Multidimensional Visualization of Hemodynamic Data

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Summary

The Multiscale Hemodynamics Project is a collaboration of doctors, physicists, and computational scientists working together to model human blood flow through the coronary arteries. Having effective visualizations of the simulation's multidimensional output are vital for the quick and thorough evaluation by a cardiologist. A user study was conducted to evaluate the utility of various methods for both 3D scalar and vector representations. As a result of the study, HemoVis was developed to aid in the visualization and analysis of the endothelial shear stress (ESS) in a patient’s coronary arteries. By identifying the areas of low ESS, cardiologists are able to determine the likely sites of atherosclerotic lesion formation and can take action to prevent further progression.

The Multiscale Hemodynamics Project

This project acquires blood flow rates and 3D images of the human coronary system via 320 slice computed tomography and simulates detailed blood flow patterns within the coronary arteries with the Lattice-Boltzmann technique. With the simulation, aspects of blood flow that can not be measured directly, including local velocity patterns and shear stress, can be studied. Of particular interest is endothelial shear stress (ESS) which has been associated with sites of atherosclerotic lesion formation and rapid disease progression in the coronary arteries. The ultimate goal of this project is to non-invasively detect regions of the coronary artery system that are at high risk for rapid progression in time to facilitate targeted local, prophylactic interventions.

User Study

As part of the motivation to develop visualizations specifically targeted for the medical audience interpreting the simulation output, a user study was conducted to evaluate the effectiveness of various display techniques and to determine the best methods for interacting with the data. Based on the survey responses, keeping the data as anatomically correct as possible is important both for ease of use for the doctors and for applicability of the data results directly to the patients. The tree diagram was well received with users saying that seeing all of the data laid-out together (3D models always have part of the artery tree occluded) and being able to compare multiple trees is extremely beneficial.

HemoVis

HemoVis is an interactive 2D visualization tool developed for viewing the Multiscale Hemodynamics simulation output. It was created using Processing. Based on the user study, the 2D ESS maps were changed (see original sketch to the left) from the traditional square cylindrical projection to the alternative centerline maps, and the tree ordering was altered to be more anatomically correct. In the “tree” mode, a tree diagram of the artery system is presented with each artery labeled with its anatomical name, color mapped to ESS, and color and size scales displayed on the left. In the alternate “individual” mode, only one artery is displayed at a time allowing the user to take care in studying particular arteries in high resolution. Future improvements to HemoVis include the addition of a 3D navigation view, pulsatile flow data, 2D display of blood flow, and the ability to easily switch between or compare patient data sets.

For more information, go to:
http://hemo.seas.harvard.edu

Visit the website for more information and to download the software.