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P2.31: Chromatic detector-based spectral µCT of iodine-perfused osteochondral samples

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Micro-computed tomography (µCT) is the gold standard for non-destructive 3D imaging of samples on the centimeter scale. Despite offering micrometric spatial resolution, conventional µCT provides limited detail visibility when applied to biological samples due to the small attenuation differences that exist among soft tissues. To overcome this limitation, highly absorbing contrast media are introduced in the sample, selectively filling structures or bonding to compounds of interest, enhancing their visibility. This technique is referred to as contrast-enhanced µCT (CEµCT) [1]. On the other hand, CEµCT does not allow for any material-specific discrimination or quantification, as the presence of the contrast is recognized purely on a morphological and/or grey-scale basis. This implies, for instance, that a contrast-medium-filled region might not be distinguishable from a contiguous highly absorbing detail (e.g., bone).
In this context, the availability of small-pixel spectral detectors equipped with multiple energy thresholds has enabled the development of spectral µCT (SµCT) systems. By using this type of detector, two (or more) images corresponding to tunable X-ray energy intervals are collected in a single shot. Owing to the different energy dependence of X-ray attenuation of different materials, these energetically binned images can be given as input to a spectral-decomposition algorithm to yield quantitative 3D density maps of selected decomposition materials. If the contrast medium has a convenient K-edge energy, images can be binned above and below the K-edge, enhancing the discrimination capabilities through material decomposition. This overcomes the intrinsic non-specificity of CEµCT and allows for the quantitative evaluation of contrast media concentration and the generation of virtual-non-contrast images.

In this contribution we present SµCT results obtained on osteochondral bovine samples perfused with a cationic iodine-based contrast medium (CA4+), having a selective affinity with negatively charged glycosaminoglycans (GAGs) in cartilage due to electrostatic attraction [2]. Images are acquired with a novel multimodal X-ray imaging system [3], integrating a CdTe spectral detector (Pixirad-PixieIII) with a pixel size of 62 × 62 µm2 over a matrix of 512 × 402 pixels (32 × 25 mm2) [4]. Pixirad features 2 energy thresholds and a charge-sharing compensation mode. The latter is of great importance as the energy crosstalk between bins induced by charge sharing negatively impacts material decomposition. Accurate spectral imaging is made possible by thorough energy response characterization and subsequent modeling, whereby the content of each energy bin can be estimated and used to compute the material-decomposition matrix (Fig. 1) [5]. Acquisitions are performed at a tube voltage of 50 kV, current of 200 µA, geometrical magnification of 1.85, and sample-to-detector distance of 65 cm.

Imaging results shown in Fig. 2 demonstrate a well-defined separation between the iodine-perfused cartilage and the underlying trabecular bone structure without requiring any manual segmentation. In addition, they allow quantifying the contrast medium concentration, reflecting the GAGs gradient naturally found across the cartilage, which can be considered as an indicator of the health state of the tissue. Compared to acquisitions CEµCT performed a commercial scanner based on a conventional integration detector (SkyScan 1072, SkyScan, Aartselaar, Belgium) and similar X-ray tube parameters and exposure, SµCT images demonstrate quantitative material discrimination capabilities and comparable spatial resolution.
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