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Method for system-independent material classification through basis material decomposition from spectral X-ray CT

We present a method for material classifications in spectral X-ray Computed Tomography (SCT) using energy-resolved, photon-counting detectors (PCD), with which one can simultaneously measure the energy dependence of a linear attenuation coefficient (LAC) of a material. The method uses a basis material decomposition taking advantage of the spectral LACs to estimate effective atomic number (Z_{eff}) of a material independently from the system or specifics of the scanner, such as the X-ray spectrum. In this decomposition we represent the LAC of a material as the sum of two basis materials with equivalent thicknesses [1, 2]. The measured spectra in photon-counting detectors working under high flux is distorted by a range of detector effects, such as charge sharing and weighting potential cross-talk, fluorescence radiation, Compton scattering, pulse pile up and incomplete charge collection. These physical effects lead to distortions of the measured LAC curves and our classification method uses a spectral correction algorithm to correct the distorted attenuation curve [3]. Using the correction algorithm the measured LACs of a material directly corresponds to the theoretical formulation in the basis material decomposition. Therefore, the method in this work gives a system-independent solution to classify materials. Brambilla et al. presented a basis material decomposition method estimating Z_{eff} of a material with a PCD, which directly uses the distorted LACs and therefore requires a calibration of the detector's spectral response for various combinations of basis materials of equivalent thicknesses [4]. However, this result in a system-dependent solution due to the dependence on the source spectrum.

In this work, we use sparse-view reconstructions from few projections which is important to achieve fast scanning in security screening. To improve reconstruction performance we employ the joint reconstruction regularization with the vectorial total variation method called L_∞-VTV [5]. L_∞-VTV correlates the image gradients using a L_∞ norm over multi energy bins and results in strong coupling between energy bins. The classification performance is estimated over a set of weighting parameters, λ defining the strength of the spectral regularization term of L_∞-VTV. We use 33 different materials in the range of $6 \leq Z_{\text{eff}} \leq 15$ for experimental validation of the method, scanned with a MultiX ME-100 v2 line array PCD. We show that using the spectral correction algorithm with the material decomposition classification method decrease the relative deviation in Z_{eff} to 2.4% from 5.2% when spectral correction is not used.

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