Development of computer vision and image processing at the National Synchrotron Light Source - II

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NATIONAL SYNCHROTRON LIGHT SOURCE II

ABSTRACT

The beamline microscopes at the National Synchrotron Light Source – II (NSLS-II) utilize X-ray imaging to enable the study of material properties and functions with nanoscale resolution. Robots help to automate the process of sample transfers and camera movement without human interference in sealed hutches. Computer vision and image analysis software is required for these processes to be automated. A general purpose computer vision module with the support of OpenCV, an open-source computer vision library, was built. Computers can determine if a robot has improperly mounted a sample or pin, and warn users and scientists of potential errors within the hutches. This wrapper module results in succinct computer vision code. Applications can determine the positon, spread, and intensity of the x-ray beams from cameras directly. Integration with the Experimental Physics and Industrial Control System (EPICS), an open source control system for scientific instruments, applications can observe and report of the status of an experiment in real-time. This will help prevent damage to the beamline while automating timely processes, such as goniostat alignment.

METHODS

BPM-1 X-Ray Analysis (IXS)

- Images captured from the BPM-1 Camera at the Inelastic X-Ray Scattering Beamline (B Hutch)
- **Purpose:** Discover position, spread, intensity, and center of mass of beam

Figure 1: Sample BPM-1 Image

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

- X-Ray Beam originates from undulator, passes though Double Crystal Monochromator and Focusing mirrors
- Image captured at 1st XBPM by reflecting X-Ray through YAG Scintillator to Prosilica camera

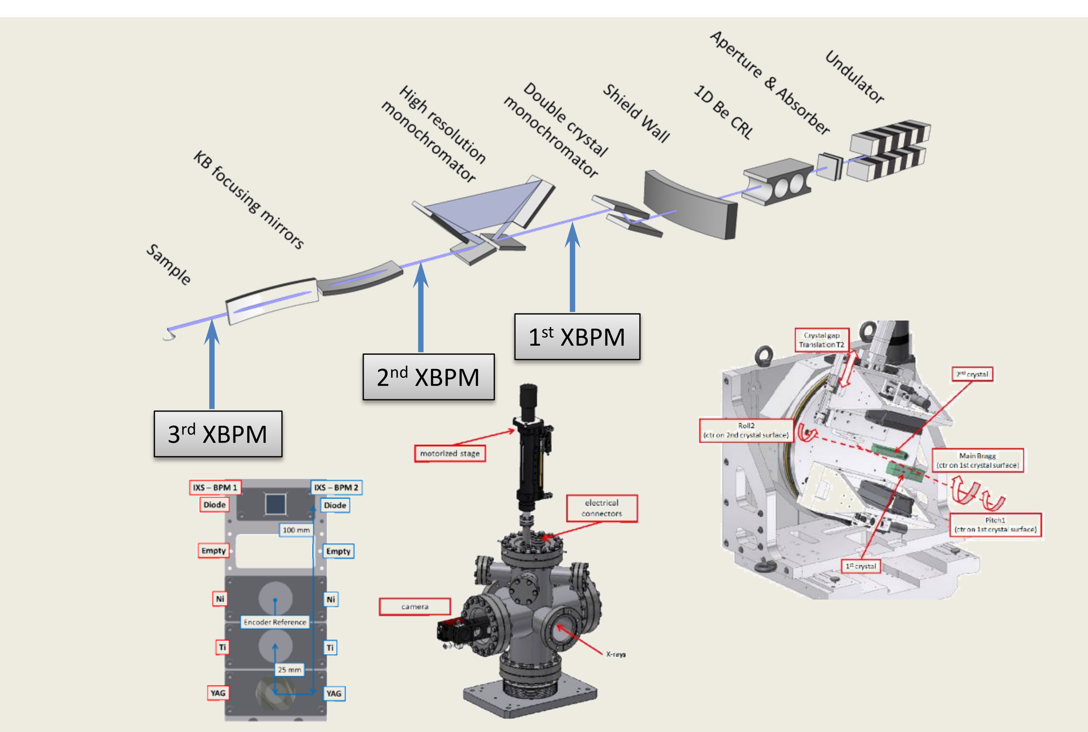
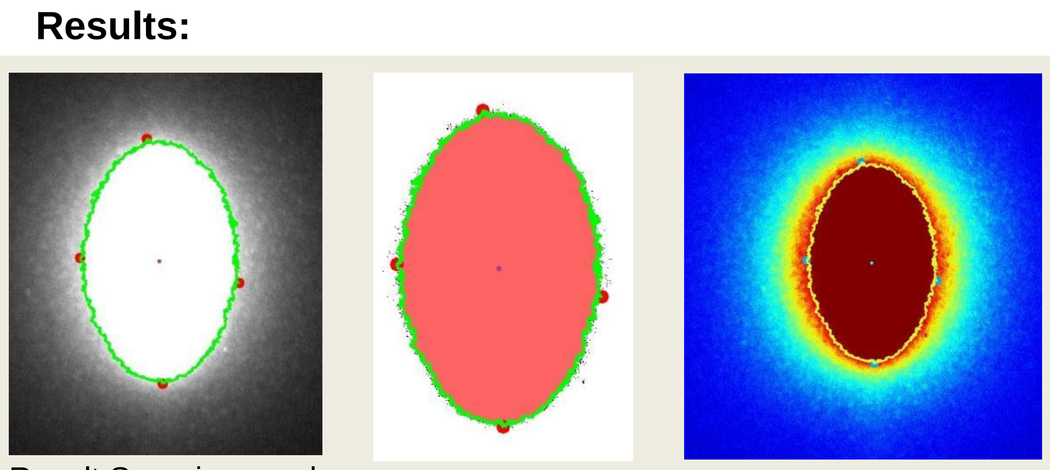


Figure 2: IXS Schematic Layout For Optical System

- **Process:** 1. Threshold, 2. Find Contours, 3. Plot, Draw, and Print Contour Data
- **Results:**



Result Superimposed on Original | Thresholding Result | Jet Color Map

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
```

Figure 3: BPM-1 Image Results

- Can use information to align beam or study properties

Merlin Quad X-Ray Detector (IXS)

- Images retrieved from the Merlin Quad Detector at IXS
- **Purpose:**
  - Isolate Individual Streaks
  - Process each Streak to lean Position, Center, Spread, Intensity, Maximum Location and Value
  - Count Intensity for each Streak

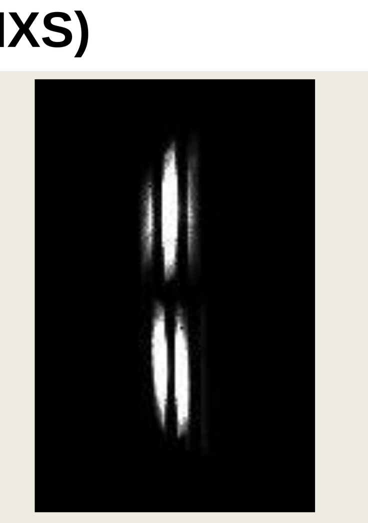


Figure 4: Merlin Sample Image
E = 9.1 keV
Direct detection
PEL size = 55 [um]

- **Results:**

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
```

Figure 5: Merlin Data Results for First (Largest) Object

- Can easily observe and record useful data regarding X-Ray Streaks

On-Axis Pin Rotational and Center Alignment (IXS)

- Images captured from the On-Axis Camera located in D hutch (IXS)
- **Purpose**:
  - Measure the offset in the x and y position of the tip of the pin
  - Plot and discover the sinusoidal regression corresponding to the pixel positions
  - Calibrate the motors to align the pin properly
  - Develop a point and click application to automate the pin adjustment from a simple

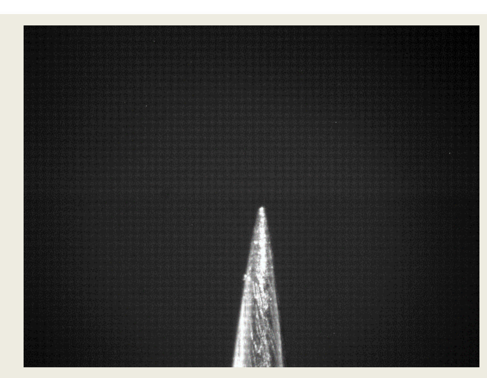


Figure 6: On-Axis Pin Sample Image (IXS – D Hutch)

- **Results:**

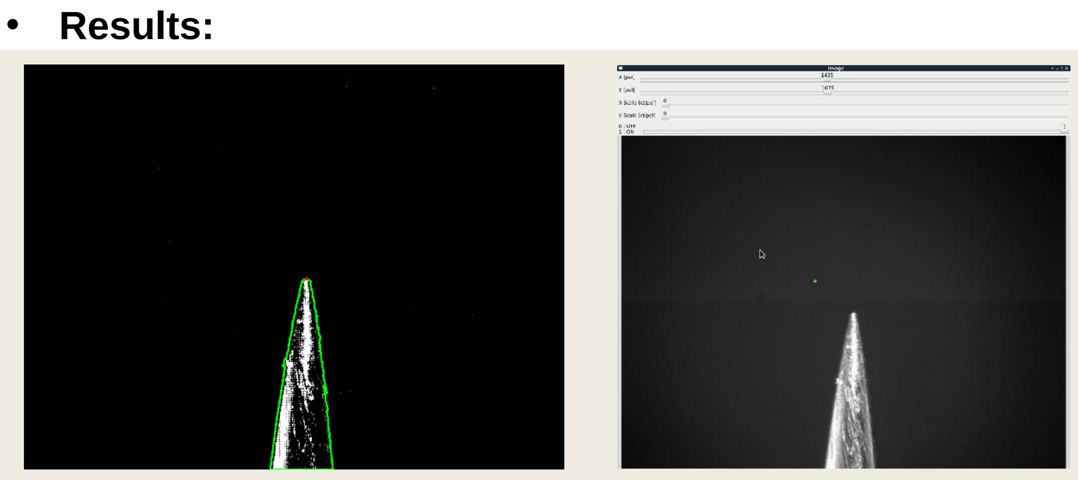


Figure 7: Left: Image Result with Contour and Top Extrema
Right: Point & Click GUI Interface (X, Y, MC Scale Bars, Green Cursor)
Console Output: `PIN TOP: (1723, 1306)`

- Can Use Extrema to calculate offset and reposition pin
- Can use rotational information to calibrate motors

ABBIX Beamline: Pins in a Robot Gripper (AMX)

- Images are from the Highly Automated Macromolecular Crystallography Beamline (AMX)
- **Purpose:**
  - Find Pin and Gripper Region of Interest (ROI)
  - Compare Apparatus to 'Perfect' for anomalies
  - Find kinks, check if properly mounted
  - Discover centroid, use extreme points as assist for alignment

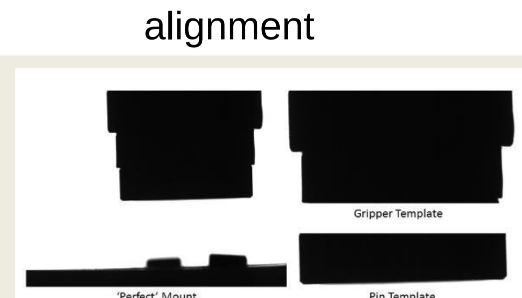


Figure 8:
Left: Template Images for 'perfect', gripper, and pin
Right: Sample Gripper and Pin Images

Overview

Computer Vision:

- Development of image analysis software backed by OpenCV
- Development of easy use python module to access OpenCV functions
- Optimized results for fast computation via C/C++ backed code, along with Intel IPP/TBB libraries
- Automate processes such as:
  - Positon, spread, and intensity of X-Ray Beams
  - Isolate crystals and X-Ray streaks
  - Provide assistance to sample mounting
  - Calibrate Goinstat Rotation and Robotic Vision

Results:

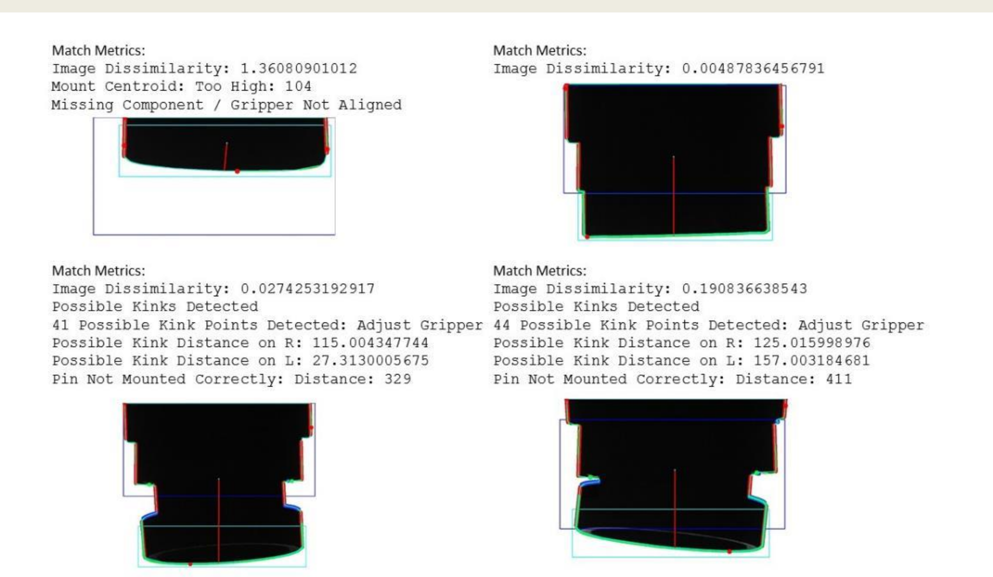
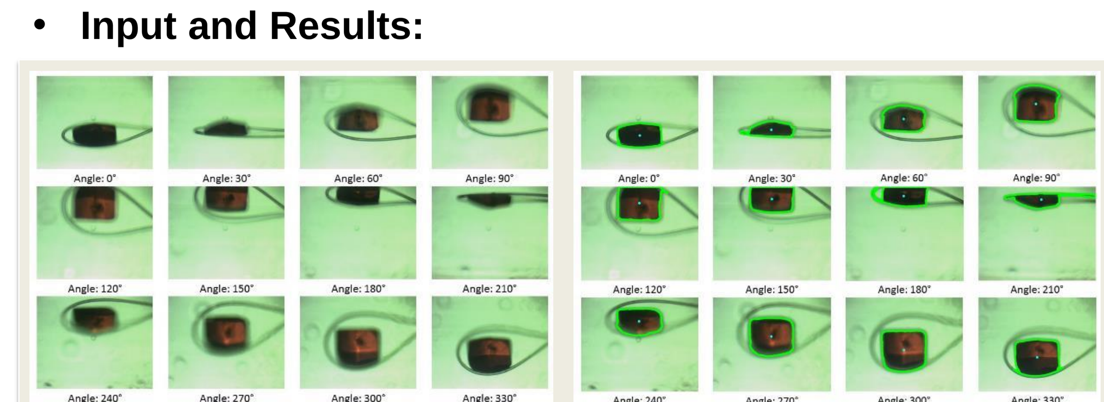


Figure 9: Sample Results Images from AMX

ABBIX Beamlines – Crystal Rotational Alignment (AMX)

- Images Provided by Jean Jakoncic, captured from Goniostat Rotation every 15° at AMX
- **Purpose:**
  - Locate and Center Crystal in Goniostat
  - Plot as a function of angle the Y Pixel coordinate of Crystal during rotation
- **Input and Results:**



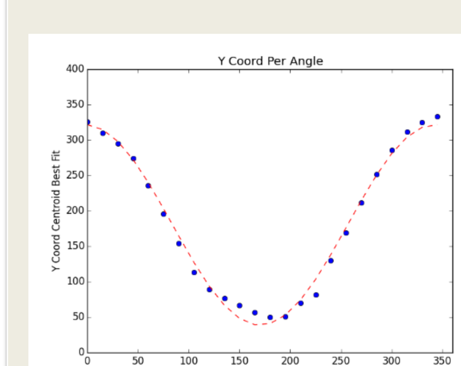


Figure 10:
Top: Input and Tracking Results
Left: Graph Produced, along with fitted sinusoidal curve

Equation:

$$141.58 \times \sin(angle + 1.61) + 180.19$$

Adjustment:

$$x = -\frac{MC}{PEL} \times Amplitude \times \sin(phase)$$

$$y = -\frac{MC}{PEL} \times Amplitude \times \cos(phase)$$

MC – Motor Count
PEL – Picture Element

- Can find a sine regression to adjust rotational motors and calibrate crystal goniostat rotation.

Conclusion

- Computer Vision provides:
  - Center Samples in Goniostat (ABBIX, IXS, etc.)
  - Automated Robotic Mounting and Sample Detection (AMX)
  - Assist in alignments if samples, crystals, and beams
  - Discovers and reports information about objects within an image
  - Prevent potential problems by reporting anomalies

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