Han Liu

Ph.D., Researcher

St. Anthony Falls Laboratory, University of Minnesota

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United States Residency Status

- Green Card holder (permanent resident)

Personal Profile

- Experienced in theoretical modeling of complex fluid systems, such as turbulence, using Computational Fluid Dynamics (CFD). Experienced in utilizing AI, quantum computing, and High Performance Computing (HPC) to develop custom codes, with a focus on data analysis, statistics, visualization, mathematical interpretation, and interdisciplinary collaboration.
- Competent in multiple programming languages and computational tools, demonstrating adaptability to different platforms and environments.
- Hands-on experience with High Performance Computing (HPC) and parallel computing, supporting large-scale data analysis and modeling efforts.

Education

2021 Qiskit Global Summer School on Quantum Machine Learning *IBM*

Certificate of Quantum Excellence in QC and QML; Grade: 100/100 *2021*

- Courses are focused on quantum computing and quantum machine learning using Qiskit

Peking University *Beijing*

Ph.D. in Mechanical Engineering - Fluid Mechanics *2018*

- Thesis: Characteristics and action mechanism of the structures in ventilated supercavity

Peking University *Beijing*

B.S. in Theoretical and Applied Mechanics *2012*

- Thesis: Numerical investigation on heavy particle pair dispersion in the inertial range of two dimensional turbulence

Memberships and Professional Societies

- American Physical Society
- American Geophysical Union

Experiences

St. Anthony Falls Laboratory, University of Minnesota *Minneapolis, MN*

Researcher *Nov 2021 - Present*

- Developed a hybrid framework combining quantum circuits with physics-informed neural networks (PINNs) to simulate incompressible turbulence.
- Applied quantum tensor networks for data compression and acceleration in turbulence simulations.
- Adapted and maintained in-house Fortran code for multi-GPU parallel computing using C++, CUDA, and CUDA-aware MPI.
- Developed a variational quantum algorithm to solve the Poisson equation.
- Investigated oil-wind-wave interactions, creating a CFD algorithm for three-phase interface capture and analyzing turbulence in bubble-oil-wave interactions.

St. Anthony Falls Laboratory, University of Minnesota *Minneapolis, MN*

Postdoctoral Associate *Sep 2018 - Nov 2021*

- Developed a novel method to simulate two-phase incompressible flows at high-density ratio and high Reynolds number, enhancing robustness.
- Researched wind-wave-bathymetry interactions near the surf zone to optimize amphibious vehicle performance, improving in-house code for interface tracking and fluid-structure interaction.
- Simulated indoor airflow and aerosol transport to study COVID-19 transmission mechanisms.
- Optimized hydro-turbine geometries using immersed boundary methods, supporting erosion protection and energy extraction from turbulence in hydropower installations.

University of Minnesota *Minneapolis, MN*

Visiting Scholar *Sep 2015 - Sep 2017*

- Developed in-house code for simulating multiphase turbulent flow, incorporating VOF, level set methods for two-phase interfaces, and immersed boundary method for solid objects.
- Researched turbulent cavitating flows interacting with ocean waves.

Peking University *Beijing*

Research Assistant *Sep 2012 - Jul 2018*

- Developed in-house code to simulate compressible multiphase turbulence.
- Researched particle preferential concentration in compressible turbulent flows, focusing on clustering, dispersion, and concentration under shock wave effects.
- Investigated Richtmeyer-Meshkov Instability and turbulent mixing, modeling the energy transfer process during turbulent mixing process.

Research Projects

Quantum-Inspired Computing for Fluid Mechanics *Minneapolis, MN*

St. Anthony Falls Laboratory, University of Minnesota *2021 - Present*

- Developing tensor network methods for solving Navier-Stokes equations with potential exponential speedup.
- Encoding velocities and pressure as matrix product states (MPS) and implementing finite differences via matrix product operators (MPO).
- Proposed tensor networks-based level set method for tracking phase interfaces in multiphase flows.

Multiphase Flow Simulation *Minneapolis, MN*

St. Anthony Falls Laboratory, University of Minnesota *2015 - Present*

- High-fidelity simulation of ventilated cavitation, air-water-oil interface dynamics, and bubble tracking.
- Developed coupled level set and volume of fluid methods for two-phase flows at high density ratios and Reynolds numbers.
- Applied to practical problems including oil spill dynamics in breaking waves and amphibious vehicle hydrodynamics.

COVID-19 Airborne Transmission Simulation *Minneapolis, MN*

St. Anthony Falls Laboratory, University of Minnesota *2020 - 2021*

- Simulated indoor airflow and aerosol transport to study COVID-19 transmission mechanisms in practical settings.
- Published as Featured Article in Physics of Fluids; featured in The Guardian.

Skills

Programming	Python, Fortran, C++, CUDA, Matlab.
HPC	Linux, Shell, PBS, Slurm, MPI, HDF5, PETSc, hypre.
CFD	Multiphase flow (Level set, VOF, FSI), linear solver (PETSc, hypre), Turbulence (DNS, LES), Finite difference, Finite volume, Parallel computing, numerical analysis (Matlab, in-house code), visualization (Tecplot, Python).
Quantum computing	Qiskit, Yao.jl, Variational quantum circuit, Quantum machine learning.
Soft Skills	Time Management, Teamwork, Problem-solving, Project proposal writing, Research paper writing, Engaging presentation.

Peer Review Experiences

Scientific Reports, *Physics of Fluid*, *Review of Scientific Instruments*, *Journal of Computational Science*, *Energies*, *Mathematics*, *Entropy*, *Applied Sciences*, *Aerospace*, *Geophysical Research Letter*, *Journal of Fluid Mechanics*, *Physical Review Letters*

Interviews

The Guardian: Bob Pape was a beloved father and foster carer. Did 'eat out to help out' cost him his life? [03/30/2021]

Service

Served as session chair for "Computational Fluid Dynamics: General III" at the 2021 American Physics Seminar, Division of Fluid Dynamics.

Selected publications

Journal Articles

A consistent adaptive level set framework for incompressible two-phase flows with high density ratios and high Reynolds numbers
Y. Zeng, H. Liu, Q. Gao, A. Almgren, A. P. S. Bhalla, L. Shen
Journal of Computational Physics, 478, 111971, 2023.

Simulation-based study of low Reynolds number flow around a ventilated cavity
H. Liu, Z. Xiao, L. Shen
Journal of Fluid Mechanics, 966, A20, 2023.

Simulation-based study of turbulent aquatic canopy flows with flexible stems
S. He, H. Liu, L. Shen
Journal of Fluid Mechanics, 947, A33, 2022.

Simulation-based study of COVID-19 outbreak associated with air-conditioning in a restaurant **[featured article]**
H. Liu, S. He, L. Shen, J. Hong
Physics of Fluids, 33, 023301, 2021.

Scale-to-scale energy transfer in mixing flow induced by the Richtmyer-Meshkov instability
H. Liu, Z. Xiao
Physical Review E, 93, 053112, 2016.

Selected Presentations

Enhancing Incompressible Two-Phase Turbulence Simulations with Quantum Tensor Networks
Han Liu, Lian Shen
APS Global Summit 2025, Anaheim, CA, 2025.

Quantum-Inspired High-Fidelity Solver for Simulating Incompressible Two-Phase Turbulence
Han Liu, Lian Shen
Bulletin of the American Physical Society, 2024.

Efficiency-Enhanced High-Fidelity Simulation Solver for Incompressible Two-Phase Flows and Fluid-Structure Interactions
H. Liu, L. Shen
Bulletin of the American Physical Society, 2023.

Simulation-based study on the interaction between flexible canopy and turbulent boundary layer flows
H. Liu, S. He, L. Shen
AGU (American Geophysical Union) 2022, Chicago, IL, 2022.

Variational quantum algorithm towards quantum computing for fluid mechanics
H. Liu, L. Shen
74th Annual Meeting of the American Physical Society's Division of Fluid Dynamics (APS DFD), Phoenix, AZ, 2021.

References available upon request.