Modified Fourier Transform Misalignment Analysis Method for Measuring Fibre Alignment in Stitched Glass Fabrics

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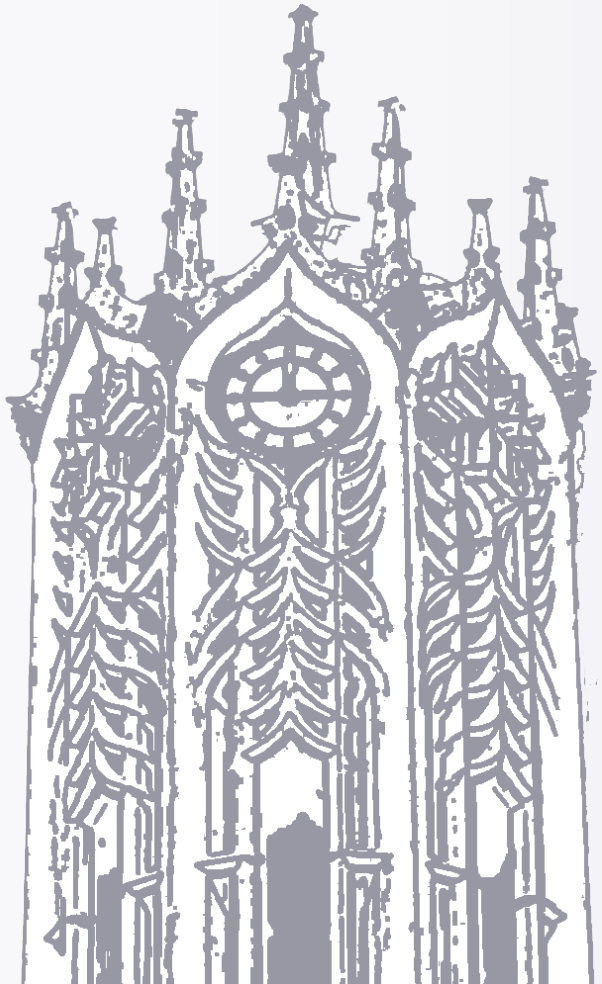

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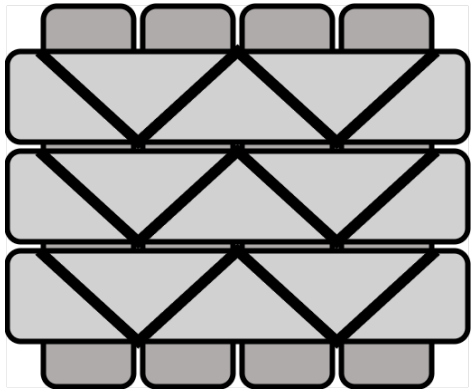
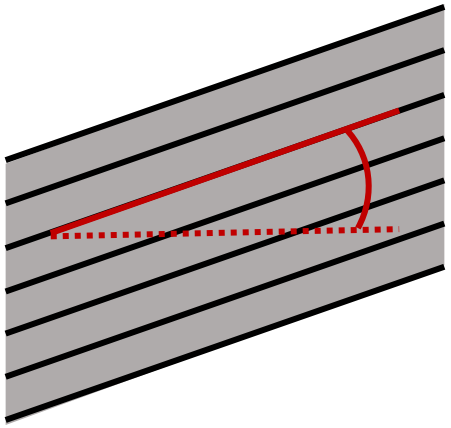
Introduction

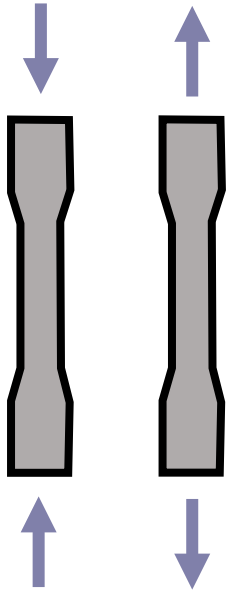
Stitched Fabrics



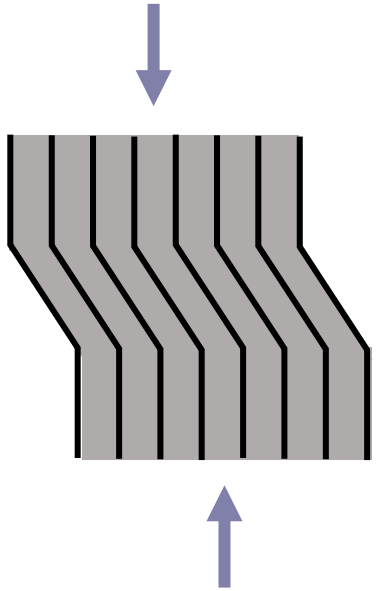
Fibre Alignment



Material Properties



Compression Strength

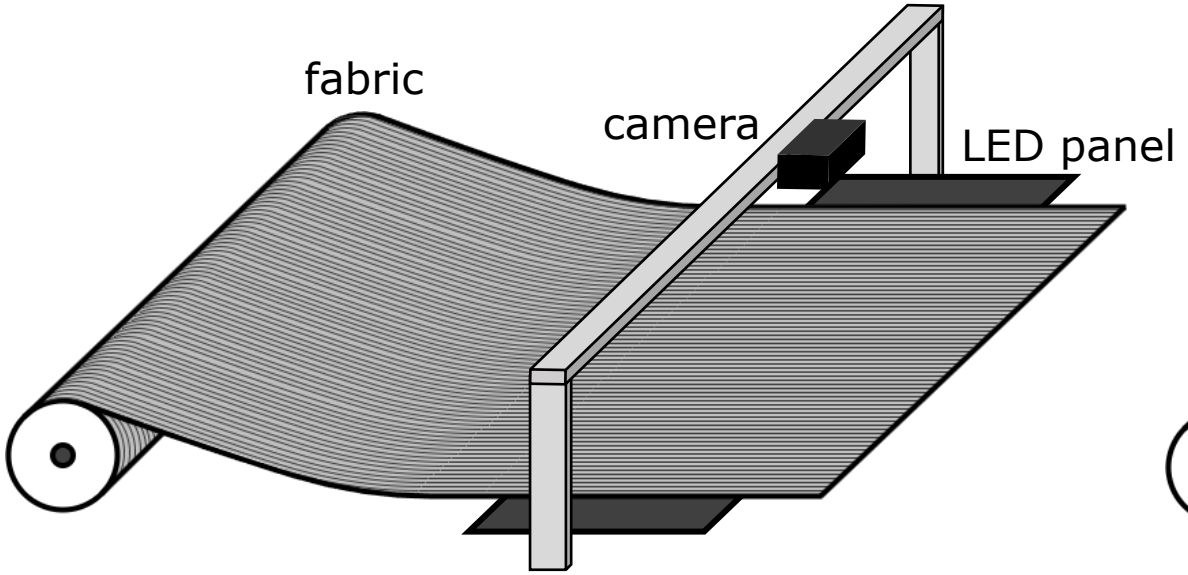


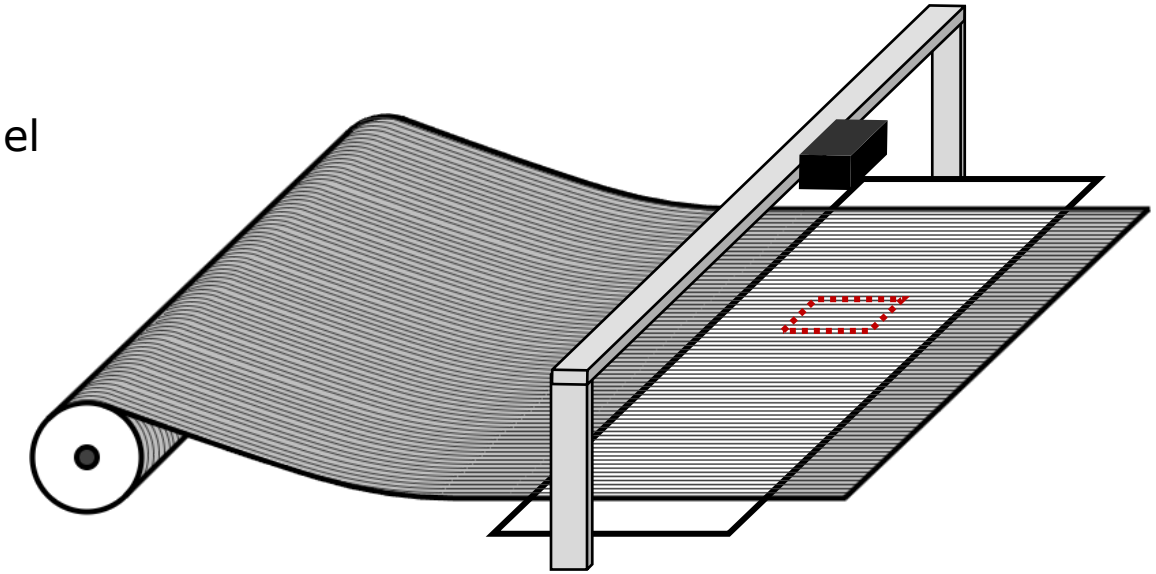
Goal

To measure fibre alignment in images of dry stitched glass fabrics

- Using images taken with a standard DSLR camera
  - Where individual fibres cannot be isolated
  - At low magnification, containing several fibre tows and several repeating units of stitching
- With a high degree of spatial resolution
- With a high degree of accuracy

Image Acquisition



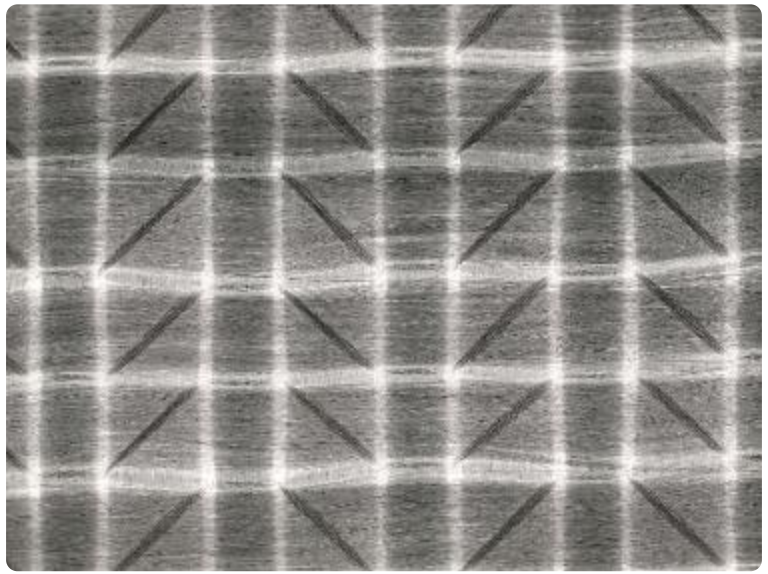


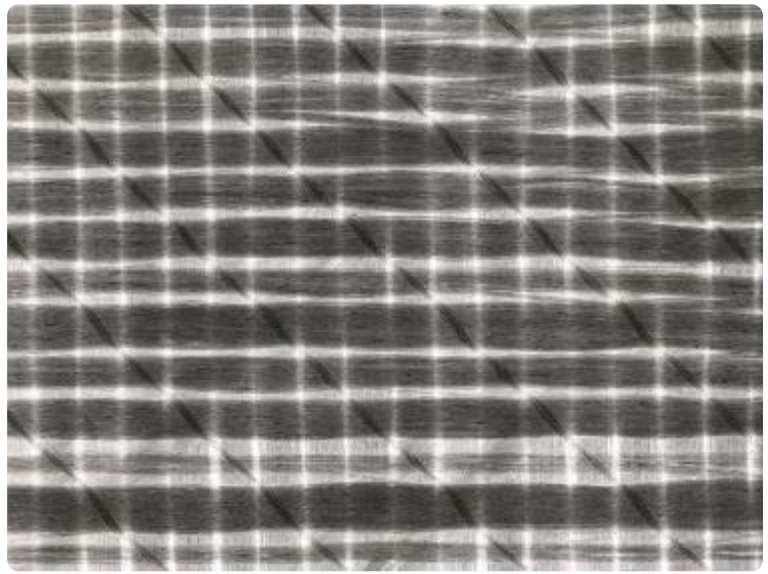
Canon 850D DSLR

4000 x 6000 pixels (24 megapixels)

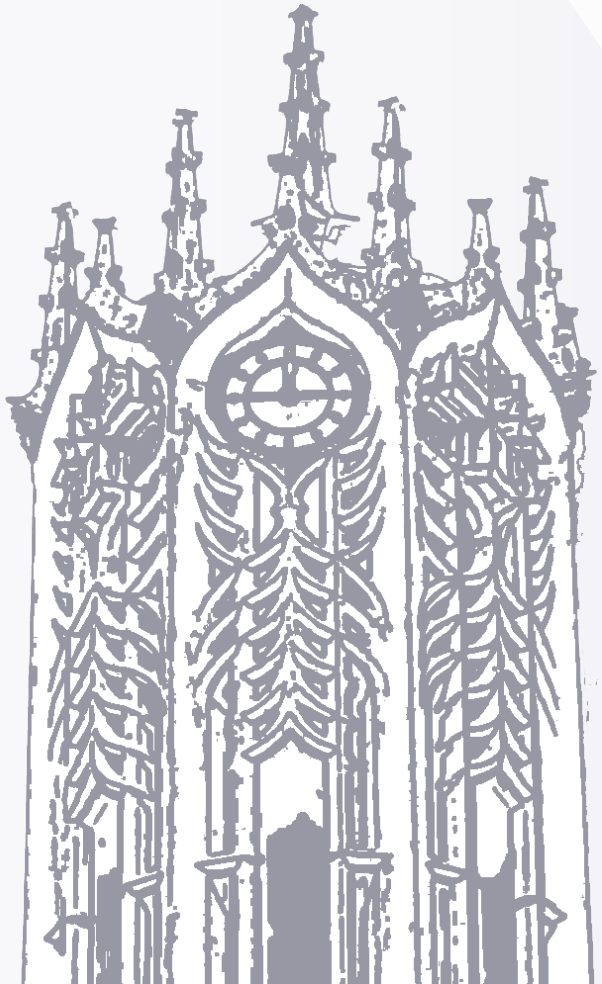
~162 pixels per mm

~6.2 µm per pixel





Modified Fourier-Transform Misalignment Analysis (FTMA) Method



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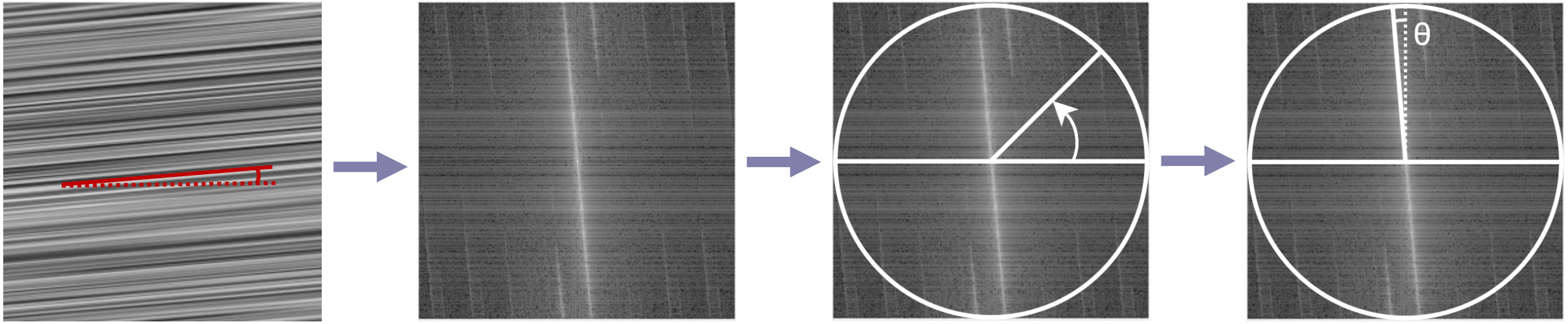
Existing FTMA Method[1]



Original Image

2D Fourier Transform

Search radii in 0.1° increments

Identified feature

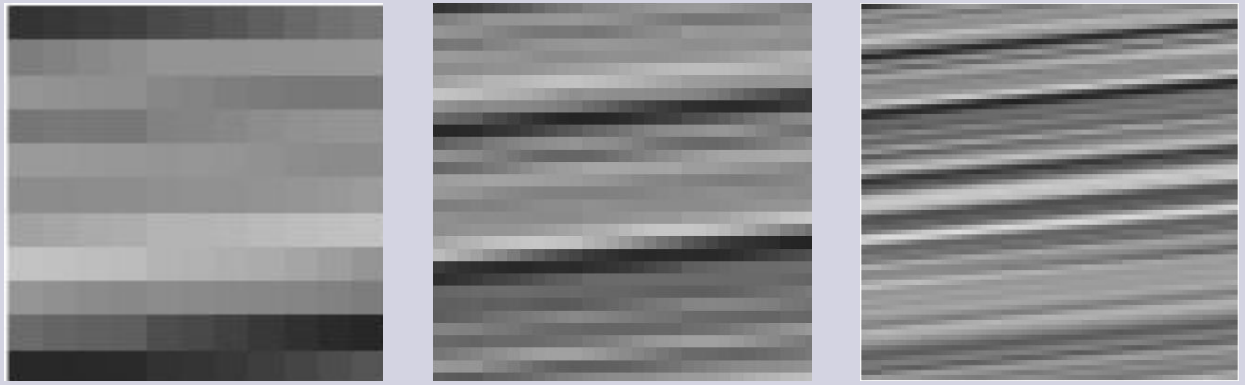
[1] K. K. Kratmann, M. P. Sutcliffe, L. T. Lilleheden, R. Pyrz, and O. T. Thomsen, "A novel image analysis procedure for measuring fibre misalignment in unidirectional fibre composites," *Composites Science and Technology*, vol. 69, no. 2, pp. 228–238, Feb. 2009,

Computer-Generated Images

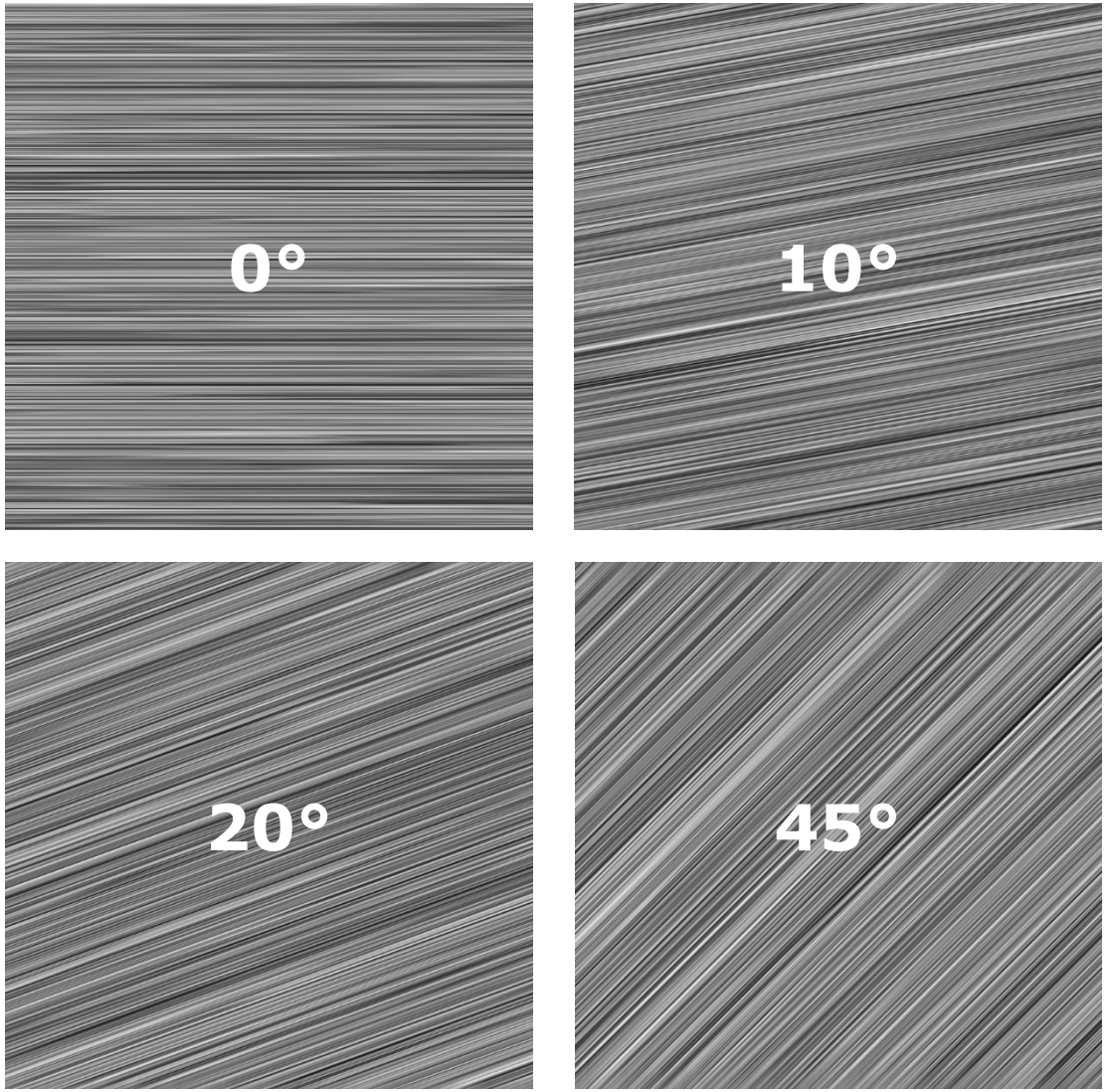
Blurred lines with randomly-generated greyscale values

Integer alignments between 0° and 45°

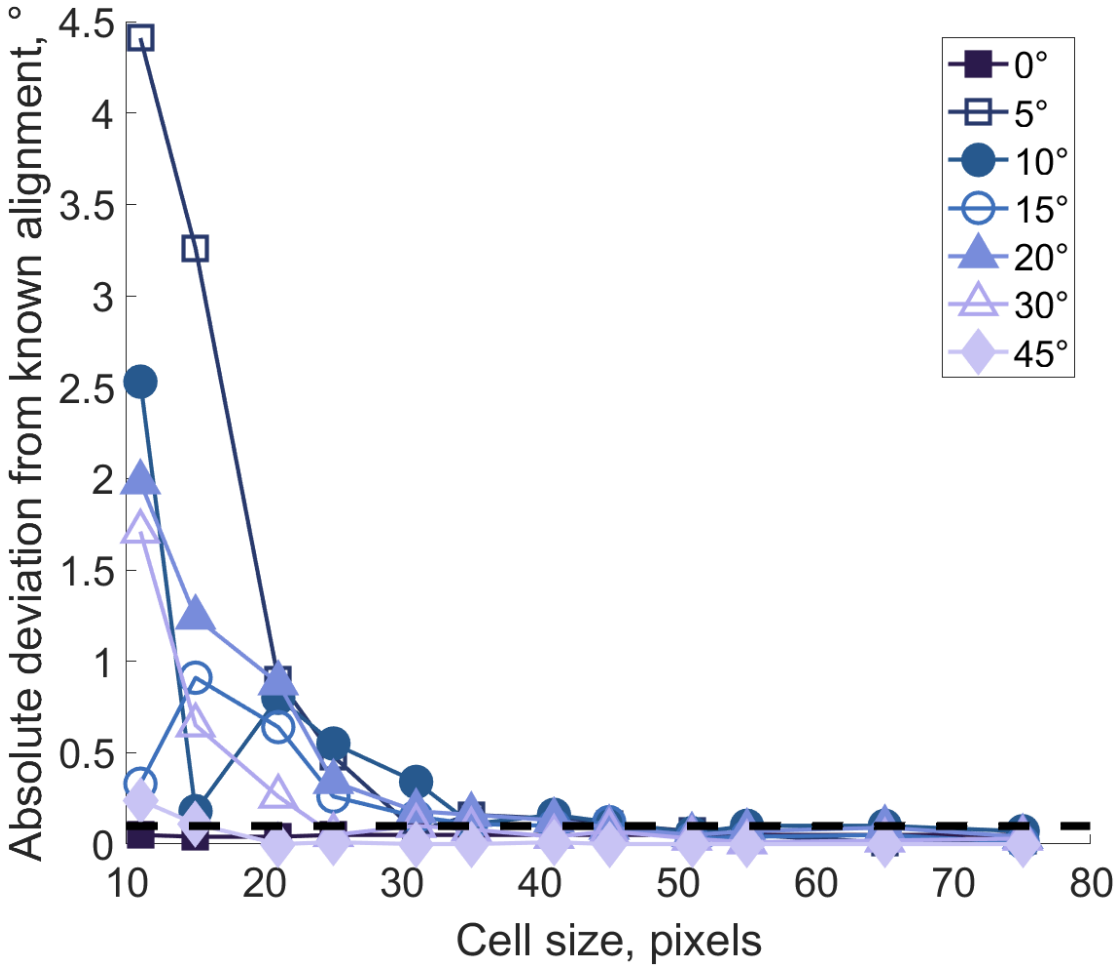
930 x 630 pixels, from which smaller ‘cells’ are extracted



11 pixels 31 pixels 75 pixels

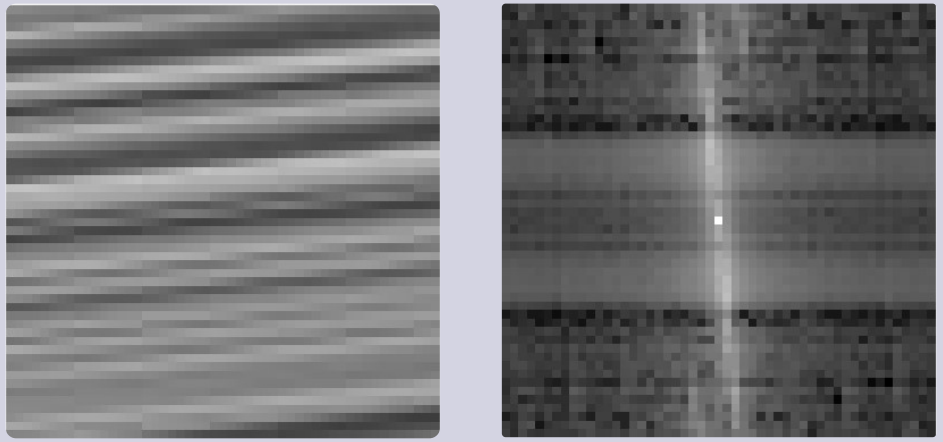


Cell Size and Windowing



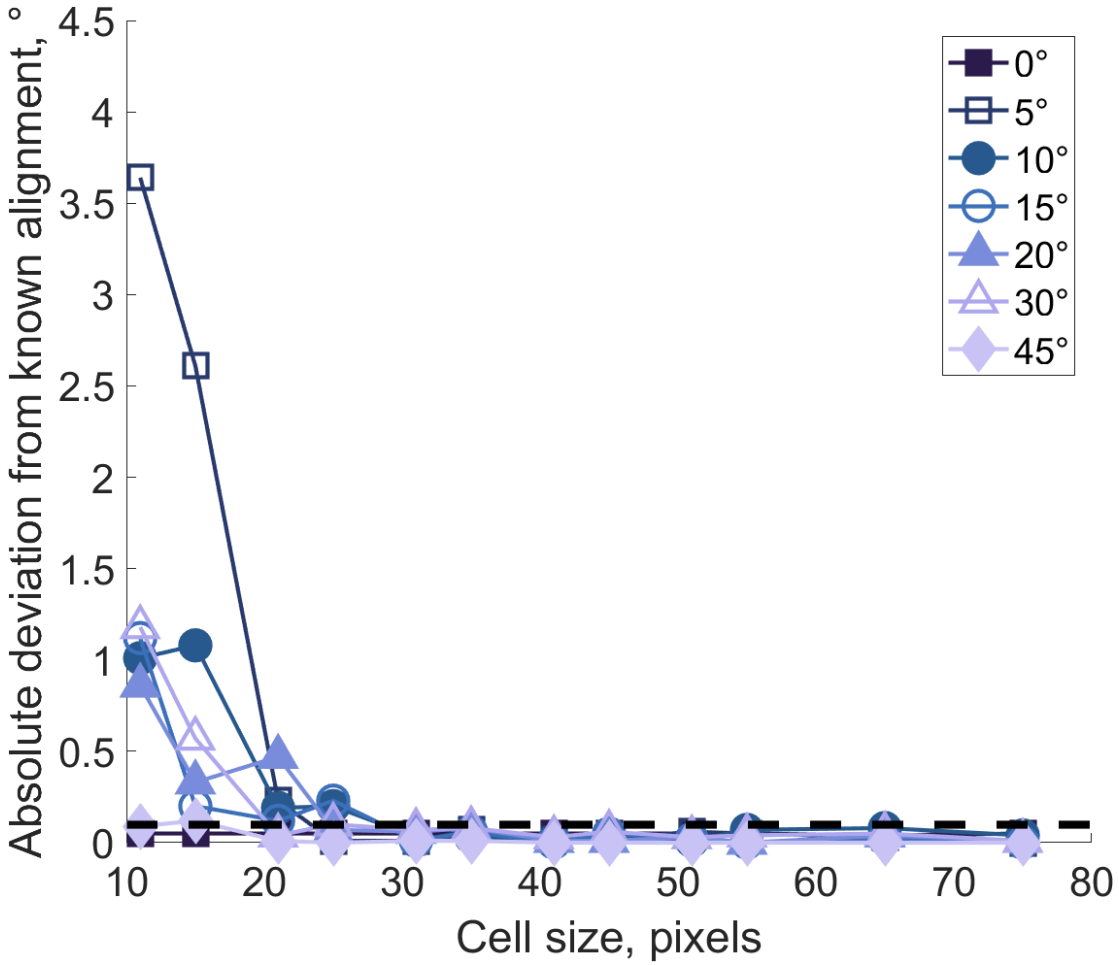
Averaged from 500 randomly-selected cells

Absolute deviation < 0.1° for cells greater than 51 pixels



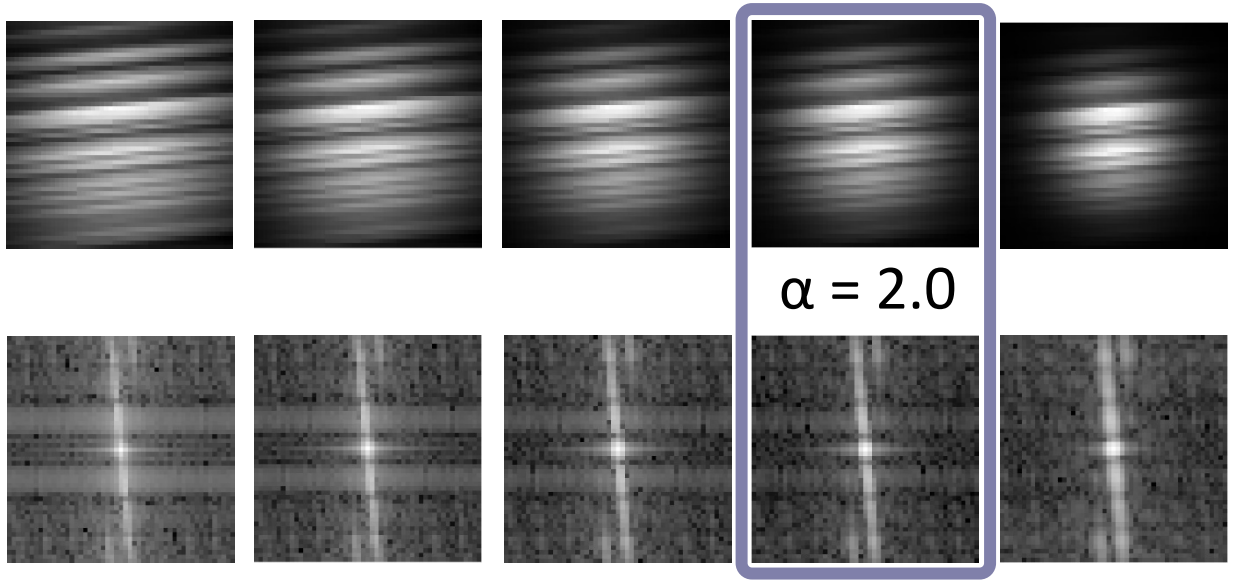
51-pixel cell

Cell Size and Windowing



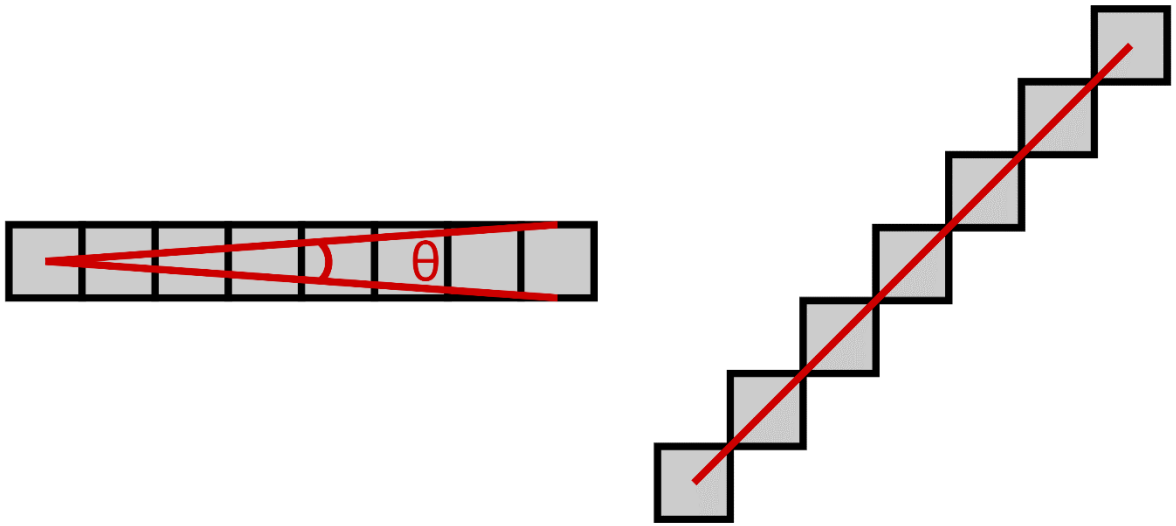
Gaussian window:

$$w(n) = exp\left[-\frac{1}{2}\left(\frac{2\alpha n}{L-1}\right)^2\right]$$



Increasing α

Alignment Dependency



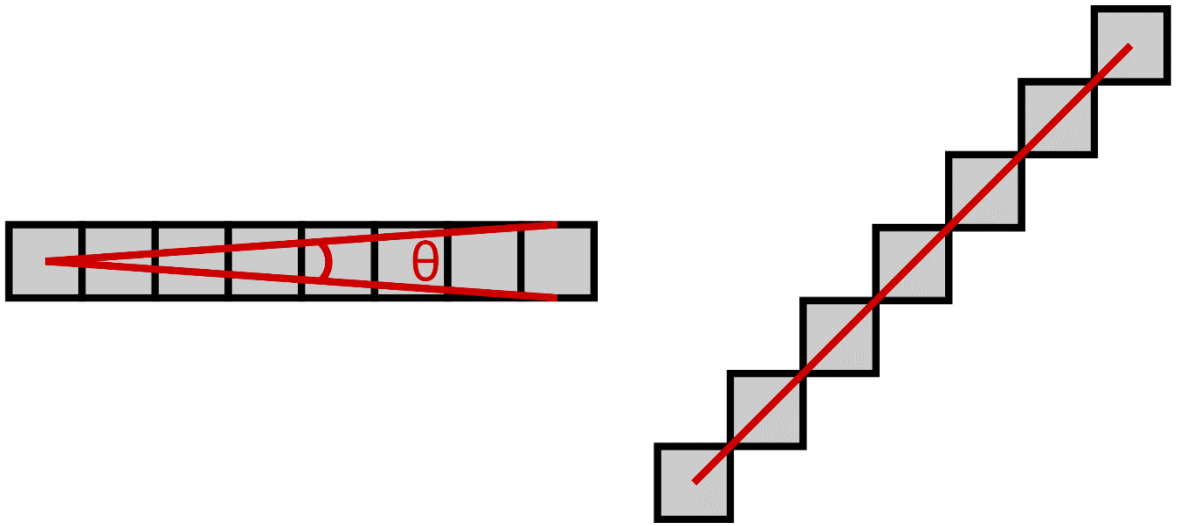
$$\theta = 2\tan^{-1}\left(\frac{1}{2r-2}\right)$$

At 0° or 90°, all radii within ±θ/2 sample the same pixels

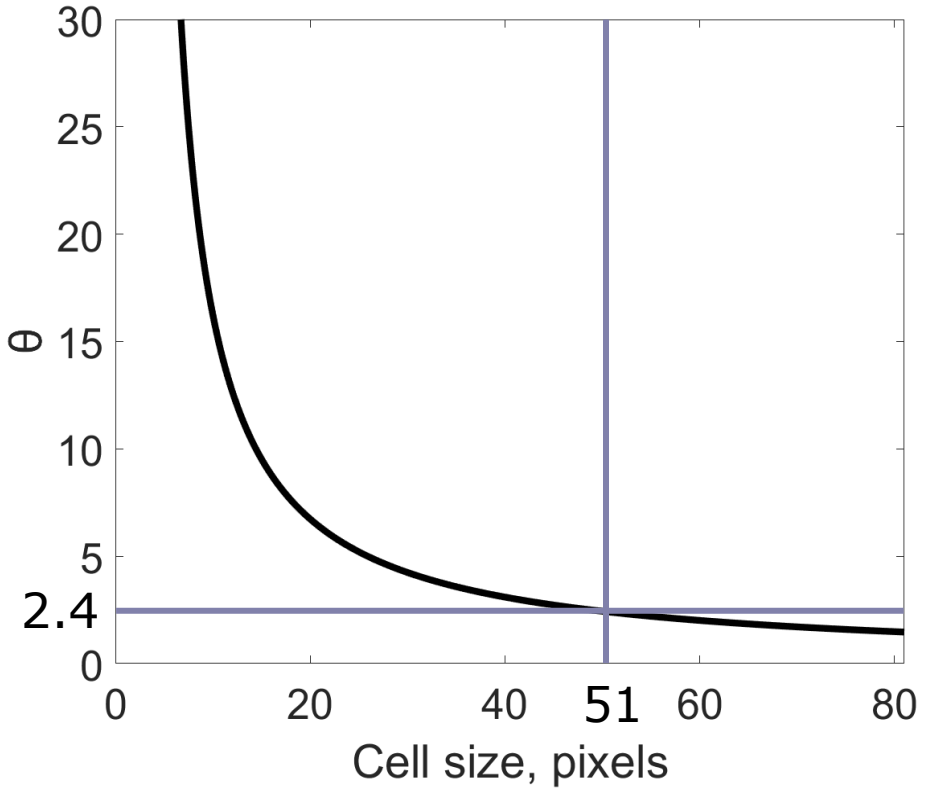
At 45°, any deviation from exactly 45° will sample new pixels

Precision depends on the alignment of features in the original cell

Alignment Dependency

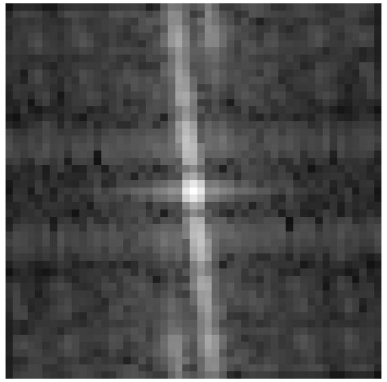
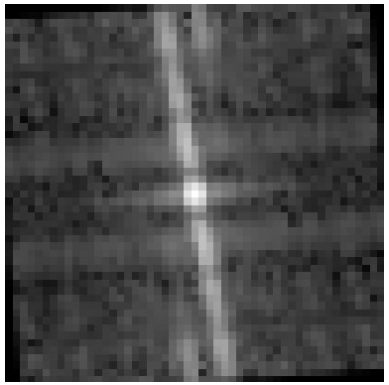
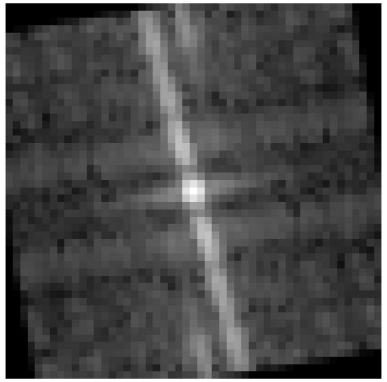
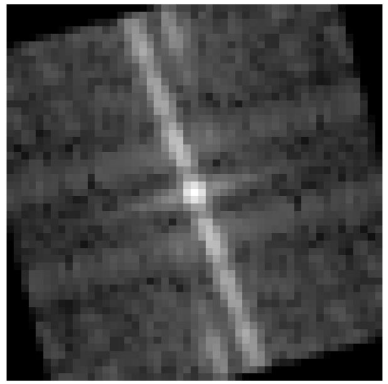
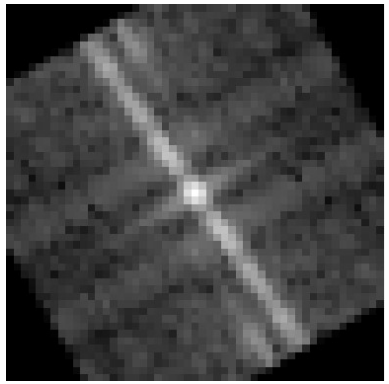
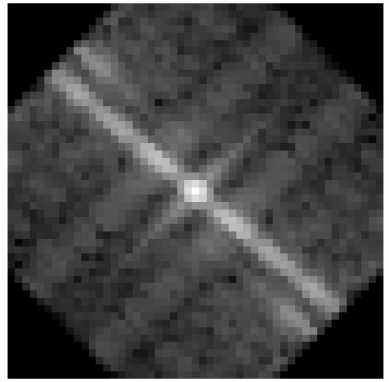


$$\theta = 2\tan^{-1}\left(\frac{1}{2r-2}\right)$$



Multi-Rotate Method

Cell Rotation
(anticlockwise)

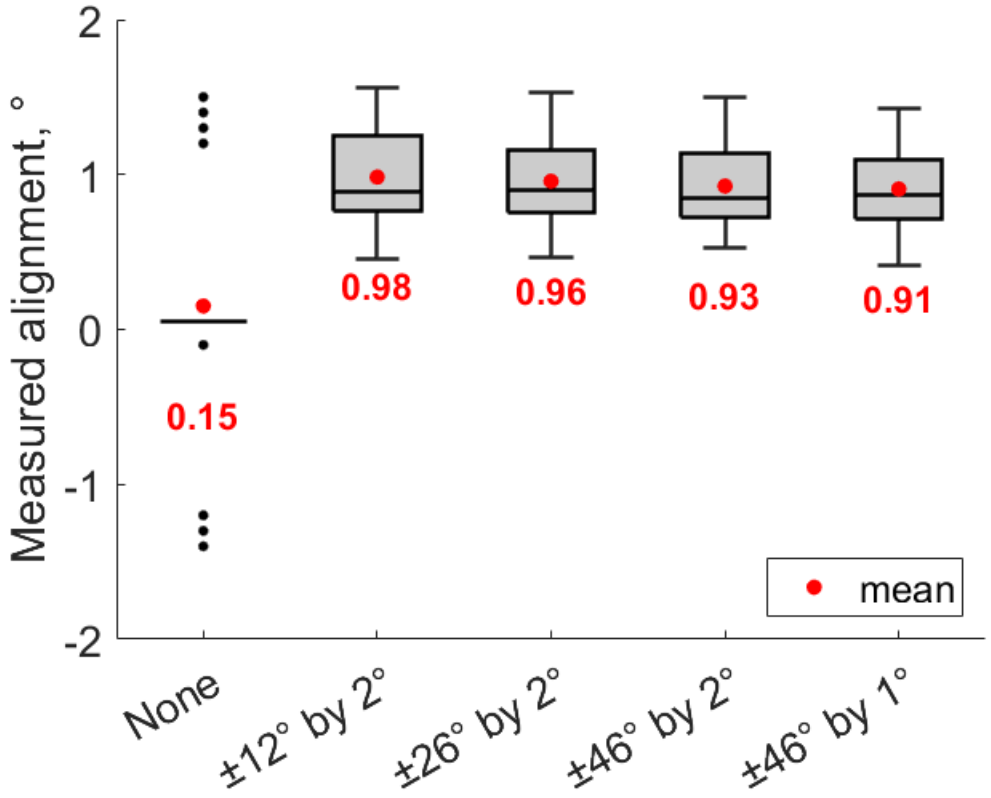
0°	5°	10°	15°	30°	45°
					
5.4°	4.9°	5.1°	5.1°	5.2°	5.1°

5.13°

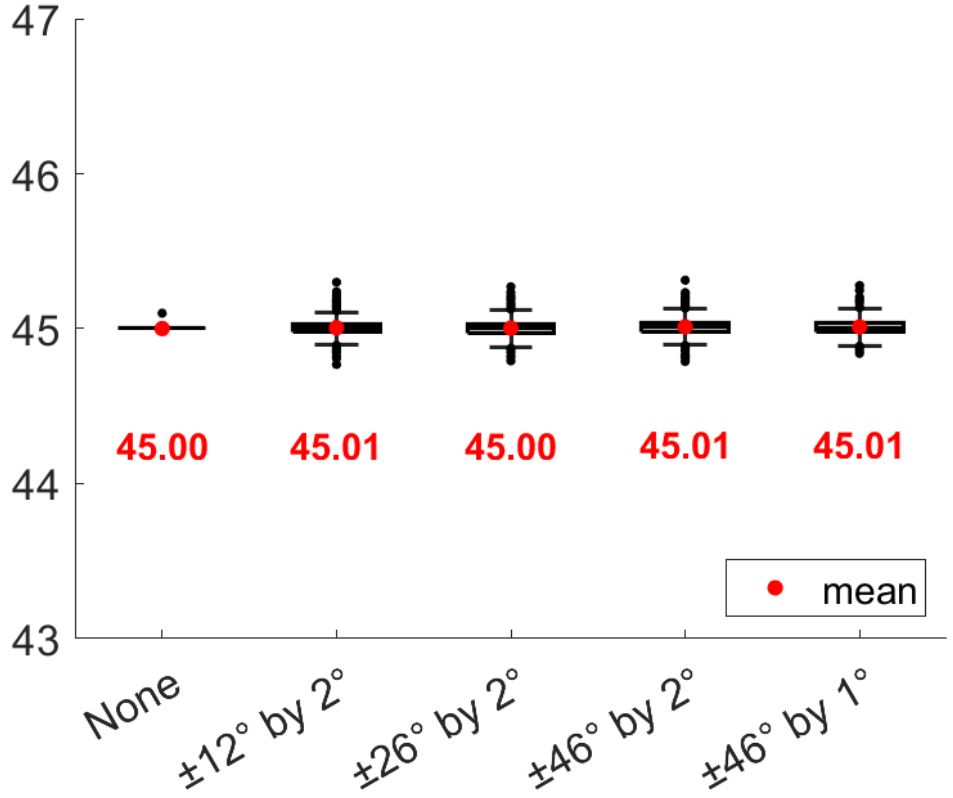
Measured Alignment
(rotation corrected)

Angle Sweep and Incrementation

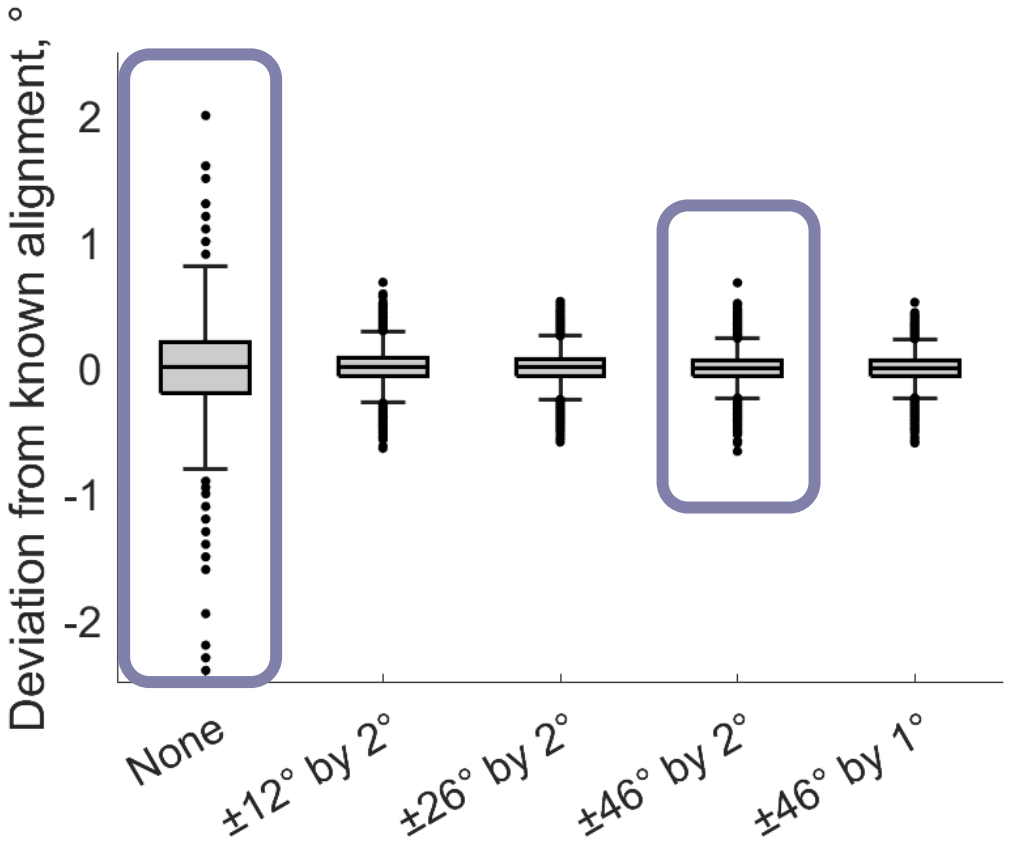
Known Alignment: 1°

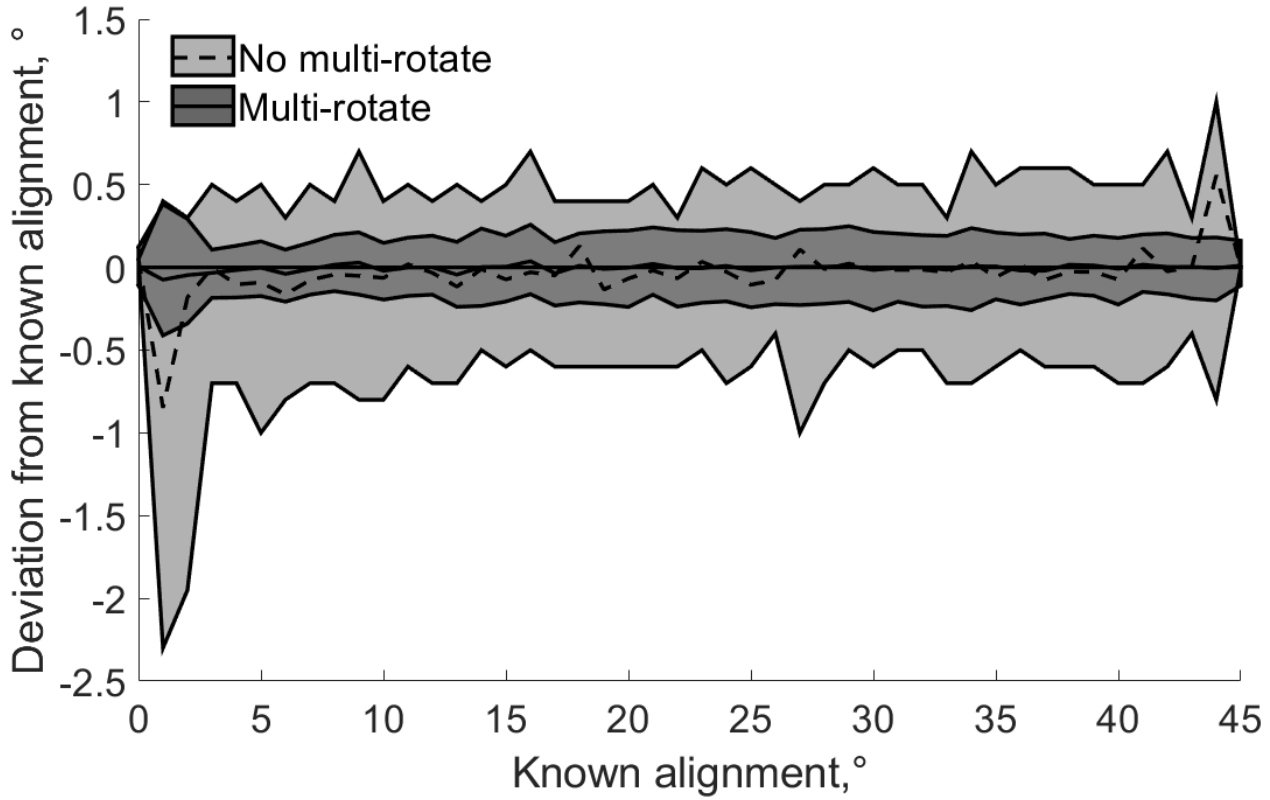


Known Alignment: 45°

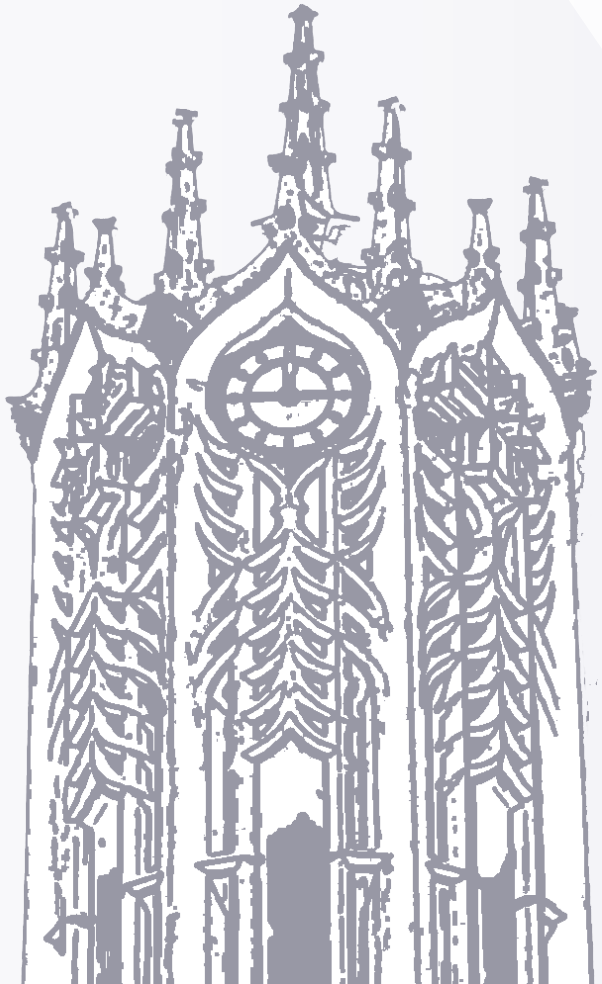


Application Across Angles 0°–45°





Application to Images of Stitched Glass Fabrics



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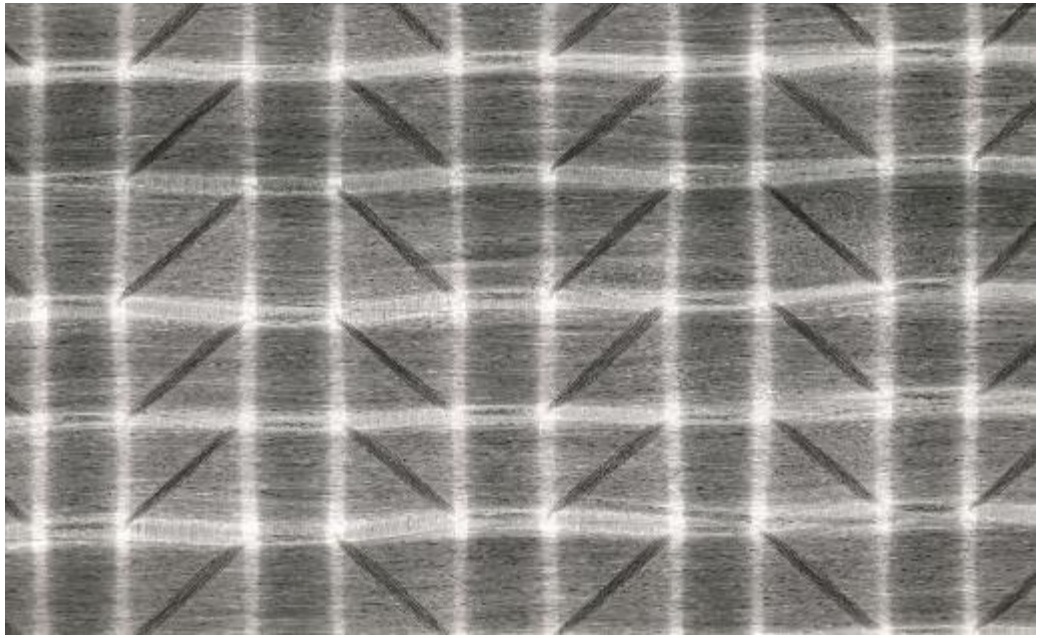
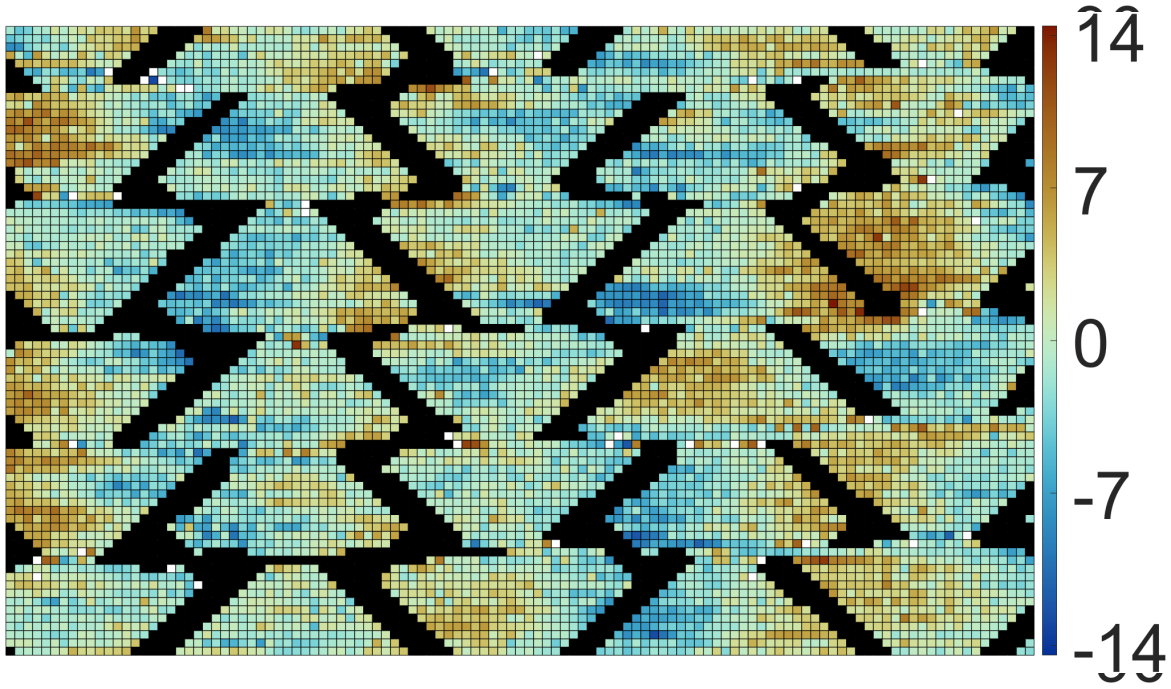
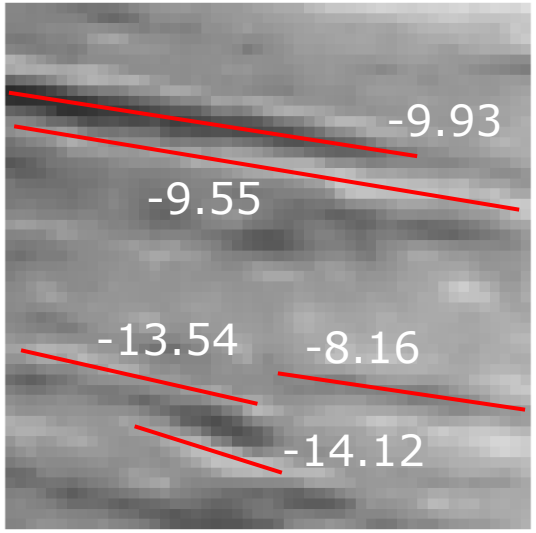
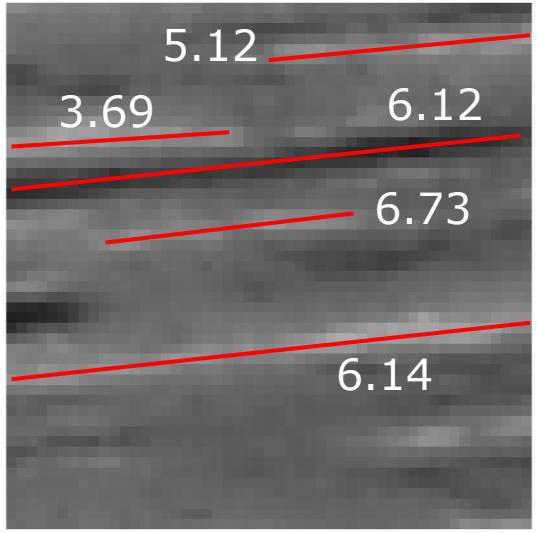
Application to Fabric Images

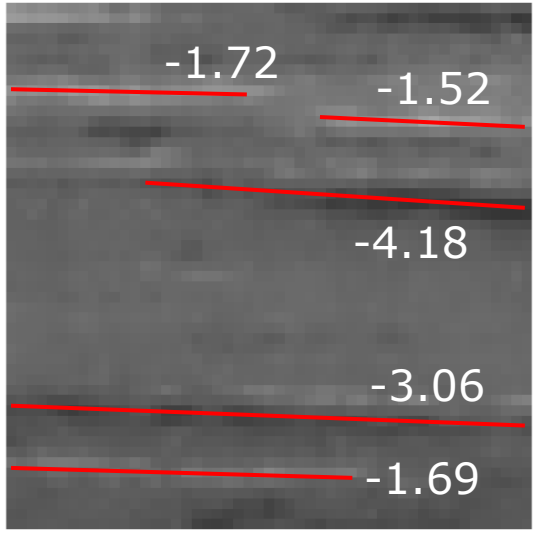


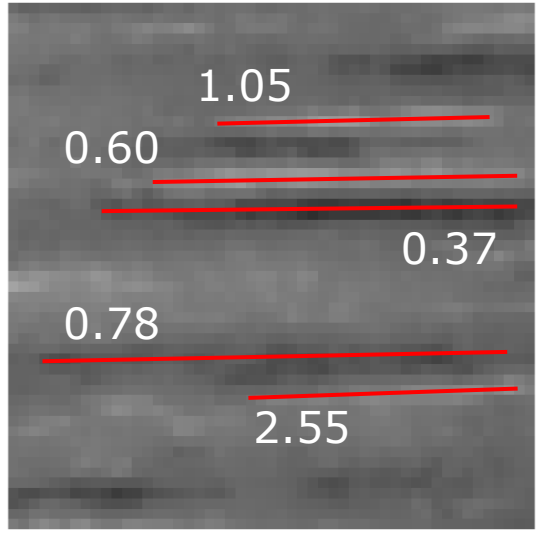


VALIDATION









FTMA	-10.97°	5.08°	-2.51°	0.78°
Manual Avg.	-11.06°	5.56°	-2.43°	1.07°
Abs. Diff.	**0.09°**	**0.48°**	**0.08°**	**0.29°**

Conclusions

The modified FTMA algorithm, with the Multi-Rotate method applied, is able to:

- Measure fibre alignment in cells with a small number of pixels
  - With an average accuracy within ±0.5 degrees, regardless of feature angle
- Measure fibre alignment in low-magnification photographs of dry stitched glass fabrics
  - With a level of accuracy that is comparable to a human
  - At sufficient spatial resolution to identify and segment out features such as stitching

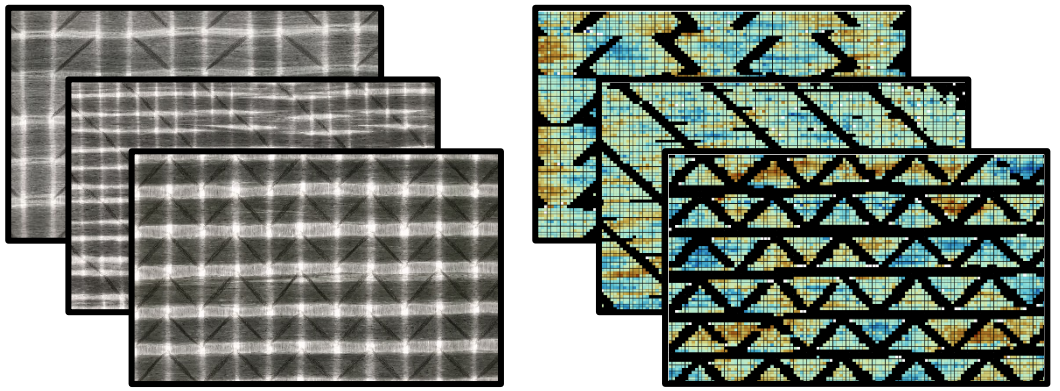
Continuing Work

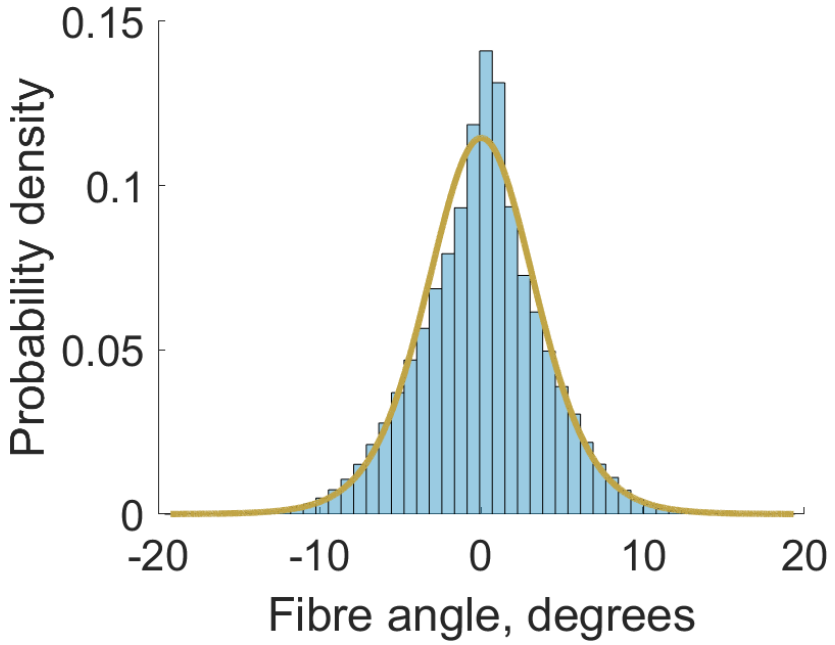
The FTMA Multi-Rotate algorithm can be applied to images from a variety of stitched glass fabrics

Very large amounts of data can be gathered very quickly

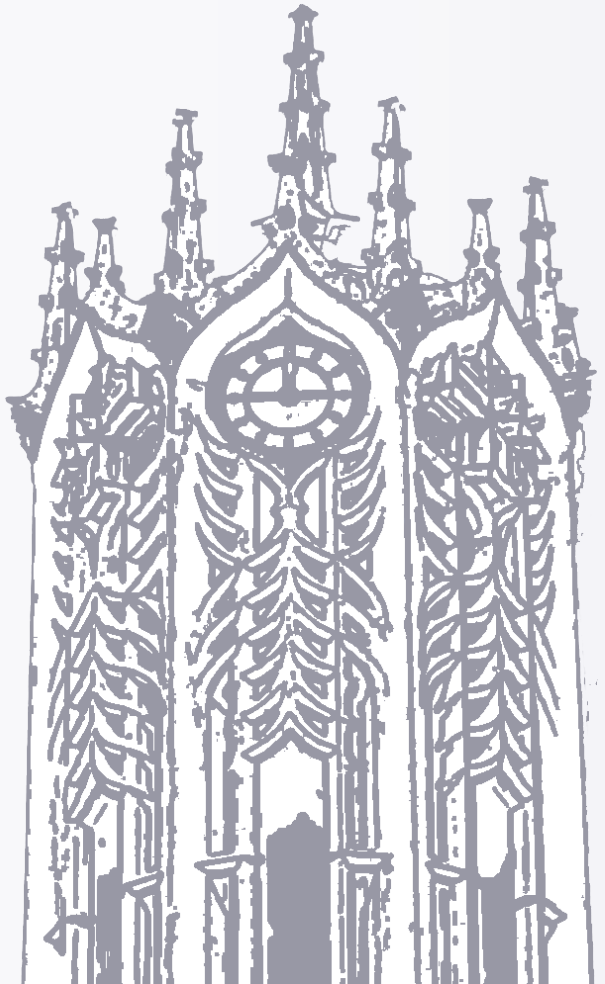
Distributions of alignment and key statistical parameters can be extracted

Comparisons can be made of average and maximum misalignment across fabric types





Thank You



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