Finding and tracking Bragg spots in GISAXS maps of block Co-Polymer thin films using cascade based feature extraction and circular Hough transformation

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Introduction

By vapor annealing ~100nm disordered thin films of block co-polymers it is possible to order them due to microphase separation. In order to monitor this change Grazing Incidence Small-Angle X-ray Scattering (GISAXS) can be used which produces scattering pattern maps in reciprocal space. One feature which can be seen in such images is a Bragg-spot. Manually going through the images produced by GISAXS to locate and track Bragg-spots is a time-consuming process which can be automated using feature extraction algorithms. A cascade based approach based on the Viola-Jones algorithm and an approach based on Circular Hough Transform have been programmed and tested.

Pipeline

1. Acquisition
2. Segmentation
3. Preprocessing
4. Haar-like Feature Extraction
5. Circular Hough Transform
6. Post Processing

Input images (Dataset)

The Dataset consists of .tiff pixel intensity maps produced during two separate GISAXS experiments conducted during vapor annealing at the Cornell High Energy Synchrotron Source (CHESS).

~1500, 407x487 images are produced during each of the ~100 minute long experiments, only a few hundred of which exhibit the Bragg spotting which is sought.

Cascade based approach

A cascade of 6 Haar-like features are used to compare rectangular sites over the entire GISAXS map. These are used one by one until either (1) a feature fails at the site or (2) all features tested at the site are valid to a correspondence degree variance specified by the user. When (1) or (2) occurs the site is moved and the process is repeated until all sites have been tested. In the second case the site is assumed to hold a Bragg-spot. The cascade itself is generated from a sample Bragg-spot and its surroundings.

This approach requires the images to be greyscale and thresholded to be effective.

Haar-like feature cascade generation algorithm

A sample Bragg-spot is chosen then for each Haar feature:
1) Start by drawing first rectangle.
2) Expand until feature is present.
3) Expand second rectangle until feature is no longer present.
4) If applicable a third rectangle is expanded until end of image.

\[ \Delta = \text{light} - \text{dark} = \frac{1}{N} \sum_{i=1}^{N} I(i) - \frac{1}{M} \sum_{j=1}^{M} I(j) \]

Where \( \Delta \): degree of correspondence, \( N \): pixels in light rectangles, \( M \): pixels in dark rectangles and \( I \): the intensity map.

Grazing Incidence Small-Angle X-ray Scattering (GISAXS)

Swelling → Drying

Bragg Spots:

\[ \theta = \theta_0 + \Delta \]

\[ \Delta = \theta - \theta_0 \]

Results

Using the cascade based approach Bragg-spots may be found at a speed of ~18 images per second\(^*\) with few to no false positives / negatives.

Using Circular Hough Transform the Bragg-spots can be found at a speed of ~70 images per second. No false positives / negatives were present for swelling images but the algorithm fails for the images captured during drying when the Bragg-spots appear more elliptical.

Summary:

- Bragg-spots exhibited in GISAXS maps can be found using the algorithms presented with a minimal number of false positives / false negatives under the right conditions.
- This will enable automatic postprocessing of size, shape, intensity and position of Bragg-spots which would otherwise be labor intensive if done manually.
- The approaches presented could be applied to simulated GISAXS experiments and other similar image-producing experiments and simulations.

Circular Hough Transform

By use of canny edge detection Bragg-spots can be approximated as circular shapes.

By superimposing similarly sized circles on these edges their positions can be identified by looking for spots where the circles overlap.

To take size variances of the Bragg-spots into account a range of radii are tested.