Rui Fang

Google Scholar | Webpage | Pittsburgh, PA | ruf10@pitt.edu | (+1) 412-897-2071

My research combines numerical methods with machine learning to enhance the accuracy and efficiency of fluid simulations. I have **three solo-authored** papers, **three papers collaborated with others**, and two additional papers currently in progress.

Education

University of Pittsburgh, Pittsburgh, PA
PhD Candidate in Mathematics, Aug 2019 - Present
Carnegie Mellon University, Pittsburgh, PA
Cross-registration: Machine Learning
University of Cincinnati, OH and **Capital Normal University**, Beijing
Dual Bachelor of Science in Mathematics, 2015-2019.

Core Skills

- **Mathematics**: numerical methods, scientific computing, iterative methods, ODE, PDE, advanced linear algebra, analysis, math finance, statistics, and stochastic calculus.
- **Machine learning**: linear regression, decision tree, KNN, logistic regression, neural networks, naive Bayes, PAC, MLE, MAP, K-Means, random forest, SVM, PCA, Boosting, Bagging.
- **Deep learning and reinforcement learning**: CNN, RNN, LSTM, imitation learning, Monte Carlo methods, actor-critic, GAN, Q-Learning, policy gradient, model-based reinforcement learning, MDP.
- **Probabilistic and generative models**: variational methods, inference methods, MCMC, Markov random fields, Bayesian networks, deep generative models (RBMs, VAEs, GANs).
- **Libraries and tools**: PyTorch, TensorFlow, Keras, NumPy, SciPy, Pandas, DOLFINx, FEniCSx, and SQL.
- **Skills**: parallel computing on GPU and SMP clusters, time series analysis.
- **Coding languages**: Python, MATLAB, and JAVA.

Publications and Manuscripts

1. **Rui Fang**, *An algorithm for fast calculation of flow ensembles with Monte Carlo*, (In preparation for submission).
2. **Rui Fang**, *Locally adaptive penalty methods for the Navier-Stokes equations*, Journal of Scientific Computing, In revision, 2024. arXiv
3. Weiwei Han, **Rui Fang**, and William Layton, *Numerical analysis of the 1/2-equation model of turbulence*, 2024.
4. **Rui Fang**, Weiwei Han, William Layton, *On a 1/2-equation model of turbulence*, *International Journal of Numerical Analysis and Modeling*, In revision, 2023. arXiv.
5. **Rui Fang**, *Penalty Ensembles for Navier-Stokes with Random Initial Conditions & Forcing*, the VIth AMMCS Conference, Waterloo, ON, Canada, 2023. arXiv.
6. **Rui Fang**, Henry Schreiner, Michael Sokoloff, et.al, *A hybrid deep learning approach to vertexing, Journal of Physics*, 2019. article.

Posters and Talks

1. Mathematical models and numerical methods for multi-physics systems conference, **Pittsburgh, PA**, May 2024.
2. Finite Element Circus, **Brown University, Providence, RI**, April 2024.
3. **3-Minute Thesis Competition of Math Department, 2nd place**, University of Pittsburgh, March 2024.
4. **Association for Women in Mathematics**, University of Pittsburgh, Pittsburgh, PA, September 2023.
5. **Applied Mathematics, Modeling and Computational Science Conference, Waterloo, ON**, Aug 2023.

Research projects

On a 1/2 equation model of turbulence [3][4]

- Reduced the complex **partial differential equation** of the 1-equation URANS models of turbulence to a simple 1/2-equation model with **ordinary differential equation** by taking the **spacial mean**.
- Conducted numerical simulations using **Dolfinx** in **Python** in **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.

An algorithm on time-dependent Navier-Stokes for fast calculation of flow ensembles [1][5]

- Allowed greater ensemble sizes with reduced complexity, and thus 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 **stability** and **optimal convergence rate** of the ensemble penalty algorithm. Extended to the **Monte Carlo** ensembles.
- Verified the theoretical result with numerical tests in **Dolfinx** in **Python**, **extends of the predictability horizon** by **2 times** with only 2 ensembles given the 1st significant digit; the **error** of the ensemble average is **5 times smaller**.

A hybrid deep learning approach to vertexing at CERN [6], Cincinnati, OH, May 2018—Aug 2018

- Transformed **sparse 3D space** of hits and tracks into a **dense 1D dataset** with 4,000 planes with a custom kernel.
- Addressed underestimating or overestimating the target values by a custom symmetric loss function. Added an asymmetric parameter to resolve favoring false positives (FPs) at the expense of efficiency. Applied masking to find PVs better.
- Achieved 90% efficiency with less than 0.2 FPs by **CNN** in **Pytorch** on **GPU** with **240,000** training data.

Leaderships and Awards

- **Vice-president** of the *Association for Women in Mathematics*, University of Pittsburgh, led initiatives to promote gender equity in mathematics and foster a collaborative environment that empowered women in science.
- **Andrew W Mellon Fellow (2023-2024)**: Awarded a prestigious fellowship in arts & sciences for outstanding achievement, emphasizing research excellence in mathematics. 2 winners among ≈ 75 math PhD students at the University of Pittsburgh.
- **Ballroom Dancer** affiliated with *Carnegie Mellon Ballroom Club*. Silver-level Semi-finalist in **USA Dance Nationals Championships 2024** for Smooth, Latin, and Rhythm.
- **College Full-tuition Scholarship (2016-2018)**, University of Cincinnati, OH, based on academic merit.