Calibration of beam size monitors

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Introduction

- Responses to previous comments
- Software status
- Hardware status

Previous comments

Previous comments - Using existing barcode recognition software

Why not repurpose existing barcode recognition software?

This is partly what's happened. I searched for some general barcode recognition libraries, then researched some of the detection algorithms and worked from there. Note that a lot of barcode recognition libraries are oriented towards reading the barcodes more than detecting them, and often take advantage of checksums or other checks that aren't present in our case.
However, there are other constraints we can utilise; eg. If multiple targets are present we can cross reference them, we're only looking for a repeated bar pattern, etc. We plan to use the overall structure of the USAF1951 microscope chart as a constraint.

Previous comments - Utilising machine learning

Lots of discussion on this topic, but some quick notes:

Positive parts

- Reasonably easy to generate artificial images, microscope charts have well defined precise geometry.
- Easy to augment training set with a given skew, scaling, rotational, or noise parameters (did simple rotation and scaling).
- As well, we can easily take real world images automatically from the current camera setup.

Previous comments - Utilising machine learning

Negative parts

- Easy to spend a lot of time on this, can end up with little consistent day to day progress.
- Optimisation of a neural net requires fine tuning of a number of parameters.
- We can end up with a black box method that doesn't tell us much about the image.
- Can also end up with a non-deterministic method.
- And finally, generalisation to other camera setups could be problematic.

Machine learning is an interesting and valid approach, but for this stage we'll look at more deterministic methods that we can then later compare and train machine learning approaches against.
Also, most of the code to date has been based around filtering and analysing areas of the chart and target once found.

Previous comments - Autofocusing

Autofocusing Many different methods, not going to list them all here. But quickly:

Canon hardware AF Uses beam splitter and separate microlenses to direct rays from opposite sides of lens onto separate AF sensor. Focusing state detected by phase difference of rays. Quick and doesn't require moving the lens backwards and forwards.

Software methods we'd use Move the lens focus backwards and forwards and compute a focus score whether by contrast maximisation, high frequency FT maximisation, etc. Choose image with best score as the focused image.

Software status

Software status

Took a closer look at the analysis results of the movement dataset:

- 20 images taken on the ThomX transfer line SST3, with the USAF1951 Microscope chart moved in 0.25mm increments
- Some regions of interest (ROIs) obscured at extreme positions
- Central positions generally analysed well
- Some depth of field effects - some ROIs well focused, others not

This dataset is a reasonable blend of good and bad imaging conditions

Software status - movement dataset

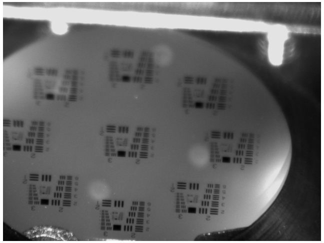


Figure 1: Far left image, leftmost ROI obscured/cut off

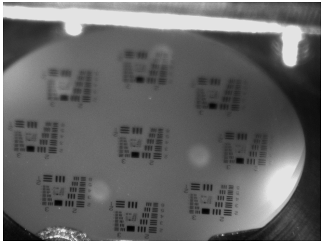


Figure 2: Central image, most targets can be seen and analysed

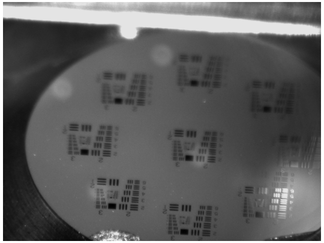


Figure 3: Far right image, image artifacts obscure ROI on right

Software status - Analysing movement set

The image analysis software was run on each image, and the results analysed to assess the consistency of the software output.. As the image is moved across at a constant increments, important points of interest should be also be moved at constant increments. Analysis process:

- Look for centroids of ROIs, and largest horizontal and vertical elements (sets of three bars) in each ROI
- Group centroids into paths as they move across, by proximity to endpoints of paths in previous image
- Compute difference of centroids, by ij/xy component or absolute
- Look at paths with at least three points

Software status - parts of image tracked

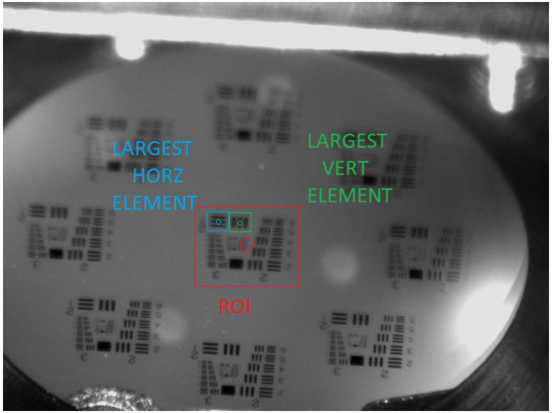


Figure 4: Image features that we'll be tracking in subsequent slides, and are used in the analysis to deduce the transformation from pixel space to geometrical space

Software status - ROI movement

ROI detected should cover cover the whole of a target portion of the USAF1951 Microscope chart, but doesn't need to be accurate beyond a couple of pixels, as it is used to narrow down the search region for other more precisely measured features.

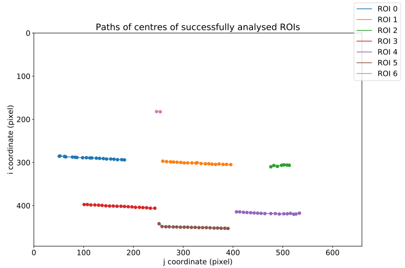


Figure 5: Paths traced out by ROI centres as we move the USAF1951 chart across the screen

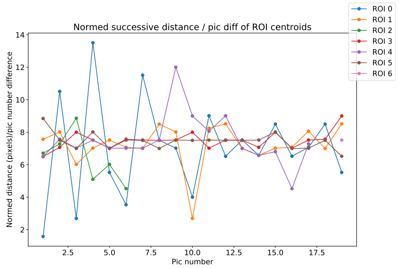
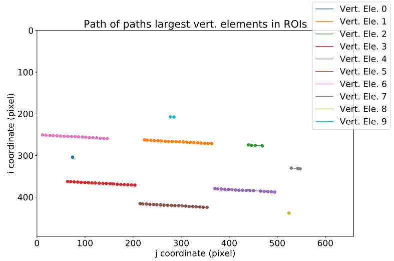
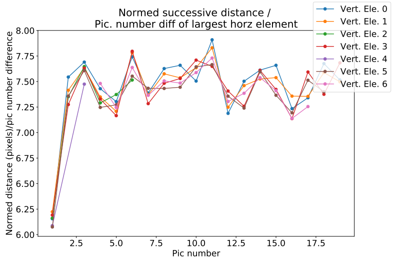


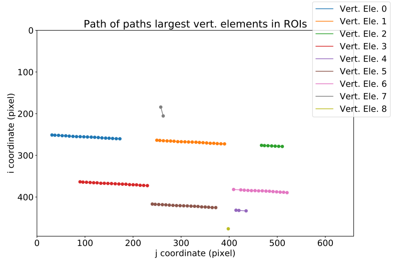
Figure 6: Normed distance between ROI centres, divided by image movement increments

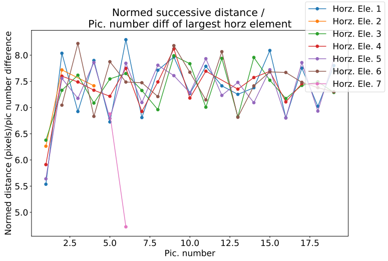
We see in the second plot that the detected ROI centres move roughly 7.5 pixels every chart movement increment.

Software status - Movements of elements of ROI









Movements of elements inside ROIs is determined more precisely.

Software status - conclusion

- We can consistently detect reasonably imaged ROIs to within a couple of pixels
- We can detect elements of those ROIs to within less than a pixel
- ROI detection less precise, but is only use to narrow search region for more precisely measured vertical and horizontal elements.
- Horizontal/vertical elements will be used for calibration in future beam size measurement.

Analysis software detecting and analysing targets of USAF1951 Microscope chart in consistent fashion.

Software status - to do

- Write manual/documentation - While in lockdown
- Code cleanup, optimisation - While in lockdown
- Test with other cameras, lighting configurations, other configurations of aperture/lens zoom/lens focus - Mostly after lockdown
- Integrate with rest of control room systems and Tango interface - While in lockdown
- Further analysis of results - While in lockdown

Hardware status

Hardware status

Attempting to continue with Canon EF lens mount reverse engineering

- Acquired lens, power supply, Arduino, other parts for home lab
- New lens is Tamron branded, uses Canon EF mount, but different model to those used on beamline

Current code tests:

- Initial connection - Lens responds to sync commands
- Serial number - Returns consistent response, but different to printed number (similar to ThomX lenses)
- Focus control - Works, can move focus up and down
- Zoom position - Works, reports position of lens (28mm-80mm)
- Aperture control - Still working on this (2020-05-06)

Lens control

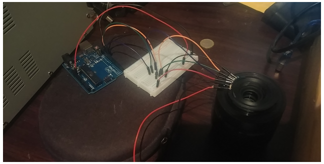


Figure 7: Arduino and lens setup

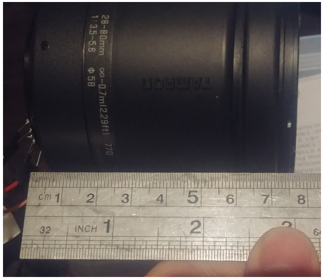


Figure 8: Lens at minimum focus

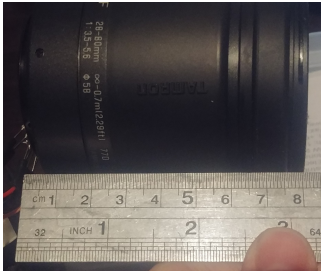


Figure 9: Lens at maximum focus

Hardware status - To do

- Finalise interface, and investigate how to set up lens control software as a Tango object - While in lockdown
- Get full control over aperture blades, and investigate depth of field effects, required exposure times - Partially while in lockdown
- Investigate mounting lens appropriately, ie. drilling holes for wires, or using extra coupling ring. To be managed by Alexandre Gonnin.
- Document results/create a manual - While in lockdown

End - backup follows

Software status - movement of elements within ROI

Move importantly, we need to be able to reliably measure elements within each ROI. We will look at the largest horizontally and vertically oriented elements (3 bars)

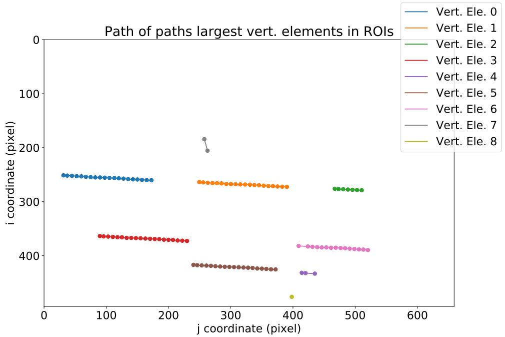


Figure 10: Paths of largest horizontal elements detected per ROI

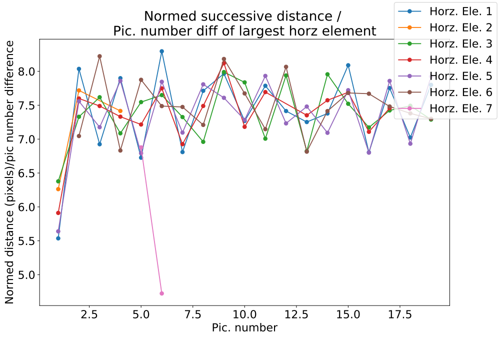


Figure 11: Normed distance between largest horizontal element centroids, divided by image movement increments

Software status - movement of elements within ROI

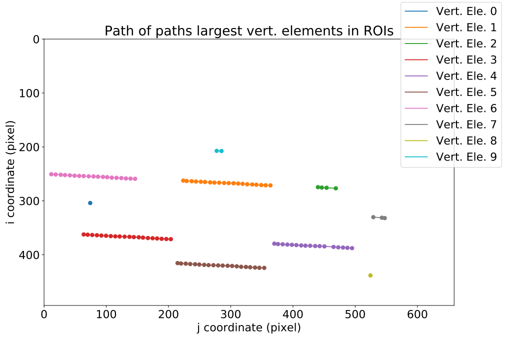


Figure 12: Paths of largest vertical elements detected per ROI

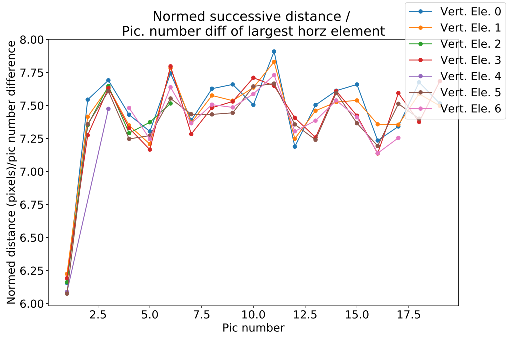


Figure 13: Normed distance between largest vertical element centroids, divided by image movement increments

Both largest horizontal and vertical largest elements are consistently found, to within a couple pixels. When the analysis successfully runs, it finds consistent results. Cause of initial jump from 6 pixels to 7 pixels unclear at this stage.