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Automated IVUS contour detection using normalized cuts

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Abstract

A broad range of high impact medical applications involve medical imaging as a visualization tool of body parts, tissues, or organs, for use in clinical diagnosis, treatment and disease monitoring. Intravascular ultrasound (IVUS) is a medical imaging technology which uses ultrasound waves to visualize blood vessels from the inside out thus representing a valuable technique for the diagnosis of coronary atherosclerosis. IVUS provides a unique method for studying the progressive accumulation of plaque within the coronary artery which leads to hart attack and stenosis of the artery. Besides plaque geometry and morphology, this technique also provides information concerning the arteries lumen and wall. The detection of lumen and media-adventitia borders in IVUS images represents a necessary step towards the geometrically correct 3D reconstruction of the arteries. In this paper a fully automated technique for the detection of media-adventitia border in IVUS images is presented. Image segmentation approach is performed to find a partition of IVUS image into regions. The local similarity measure between pixels is computed in the intervening contour framework using peaks in contour orientation energy. When the similarity matrix is obtained, the spectral graph theoretic framework of normalized cuts is used to find image partitions. Compared to those of manual segmentation the proposed method performs reliable automated segmentation of IVUS image. Our segmentation approach is experimentally evaluated in large datasets of IVUS images derived from human coronary arteries.

Problem statement: The detection of media-adventitia border in IVUS images

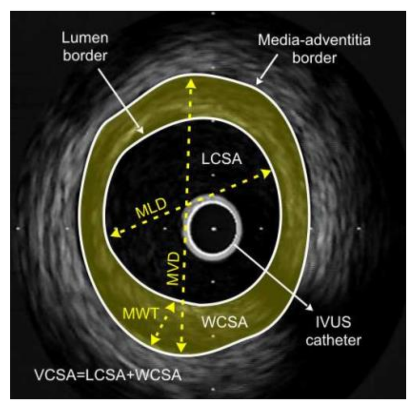


Figure 1. IVUS image with the lumen and media-adventitia borders demarcated (LCSA, lumen cross-sectional area, VCSA, vessel cross-sectional area, WCSA, wall cross-sectional area). (Reprinted from Giannoglou et al. (2007))

Other approaches:

Threshold, color-based and texture based image segmentation

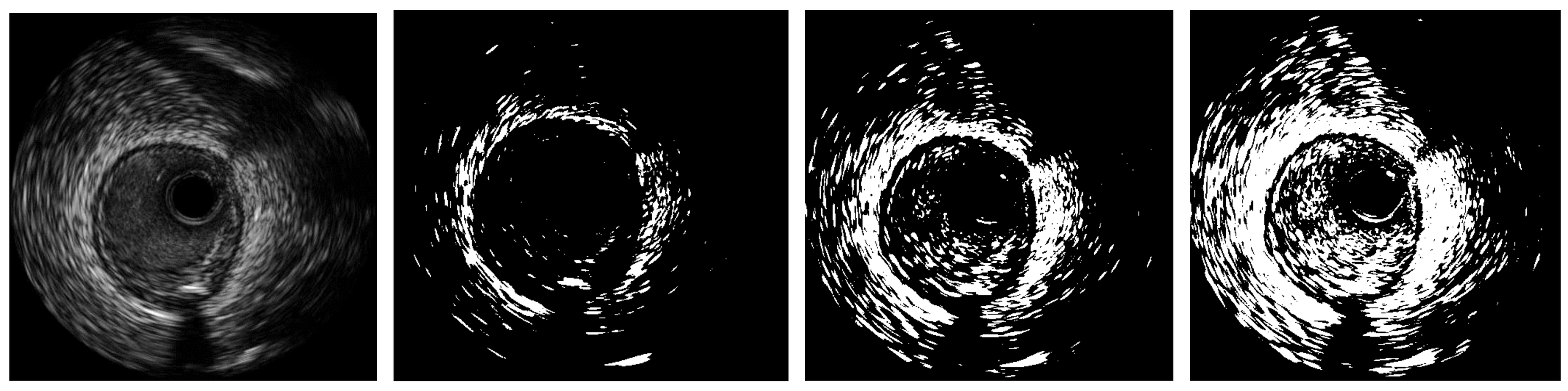


Figure 2. Original image and images with threshold

METHODOLOGY

Image segmentation based on concepts from spectral graph theory. Image is represented as a weighted graph $G = (V, E)$ where:

- V is a set of pixels
- E is a set of edges where the weight on certain edge should reflect the likelihood that the two pixels belong to one object

Image segmentation algorithm consists of the following steps:

1. **Defining the weights between vertices:** The local similarity measure between pixels i and j due to the contour cue is computed in the intervening contour framework of Leung and Malik (1998) using peaks in contour orientation energy.
2. **Graph partitioning:**
   - The optimal bipartitioning of a graph $G = (V, E)$ into two disjoint sets, A, B, is the one that minimizes the *normalized cut (Ncut)*:

$$Ncut(A,B) = \frac{cut(A,B)}{assoc(A,V)} + \frac{cut(A,B)}{assoc(B,V)},$$

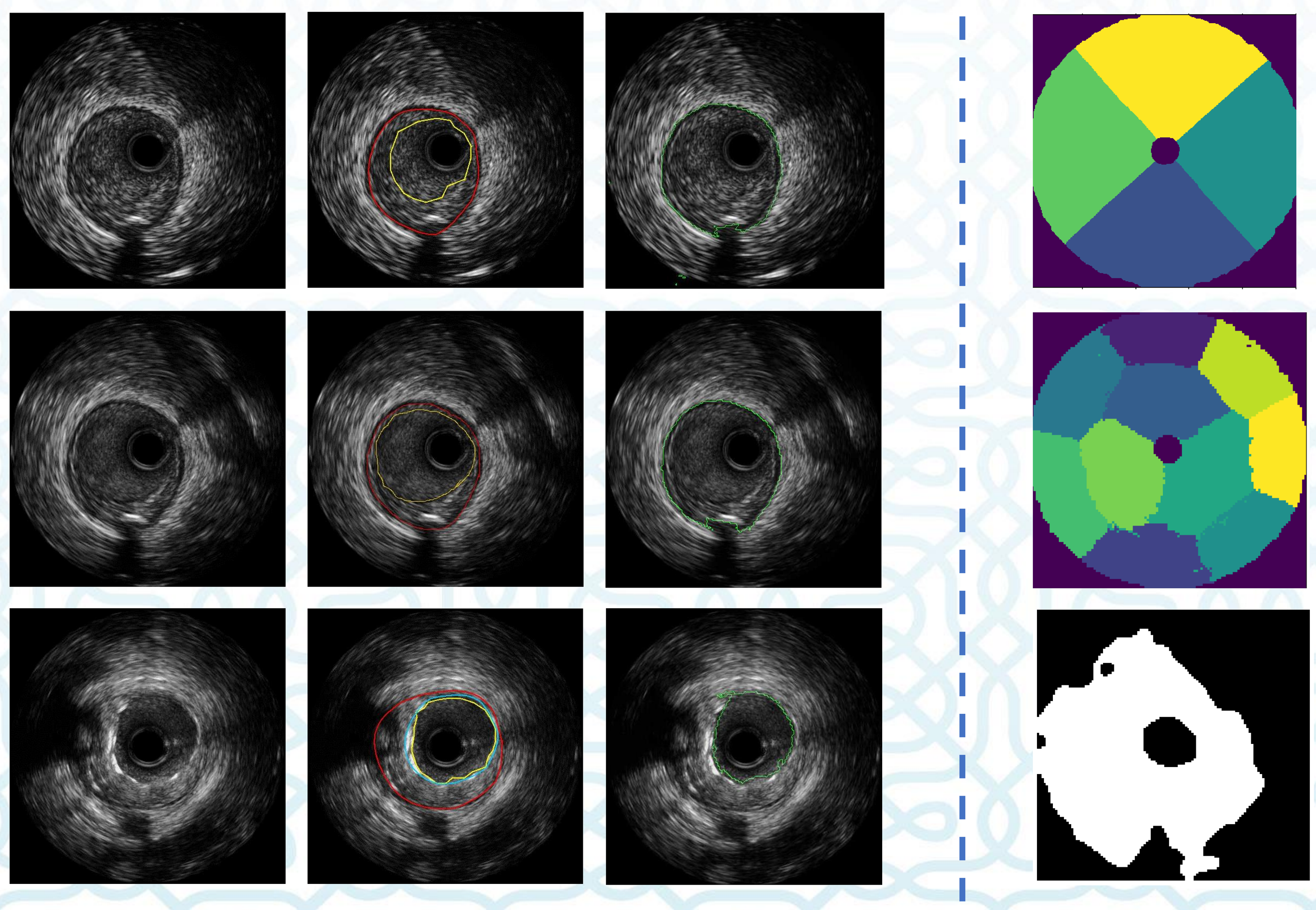
   where $cut(A,B) = \sum_{u\in A, v\in B} w(u,v)$ and $assoc(A,V) = \sum_{u\in A, t\in V} w(u,t)$ is the total connection from nodes in A to all nodes in the graph.
   - It can be shown that the second smallest eigenvector of the generalized eigensystem $(D-W)y = \lambda D y$ is the real valued solution to the normalized cut problem.
3. **Finding a partition of the image:** find the clusters in these eigenvectors by using K-means algorithm or an optimal discretization problem, which seeks a discrete solution closest to the continuous optima.

Figure 3. The leading 5 eigenvectors

RESULTS

Experiments were performed on 1000 IVUS images.

IVUS images | **Doctor's labels** | **Results** | **More baselines**



Conclusion

In this paper a fully automated technique for the detection of media-adventitia border in IVUS images is presented. Future work includes plaque and lumen border detection.

Acknowledgments

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