Mehdi Soleimanifar

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Overview

- Excited about developing agentic AI systems with advanced reasoning capabilities to uncover novel insights, solve complex problems, and perform sophisticated multi-step tasks.
- Experienced in integrating LLMs with RL and search, designing multi-step reasoning evaluations, and fine-tuning models for instruction following and mathematical reasoning.
- Publications in leading CS and physics venues (Nature Physics, FOCS/STOC/SODA), MIT teaching award, and prize for technical conference presentations.

Education and Employment

Ph.D. in Theoretical Physics, Massachusetts Institute of Technology — 2016-2022
Thesis: Efficiently Learning, Testing, and Simulating Quantum Many-Body Systems
Advisor: Aram Harrow

Postdoctoral Researcher, California Institute of Technology — 2022-2025
Hosted by: John Preskill and Urmila Mahadev

AI/ML Research Experience

- **LLM-Guided RL for Out-of-Distribution Tasks:** Developed a system where an LLM (with semantic and visual inputs) intermittently guides a pretrained vision-based RL agent (DreamerV3) with high-level action sequences to accomplish novel tasks. The system enabled complex behaviors like bridge and tunnel construction in the Minecraft-style game Crafter without retraining, achieving 91% success on new tasks while maintaining baseline performance. **Code** | **Technical Report**
- **TinyLabs: Benchmark for AI-Driven Scientific Discovery:** Created a synthetic pipeline for generating interactive environments to evaluate LLM capabilities in scientific reasoning across domains (e.g., genomics, climate modeling, economics). Supports systematic assessment of pattern recognition, causal inference, and hypothesis generation. **Code** | **Technical Report**
- **LLM-Guided Heuristic Discovery (Simplified AlphaEvolve):** Implemented a lightweight version of DeepMind's AlphaEvolve demonstrating how LLMs can iteratively generate and refine heuristic algorithms for optimization problems through population-based search. Achieved competitive performance on NP-hard bin packing using modest compute (GPT-4.1-nano). **Code** | **Technical Report**

Skills

Machine Learning & AI: Optimized neural architectures (Transformer, GRU, RNN) for physics simulation; Fine-tuned open source models (Qwen, Llama) with PPO and GRPO on GSM8K and MATH datasets using correctness- and process-based reward functions; Implemented PPO-based RLHF on the OpenAssistant dataset for model alignment with human preferences; Applied parameter-efficient supervised fine-tuning (PEFT / SFT) and prompt engineering to enhance reasoning consistency; Experimented with reasoning agents combining planning, search, and tool-use (e.g., STaR, PlanSearch, ReAct) to improve reasoning and decision-making.

Programming & Infrastructure: Python, PyTorch, NumPy, SciPy, Hugging Face (Transformers, TRL), Stable-Baselines3, Gymnasium; distributed training on HPC clusters (Caltech H100/A100 GPUs); WandB and TensorBoard; Git-based version control and reproducible workflows.

Academic Research Experience

- **Quantum System Learning:** Developed sample-efficient ML algorithms for learning quantum many-body systems, achieving exponential reduction in sample complexity with provable performance guarantees **Article 1** | **Article 2**| **Article 3**
- **Quantum and Classical Simulation Algorithms:** Developed algorithms for simulating physical properties of quantum many-body systems, combining theoretical and mathematical analysis with numerical validation **Article 1** | **Article 2**| **Article 3**

Selected Publications

** Indicates alphabetical order and equal contribution.*

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

2. H. Huang*, J. Preskill*, M. Soleimanifar*. *Certifying Almost All Quantum States with Few Single-Qubit Measurements*. Nature Physics (2025): 1-8; FOCS 2024, pp 1202-07.

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

4. M. Soleimanifar*, J. Wright*. *Testing Matrix Product States*. SODA 2022, pp 1679–1701.

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

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:** QIP 2025, TQC 2025
- **Reviewer:** Nature Physics, Nature Communications, Physical Review Letters, 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)
- Certifying Almost All Quantum States with Few Single-Qubit Measurements, FOCS (2024)
- New Features of Interacting Quantum Systems and Algorithmic Applications, IQC Waterloo (2022)
- Sample-Efficient Learning of Quantum Many-Body Systems, FOCS (2020)