TOWARDS A PREDICTIVE AUTOFOCUS ALGORITHM FOR SEM

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When an electron beam enters a specimen at some point, the resulting yield of secondary electrons is directly proportional to the incident beam current [1, 2]. Using this along with the linearity of the Everhart-Thornley detector [1], it is possible to model the image formation process by

$$f(x,y) = \delta(x,y) \otimes h(x,y)$$

Here f is the observed image, δ a constant function for any specimen viewed from a fixed direction, and h a beam-dependent point spread function (PSF). It turns out that if δ is considered to be the usual secondary electron yield coefficient, then $h(x,y)$ is the current density distribution of that cross-section of the beam which samples the specimen. Note that δ here is not the impulse or sampling function.

As the focus changes, $\delta(x,y)$ remains constant but $h(x,y)$ is affected [3]. It is hypothesised that for each stigmated beam there is some function $h_n(x,y)$ such that the current density PSF $h(x,y)$ in a horizontal plane at any point along the beam can be written as

$$h(x,y) = k^2 h_n(kx, ky)$$

for some value of k. In the frequency domain this corresponds to the transfer function for an image taken at any focal length being a simple stretching or compressing of $H_n(\omega_x, \omega_y)$, where H_n is the Fourier transform of h_n. This can indeed be seen to be the case in Figure 1: each plot shows a radial cut through the modulation transfer function (MTF) associated with a different focal length. The MTF corresponding to $H_n(\omega_x, \omega_y)$ is just the function $|H_n(\omega_x, \omega_y)|$.

If two images f_1 and f_2 are taken of a specimen from the same distance but with different focal lengths, then the image formation process can be modelled by

$$f_1(x,y) = \delta(x,y) \otimes h_1(x,y)$$
$$f_2(x,y) = \delta(x,y) \otimes h_2(x,y)$$

with h_1 and h_2 the point spread functions of the beam at those respective positions where it strikes the specimen. In the frequency domain, these relations can be expressed as

$$F_1(\omega_x, \omega_y) = \Delta(\omega_x, \omega_y) H_1(\omega_x, \omega_y)$$
$$F_2(\omega_x, \omega_y) = \Delta(\omega_x, \omega_y) H_2(\omega_x, \omega_y)$$

Here the upper case functions are the 2-dimensional Fourier transforms of the corresponding spatial functions.

The ratio F_1/F_2 can be seen to be a specimen independent quantity which depends only on the PSFs used to create the two images. According to the hypothesis presented above, this ratio may be written as

$$F_1/F_2 = \frac{H_n(k_1\omega_x, k_1\omega_y)}{H_n(k_2\omega_x, k_2\omega_y)}$$

with $H_n(\omega_x, \omega_y)$ a constant for any beam configuration.

Currently work is being done into using this quantity to determine at which positions along the beam the images were taken. Having this, and knowing the beam shape, it should be possible to predict the optimal focal length.

References

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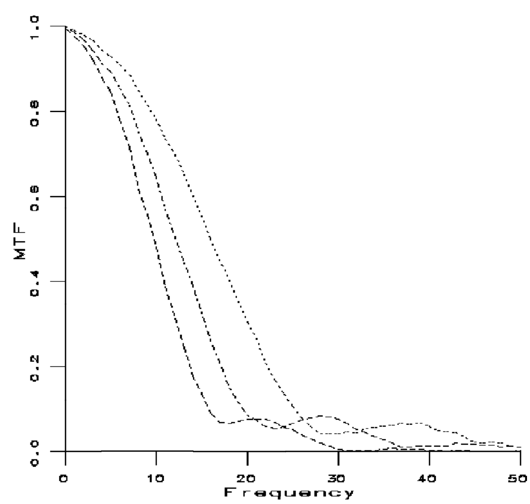

Figure 1: Radial cut through resulting MTFs for images taken of a specimen at three different focal lengths. On the frequency axis one pixel represents 31.93mm^{-1}.