Rapid Segmentation of the Median Nerve for a Video-Guided Ultrasound System

Aaron Sun[1], Vikas Shivaprabhu[1], Jihang Wang[1], John Galeotti[1,3],
Vijay Gorantla[2], George Stetten[1,3]
Departments of Bioengineering[1] and Reconstructive Surgery[2], University of Pittsburgh
Robotics Institute, Carnegie Mellon University[3]

Purpose

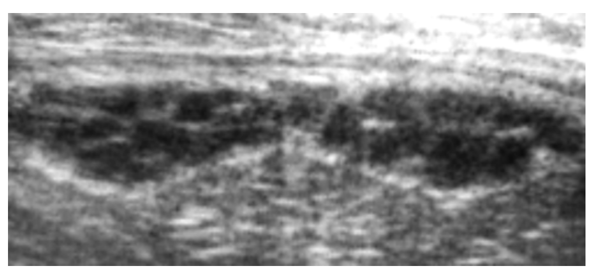
We seek to provide a rapid yet effective method towards segmentation that lends itself to parallelization through GPU technology. In this particular application, the target is identification of fascicles in 2D and 3D high resolution ultrasound scans (HRUS) of the median nerve at 50 MHz as part of a new system combining video from a probe-mounted camera with ultrasound data to monitor the progression of blood vessels and nerves after reconstructive surgery.

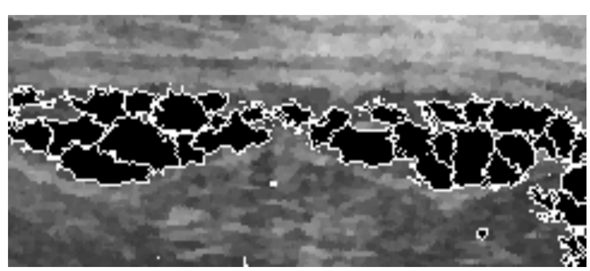
Methods

The method involves three parts: formation of pixel clusters (*patches*), identification of boundary points and medial points, and segmentation by grouping. We begin by constructing patches of homogeneous pixels using a directed graph of edges between neighboring pixels in order to reduce noise and subsequent computational cost while preserving meaningful structures. Pixel intensity as well as variance are factored into a descending variance graph, where the variance and mean are calculated within a sphere of radius *r* centered at the pixel. Each pixel points to the neighbor with the lowest magnitude of the ratio of difference in intensity to difference in variance, and the pixels in the corresponding disjoint trees set their intensities to the mean of the root pixel. Next, each patch finds the point where a line drawn between its root and the root of a bordering patch intersects the boundary between them (the *boundary point*). Given the set of all boundary points, we find *medial points* that lie equidistant from any two boundary points within a desired range of distances. For these medial points to form, the patches that the lines between the medial point and its two boundary points intersect must also meet a minimum threshold for homogeneity. Thus, medial points are a measure of association: the more medial points formed by the same pair of boundary points, the stronger the association between those boundary points. Utilizing this, boundary points are clustered into mutually exclusive *boundary point sets* by linking each boundary point with its highest N associated boundary points, where N is user-defined (in our case, 5). The final step involves matching patches to boundary point sets by having each medial point within a patch vote for a boundary point set only if that set contains both of the boundary points associated with that medial point.

Results

Segmentation of the median nerve imaged at 50 MHz was performed using 2D data (< 1 second) and reconstructed 3D data (< 7 seconds) with image sizes of 256x256 and 256x256x18. Results of a slice from the latter are shown to the right. Fascicles are identified despite noise in the original image and incomplete boundaries.





Conclusions

Our method shows effective segmentation of the median nerve in 2D and 3D in HRUS ultrasound data, with rapid computation times due to GPU implementation. Further optimization and development of these routines hold promise for our application of combining ultrasound analysis and video navigation in real time.