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Measurement of Atomic Density with a Photon Counting X-ray CT

Koichi Ogawa, Ryo Ito
Graduate School of Science and Engineering, Hosei University
3-7-2 Kajinocho, Koganei, Tokyo 184-8584, Japan
ogawa@hosei.ac.jp

Extended Abstract

In the planning of radiation therapy such as heavy ion radiation therapy, electron densities of materials in a patient body are very important to calculate an accurate dose distribution[1]. The aim of this paper is to measure a more accurate distribution of an atomic density using a photon counting X-ray CT than a method with a conventional X-ray CT. Photon counting detectors have been developed recently for purposes such as material identification and correction of beam hardening[2]-[3]. They enable measurement of the number of photons with some energy bins, and with this information, we can measure atomic densities using a singular value decomposition (SVD) method. The method to calculate the atomic densities is as follows. First we measure photon counting projection data with many energy bins with a photon counting detector. These measured data are assumed to be a linear combination of the mass attenuation coefficient of an atom at a specified energy and the areal density of the atom at a specified pixel[4]. This equation can be solved with the SVD method. The areal density matrix is the line integral of densities, and we can reconstruct the density of an atom at a given pixel with the CT image reconstruction technique. To evaluate the feasibility of our proposed method, we conducted some simulations using two cylinder phantoms: Phantom-1 was a cylinder with a diameter of 30 mm filled with water (H_2O) with different concentrations (10~90%) of benzene (C_6H_6). Phantom-2 was a cylinder with a diameter of 30mm filled with water, in which we located a small cylinder with a diameter of 13mm filled with 75% ethanol (C_2H_6O) solution. We assumed an x-ray tube with a tube voltage of 90 kV with an Al filter with a thickness of 2mm. The size of a detector pixel was $0.5 \times 0.5 \text{mm}^2$ and the number of pixels was 128. In the detection of x-rays, we assumed a photon counting detector and set many energy windows with a width of 1keV. We ignored the distortion caused by the energy resolution of the detector. The projection data were acquired with fan-beam geometry. The distance between the X-ray tube and rotational center was 72 cm and that between the rotational center and detector was 8 cm. The number of projection data was 360. We ignored the collimator. CT images of hydrogen, carbon and oxygen were reconstructed with a filtered backprojection method. The image matrix was 128x128 with a pixel size of $0.5 \times 0.5 \text{mm}^2$. The results of simulations with Phantom-1 showed that if we set energy windows from 41keV to more than 60keV, the mean error ratios of hydrogen, carbon and oxygen were less than several % and the error ratio increased when the concentration of benzene increased. The results of simulations with Phantom-2 showed that if we set energy windows from 20~30keV to more than 75keV, the mean error ratios of hydrogen, carbon and oxygen were less than 5%. In conclusion, the photon counting X-ray CT is a promising tool for the measurement of atomic densities.

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