Mehdi Soleimanifar

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Overview

- Postdoctoral researcher with a background in theoretical physics and quantum computing, currently transitioning into AI research.
- Interested in developing safe and capable AI systems that can advance scientific discovery and technological progress.
- Experienced in designing, analyzing, and validating machine learning algorithms to address complex, high-dimensional problems of scientific interest in physics and quantum computing.

Education

Ph.D. in Theoretical Physics, Massachusetts Institute of Technology 2022
Thesis: Efficiently Learning, Testing, and Simulating Quantum Many-Body Systems
Advisor: Aram Harrow

B.Sc. in Physics and Electrical Engineering, Sharif University of Technology, Tehran, Iran 2016

Skills

Machine Learning & Artificial Intelligence: Familiar with large language model evaluation, fine-tuning and prompt engineering, reinforcement learning with LLM-shaped rewards, neural architecture optimization (Transformer, GRU, MLP), experiment tracking (Weights & Biases, TensorBoard), custom loss and reward design for scientific applications.

Programming & Experimental Infrastructure: Python; ML/AI libraries (PyTorch, NumPy, SciPy, Stable-Baselines3, Gymnasium), distributed training on HPC clusters (Caltech GPU nodes: H100s/A100s) using job schedulers (SLURM), version control (Git), reproducible experiment design and implementation.

Algorithm Design & Optimization: Sample-efficient learning algorithms, complexity and performance analysis, specialized ML and simulation algorithms for physical systems.

Research & Collaboration: Interdisciplinary research, project leadership, scientific writing, peer-reviewed publications, conference presentations, mentorship, team coordination.

Research Experience

Postdoctoral Researcher, California Institute of Technology 08/2022–Present

Hosted by John Preskill and Urmila Mahadev

- Developing a framework for lightweight, structured virtual environments to train and evaluate AI systems on scientific reasoning. Preliminary write-up: https://mehdis.me/files/AIScientist.pdf
- Designed, implemented, and evaluated machine-learning tools to simulate quantum systems, including efficient neural representations, sample-efficient training, and inference of physical properties.
- Published results in leading journals and conferences (e.g., Nature Physics, FOCS, PRX Quantum, QIP).
- Mentored undergraduate researchers on quantum computing and ML projects (2023, 2024).

Ph.D. Research Assistant, Massachusetts Institute of Technology 09/2016–05/2022

Advised by Aram Harrow

- Designed and validated new algorithms for key statistical, machine learning, and simulation tasks in physics and quantum computing, including Hamiltonian learning, entanglement detection, and ground-state energy estimation.
- Conducted rigorous theoretical analysis demonstrating that physical systems exhibit latent

structure—such as strong convexity of free energy and patterns of entanglement spread—that enable efficient machine learning and simulation of quantum phenomena.

- Published research in premier physics and computer science venues (Nature Physics, PRL, FOCS, STOC, SODA).

Selected Publications

* *Indicates alphabetical order or equal contribution.*

1. T. Yang*, M. Soleimanifar*, T. Bergamaschi, J. Preskill. *When Can Classical Neural Networks Represent Quantum States?* Preprint, arXiv:2410.23152.

2. A. Anshu*, S. Arunachalam*, T. Kuwahara*, M. Soleimanifar*. *Sample-Efficient Learning of Interacting Quantum Systems*. Nature Physics 17, 931–935 (2021); also in the proceedings of FOCS 2020, pp 685-691.

3. H. Huang*, J. Preskill*, M. Soleimanifar*. *Certifying Almost All Quantum States with Few Single-Qubit Measurements*. To appear in Nature Physics; also in the proceedings of FOCS 2024, pp 1202-07.

4. A. Anshu*, A. Harrow*, M. Soleimanifar*. *Entanglement Spread Area Law in Gapped Ground States*. Nature Physics 18, 1362–1366 (2022).

5. M. Soleimanifar*, J. Wright*. *Testing Matrix Product States*, in proceedings of SODA 2022, pp 1679–1701.

6. A. Bene Watts*, D. Gosset*, Y. Liu*, M. Soleimanifar*. *Quantum Advantage from Measurement-Induced Entanglement in Random Shallow Circuits*. PRX Quantum 6, 010356; arXiv:2407.21203.

7. A. Ramkumar, M. Soleimanifar, *Mixing Time of Quantum Gibbs Sampling for Random Sparse Hamiltonians*. To appear in proceedings of TQC 2025, arXiv:2411.04454.

Selected Awards

- AWS Quantum Postdoctoral Scholarship, Caltech (2022-2025)
- Quantum Innovator in Computer Science and Mathematics, IQC Waterloo (2022)
- IBM Prize for Excellent Contributed Talk, Physics of Computation Conference (2021)
- Buechner Graduate Teaching Prize, MIT (2020)
- Presidential Fellowship for Graduate Studies, MIT (2016-2017)

Professional Activities

- **Program Committee Member:** QIP 2025, TQC 2025
- **Journal & Conference Reviewer:** Nature Physics, Nature Communications, PRL, PRX Quantum, Physical Review A, SIAM Journal on Computing, Quantum, STOC, FOCS, QIP, ESA, ICALP, TQC, ITCS

Selected Talks

- When Can Classical Neural Networks Represent Quantum States? AWS–Chan Meeting, Caltech (2024)
- Machine Learning Models of Quantum States, Google Quantum-CS Seminar (2024)
- Sample-Efficient Learning of Quantum Many-Body Systems, FOCS (2020)
- Certifying Almost All Quantum States with Few Single-Qubit Measurements, FOCS (2024)
- New Features of Interacting Quantum Systems and Algorithmic Applications, IQC Waterloo (2022)