Automatic geometry calibration based on metric optimization in stationary computed tomography baggage scanner with 2π-angle sparsity

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Two-dimensional (2D) X-ray inspection systems are widely used in airports for aviation security. However, they have inherent limitations in recognizing the 3D shapes of the hidden threats. Therefore, there is a growing demand for the implementation of advanced 3D X-ray inspection systems at airports for more accurate detection of threats in luggage and personal belongings. In a previous study [1], SSTLabs Co., collaborated with us, developed a prototype stationary CT baggage scanner with 2π-angle sparsity, comprising 20 pairs of monoblock-type X-ray sources and linear array-type dual-layer detectors (X-Card 1.5-64DE, Detection Technology Co.) arranged within a scan angle of 360° at an equiangular distance, as shown in Fig. 1. This type of CT configuration is considerably less noisy owing to the limited mechanical vibration, thus more suitable than the rotating gantry-type configuration for routine carry-on baggage inspection. In addition, we implemented a CT reconstruction method for the specific (i.e., very sparse-view) system configuration by adopting an iterative algorithm based on the popular compressed-sensing (CS) mathematical theory [2]. However, the image quality of the reconstructed images was rather poor possibly owing to the mismatch of scan parameters between the designed (nominal) and actual values used in reconstruction. The CS-based reconstruction algorithm is sensitive to the accuracy of the scan parameters. In this study, continuing our research on X-ray research and development, we propose a pragmatic geometry calibration method based on the metric optimization of the mean structural similarity index measure (MSSIM) to obtain high-quality reconstruction in the developed stationary CT baggage scanner (Fig. 2). Figure 3 shows some examples of the projection data of a glass bottle and a fire extinguisher acquired from the developed CT baggage scanner. Figure 4 shows the reconstructed CT images before and after applying the proposed geometry calibration algorithm. Our preliminary results indicate that the proposed method can extract precise scan parameters (e.g., transverse shift in Fig. 3) and thus produce high-quality reconstruction. The proposed method does not require any calibration phantom and, thus, is automatic; it can reduce the cost of ensuring precise mechanics and reduces the labor in fine tuning the system. More quantitative simulation and experimental results will be presented in the paper.

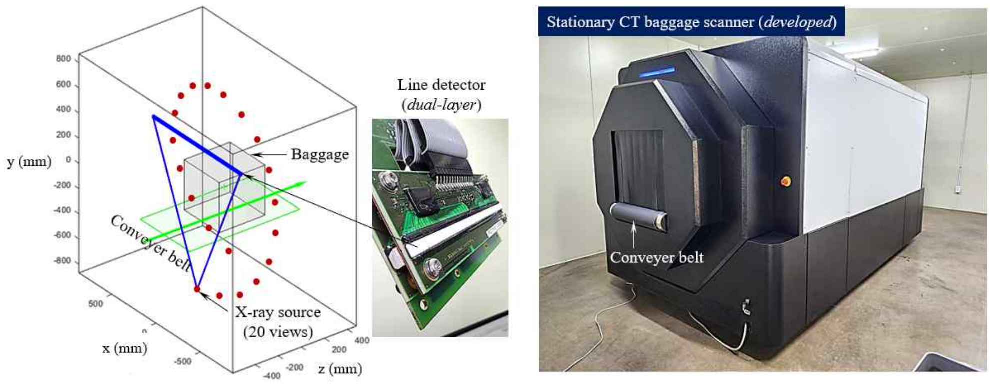

Figure 1. Schematic of a stationary CT baggage scanner designed with 2π-angle sparsity (left) and its realization (right).

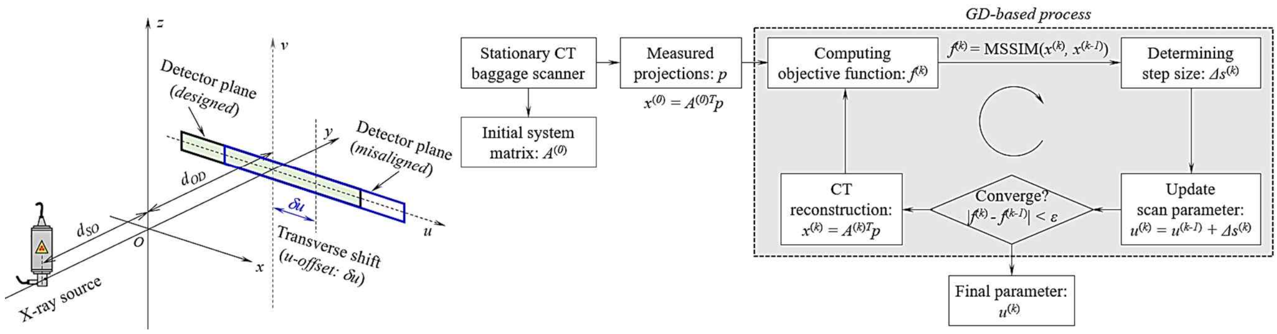

Figure 2. Simplified diagram of the proposed automatic geometry calibration based on the MSSIM metric optimization for the developed stationary CT baggage scanner.

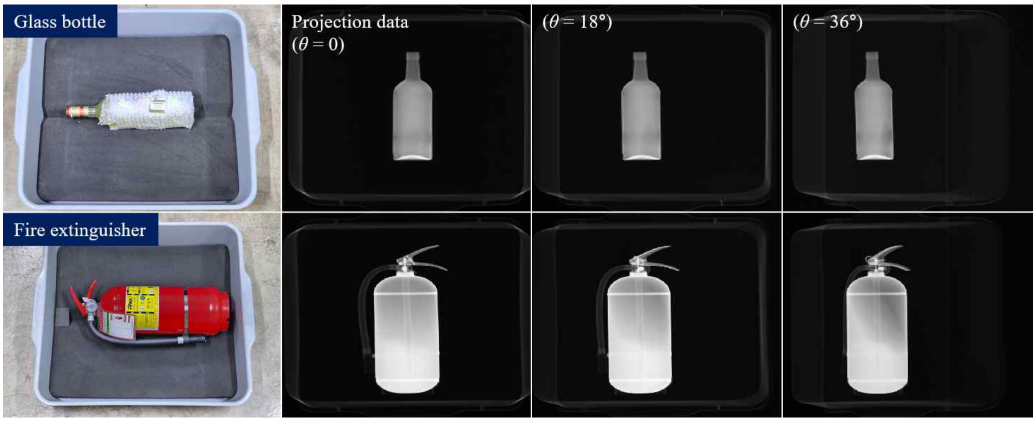

Figure 3. Examples of the projection data of a glass bottle (top) and a fire extinguisher (bottom) acquired from the developed stationary CT baggage scanner.

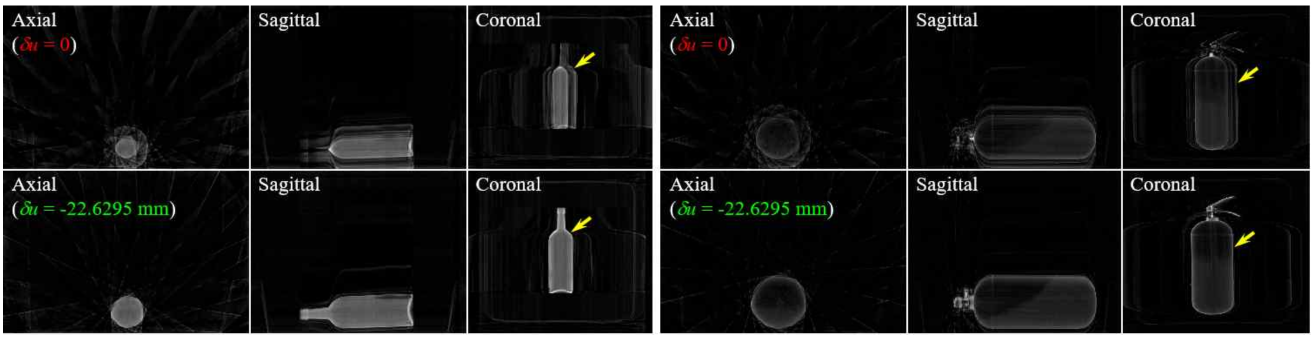

Figure 4. Reconstructed CT images of a glass bottle (left) and a fire extinguisher (right) before (top) and after (bottom) applying the proposed geometry calibration algorithm.

Reference

[1] SHIM, J., et al., Journal of Instrumentation, 2023, 18: C11003.
[2] SHIM, J., et al., Journal of Instrumentation, 2022, 18: C01058.