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A Digital Micrograph Script for Detection of Astigmatism in TEM Images

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Minimization of astigmatism of the objective lens is a critical instrument alignment task essential for high resolution TEM imaging. Fast and sensitive detection of astigmatism is needed for providing real-time feedback and adjusting the stigmators to efficiently reduce astigmatism. Currently the method used by many microscopists is to visually examine the roundness of a diffractogram (Thon rings) and adjust stigmators to make the Thon rings as circular as possible. The drawbacks of this method are its limited sensitivity for small astigmatism and bias by the astigmatism of human eyes. In this paper, a Digital Micrograph script was developed to allow fast and sensitive detection of the astigmatism in TEM images for real-time feedback adjustment of objective lens stigmators.

After the Digital Micrograph software has acquired a new image, our DM script is triggered to compute the Fast Fourier Transformation (FFT) of the image to produce the 2-D power spectra (Figure 1). The Thon rings in the power spectra oscillate faster as the distance from center increases. Next, the power spectra are converted to s^2 power spectra (Figure 2) by resampling to make the radii represent the square of spatial frequency (s^2) instead of spatial frequency (s) [1]. It is noticed that the intervals between rings become obviously uniform from low to high resolution (i.e. from center to edge) after this conversion. Then, a second FFT is performed on the s^2 power spectra to obtain a single ring (Figure 3) which represents the frequency of the oscillations in s^2 power spectra. Since the radii of this ring is linearly proportional to the defocus of the image, the ring would become elliptical for astigmatic images and the ellipticity of this ring thus represents the amount of astigmatism of the image. In order to detect the roundness of the ring with higher sensitivity, the ring (Figure 3) is unwrapped (Figure 4). An elliptical ring in Figure 3 would result in a wavy curve in Figure 4, which suggests residual astigmatism in the image. Finally, the radii of the ring are calculated along different directions and plotted as function of angles (Figure 5). When the astigmatism is minimized, the plot in Figure 5 will change to a straight line.

Our approach thus converts a roundness detection to a straightness detection, which is able to significantly reduce objective lens astigmatism. This is because human eyes are more sensitive and accurate in detecting straightness of narrow lines (this new method) than roundness of diffused rings (current popular method).

Reference:

[1] Jiang W, Guo F, Liu Z, Journal of structural biology **180.2** (2012), p. 343–351.

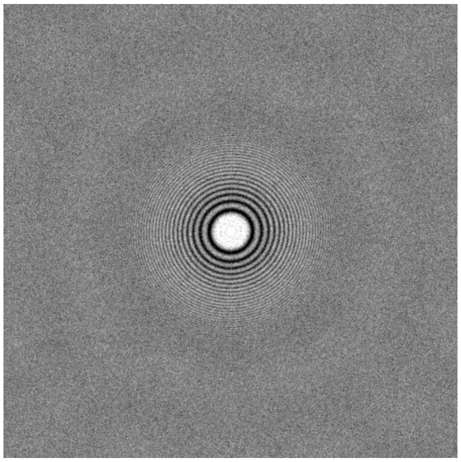

Figure 1. 2-D regular power spectra of an image.

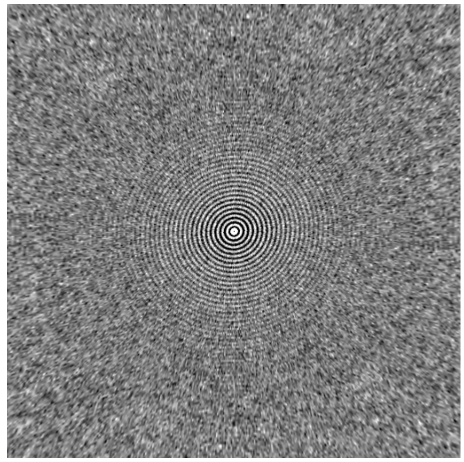

Figure 2. 2-D s^2 power spectra generated from Figure 1.

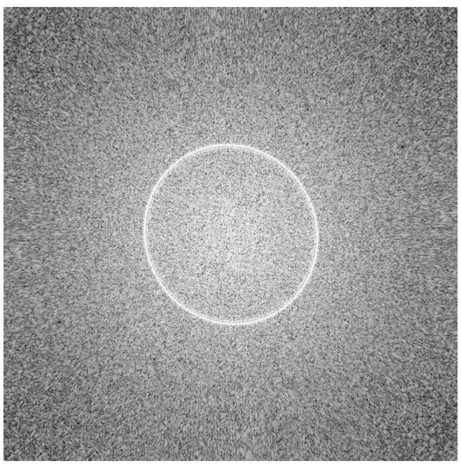

Figure 3. FFT of s^2 power spectra shown in Figure 2.

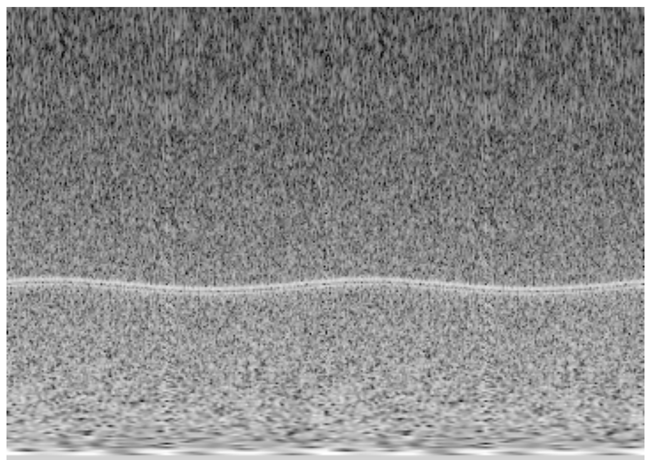

Figure 4. Transformation of Figure 3 from Cartesian to polar coordinates.

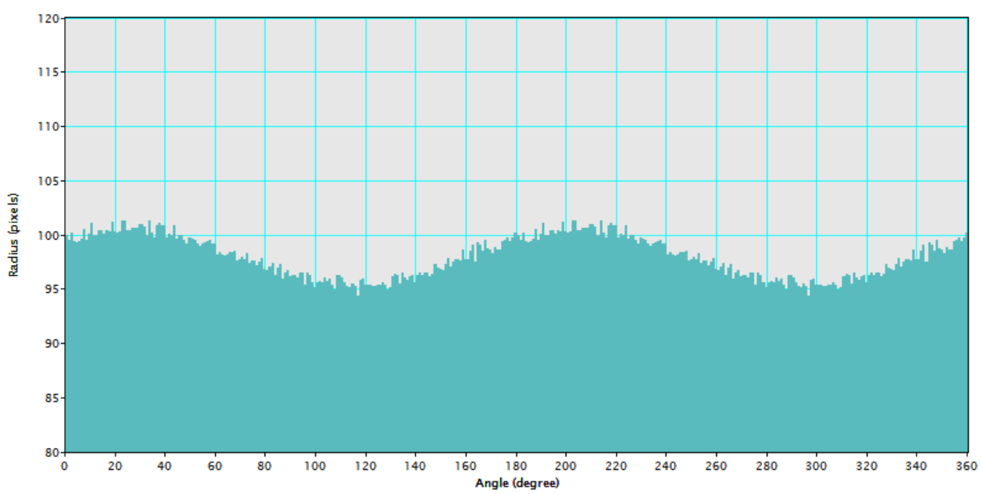

Figure 5. A plot of radii of ring in Figure 3 along different directions.

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