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Large-scale computational reconstruction of three-dimensional neural connectivity

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This project addresses the problem of building three-dimensional (3D) connectivity maps for neurons from sectional electron microscopy. Sectional data consists of a stack of very high-resolution, two-dimensional images that are oriented to capture cross sections of elongated neuronal processes. High magnification serial microscopy images have the potential to expand the field of neurophysiological modeling by providing ground-truth neuroanatomical data. However, their complexity and vast size make them impractical for human interpretation.

The work focuses on two driving biological applications. The first application is the development of complete connectivity maps for ganglion cells in the mammalian retina. About 15 ganglion cell classes are arrayed in a planar ganglion cell layer (GCL) while the inner nuclear layer contains bipolar and amacrine cells. To better understand the organization of these cells, a retinal patch is serially sectioned in the plane of the GCL capturing multiple instances of every class. Neurons are classified by molecular phenotyping, and connections mapped in overlapping tiles using transmission electron microscopy (TEM). In the first year of the project, we have built the software tools that are necessary for the automatic assembly of 3D volumes from stacks of serial-section TEM images [1].

The second driving application is the study of the organization of axons in the optic tract of the wildtype and mutant zebrafish. 3D cell segmentations can divulge precisely how retinal axons maintain and rearrange their neighbor relationships in the optic tracts. Optic tract axons are mapped in whole embryonic zebrafish brains using a new sectioning/imaging technique called serial block-face scanning electron microscopy. In the first year of the project, we have built an initial axon-tracking algorithm, which has been demonstrated to successfully track individual axons up to 600 slices without user intervention [2].

Project (or PI) Website

www.cs.utah.edu/~tolga

Publications

1. P. Koshevoy, T. Tasdizen, R. Whitaker, B. Jones and R. Marc, “Assembly of Three-Dimensional Volumes from Serial-Section Transmission Electron Microscopy,” under review.

2. E. Jurrus, T. Tasdizen, P. Koshevoy, T. Fletcher, M. Hardy, C.-B. Chien and R. Whitaker, “Axon Tracking in Serial Block-Face Scanning Electron Microscopy,” under review.