Better Living Through High-Performance Computing (HPC)

High-fidelity simulation provides the missing ingredient to data-driven health tracking

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For the past 10 years, scientists at Duke University and LLNL have worked together to harness HPC to improve characterization and treatment of circulatory disease. Remarkable advances in scale and accuracy have been achieved by leveraging LLNL's considerable expertise in scalable simulation, but the ability to directly impact patients was still limited by the barrier between the supercomputer and daily life.

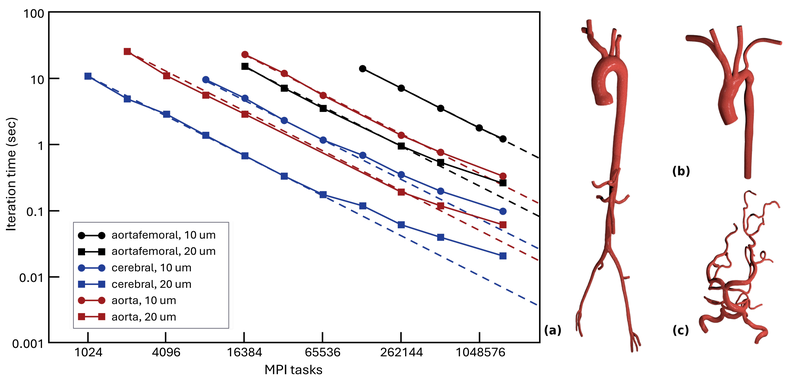
This 10-year project has been funded by LDRD and ASC at LLNL (~0.1 FTE/year) and by NIH at Duke University. Computing support provided by the Computing Grand Challenge program.

Why do this at LLNL?

- Shared exascale components
- AI + mod-sim
- Visibility/recruitment

HPC Has Pushed Circulatory Simulation to Unprecedented Fidelity

In 2015, Lawrence Fellow Dr. Amanda Randles collaborated with LLNL scientists to scale the HARVEY circulatory modeling code to the full IBM Blue Gene/Q Sequoia machine. This led to the highest resolution (<10 μm) full body arterial simulation ever performed (SC15 Gordon Bell Award Finalist).

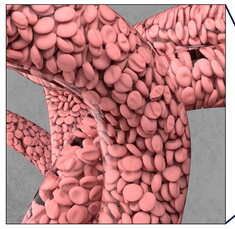


Strong scaling of HARVEY fluid simulations on the Sequoia IBM Blue Gene/Q supercomputer, on three different arterial geometries: (a) aortofemoral; (b) aorta; (c) cerebral.

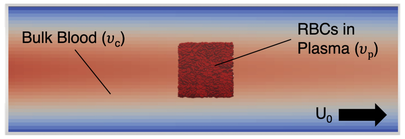
New Multiphysics Algorithms Provide a Critical Boost

Capturing cellular dynamics requires high-resolution fluid-structure interaction simulations.

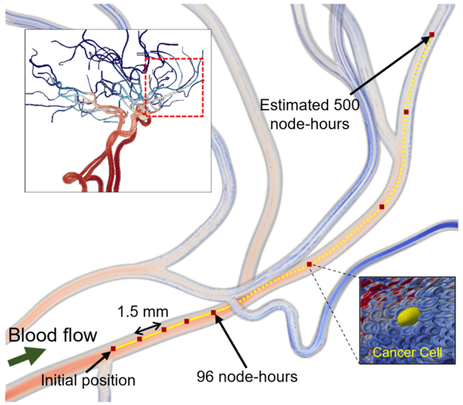
Our new "moving window" algorithm allows a high-fidelity physics region to move through a larger arterial geometry.

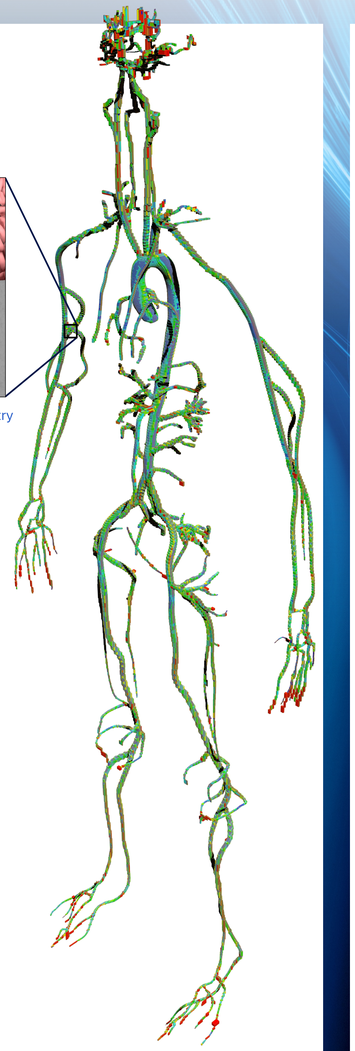


Red blood cells in arterial geometry (Image: Liam Krauss, LLNL).



High-fidelity "moving window" with explicit red blood cells (RBCs) embedded in lower-resolution bulk fluid.

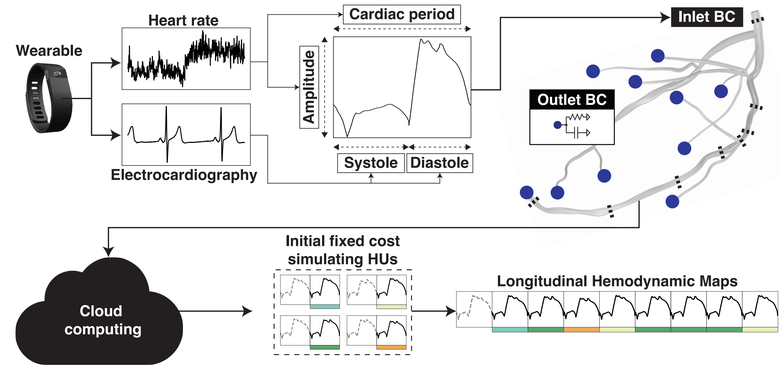




Domain decomposition of HARVEY fluid simulation of a full-body arterial geometry.

Combine Wearable Data with Predictive Simulation to Improve Health Outcomes

Wearables capture the full range of conditions a person experiences, not just limited measurements in a doctor's office. Patient-specific simulations can be used to translate this simple information into more robust hemodynamic maps, which provide personalized risk assessment and early detection of disease.



Proposed modeling pipeline to augment wearable data with patient-specific simulation of characteristic hemodynamic units (HUs) scoped to tractably run on cloud HPC resources.

Conclusions

Wearable data is by necessity either patient-specific or predictive, but not both. Leadership-scale HPC simulations can give AI models the missing information they need to build patient-specific, predictive models that can influence health outcomes.

Collaborators and Next Steps

Working with Duke University, we will look for opportunities to leverage new AI capabilities to flag actionable events and identify potential gaps in simulation data.

Duke UNIVERSITY

NIH National Institutes of Health *Turning Discovery Into Health*

HPC by itself is not enough, but it provides critical predictive information that exists nowhere else

Lawrence Livermore National Laboratory

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NNSA National Nuclear Security Administration