Using `tweak` for some simple image processing

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1 Introduction

This is the October 31, 2004 version of the manual for using the IDL program `tweak` for some simple image processing. The Wiener and deconvolution aspects of the program are described in one paper [1]. The main menu of the program is shown in Fig. 1. A typical sequence of steps in using it is as follows:

1. Read an image file in. The program is set up to read X1A scanning transmission x-ray microscope (STXM) files; however, it can also read general binary files in which case the menu in Fig. 2 pops up.

2. Win an image read in, you can adjust the display limits by viewing a histogram of image intensities as is shown in Fig. 3.

3. If the image has a general trend of brightness from one point to another, you can remove that with the **Flatten background** option of the program. You will asked to select regions through which to fit a plane (Fig. 4), and the fitted plane will then be subtracted from the image.

4. If the image has noise at specific spatial frequencies, you should probably first click on **Do edge smoothing**. This will roll the edges of the image off to a constant value with a Gaussian, so that there are not discontinuities of the image from left to right and top to bottom in the “tiled” repetition of images that is implicit in discrete Fourier transforms. You can then select **Go to Fourier space for filtering**, in which case you will see the Fourier transform of the image (Fig. 5). You can then use the **Zero (another) region** button to zero out certain regions (Fig. 4), and click on **Apply filter(s) and go back to image space**.

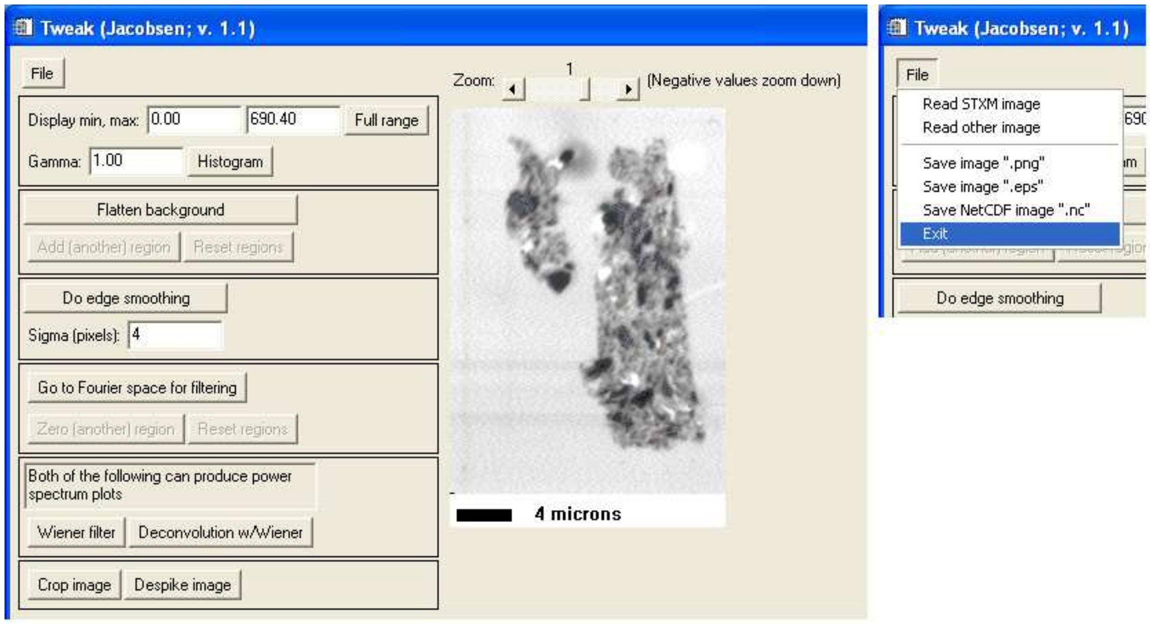

Figure 1: The main menu of the program `tweak`. The drop-down options of the **File** button are shown at right.

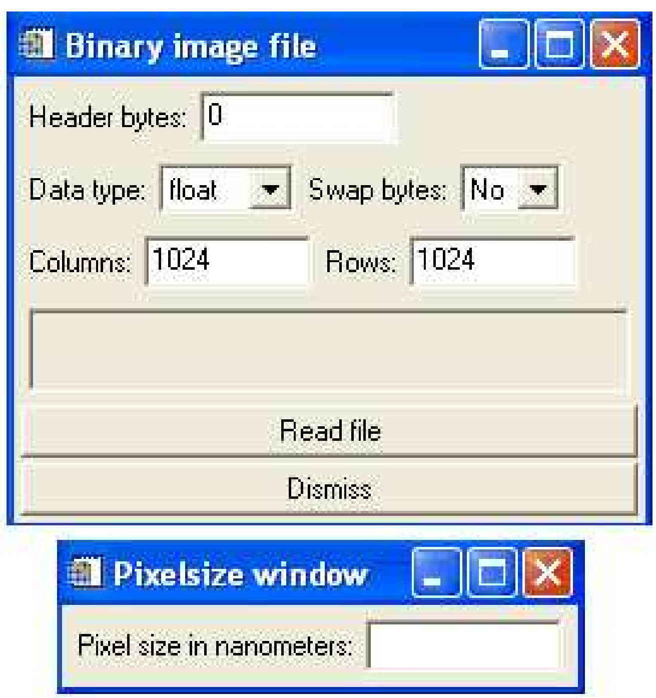

Figure 2: The pop-up menu for reading binary files. Based on the size of the file and the data type chosen, the program will attempt to guess at the file dimensions.

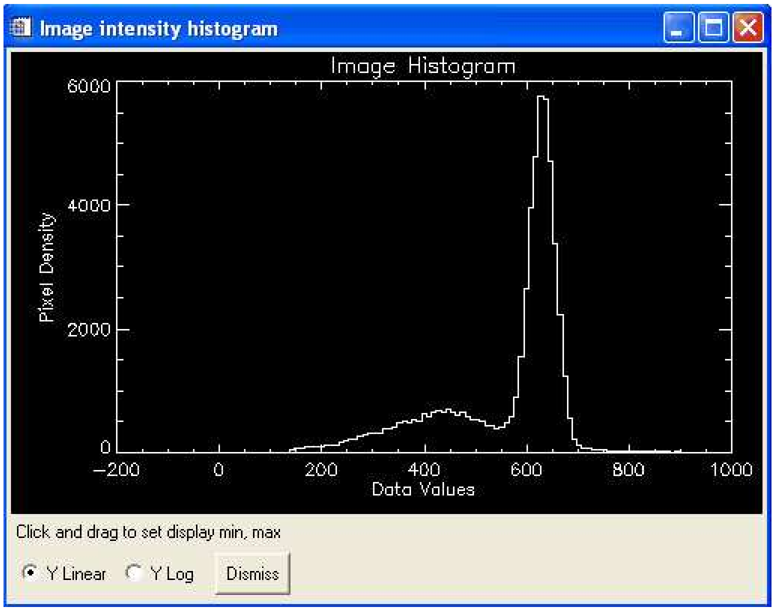

Figure 3: The image intensity histogram pop-up window. This window can be useful for altering the contrast of the displayed image.

5. Two related operations can be performed on an image in Fourier space. For both of these, it is advisable that you first select **Do edge smoothing**. One option is to apply a Wiener filter to an image; this is defined based on the spatial frequency f dependence of signal $S(f)$ and noise $N(f)$ as

$$W(f) = \frac{|S(f)|^2}{|S(f)|^2 + |N(f)|^2} \tag{1}$$

In most images, the signal tends to decline as a power of the spatial frequency f, while photon statistics sets a f-independent noise floor (since statistical variations are uncorrelated pixel-to-pixel, they are like δ functions which have a flat power spectrum). From the Wiener filter pop-up window if Fig. 6, you first select the noise floor, and then two points on the trendline of the image signal near where it reaches the noise floor. This lets you determine the Wiener filter function of Eq. 1, which is multiplied with the image in Fourier space before transforming back to object space.

6. If you have a zone plate optic that you believe performs according to its theoretical expectations, you can attempt a simple deconvolution of the optic's point spread function from the image. Since an incoherent brightfield image is a convolution of the object absorption with an intensity point spread function

$$\text{image} = \text{object} * \text{psf}, \tag{2}$$

the object can be estimated from the inverse Fourier transform of the ratio of the image transform (IMAGE) and point spread function transform (PSF) according to

$$\text{object} = \mathcal{F}^{-1}\left\{\frac{\text{IMAGE}}{|\text{PSF}|}\right\} = \mathcal{F}^{-1}\left\{\frac{\text{STXM}}{\text{MTF}}\right\} \tag{3}$$

where the modulation transfer function MTF is the absolute value of the transform of the intensity point spread function. The problem with Eq. 3 is that the modulation transfer function MTF ap-

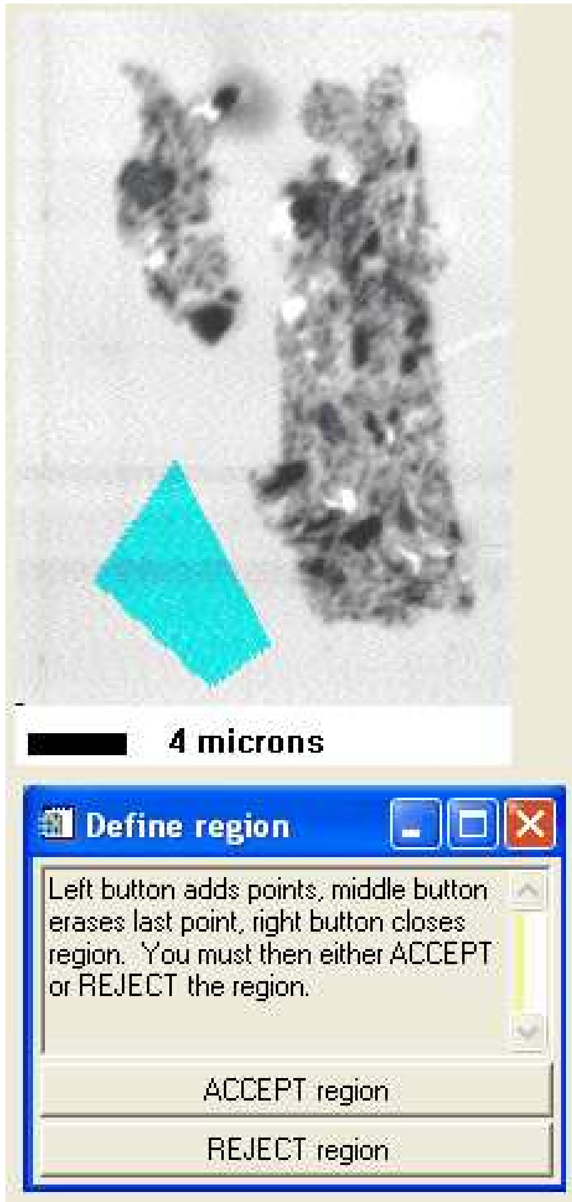

Figure 4: Defining regions in `tweak`. Further information is provided in the documentation of the IDL `defroi` function.

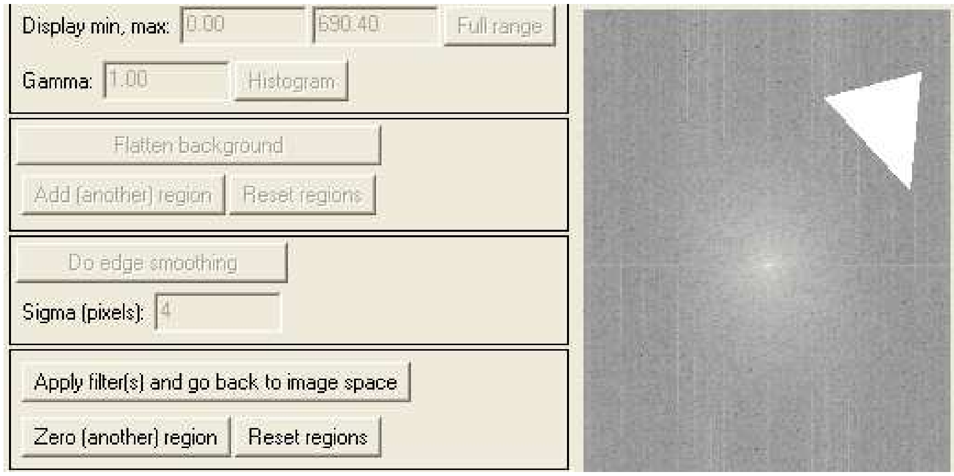

Figure 5: Fourier filtering an image. Regions of interest are selected to be zeroed in Fourier space before returing to real space.

proaches values near zero near its cutoff, which would make division problematic. Our solution is to incorporate a Wiener filter function, and a minimum value of the MTF, into a deconvolution filter function D of

$$D = \frac{W(f)}{\max[\mathrm{MTF}, \mathrm{MTF}_{\mathrm{min}}]}. \tag{4}$$

With this function, one can then estimate the object with

$$\text{object} = \mathcal{F}^{-1}\left\{\mathrm{STXM} \cdot D\right\}. \tag{5}$$

Because this deconvolution requires a Wiener filter, one should select either the **Wiener filter** button or the **Deconvolution w/Wiener** button but not both. An example of using the **Deconvolution w/Wiener** button is shown in Fig. 7.

7. After image modification, one can save the result in varous file times by using the options under the **File** button as shown in Fig. 1.

References

[1] C. Jacobsen, S. Williams, E. Anderson, M.T. Browne, C. J. Buckley, D. Kern, J. Kirz, M. Rivers, and X. Zhang. Diffraction-limited imaging in a scanning transmission x-ray microscope. *Optics Communications*, 86:351–364, 1991.

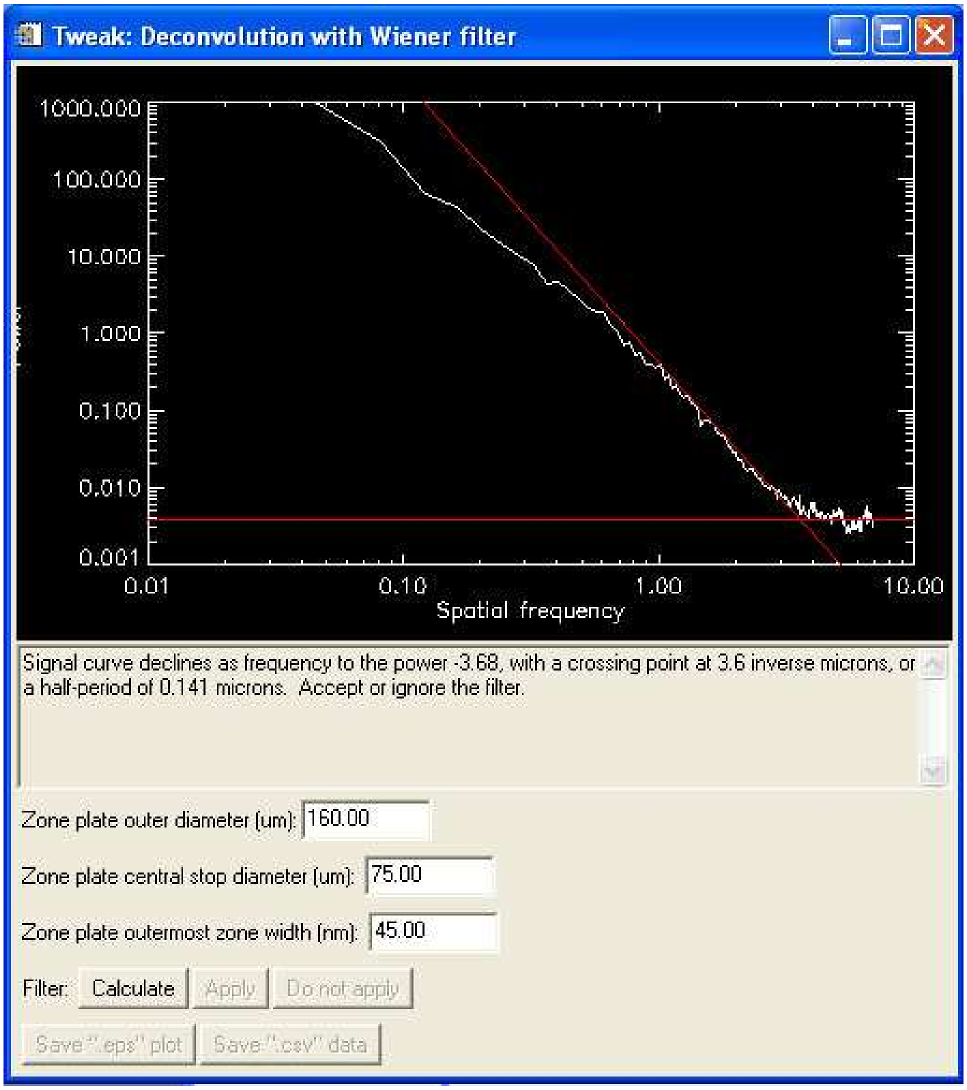

Figure 6: Wiener filtering from an estimate of the power spectrum of the image's signal (typically a declining function on a log-log graph) and the image's noise (typically a frequency-independent term).

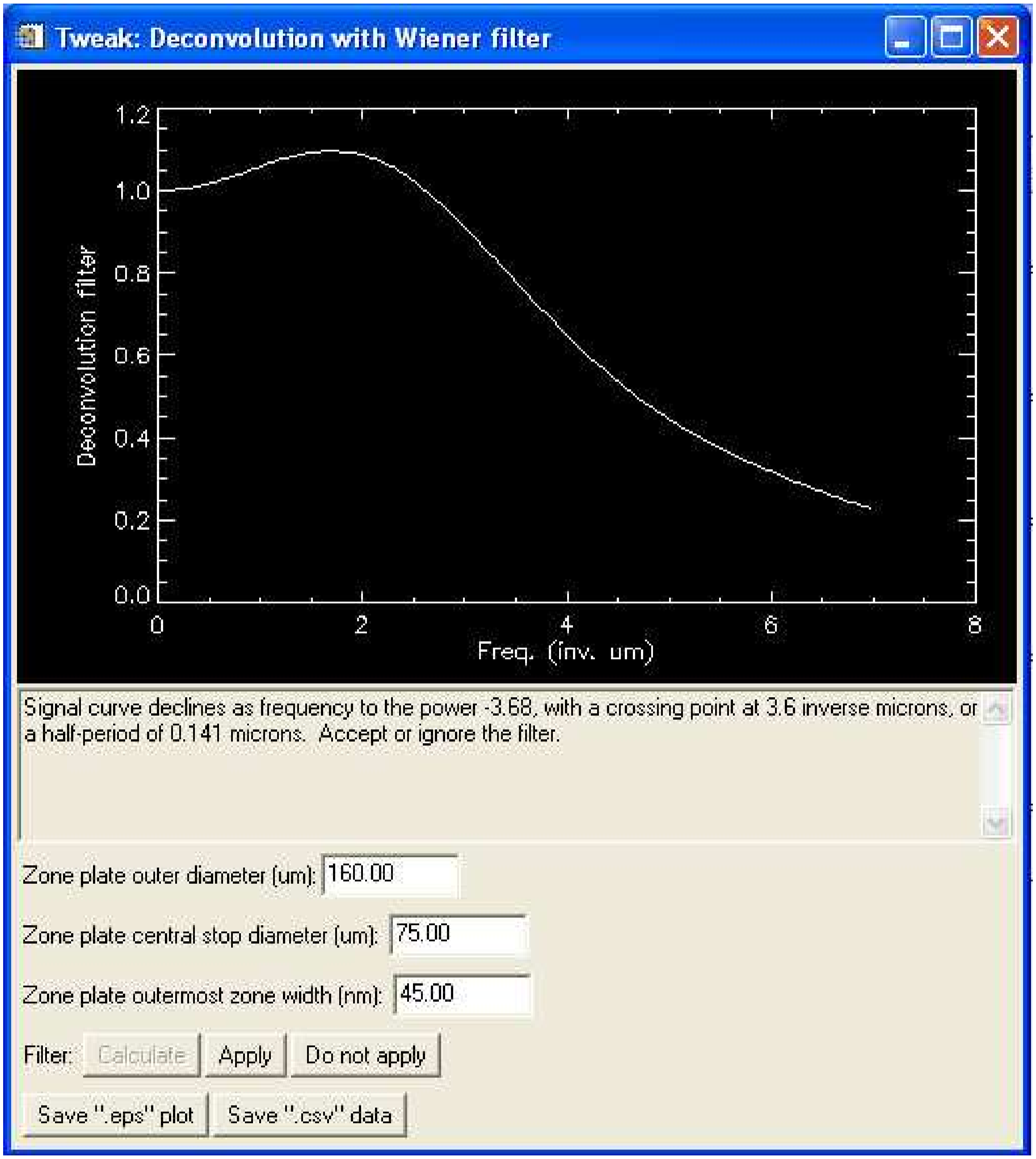

Figure 7: Image deconvolution, based on the assumption that the zone plate optic peforms according to theory. The deconvolution filter D (Eq. 4) incorporates both the transform of the intensity point spread function (the MTF), as well as a Wiener filter.