Zirui Xu

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EDUCATION

Columbia University, Fu Foundation School of Engineering and Applied Science — New York, NY
Ph.D. in Applied Mathematics — Sep 2018 – Aug 2024

- GPA: 4.08/4.33 Distinction in doctoral qualifying exam: scoring 192/200
- Coursework: functional analysis, analytic methods for PDE, numerical methods for PDE, dynamical system, stochastic process, machine learning and high-dimensional data, computer animation

Peking University, School of Mathematical Sciences — Beijing, China
B.Sc. in Computational Mathematics — Sep 2014 – Jul 2018

- GPA: 3.79/4.00 Ranking in department: 2/19 Ranking in school: 10/190
- Coursework: optimization method, stochastic simulation, partial differential equation (PDE), numerical analysis, numerical algebra, machine learning, deep learning, big data analysis

RESEARCH AREAS

- Calculus of variations: Γ-convergence, nonlocal isoperimetric problem
- Pattern formation: Ohta–Kawasaki energy, Helfrich energy, Willmore energy
- Partial differential equation: phase-field model, Cahn–Hilliard dynamics
- Numerical method: Fourier spectral method, semi-implicit scheme, convex splitting scheme
- Rare event: minimum energy path, transition state, string method, shrinking dimer method
- Numerical simulation: scientific computing, high performance computing
- Asymptotic analysis: bifurcation theory, method of matched asymptotic expansions
- Fractional derivative: fractional initial value problem, fractional stochastic process

RESEARCH EXPERIENCE

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Graduate Research Assistant advised by Qiang Du — Sep 2018 – Aug 2024

- Studied Ohta–Kawasaki energy which is an elegant mathematical model of pattern formation observed in many material, physical, and biological systems. Conducted extensive numerical simulations on high-performance computing clusters with GPU acceleration in MATLAB. Studied asymptotics of energy minimizers using the method of matched asymptotic expansions. Provided new mathematical insights into self-assembly of block copolymers, atomic nuclei, and amphiphiles
- Studied a fractional stochastic process and solved the initial value problem of its Feller generator using a representation similar to the Feynman–Kac formula. Solved the exit problem using the solution to the relaxation equation, thereby establishing the connection between this stochastic process and a new type of time-fractional diffusion

Peking University, Elite Undergraduate Training Program in Applied Math & Stats — Beijing, China
Undergraduate Research Assistant advised by Lei Zhang and An-Chang Shi — Jun 2016 – Jul 2018

- Simulated fusion processes of bilayer membranes based on a density functional theory. Obtained energy local minimizers using Cahn–Hilliard gradient flow dynamics. Obtained minimum energy paths and transition states using the string method, thus providing the most probable transition path of membrane fusion

TEACHING EXPERIENCE

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Teaching Assistant of APMA E2000 Multivariable Calculus — Spring 2024

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Grader of APMA E6301 Analytical Methods for Partial Differential Equations — Fall 2021

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Teaching Assistant of APMA E2000 Multivariable Calculus — Spring 2021

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Teaching Assistant of APMA E2000 Multivariable Calculus — Fall 2020

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Grader of APMA E6302 Numerical Analysis of Partial Differential Equations — Spring 2020

Columbia University, Department of Applied Physics and Applied Mathematics — New York, NY
Teaching Assistant of APMA E4302 Methods in Computational Science — Fall 2018

PUBLICATIONS

[d] denotes supplementary data set. In some publications, authors are listed in alphabetical order.

[5] Qiang Du, James M. Scott, Zirui Xu. Ohta–Kawasaki energy for amphiphiles: asymptotics and phase-field simulations. *Nonlinear Analysis* **250**: 113665 (2025)

[d] Qiang Du, James M. Scott, Zirui Xu. Degenerate Ohta–Kawasaki energy for amphiphiles. *Open Science Framework* (2024)

[4] Zirui Xu, Qiang Du. Bifurcation and fission in the liquid drop model: a phase-field approach. *Journal of Mathematical Physics* **64**(7): 071508 (2023)

[d] Zirui Xu, Qiang Du. Numerics of liquid drop model. *Open Science Framework* (2023)

[3] Zirui Xu, Qiang Du. On the ternary Ohta–Kawasaki free energy and its one-dimensional global minimizers. *Journal of Nonlinear Science* **32**(5): 61 (2022)

[2] Qiang Du, Lorenzo Toniazzi, Zirui Xu. Censored stable subordinators and fractional derivatives. *Fractional Calculus and Applied Analysis* **24**(4): 1035–1068 (2021)

[1] Yucen Han, Zirui Xu, An-Chang Shi, Lei Zhang. Pathways connecting two opposed bilayers with a fusion pore: a molecularly-informed phase field approach. *Soft Matter* **16**(2): 366–374 (2020)

PRESENTATIONS

NJIT, SIAM New York-New Jersey-Pennsylvania Sectional Meeting — Newark, NJ
Bifurcation and fission in the liquid drop model: a phase-field approach — Oct 2023

Columbia University, APAM Graduate Student Research Symposium — New York, NY
Bifurcation and fission in the liquid drop model: a phase-field approach — Apr 2023

Peking University, Elite PhD Seminar in Computational and Applied Mathematics — (virtual) Beijing, China
Fission in liquid drop model: a phase-field approach — Sep 2022

David L. Lawrence Convention Center, SIAM Conference on the Life Sciences — Pittsburgh, PA
Pathways connecting two opposed bilayers with a fusion pore — Jul 2022

University of South Alabama, AMS Southeastern Sectional Meeting — (virtual) Mobile, AL
On the ternary Ohta–Kawasaki free energy and its one-dimensional global minimizers — Nov 2021

PEER REVIEWER

Numerical Methods for Partial Differential Equations

COMMUNITY OUTREACH

Mentor of incoming PhD students in the Department of Applied Physics and Applied Mathematics — 2021

Mentor of Columbia undergraduate teams for Mathematical Contest in Modeling (MCM)	Jan 2021
Cohost of Mid-Autumn Festival Party by Columbia University Chinese Association (CUCSSA)	Sep 2019
Volunteer for welcoming pickup of Columbia new students from JFK Airport with CUCSSA	Aug 2019
Mentor of incoming PhD students in the Department of Applied Physics and Applied Mathematics	2019
Volunteer of Unite the Force for Good · Love Package to fundraise for rural pupils in China	Oct 2014

HONORS & AWARDS

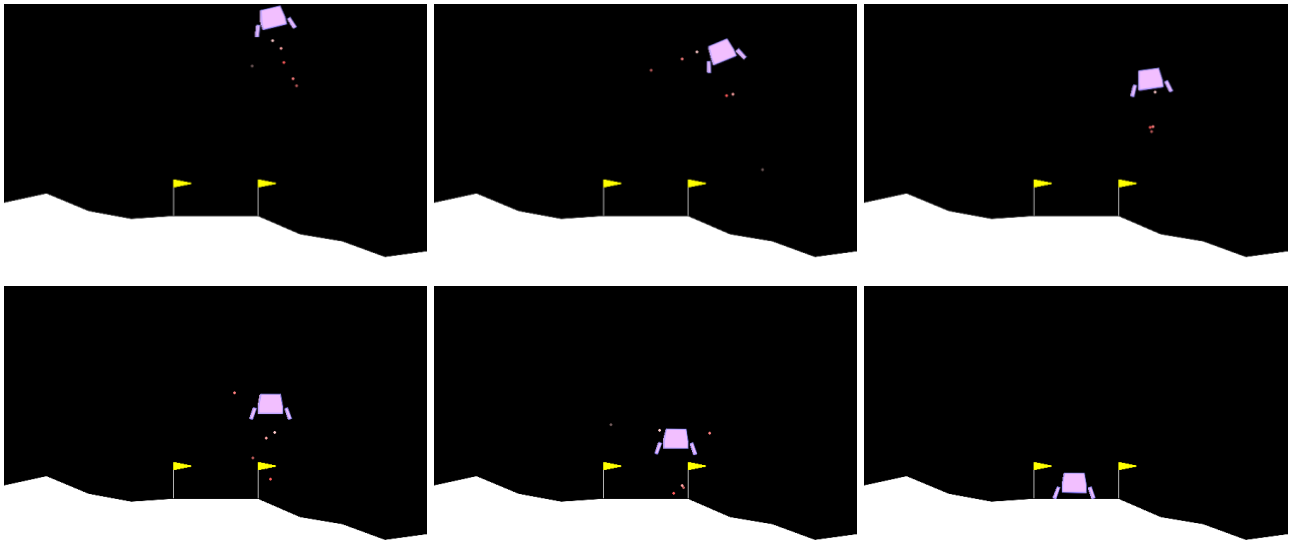
Best Presentation in Applied Mathematics of Graduate Research Symposium	$200	Apr 2023
SIAM Student Travel Award	$650	Jul 2022
NYCRUNS Brooklyn Half Marathon Finisher with Columbia University Road Runners (CURR)		Apr 2022
Golden Bunny Award for Best Creative Scenes in the computer animation course		Dec 2018
National Southwest Associated University Scholarship	¥8000	Oct 2017
National Scholarship	¥8000	Oct 2017
Merit Student Pacesetter		Oct 2017
Samsung Scholarship	¥7000	Oct 2016
Merit Student Pacesetter		Oct 2016
First Prize in China Undergraduate Mathematical Modeling Contest		Sep 2016
First Prize in China Undergraduate Physics Contest		Dec 2015
Tung OOCL Scholarship	¥5000	Oct 2015
Merit Student		Oct 2015
One-Star Certificate from China Foundation for Poverty Alleviation		Dec 2014

SKILLS & INTERESTS

Matlab, Mathematica, C++, Python, LaTeX, Linux
Running, Swimming, Badminton, Documentaries

RECENT PROJECTS

- Implemented deep Q-network for reinforcement learning in Open AI's lunar landing environment. Successfully trained the agent to land on the moon with high scores 235~325 (according to Open AI's gym documentation, "an episode is considered a solution if it scores at least 200 points"). Snapshots shown below, more details at https://ziruixu.github.io/blog/lunar-lander-dqn



- Implemented C++ program using min heap to merge sort 10000 individually sorted data files (100 GB in total). Time complexity is $O(100\ \text{GB} \times \log 10000)$. Employed customized I/O buffers and determined the optimal buffer sizes using the Lagrange multiplier. More details at https://ziruixu.github.io/blog/merge-sort-cpp