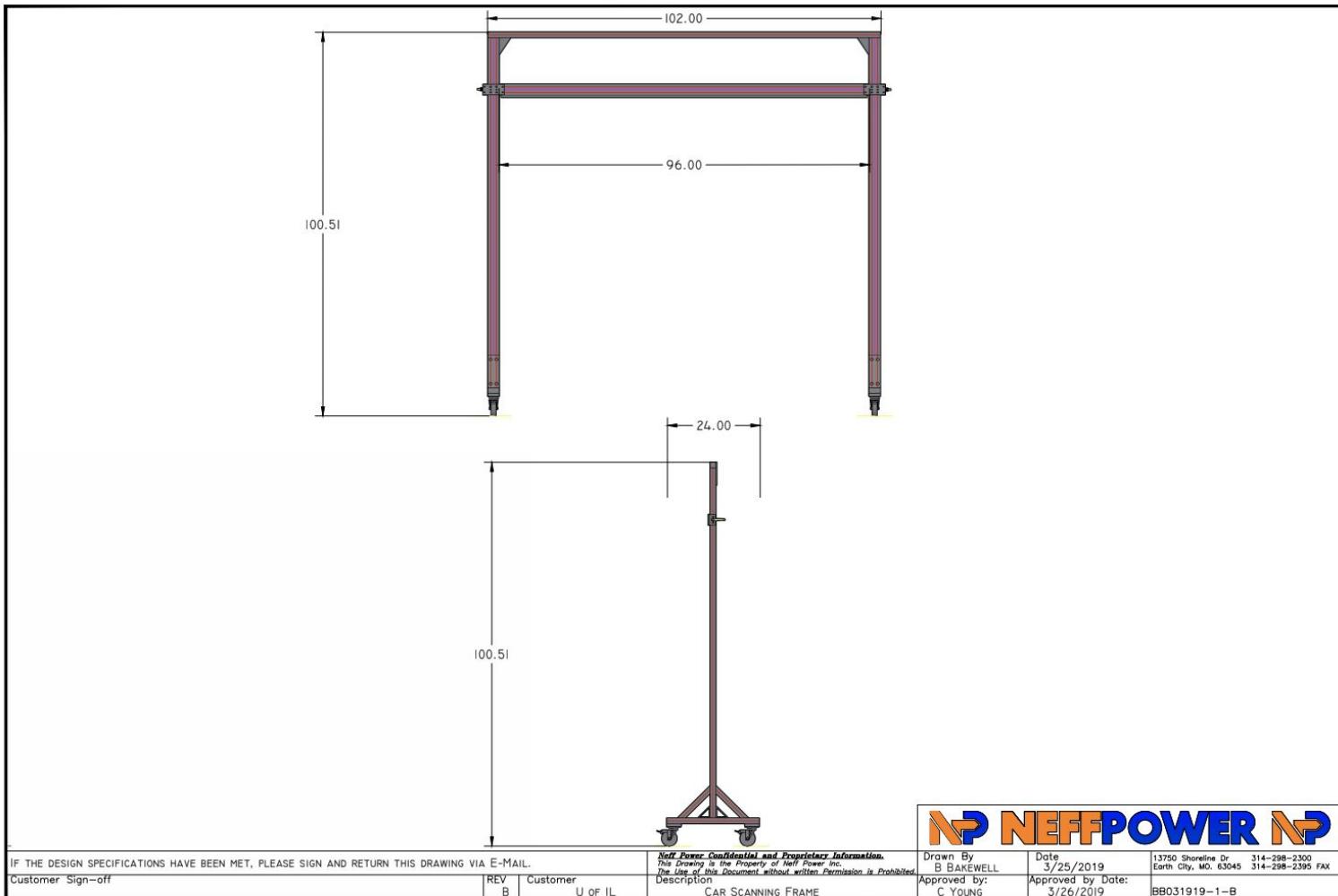


# Fluorescent Light Panel

- Can cover the length of the panel
- Very bright, with high contrast
- Economical



# Mounted Rig



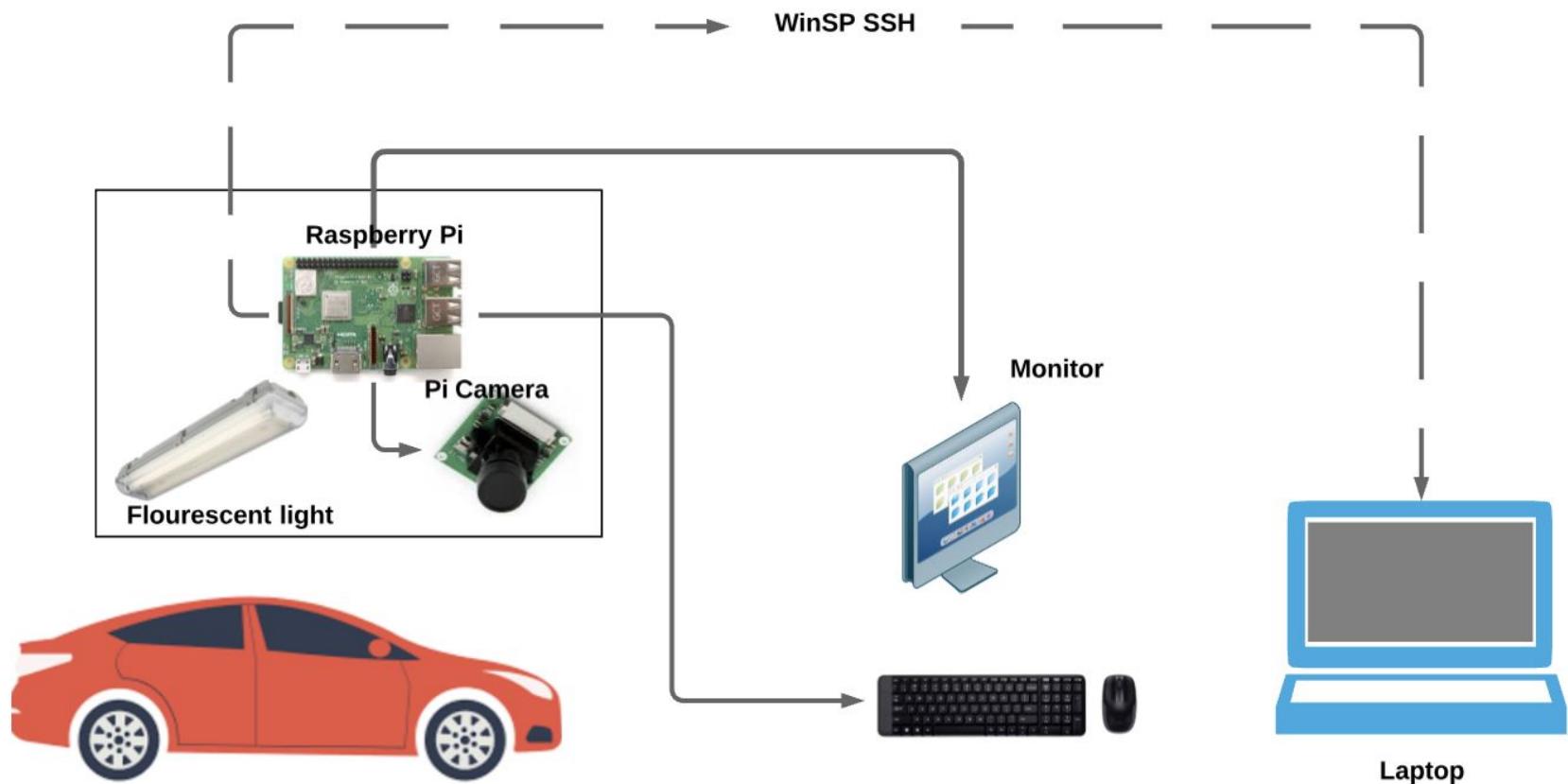
# Finished Prototype

- PBC rail provides smooth light mount movement
  - Greatly improves image stitching
- Vertical slide/lock mechanism for scanner height adjustment



# Image Processing

# System Layout

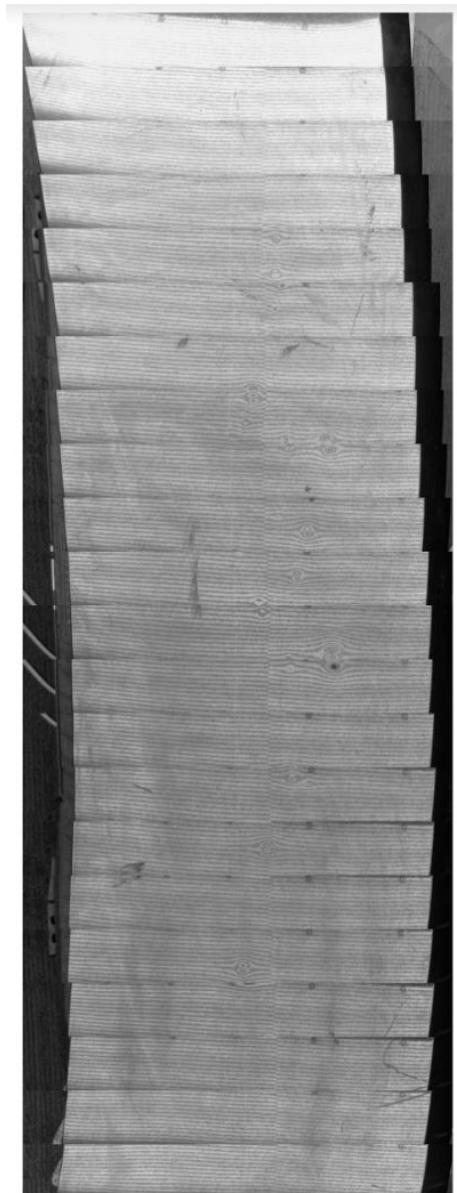


# Stitching

- Stitching
- Cropping according to shape
- Excluding Background



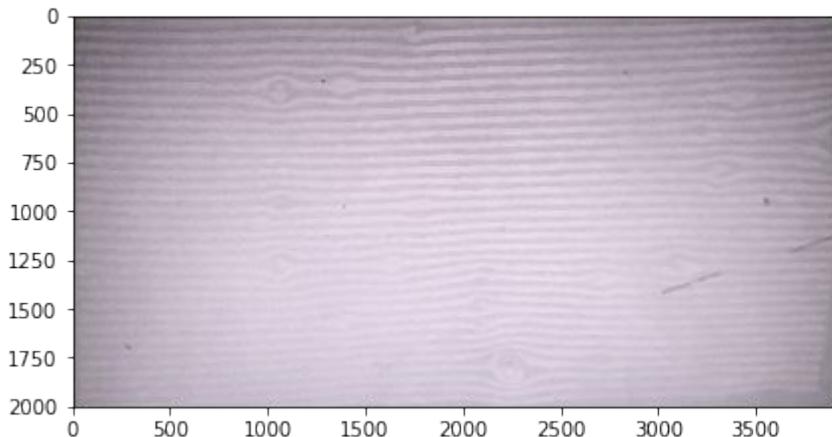
Original photos



Stitched image

# Uneven Intensity Issue

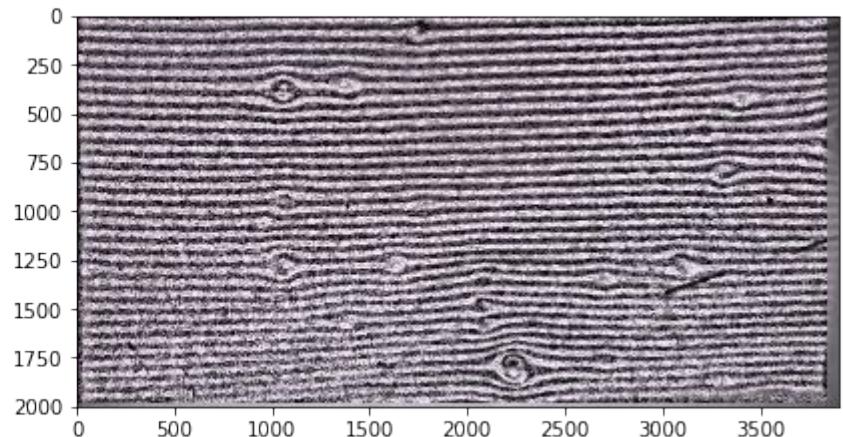
Silver panel



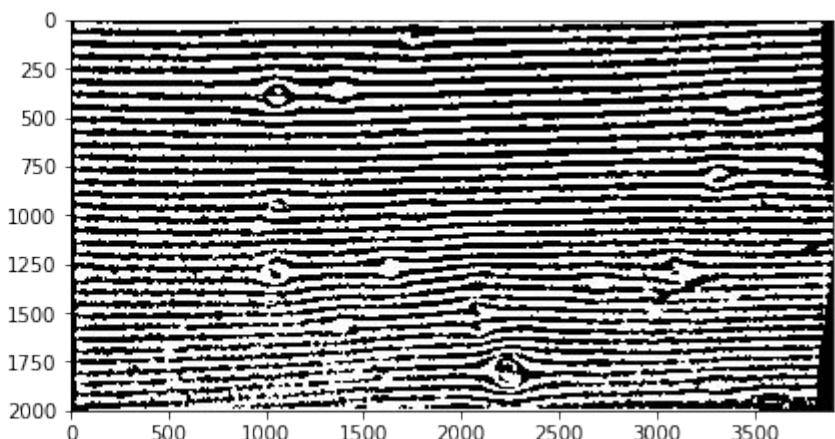
Binarizing without normalization



Normalized

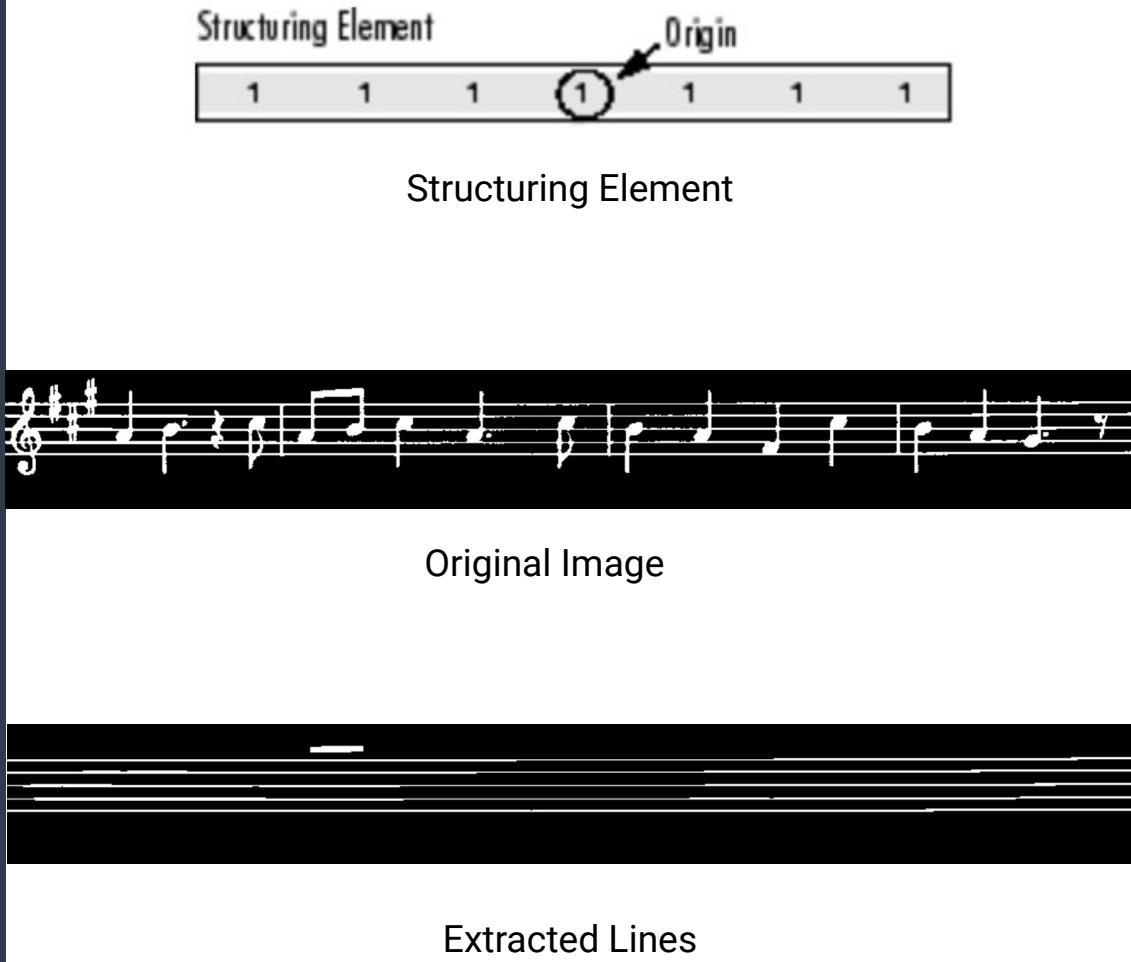


Binarized after normalization



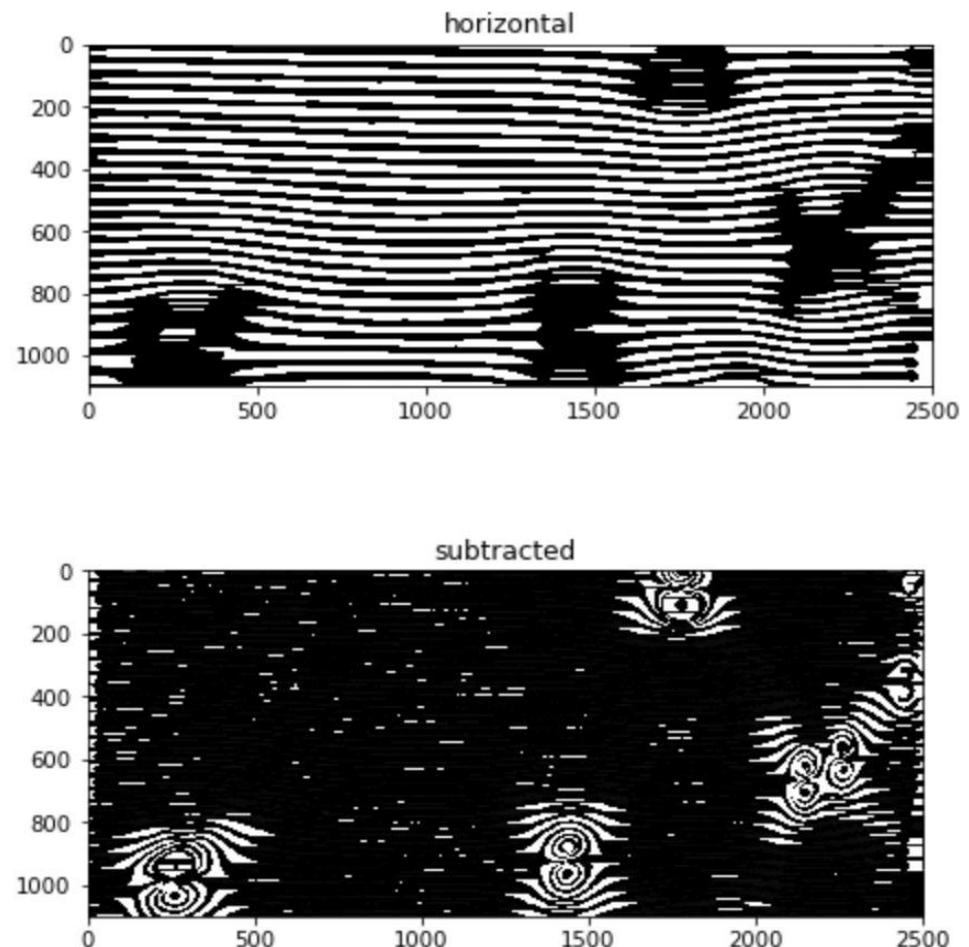
# Shape Extraction

- Structuring element is a pixel shape with an anchor.
- In erosion, if not all pixels in the structuring element have the white color in the source image, all pixels will be turned into black color.
- If all pixels have the white color in the source image, it creates a white pixel at the anchor.



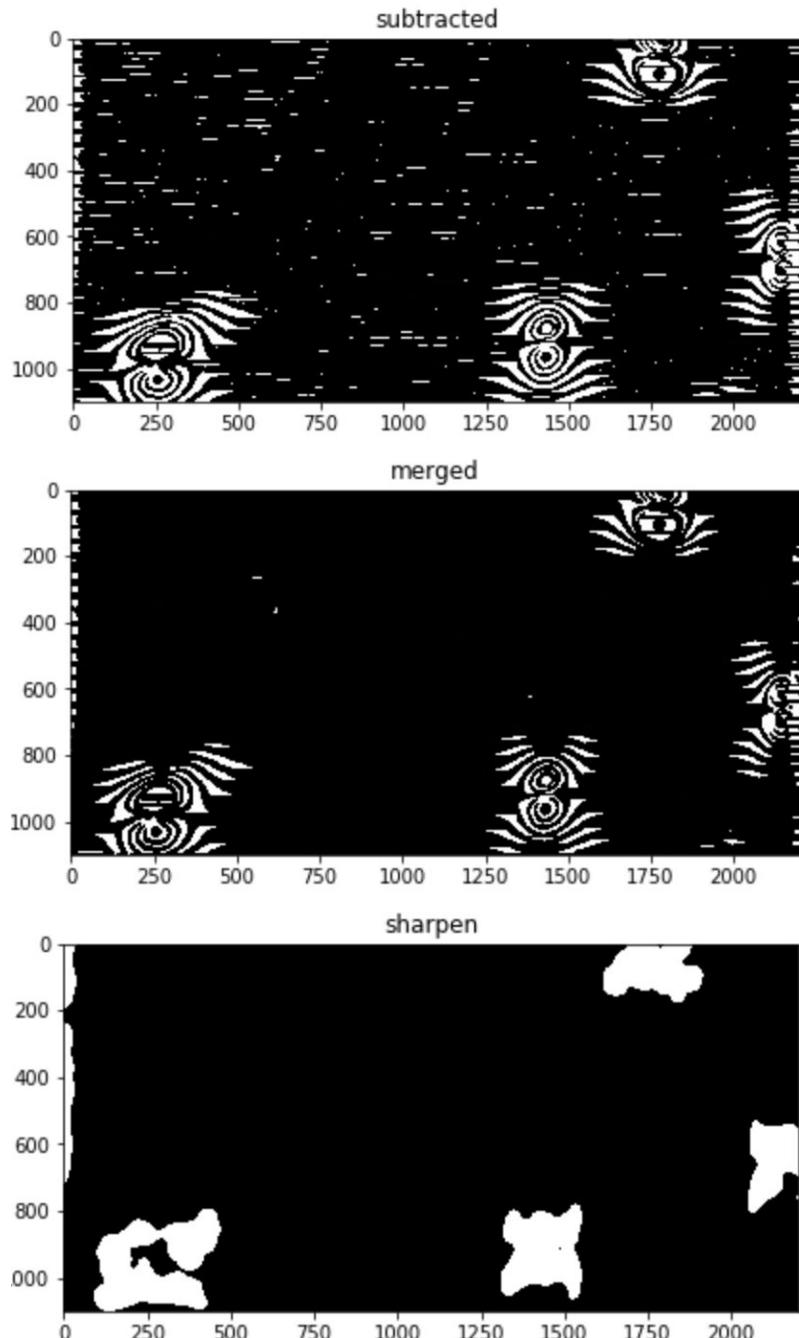
# Straight Line Extraction

- Erode the image with structuring element to extract horizontal lines
- Subtract the horizontal lines from the original image



# Detection Algorithm

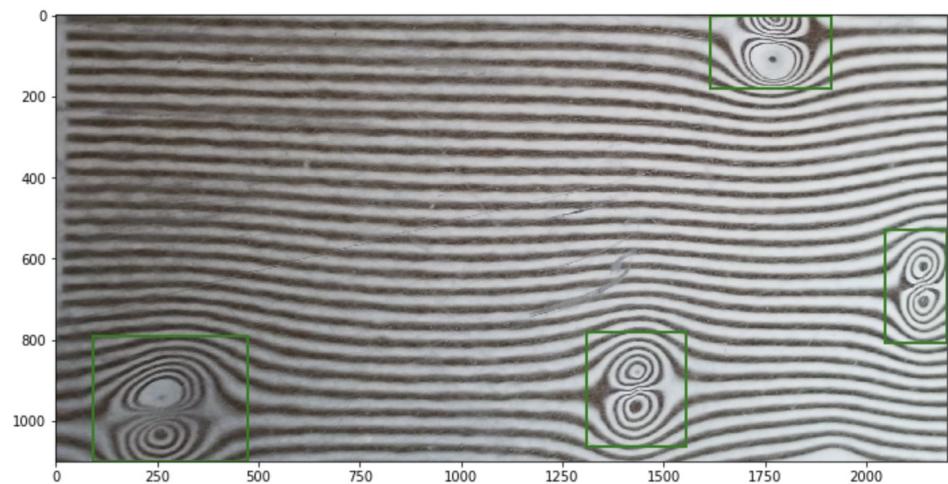
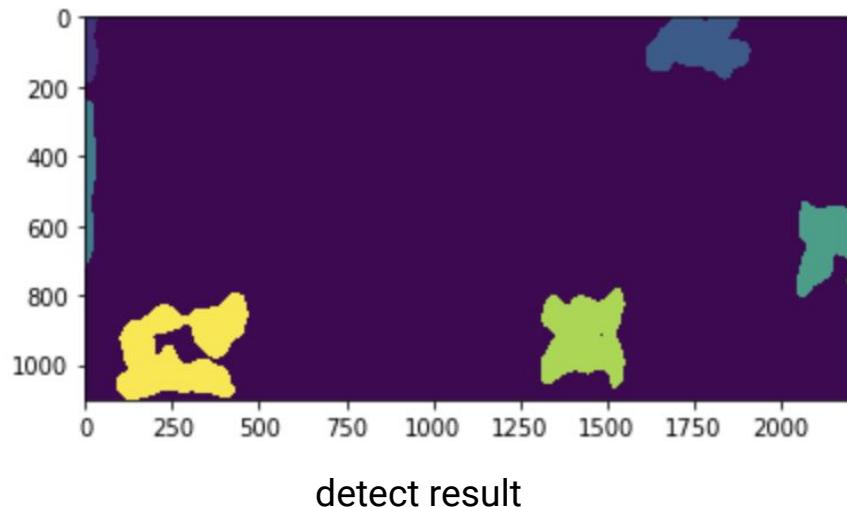
1. Extract horizontal lines
2. Subtract from original image
3. Shift image to denoise
4. Blur image to cluster nearby segments
5. Sharpen image to obtain clear boundaries



# Rectangle fitting

1. Label image regions
2. Measure region areas
3. Perform rectangle fitting

```
region area: 38316  
region area: 28826  
region area: 50505  
region area: 70647
```



# Actual Image Size Conversion

- Implement the principle of image formation of lens
- Assume the camera has a fixed distance of 20 inches to surface
- The error of area calculation is below 15% with 10% tolerance for camera position

Pixel Area Range	Nominal Area in Terms of Coin Sizes
[2700, 7000]	Half dollar or Greater
[2000, 2700]	Quarter size
[1400, 2000]	Nickel size
[1000, 1400]	Dime size

# Software Demo

# Conclusions

# Budget

Item	Unit Price \$/Unit	Quantity Unit	Total \$
Rail Rig	-	-	940.33
Fluorescent Lights	4.99	3	14.97
Shoplight Frames	17.98	2	35.96
T-nuts	2.30	7	16.10
L-brackets, washers, hex screws	-	-	21.18
Acrylic	13.48	2	26.96
Transparency Sheets	-	-	43.19
Window Frost Application	-	-	31.46
Miscellaneous Prototyping Materials	-	-	193.88
<b>Total Cost</b>			<b>\$1324.03</b>

# Future Work

- Improve stitching
- Automate image acquisition
- Implement encoder to improve positional accuracy
- Use alternate rig design with adjustable height



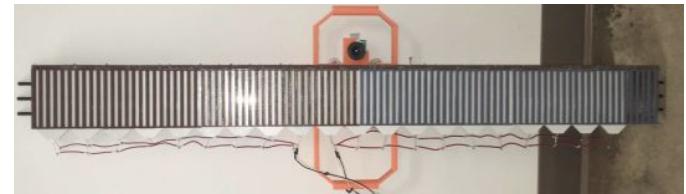
# Conclusion

- We improved the previous team's efforts at hail detection
- A physical rig to improve image acquisition
- Our setup works for both light and dark panels unlike the previous prototype.
- Developed an image processing algorithm with a greater accuracy than the previous team's

# Acknowledgements



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Professor Blake Everett Johnson



Christopher James Marry

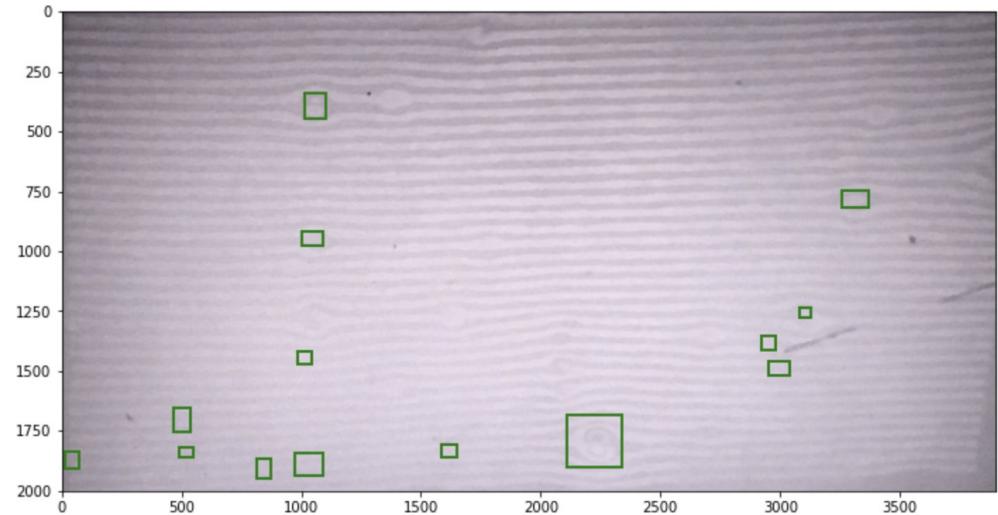
Vedant Jain

# Appendix

# Panel Color Issue

- Challenging to obtain high contrast images
- Normalizing causes line discontinuity
- Discontinuous lines cannot be extracted

Silver panel result



# Column Matrix Pattern

- Striped pattern printed onto transparency sheets
- 0.18 in. stripe width and gap width

