PREDICTIVE DIAGNOSIS OF CORONARY ARTERY DISEASE

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Abstract

Coronary artery disease is a leading cause of death in the industrialized world. By building a spatially accurate 3D model of the vasculature using image data, and of the disease using plaque characterization derived from analysis of the ultrasound signal, hemodynamic simulation of the vasculature, and enzymatic biomarkers measured by the physicians collecting the image data, we aim to build a model with which to accurately predict the development and progression of atherosclerotic plaque.

Aims

- Perform robust automated segmentation of Intravascular Ultrasound (IVUS) data sets
- Geometrically register the IVUS data with angiograms for spatially accurate reconstruction
- Perform computational fluid dynamic (CFD) analysis on the reconstruction to assess hemodynamic factors in plaque development
- Develop a model for inclusion of arterial branches in the CFD simulation that accurately depicts their impact on plaque development
- Develop and train a classifier on various clinical and demographic parameters that can make meaningful predictions about the progression of CVD on a 1 year timescale

References

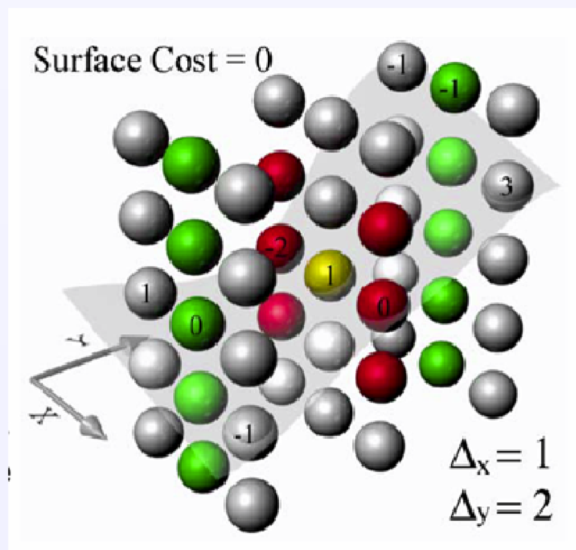
[1] Wahle A., Lopez J., Olszewski, M., Vigmostad, S., Chandran, K., Rossen, J., Sonka, M. Plaque development, vessel curvature, and wall shear stress in coronary arteries assessed by X-ray angiography and intravascular ultrasound, in *Medical Image Analysis*, 2006

[2] Li K., Wu X., Chen D., Sonka M. Optimal surface segmentation in volumetric images–a graph theoretic approach, in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2006

[3] Downe R., Wahle A., Kovarnik T., Hirak J., Skalicka H., Lopez J., Sonka M. Segmentation of intravascular ultrasound images using graph search and a novel cost function. *The 2nd International Workshop on Computer Vision for Intravascular and Intracardiac Imaging*, 2008

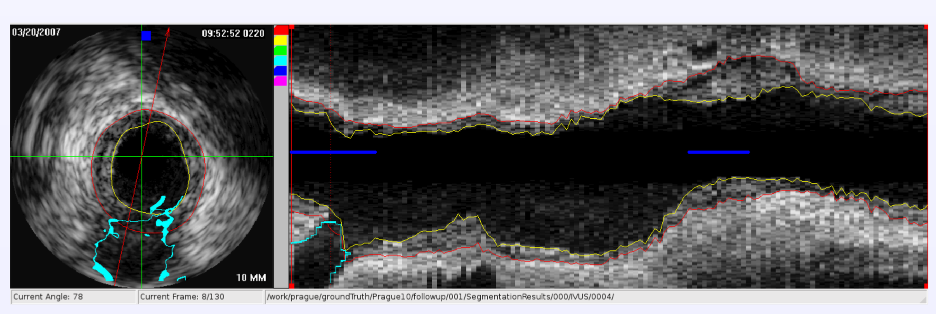
IVUS Segmentation

- Uses optimal surface detection adaptation of graph cut methods presented by Li, Wu, Chen, and Sonka[2].
- A cost function is derived from a combination of an active contour estimate (computed in 2-D, frame-by-frame) and local neighborhood information (computed in 3-D, with a spherical kernel)[3].
- Graph search produces a result that is optimal with respect to the cost function (though also at the mercy of the cost function).



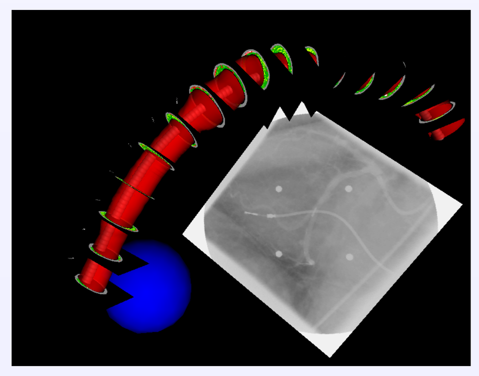
Branch Modelling

- Arteries do not in practice conform to the straight tube model of fluid flow: they have branches as they grow narrower to feed dispersed tissues throughout an area.
- Most existing CFD models of arterial hemodynamics ignore branching both to simplify the model and because of difficulty in obtaining the relevant data to add to the model.
- We aim to augment the model by segmenting the branches separately from the rest of the vessel, determining their diameter and orientation, and grafting them onto the reconstruction.



3D Reconstruction

- Computed by registering the segmented IVUS with a biplanar angiogram to derive spatially accurate represenation of vessel.
- Can be used to infer morphologic parameters of the coronary artery, such as plaque cross sectional surface area and vessel curvature.
- *Curvature index* parameter is the projection of the curvature of the centerline of the vessel onto the vessel wall at each point. This provides information about the bending of the vessel wall relative to the bending of the vessel as a whole. This features prominently in the CFD analysis in terms of analysing vessel wall shear stress and its impact upon plaque development.



CFD Analysis

- Points from 3D reconstruction are used to compose a triangular mesh.
- Surface normals are computed, ends of mesh are capped, and interior is further elaborated into a finite element volume within which fluid flow can be simulated and computed.
- Branches are grafted onto the mesh using a nearest neighbor approach at the junctions.
- Subsequent run by the CFD solver computes wall shear stress throughout the vessel allowing for detailed analysis of plaque growth and development.

Acknowledgements

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