Radiation optimized field of view expansion in synchrotron radiation X-ray tomographic microscopy

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Introduction

THE acinus represents the functional lung unit of the pulmonary gas-exchange area. Until now, the investigation of full acini was either limited by the resolution of the imaging method or the sample volume. Even if synchrotron-based tomographic microscopy can be performed at a resolution down to a voxel size of 350 nm, the available sample volume at this resolution was limited. Tomographic scans performed at the pixel size needed to unambiguously distinguish the tissue septa in the gas-exchange region of the lung (0.74 µm) result in a limited field of view of 1.52×1.52 mm, which is insufficient for the imaging of entire acini at high resolution.

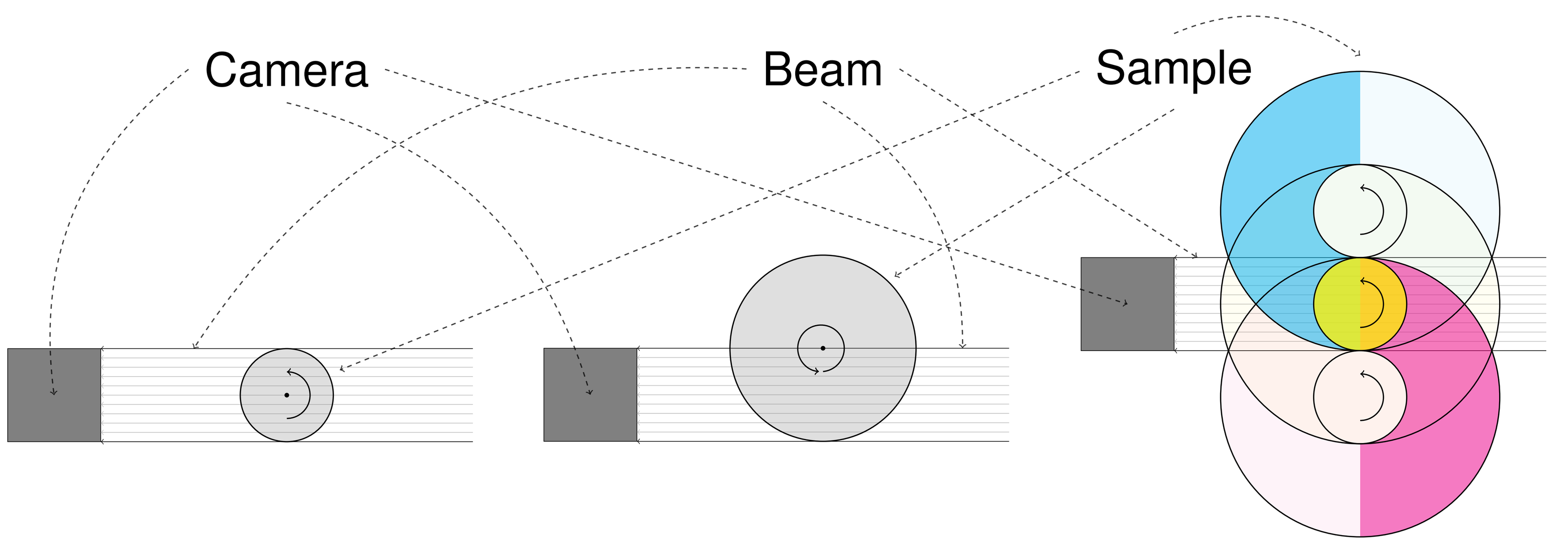
AT the TOMCAT beamline [1] at the Swiss Light Source of the Paul Scherrer Institut in Villigen, Switzerland we developed a method to combine multiple, independently acquired synchrotron-based x-ray tomographic scans to increase the field of view of the tomographic dataset perpendicular to its rotation axis.

THE acquisition protocol can be tuned as a function of the reconstruction quality and scanning time. Since the scanning time is proportional to the radiation dose imparted to the sample, this method can be used to increase the field of view of tomographic microscopy instruments while optimizing the radiation dose for radiation-sensitive samples and keeping the quality of the tomographic dataset on the required level.

Materials and Methods

RAT lung samples, prepared according to Tschanz and Burri [2] and Luyet et al. [3] were used as test objects for the evaluation of the scanning protocols.

THE field of view of the TOMCAT beamline was increased by moving the sample in the synchrotron radiation beam while acquiring several partial tomograms, as shown in Figure 1(c). The several sets of projections were subsequently stiched to large projections and reconstructed using the classic workflow present at the beamline (as described by Hintermüller et al. [4]).



(a) 180° scan (b) 360° scan (c) Wide-field scan

Figure 1: *Covering the field of view of differently sized samples with one 180° scan (a), one 360° scan (b) or, in the case of the so-called wide-field scanning, with three subscans (c). The filled segments mark the region of the sample which are covered while scanning the respective positions (position 1: magenta; position 2: yellow; position 3: cyan).*

Results

NINETEEN tomographic scans with varying amount of projections and thus total scanning time have been first simulated using an in-house MATLAB-script. After simulation, the protocols have been scanned at TOMCAT and the quality of the scans has been assessed in comparison with the simulation.

FIGURE 2 shows that we were able to both match the simulated quality and were additionally able to decrease the total scanning time by 84 % while keeping the quality of the reconstructed tomographic datasets at a level which permits automatic segmentation and three-dimensional visualization, as shown in Figure 3.

THE reduction in acquisition time obviously reduces the time during which the sample is irradiated by synchrotron radiation and thus reduces the radiation dose imparted on the sample.

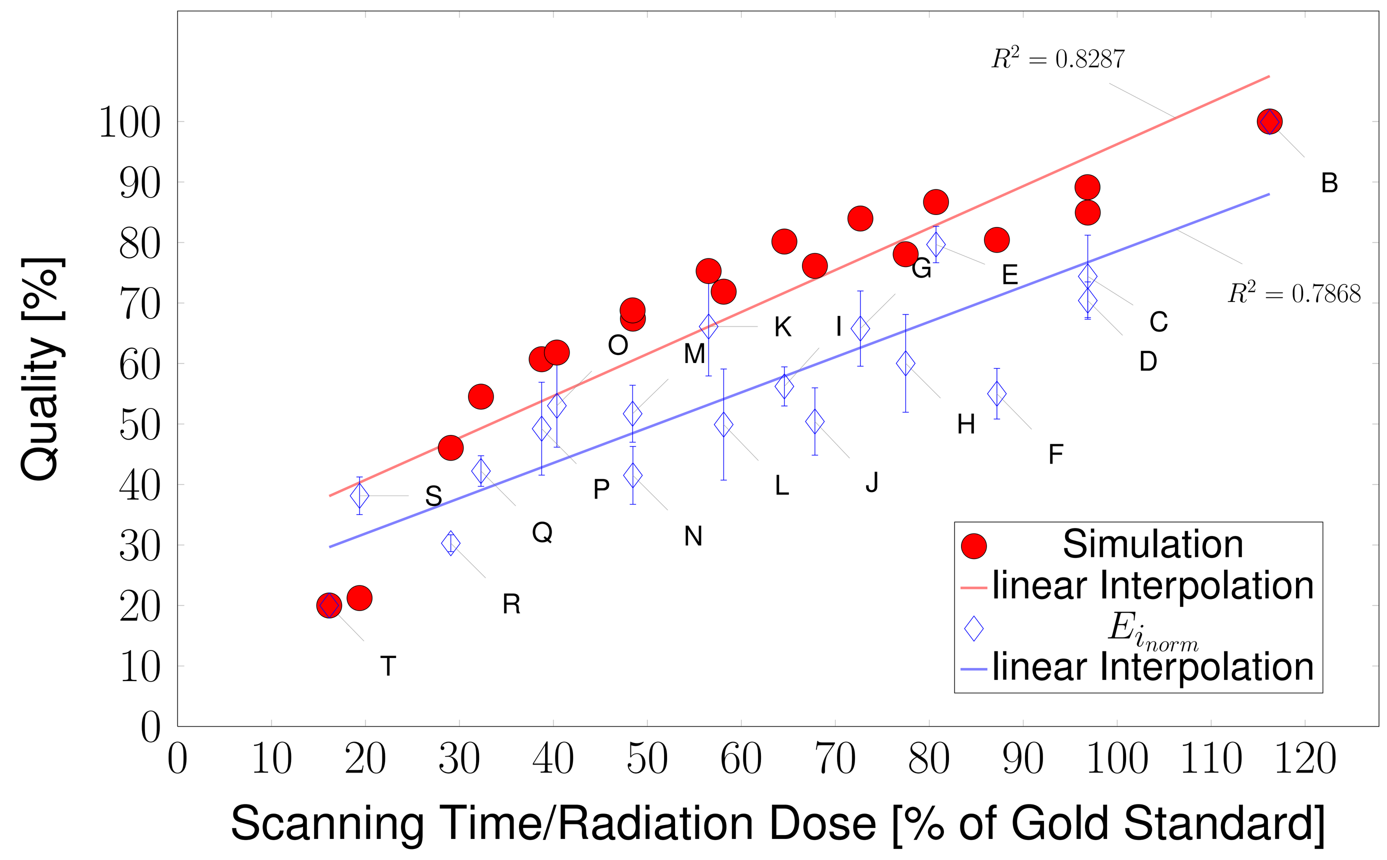


Figure 2: *Plot of normalized difference value (blue diamonds) and simulated quality (red dots) for the 19 scanned protocols. The abscissa shows the scanning time in percentage of time used for the gold standard scan.*

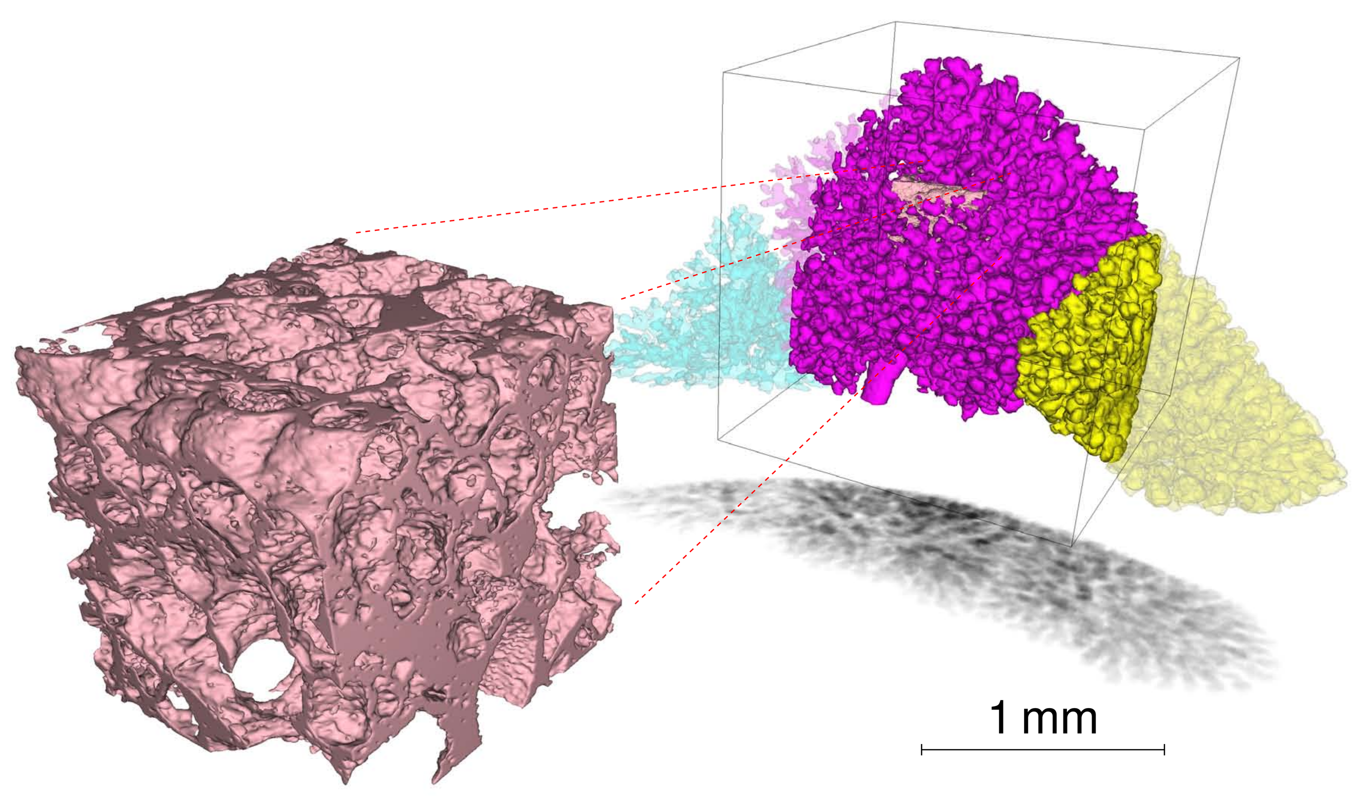


Figure 3: *Visualization of the gas-exchanging region of a rat lung. The transparent parts of the 4 mm-wide rat lung sample on the right show the enhancement in field of view with the proposed method, the magnified inset on the left with a side length of 380 µm shows the details achievable with our method.*

Discussion

THE presented method, dubbed wide-field synchrotron radiation tomographic microscopy, increases the lateral field of view of tomographic imaging stations up to five times and has been successfully applied for the three-dimensional imaging of several entire rat lung acini with a diameter of 4.1 mm at a voxel size of 1.48 µm [5]. Through optimization of the scanning method, the radiation dose can be reduced by 84 % which might be a significant step towards tomographic imaging of sensitive samples using ultrahigh resolution and enhanced field of view. A detailed explanation of the method is presented by Haberthür et al. [5].

Acknowledgments

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References

[1] M. Stampanoni, A. Groso, A. Isenegger, G. Mikuljan, Q. Chen, D. Meister, M. Lange, R. Betemps, S. Henein, and R. Abela. TOMCAT: A beamline for TOmographic Microscopy and Coherent rAdiology experimenTs. *AIP Conference Proceedings*, 879(1):848–851, 2007. URL http://dx.doi.org/10.1063/1.2436193.

[2] Stefan A Tschanz and Peter H Burri. A new approach to detect structural differences in lung parenchyma using digital image analysis. *Experimental Lung Research*, 28(6): 457–471, September 2002. URL http://dx.doi.org/10.1080/01902140290096719.

[3] Cedric Luyet, Peter H Burri, and Johannes C Schittny. Suppression of cell proliferation and programmed cell death by dexamethasone during postnatal lung development. *American Journal of Physiology- Lung Cellular and Molecular Physiology*, 282(3):477–483, 2002. URL http://dx.doi.org/10.1152/ajplung.00406.2000.

[4] C. Hintermüller, F. Marone, A. Isenegger, and M. Stampanoni. Image processing pipeline for synchrotron-radiation-based tomographic microscopy. *Journal of Synchrotron Radiation*, 17(4), Jul 2010. URL http://dx.doi.org/10.1107/S0909049510011830.

[5] David Haberthür, Christoph Hintermüller, Federica Marone, Johannes C. Schittny, and Marco Stampanoni. Radiation dose optimized lateral expansion of the field of view in synchrotron radiation X-ray tomographic microscopy. *Journal of Synchrotron Radiation*, 17(5):590–599, Sep 2010. doi: 10.1107/S0909049510019618. URL http://dx.doi.org/10.1107/S0909049510019618.

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