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Measurement of Features from Tomographic Images of Materials Structures

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In materials' science, as well as in other research fields, the Euler number (or its density) is used as a characteristic describing the connectivity of the components (constituents) of a composite material or the pore space of a porous medium, see [1].
From a theoretical point of view the Euler number of a 3-dimensional set X in the Euclidean space is a basic quantity of integral geometry. By means of Crofton's intersection formulae, the intrinsic volumes (e.g. the surface area, the total length of curved fibres, the mean breadth of a particle, the integral of Germain's curvature) can be expressed in terms of the Euler numbers of intersections of X with lines and planes, respectively. This is the basis of the measurement of the quantities in 3d-image analysis.
The observation of a set X on a homogeneous point lattice implies a discretization of the Crofton's formulas. This leads to an efficient expression of the intrinsic volumes as a scalar product of two vectors. The fist vector depends on the image. Its components (the frequencies of pixel configurations) can easily be measured by a marching cube method. The second vector is independent of the image. Its components depends on the lattice spacings (lateral resolution), the adjacency system assumed for the pixels and the quadrature rule applied in the numerical computation of the integrals occuring in Crofton's formulas [2,3].
The approach basing on Crofton's intersection formulas has clear advantages over other methods where the weights are determined more or less empirically. It leads to higher accuracy of measurement, it can be applied to a wide range of features and it supplies multigrid convergence under weak conditions for the discretization of the set X.
The applicability of the method is demonstrated for a wide range of materials, e.g. open foams, fleeces and autoclaved aerated concrete.

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Absorption-contrast synchrotron-radiation-based micro computed tomography in medicine, biology, and materials science

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Synchrotron radiation sources offer high photon flux in a wide spectral range. Although monochromators considerably reduce the flux, they allow realizing a tuneable X-ray source. Because the X-ray absorption strongly depends on the photon energy, tomographic imaging can be performed under optimized conditions, where the sample is semitransparent and beam hardening is significantly suppressed.
Clinically applied tomography has a spatial resolution of 0.4 mm at maximum. Blood vessels with diameters on the micrometer scale, which play e.g. a crucial role in neo-vascularization are invisible. Biopsies or tissue samples of sacrificed animals are matter of research in micro computed tomography. For hard tissue (bone) the relatively simple laboratory systems using bremsstrahlung are often well suited. But the quantitative analysis of bony tissue around Ti-explants already requires the monochromatic synchrotron radiation [1].
The microstructure or morphology of soft tissue and biological cells is much more difficult to visualize because the differences in absorption are extremely small. Appropriate staining protocols, however, allow uncovering the structures of interest. For example, the capillaries, i.e. the smallest blood vessels, can be stained by sulphate particles of micrometer size [2]. Binding gold chemically to the cell membranes, the morphology of individual biological cells seeded on three-dimensional textile scaffolds becomes to light [3]. Dedicated protocols, such as osmiumammine-B staining, even enable us to discriminate between vital and necrotic cells in clusters of millimetre size [4]. The exact three-dimensional shape of osmium-stained membranes within the cochlea can be extracted with high precision [5], because the cutting, necessary for microscopic imaging is avoided.
Recently, we discovered that several features of soft tissue are visible without staining. This includes brain tissue, where the inferior olivary nucleus shows stronger absorption than the surrounding tissue [6]. Hierarchical binning, although time-consuming, allows improving the contrast and the identification of many details [7].
Finally, the application of sophisticated computer vision tools is very helpful to make visible the morphology of features such as fatigue cracks in dental ceramics without staining [8].

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