TEMPLATE-BASED FINITE ELEMENT MESH GENERATION FROM MEDICAL IMAGES

Leila Baghdadi[1,2], Hanif M. Ladak[1,2,3], David A. Steinman[1,2,*]

[1]Imaging Research Laboratories, The John P. Robarts Research Institute, London, Canada, www.irus.rri.ca
[2]Department of Medical Biophysics, University of Western Ontario, London, Canada
[3]Department of Electrical and Computer Engineering, University of Western Ontario, London, Canada
[*]Corresponding author: steinman@irus.rri.ca, www.irus.rri.ca/~steinman

INTRODUCTION

Fluid mechanical factors have been linked to both the initiation and progression of atherosclerotic plaques; however, the exact mechanisms are not clearly understood. Currently, our laboratory is undertaking a study in which we are attempting to correlate plaque progression at the carotid bifurcation with computed fluid mechanical indices. Using black blood magnetic resonance (MR) imaging, arterial geometry and plaque distributions are measured annually in human subjects over a number of years. From each annual MR scan, finite-element meshes of the lumen geometry are generated and patterns of fluid mechanical indices are derived from computational fluid dynamic (CFD) simulations. Creating such finite element meshes requires substantial user effort, and the resulting models can exhibit variability caused by subjective modeling decisions made by the operator. In this abstract we propose a technique to minimize this by using the manually generated "baseline" finite element meshes as a template to be automatically deformed to match "follow-up" MR image data.

METHODS

The initial tetrahedral finite element mesh (e.g., Figure 1a) is first generated from the "baseline" serial MR images using the procedure previously described by Steinman et al. (2002). Briefly, a 2-D discrete dynamic contour (DDC) is used to semi-automatically extract the lumen boundary from each serial MR image. These lumen contours are then used as masks to create a binary 3-D image dataset, within which a 3-D DDC (Ladak et al., 2000) is inflated to provide the 3-D lumen boundary for subsequent octree-based generation of the tetrahedral finite element volume mesh. The deformation procedure begins by manually orienting the initial mesh within the "follow-up" MR image data. An image-based force field is calculated from the 3-D image (Ladak et al., 2000), and then used to drive the vertices of the "baseline" FE mesh to the "follow-up" lumen boundary. To keep the model smooth in the presence of noise and to maintain the quality of the finite elements for subsequent CFD simulation, at each iteration Laplacian smoothing is applied to the deformed surface triangulation and then, with the surface triangles fixed, to the volume tetrahedral elements.

RESULTS AND DISCUSSION

To test this algorithm a "follow up" dataset was created by manually deforming the lumen boundaries of the "baseline" binary 3-D image data to simulate the growth of small plaques (maximum height of 3 and 6 pixels normal to the original wall) at the internal carotid artery just distal to the bifurcation. As illustrated in Figure 1b, automated deformation and smoothing of the mesh was able to capture even a 6-pixel change in the lumen geometry. Element quality, as measured via the radii-ratio metric (Pebay et al., 2001), was found to be comparable to that of the "baseline" mesh.

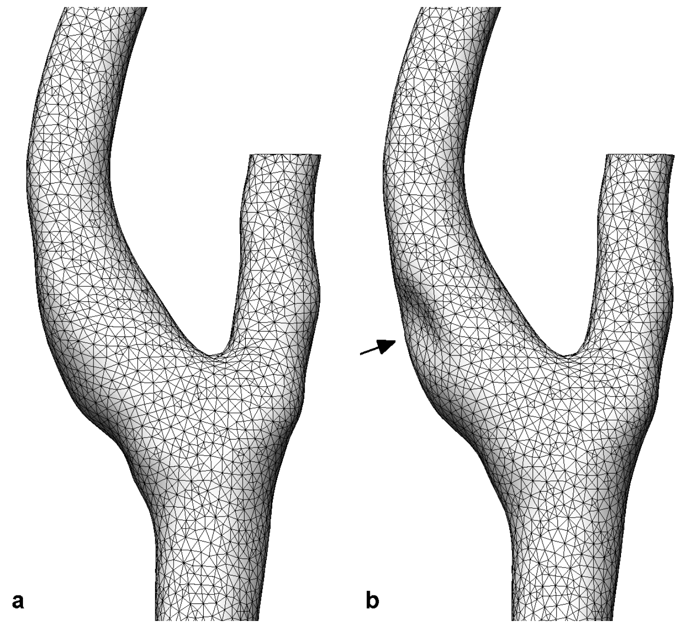

Figure 1: (a) "Baseline" finite element surface mesh; (b) Deformed and smoothed mesh after introduction of the 6 pixel high mild plaque (indicated by arrow).

SUMMARY

Our tests demonstrate that the proposed method can deform the "baseline" finite element mesh to match the corresponding "follow-up" image while maintaining mesh quality. Future work will focus on optimizing the algorithm, via selection of appropriate Gaussian kernel and iteration parameters, to allow for the capture of larger and more complex deformations.

REFERENCES

Ladak H. M. et al. (2000). *J. Biomech. Eng.*, **122**, 96-99.
Pebay, P. P. and Baker, T. J. (2001). *Proc. 10th International Meshing Roundtable*, 327-340.
Steinman D. A. et al. (2002). *Magn. Reson. Med.*, **47**, 149-159.