Quality-guided synchrotron-based tomographic microscopy of large lung samples

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Introduction

SYNCHROTRON-BASED tomographic microscopy is used to investigate objects at a resolution down to a voxel size of 360 nm. Until now the investigation of the three dimensional structure of an entire acinus—the functional lung unit—was either limited by the resolution of the imaging method or the sample volume. At the TOMCAT beamline [1] at the Swiss Light Source of the Paul Scherrer Institut in Villigen, Switzerland we developed a synchrotron-based tomographic microscopy method to overcome this limitation.

THE field of view (FOV) of tomographic scans can be increased in vertical direction through stacking of several acquired tomograms (figure 1(a)). To increase the FOV in horizontal direction, the acquired projection images of the sample have to be merged into one projection image covering the full FOV prior to reconstructing the sample (figure 1(b)).

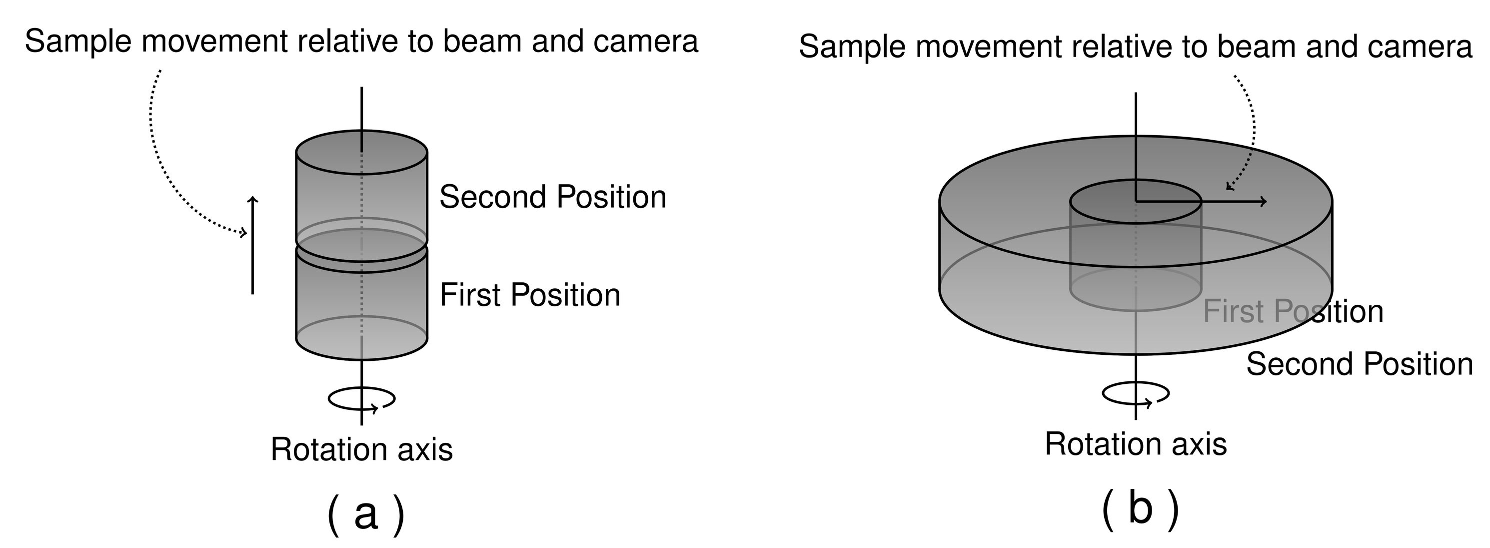

Figure 1: *Enhancing the field of view of tomography based imaging methods: Left: Stacking severals scans in vertical direction. Right: Merging several scans in horizontal direction.*

Materials and Methods

CUSTOM-MADE software is used to calculate different protocols, varying in expected reconstruction quality and image acquisition time. After a suitable protocol has been chosen, the data acquisition and merging of the images is performed without user intervention.

A sequence of 19 protocols of the same distal-medial edge of the right lower lung lobe of a Sprague Dawley rat, obtained postnatally at day 21 [2] has been scanned.

Results

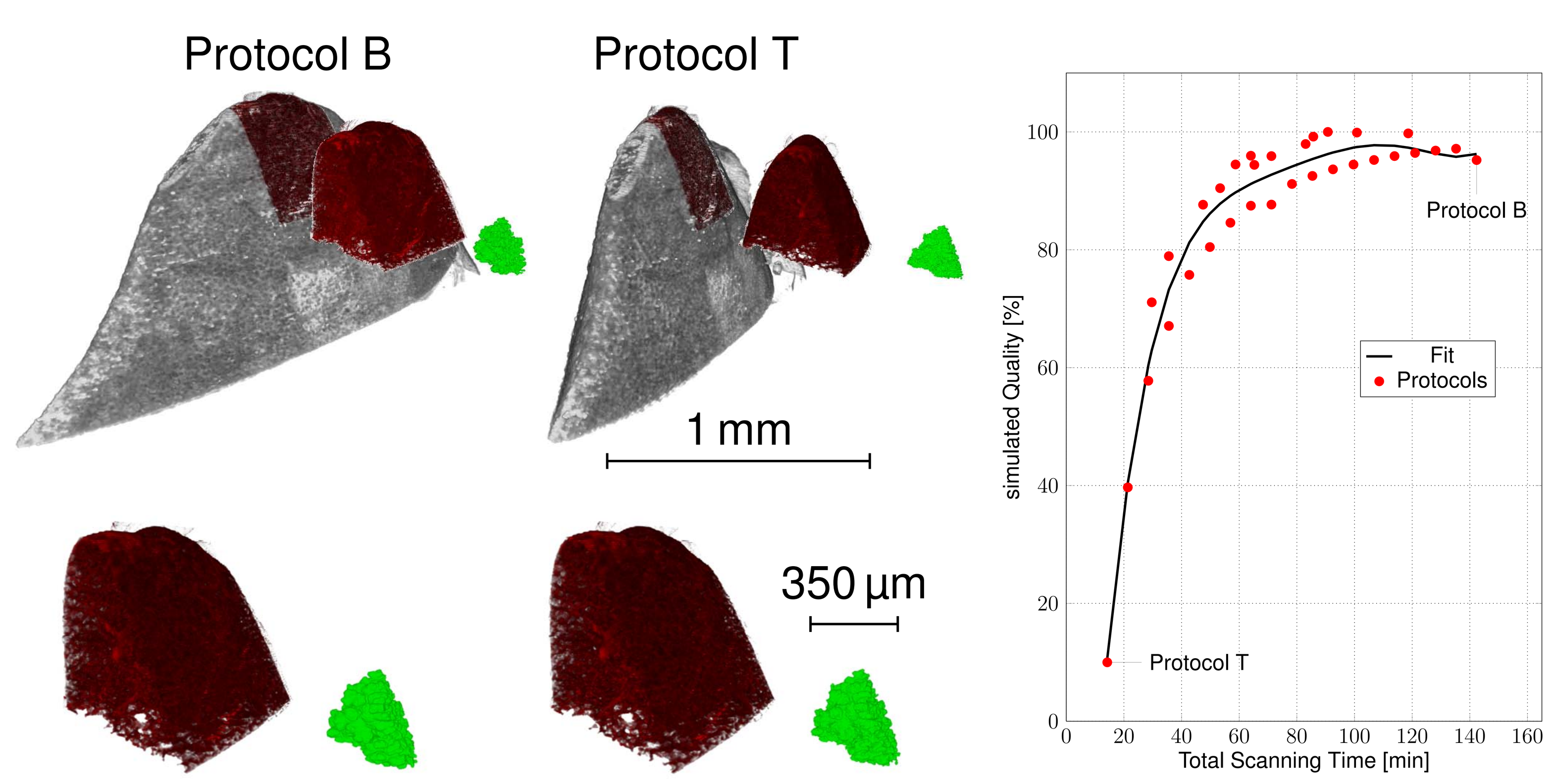

Figure 2: *Visualization of two different scans of the distal-medial edge of the lower lung lobe of a Sprague Dawley rat: Top: Volume rendering of the lung lobe (gray) with a size of approximately 2712×952×1024 pixels at a voxel size of 0.70 µm. The red segment shows an extracted region of interest (ROI) with a side length of 512 pixels. The green structure has been automatically segmented using a region growing algorithm. The acquisition time of protocol T is only 14 % of the acquisition time of protocol B. Bottom: Close-up of the ROI of both protocols. Right: Resulting plot of the different results calculated with the aforementioned MATLAB-program. The red dots show the simulated qualities for 32 calculated protocols, 19 of which have been scanned. The line shows a polynomial fit through the data points.*

THE calculated protocols are designed in such a way that the total scanning time—which essentially scales with the amount of obtained projections—is greatly reduced. With our 19 scanned protocols, we have been able to reduce the acquisition time by 86 %. Albeit that this reduction introduced some artifacts in the dataset, an automated segmentation of the airways is still possible.

WE have been able to extend the FOV of TOMCAT even more through adding a third lateral image acquisition position. A reconstruction of such an extended projection is shown in figure 3.

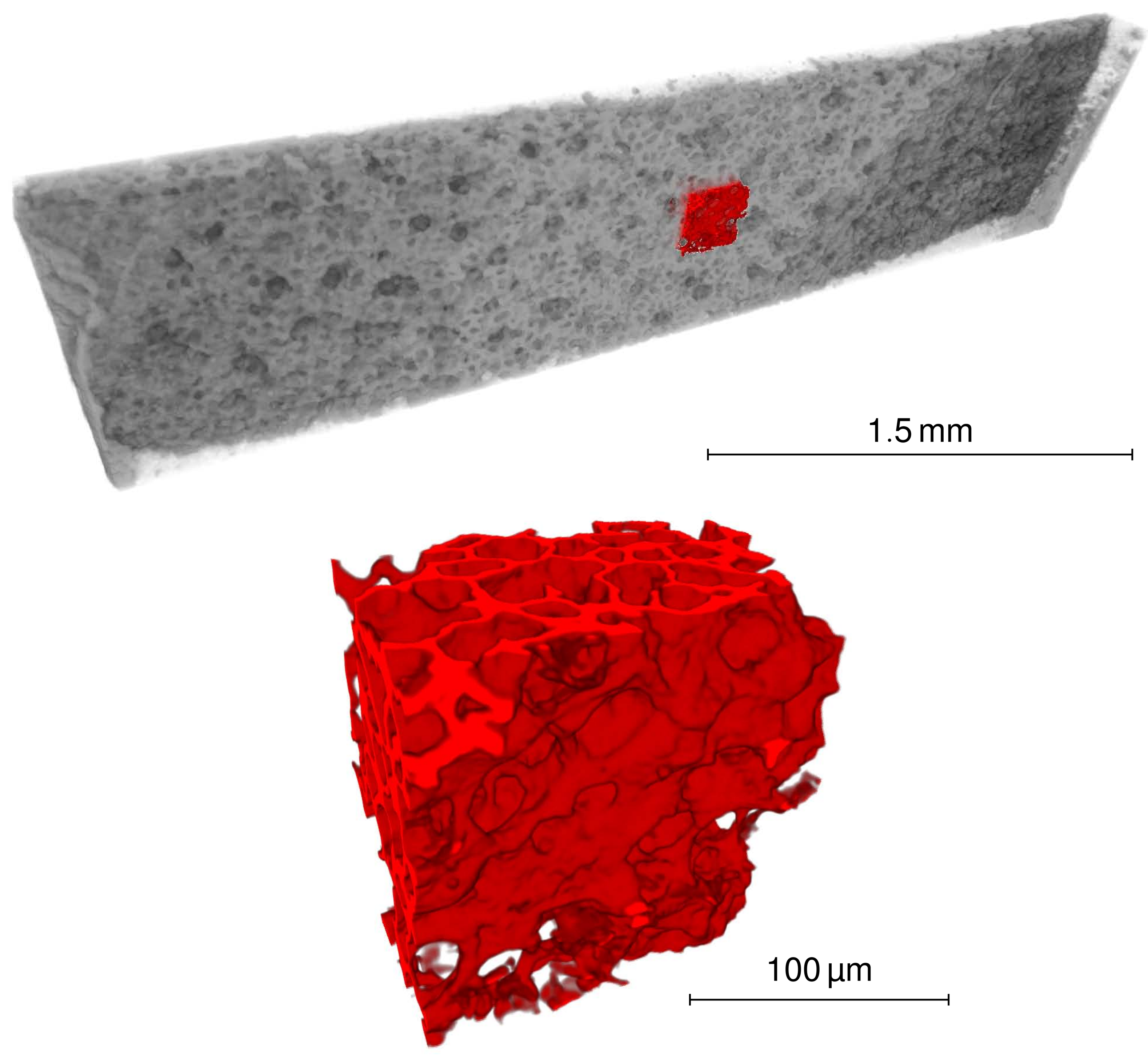

Figure 3: *Visualization of lung tissue slice [3]: Top: Volume rendering of slice of lung tissue with a size of 554×4854×1024 pixels at a voxel size of 0.7 µm. The inset red cube has a size of 256 pixels and was automatically segmented using a region growing algorithm. Bottom: Close-up of inset cube. Single alveoli of the lung are clearly visible.*

Discussion

THE lateral FOV of TOMCAT can be greatly increased while keeping the quality of the scan at a very high level. We provide the possibility to acquire quality-guided tomographic wide field scans of arbitrary samples in an unattended, automatic way. Up to now, if a ROI of a wide sample had to be scanned with high resolution, a multi-step process was involved; an overview scan was performed at low magnification, the user had to define the ROI and finally perform a navigated high resolution scan of this ROI at TOMCAT.

THE proposed scanning method will—once fully integrated in the beamline workflow—provide the possibility to scan wide samples with full resolution in one step in a very fast way and to selectively reconstruct ROIs defined by the end-user.

Acknowledgments

This work has been funded by grant 3100A0-109874 of the Swiss National Science Foundation. We thank Dr. Federica Marone, beamline scientist at TOMCAT, for expert help with the reconstructions. We thank Dipl.-Ing. Sophie Rausch of the Institute for Computational Mechanics, Technische Universität München for providing the lung samples shown in figure 3.

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