

Arjun Karuvally

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EDUCATION

- **College of Information and Computer Sciences (CICS), University of Massachusetts (UMASS)** Amherst, MA, USA
PhD in Computer Science. Candidacy achieved on 06 December 2022. Aug. 2019 – Sept 2024
- **College of Information and Computer Sciences (CICS), UMASS** Amherst, MA, USA
MS in Computer Science Aug. 2017 – May 2021
- **National Institute of Technology** Trichy, Tamil Nadu, India
Bachelor of Technology in Computer Science and Engineering Aug. 2013 – May. 2017

CURRENT RESEARCH

- **Biologically Inspired Neural and Dynamical Systems Laboratory** UMASS Amherst
Research Assistant January 2021-Present
 - **Temporal Memory Models:** I introduced a new class of energy-based biological memory models called the General Sequential Episodic Memory Model (GSEMM), which exhibits a temporal energy surface. I applied non-linear dynamical systems theory, energy-based memory modeling, and dynamical system simulations to design and simulate GSEMM. Currently, GSEMM theory has improved the sequence memory capacity of 100-neuron memory models from 14 memory sequences to greater than 1000 memory sequences.
 - **Mechanistic Understanding of Nueural Networks using GSEMM:** I introduced a framework that connects memory models with contemporary neural networks - both feed-forward and recurrent. I applied non-linear dynamical systems analysis, abstract algebra from physics to develop theoretical tools, tasks, and models applications. Currently, we have exploited this connection to form a mechanistic understanding of RNN computations which has fully explained the behavior of trained RNNs.

RELEVANT PUBLICATIONS

- **Karuvally, A.,** DelMastro, P., and Siegelmann, H.T. (2023). Episodic Memory Theory for the Mechanistic Interpretation of Recurrent Neural Networks. ArXiv, abs/2310.02430.
- **Karuvally, A.,** DelMastro, P. and Siegelmann, H.T.. (2023). Episodic Memory Theory of Recurrent Neural Networks: Insights into Long-Term Information Storage and Manipulation. *Proceedings of 2nd Annual Workshop on Topology, Algebra, and Geometry in Machine Learning (TAG-ML)*, in *Proceedings of Machine Learning Research* 221:371-383 Available from <https://proceedings.mlr.press/v221/karuvally23a.html>.
- **Karuvally, A.,** Sejnowski, T. and Siegelmann, H.T.. (2023). General Sequential Episodic Memory Model. *Proceedings of the 40th International Conference on Machine Learning*, in *Proceedings of Machine Learning Research* 202:15900-15910 Available from <https://proceedings.mlr.press/v202/karuvally23a.html>.
- **Karuvally, A.,** Sejnowski, T., and Siegelmann, H.T. (2022). Energy-based General Sequential Episodic Memory Networks at the Adiabatic Limit. ArXiv, abs/2212.05563.

OTHER PUBLICATIONS

- **Karuvally, A.,** and Moss, J.E. (2023). Model Complexity of Program Phases. ArXiv, abs/2310.03865.
- Ahmed, Z., **Karuvally, A.,** Precup, D., and Gravel, S. (2019). Learning proposals for sequential importance samplers using reinforced variational inference. DeepRLStructPred@ICLR.
- Jha, R., **Karuvally, A.,** Tiwari S., and Moss J. E. B. (2018). In Annual Conference on Neural Information Processing Systems, 2018. *ML for Systems Workshop*. URL: http://mlforsystems.org/assets/papers/neurips2018/cache_jha_2018.pdf

COMMUNITY INVOLVEMENT

- **Reviewer:** Associative Memory and Hopfield Networks workshop at NeurIPS 2023, Topology Algebra and Geometry Workshop at ICML 2023, Neural Computation PubMed 2022.
- **Program Committee:** Associative Memory and Hopfield Networks workshop at NeurIPS 2023

SKILLS

- **Physics:** energy-based memory models, neural networks as dynamical systems
- **Programming Languages:** C, C++, Python, Rust, GoLang
- **Machine Learning Frameworks:** Pytorch, Tensorflow, Scikit-learn

AWARDS AND HONORS

- **Travel Grant (2023):** Obtained a travel grant from CICS for attending the ICML 2023 conference in Honolulu, Hawaii.
- **Best Student Project at IBM (2017):** Obtained the best student project award from IBM for my project on *EDI Spec Creator*.
- **Best Paper Award (2016):** Computing, Communication and Sensor Networks conference 2016 for "Framework for Emotional Context Aware Music Recommendation System"

TEACHING

- **Instructor:** First Year Seminar - Nature Inspired Design in Computing: Fall 2023
- **Teaching Assistant:** Neural Networks: From Neuroscience to the forefront of AI: Spring 2023; Introduction to Computing: Spring 2023; Web Technology: Spring 2022; Systems: Fall 2021; Mobile Health Sensing and Analytics: Spring 2021; Programming Methodologies: Fall 2020; Machine Learning: Spring 2020; Web Technology Spring, Fall 2019;

RELEVANT COURSES

- **AI:** Machine Learning, Neural Networks: Modern Intro, Reinforcement Learning, Advanced Natural Language Processing, Computer Vision, Algorithms for Data Science, Neural Networks: Neuroscience to AI, Probabilistic Graphical Models.
- **Mathematics:** Networks and Spectral Graph Theory, Applied Mathematics and Mathematical Modeling, Differential Equations and Dynamical Systems.

CURRICULAR ACTIVITIES

- **UMass Rescue Lab Hackathon (Oct 13, 2023):** UMass Rescue Lab Hackathon, focusing on building tools to keep children safe online. I created a CLiP vision transformer based model to tackle the issue of image classification in low data regimes.
- **Visiting Researcher at JKU, Linz. (May-August, 2023):** I was invited for a scientific visit to Sepp Hochreiter's Institute for Machine Learning in Johannes Kepler University, Linz. Had an amazing experience interacting with the JKU folks.

EXTRA-CURRICULAR ACTIVITIES

- **Undergraduate Research Volunteer (Dec-Feb 2022, 2021, 2019):** URV is an opportunity for undergraduate students to pursue real-life applications of research. I mentored undergraduate teams for the completion of their research project.
- **PhD. Applicant Support Volunteer (2022, 2021, 2020, 2019):** The PhD Applicant Support Program is a pre-application program that aims to support underrepresented or marginalized minority applicants in UMASS CICS.

INDUSTRY WORK EXPERIENCE

- **Data Science for Common Good, UMASS** Amherst
Data Science Intern *May 2019 - August 2019*
 - **Exploratory Analysis:** Developed a tool to identify and improve course recommendations to students based on a model of success created from course trajectories of previous students. The work was done in collaboration with UMASS CICS Center for Data Science(CDS) and Springfield Public School(SPS). We used a Bayesian network to model the causal relationship between student course trajectories and their success probability. The model has been successfully used by career counselors in SPS to advice students on the courses to take.
- **Google Summer of Code with C3G, Canada** May 2018 - August 2018
Research Intern
 - **Reinforcement Learning:** The problem of inferring unobserved values in a partially observed trajectory from a stochastic process can be considered as a structured prediction problem which is traditionally conducted using heuristic-based Monte Carlo methods. In this project, I studied the application and effectiveness of learning proposals for sequential importance samplers using the concept of reinforced variational inference. Work done was published in ICLR 2019, Deep Reinforcement Learning Meets Structured Prediction workshop. The final product is an open source framework that provides a convenient interface for researchers to create and manage Reinforced Variational Inference experiments.
- **Summer Intern at Flipkart** Bangalore, India
Intern *May 2016 - July 2016*

- **Data Science:** Engineered improvements to the efficiency of the company's existing *fraud detection* technology using Decision Trees which improved their detection capabilities by 10 percent. Developed a *skill tracker* application for employees in the company. Developed a *chrome plugin* to enable new and existing employees to discover and learn acronyms used in the company.

Bangalore, India

February 2016 - April 2016

• Remote Mentorship Program at IBM

In semester project

- **Data Science:** Developed a model to automatically assign teams to customer support tickets based on the description of the issue in the ticket using Natural Language Processing techniques. The project was part of the Remote Mentorship Program to create an *EDI Spec Creator* Application led by Mr. Manjit.S.Sodhi, IT Architect, IBM.

OTHER PROJECTS

• Distributed Chat Application

Distributed Systems - Secure and Fault Tolerant Systems

- **GoChat Application:** Created a chat application in Golang that is totally distributed with a single central discovery server. The messages sent via the application is encrypted using AES wrapped in GCM using 16 byte keys generated from the invite code. A fault detection and recovery mechanism also was built into the application using various techniques like checkpoints and state messages.

• Memory Management System

Computer Engineering - Garbage Collection

- **System Memory Management:** Implemented and researched the effectiveness of an alternative memory management system for linux using Rust language. The memory manager was designed to be thread safe with fine-grained locks instead of a single coarse lock for thread protection. The use of fine grained locks led to almost 20 percent average performance gain in various standard memory management benchmarks.

• Effectiveness of Gated Attention in Visual Question Answering

Natural Language Processing, Computer Vision

- **Visual Question Answering:** Created a Gated Attention based model for the task of Visual Question Answering(image and a question is input and the output will be the answer to the question based on the image provided). The performance and effectiveness of the Gated Attention model was quantified in comparison to existing baseline and state of the art models.

• Car Warning System using Reinforcement Learning

Reinforcement Learning

- **Autonomous Car Warning System:** Created a reinforcement learning based car warning system that adapts to different users. The idea was to model the Fatality Analysis Reporting System(FARS) data and other experimental data of various accidents into a novel reinforcement learning framework with an agent trained to warn the user and mitigate accidents.

• Leveraging Structural Similarities in Generative Adversarial Networks

Deep Learning, Generative Models

- **Generative Modeling of Faces:** Created a novel architecture that leverages the structural similarities of generator and discriminator networks and studied the improvement on the performance of GANs.

• Automatic Planning of trips using social network data

Data Mining; Social network analysis; Planning

- **Recommender Systems:** Created a recommendation system that functions as a planner for tourist destinations. The system uses social network data to create personalized recommendations. *Github Repository:* <https://github.com/arjun23496/auto-tour-planner>

• Music Recommendation based on user emotion in microblogs

Data Mining - Social Network Analytics - Sentiment Analysis - Natural Language Processing

- **Recommender Systems:** Implemented a framework to analyse user emotion in twitter and recommend music based on the emotional context of user. Presented the research paper in *IEEE-EDS Kolkata Chapter Sponsored 5th International Conference on Computing, Communication and Sensor Network* *Github Repository:* <https://github.com/arjun23496/music-recommendation>

• Genetic algorithm to evolve neural networks to play Checkers

Genetic Algorithms-Artificial Intelligence-Game Playing

- **Game-Playing AI:** Implemented a genetic algorithm to evolve neural networks for playing checkers. The moves are computed using min-max algorithm(with alpha-beta pruning for efficiency) using neural network to compute the heuristic cost function of different configurations of the board. A web interface was created for users to test the performance of the artificial intelligence implemented. *Github Repository:* <https://github.com/arjun23496/checkers-sp>