Geometric calibration based on a simple phantom for multi-lens microscopic CT

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Abstract

Conventional micro-CT improves the spatial resolution by reducing the spot size of X-ray source or relying upon the geometric magnification by moving the scanned samples between the source and the detector. However, further improvement on spatial resolution is constrained by the nature of conventional micro-CT, which can hardly makes the resolution to submicron level. The multi-lens coupled microscopic CT system, which conducts secondary optical amplification by visible light in addition to original X-ray amplification, can improve the spatial resolution to hundreds nanometer. Moreover, the multi-lens configuration of microscopic CT system is also able to resolve the contradiction between size of field of view (FOV) and resolution to some extent. Thus this kind configuration can be employed into many applications such as interior reconstruction. Along with the spatial resolution improving, the multi-lens microscopic CT system requires higher calibration precision to meet requirements for different studies. Other than the conventional calibration methods which all aim at CT system with single detector, the geometric calibration for multi-lens system is much more complicated because of its additional geometrical shifting involved in different lens. Thus the high-precision calibration of multi-lens microscopic CT is not only needed to handle basic geometry of cone-beam system but also to incorporate the position parameters of different lens into correction procedures.

In order to effectively perform geometric calibration on multi-lens system, existing calibration method is the two-steps solution that is to calibrate each single detector first, and then register images among multi-lens. On one hand, the calibration error of detectors is hard to be ignored, and on the other hand, the existing multi-lens calibration neglects the inherent relationship between detector calibration and multi-lens registration which results in the further propagation of the error along with the two-steps solution. Therefore, the existing solution has inherent drawbacks to resolve the multi-lens calibration. In this paper, the relationship between detector calibration and multi-lens registration of the microscopic CT is further analyzed and a new geometric calibration algorithm based on one single micro-sphere is proposed. We establish the relationship among different image space under different resolutions and combine detector calibration and multi-lens registration to the same optimization process. This algorithm can effectively perform high-precision geometric calibration on multi-lens microscopic CT system. Besides, the calibration procedure is easy to implement and can obtain all calibration parameters within only one optimization process.

The simulation experiment shows that the geometric calibration algorithm proposed in this paper is high-precision, robust and has good property of convergence. In addition, the image reconstruction based on the registered images of the bamboo stick sample under the 5X and 10X lens proves that the new calibration algorithm performs better property about the calibration accuracy compared with the conventional two-steps solution.

Keywords: Geometric calibration, simple phantom, multi-lens, microscopic CT