Mesh generation for the simulation of water diffusion in brain tissue

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Diffusion MRI encodes the water diffusion in tissue at the voxel level. The tissue structure in a voxel of the brain gray matter is geometrically and organizationally complex, but in a rather special way. In a voxel of 2mm x 2mm x 2 mm, the MRI signal is averaged over many neurons, glial cells (that can be modeled by spheres), and the extra-cellular space. Neurons have a solid cell body, 1 to 10 μm in diameter. Attached to the neuron body are axons (cylinders) and dendrites (trees) that measure, respectively, 0.5 and 0.9 μm in average diameter, and 100s μm in length; The extra-cellular space is very thin and geometrically complex. The extra-cellular space occupies 6% of brain cortex volume and is 10–30 nm in width. It is "hallowed out" by spheres, cylinders and tree objects (neuron bodies=12% of volume, axons=34% of volume, dendrites =35% of volume). The cells are permeable meaning water can move between the cells and the extra-cellular space. The main challenge is to understand diffusion in a volume containing many embedded interfaces that are the surfaces of arbitrarily oriented and densely packed trees-shaped cells. I will describe some of the progress we made in this direction and future challenges.