Steering Supercomputers to Simulate Interaction of Blood Flow and Blood Vessel in Real Time

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Fluid Structure Interaction (FSI) studies the complex interplay between fluids and elastic/flexible immersed structures. FSI can be found in both natural and industrial environments, e.g., parachutes dropping from aircrafts, ships cruising in oceans, and blood cells flowing through human vessels. This project focuses on scientific computing of how arterial vessels interact with blood flow, i.e., arterial blood flow, at an extreme scale. The shape of the simulated artery is continuously changing, both shaping and being reshaped by the flow of blood through it, i.e., the mesh is elastic.

Because FSI simulations require extreme computational resources, we designed and implemented a software framework to realize real-time simulation thereof. This software framework runs on Big Red II, the 1 Petaflops supercomputer at IU. It consists of four components: 1) an FSI Application Programming Interface (API) provided by OOMPH-lib featuring convenient abstractions such as mesh objects and pressure pinning, 2) a parallelization wrapper provided by OOMPH-lib featuring domain decomposition and optimized cross-processor communication designed for physics computing to supplement the more general-purpose Message Parsing Interface (MPI) which is used primarily by Libsim and VisIt, 3) Libsim, a parallel visualization API/library, and 4) an in-situ visualization of the FSI simulation via VisIt. Since OOMPH-Lib is able to receive various types of input from different science and engineering domains, and then analyze raw data via abstractions useful for numerous sorts of physics problems, we will generalize the framework for simulation of any FSI problem and in-situ visualization thereof. The final software framework will be made available on virtual machines and released to FSI-related communities on the NSF Jetstream cloud platform. Furthermore, we will prepare intuitive tutorials and documentation for non-computer-science users to rapidly learn complex topics useful for FSI simulations, such as Unix, supercomputing, MPI, and VisIt.