

Qi Wang

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Summary

My research exploits state-of-the-art mathematical and computational methods to address important challenges in turbulence. High-performance simulation techniques are developed and adopted to predict and optimize complex aerodynamic flows, and to optimally place sensors and optimize the interpretation of their measurements. My past research helped to answer this question by exploiting the discrete adjoint operator in different scenarios: passive scalar source reconstruction and localization from noisy sensor measurement, initial flow state reconstruction from wall friction measurements, sensitivity analysis for transitional compressible boundary layer, and data augmentation in stratified flows.

Work Experience

San Diego State University

Assistant Professor in Aerospace Engineering

San Diego, CA, United States

2021 – Present

Johns Hopkins University

Postdoc in Mechanical Engineering

Baltimore, MD, United States

2020 – 2021

Education

Johns Hopkins University

Postdoc in Mechanical Engineering

Baltimore, MD, United States

2020 – Present

Johns Hopkins University

Ph.D. in Mechanical Engineering

Baltimore, MD, United States

2016–2020

Johns Hopkins University

MSE in Mechanical Engineering

Baltimore, MD, United States

2014–2016

Beijing University

Bachelor of Science in Theoretical & Applied Mechanics

Minor degree in Mathematics

Beijing, China

2010– 2014

Honors and Awards

JHU Mech Eng Graduate Research Fellowship

Johns Hopkins University

AUG. 2014 – AUG. 2015

CUHK Research Internship Scholarship

Financial Stipend awarded

Chinese University of Hong Kong

JUN. 2013 – AUG. 2013

President

Peking University Piano Association

Peking University, China

SEPT. 2012 – SEPT. 2013

Third prize

China Undergraduate Mathematical Contest in Modeling

Peking University, China

MAY. 2011

Silver Medal

The 25th China Mathematics Olympiad

Bronze Medal

The 24th China Mathematics Olympiad

Gold Medal

Seattle International Piano Competition

Chong Qin, China

APRIL. 2010

Hai Nan, China

APRIL. 2009

Washington, Seattle, USA

OCT. 2019

Publications

- **Qi Wang**, Mengze Wang, and Tamer A. Zaki. "From wall observations to turbulence: The difficulty of flow reconstruction." arXiv preprint arXiv:2106.09169 (2021).
- **Qi Wang**, Yosuke Hasegawa, and Tamer A. Zaki. "Spatial reconstruction of steady scalar sources from remote measurements in turbulent flow." *Journal of Fluid Mechanics* 870 (2019): 316-352.
- Vincent Mons, **Qi Wang**, and Tamer A. Zaki. "Kriging-enhanced ensemble variational data assimilation for scalar-source identification in turbulent environments." *Journal of Computational Physics* 398 (2019): 108856.
- Mengze Wang, **Qi Wang**, and Tamer A. Zaki. "Discrete adjoint of fractional-step incompressible Navier-Stokes solver in curvilinear coordinates and application to data assimilation." *Journal of Computational Physics* 396 (2019): 427-450.
- **Qi Wang**, Vincent Mons, and Tamer A. Zaki. "Optimal sensor placement for spatial reconstruction of scalar sources in a turbulent channel flow." under review.
- **Qi Wang**, Mengze Wang, and Tamer A. Zaki. "From wall observations to turbulence: The difficulty of flow reconstruction." Under review.
- **Qi Wang**, and Tamer A. Zaki. "An eigen-ensemble-variational algorithm for characterization of scalar sources in turbulent environment." Under review.

Presentations

- Wang, Qi, and Tamer Zaki. "An eigen-ensemble-variational algorithm for identifying scalar sources from remote measurements in turbulent environments." *Bulletin of the American Physical Society* (2019).
- Wang, Qi, and Tamer Zaki. "Fundamental limitations in initial-state estimation using surface measurements in wall turbulence." *Bulletin of the American Physical Society* (2018).
- Mons, Vincent, Qi Wang, and Tamer Zaki. "Ensemble-based data assimilation and optimal sensor placement for scalar source reconstruction." *APS Meeting Abstracts*. 2017.
- Wang, Qi, et al. "Adjoint-optimization algorithm for spatial reconstruction of a scalar source." *APS Division of Fluid Dynamics Meeting Abstracts*. 2016.
- Wang, Qi, Mengze Wang, and Tamer A. Zaki. "Difficulty of State Estimation from Wall Measurements in Turbulent Channel Flow" November 2018, Graduate Seminar in the Department of Mechanical Engineering, Johns Hopkins University.
- Wang, Qi, and Tamer A. Zaki. "Direct Numerical Simulations of Wake-Induce Transition in Three-Dimensional Boundary Layer" December 2016, Graduate Seminar in the Department of Mechanical Engineering, Johns Hopkins University.
- Wang, Qi, Vincent Mons, and Tamer A. Zaki. "Data-Assimilation for Scalar-Source Reconstruction" April 2017, Graduate Seminar in the Department of Mechanical Engineering, Johns Hopkins University.
- Wang, Qi, Vincent Mons, and Tamer A. Zaki. "An Adjoint-Based Algorithm for Detection

of Scalar Release" October 2015, Graduate Seminar in the Department of Mechanical Engineering, Johns Hopkins University.

Research Experience

Data assimilation and state estimation in turbulent flows **Advisor: Tamer Zaki**

Fundamental limitations in initial-state estimation in wall turbulence 2018 – 2020

- o Interpreted the Hessian matrix of the cost function mathematically as the ensemble average of cross-correlation of the adjoint fields.
- o Developed code to compute the leading eigenvalues and eigenvectors of the Hessian matrix.
- o Evaluated the sensitivity of wall measurements according to the leading eigenvectors of the Hessian matrix.

Olfactory search algorithms in turbulent environments **Advisor: Tamer Zaki**

Research Assistant, Johns Hopkins University 2015 – 2019

- Investigated the behavior of forward and adjoint scalar field in turbulent environments.
- Developed codes with massively parallel adjoint optimization to identify source location and profile generating a scalar field in turbulent channel flow.
- Devised innovative algorithm that tracks leading subspace of source-response system and minimizes condition number to find optimal sensor placements.
- Performed uncertainty quantification of scalar source localization when measurements are subject to noise.

Wake-induced cross-flow instability on a swept airfoil **Advisor: Tamer Zaki**

Research Assistant, Johns Hopkins University 2014 – 2017

- Designed simplified physical model using cylinder placed in front of airfoil to simulate leading-edge slat of modern airplanes.
- Constructed body-fitted mesh for leading edge and applied Immersed Boundary Method (IBM) for cylinder.
- Determined the physical mechanism of boundary layer transition by comparing with Linear Stability Theory (LST).

Numerical Study of Transonic Flow around a Supercritical Airfoil **Advisor: Zuoli Xiao**

Degree Thesis, Beijing University APRIL. 2013 – JULY. 2014

- Enhanced parallel-FORTRAN code for compressible flow with Smagorinsky, S-A and SST turbulence models to simulate high Reynolds and high Mach number flow around supercritical airfoil.
- Obtain body-fitted orthogonal mesh by solving elliptic equation.
- Conducted numerical simulations using DNS, RNS and LES to study shock-wave oscillation on the airfoil.
- Tested newly developed Constrained-LES in shock-wave oscillation scenario.

Numerical Simulation of Boat maneuvering **Instructor: Yunhui Liu**

Research internship, Automation Department, CUHK JUNE. 2013 – AUG. 2013

- Designed VOF model to simulate a boat on water surface.
- Obtained body-fitted 3D unstructured mesh using autoCAD and Gambit.
- Performed numerical simulations with Ansys Fluent to determined parameters in Fossen's boat dynamic model. Determined parameters agreed with experiments and were important references for future studies.

Teaching Experience

Teaching Assistant, Johns Hopkins University

Professor: Tamer Zaki

Hydrodynamic Stability, Graduate class, evaluation score 4.72/5.00 JAN. 2017 – MAY. 2017

- Delivered lectures on spectral methods to computationally prepare students for stability analysis.
- Composed homework questions and created sample solutions.
- Graded the homework with comments and suggestions for students.
- Designed midterm exams and composed solutions.

Teaching Assistant, Johns Hopkins University

Professor: Tamer Zaki

Numerical Methods, Graduate class, evaluation score 4.63/5.00 SEPT. 2015 – JAN. 2016

- Delivered complementary lectures based on problems in homework. Conducted weekly TA sections for grad students.
- Composed homework questions and created sample solutions.
- Graded the homework with comments and suggestions for students.
- Designed midterm exams and composed solutions.

International collaborations

Hasegawa Yosuke, Department of Mechanical and Biofunctional Systems, Tokyo University.
Vincent Mons, Research Scientist, ONERA.

Professional Affiliations

American Physics Society
American Institute of Aeronautics and Astronautics

Grant Applications

- Enhanced-Fidelity Simulations and Interpretation of Measurements in Turbulent Flows.
- Data assimilation and state estimation in transitional and turbulent flows: Optimal sensing parameters & bounds on prediction accuracy
- Optimal interpretation of scalar and velocity observations in stratified turbulence.