Zirou Qiu

zirouq.me
zq5au@virginia.edu
+1 (864) 633-4466

Research Interest

My research advances the foundational understandings of **large-scale complex systems** (e.g., social systems, infrastructure systems, multi-agent systems) through the lens of *machine learning*, *computational modeling* and *optimization*. I focus on developing **formal computational models and techniques** to simulate, analyze and optimize these large systems, with the goal of improving system performance and benefiting the **social good**. Particularly, I have performed abundant research in related issues such as improving fairness in social systems, resource allocation, multi-agent system planning, large-scale agent-based modeling, and black-box system inference.

Education

University of Virginia — *Charlottesville, USA*
Ph.D. Candidate in Computer Science (GPA: 4.0) - Advisor: Madhav Marathe — *Aug 2020 – **Present***

Clemson University — *Clemson, USA*
M.S. in Computer Science (GPA: 3.75) - Advisor: Ilya Safro — *Aug 2018 - May 2020*

Southeast Missouri State University — *Cape Girardeau, USA*
B.S. in Computer Science (GPA: 3.7) - Dean's List, Cum Laude — *Aug 2013 - May 2018*

Research Projects and Papers

Project I: Optimal Resource Allocation on Large-scale Systems

Lead Researcher — *Advisor: Prof. Madhav Marathe*

- Project goal: Design formal models and methodologies for *optimal* resource allocation on real-world large-scale systems.
- Proposed formal frameworks for modeling resource allocation on large systems.
- Developed multiple efficient allocation algorithms that are *provably* optimal or near-optimal, while accounting for fairness and diversity.
- Conducted comprehensive agent-based simulations for resource allocation in large systems.

Project Outcomes:

[1] Welfare Optimization for Resource Allocation with Peer Effects — ***In Submission to PNAS***
***Zirou Qiu**, Daniel Rosenkrantz, Matthew O. Jackson, Simon Levin, S. S. Ravi, Richard Stearns, Madhav Marathe*

- We developed a principled model for resource allocation with externalities (e.g., mutual influences among the resources or the population) in real-world social and multi-agent systems.
- We proposed efficient strategies that guarantees optimal or near-optimal welfare outcomes for realistic resource allocation scenarios.

[2] Assigning Agents to Increase Network-Based Neighborhood Diversity [pdf] — ***AAMAS-23** (Acc: 23.3%)*
Zirou Qiu**, Andrew Yuan, Chen Chen, Madhav Marathe, S.S. Ravi, Daniel Rosenkrantz, Richard Stearns, Anil Vullikanti* — (Oral***)

- We developed a formal model for real-world spatial resources allocation problems, such as public housing assignment and urban spatial planning.
- We presented rigorous methodologies for resource allocation with provable close-to-optimal guarantees, while achieving social diversity and fairness.

Project II: Efficient Inference of Large-scale Black-box Systems

Lead Researcher — *Advisor: Prof. Madhav Marathe*

- Project goal: Develop efficient algorithms for learning unknown components in large-scale systems.
- Proposed several efficient and highly scalable learning methods for black-box system inference.
- Established the performance guarantee of the proposed methods both theoretically and experimentally.

Project Outcomes:

[1] Learning Discrete Dynamical Systems under Classification Noise [pdf] ***In submission to NeurIPS-2024***

Zirou Qiu*, Zakaria Mehrab*, Abhijin Adiga, Madhav Marathe, S.S. Ravi, Daniel Rosenkrantz, Richard Stearns, and Anil Vullikanti*

- We proposed efficient noise-tolerant algorithms for learning the behaviors of large-scale systems in realistic noisy environments, with a provable high learning accuracy.
- Our algorithms are highly scalable to large networks, and the amount of training data required is provable near-optimal.

[2] Theoretical Foundations for Parent Divorcing Transformations [pdf] ***In submission to TCS***

*Daniel Rosenkrantz,$^{(\alpha\text{-}\beta)}$ Madhav Marathe, **Zirou Qiu**, S.S. Ravi*

- We estabilished a theoretical groundwork for dimensionality reduction in Bayesian inference.
- We proposed efficient algorithms for dimensionality reduction with provable guarantees.

[3] Efficient PAC Learnability of Dynamical Systems Over Multilayer Networks [pdf] ***ICML-24*** *(Acc: 27.8%)*

Zirou Qiu*, Abhijin Adiga, Madhav Marathe, S.S. Ravi, Daniel Rosenkrantz, Richard Stearns, and Anil Vullikanti*

- We proposed the first efficient learning method for inferring the behaviors of large-scale multilayer social systems and multi-agent systems.
- We lay a theoretical foundation of learning multilayer systems with an exact analysis of the model complexity and expressiveness.

[4] Learning the Topology and Behavior of Discrete Dynamical Systems [pdf] ***AAAI-24*** *(Acc: 23.8%)*

Zirou Qiu*, Abhijin Adiga, Madhav Marathe, S.S. Ravi, Daniel Rosenkrantz, Richard Stearns, and Anil Vullikanti*

- We investigate the core principles of learning both the behaviors and the topology of black-box social systems and multi-agent systems.
- We proposed several efficient learning algorithms with provable guarantees for realistic scenarios of learning large systems.

[5] Learning Networked Dynamical Systems Via Active Queries [pdf] ***ICML-22*** *(Acc: 22%)*

*Daniel Rosenkrantz,$^{(\alpha\text{-}\beta)}$ Abhijin Adiga, Madhav Marathe, **Zirou Qiu**, S.S. Ravi, Richard Stearns, and Anil Vullikanti* (***Spotlight***)

- We presented the first collection of active learning based methods for inferring both the behaviors and the topology of black-box social systems and multi-agent systems.
- We conducted an extensive experimental study on the empirical performs on the proposed algorithms on real-world networks over various learning scenarios.

Project III: Modeling and Simulation of Complex Systems

Lead Researcher *Advisor: Prof. Madhav Marathe*

- Project goal: Reveal novel phenomena and properties of large systems via (agent-based) simulation.
- Designed principled models for multi-contagion diffusion on complex systems.
- Performed extensive simulations for dynamic processes over large systems on real datasets.
- Revealed novel phenomena and intrinsic properties of complex system dynamics.
- Derived policy guidelines for betterment of social good.

Project Outcomes:

[1] Airborne disease transmission during indoor gatherings over multiple time scales [pdf] ***PNAS-23***

*Avinash Dixit, Baltazar Espinoza, **Zirou Qiu**, Anil Vullikanti, and Madhav Marathe*

- We introduced a principled modeling framework that couples the fast dynamics of viral loads in the local scale and the slow dynamics of disease progression at the population level.
- We derived policy guidelines to lessen the negative impact of epidemics.

[2] Understanding the Co-evolution of Mask-wearing and Epidemics [pdf] ***PNAS-22***

Zirou Qiu*, Baltazar Espinoza, Vitor V. Vasconcelos, Chen Chen, Sara M. Constantino, Stefani A. Crabtree, Luojun Yang, Anil Vullikanti, Jiangzhuo Chen, Jörgen Weibull, Kaushik Basu, Avinash Dixit, Simon Levin, Madhav Marathe*

- We presented a fundamental model for dueling dynamics of social and biological contagions both cooperating and completing in a population.

- Through our modeling, we uncovered a collection of previously unknown phenomena in contagion dynamics.
- We derived corresponding policy guidelines to suppress epidemics and prevent their resurgence.

Project IV: Dynamics and Stability of Complex Systems

Lead Researcher *Advisor: Prof. Madhav Marathe*

- Project goal: Investigate the foundations of stochastic behavior and stability of complex systems.
- Conducted rigorous analytical studies of diffusion in complex systems.
- Performed extensive agent-based simulations of dynamic processes on complex systems.

Project Outcomes:

[1] Networked Anti-Coordination Games Meet Graphical Dynamical Systems [pdf] ***AAAI-23*** *(Acc: 19.6%)*
Zirou Qiu*, Chen Chen, Madhav Marathe, S.S. Ravi, Daniel Rosenkrantz, Richard Stearns, and Anil Vullikanti* (***Oral***)

- We presented a theoretical groundwork for stability and convergence in real-word strategic situations such as resources sharing and competition within a society.

[2] Finding Nontrivial Minimum Fixed Points in Networked Dynamical Systems [pdf] ***AAAI-22*** *(Acc: 15%)*
Zirou Qiu*, Chen Chen, Madhav Marathe, S.S. Ravi, Daniel Rosenkrantz, Richard Stearns, and Anil Vullikanti* (***Oral***)

- We established the principles of finding equilibrium points in contagion diffusion within a population, with the goal of minimizing the overall scale of infection in a society.

Other Papers

[1] ELRUNA: Elimination Rule-based Network Alignment [pdf] ***ACM JEA-2021***
Zirou Qiu*, Ruslan Shaydulin, Xiaoyuan Liu, Yuri Alexeev, Christopher S. Henry, Ilya Safro*

- We propose novel algorithms for the network alignment problem that outperforms the state-of-the-art methods, with applications in computational biology and social network analysis.

Research Experience

Biocomplexity Institute and Initiative *Advisor: Madhav Marathe; Mentors: S. S. Ravi, Dan Rosenkrantz*
Research Assistant *Fall 2020 – **Present***

- Investigated the foundations of social systems and multi-agent systems from the perspective of computational modeling, optimization, machine learning, and game theory.
- Developed large-scale frameworks for socio-technical system modeling.
- The lead researcher for four research projects, all resulted in multiple publications.
- Eight published works (PNAS 22 & 23, AAMAS 23, AAAI 22, 23 & 24, ICML 22 & 24), plus three in-submission papers.
- Worked in a team with over 40 scientists from various domains such as CS, social science, and economics.

Clemson University *Advisor: Prof. Ilya Safro*
Graduate Research Assistant *Jan 2019 - May 2020*

- Studied computational problems in quantum computing and biology.
- Built a pipeline for microbiome modeling. Discovered novel microbiome migration pattern.

Argonne National Laboratory - Data Science Division *Host: Chris Henry*
Graduate Research Aide *Summer 2019*

- Performed comprehensive analysis of microbiome data.
- Investigated the network alignment problem with applications in computational biology.
- One first-author published work at ACM-JEA.