Robust Adaptive 3-D Segmentation of Vessel Laminae from Fluorescence Confocal Microscope Images

by

Arunachalam Narayanaswamy

A Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the degree of

MASTER OF SCIENCE

Major Subject: Electrical Engineering

Approved:

____

Dr.Badrinath Roysam, Thesis Adviser

Rensselaer Polytechnic Institute
Troy, New York

December, 2007

ABSTRACT

The problem of accurately and completely delineating vasculature in three-dimensional (3-D) space is of central interest to a large number of biological studies ranging from neuroscience, tumor biology, stem-cell niches and cancer stem-cell niche studies. Once delineated, many valuable measurements can be generated, such as the spatial distribution of various cell types within the tissue relative to the vasculature.

We consider the case when a vessel is imaged by fluorescently labeling a molecule that is specific to their inner membranous surface (laminae), rather than the lumenal volume (i.e., blood flow). Such signals are weak (often comparable to the image background), noisy, non-uniform, and low contrast. The signal exhibits gaps, and the overall structure deviates significantly from a tube model.

This paper presents a robust and adaptive method to segment vessel laminae from 3-D fluorescence confocal images. The method segments the surface without applying a higher level model (cylindrical or ellipsoidal) and has an adaptive contiguous extension algorithm to accurately segment regions of low signal-to-noise ratio. After detecting the surface voxels, it generates a 3-D mesh representation for the surface with estimates of local curvature, orientation, thickness and surface area. The method also produces relative confidence estimates of the segmentation at each surface voxel. Validation was performed using phantom images in the presence of Poisson and Gaussian noise. The adaptive algorithm proved to be very robust with an average error of about 1 voxel per face of the triangulated mesh even with a standard deviation of 90(gray scale units) for the Gaussian noise.