CASE STUDY

The Pawsey Centre's Cray® XC40™ Supercomputer "Magnus" Gives Researchers a Big Advantage in Fight Against Lung Disease

Organizations
Curtin University
School of Public Health
Perth, Australia
http://healthsciences.curtin.edu.au

Pawsey Supercomputing Centre
Kensington, Australia
www.pawsey.org.au

Scientific Field
Life Sciences

Application
OpenFOAM, an open-source suite of CFD applications and solvers

About the Pawsey Centre & Magnus
The Pawsey Supercomputing Centre supports researchers with supercomputing, data and visualization services across a range of scientific fields. "Magnus" is a petascale Cray® XC40™ supercomputer and the most powerful system in the Southern Hemisphere.

"HPC means our experiments are a thousand times faster."

— Professor Ben Mullins
School of Public Health
Curtin University

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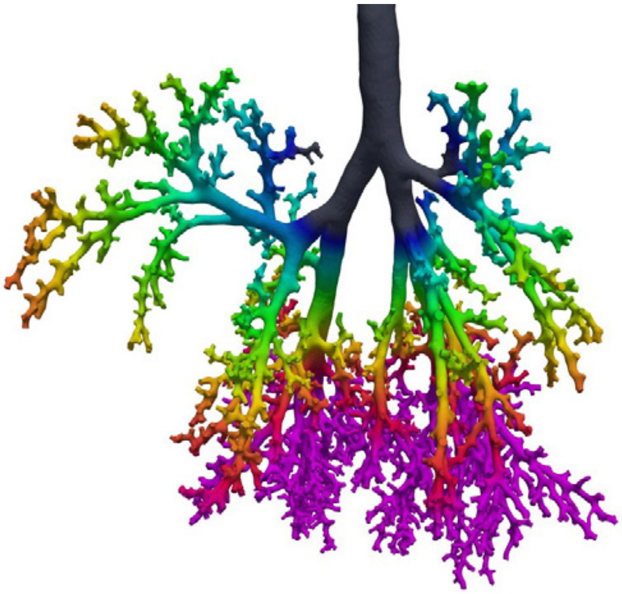
Background
Chronic respiratory diseases interrupt the airways and other structures of the lung — and they affect hundreds of millions of people worldwide. Some 235 million individuals suffer from asthma. Chronic obstructive pulmonary disease (COPD) kills 3.1 million people a year. And millions more suffer from a variety of additional conditions that comprise this category of diseases.

Not only are chronic respiratory diseases debilitating and ofttimes fatal, but the associated health-care costs are staggering. For example, in 2010 the cost to the U.S. for COPD alone was approximately $50 billion.

Improved delivery of aerosolized medications (inhalers) could go far toward more efficiently managing these damaging lung diseases. In Australia, for example, the population spends $358 million per year on asthma medication. But more than 95 percent of that medication is wasted due to ineffective delivery. Optimizing medication delivery has the potential to save lives and reduce health-care costs. However, doing so requires a better understanding of how aerosols move through the lungs.

In search of the answer, a team of researchers led by Ben Mullins from Curtin University's School of Public Health created a first-ever 3D model of the lung using "Magnus," Pawsey Supercomputing Centre's Cray® XC40™ supercomputer. The model is the largest lung simulation in the world and is allowing them to simulate respiratory airflow and particle deposition during lung expansion and contraction.



Challenge
The human lung is exceedingly complex. First, simulating airflow and aerosol deposition within the lung requires an understanding of multiple areas of science — from biomechanics to aerosol science. Then, it requires resolving localized flow and pressure fields within this delicate organ.

Researchers have taken on these tasks previously, but always using simplified geometries and/or unidirectional flow. These approaches are computationally efficient, but not physiologically realistic. Ultimately, the team needed to create a model where the lung actually expands and contracts.

Computational fluid dynamics (CFD) offers a technique for simulating the fluid transport processes within the lungs. But it requires properly constructed and validated models and is highly computationally intensive.

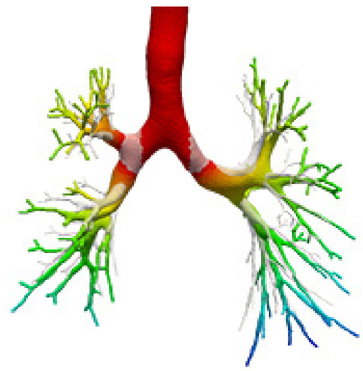
"The expansion and contraction of the lungs is responsible for the flow of air, and any particles present in the air, in and out," says Prof. Mullins. "If we want completely accurate computer models for studying aerosol drug delivery this must be taken into account."

Solution

Using Magnus, a petascale Cray XC40 supercomputer at the Pawsey Supercomputing Centre, the team developed the most advanced and physiologically realistic lung model ever used to simulate airflow.

Their solution required the use of high-resolution computerized tomography (CT) scans of live animals or humans, and OpenFOAM, an open-source suite of CFD applications and solvers. Mullins' team applied fluid dynamics modeling to create a moving mesh model, breaking the surface of the airway into discrete regions to then allow the simulation of physiologically accurate movement. The moving mesh allowed them to simulate realistic flow rates and deposition patterns as each lung is expanded by a predefined amount in the x, y and z directions at a prescribed breathing rate.

However, resolving the particle code and the moving mesh algorithm is so computationally intensive that it requires a huge data transfer between cores in order to reach a solution within a reasonable amount of time. This kind of data transfer is possible only with a supercomputer like the Cray XC40 system. In this case, the system's combination of 12-core Intel® Xeon® E5 processors and Cray's high-speed, low-latency Aries interconnect delivered the computational speed and power to make the team's lung model possible.



DEEP BREATH: The image shows a high-resolution simulation performed on the Magnus supercomputer of airflow and expansion (breathing) of a lung. The lung geometry used for the simulation is obtained from a 3D computed tomography (CT) scan

"HPC means our experiments are a thousand times faster," says Prof. Mullins. "Simulations like these are possible … because of our access to the Pawsey Supercomputing Centre."

The team's research will inform several areas of respiratory health, including aerosol drug delivery, invasive lung surgery and the deposition of air pollutants in lungs.

For more information:

The Pawsey Centre
Case study "Canonical Simulation of Respiratory Airflow"
www.pawsey.org.au/case-study/clinical-simulation-of-respiratory-airflow

Journal of Aerosol Science
"Computational fluid dynamics (CFD) simulation of liquid aerosol coalescing filters"
www.sciencedirect.com/science/article/pii/S0021850213000700