Stochastic 3D Modeling of Tomographic Image Data

Volker Schmidt

Universität Ulm, Institut für Stochastik

The morphological microstructure of complex porous or composite materials is closely related to their physical properties, in particular with transport processes of gases, fluids, or charges, and with degradation mechanisms occurring in these materials. Thus, the systematic development of ‘designed’ morphologies with improved physical properties is an important problem which has various applications, e.g., in batteries, fuel cells, and solar cells. Mathematical models from stochastic geometry can help to solve this problem, since they can be used to provide a detailed, quantitative description of complex microstructures in existing materials. Moreover, systematic modifications of model parameters and the combination of stochastic microstructure models with numerical transport models offer the opportunity to construct new ‘virtual’ morphologies with improved physical properties, using model-based computer simulations.

In this talk we present a new approach to stochastic segmentation and modeling of 3D images, which show complex microstructures reconstructed by electron or synchrotron tomography. Using a multiscale approach, it is possible to decompose complex microstructures into several (less complex) components. In particular, a macroscale component is determined by morphological smoothing, which can be represented by unions of overlapping spheres. This leads to an enormous reduction of complexity and allows us to model the macroscale component by random marked point processes, which is one of the most fundamental classes of models in stochastic geometry. On the other hand, by the morphological smoothing, a small fraction of voxels is misspecified. The set of these misspecified voxels is interpreted as the microscale component of the microstructure. It is modeled separately, using random particle systems of Cox type. Finally, integrating the microscale model into the macroscale model, a complete stochastic model is obtained for geometrically complex 3D morphologies.