doi:10.1017/S1431927618002982
Microsc. Microanal. 24 (Suppl 1), 2018

High-speed Fly-Scan Volumetric Imaging

Doğa Gürsoy[1,2]

[1.] Advanced Photon Source, Argonne National Laboratory, Lemont, USA.
[2.] Department of Electrical Engineering & Computer Science, Northwestern University, Evanston, USA.

Fly-scan, i.e. acquiring data while motors are moving, has been shown to improve scanning speeds dramatically both for full-field and scanning-probe X-ray microscopy systems. Although scanning can be continuous, current tomographic reconstruction methods assumes that the data are taken at discrete time intervals. This yields motion-blur artifacts in reconstructed images, if the exposure times are longer, or if the probe is moving faster, than the highest setting of the detector read-out times. For object recovery in this high-speed imaging setting, long exposure durations can be represented by multiplexing of a series of short exposure photon detection processes. To this end, the existing iterative reconstruction methods were modified to incorporate multiplexed probe geometries, and simulation tests were performed to evaluate the feasibility of object recovery in the case of high-speed rotational fly-scanning scheme.

Differences between translational and rotational fly-scanning schemes are depicted in Fig. 1. In the conventional translational-scanning, data is acquired while continuously moving the probe for a series of fixed rotation angles. In rotational-scanning, the object is continuously rotated for each translation position. Rotational scanning was recently proposed as a way to reduce scanning times [1] and as a way to alleviate the overlapping probe constraints in 3D ptychography [2].

A simulation was carried out to test the feasibility of the proposed method. The Lena image was rotated multiple times for each translation point. 30 data points were acquired for each full rotation, corresponding to a rotational sweep of 12 degrees, and 6 rotations were performed that yields 180 data points for each translation point (i.e., the camera is exposed to photons between intervals of 0-12, 12-24, …, 1-13, 13-25, … degrees for each translation point). Algebraic Reconstruction Technique (ART) algorithm available in TomoPy [2] was modified for this new multiplexed scanning geometry. Fig. 2 presents the reconstructions of Lena with and without blur-correction (multiplexed-probe ART) together with the absolute error images. Because the angular distance traveled by the probe is higher with increasing distances from the rotation center, motion-blur artifacts become prominent at points away from the rotation center when the rotational sweep is not taken into consideration. On the other hand, multiplexed-probe ART yielded satisfactory reconstructions, suggesting the potential of the proposed reconstruction approach.

The proposed scanning method can be used as a new approach to overcome some the limitations of the conventional interlaced-scanning approach [4]. In interlaced-scanning, in fact, the exposure time for each datum must be small enough (given by the Crowther criterion) not to blur the data (e.g., angle ranges when shutter is open are 0-1, 12-13, …, 1-2, 13-14, …). This can be realized with a control mechanism, like a fast shutter, to select exposure times of the camera only at specific angle ranges. However, photons at intermediate angles are lost, and because the exposure times are short, the data is usually noisy. With the proposed approach, the shutter is always open, and data can be read-out continuously (e.g., angle ranges when shutter is open are 0-12, 12-24, …, 1-13, 13-25, …), thus yielding better photon statistics, owing to the longer exposure times. Fig. 2 presents a comparison of these two approaches for recovery of a noisy Lena image. The proposed scanning method provides an improved signal-to-noise ratio and suggests a new and generalized way of interlaced-scanning [5].

References:

[1] M De Jonge *et al*, Optics Express **25**, (2017), p. 23446.
[2] D Gursoy, Optics Letters **42**, (2017), p. 3169-3172.
[3] D Gursoy, F De Carlo, X Xiao and C Jacobsen, J. Synchrotron Rad. **21**, (2014), p. 1188-1193.
[4] A Mohan *et al*, IEEE T. Comp. Imag. **1**, (2015), p. 96-111.
[5] This work is supported by the U.S. Department of Energy under Contract No. DE-AC02-06CH11357.

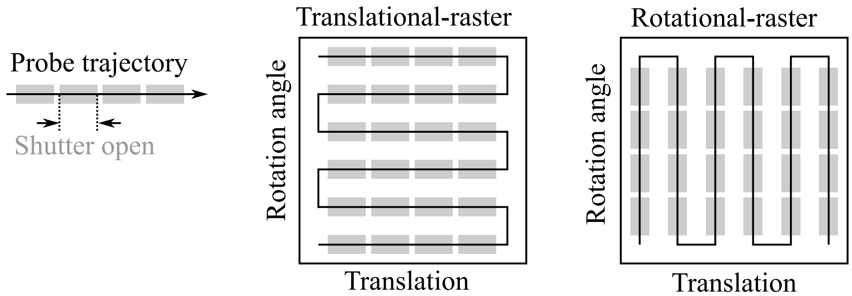

Figure 1. Fly-scan probe trajectories and registered exposure times are demonstrated for two different scanning schemes. In traditional translational-raster-scanning data is acquired while translating the probe for a series of fixed rotation angles, whereas, in rotational-raster scanning, the data is acquired during rotation for a fixed translation position. High-speed scanning introduces motion-blur in data because of the longer exposure times needed for data collection.

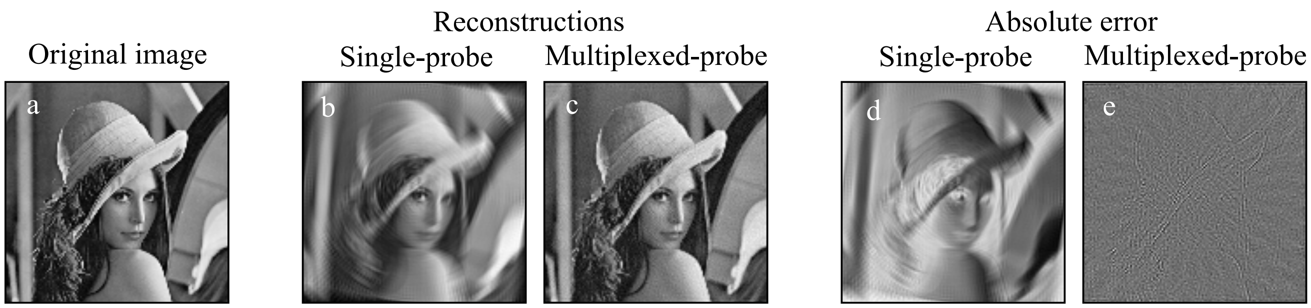

Figure 2. Reconstructions of the Lena image of size 128x128 are presented with conventional single and the proposed multiplexed-probe reconstruction method together with the corresponding absolute error images that show their difference with respect to the ground truth. Images are rescaled in their own dynamic ranges.

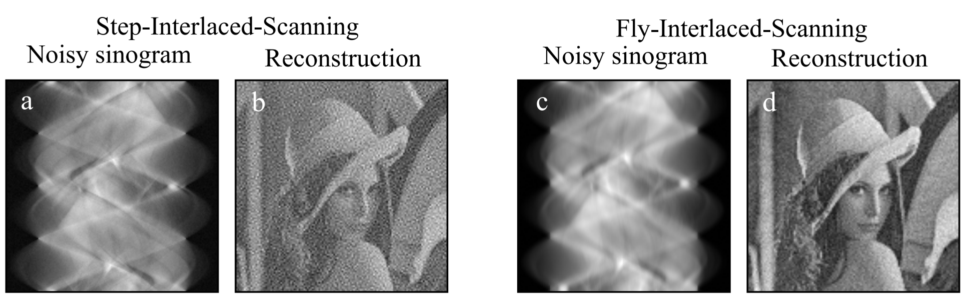

Figure 3. Comparison of step- and fly-interlaced scanning schemes. The fly-interlaced mode yields motion-blurred data with an improved SNR, whereas step-interlaced mode provides noisy data with no blur. Images are rescaled in their own dynamic ranges.