Massive Data on Aortic Coarctations

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Introduction

Using computational fluid dynamics (CFD) to simulate blood flow in patient-specific geometries is a growing field that is generating massive results. Previously, Markl et al. and others have provided evidence that areas of low wall shear stress (WSS) are more likely to develop atherosclerosis. By exploring whether regions downstream of the coarctation with low WSS flow profiles can be predicted by looking at flow near the coarctation, we could better focus simulations with decreased domain sizes, increased resolutions, perform studies with larger sample sizes, and extend the work to predicting outcomes in other parts of the vasculature.

Objective

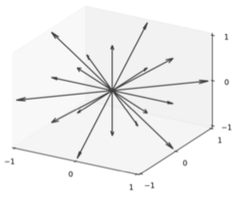
- To uncover new relationships between flow properties, aortic coarctation, and wall shear stress throughout the aorta.
- Prototype different methods of analyzing data produced by massively parallel CFD simulations.

Lattice Boltzmann Method

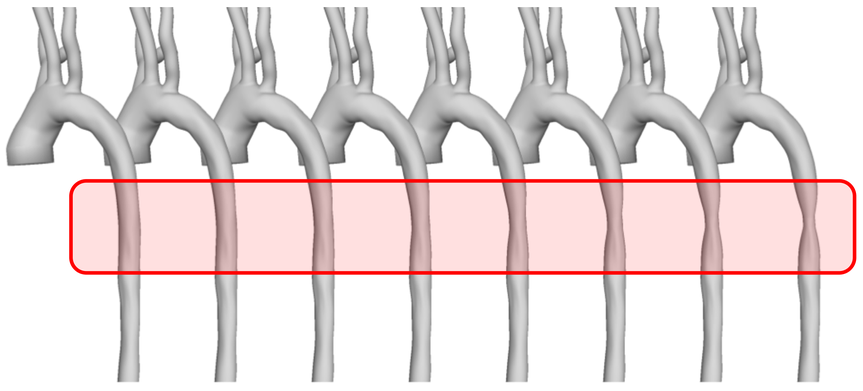
HARVEY solves the Navier-Stokes equations using the lattice Boltzmann method, which represents fluid as a probability distribution function f of particles. Fluid velocity and pressure are computed from the summed behavior of particles.

- HARVEY is parallelized using MPI and OpenMP.

$$f_i(\mathbf{x}+\mathbf{c}_i\delta t, t+\delta t) - f_i(\mathbf{x},t) = -\Omega\Big(f_i(\mathbf{x},t) - f_i^{eq}(\mathbf{x},t)\Big)$$

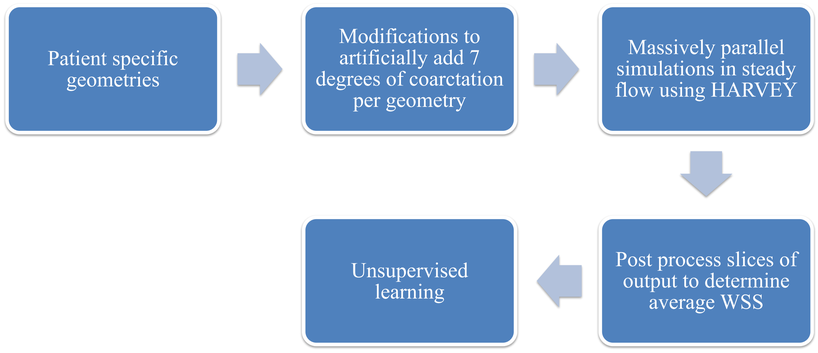


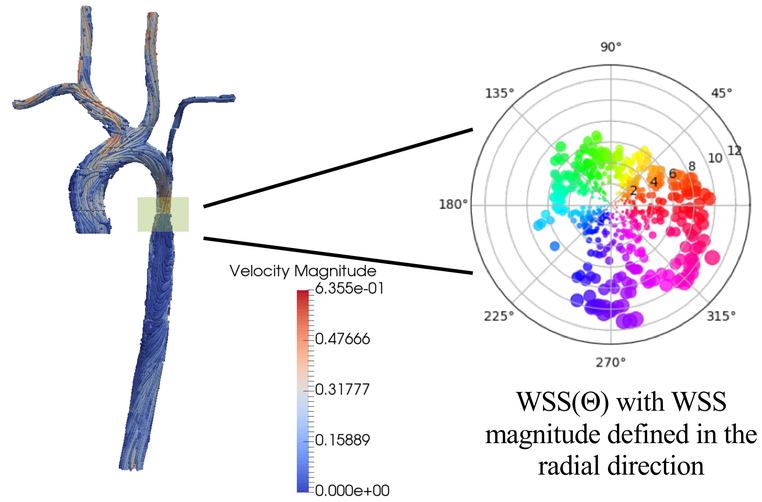
Aortic Coarctation



0 → 70
Percent occlusion

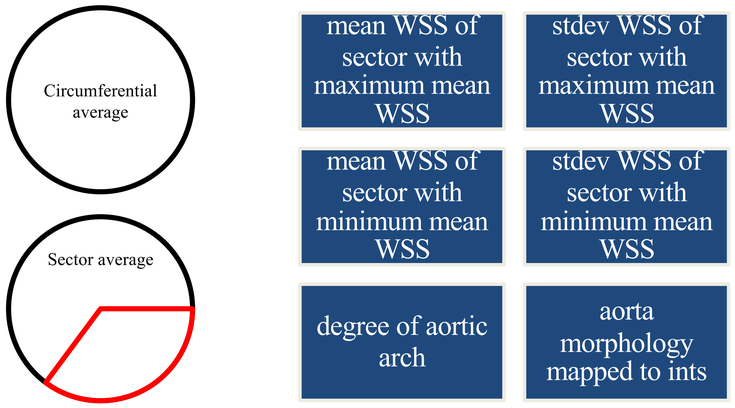
Overview





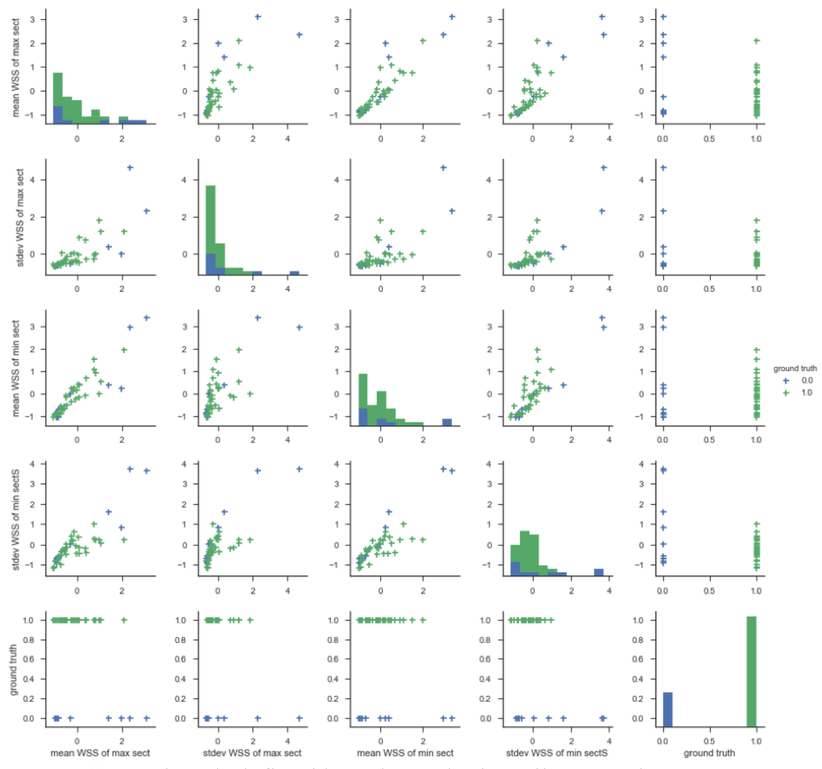
WSS(Θ) with WSS magnitude defined in the radial direction

Features



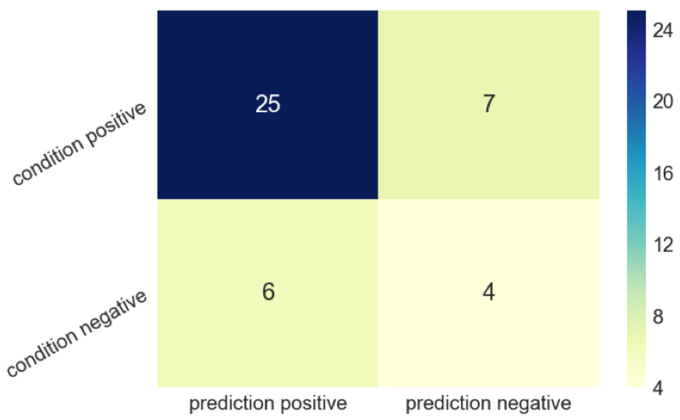
Results

Unsupervised learning with Kmeans



Ground truth defined based on whether all sectors have low wall shear stress (below a threshold)

Results Continued



Precision: 80.6%
Recall: 78.1%

Future Work

New simulations with more realistic flow parameters:
- Pulsatile flow
- Patient specific flow profiles
- Realistic boundary conditions

Temporal and frequency analysis

References

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Acknowledgements

Computing support for this work came from the Lawrence Livermore National Laboratory (LLNL) Institutional Computing Grand Challenge program.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, by the NIH under Award Number DP5OD019876, and is supported by NIH Grant #T32-EB001040. This work is also supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. 1644868 and by the Big Data-Scientist Training Enhancement Program (BD-STEP) of the Department of Veterans Affairs. The content is solely the responsibility of the authors and does not necessarily represent the official views of the DOE, NSF, or NIH.