Meshing Cardiac Tissue Cell by Cell

Mark Potse

Université de Bordeaux, Inria, CNRS UMR 5251
Bordeaux, France

Many cardiac arrhythmia originate in scarred or myopathic tissue where sparse networks of surviving myocytes can set the stage for unidirectional block and microscopic reentrant circuits. These phenomena can only be simulated faithfully with models that represent the tissue cell by cell. As such simulations are becoming computationally feasible, there is a growing demand for realistic three-dimensional meshes of the myocardium, which represent the shape of the individual cells and their interconnections.

To be comparable to experimental conditions, such meshes must represent thousands to millions of cells. Current imaging data are too limited in either size or resolution to derive such meshes. Therefore I developed methods to produce entirely synthetic meshes. First, a random network of cell centers and links is created. A volumetric mesh covering the tissue volume is then divided between the half-links. The cell membrane is obtained by discretizing a level set, while retaining the subvolumes, and the resulting intracellular volumes are combined into cells. This method was parallelized so that thousands of small volumes can be built simultaneously. A tailored parallel remesher ensures that the combined mesh is of sufficient quality.

With these methods, it has been possible to mesh more than 10 cubic millimeters of tissue, with more than 60 thousand cells and nearly 2 billion tetrahedra. These meshes are being used to test the newly implemented intracellular-membrane-extracellular (EMI) simulation functionality in openCARP, a widely used cardiac simulation code. This work opens the way to cell-by-cell models of complete rodent hearts in the near future.