Contribution ID: **66** Type: **poster**

Optimizing robot-CT trajectories for data completeness

Computed tomography (CT) generates 3D volumetric images by numerically processing projection views obtained from various angles, and is widely used both in medical and industrial fields. However, industrial CT faces challenges, such as limited field of view for large objects and severe photon starvation or metal artifacts. These artifacts can be reduced or eliminated by avoiding highly attenuating regions during scanning. However, this approach is rarely implemented in cone-beam CT (CBCT) with a conventional circular gantry. To address these limitations, recent studies have proposed robotic CT [1], in which the X-ray source and detector are mounted on a 6-degree-of-freedom robotic arms, enabling projection acquisition along arbitrary trajectories. However, robot CT with poorly designed scanning paths can reduce data completeness and degrade the quality of reconstructed images. Data completeness is essential for the exact reconstruction. The Tuy-Smith condition [2,3] states that any plane passing through the object must intersect the scanning trajectory at least at once.
In this study, we propose an algorithm based on the Tuy measure to optimize the scanning trajectory of a robotic CT system. The goal is to maximize data completeness within a specific volume of interest (VOI) while achieving high-quality images with a minimal number of projections. Additionally, the algorithm evaluates the quality of each projection to filter out those that may cause metal artifacts within the VOI.
To simulate a two-robot-arm system, we developed a laboratory-scale robot-CT system that uses a single robotic arm to manipulate the motion of the object to be scanned, as shown in Fig. 1(a). As an example, a postmortem mouse was used, with 5-mm-diameter metal balls attached around it to induce metal artifacts. The projections were acquired over a rotation range of θ from 0° to 360° with a 2° interval. For each θ, tilted angles ϕ of 0°, 30°, and 45° were considered, resulting in a total of 540 possible projections. Image reconstruction was performed using the FDK algorithm. Fig. 1(b) shows the reconstruction results using the trajectory determined by the proposed algorithm. In each sub-panel, the number of projections used for reconstruction is displayed in the top-right corner, and the corresponding trajectory (ϕ or arbitrary) is shown in the bottom-right corner. The results demonstrate a significant reduction in metal artifacts with the optimized trajectory. Although some data loss is inevitable compared to the conventional circular trajectory (180 projections at $\theta = 0°$), the optimized trajectory with only 46 projections was able to reconstruct most of the internal structures of the mouse. A detailed description of the proposed algorithm, including systematic examples for finding optimal trajectories for various sample objects, will be provided.

Reference

[1] W. Holub, F. Brunner, and T. Schön, RoboCT application for in-situ inspection of join technologies of large scale objects, International Symposium on Digital Industrial Radiology and Computed Tomography, 2019.
[2] H. K. Tuy, An inversion formula for cone-beam reconstruction, SIAM Journal on Applied Mathematics, Vol. 43, No. 3, pp. 546-552, 1983.
[3] B. D. Smith, Image reconstruction from cone-beam projections: Necessary and sufficient conditions and reconstruction methods, IEEE Transactions on Medical Imaging, Vol. MI-4, No. 1, pp. 14-25, 1985.

Acknowledgement
This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (RS-2024-00340520).

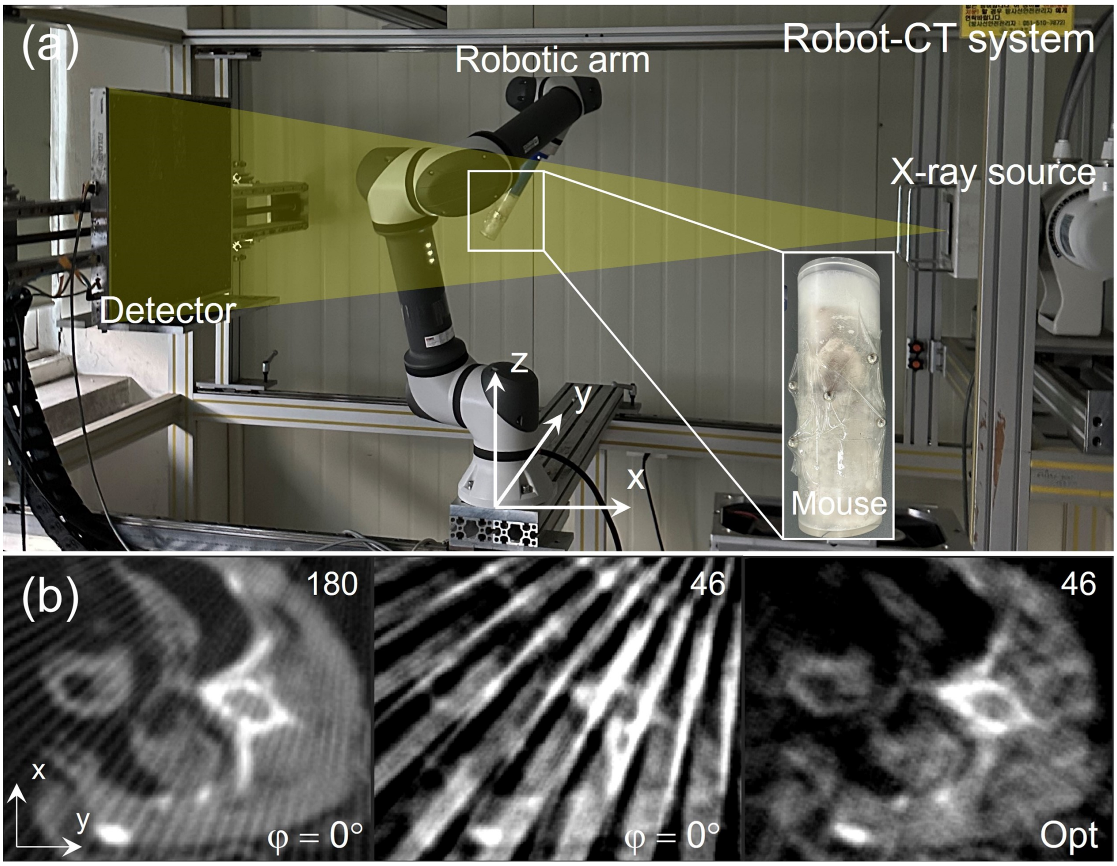

Figure 1: (a) A laboratory-scale robot-CT system enabling flexible X-ray imaging trajectories. (b) FDK results using 180 and 46 projections at a tilted angle $\varphi = 0^\circ$ (i.e., the conventional circular trajectory) and the optimized trajectory determined by the algorithm proposed in this study.

Workshop topics

Applications

Authors: YOO, Seungjun (Computational X-ray Imaging Laboratory, School of Mechanical Engineering, Pusan National University); KIM, Ho Kyung (Computational X-ray Imaging Laboratory, School of Mechanical Engineering, Pusan National University)

Co-authors: OH, Seokwon (Computational X-ray Imaging Laboratory, School of Mechanical Engineering, Pusan National University); PARK, Seongbon (Computational X-ray Imaging Laboratory, School of Mechanical Engineering, Pusan National University); LEE, Junho (Computational X-ray Imaging Laboratory, School of Mechanical Engineering, Pusan National University)

Presenter: YOO, Seungjun (Computational X-ray Imaging Laboratory, School of Mechanical Engineering, Pusan National University)