Rui Fang
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PROFESSIONAL SUMMARY

Passionate about numerical analysis and scientific computing, I am a 5th-year math Ph.D. candidate working on improving fluid flow simulation accuracy. My research explores penalty ensembles for the Navier-Stokes equations, and combines machine learning techniques. As an Andrew Mellon Fellow 2023-2024, I am dedicating myself to my research.

EDUCATION

2019 - Present	**Ph.D. in Mathematics**, University of Pittsburgh, Pittsburgh, PA, USA **Ph.D. candidate since Dec 2023, Andrew Mellon Fellow 2023-2024.**
2015 - 2019	**Dual B.S. in Mathematics** University of Cincinnati, Cincinnati, OH, USA (**Full-tuition scholarship**) Capital Normal University, Beijing, China

MILESTONES:

Completed **preliminary exams** in Jan 2021, **comprehensive exams** in Feb 2022, and **Ph.D. thesis proposal** in Dec 2023.

TEACHING EXPERIENCE (2019-2023):

Since 2019, I have been assisting in Calculus I, II, and III, business calculus, and graduate course linear algebra at Pitt. I help students succeed. Described as pleasant, high-energy, and kind, I am dedicated to motivating students and creating engaging, joyful classes.
My students say that I teach in a way that everyone understands! I am enthusiastic, eager to explain, kind, prepared, approachable, helpful, supportive, and well-spoken, and I try my best to interact with them and help them!

PUBLICATIONS AND MANUSCRIPTS

1. **Rui Fang**, Weiwei Han, William Layton, On a 1/2-equation model of turbulence. In revision Computers & Fluids, 2023. https://arxiv.org/abs/2309.03358
2. **Rui Fang**, Penalty ensembles for the Navier-Stokes, the VI th AMMCS Conference, Waterloo, ON, Canada, 2023, https://arxiv.org/abs/2309.12870.
3. **Rui Fang**, Henry F Schreiner, Michael D Sokoloff, Constantin Weisser, and Mike Williams, A hybrid deep learning approach to vertexing. Citation: 2020 *J. Phys.: Conf. Ser.* 1525 012079. DOI 10.1088/1742-6596/1525/1/012079. https://arxiv.org/abs/1906.08306
4. **Rui Fang**, An algorithm for fast calculation of flow ensembles, manuscript complete, aim for a journal to submit.
5. **Rui Fang**, A Doubly Pointwise Adaptive Penalty Method for the Navier Stokes Equations, analysis complete, numeric in pending.
6. Weiwei Han, **Rui Fang**, Numerical analysis of a 1/2-equation model of turbulence, manuscript complete, aim for a journal to submit.

COURSES AND CORE SKILLS

- **Mathematics**: numerical methods, advanced scientific computing, finite element methods, iterative methods, ODE, PDE, analysis, linear algebra, 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, JAVA, and MATLAB.

RESEARCH PROJECTS

Ongoing research on a doubly pointwise adaptive penalty with ensembles [5]: The velocity error is sensitive to the choice of penalty parameter. Adapting the penalty parameter by monitoring an estimator is a natural idea. Imposing the

global condition locally suggests but does not imply the local condition is satisfied. I propose an algorithm that updates the penalty parameter locally to the ensemble local condition. I adapt the penalty parameter in time to increase the prediction accuracy. This is helpful for flow changes greatly over time. I have proved that $\sum_{\Delta} \epsilon_{\Delta}^{-1} |\nabla \cdot u_{\epsilon}^{h}|^2 = O(1)$. This equation suggests an estimator $\nabla \cdot u_{\epsilon}^{h}$ for adapting penalty parameter ϵ. I have verified the stability and convergence of the locally adaptive method.

Ongoing research on machine learning to calibrate adaptive parameters: Monitoring estimators to adapt penalty parameters may produce many rejections in numerical tests and could be costly. To avoid rejections, I combine numerical methods with machine learning techniques to better predict fluid flow. I will apply machine learning to tune the penalty parameter, time step size, and order of methods.

Ongoing research on the 3/2-equation model of turbulence: Unsteady Reynolds averaged Navier Stokes models approximate time average of the solutions. A variety of equations include 0-equation, 1-equation, and 2-equations. The predictability ability increases as the model complexity increases. I will take the space average of the frequency equation of the 2-equation model by Kolmogorov. I will develop the analysis and simplify further with the penalty approach.

On a 1/2 equation model of turbulence [1][6]

- 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 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.

An algorithm on time-dependent Navier-Stokes for fast calculation of flow ensembles [2] [4]

- 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, extending 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 [3]

- Transformed the 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 better find PVs.
- Achieved 90% efficiency with less than 0.2 FPs per event by CNN in Pytorch on GPU with 240,000 training data.

LEADERSHIP AND SERVICE

- **Vice president** of the *Association for Women in Mathematics* Student Chapter
- **Student officer** *of the Mathematics Graduate Student Organization* at Pitt

HONORS AND REWARDS

Andrew Mellon Fellowship	Fall 2023- Spring 2024
National Science Foundation Fellowship	Summer 2020-2023, May -July 2018
Arts and Sciences Graduate Fellowship	Jan – May 2020
Beijing Government Full Tuition Scholarship	2016 – 2018

EXTRACURRICULAR ACTIVITIES

- *Ballroom Dance:* I discovered my passion for dancing upon joining the math department at Pitt. Starting with Salsa and Bachata, I immersed myself in ballroom dance since 2022.
  - 1st place in Bronze Rhythm Chachacha and Rumba, and swing at **the USA Dance Sports Champions Chicago** Oct 2023.
  - 2nd place in Bronze Latin Chachacha and Rumba, 3rd place in pre-bronze Standard Waltz, and Quickstep at the **Ohio Star Ball**, Nov 2022, one of the biggest ballroom competitions in the States for over 40 years of history.
- *Math Co-ed Soccer Team:* Soccer serves as a dynamic and enjoyable connector for the math enthusiasts at Pitt.