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High Fidelity Geometric Modeling and Mesh Generation for Computational Mechanics

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Summary

High fidelity geometric modeling and mesh generation play a critical role in computational mechanics. This paper presents four main meshing pipelines, explaining how to construct analysis-suitable geometric models and meshes for applications in computational mechanics, especially quality piecewise-linear 2D/3D meshes and solid NURBS (Non-Uniform Rational B-Spline) construction from volumetric imaging data.

The first meshing pipeline starts from imaging data, which are often of poor quality and make it difficult to generate quality meshes for regions of interest. To circumvent this problem we pass the raw imaging data through a preprocessing pipeline where the image quality is improved by enhancing the contrast, filtering noise, classifying, and segmenting regions of various materials. The improved imaging data is then fed to the meshing software developed by Zhang, LBIE-Mesher (Level-set Boundary Interior and Exterior Mesher), to construct 2D or 3D finite element meshes. The mesh quality is improved before finite element simulations, and this octree-based meshing approach has been extended to mesh a domain with multiple materials. Given geometry (Pipeline 2) or PDB data (Pipeline 3), we first construct volumetric density map using signed distance function or a summation of Gaussian Kernel function, then use LBIE-Mesher to generate various kinds of meshes. The last pipeline is to construct solid NURBS for cardiovascular system. The surface model is extracted from the processed imaging data, and the vessel path is obtained after skeletonizing the volume bounded by the surface. A skeleton-based sweeping method will then be used to generate hexahedral control meshes for solid NURBS construction and isogeometric analysis.