

Trace Driven Registration of Neuron Confocal Microscopy Stacks

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Introduction

Long range connectivity studies of brain histology may one day provide insight into brain pathologies. In this work we align serial sections of confocal microscopy axonal image stacks using registration landmarks derived from in-section traces. Tissue deformations make it necessary to account for local warping in addition to the global rotation and translation of sections in the process of restoring axon continuity.

Methods

Overview

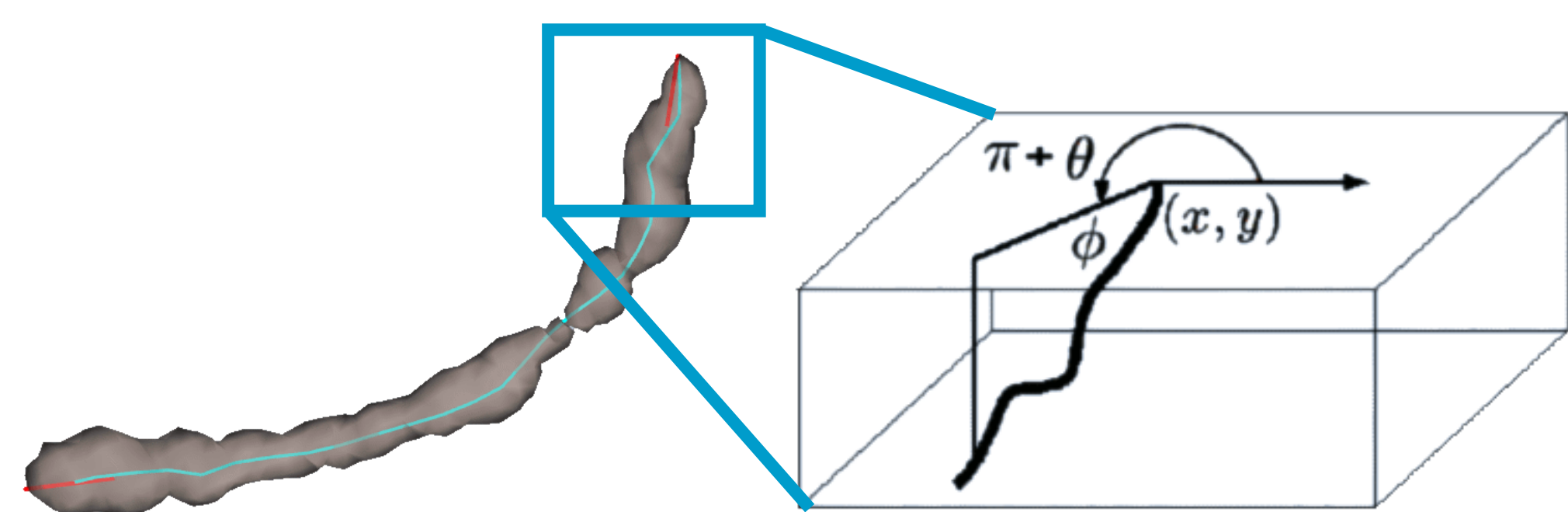
- Pair axons across sections using a metric indicating how well axons match.
- Derive stack transformations from corresponding axons.



Figure 1. Example showing 5 aligned axonal serial sections.

Calculate Centerlines

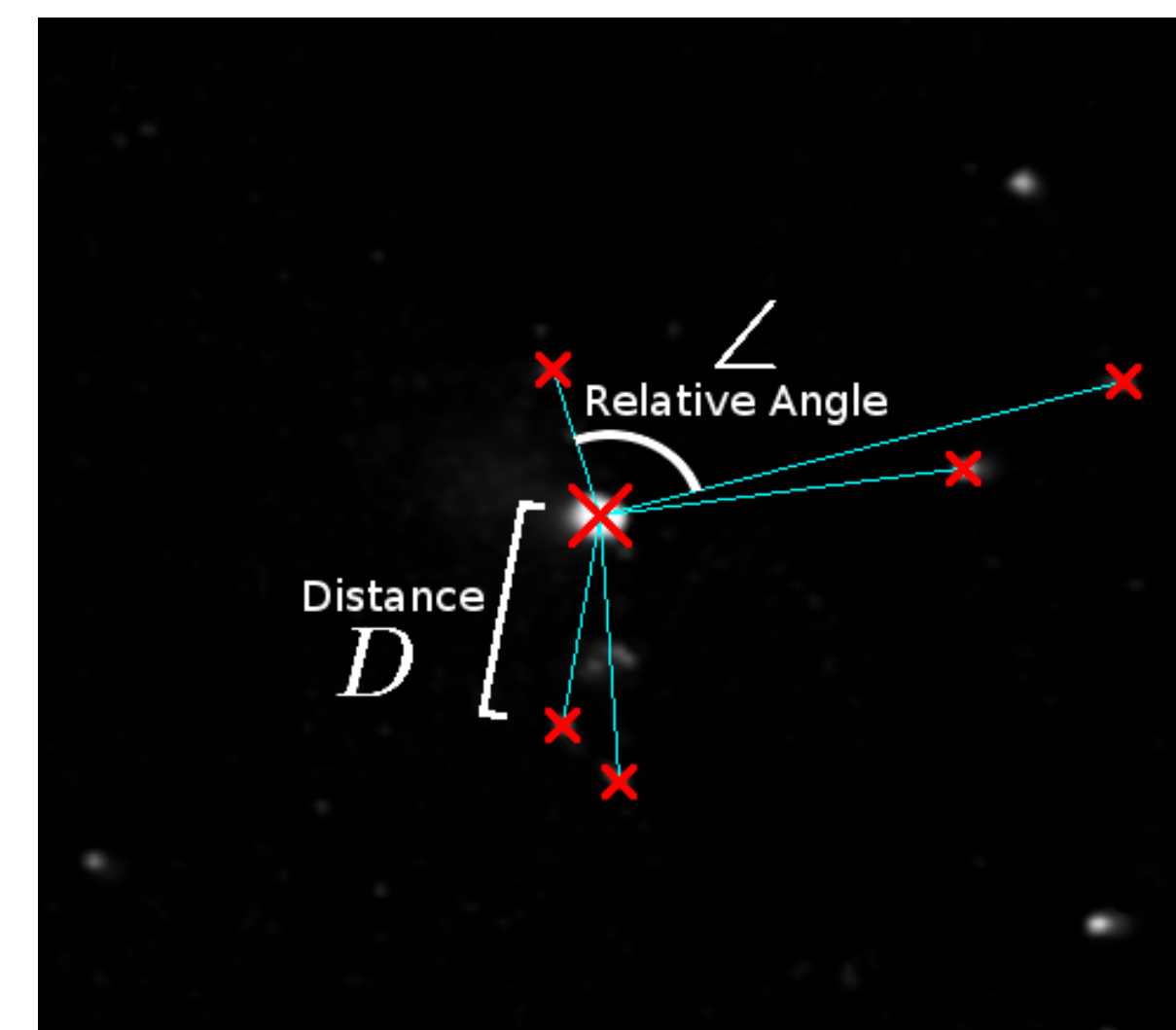
- A semi-automated approach based on the LiveWire paradigm is used for tracing centerlines.
- We extract point landmarks where axon centerlines intersect section boundaries and calculate angles that describe an axon's orientation.



Correspondence Metric

- Axons are matched according to angles of approach at the section boundaries and neighborhood configurations.
- Correspondences are assigned using weighted bipartite matching.

$$\gamma_{m,n} = \omega_1 \left(\sum_{z=1}^{k_s} |D_{m,z} - D_{n,z}| \right) + \omega_2 \left(\sum_{z=1}^{k_s} |\angle_{m,z} - \angle_{n,z}| \right) + \omega_3 (|\phi_m - \phi_n|)$$



Coarse Alignment

- A rigid transformation needs to be found to account for global rotation and translation of the sections.
- We use RANDOM SAMPLE CONSENSUS (RANSAC) and a least squares solution to the rotation/translation model in identifying correct correspondences.

Updated Correspondence Metric and Warping

- We use the knowledge that the sections are roughly aligned for refinement.

$$\Gamma_{m,n} = \omega_4 \xi_{m,n} + \omega_5 (|\theta_m - \theta_n| - \pi) + \omega_6 (|\phi_m - \phi_n|)$$

- Correspondences are again assigned using weighted bipartite matching
- We warp stacks using the interpolating thin-plate spline and use the assigned correspondences to define source/destination landmarks.

Results

Table 1. Correspondence accuracies

Stacks	Before Rigid Transform	Before Non-Rigid Transform	
		Nearest Neighbor	Our Method
1 & 2	6/35 (17.1%)	28/35 (80.0%)	33/35 (94.3%)
2 & 3	6/47 (12.8%)	31/47 (66.0%)	37/47 (78.7%)

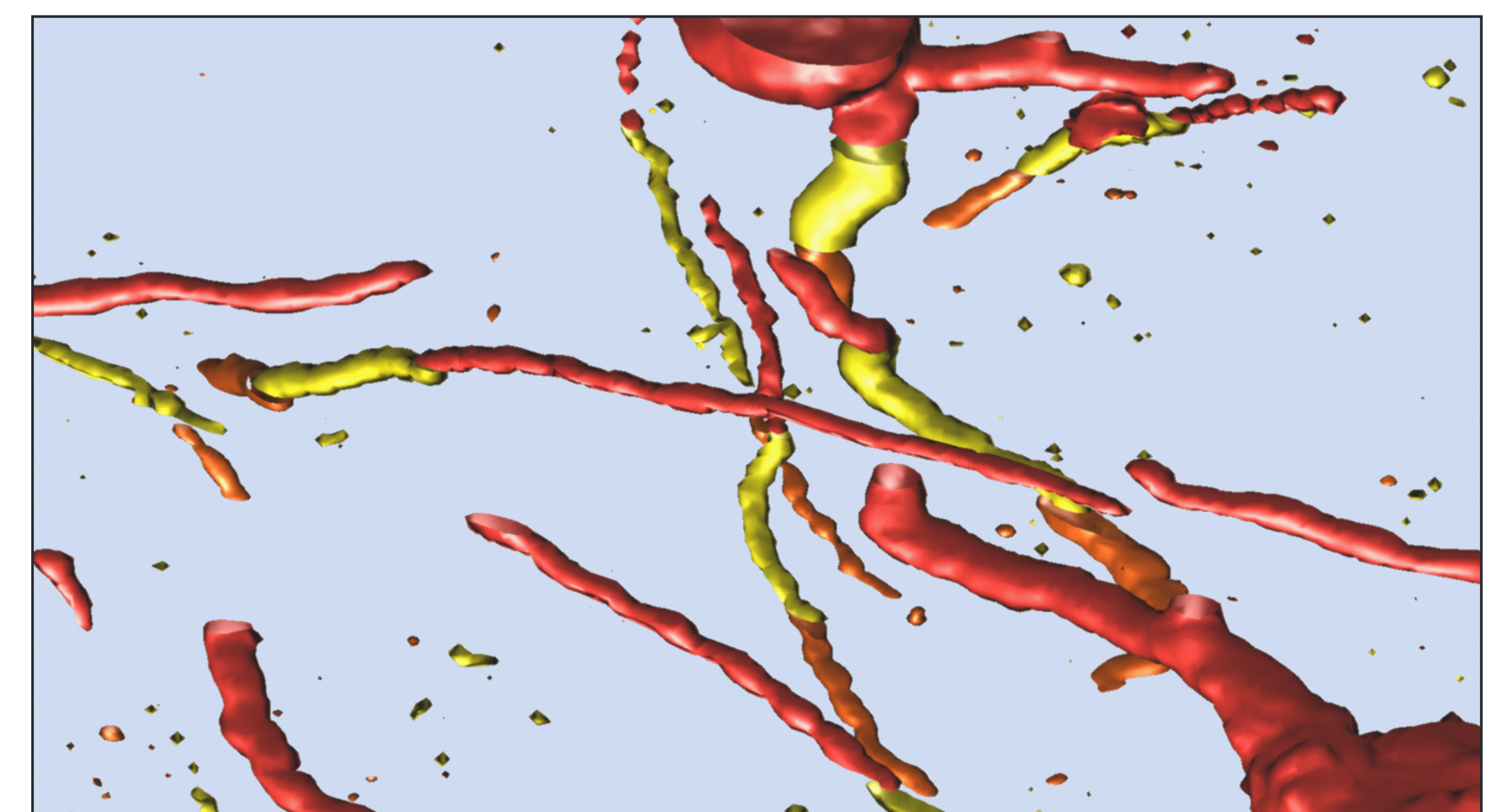
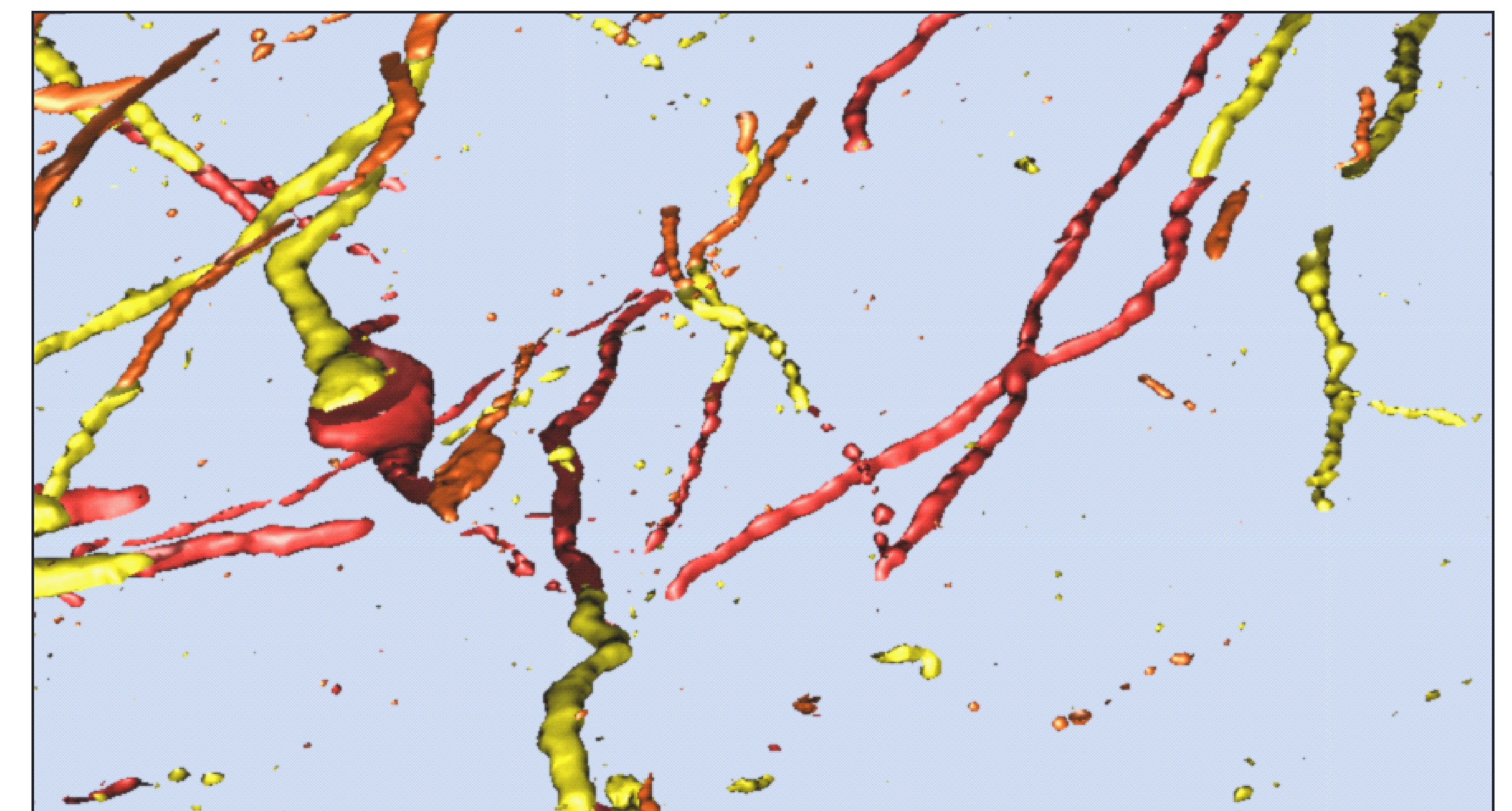


Figure 2. Two regions of 3 aligned axonal serial sections using the method presented. Each section is assigned a different color.

Acknowledgments

This work was supported under NIH grant 1RC1NS069152-01: A Computational Framework for Mapping Long Range Genetic Circuits