On-axis 3D Microscope for X-ray Beamlines at NSLS-II

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Outline

- Overview – NSLS2
  - Beamlines (19 operational + 9 under constr.)
  - Endstations
  - Beam size(s) @ sample 1 [um], 4 [um], 4x6 [um]
  - Sample/features: 1 [um]
- On-axis microscope(s): Non-dispersive (mirror) optics
- Computer Vision
  - Goniostat centering (17-ID, 19-ID)
  - X-ray beam detection, stability studies
  - Real time image processing
  - Focus stacking
  - 3D microscope
- Credits
On-axis beamline microscopes

IXS (10ID) WD=60 cm
3 [um]
3 x

Diamond cell (IXS)

AMX/FMX (17ID) 30x, 5x 1 [um]


Endstation microscopes (TXM)

- 2 X-ray detecting microscopes
- 2 optical alignment microscopes

All are home assembled microscopes
Endstation microscopes (FXI)

X-ray imaging, TXM

Sample imaging
X-ray eye: 10ID (KB mirror - VFM)

Cam
Focus
20x
X-ray

Mirror
CWO

KB mirror (VFM)

7 um
FWHM = 5 um

Profile of XF:10IDD-BI(XrayEye-Cam:3)image1

Value

Distance (pixels)
Computer Vision

Computer Vision for beamline with openCV:
- 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.
- GPU role.
- Camera -> areaDetector { | IP based} -> Comp. Vision -> Results {sorted size, intensity, position, pattern,…} -> EPICS PV { | file | control software | …}
- Automate processes such as:
  - Position, spread, and intensity of X-Ray Beams
  - Isolate crystals and X-Ray streaks
  - Provide assistance to sample mounting
  - Calibrate Goniostat Rotation and Robotic Vision
- 3D microscope
Computer Vision – loop center (5s)

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

Equation:
\[ 141.58 \times \sin(\text{angle} + 1.61) + 180.19 \]

Adjustment:
\[ x = -\frac{MC}{PEL} \times \text{Amplitude} \times \sin(\text{phase}) \]
\[ y = -\frac{MC}{PEL} \times \text{Amplitude} \times \cos(\text{phase}) \]
Computer Vision

IXS – BPM1

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

IXS: Merlin Data Results for First (Largest) Object

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

AMX: Robot gripper – sample detection

IXS Point & Click: 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)
Resolution and Depth of Focus

- Resolution = wavelength / (2*NA)
- Depth of field = wavelength*n/(NA)^2; n=1 for air
- Depth of field = 4*Resolution/wavelength

Shallow DoF is a Weakness
Focus – Horse Fly
Focus Stacking – Horse Fly (5x)

Original 38 Image Stack

ECC

Edge Detection

Gaussian Blur/Laplacian

Alignment

ORB

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The code

OpenCV

python

Real Time

OpenGL

EPICS

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Beetle (10ID, 3x/3um)

Two examples out of a stack of 19 images. First we performed focus stacking and gamma correction. Images were taken at the IXS 10ID beamline.
https://www.youtube.com/channel/UC-SfBpwDIiuw41_r0qqYkZQ?view_as=subscriber
The Beetle – merged/gamma corrected (3x)
The Beetle – depth map
The Beetle: focus=3\textsuperscript{rd} dimension

https://www.youtube.com/watch?v=UFx2EDouO-k
Mineral

https://www.youtube.com/watch?v=FdpdAdoirwA
Crystal images are all courtesy of Alexei Soares and the Click to Mount Team. Focus stacks of 15 images.

Crystal are sonicly ejected only from top layer, and surface layer moves (with crystals) to “heal” the surface.

Crystals from lower layers are not harvested.
Crystal harvesting

Sonic harvesting of crystals is driven by surface tension.

Crystals are ejected from surface layer

L1 Surface

L2 Middle

Ln Deep

\[\sim 10 \text{ um}\]

Sonic source

Conclusion 1:
Prevent crystals from settling to the bottom. Thus consider using Bingham fluid solutions. (to be published)

SUMMARY: Converted weakness (shallow DoF) into strength (recovered 3rd depth dimension)

“OpenCV Library.” *OpenCV Library*, opencv.org/.

Credits

Jakub Wlodek (focus stack)
Yong Cai (10ID)
Bill Watson (comp. vision)
Scott Coburn (mechanical)
Stephen Antonnelli (mechanical)
Bruno Martins
Martin Fuchs (17ID)
Jean Jakoncic (17ID)

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