Finding Medial Points Using Homogeneity Ascent Graphs in High-Frequency Ultrasound

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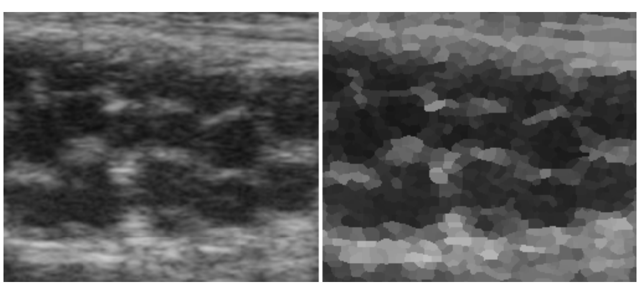
Introduction: In previous work, our laboratory has developed a framework for image analysis called Shells and Spheres (SaS), which applies statistical analysis to pixel intensity within circular (or spherical) regions around each pixel in 2D (or 3D images). We change the radius of the circle (or sphere) by adding or subtracting *shells*, yielding an efficient means to analyze the image across a range of radii [1]. We have recently developed an approach based on SaS in which spheres are first used to calculate local intensity variance. Graphs are the constructed with nodes at every pixel and edges directed between neighboring pixels pointing towards lower variance to converge at local minima in variance. We call this structure a Homogeneity Ascent Graph (HAG), since as variance decreases homogeneity increases. (Eventually other measures of homogeneity may be substituted for variance.) The HAG consists of a set of disjoint trees, each with a single root at a local minimum in variance, and separated from other such trees by relative ridges in variance. When the nodes (pixels) in each tree are all set to the mean of the root, we call the resulting homogeneous regions *HAG patches*. HAG patches tend to preserve sharp boundaries between objects while significantly reducing noise within them (see figure below). The only parameter is the radius of the sphere used to compute variance [2]. Our present goal is to cluster HAG patches to represent anatomical structures, using a medial based approach. Medialness is the property of being at the center of an object, equidistant from at least two closest points on the boundary of the object.

Materials and Methods: Our initial application is to high-frequency ultrasound imaging of peripheral nerves, capable of delineating individual fascicles, for the purpose of studying nerve damage and regeneration. Ultrasound scans of a human medial nerve were taken using a Vevo 2100 scanner from VisualSonics (with IRB consent) operating at 50MHz (resolution ~30µm). Our analysis method was coded in Java as a plug-in to the image analysis software, ImageJ.

Results and Discussion: A sample ultrasound image of the median nerve is shown in the figure below. The left panel shows the raw image, and the right panel shows the HAG patches resulting from spheres with a radius of 3 pixels to compute variance. As can be seen, boundaries are preserved while noise is reduced. Ongoing efforts to cluster HAG patches are based on the detection of medialness, by adding shells to a sphere and testing new patches as they are first encountered. Determination of whether a new patch should be included in the cluster is based on what its effect would be on the intensity variance of all the pixels in the cluster. If the new patch is determined to be unacceptable for the cluster, a nearest boundary is thus established, and the presence of other unacceptable patches in the shell establishes medialness. We have developed, and are now testing, an efficient method of conducting this combinatorial search for multiple boundaries within a shell, depending on their angular relationship to each other.



Conclusions: The contribution of our work, we believe, is to provide a rapid and effective method to find medial points in 2D or 3D images. Clusters of HAG patches around such medial points may then be used to segment anatomical structures.

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References:

[1] Shivaprabhu, V., Automated method for n-dimensional shape detection based on medial image features, M.S. Thesis, Department of Electrical and Computer Engineering, University of Pittsburgh. 2011.
[2] Stetten, G., et al. Descending Variance Graphs for Segmenting Neurological Structures. PRNI 2013.