Engineering Capstone Project – Computer Vision

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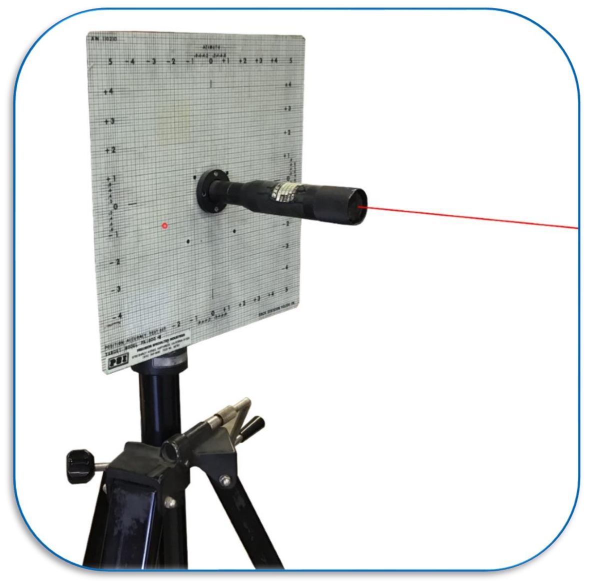
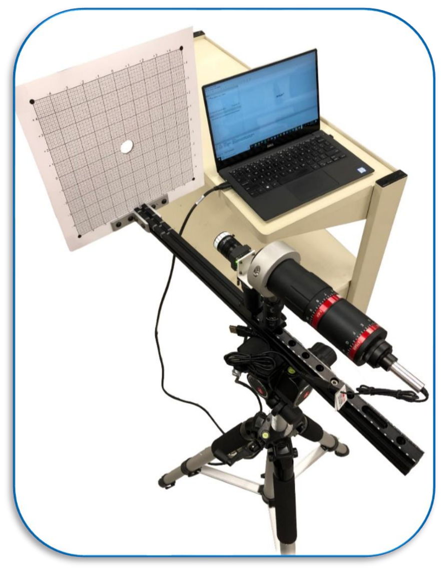
Background

Rotating Precision Mechanisms Inc. (RPM) designs, manufactures and tests antenna positioning equipment that are critical components in many radar and sensing systems of aircrafts, satellites, and many other applications. The accuracy and precision of these positioning equipment are currently verified using a laser based optical test performed by a human operator. Since the operator records the 'x' and 'y' coordinates of the laser spot on a grid, the highest attainable accuracy is to the tenth of an inch.

Here we will present a faster and more accurate method for measuring offsets using computer vision. The computer vision solution uses an industrial camera, C++ algorithms, and a testing laptop to track and record the position of the laser in real-time with an accuracy and speed that surpasses the human eye.



Current laser based optical testing system.



New laser based automated testing system.

Introduction

The main goal of this system is to detect and track a red 635 nm wavelength laser spot with offsets as small as 0.025 inches on a 10 x 10 inch grid accurately and precisely.

Designing this system involved three major criteria: camera selection, data processing hardware, and algorithm performance.

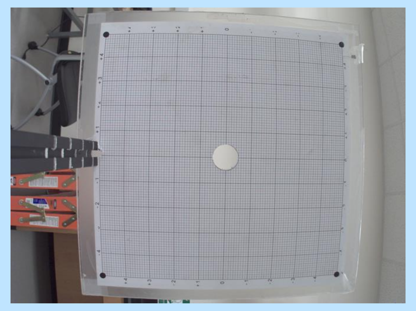
- **Camera Selection Requirements:** Compact in size, covered the entirety of the grid at less than 11 inches away, and captured high quality images.
- **Data Processing Hardware:** Speed, portability, and maintenance.
- **Algorithm Performance:** Ability to detect the laser spot, precision in tracking, and repeatability.

These design considerations guided the down selects for the final components used in this system.

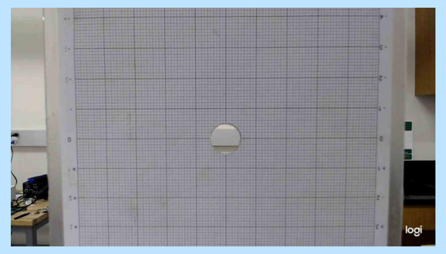
Method

Camera Selection:

CAMERA SELECTION		
Technical Specification	Logitech C920	Basler Dart Camera with Lens
Resolution	1080 x 1920 (3MP)	2592 x 1944 (5MP)
Pixel Size	~ 2.0 x 2.0 µm	2.2 x 2.2 µm
Sensor Format	~1/3"	1/2.5"
Size	3.7 x 1.1 x 1.0"	2.4 x 1.1 x 1.1"
Frame Rate	30	14
Working Distance	15.0 in	10.5 in
FOV Horizontal	70.4°	68.2°
FOV Vertical	43.3°	53.9°



Sample image taken with the Basler Dart camera at 10.5 inches



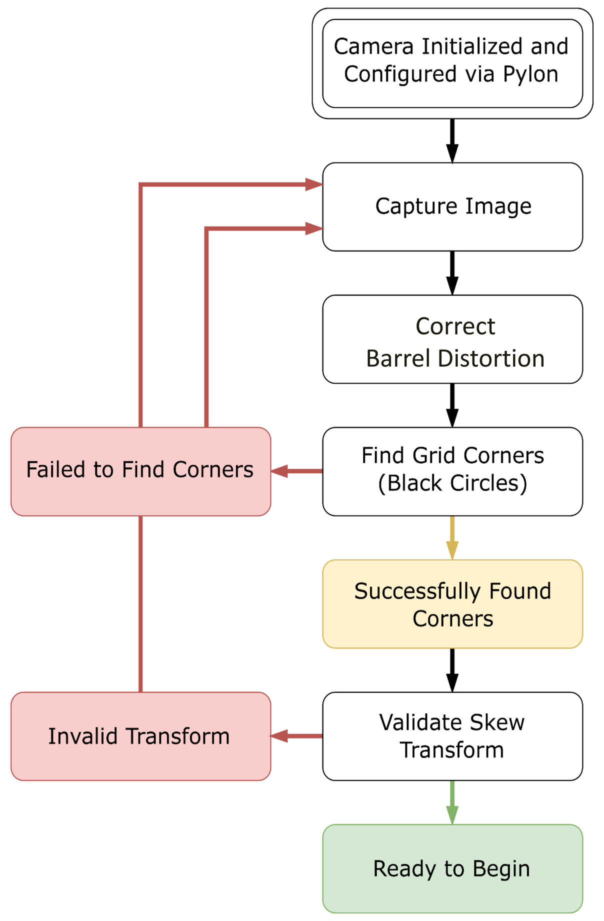
Sample image taken with the Logitech camera at 10.5 inches

- The Basler Dart industrial camera surpassed the image quality obtained by the Logitech's webcam
- The working distance and field of view of the Basler Dart camera allowed testing to be perform at 10.5 inches from the grid

Raspberry pi vs. Testing Laptop

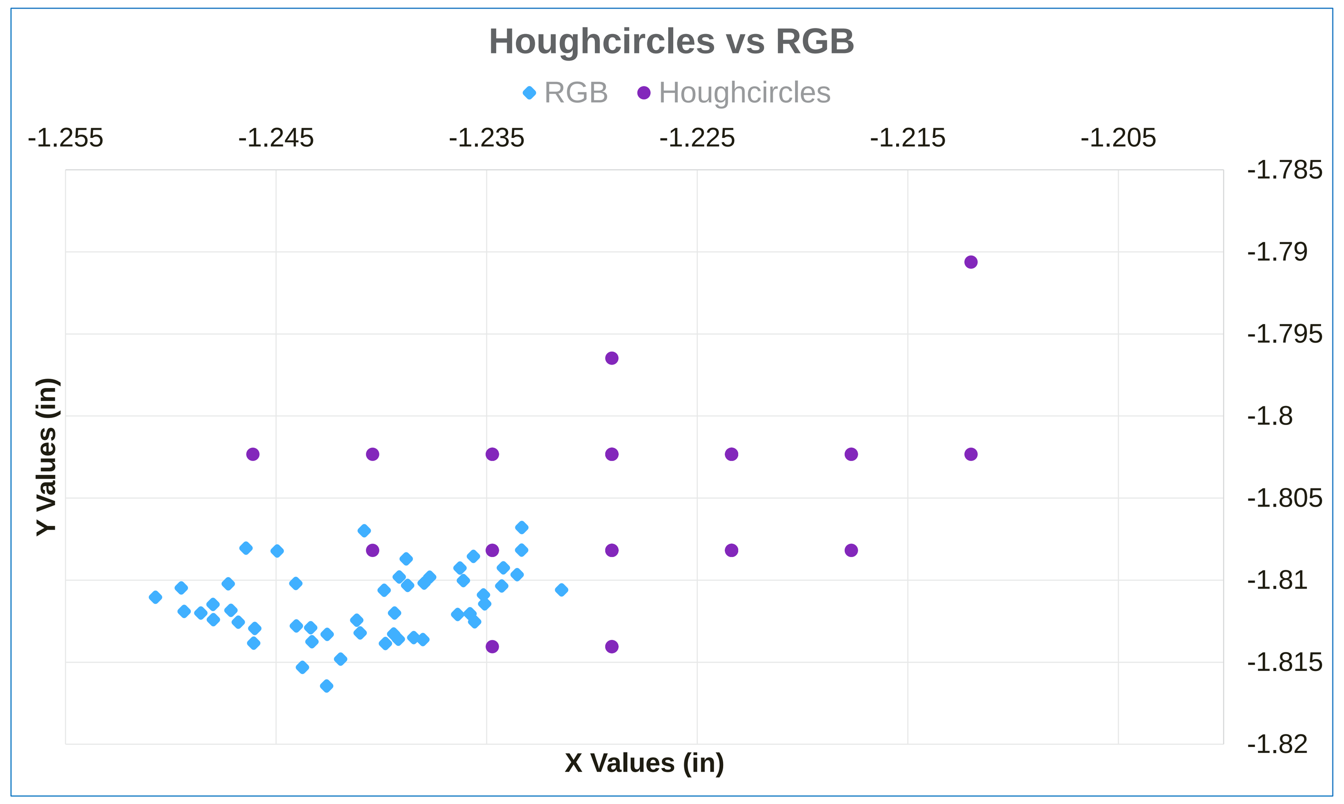
PROCESSING HARDWARE		
Criteria	Raspberry Pi	Standard Testing Laptop
Processor Type	ARM Cortex-A53	Intel Core i5
Processor Speed	1.2 GHz	4.1 GHz
Port	USB 2.0	USB 3.0
Port Speed	60 mbps	640 mbps
Connectivity	Bluetooth	USB Cable
Maintenance	Yes	No

Algorithm:



Results

Precision Test - Houghcircles vs RGB



ALGORITHM PRECISION TEST						
	X Values		Y Values		Range	
Algorithm	Min	Max	Min	Max	X Range	Y Range
RGB	-1.251	-1.231	-1.816	-1.807	0.019	0.009
Houghcircles	-1.246	-1.212	-1.814	-1.791	0.034	0.023

Human Eye vs Computer Vision Accuracy:

- The current testing set up can only accurately record to the closest tenth of an inch.
- Computer Vison (CV) uses the number of pixels in an image to determine the location of the laser dot
- CV Steps:
  1. Find # of pixels in the x and y direction of a picture
  2. Divide corresponding # of pixels by 10
- Increasing the number and size of the pixels increases the accuracy of the system

Conclusion

Pros:

- Increase in accuracy and precision of calibration test
- Elimination of operator bias
- Test speed decreased from 15 minutes to 6 minutes

Cons:

- Barrel distortion of image adds error to the system
- Brightness of laser causes distortion in laser spot and causes a false centroid reading

Next Steps

In order to improve the accuracy and precision of the current system, additional cameras may be explored to improve the resolution without the compatibility restrictions imposed by the Raspberry Pi. Additionally, continued testing will allow us to edit and improve the algorithm.