Development of Computer Vision and Image Processing at NSLS-II

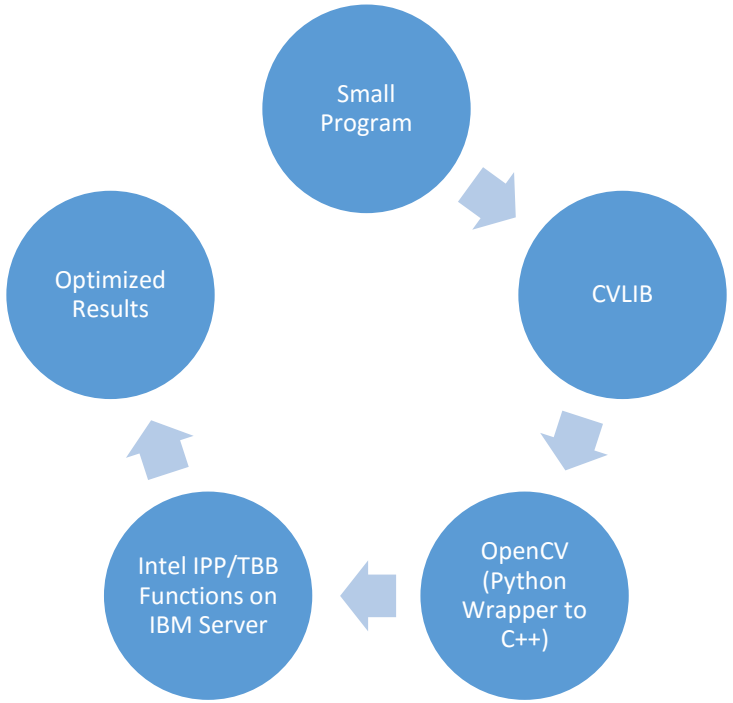
William Watson

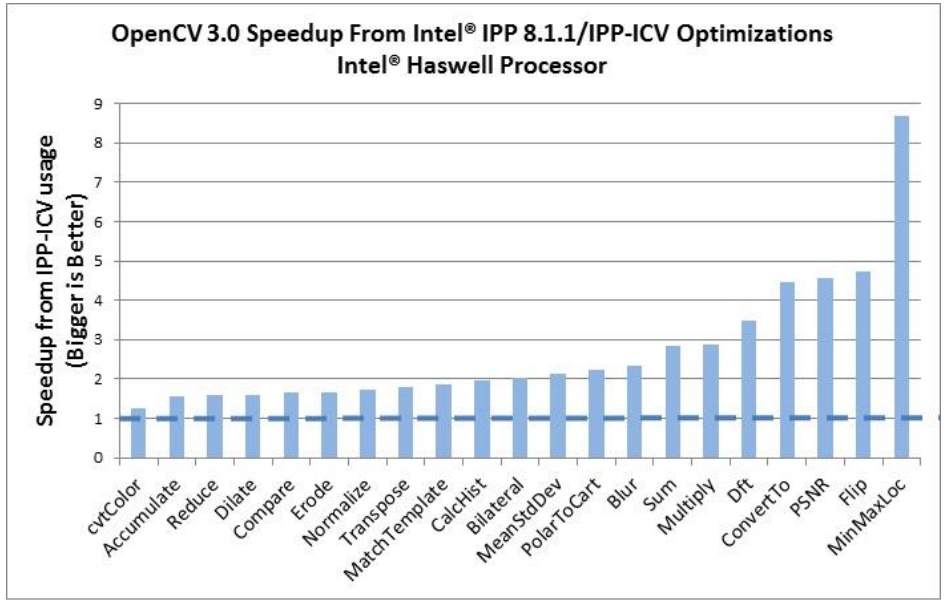
Purpose

- Development of image analysis software backed by OpenCV
- To provide an easy use python module to access computer vision functions
- Optimized results for fast computation, via C++, Intel IPP/TBB
- Automate processes from image input such as:
  - Positon, spread, and intensity of X-Ray Beams
  - Isolating and computing data on multiple objects
  - Provide assistance to mounting samples and report any errors

OpenCV and CVLIB

- Small Programs call upon functions in CVLIB
- CVLIB calls upon OpenCV, which has a Python Wrapper for C++
- OpenCV 3.0 supports optimization via Intel's IPP Low Level Functions, Intel TBB
- Computation is done on a dedicated IBM Image Server





Sergey Sivolgin, 2014-08-11 11:25 am

BPM-1 X-Ray Analysis (IXS)

Purpose:

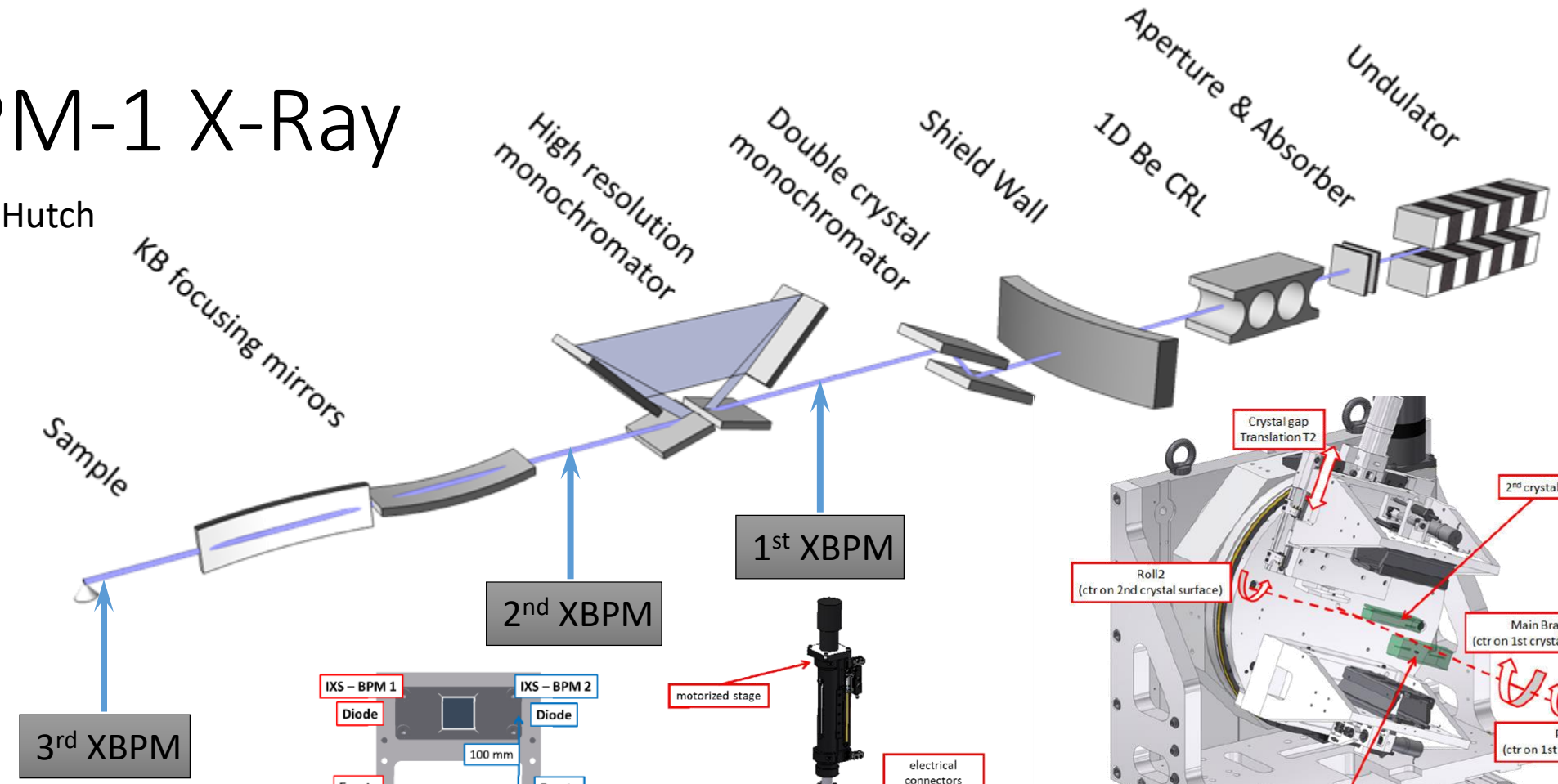
- Discover Position of Beam
- Discover Spread of Beam
- Discover Intensity of Beam
- Discover the Centroid of the Beam

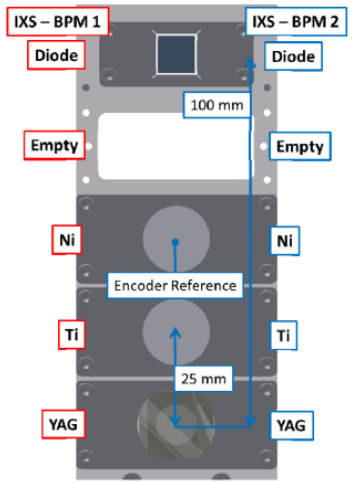
E = 9.1 keV
Scintillator: YAG
Camera: Prosilica
Magnification: 5x

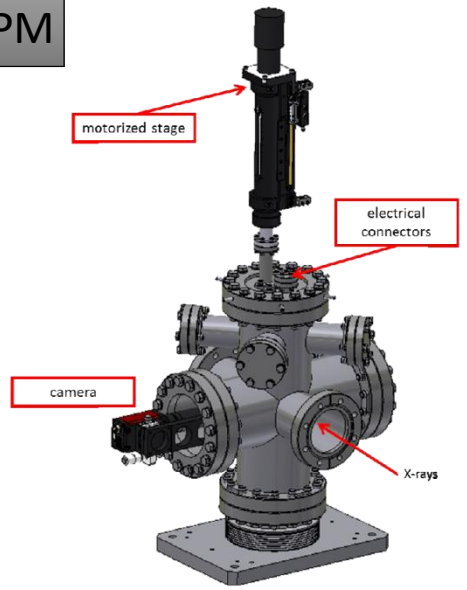
Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

BPM-1 X-Ray

Located in B Hutch (IXS)







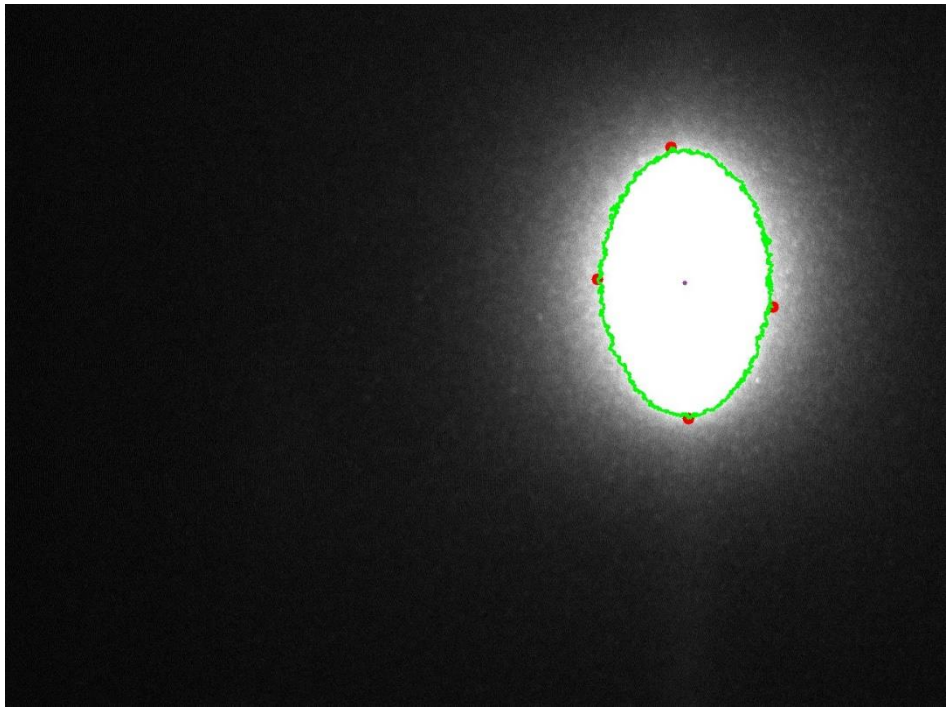
Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

BPM-1 Image Results

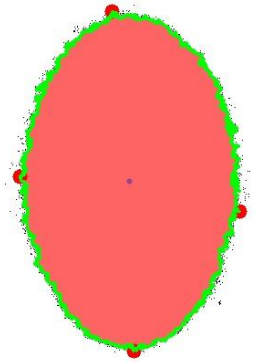
Process:

- Threshold
- Find Contours
- Interpret Contour Data (Plot, Draw, and Print)

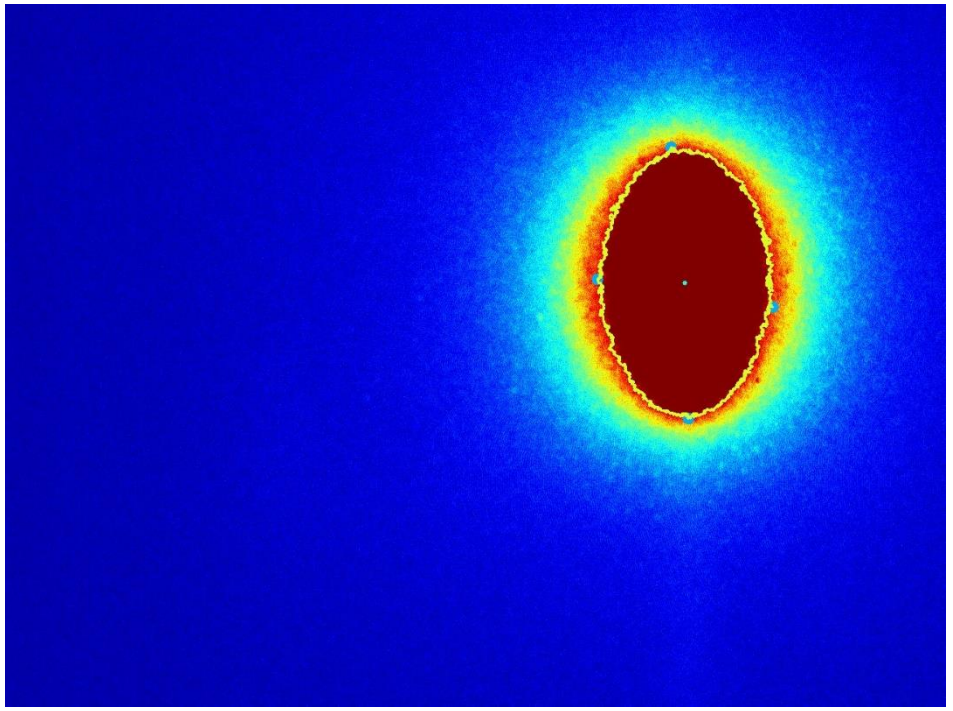
Result Superimposed on Original



Thresholding Result

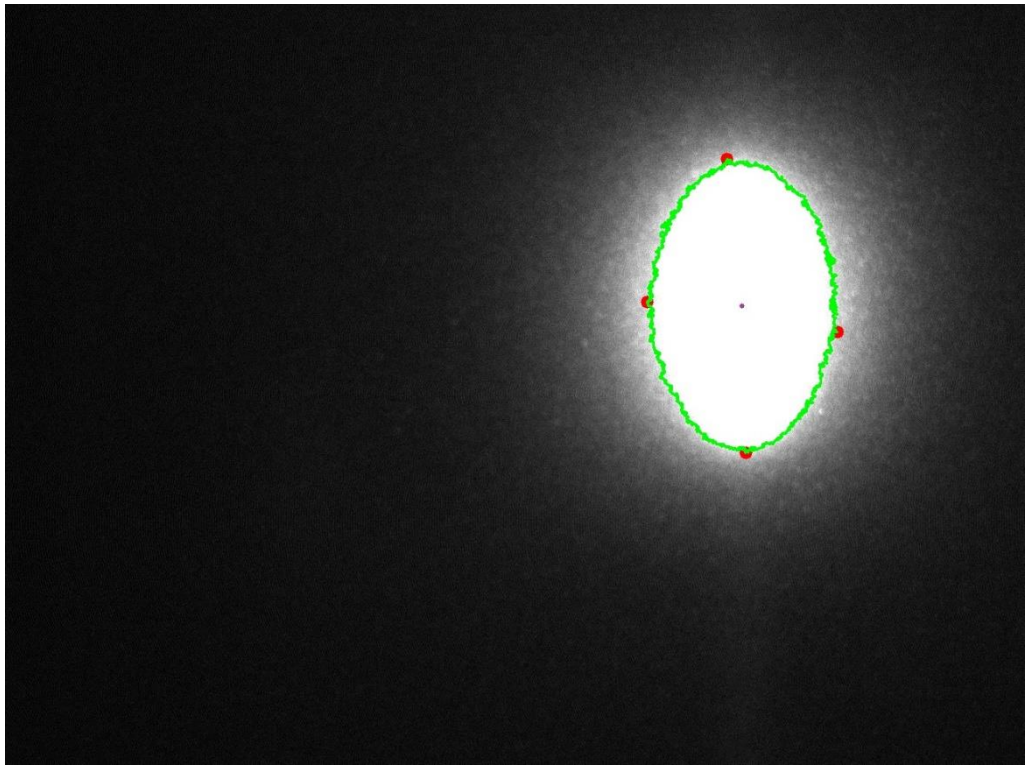


Jet Color Map



Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

BPM-1 Data Results



Console Output:

```
Object Details:

perimeter: 2356.99022925
orientation: 179.838363647
max: (925, 198)
height: 372
extrema: {'B': (938, 568), 'R': (1054, 415), 'L': (813, 377), 'T': (914, 196)}
area: 65058.5
min: (1047, 564)
sum intensity: 20426526
width: 241
centroid: (933, 382)
mean intensity: 227.842390577
```

Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

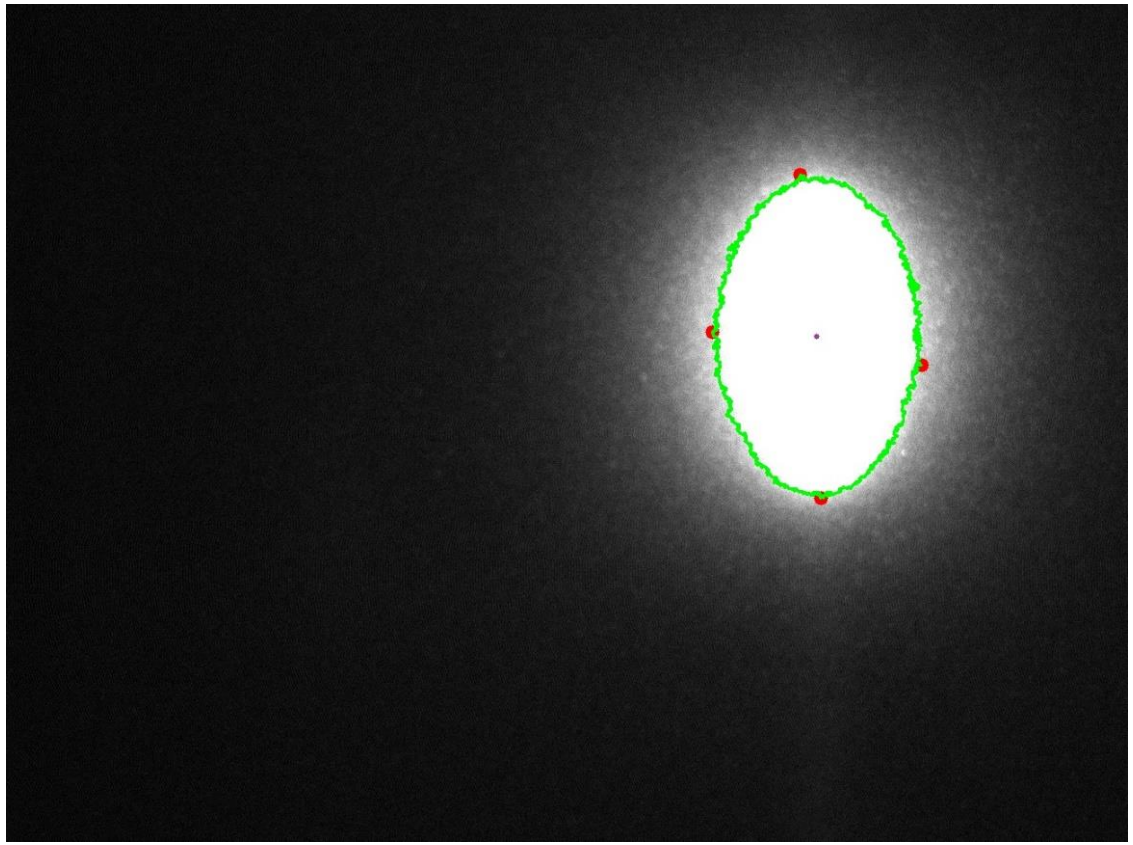
BPM-1 Results

- Use Centroid and Extrema to adjust beam within image
- Sum of the Pixels displays the total intensity of the beam
- The Maximum point of intensity, and maximum intensity discovered
- Area and Perimeter of Beam
- Height and Width of the current Beam
- Average Intensity of the Beam

BPM-1 Time

BPM-1 (Single):

```
Real    0m0.350s
User    0m0.300s
Sys     0m0.068s
```



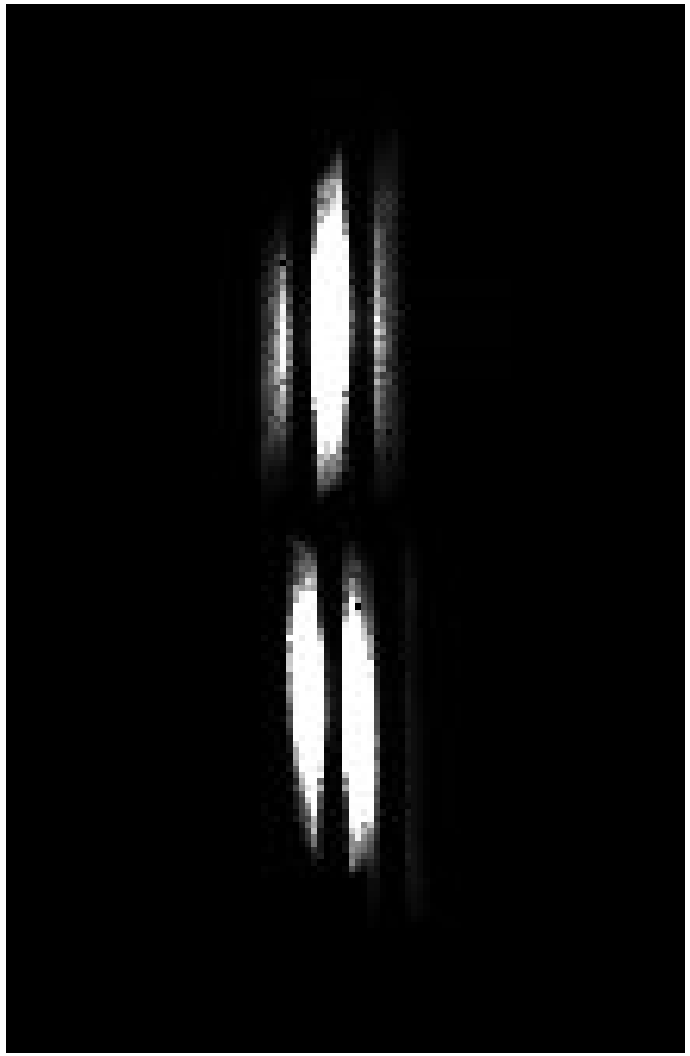
Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

Analysis -Merlin Quad X-Ray Detector (IXS)

- Data Retrieved from the Merlin Detector at IXS

Purpose:

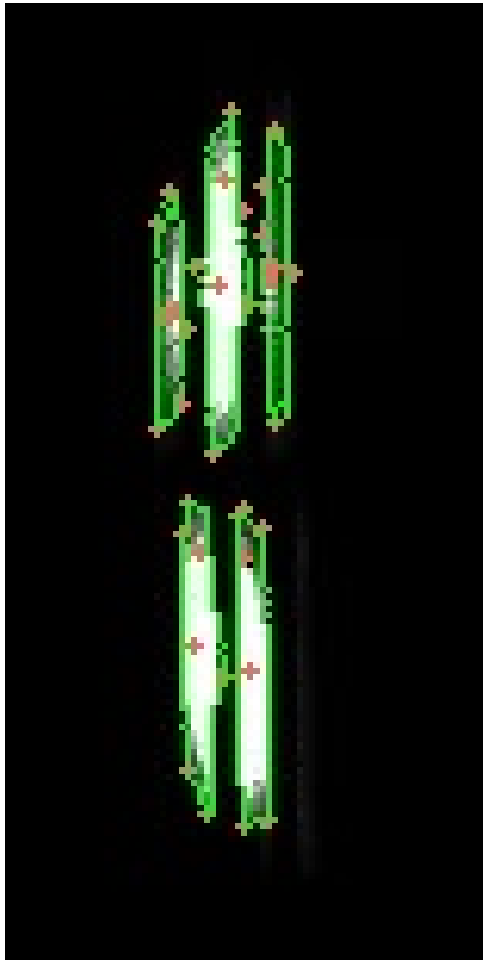
- Isolate Individual Streaks
- Process each Streak to learn Position, Center, Spread, Intensity, Max Values, etc.
- Count Intensity in each streak



E = 9.1 keV
Direct detection
PEL size = 55 [um]

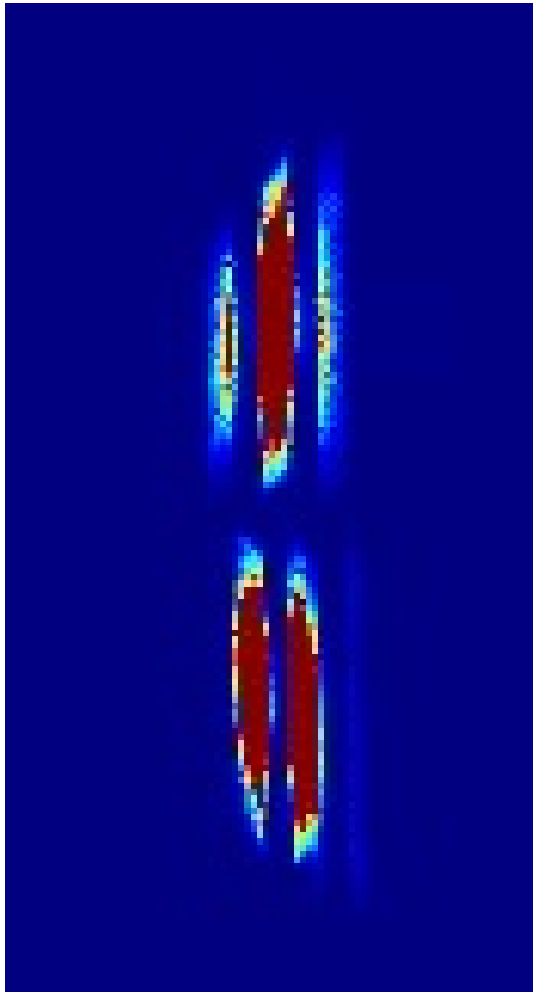
Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

Merlin Image Results



Process:

- Convert to Grayscale
- Threshold Image
- Find and filter contours by size
- For each object:
  - Print Object's Data
  - Plot Points of Interest
- Draw Contours
- Apply JET

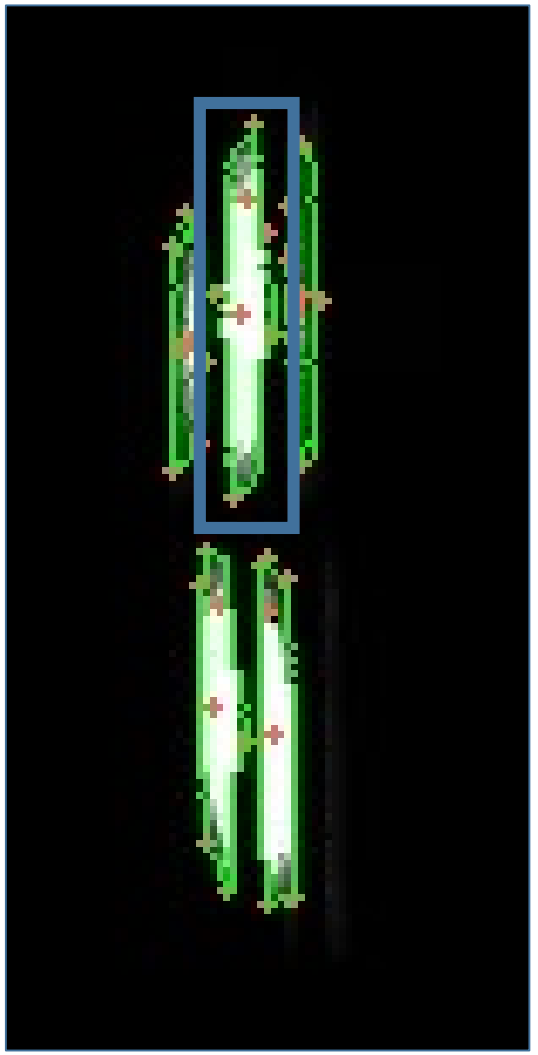


Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

Merlin Data Results for First Object (Largest)

Console Output:

```
Object 1:
perimeter: 125.840619564
orientation: 179.981033325
max: (131, 78)
height: 55
extrema: {'B': (129, 122), 'R': (135, 98),
          'L': (126, 92), 'T': (132, 67)}
area: 270.5
min: (134, 83)
sum intensity: 62689
width: 9
centroid: (130, 95)
mean intensity: 126.644444444
```

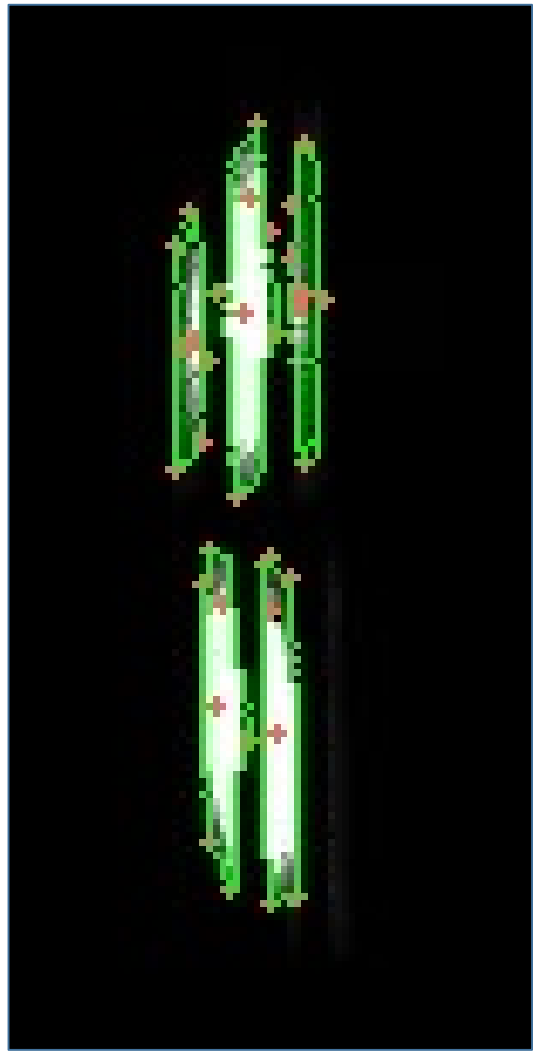


Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

Merlin - Time

Merlin (1 Image Standalone):

```
Real    0m0.321s
User    0m0.284s
Sys     0m0.036s
```

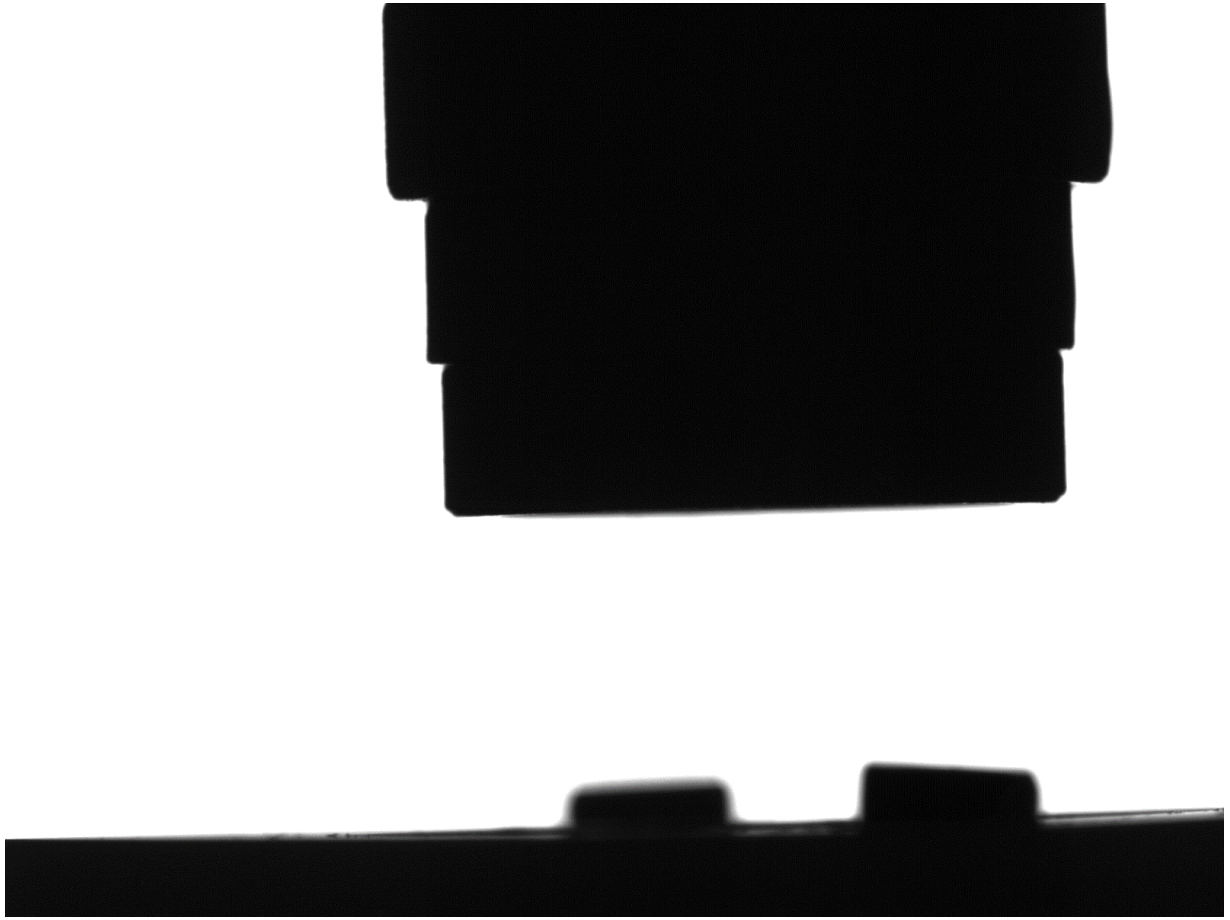


Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

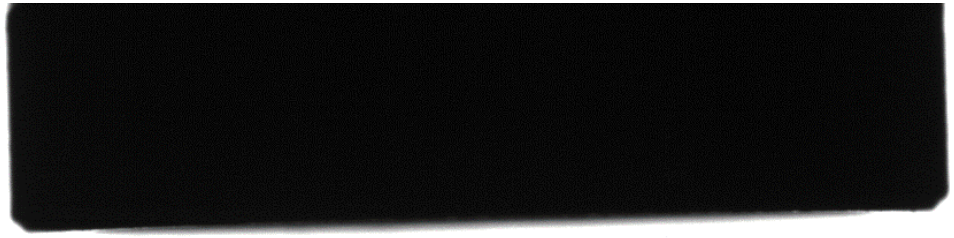
ABBIX Beamlines (AMX): Pins in a Robot Gripper

- Images are from AMX, Displays a Pin and a Gripper, in an attempt to grab the pin

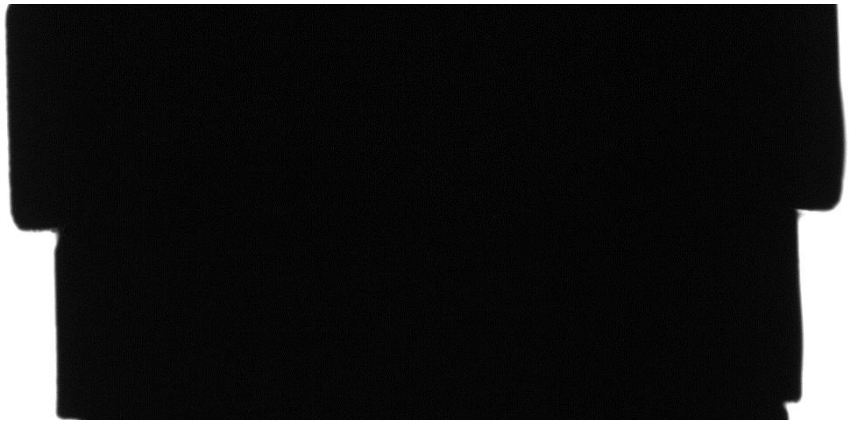
Pin and Gripper ‘Perfect’ Image



Pin Template Image



Gripper Template Image



Images Courtesy of: Jean Jakoncic, AMX Beamline

Robot Gripper - Purpose

Purpose:

- Find if Pin is in the Gripper
- Determine if Pin is properly mounted
  - Analyze the position of the Gripper and Pin within the image
  - Find the Region of Interest (ROI) for the Pin and Gripper
  - Compare the Pin and Gripper to a ‘Perfect’ Image to determine if anomalies are present
  - Advise the user to any potential problems

Images Courtesy of: Jean Jakoncic, AMX Beamline

Robot Gripper– ‘Perfect’ vs Test Cases

‘Perfect’

Image 1

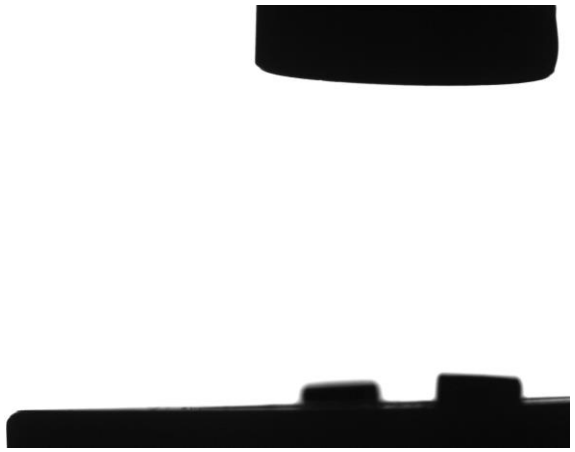
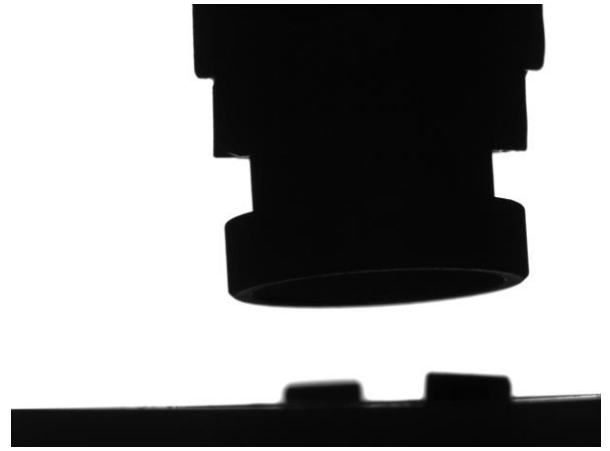


Image 2

Image 3

Image 4



Images Courtesy of: Jean Jakoncic, AMX Beamline

Robot Gripper- Results

Console Output:

```
Template: 0.0 Disim
Image-1: 1.36311088973 Disim
Image-2: 0.0286209618648 Disim
Image-3: 0.0045508842333 Disim
Image-4: 0.190357587177 Disim
```

Image 2

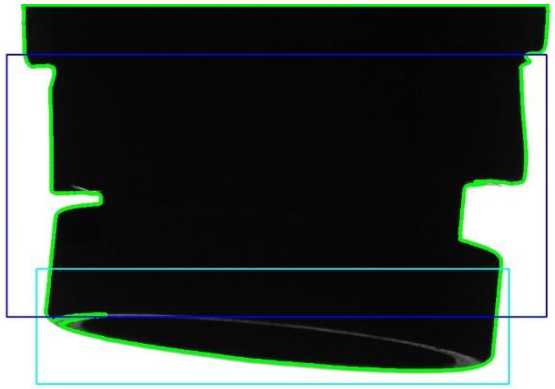


Image 3

‘Perfect’

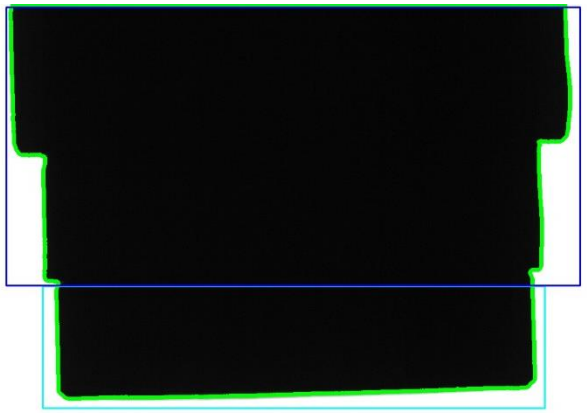


Image 1

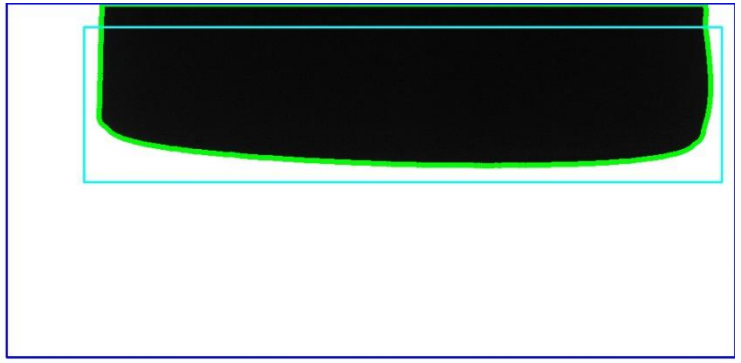
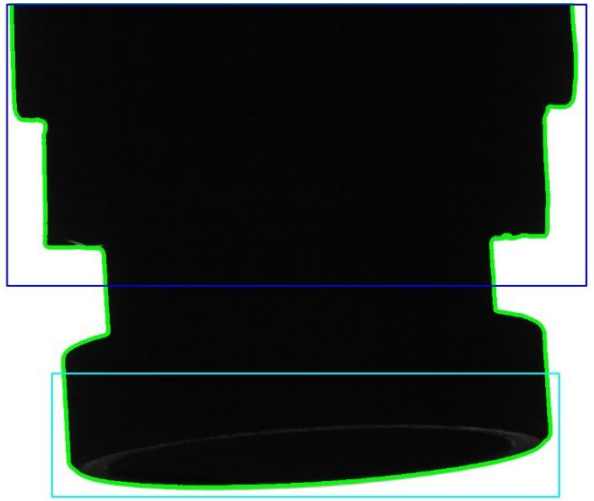


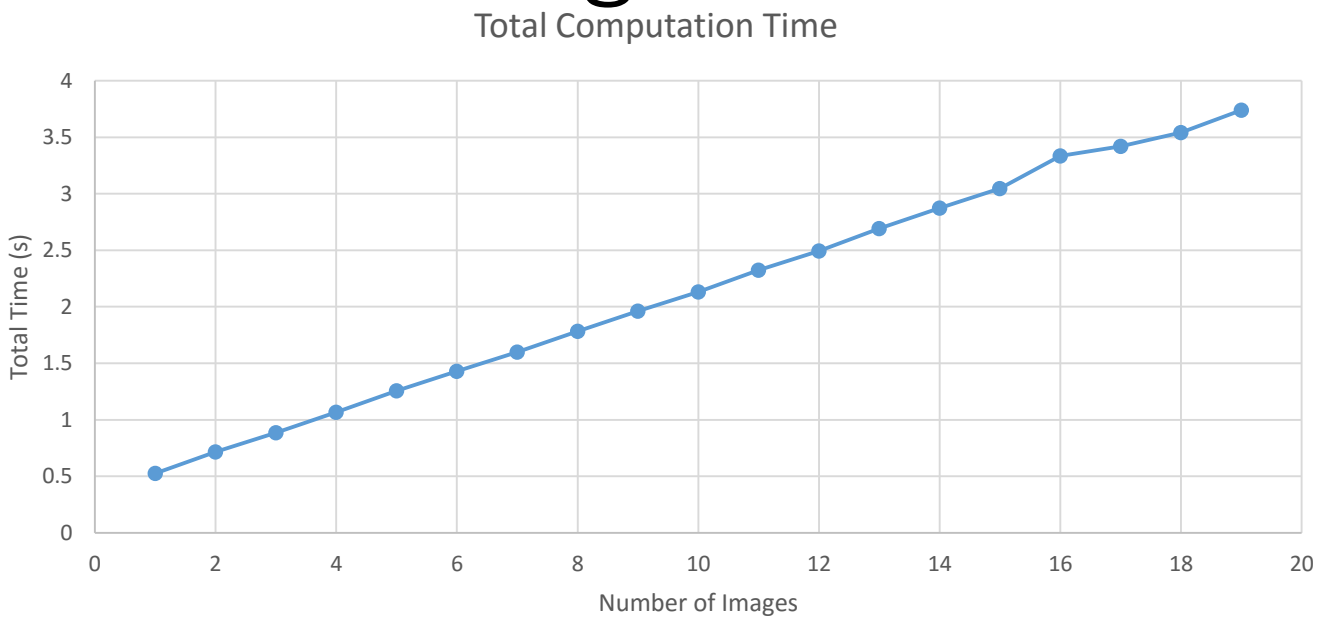
Image 4

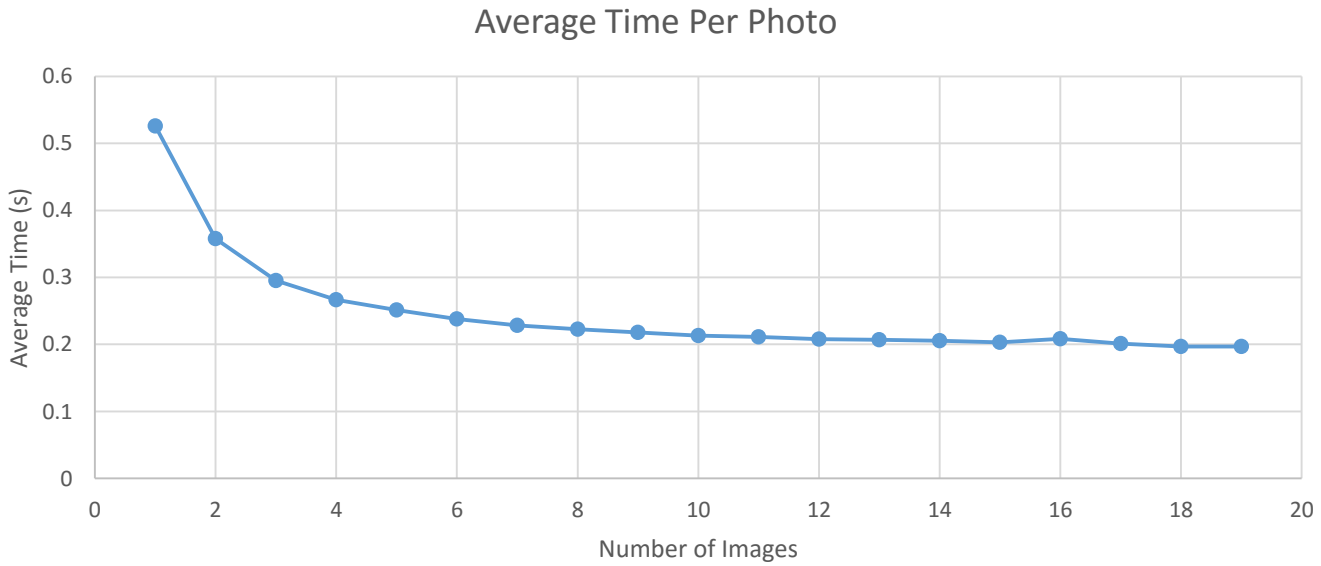


Images Courtesy of: Jean Jakoncic, AMX Beamline

Robot Gripper Time – 1-19 Images

Number of Images	Total Time	Average Time
1	0.526	0.526
2	0.716	0.358
3	0.886	0.29533333
4	1.066	0.2665
5	1.256	0.2512
6	1.429	0.23816667
7	1.6	0.22857143
8	1.783	0.222875
9	1.962	0.218
10	2.131	0.2131
11	2.324	0.21127273
12	2.493	0.20775
13	2.692	0.20707692
14	2.875	0.20535714
15	3.046	0.20306667
16	3.335	0.2084375
17	3.42	0.20117647
18	3.543	0.19683333
19	3.74	0.19684211





Pin/Gripper – ‘Perfect’ vs Test Cases

‘Perfect’

Image 1

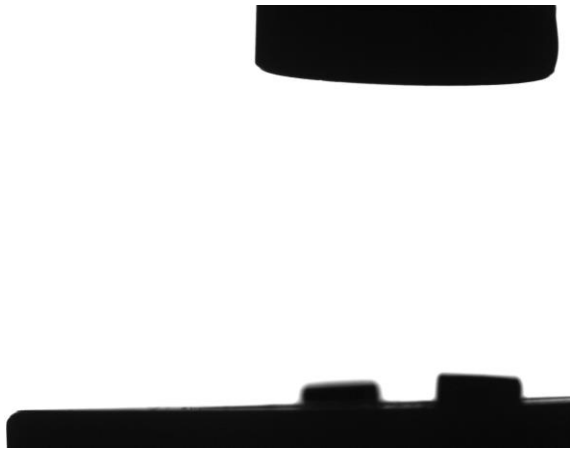
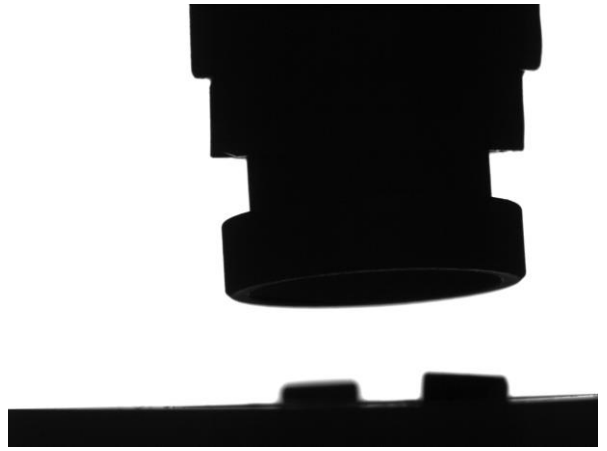


Image 2

Image 3

Image 4



Images Courtesy of: Jean Jakoncic, AMX Beamline

Pin/Gripper Detailed Analysis

Purpose:

- Find Pin and Gripper ROI’s
- Compare Apparatus to ‘Perfect’ for anomalies
- Discover Possible Kinks within image
- Discover if Pin is not properly mounted
- Discover the Center of Mass
- Use Extreme Points as an assist for Alignment, along with Centroid

Pin/Gripper Image Analysis – Results – Image 1

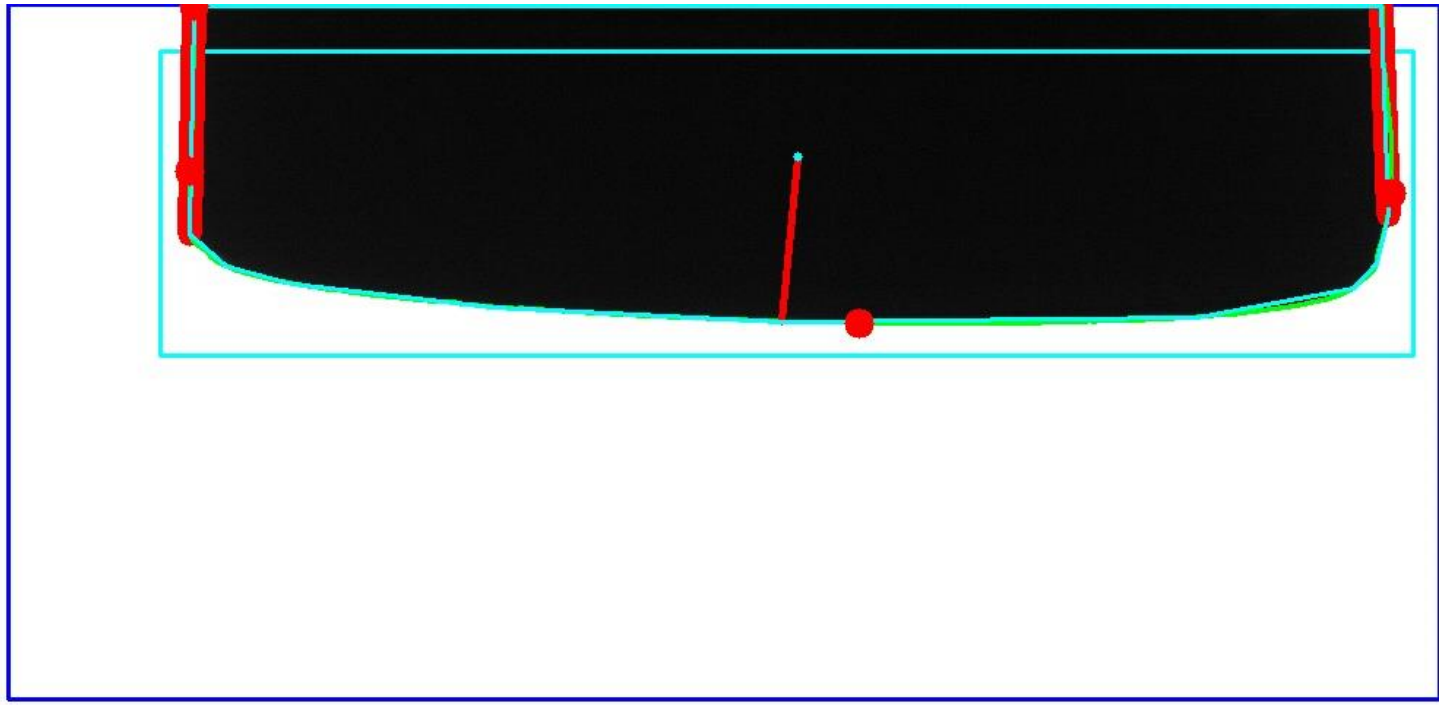
Console Output on Image 1:

Image 1:

```
perimeter: 2017.74725473
max: (745, 1)
height: 217
extrema: {'B': (1203, 218), 'R': (1567, 129),
          'L': (745, 114), 'T': (748, 1)}
area: 168731.5
min: (793, 1)
sum intensity: 4280971
width: 822
centroid: (1161, 104)
mean intensity: 23.999971969
```

Match Metrics:

```
Image Dissimilarity: 1.36080901012
Mount Centroid: Too High: 104
Missing Component / Gripper Not Aligned
```



Images Courtesy of: Jean Jakoncic, AMX Beamline

Pin/Gripper Image Analysis – Results – Image 2

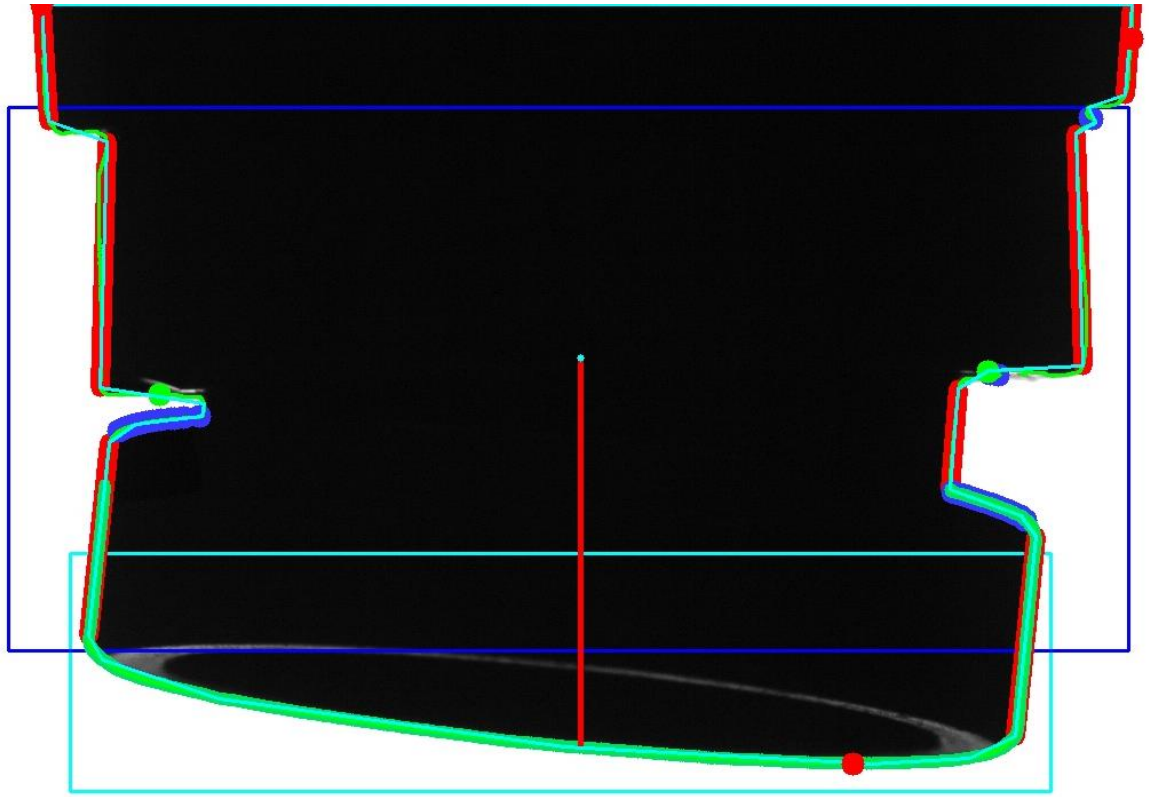
Console Output:

Image 2:

```
perimeter: 3512.21232665
max: (497, 66)
height: 664
extrema: {'B': (1206, 665), 'R': (1450, 31),
          'L': (497, 1), 'T': (497, 1)}
aspect ratio: 1.43458646617
area: 532620.5
min: (515, 1)
sum intensity: 30095708
width: 953
centroid: (968, 310)
mean intensity: 47.5601903943
```

Match Metrics:

```
Image Dissimilarity: 0.0274253192917
Possible Kinks Detected
41 Possible Kink Points Detected: Adjust Gripper
Possible Kink Distance on R: 115.004347744
Possible Kink Distance on L: 27.3130005675
Pin Not Mounted Correctly: Distance: 329
```



Images Courtesy of: Jean Jakoncic, AMX Beamline

Pin/Gripper Image Analysis – Results – Image 3

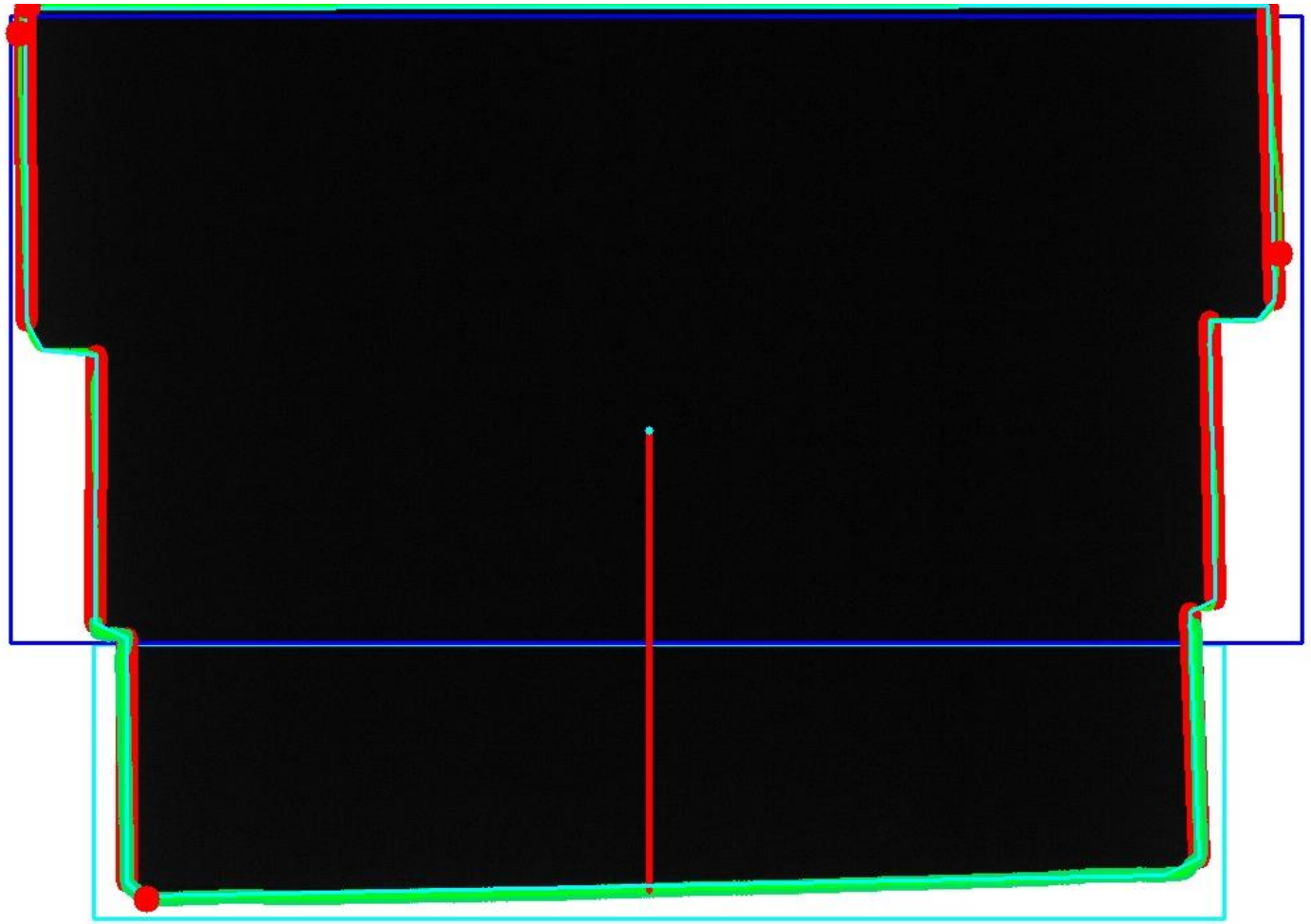
Console Output:

Image 3:

```
perimeter: 3272.13917053
max: (496, 1)
height: 677
extent: 0.902237973263
extrema: {'B': (593, 678), 'R': (1452, 189),
          'L': (496, 22), 'T': (503, 1)}
area: 585413.5
min: (525, 1)
sum intensity: 20199272
width: 956
centroid: (974, 323)
mean intensity: 31.2096685476
```

Match Metrics:

```
Image Dissimilarity: 0.00487836456791
```



Images Courtesy of: Jean Jakoncic, AMX Beamline

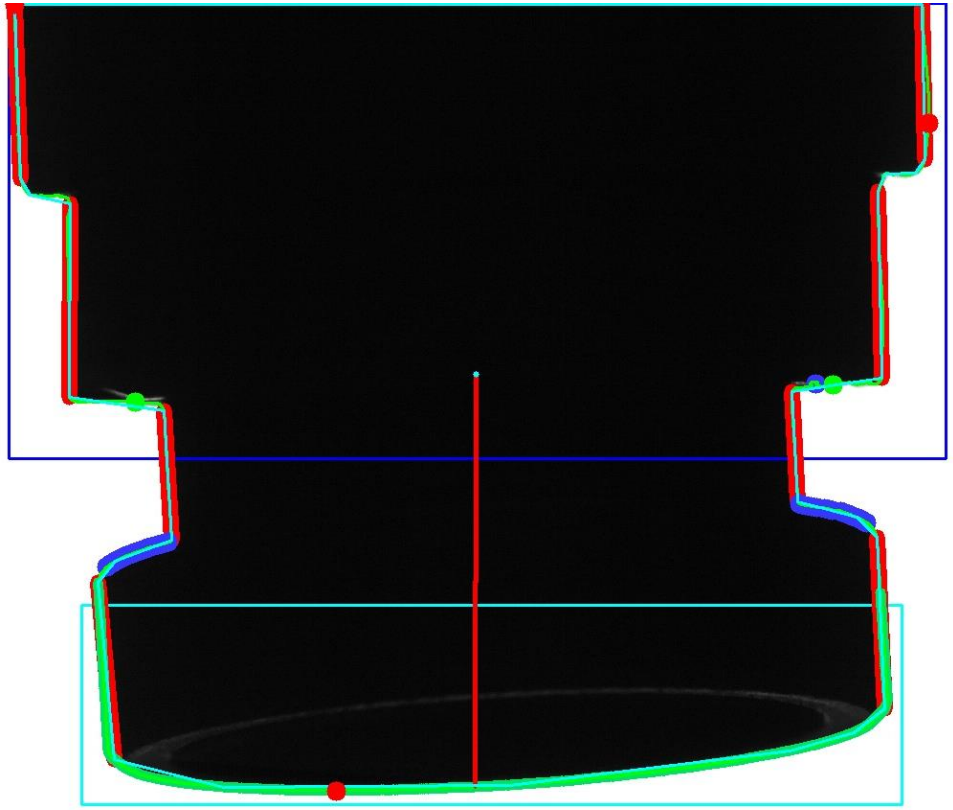
Pin/Gripper Image Analysis – Results – Image 4

Console Output:

```
Image 4:
perimeter: 3790.45496655
max: (1443, 1)
height: 821
extrema: {'B': (828, 822), 'R': (1447, 125),
          'L': (492, 1), 'T': (492, 1)}
aspect ratio: 1.16301703163
area: 664209.0
min: (503, 1)
sum intensity: 35452804
width: 955
centroid: (974, 387)
mean intensity: 45.2172411374
```

Match Metrics:

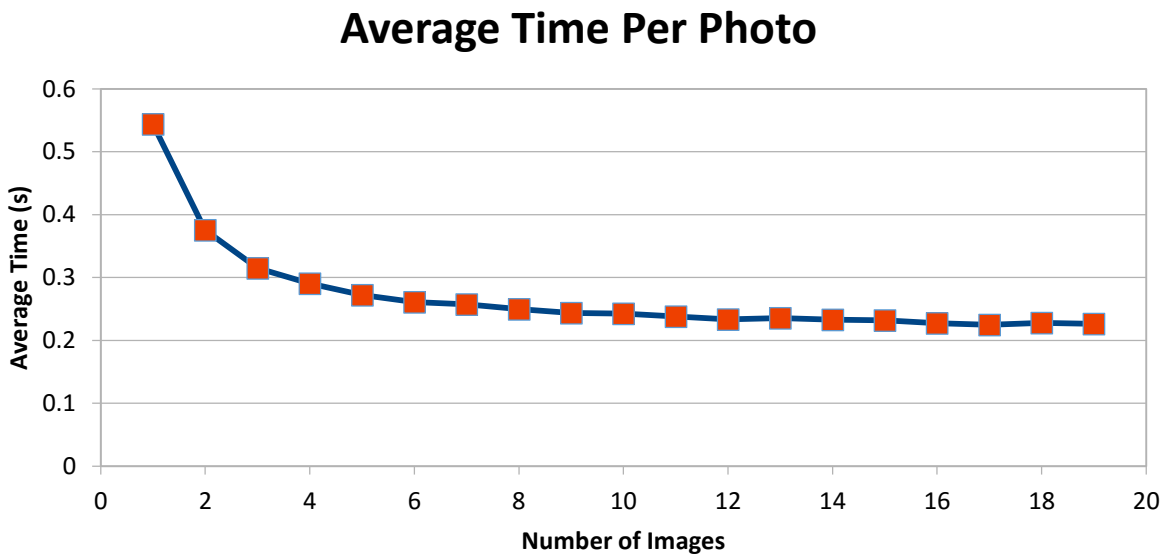
```
Image Dissimilarity: 0.190836638543
Possible Kinks Detected
44 Possible Kink Points Detected: Adjust Gripper
Possible Kink Distance on R: 125.015998976
Possible Kink Distance on L: 157.003184681
Pin Not Mounted Correctly: Distance: 411
```

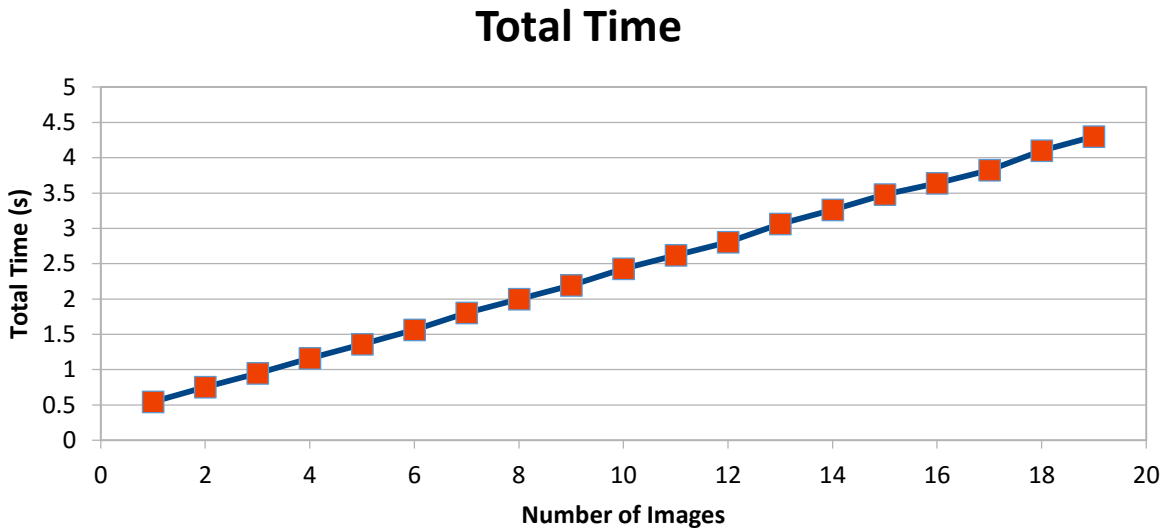


Images Courtesy of: Jean Jakoncic, AMX Beamline

Pin/Gripper Time – 1-19 Images

Number of Images	Total Time	Average Time
1	0.544	0.544
2	0.751	0.3755
3	0.945	0.315
4	1.162	0.2905
5	1.361	0.2722
6	1.565	0.26083333
7	1.802	0.25742857
8	1.999	0.249875
9	2.192	0.24355556
10	2.429	0.2429
11	2.621	0.23827273
12	2.803	0.23358333
13	3.064	0.23569231
14	3.264	0.23314286
15	3.482	0.23213333
16	3.637	0.2273125
17	3.824	0.22494118
18	4.1	0.22777778
19	4.302	0.22642105

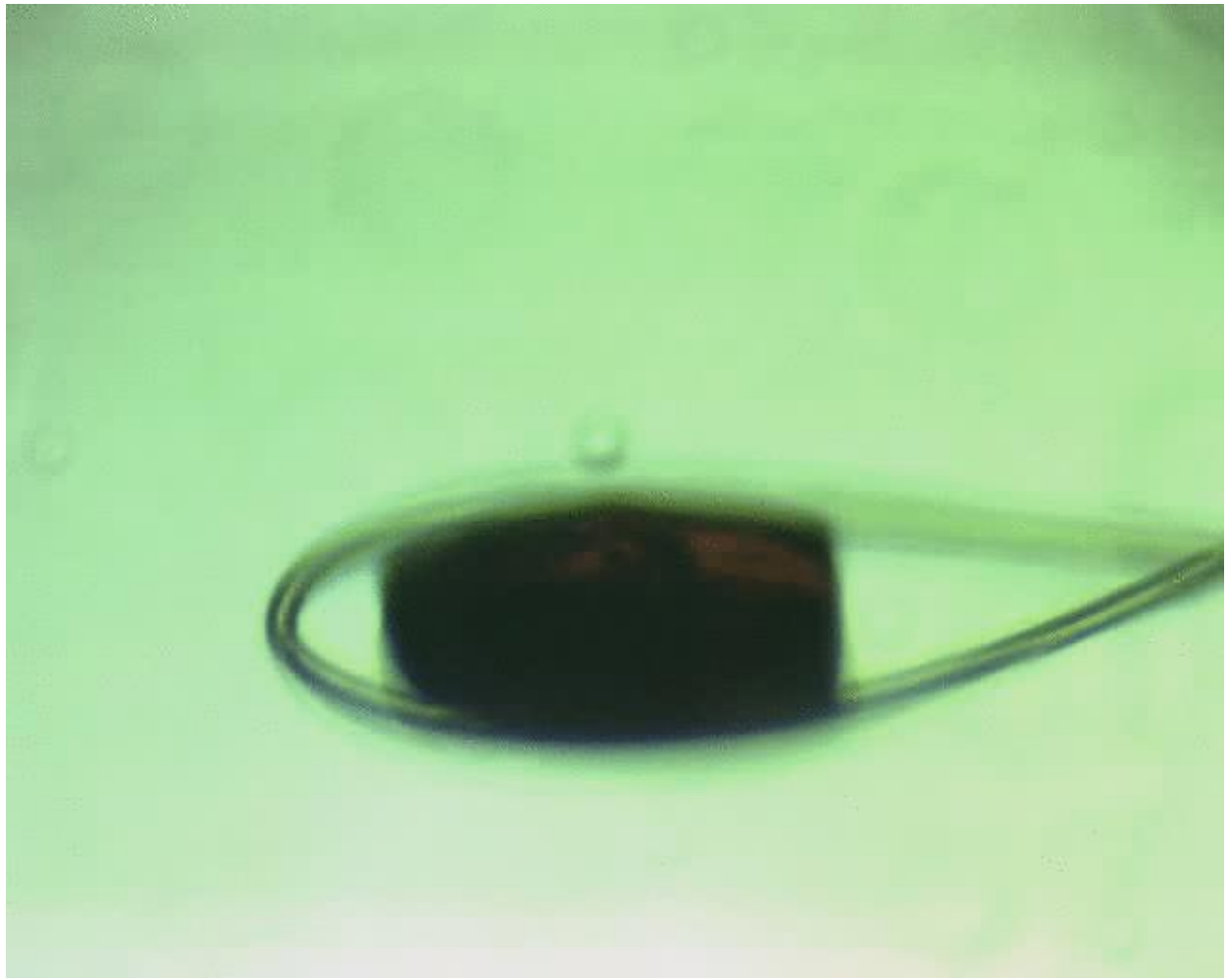




Crystal Rotational Alignment - AMX

Purpose:

- Locate the Crystal
- Center the Crystal in Goniostat
- Plot as a function of angles the Y Pixel coordinate of Crystal during rotation

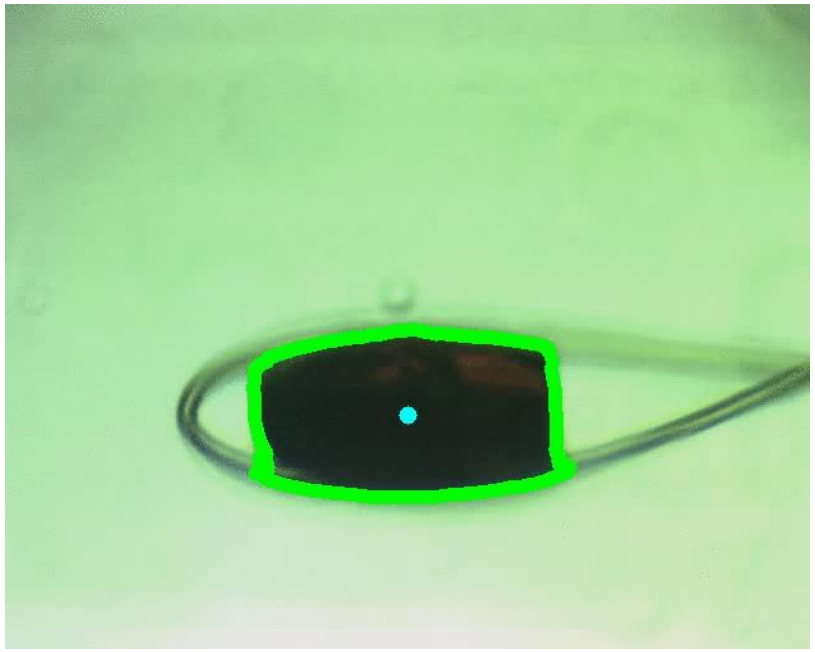


Images Courtesy of: Jean Jakoncic, AMX Beamline

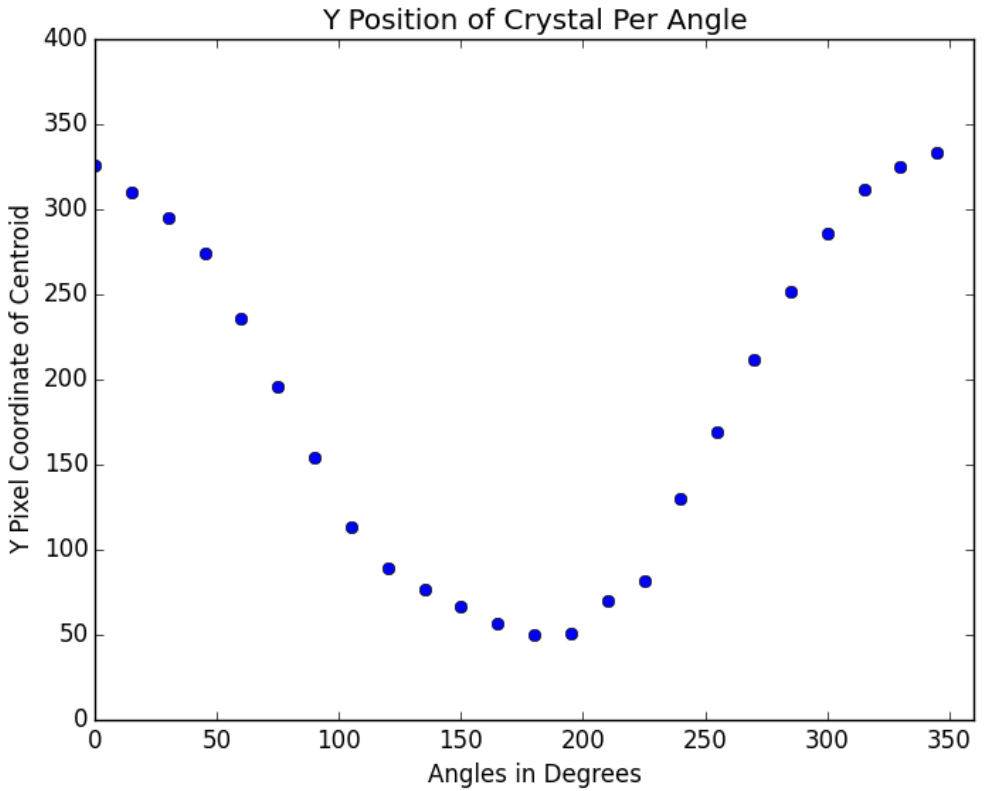
Crystal Rotational Alignment - AMX

- Centering Crystal:

Total Time (24 Img): 0.858s Average Time: 0.035s



Images Courtesy of: Jean Jakoncic, AMX Beamline

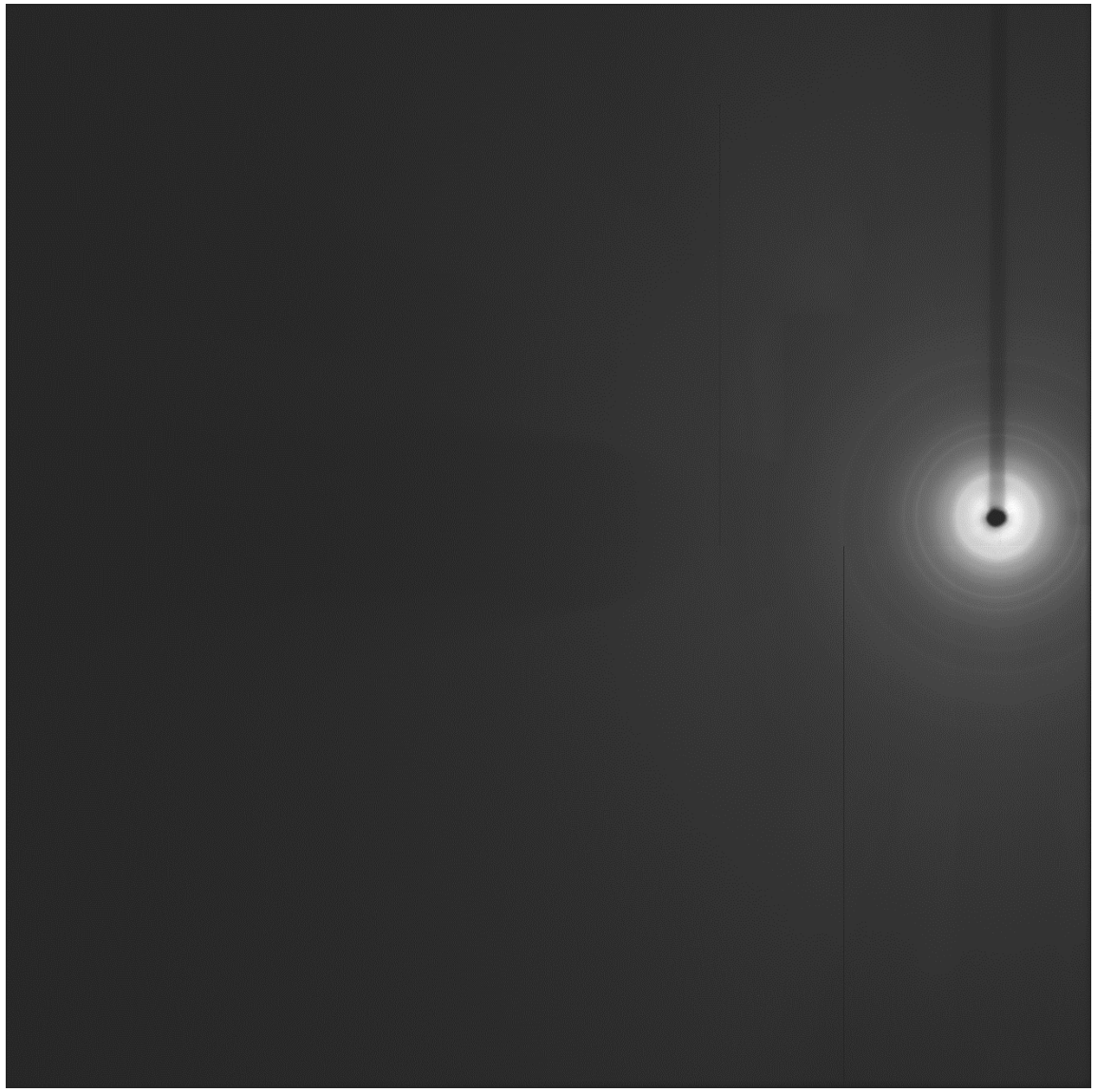


Conclusion

- Computer Vision provides:
  - Center Samples in Goniostat (ABBIX, IXS, etc.)
  - Automated Robotic Mounting and Sample Detection (AMX)
  - Assist in alignments of samples, crystals, and beams
  - Discovers and reports information about objects within an image
  - Prevent potential problems by alerting users of anomalies
- With OpenCV 3.1.0 and the Intel IPP Library, all CV functions run at optimized speeds, providing the best computational results currently available.

Future Plans - XPD

- XPD X-Ray Diffraction Scoring Analysis:
  - Discover Diffraction Circles
  - Integrate Intensities
  - Count Number of Circles
  - Count Total Diffraction in each Frame



Images Courtesy of: Sanjit Ghose, XPD Beamline