Rui Fang

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SUMMARY

- My research improved the predictability, accuracy, and efficiency of fluid flow simulations by addressing data uncertainty and the chaotic behavior of flows.
- **Authored 7 peer-reviewed publications, including 3 solo papers, with 2 are currently under review** (https://www.researchgate.net/profile/Rui-Fang-39).
- **Delivered 5 conference talks in the United States and internationally**.
- **Awards:** ***Andrew W. Mellon Fellow*** 2023-2024.
- **2nd Place in 3-Minute Thesis Competition**, Department of Mathematics, University of Pittsburgh.
- The referee for the *Pittsburgh Interdisciplinary Mathematics Review*, a peer-reviewed journal.
- President of the *Association for Women in Mathematics*, Pittsburgh Chapter, University of Pittsburgh.
- Student officer of the *Mathematics Graduate Student Organization*, University of Pittsburgh.

RESEARCH INTERESTS

- Data assimilation, ensemble simulations, turbulence modeling.
- Numerical analysis, scientific computing, computational fluid dynamics, and finite element methods.
- Machine learning, deep learning, probabilistic graphical models, deep reinforcement learning.

EDUCATION

- **PhD Candidate in Mathematics**, 2019 – Expected Summer 2025.
  University of Pittsburgh, Pittsburgh, PA
  Carnegie Mellon University, Machine Learning (cross-registration)
- **Dual BSc in Mathematics**, 2015 – 2019.
  University of Cincinnati, Cincinnati, OH, and Capital Normal University, Beijing

SKILLS

- **Numerical methods:** Monte Carlo, data assimilation, finite difference, finite element, ODE, PDE.
- **Quantitative:** Regression analysis, time series analysis, Bayesian statistics, stochastic differential equations.
- **Machine learning**: Linear regression, logistic regression, decision trees, random forests, k-nearest neighbors, k-means, Naive Bayes, SVM, PCA, Bayesian networks, deep learning, reinforcement learning.
- **Libraries and tools**: Linux, PyTorch, TensorFlow, Keras, NumPy, SciPy, Pandas, SQL, DOLFINx, FEniCSx, FreeFEM.
- **Coding languages**: Python, MATLAB, Java.
- **Soft skills**: presentation, scientific writing, collaboration, leadership, problem-solving, commitment.

PUBLICATIONS

Published/Accepted for Publication

1. A. Çıbık, **R. Fang**, W. Layton, F. Siddiqua, "Adaptive parameter selection in nudging-based data assimilation", *Computer Methods in Applied Mechanics and Engineering*, Accepted, 2024. arXiv

2. W. Han, **R. Fang**, W. Layton, "Numerical analysis of a 1/2-equation model of turbulence", *Physica D (Nonlinear Phenomena)*, Accepted, 2024. arXiv
3. **R. Fang**, W. Han, W. Layton, "On a 1/2-equation model of turbulence", *International Journal of Numerical Analysis and Modeling*, Accepted, 2023. arXiv
4. **R. Fang**, "Penalty ensembles for Navier-Stokes with random initial conditions and forcing", *the VIth AMMCS Conference, Waterloo, ON, Canada,* Accepted, 2023. arXiv
5. **R. Fang**, H. Schreiner, M. Sokoloff, C. Weisser, M. Williams, "A hybrid deep learning approach to vertexing", *Journal of Physics*, 2019. Article

Preprints

6. **R. Fang**, "Numerical analysis of penalty-based ensemble methods", *Numerical Algorithms*, Under review, 2024. arXiv
7. **R. Fang**, "Numerical analysis of locally adaptive penalty methods for the Navier-Stokes equations", *Journal of Scientific Computing*, Under review, 2024. arXiv
8. A. Çıbık, **R. Fang**, W. Layton, F. Siddiqua, "Data assimilation to correct model errors", 2024.

CONFERENCE TALKS

- *The 42nd Southeastern-Atlantic Regional Conference on Differential Equations (SEARCDE), West Virginia University, Morgantown, November 9-10, 2024.*
- *Mathematical Models and Numerical Methods for Multi-Physics Systems*, Pittsburgh, PA, May 2024.
- *Finite Element Circus*, Brown University, Providence, RI, April 2024.
- *Association for Women in Mathematics*, University of Pittsburgh, Pittsburgh, PA, September 2023.
- *Applied Mathematics, Modeling and Computational Science*, Waterloo, ON, Aug 2023.

Upcoming:

- *JMM, Seattle, 2025, "Recent Advancements in the Numerical Analysis of Nonlinear Partial Differential Equations".*

TEACHING EXPERIENCE

Teaching Fellow at the University of Pittsburgh Fall 2019 – Spring 2023

- Undergraduate Courses: Calculus I, II, III, and Business Calculus.
- Graduate Courses: Matrices and Linear Operators.

RESEARCH PROJECTS

Monte Carlo forecasting for turbulent flows [2, 6]

- Allowed greater ensemble sizes with reduced complexity and gave a longer predictability horizon of fluid simulation by uncoupling velocity and pressure and a shared coefficient matrix in parallel.
- Derived the mathematical proof of the ensemble penalty algorithm's stability and optimal convergence rate. Extended to the **Monte Carlo** ensembles.
- Verified the theoretical result with numerical tests in DOLFINx in **Python**, **extended the predictability horizon by 2 times** with only two ensembles given the 1st significant digit; the error of the ensemble average is **5 times smaller**.

Adaptive parameter selection in nudging-based data assimilation [1]

- Nudged imperfect and coarse observations into numerical models to improve the predictability.
- Developed and analyzed **2 self-adaptive methods** for nudging parameter selection that respond to flow behavior in time.
- Conducted numerical tests that demonstrated the effectiveness of the methods, achieving more accurate predictions with efficient nudging parameter values.

On a 1/2 equation model of turbulence [4, 5]

- Reduced the complex partial differential equation of the 1-equation URANS turbulence models to a simple 1/2-equation model with an ordinary differential equation by taking the spatial mean.
- Conducted **3D numerical simulations** in **Python** with the SMP cluster. In comparative tests in 2D and 3D, the velocity statistics produced by the 1/2-equation model are comparable to those of the full 1-equation model.
- Proved a comprehensive stability, convergence, and error analysis of the 1/2-equation URANS model.

A hybrid deep learning approach to vertexing [7]

- Transformed sparse 3D space of hits and tracks into a dense 1D dataset with 4,000 planes using a custom kernel.
- Developed a **custom symmetric loss function** to address target value estimation issues. Added an asymmetric parameter to balance false positives and efficiency, and applied masking to improve primary vertex detection.
- Achieved 90% accuracy using **convolutional neural networks** in **PyTorch** with 240,000 data.
- **Published** in the *Journal of Physics* and **presented** at the 2019 *ACAT conference*.

RESEARCH REFERENCES

Professor William Layton
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