PhD Oral Examination

GEOMETRIC ALGORITHMS AND SOFTWARE ARCHITECTURE FOR COMPUTATIONAL PROTOTYPING: APPLICATIONS IN VASCULAR SURGERY AND MEMS

Nathan Wilson
Department of Mechanical Engineering

Tuesday, November 12, 2002
9:30AM CISX-101
(Refreshments will be served at 9:15AM in the lobby of CISX)

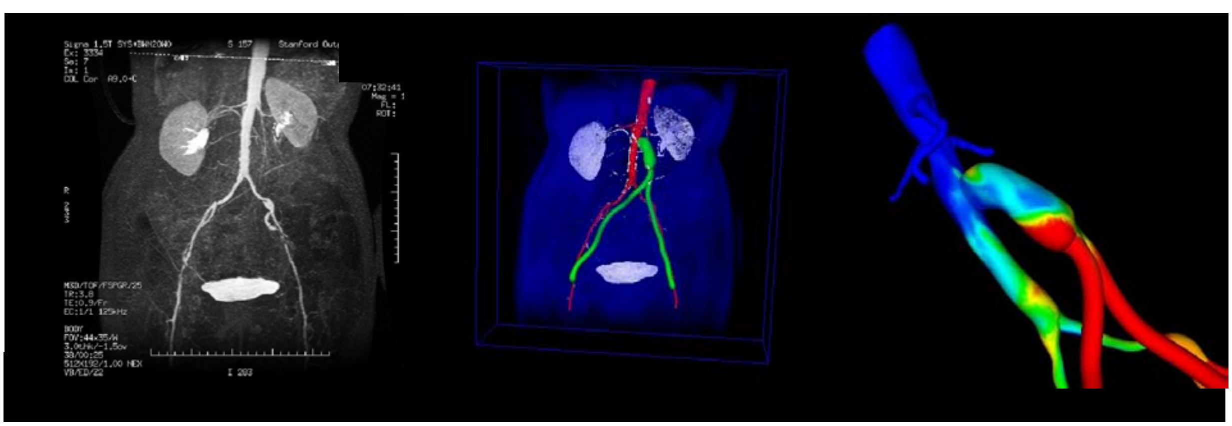
ABSTRACT

Traditionally, engineers have constructed and tested physical prototypes to create new devices and improve on existing designs. Since the advent of digital computing over 50 years ago, significant efforts have been underway to supplement (and in some cases replace) the need for physical prototypes with computational prototypes created and simulated on a computer. Most of the commercially available design software systems existing today originated in support of the automotive, aerospace, defense, and semiconductor industries thus making it difficult to apply these existing systems in new application areas such as medicine.

This PhD dissertation details a general, extensible, modular software framework developed for computational prototyping. The framework integrates the three major stages in computational prototyping: creating geometry, discretization, and numerical simulation. To highlight the versatility and extensibility of the framework, two specific applications were demonstrated.

The first area of application of the software framework was in the field of vascular surgery. When planning a surgical procedure to restore blood flow to the lower extremities for a given patient, vascular surgeons typically rely mainly on intuition and past experience to develop a surgical plan. In this work, a surgical planning system was developed permitting a vascular surgeon to create alternative operative plans prior to surgery for a given patient. Hemodynamic (i.e. blood flow) simulations were performed for the operative plans for two aortic-femoral bypass patients and compared with actual postoperative data. The information that can be obtained from hemodynamic simulation (e.g. wall-shear stress) may provide clinically relevant information to vascular surgeons in the future to assist in planning surgical interventions.

The software framework was also extended for use in computational prototyping of micro-electro-mechanical-systems (MEMS). While MEMS are typically constructed utilizing integrated-circuit fabrication techniques, the size and aspect ratios of typical MEM structures differ significantly from those traditionally found in the VLSI community. In this work, geometric algorithms were developed to incorporate 2-D and 3-D process simulation from VLSI to construct three-dimensional geometric models for simulation-based design of MEM devices with particular emphasis given to geometric modeling of a radio-frequency micro-switch.



Preoperative 3-D medical imaging data is acquired for a given patient and a preoperative geometric model is created (shown in red). A surgeon then creates an operative plan (shown in green). Flow simulations are performed for each plan and quantities of interest (e.g. particle residence time) are calculated.