A COMPUTATIONAL FRAMEWORK FOR MAPPING OF NEURAL CIRCUITRY

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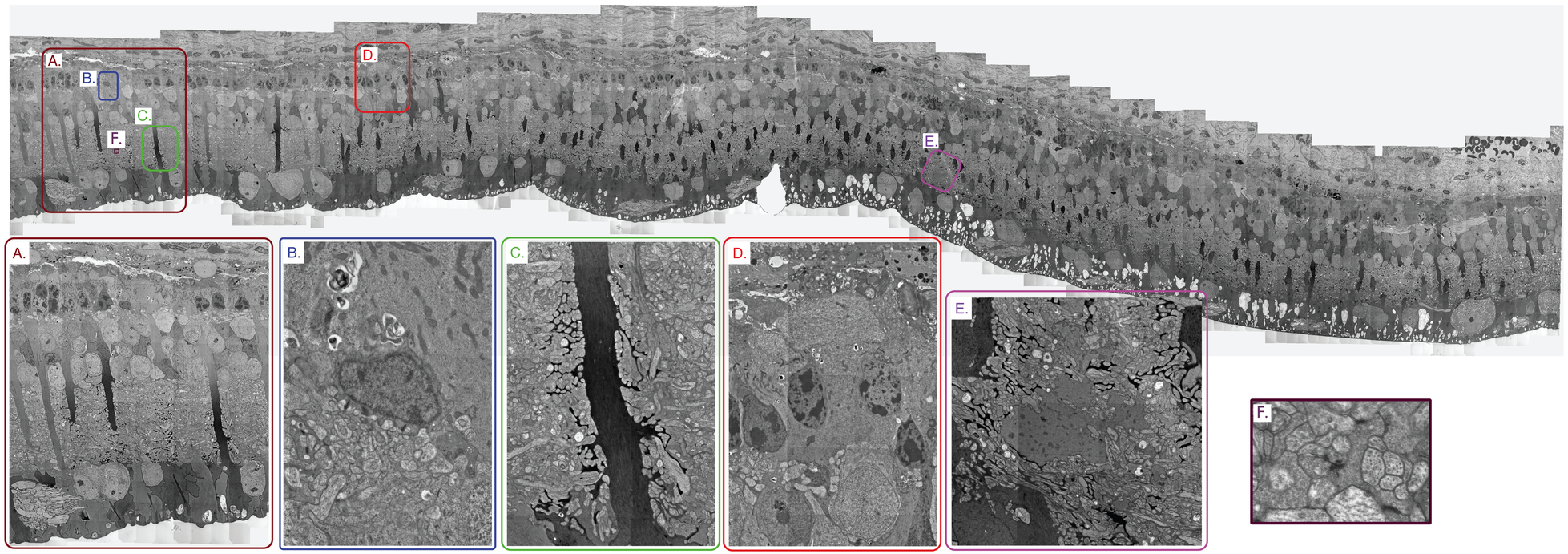

Figure 1. Image of a transgenic rabbit retina is a mosaic of over 2200 separate TEM assembled in a completely automated fashion through solutions derived from the previous funding phase of this project. Each tile is an image with approximately 4000 x 4000 pixels. Insets show several areas at varying levels of zoom to demonstrate the amount of information available in the mosaic.

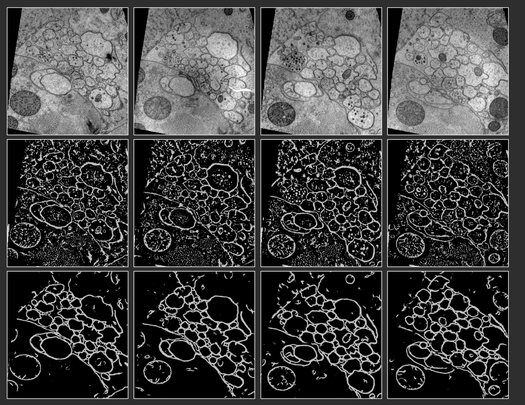

Figure 2.
Row 1: Cross-section of the ventral nerve cord from a nematode C. elegans acquired using EM.
Two demonstrated segmentation techniques:
Row 2: Thresholded boundary confidences from a single artificial neural network trained using Hessian eigenvalues[3]
Row 3: Artificial neural networks, run in serial, trained using stencils and auto-context[5]

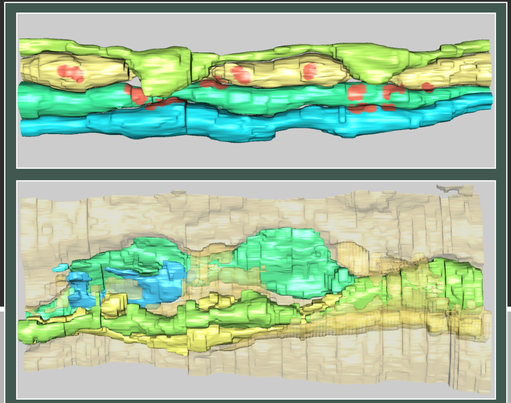

Figure 3. Reconstruction of the ventral nerve cord (top) and nearby muscles (bottom) of the C. elegans.

Introduction

Deciphering and reconstructing complete neuronal networks is one of the grand challenges in neuroscience. Defining connectomes or complete network maps for canonical regions of any tissue requires robust cataloguing of classes, mapping of statistically distinct patterns and tracing of characteristic connections. Serial-section transmission electron microscopy (ssTEM) is capable of providing the image data necessary for reconstructing the connectivity of large-scale neural networks. With automated image acquisition, we can now capture approximately 4000 tiles in 24hrs. There are two major computational barriers to large-scale reconstruction of neural circuity from ssTEM: volume assembly and process tracking/synapse detection.

Registration and Mosaicking Tools

In [1] we demonstrate completely automatic and robust approaches for mosaicking of TEM sections from thousands of tiles and for three-dimensional volume assembly by section-to-section registration. Our algorithm uses the shift property of Fourier transform applied at the tile to determine translations between tiles. The same property of the Fourier transform is also used at a sub-tile level to correct non-linear deformations between tiles and between sections [1,2]. Figure 1 shows a mosaic of a single-section from transgenic rabbit retina acquired and assembled with these tools. Currently, the time required for mosaicking a section is less than the time required for the acquisition of that section.

Reconstruction Tools

Tracking neuronal processes is fundamentally an image segmentation problem. The textured nature of the images due to specimen preparation renders traditional methods for medical image segmentation of little use in this application. However, the texture is due to staining of the intracellular structures which is needed for reliable detection of synapses. Mischenko has demonstrated that a perceptron learning algorithm combined with post-processing can be used for membrane detection in textured TEM images [3]. In [4,5] we show how local context information can be combined with such a simple classifier to improve membrane detection in TEM images (see figure 2). Once membranes in a section are detected, individual cells can be segmented and tracked across the volume [6] (see figure 3). Our goal is to improve the accuracy of membrane detection in TEM images to the point where the amount of user time for editing of the results becomes comparable to the image acquisition time.

References

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