Single-exposure material decomposition in digital tomosynthesis using a CdTe-based photon-counting detector: Simulation study

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Chest radiography is one of the most important medical imaging modalities for lung disease diagnosis and bone fractures. However, lesions located behind the ribs or clavicle are difficult to detect because of the anatomical structure overlap in chest radiographs. To reduce inaccurate diagnosis, several studies have been conducted to identify and remove the effect of the overlapping structure of chest radiography using the dual-energy material decomposition (DEMD) technique [1]. DEMD enables the selective imaging of two relevant materials, namely, soft tissue and bone structures, capturing two X-rays with different energy levels (E_2 = 62 keV and E_4 = 81 keV were used in this study). However, it requires double exposures, which results in increased radiation dose to patients and misregistration errors attributed to patient movement between the two scans. Another approach is the use of 3D imaging modalities, such as digital tomosynthesis (DTS) and computed tomography, that can reduce the visual complexity of overlying anatomy in chest radiographs. In this study, to further improve abnormality detection in chest X-rays, we propose a single-exposure material decomposition method in chest DTS using a photon-counting detector (PCD) [2]. PCD, unlike typical energy-integrating detector (EID), can classify X-ray photons into several different energy bins (four bins of E_1–E_4 were used in this study) depending on the threshold level, which allows for more precise measurements of X-ray attenuation. To validate the efficacy of the proposed approach, we conducted a feasibility study using numerical simulation before its practical implementation. Figure 1 shows the schematic of a chest DTS geometry installed with a CdTe-based PCD. Figure 2 shows a simplified data process of the proposed single-exposure material decomposition in chest DTS using a CdTe-based PCD where two main steps are involved: generation of a pairwise look-up table and material decomposition followed by DTS reconstruction. Figure 3 shows some preliminary simulation results: DTS images of a chest phantom emulated with an EID and a CdTe-based PCD. According to our simulation results, the proposed method effectively separated soft-tissue and bone images of high selectivity in both chest radiography and DTS, demonstrating its efficacy despite the reduced dosage. More quantitative simulation results will be presented in the paper.

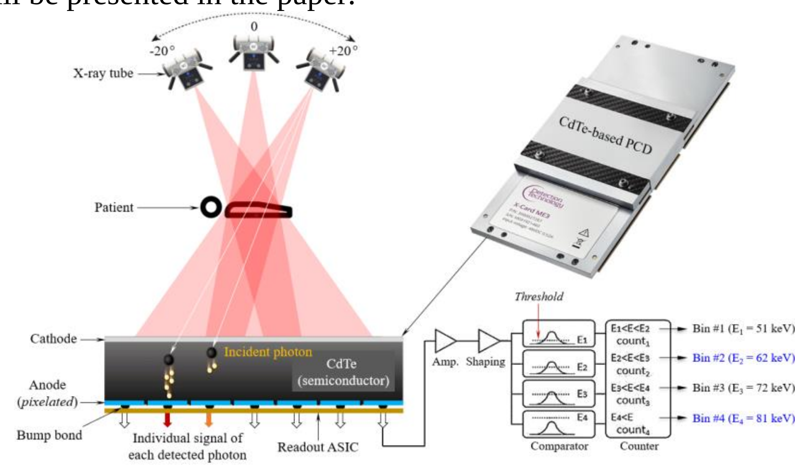

Figure 1. Schematic of a chest DTS geometry installed with a CdTe-based PCD for single-exposure material decomposition. PCD can classify X-ray photons into several different energy bins, depending on the threshold level.

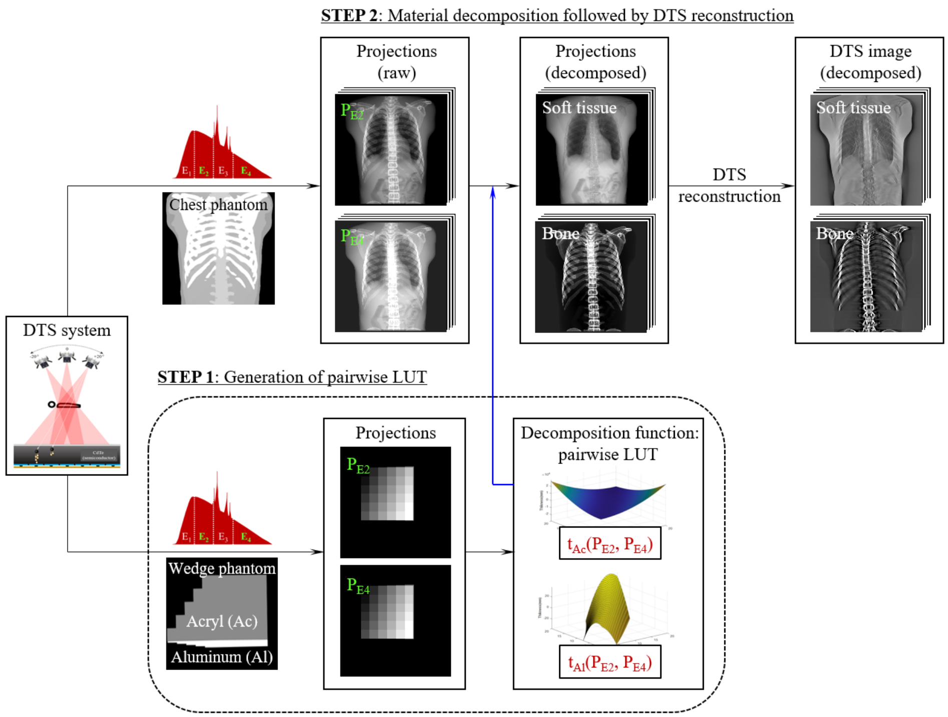

Figure 2. Simplified data process of the proposed single-exposure material decomposition in chest DTS using a CdTe-based PCD. Two main steps are involved: generation of a pairwise LUT (Step 1) and material decomposition followed by DTS reconstruction (Step 2).

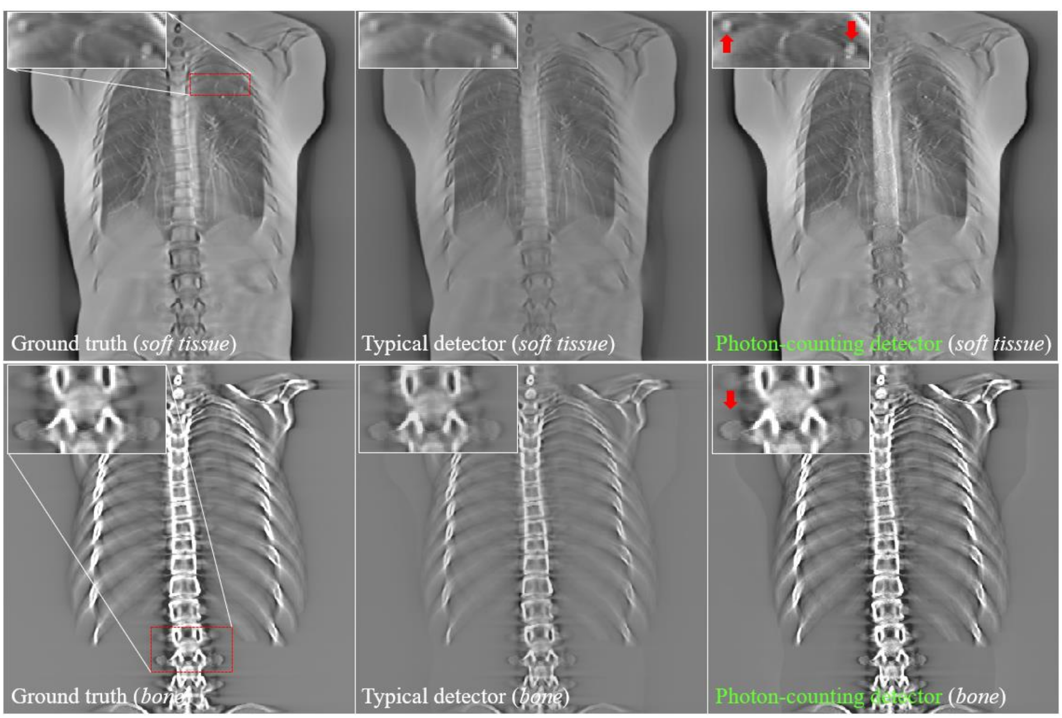

Figure 3. Preliminary simulation results: DTS images of a chest phantom emulated with an EID (middle) and a CdTe-based PCD (right). The corresponding ground truths are shown on the left for comparison.

Reference

[1] M. Freedman et al., Radiology, **260** (2011), 265–273.
[2] S. Lee et al., Nucl. Inst. Method A, **1062** (2024) 169221.