A PREDICTIVE AUTOFOCUS ALGORITHM FOR SEM

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It has been shown[1] that for some purposes a valid model of the PSF of a defocused but non-astigmatic imaging system is described by the relation

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

where $h_n(x,y)$ is some system-dependent function and k a scalar quantity which depends on the amount of defocus. Essentially, this implies self-similarity of the beam profile, with defocus causing only a change in the overall width. If the Fourier transforms F_1 and F_2 of two images taken at different levels of defocus is considered, then the image formation process along with this model leads to an approximate relation

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

with $H_n(\omega_x, \omega_y)$ the transform of $h_n(x,y)$.

Given a further assumption of local linearity of k with distance from focus, the aperture-specimen distance d can be inferred from this ratio under fairly general conditions, if the proportionality constant between k and d is known. In the absence of knowledge of this constant, however, a second ratio F_2/F_3 can be used to eliminate the dependence, and provide an unambiguous estimate of d. In short, the algorithm requires three images captured at differing focal lengths, where the differences between these focal lengths are known[2].

An indication of the effectiveness of the method is demonstrated in Figure 1. The algorithm was applied to all combinations of three images chosen from a test set of seven (each corresponding to a different distance from focus). For perfect prediction, the crosses will in all cases lie on the solid line. Note that the algorithm requires only the distances between the images to be known. The actual distance from focus is obtained by extrapolating to the position that would produce an infinitely narrow PSF.

It can be seen that the method performs well for most image sets under the restriction that the distance from focus is not too large. The distribution of the images in the set also plays a part.

References

1. Nicolls, F.C., de Jager, G., and Sewell, B.T. (1994). Towards a predictive autofocus algorithm for SEM. Proc. Electron Microsc. Soc. South Afr. 24, 11.

2. Nicolls, F. (1996). The development of a predictive autofocus algorithm using a general image formation model. Master's thesis, University of Cape Town.

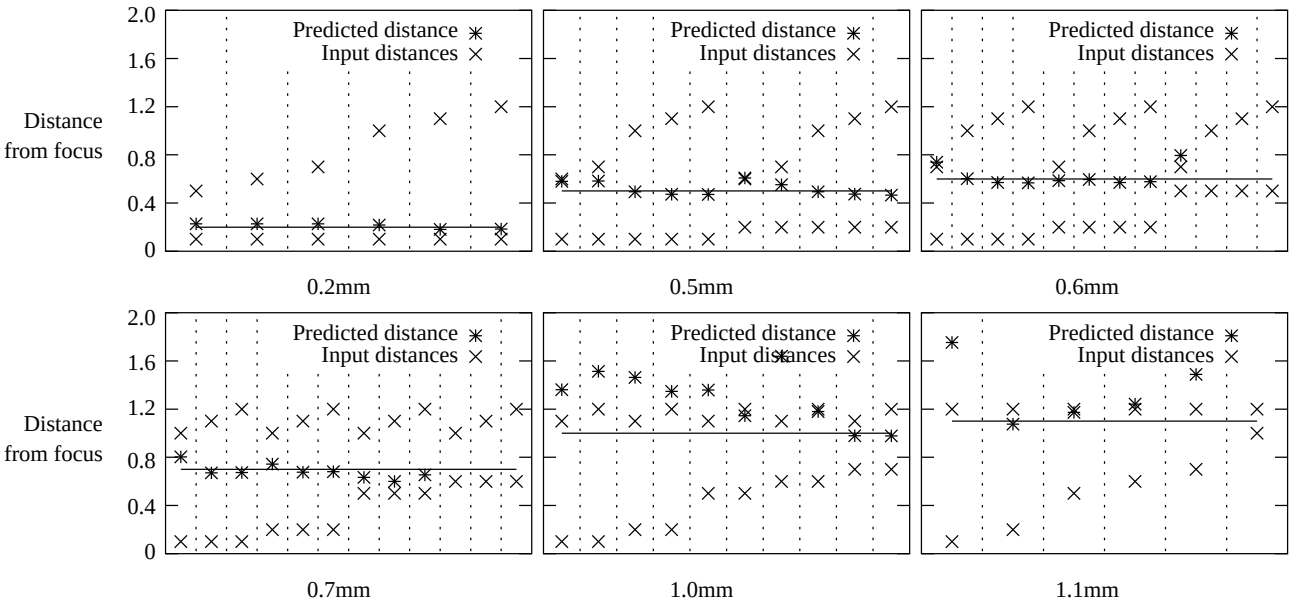

Figure 1: Each graph represents an attempt at predicting the distance from focus of an image captured at the distance indicated by the solid line. Information from two further images of the same area taken at known offsets from the original distance ($\times$) was used to predict the distance from focus ($*$) of the original image.