An Interactive Framework for Reconstructing 3D Neuronal Structures

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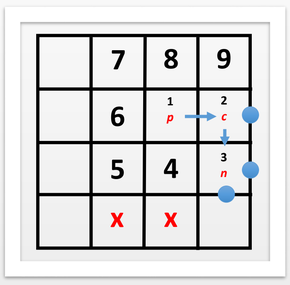
KEY CONTRIBUTIONS

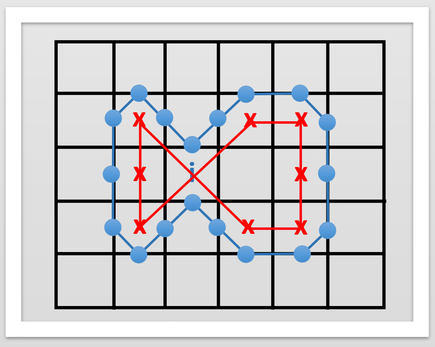
- an integrated framework for neuronal surface reconstruction with minimal user investment to generate a flexible reconstruction.
- a robust system for extracting boundary polygons within 2D images independent from imaging modalities
- a modification of the β-connection algorithm to reconstruct the neuronal surface with correct branching from a set of contours
- a novel approach to handle discontinuities in dye stained structures of neuron to produce a connected model.

CONTOUR EXTRACTION

- simplifies the boundary extraction process and produces non-intersecting closed boundary polygons.
- uses pre-defined path templates to define the boundary of contour that ensures linking on vertices in contour are single pixel wide.



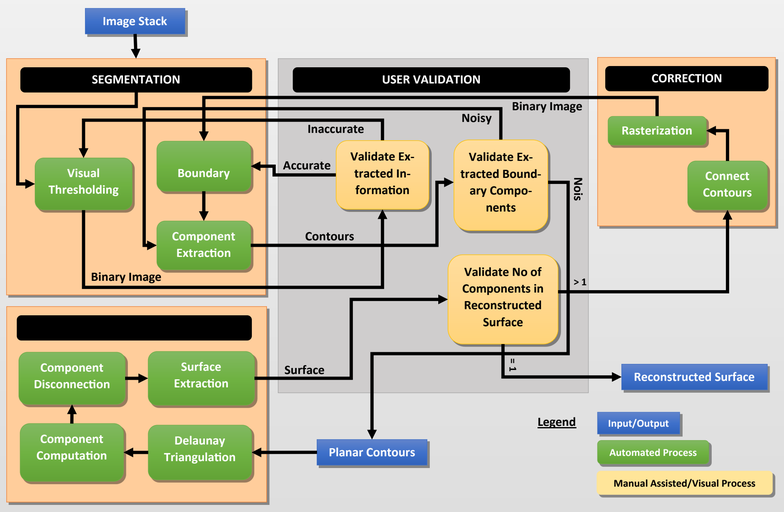
Path-template for the given ordering of unscanned pixels (p, c, n) in neighborhood



A linked boundary (blue) constructed using the path templates generates non-intersecting contours.

THE FRAMEWORK

- modularizes the task of reconstruction of the neuron structure from stack of image data.
- employs automatic methods while allowing a user to provide expert input if the results are unsatisfactory.
- requires only numerical input parameters to guide the reconstruction process
- provides visual tools for user to validate the output of automated methods.
- supports an automated pipeline with calculation of optimal driving parameters for reconstruction
- handles discontinuities to produce a connected geometric model of neuron structure.



Segmentation module extracts the boundary of neurite structures within each image.

Reconstruction module finds a best surface consistent with the extracted polygons in segmentation module.

Connection module handles the discontinuities to produce a connected model, often emerging from insufficient resolution of images.

VISUAL TOOLS FOR SEGMENTATION

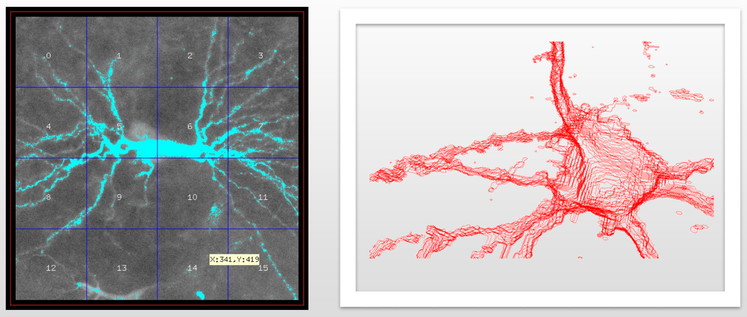
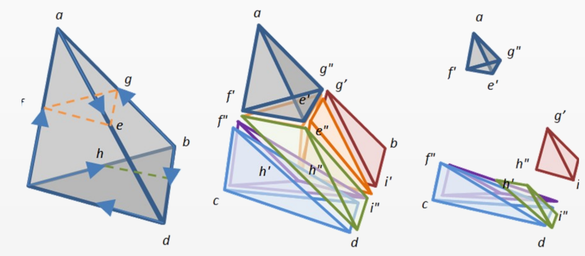
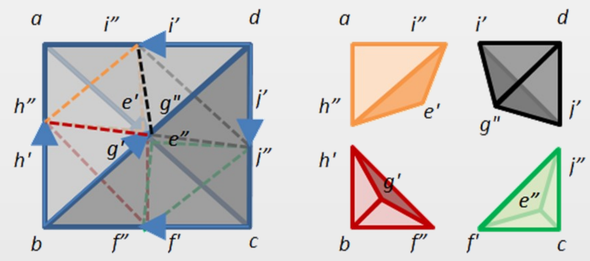


Figure 4 : Visual tools for structure extraction

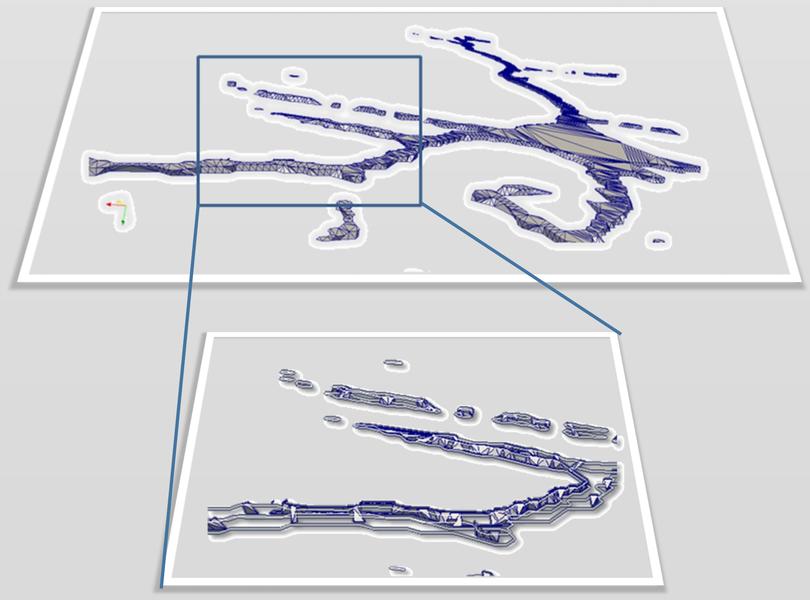
THE DISCONNECTION ALGORITHM

- A systematic disconnection method that correctly handles the branching problem in inter-slice region for reconstruction of neuron like structures.
- maintains the neighborhood around the vertex of edges which are lying on the contour ensuring that reconstructed object is a manifold.
- disconnects tetrahedra whose elimination generate singularities based on their orientation and edge classification as:
  - divides along the external and intra-section edges and then translate the vertices along these edges (as shown in figure below where cb and bd are the external edges). For tetrahedra having three of its edges lying in external region, we follow the division criteria as shown in figure below where cb, dc and bd are the external edges.





  - divides along all of its external edges and translate the vertices along these edges (as shown in figure above where ad and bc are external edges). For tetrahedra having two of its edges on contour boundary and one external edge, divides them as shown in figure on top of this section, where dc is the external edge.



Results of disconnection algorithm applied to a pair of sections in the dataset.

RESULTS

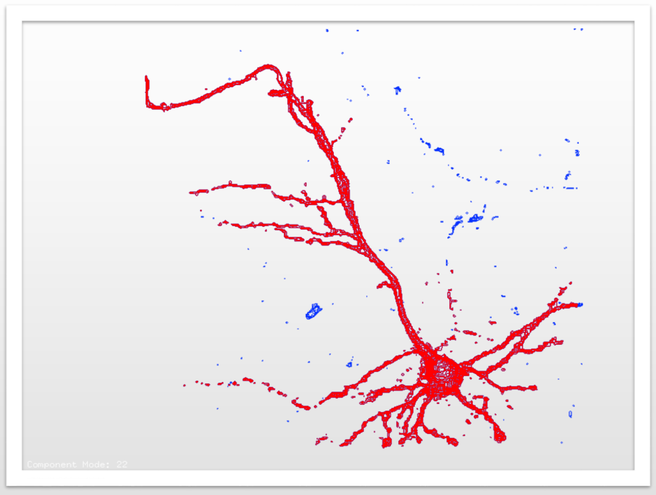


Figure 8 : Noise filter via largest component selection

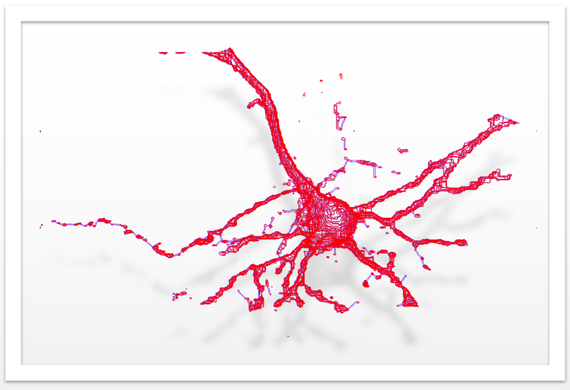


Figure 9 : Contour connection for connected model generation

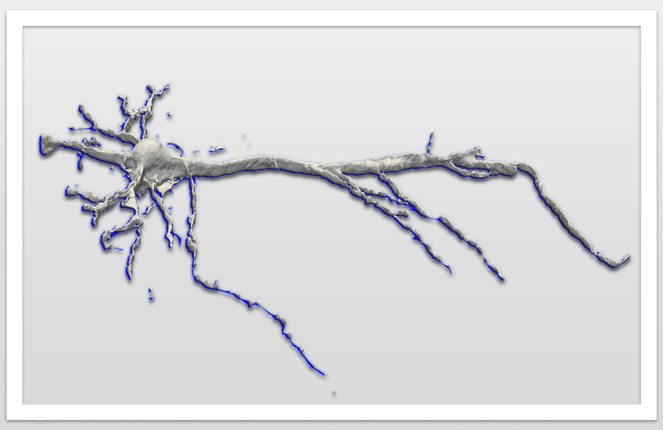


Figure 10 : Contour connection for connected model generation

ACKNOWLEDGEMENTS

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