

## I. Research goals

The morphology and distribution of dendritic spines are correlated with disease, substance abuse, and aging; but a quantitative understanding of this correlation has been elusive. A growing array of tools is available to study this through simulation, but this requires quality models. We produce, from stacks of electron microscopy (EM) images, quality surface meshes from which we generate derivative models suitable for various simulation environments.



### II. Surface mesh reconstruction



Our pipeline of algorithms converts EM images to spatially realistic models of neuronal processes. There are four main phases. The first two deal with 2D processing. The third bridges the gap from 2D to 3D. The last two process the 3D data to render simulation quality surface meshes as well as reduced models.

Our criteria for surface mesh models that are suitable for analysis are derived from requirements in visualization, cable model, boundary element (BEM), finite element (FEM) and WEB-spline analysis.

- 1. water-tight
- 2. consistently oriented surface normals
- 3. non-intersecting
- 4. no mesh irregularities
- 5. manifold edges and vertices
- 6. low aspect ratio triangles
- 7. topologically correct

Components are singly reconstructed from the contours [1]. Contours are shown in red on the image slices. Components are added to the full reconstruction forming a tightly packed block of geometries.

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# Analysis-ready meshes of neuronal forests\* CVC: John Edwards, Alexander Rand, Chandrajit Bajaj\*\* SALK: Justin Kinney, Terrence Sejnowski, Tom Bartol CLM: Daniel Johnston, Kristen Harris





Because components are traced independently of each other, 2D overlap errors can occur and must be curated



Because of tight packing and high tortuosity, interpolation between slices frequently yields inter-component intersections that must be curated [2].



### With intersections removed we can now run our mesh improvement algorithm, which includes both decimation and smoothing.



Triangle quality histograms before and after mesh im- Table of tiling timing and triangle provement. The ratio of an equilateral triangle is equal to 1.

### **III.** Visualization



Our VolumeRover software visualizes geometries and volumes. An apical dendrite is shown with some transparency revealing reconstructions of endoplasmic reticulum (ER) inside. The dendrite is volume-rendered and the ER uses standard geometry rendering. Hierarchical data storage and rendering enables rendering the volume-rendered dendrite at two scales simultaneously.

http://cvcweb.ices.utexas.edu/cvc/

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dataset	slices	reconstruction	num
ualaset	SILCES	reconstruction	IIuIII
		time (s)	triangles
CA1 (axons)	116-117	78.6	50308
CA1 (axon a001)	61-160	12.2	7199
CA3 (2 dendrites)	149-150	99.1	7607

statistics.

### IV. Derivative models and simulation



A skeletonization (center) is constructed from the dendrite surface mesh (left). Cylinders (right) centered on skeleton segments are then computed using cross-sectional surface area. These cylinders are used in the cable model simulation.





Our software can tetrahedralize surface meshes. On the left is a dendrite cut-away with interior tetrahedra in purple. In the center are two axons in green and extracellular space in red. These models can be used for continuous ion density model studies (right).





Our tetrahedralizations can also be used for local discrete ion diffusion simulation.

### References

[1] C. Bajaj, E. Coyle, and K. Lin. Arbitrary topology shape reconstruction from planar cross sections. *Graphical Models and Image Processing*, 58(6):524–543, 1996.

[2] J. Edwards and C. Bajaj. Topologically correct reconstruction of tortuous contour forests. *Computer-Aided Design*, 43(10):1296 – 1306, 2011.



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