Cell Shape Matters: Enabling Physical Simulations with Realistic Subcellular Geometries Derived from Electron Microscopy

Abstract:
Recent advances in electron microscopy have, for the first time enabled imaging of single cells in 3D at a nanometer length scale resolution. An uncharted frontier for in silico biology is the ability to simulate cellular processes using these observed geometries. However, this will require a system for going from EM images to 3D volume meshes which can be used in finite element simulations. In this paper, we develop an end-to-end pipeline for this task by adapting and extending computer graphics mesh processing and smoothing algorithms. Our workflow makes use of our recently rewritten mesh processing software, GAMer 2, which implements several mesh conditioning algorithms and serves as a platform to connect different pipeline steps. We apply this pipeline to a series of electron micrographs of dendrite morphology explored at three different length scales and show that the resultant meshes are suitable for finite element simulations. Our pipeline, which consists of free and open-source community driven tools, is a step towards routine physical simulations of biological processes in realistic geometries. We posit that a new frontier at the intersection of computational technologies and single cell biology is now open. Innovations in algorithms to reconstruct and simulate cellular length scale phenomena based on emerging structural data will enable realistic physical models and advance discovery.