Dissertation Defense

Reduced Models and Parallel Computing for Uncertainty Quantification in Cardiovascular Mathematics

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Abstract: Computational fluid dynamics (CFD) has been progressively adopted in the last decade for studying the role of blood flow in the development of arterial diseases. While computational (*insilico*) investigations - compared to more traditional *in vitro* and *in vivo* studies - are generally more flexible and cost-effective, the adoption of CFD for computer-aided clinical trials and surgical planning is still an open challenge. The computational time to accurately and reliably solve mathematical models can be too long for the fast-paced clinical environment - especially in emergency scenarios, and quantifying the reliability of the results comes at an even higher computational cost. Moreover, the *in silico* analysis of large numbers of patients calls for significant computational resources. Hospitals and healthcare institutions are expected to outsource numerical simulations, which, however, raises concerns about privacy, data protection, and efficiency in terms of cost and performance. In such an articulated and complex scenario, this work addresses the challenges described above by (i) introducing a novel reduced model that guarantees levels of accuracy comparable to those achieved by high-fidelity 3D models, roughly at the same computational cost as the inexpensive yet inaccurate 1D models, by combining the Finite Element Method to describe the main stream dynamics with Spectral Methods to retrieve the transverse components; (ii) designing a new method for uncertainty quantification in large-scale networks that greatly enhances parallelism by performing uncertainty quantification at the subsystem level, and propagating uncertainty information encoded as polynomial chaos coefficients via overlapping domain decomposition techniques; (iii) providing an objective criterion to measure the performance of different parallel architectures based on the user's priorities in terms of budget and tolerance to delay, and reducing the execution time by choosing a task-worker mapping strategy ahead of simulation time, and optimizing the amount of overlap in the domain decomposition phase.

Thursday, March 21, 2019, 10:00 am
Mathematics and Science Center: E308A

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