Subject-specific cardiovascular simulation: Current Applications, Challenges, and Opportunities

In this talk, we will provide an overview of current applications, challenges and opportunities in subject-specific blood flow modeling, a field to which computational mechanics has so much to contribute.

Our laboratory is particularly interested in developing novel methods for:

- Situations of dynamic changes in flow and pressure such as those induced by exercise, hemorrhage, changes in posture and anesthesia. Simulating these conditions requires implementing a ‘control systems’ approach whereby reduced order models of the circulation are dynamically adapted following certain auto-regulatory responses of the cardiovascular system.

- Simulation of various types of fluid-structure interactions in both the arterial and venous systems.

- Developing methods for automatic parameter estimation based on filtering techniques.

We will discuss novel applications in the areas of surgical planning and cardiovascular disease research. Lastly, we will briefly provide an overview of CRIMSON, the simulation framework currently developed in our laboratory (www.crimson.software)

Full-body scale 3D hemodynamics in an image-based fluid-structure interaction model of the main vessels of the human vasculature. Xiao, Humphrey and Figueroa, JCP 2013.
Optimization of endovascular procedure for optimal distribution of hepatic factors between both lungs.
Dr. Figueroa is an Associate Professor in Biomedical Engineering and Vascular Surgery at the University of Michigan. He also has an appointment as Honorary Senior Lecturer in the Department of Biomedical Engineering at King's College London. Dr. Figueroa has a well-established record of research in the field of multi-physics and multi-scale computer modeling of hemodynamics. He holds a PhD in Mechanical Engineering from Stanford University, where he developed novel algorithms to perform fluid-structure interaction simulations of anatomically accurate cardiovascular models constructed from image data. His laboratory focuses on developing tools for non-invasive parameter estimation of material properties from medical image data, and on modeling cardiovascular auto-regulatory mechanisms such as the baro-reflex and local auto-regulations. The algorithms developed in his laboratory have made it possible to simulate blood flow and arterial dynamics in full-body scale arterial models, a feat that had not been accomplished before. His research also has an important translational component such as in the area of medical device design and performance evaluation, specifically for abdominal and thoracic aortic endografts. His modeling tools have been also applied to the study of systemic hypertension, using mice data on anatomy, hemodynamics, and biaxial regionally-varying vessel tissue properties to perform full-body scale fluid-structure interaction simulations of mice hemodynamics.

The research goals of his group are to develop computational tools for image-based cardiovascular simulation, to apply these tools to enhance our understanding of the pathophysiology of cardiovascular disease, and to walk towards the ultimate goal of developing a computer simulation environment capable of assisting physicians in the task of surgical planning.