3D Segmentation of Neural SBFSEM Image Data

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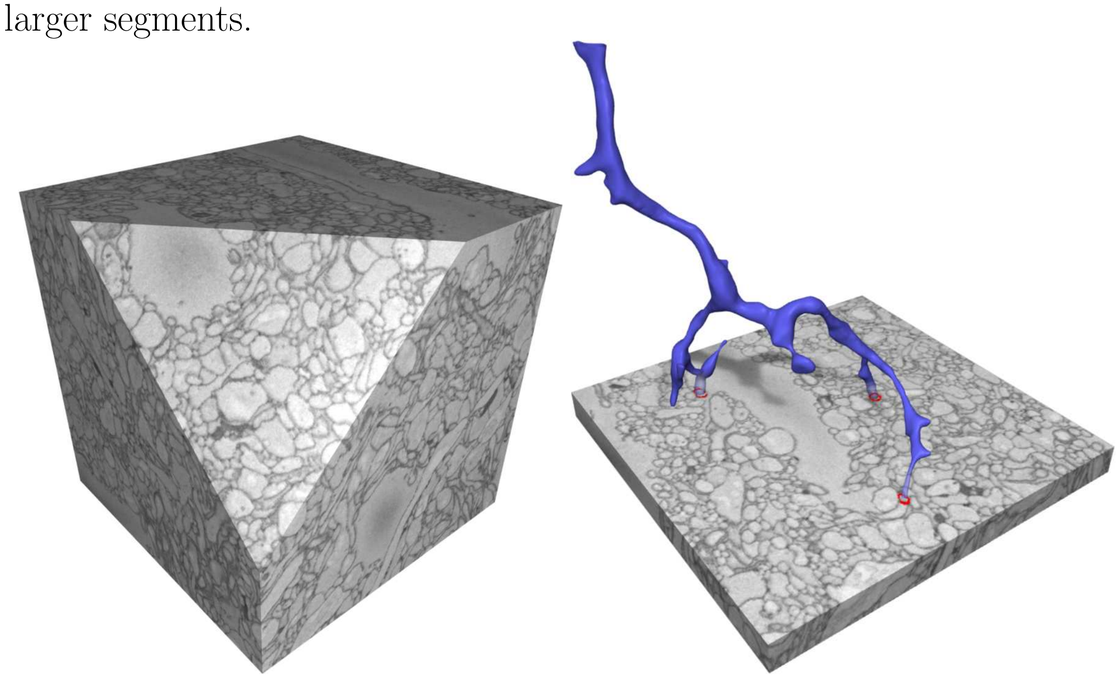
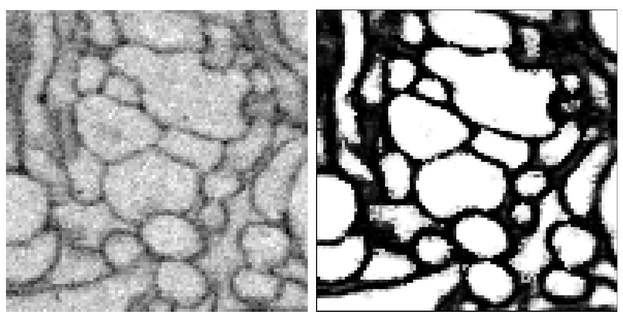
Abstract

Serial Block Face Scanning Electron Microscopy (SBFSEM) has made it possible to obtain 3D imagery of nervous systems at an isotropic resolution of 25 nm per voxel. SBFSEM has thus opened the door to the reconstruction of complete neuronal circuits. The segmentation of SBFSEM imagery is however challenging because the thinnest neuronal structures measure only 50 nm in diameter. We propose a hierarchical approach where the volume is first over-segmented into supervoxels. In the second stage, global optimization in a graphical model merges supervoxels into larger segments.



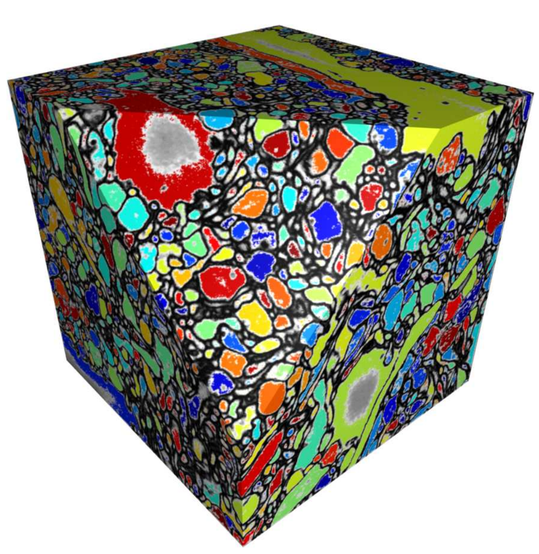
Voxel Classification

- Bank of rotation invariant 3D filters
- Training set of 100^3 voxels manually traced by experts
- Supervised learning of a random forest classifier

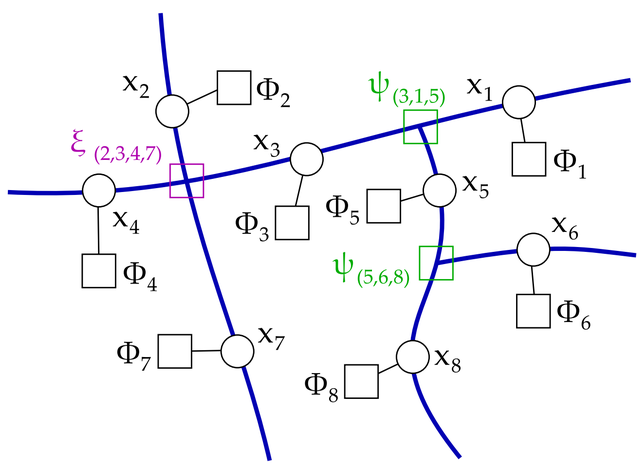


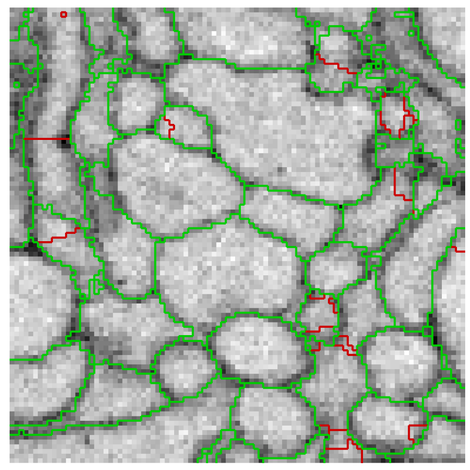
3D Over-Segmentation

- Marker-controlled watershed segmentation
- Elevation map: probability map of the random forest classifier
- Markers: connected components of voxels representing cell membranes with a probability inferior to 0.2%



Supervoxel Boundary Classification



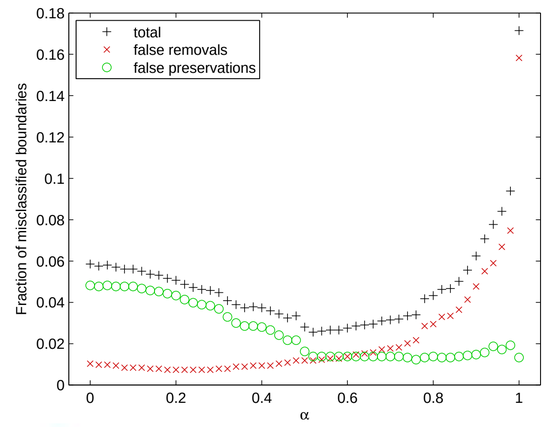


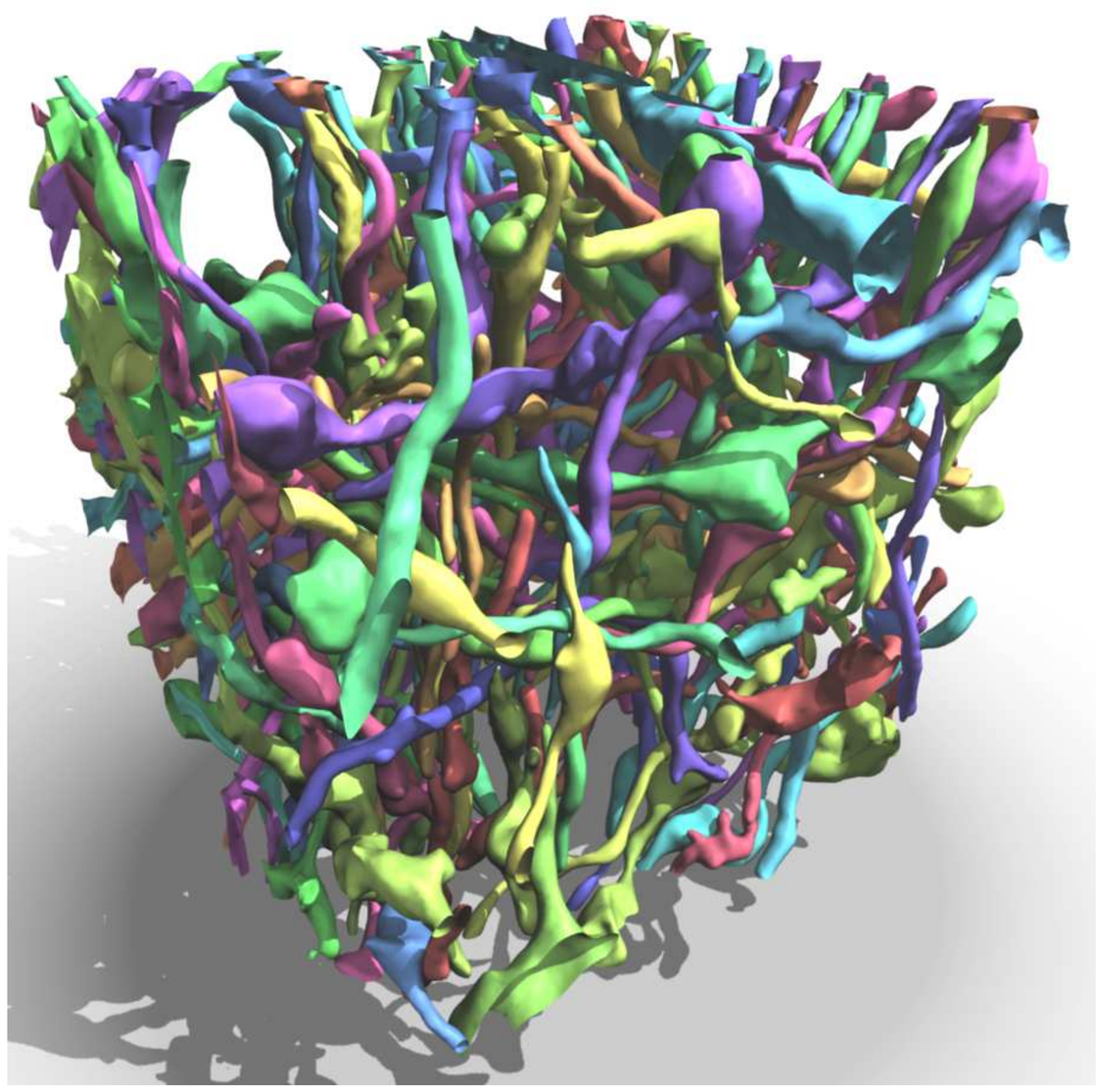
The graphical model has one variable $x_j \in \{0,1\}$ for each boundary. Unary potentials $\phi_j : \{0,1\} \to \mathbb{R}^+$ capture the predictions of a boundary classifier. 3rd order potentials $\psi_c : \{0,1\}^3 \to \mathbb{R}^+$ encode the predictions of a classifier trained to distinguish configurations of three adjacent boundaries. 4th order potentials $\xi_c : \{0,1\}^4 \to \mathbb{R}^+$ ensure the closedness of boundaries at curves where four supervoxel boundaries meet.

$$E(x) = (1-\alpha)\sum_{j=1}^{N}\phi_j(x_j) + \alpha\sum_{c=(r,s,t)\in B_3}\psi_c(x_r,x_s,x_t) + \alpha\sum_{c=(r,s,t,u)\in B_4}\xi_c(x_r,x_s,x_t,x_u)$$

Results

- The geometry at boundary intersections is exploited.
- Global optimization outperforms both local classification of boundaries and classification from only geometric features.
- 3D reconstructions are facilitated.





References

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[3] W. Denk and H. Horstmann, "Serial block-face scanning electron microscopy to reconstruct three-dimensional tissue nanostructure," *PLoS Biology*, vol. 2, pp. 1900–1909, Nov 2004.

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