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Material decomposition in low-energy micro-CT using a dual-threshold photon counting x-ray detector

Material decomposition in computed tomography is a method for differentiation and quantification of materials in a sample and utilises the energy dependence of the linear attenuation coefficient [1]. While in clinical applications, the x-ray spectrum is manipulated by changing the acceleration voltage between acquisitions [1], a photon-counting detector directly utilise the polychromatic spectrum of an x-ray tube [2]. Via multiple energy-discriminating thresholds, specific energy windows can be created containing only photons within a specific energy range. Acquiring an energy window on each side of an absorption edge of a material allows to decompose a sample into specific materials [3].
In this study, a micro-CT system with a dual-threshold photon-counting detector is used to construct a post-reconstruction material decomposition method [2] utilising K-edges in the range 4-11 keV. This energy range allows to identify naturally occurring elements in organic tissue ($Z \leq 36$). In comparison, clinical applications often utilise iodine- or gadolinium-based contrast agents with absorption edges at around 33 keV and 50 keV respectively, which have to be introduced into the sample.
The implemented method was verified with a phantom made of copper and aluminium and then applied to paraffin embedded human atherosclerotic plaques containing calcifications and areas with haemorrhages and were therefore decomposed into iron, calcium and paraffin. Using two energy windows, the samples could be decomposed into three base materials using manually selected regions to obtain attenuation values for the specific materials. While the method suffers from strong ring and beam hardening artefacts due to significant absorption in air in the low energy range and limited number of photons due to the required small size of the energy windows, the decompositions show distinct distributions of the expected materials within the samples without the need for staining.

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