Data Workflow in Large Scale Simulations of Blood Flow in Aneurysms

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Role of Hemodynamics in Vascular Biology

Hemodynamic loads regulate the processes of adaptation, growth, and remodeling within healthy and pathologic blood vessels. All vascular cell types are affected.

Endothelial cells. Flow-induced *wall shear stress* and pressure-induced *cyclic stretch* of arteries affect the endothelial production of several *biologically active* molecules (proteolytic, growth regulatory, vasoactive, inflammatory, thrombotic). Moreover, the *integrity* of the endothelium can be compromised by very low or high wall shear stresses.

Vascular Smooth Muscle Cells. The gene expression of smooth muscle cells is modulated by several *chemomechanical* stimuli. Increased cyclic stretches stimulate the production and release of *cytokines* like TGF-ß (ECM synthesis), *growth factors* like PDGF (cell proliferation), and *bioactive molecules* like angiotensin-II.

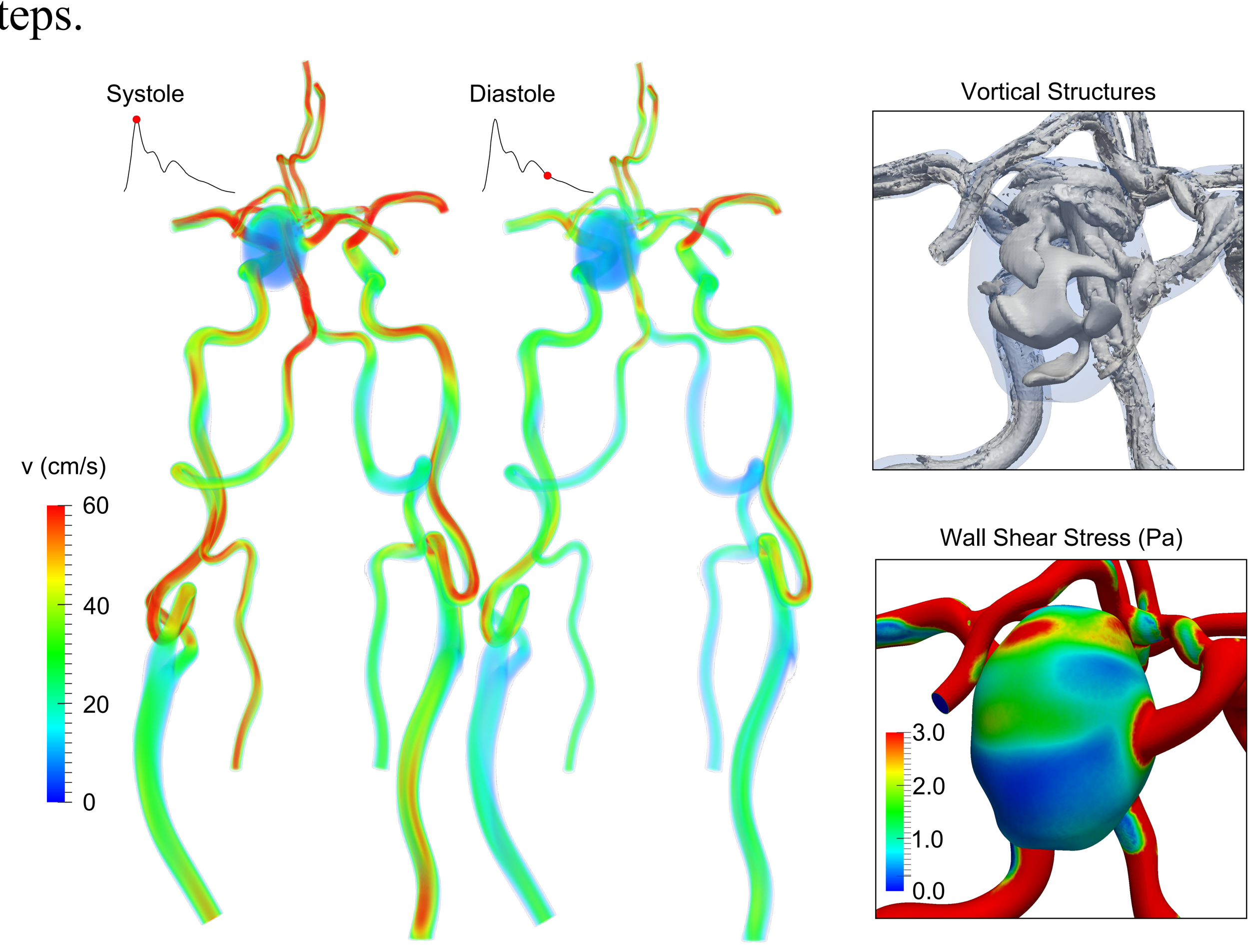
Adventitial Fibroblasts. Fibroblasts contribute to the *maintenance of the structural integrity* of the vascular wall. In response to a modified mechanobiological environment (e.g. in disease), fibroblasts can *modulate their phenotype*, proliferate, and synthesize new ECM.

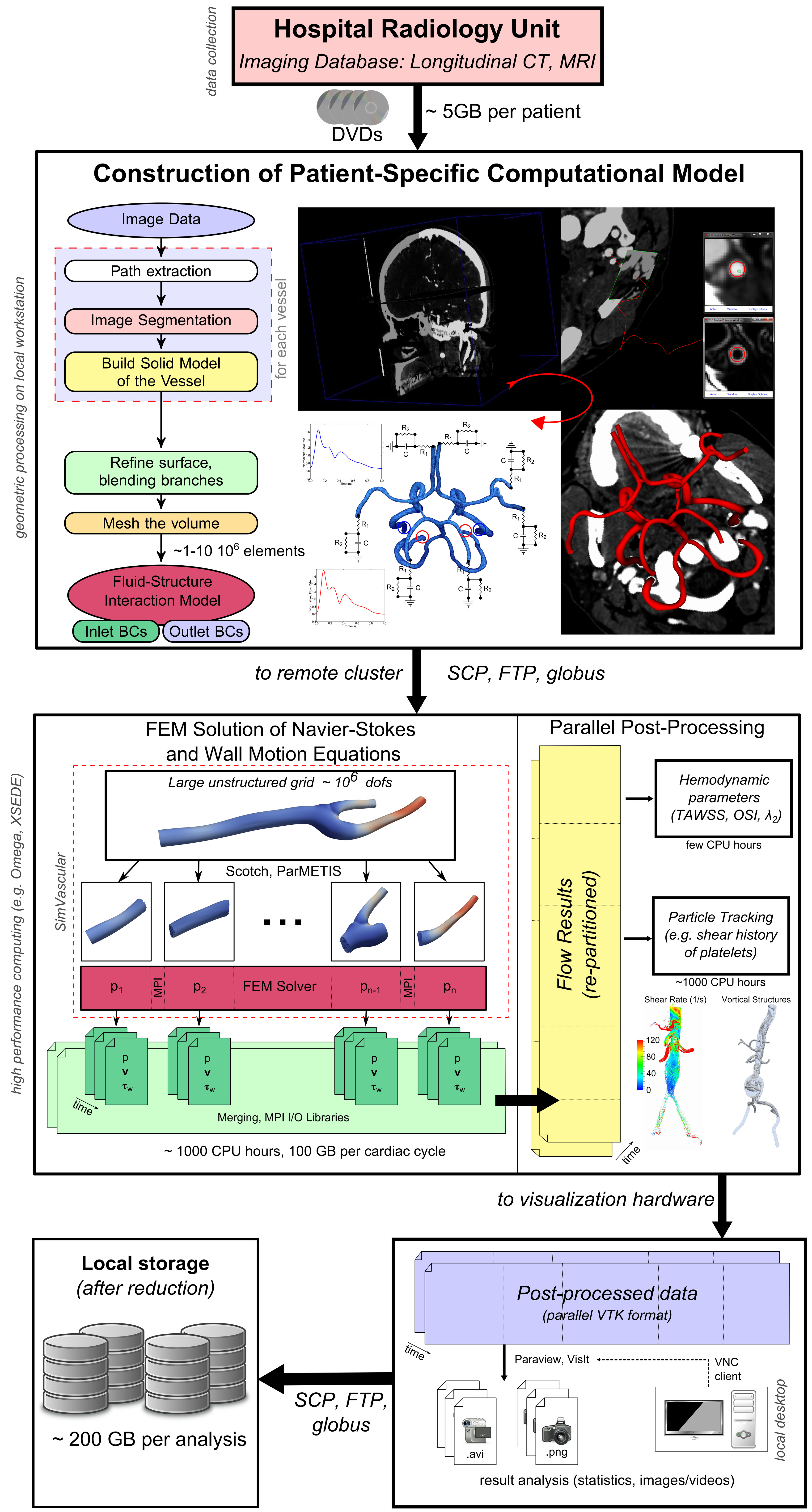
Circulating Cells. Many different types of cells are transported within the blood. Hemodynamics can have an important role in modulating the biologic functions of these cells. For example, after *activation* in regions of *high fluid shear stress*, platelets can aggregate on a *receptive endothelium* and release bioactive molecules like PDGF and serotonin.

Large Scale Fluid-Solid Interaction Models

Numerical simulations are an effective tool to compute realistic distributions of fluid dynamical and intramural stress fields within the vasculature. Our group investigates the interactions between flow and the arterial wall in pathologies such as aortic and cerebral aneurysms that are characterized by altered geometries, material properties, and complex flows.

In order to capture the unique anatomical features of the human vascular network as well as to minimize solution dependence on applied boundary conditions we tend to include large portions of the vasculature in our model. Geometric domains are typically subdivided into millions of elements whereas the unsteadiness of arterial blood flow requires us to split each cardiac cycle into 40,000 or more timesteps.





Blood Flow Simulations Generate Large Amounts of Data

Realization of patient specific models of the blood circulation necessitates a complex *computationally and data intensive* procedure that starts from the collection of medical images in a clinical setting and encompasses several stages of data *processing* on (and transfer to and from) *specialized hardware*, which include *high-performance and visualization* clusters as well as consumer workstations and *local drives* for final storage.

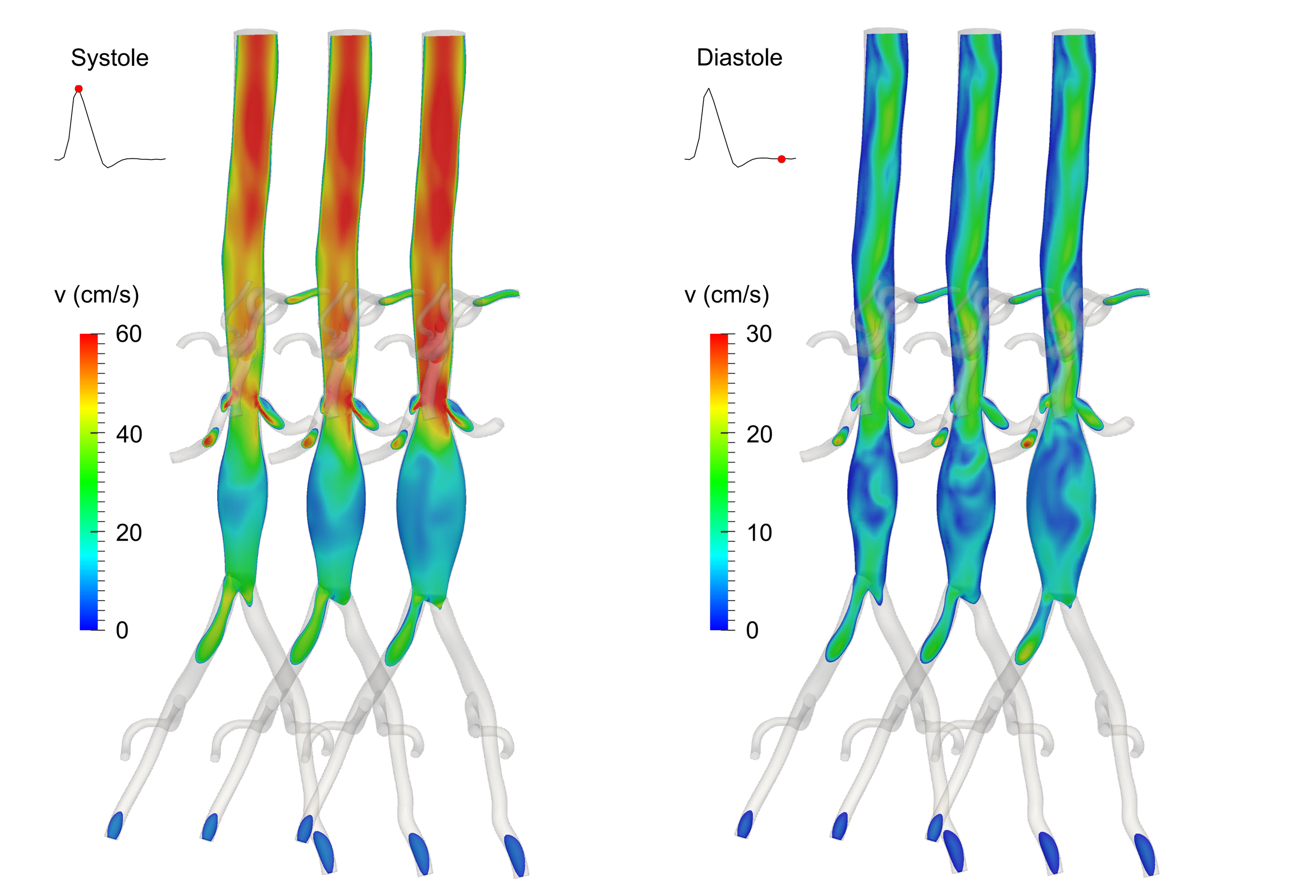
Opportune domain partitioning and distributed data processing techniques are thus essential to cope with our large unstructured domains. We currently heavily rely on domain decomposition libraries (e.g. *ParMetis*) and MPI for our analyses. In the future, we plan to empower our tools with a more thorough integration with high performance parallel file formats such as HDF5 (through the MPI I/O libraries) to reduce bottlenecks at file system level and to allow better scaling on even larger machines.

Towards Fluid-Solid-Growth Models of Aneurysms

Aneurysms are responsibile for significant *morbidity and mortality*, and there is a need for an increased understanding of all the aspects of the *natural history* of these lesions. We are currently working to extend our analyses with the goal of creating models of *aneurysmal progression* that are able to predict rupture risk through the description of the evolving geometry, structure, properties, and loads.

Appropriate management of the *massive amount of data* produced by such Fluid-Solid-Growth models will be a pivotal factor for their success.

Evolution of Hemodynamics in In-Silico Grown Aortic Aneurysms



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