Simultaneous De-Noising in Phase Contrast Tomography

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De-noising of images is a large field which recently attracted a lot of attention in conventional computed tomography. In particular edge-preserving de-noising algorithms provide a powerful alternative to the traditional noise reduction method of apodizing the filter kernel, resulting in a global smoothing of the image.

Here, we adapt the bilateral filtering [1] to the situation of phase contrast imaging using gratings, where up to three independent images acquired in exactly the same geometry are available. In conventional bilateral filtering, the image is filtered by calculating weighted local averages of neighboring pixels using in addition to a distance dependent weight also weights of the form $w = \exp(-\Delta^2/2\sigma^2)$, where Δ is the difference of the two pixel values and σ^2 is an estimate of the noise variance in the image. These weights ensure that no smoothing is performed across edges, if the contrast of the edge is larger than σ. In the proposed method, each image is smoothed individually using weights depending on the contrast in all images. Specifically, weights of the form $w = \exp\left(-\Delta_a^2/2\sigma_a^2 - \Delta_p^2/2\sigma_p^2\right)$ are used where the subscripts a and p refer to the absorption and phase contrast image, respectively (optionally, the de-coherence image can be used in addition). These weights ensure that no smoothing is performed across edges if the contrast is larger than the noise level in at least one of the two images. Thus, edges in the image are preserved even if the contrast of the edge is well below the noise level in the image as soon as the contrast is above the noise level in the other image. Since the contrast of objects can differ greatly in the different images [2], there is a mutual benefit for the quality of the de-noising result of all images.

The method is evaluated using simulations. Results obtained by the proposed de-noising technique are compared to results obtained by iterative reconstruction with edge preserving regularization. Both methods can improve the signal to noise ratio substantially, where the proposed method is orders of magnitude faster.

[1] C. Kervrann and J. Boulanger, *IEEE Trans. Imag. Proc.*, **15** (2006), 2866

[2] J. Herzen et al., *Optics Express* **17**, (2009), 10010.