Introduction
Super-resolution describes a method estimating a single high-resolution image from several slightly shifted low-resolution images. Using hybrid pixel detectors together with a micro-focus X-ray source allows to significantly reduce the required post-processing of high-resolution images. Since such detectors are almost noise-free and the magnified X-ray spot is smaller than a single pixel, the point spread function (PSF) of the imaging system can be neglected. Thus, the resulting images typically do not require further processing [1]. Therefore, this approach is interesting for imaging with pixel detectors, since such detectors have a limited amount of pixels at high cost.

Interpolation methods
Comparing interpolation methods shows that spline provides the best edge quality and the highest signal to noise ratio. Moreover, cubic and makima interpolation perform slightly worse on edge quality, but provide higher contrast to noise ratios.

Upscaling factor and amount of images
Using 4x4 images shows that upscaling factors between 2-4 provide the best results in terms of sharp features. The SNR is almost unaffected by the upscaling factor, while the SNR increases, except when using nearest neighbour interpolation.

Image translation
Examining 4x4 images with 4-times interpolation, best visual results have been achieved with a total image translation of 3 pixels. However, the highest CNR can be achieved with a translation of 4 pixels, i.e. a shift of 1 pixel in (x,y) between the images.

Conclusions
Our experiments have shown that hybrid pixel detectors are a viable choice for super-resolution imaging. The optimal interpolation methods depends on the kind of image. However, the best compromise seems to be spline, while cubic and makima interpolation provide higher CNRs, but perform worse on sharp edges.

Method
Our setup consists of a prototype solid anode Excillum micro-focus source and a Pilatus 100K detector. The source has the intrinsic capability to accurately position the e-beam, which makes it possible to precisely move the X-ray spot. To achieve super-resolution, the X-ray spot is moved in a NxN grid pattern and one image is taken per position. Further, the total translation of the sample on the detector is set by calculating the grid spacing based on the geometry of the imaging setup [1]. A high-resolution image is estimated by registering the translation between the low-resolution images [2] and interpolating them onto a finer high-resolution grid [3]. Finally, the resulting high-resolution images are then averaged to create a super-resolution image [4].

Here we investigate the effect on the resulting image using different interpolation methods, upscaling factors, number of low-resolution images, and sample translation on the detector. Further, we demonstrate that this technique can be applied to tomography as well.

Image quality is assessed via the signal to noise ratio (SNR), contrast to noise ratio (CNR), and the modulation transfer function (MTF).

Super-Resolution images

Super-Resolution tomography

References

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