ISAAC LIAO

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EDUCATION

Massachusetts Institute of Technology *Sep 2023 - Jun 2024 (Expected)*
Master of Engineering, Electrical Engineering and Computer Science
Advisor: Max Tegmark

Massachusetts Institute of Technology GPA: 5.0/5.0 *Sep 2019 - Jun 2023*
Bachelor of Science, Double major in Computer Science and Physics
Classes (*Graduate): Bayesian Modeling and Inference*, Statistical Learning Theory*, Information Theory*, Quantum Physics I-III, Computer Vision, Statistical Mechanics I, Experimental Physics I.

RESEARCH EXPERIENCE

Researcher - Tegmark AI Safety Group *Sep 2023 - Present*
Advisor: Max Tegmark

- Design of algorithms for proving the validity of a bijection between recurrent neural networks and finite state machines, for AI safety purposes.
- Construction of systems for simplification of neural networks, to facilitate mechanistic interpretation.

Researcher - Beneficial AI Foundation *Jul 2023 - Aug 2023*
Advisor: Max Tegmark

- Introduction of a novel hypernetwork architecture for generative modeling of mechanistically interpretable neural networks.
- Architecture is a merge of Pareto hypernetworks, hierarchical VAEs, and graph transformers.
- Reverse-engineering of 4 learned algorithms, with algorithmic phase transitions using order parameters and visualization via force-directed graph drawing.

Researcher - Soljacic Group *Jun 2020 - Jun 2023*
Advisor: Marin Soljacic

- Invented a novel machine learning optimization algorithm which blends learn to optimize (L2O) meta-learning techniques, quasi-Newton optimization methods, and sparse neural networks.
- Theoretical results regarding convex and nonconvex stochastic convergence, and sparse neural network expressiveness, both with experimental support.

PROJECTS

Bayesian Recommender Systems *Feb 2023 - May 2023*
Class Final Project: Graduate Bayesian Modeling and Inference

- Probabilistic reformulation of the alternating least squares algorithm for low rank approximations in large matrix completion problems.
- Extension of algorithm from within the Bayesian framework to accommodate an expanded posterior class, using coordinate ascent variational inference and mean-field approximation.
- Experiments to support over a 2% improvement in Netflix Prize Dataset RMSE, and ablative analyses of structures in the learned posterior.

Parameter-Efficient Approximation by Exploitation of Sparsity *Sep 2022 - Dec 2022*
Class Final Project: Graduate Statistical Learning Theory

- Novel theorems regarding the expressiveness sparse neural network architectures, more specifically their ability to parameter-efficiently replicate any other sparse architecture. Proofs draw from ideas about the Pinsker inequality, Cheeger inequality, card shuffling, algrebraic connectivity, and transposition graphs.
- Experimental evaluation of the ability of sparse architectures to perform compositionally sparse linear operations.

A Perturbative Approach to Random Matrix Spectra *Feb 2022 - May 2022*
Class Final Project: Quantum Physics III

- Derivation of the joint eigenvalue distribution of random Hermitian matrices and the Wigner semicircle law, using a combination of second-order quantum perturbation theory, Metropolis-Hastings, and Brownian motion.
- Simulation-based exploration of connections to chaotic quantum billiards and application to emission spectra of quantum dots.

Swarm Intelligence for MIT Battlecode AI Programming Competition *Jan 2020 - Jan 2022*

- Developed novel swarm intelligence algorithms to play multi-agent incomplete information real time strategy games.
- Championed the tournament in 2022 on a one person undergraduate team up against ∼200 teams of up to four graduate students from MIT, other top institutions in the US, and around the world.
- Won a total of $9500.

Differential Entropy Codes for Trained Image Compression *Feb 2021 - May 2021*
Class Final Project: Computer Vision

- Development of neural network based image compression techniques.
- Use of information theory to develop channel codes for compression that resemble the forward passes of VAEs and BNNs.
- Reinvented reparameterization gradients, hierarchical depth, and KL annealing schedules in the process, without prior knowledge of variational inference.

TEACHING EXPERIENCE

Teaching Assistant - MIT 8.01 Classical Mechanics I *Sep 2023 - Present*

- Ideation, prototyping, and testing of novel methods for making use of language models for teaching purposes. Collaborative construction of a large language model for generating physics problems used to teach ∼700 students and for answering student questions.
- Drafting of manuscripts for publication in journals on physics education.
- Office hours, grading, exam proctoring, review of course websites and other materials for errors.

PUBLICATIONS AND PREPRINTS

- **Isaac Liao**, Rumen Dangovski, Jakob Nicolaus Foerster, and Marin Soljačić. Learning to optimize quasi-newton methods. *Transactions on Machine Learning Research*, 2023a. ISSN 2835-8856. URL `https://openreview.net/forum?id=Ns2X7Azudy`
- **Isaac Liao**, Ziming Liu, and Max Tegmark. Generating interpretable networks using hypernetworks, 2023b. URL `https://arxiv.org/abs/2312.03051`

INVITED TALKS

- Massachusetts Institute of Technology SuperUROP Showcase, "Learning to Optimize Quasi-Newton Methods (LODO)", Cambridge, MA, May 2023.

AWARDS AND HONORS

MIT Battlecode Competition: Champion. $8000 prize. *Jan 2022*
MIT Battlecode Competition: 7th place. $1000 prize. *Jan 2021*
MIT Battlecode Competition: Champion of Newbie division. $500 prize. *Jan 2020*
International Physics Olympiad: *Silver Medal.* *Jul 2019*
International Physics Olympiad: *Honorable Mention.* *Jul 2018*