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Identification of individual fibers from 3d digital images

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Fibrous structures are present in many materials, including non-woven filter media used for filtration, carbon-fiber reinforced plastics or glass-fiber reinforced plastics used in mechanical applications, or gas-diffusion layers used in fuel cells. Spatial distribution, orientation, length, curvature and center line of fibers in materials like these are essential characteristics needed to know in modern material design. Being able to analyze these properties from micro-CT scans is highly important to create precise models of existing materials.

Most algorithms currently used to extract the statistics of the fiber orientations [1, 2, 3] first split the image space into many small fiber segments and try to recombine the over-segmented fiber segments afterwards. These methods lack accuracy, because they often connect fiber center lines incorrectly. The center line determination is especially challenging in places where two or more fibers touch.

We propose a machine learning based algorithm to identify and extract the individual fibers in segmented 3D images to be able to fully characterize the fibers and the overall composition of a material. Machine learning based on deep neural networks requires massive amounts of training data, in our case known fiber center lines. One approach could be to create these manually. However, this is not feasible for 3d data sets. Instead, we use GeoDict's [4] fiber structure modelling capabilities and scripting capabilities to generate training data sets, which consist of voxelized 3d fiber models and analytically known fiber center lines.

When applied to a micro-CT scan, the trained neural network first labels the contact voxels (or bond points in the case of bonded fibers) between two fibers. Second, the labeled contact voxels are removed from the segmented image. In the final step, the resulting connected components are analyzed, and a skeleton-based approach is used to obtain analytic descriptions of every fiber. The center lines can then be used to analyze the material, e.g. to find spatial distributions, fiber orientation, fiber length, fiber curvature, etc. It is also possible to create a beam element model of the original micro-CT scan.

References

- [1] R. Thiedmann et al., "Stochastic 3D Modeling of the GDL Structure in PEMFCs Based on Thin Section Detection.", Journal of The Electrochemical Society, vol. 155, 2008.
- [2] G. Gaiselmann et al., "Extraction of curved fibers from 3D data." Forum Bildverarbeitung 2012. KIT Scientific Publishing, 2012.
- [3] H. Zauner et al. "3D image processing for single fibre characterization by means of XCT." Acta Stereologica, 2015.
- [4] GeoDict, the Digital Material Laboratory, www.geodict.com.

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