### Aishwarya H. Balwani

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# Research Interests

**Machine Learning, Theoretical & Computational Neuroscience**

* Analysis of Artificial & Biological Neural Networks
* Predictive Coding, Structure-Function Relationships in Neural Networks
* Information Geometry, Topological Data Analysis, Optimization, Group Theory
* AI Safety: Alignment, Robustness, Misgeneralization

# PhD Thesis

**Through the Recurrent Neural Network Looking Glass: Structure-Function Relationships in Cortical Circuits for Predictive Coding**

* Inductive Biases and Predictive Coding in the Canonical Cortical Microcircuit
  + Used RNN models of the cortical microcircuit to explore the impact of inter-areal laminar connections and a predictive-coding inspired training strategy on hierarchical information processing and the geometry of neuronal representations.
* Constructing Biologically Constrained RNNs and their Application
  + Designed and implemented RNNs that incorporate Dale’s law and sparse, anatomically-consistent connectivity motifs in a mathematically-grounded manner, with performance guarantees under specific conditions.
  + Applied the constrained RNNs to reconstruct 2-photon calcium imaging data from visual behaviour in mice, revealing multi-regional functional neuronal interactions consistent with predictive coding theory.

# Education

**Georgia Institute of Technology**

* PhD, Electrical & Computer Engineering, 2018-Present.

Minor(s): Mathematics, Computer Science

* MS, Electrical & Computer Engineering, 2016-2018.

**University of Mumbai**

* BE, Electronics & Telecommunication, 2012-2016. (First Class with Distinction)

# Selected Publications, Preprints & Peer Reviewed Abstracts

**In Preparation**

* **Balwani A.**, Wang A. Y., Najafi F., Choi H. "Constructing Biologically Constrained RNNs via Dale’s Backpropagation and Topologically-Informed Pruning."

**Preprints and In-Submission**

* **Balwani A.**, Cho S., Choi H. "On the Architectural Biases of the Canonical Cortical Microcircuit."*bioRxiv*, 2024.

**Publications**

* **Balwani A.**, Krzyston J. "Zeroth-order Topological Insights into Magnitude-based Neural Network Pruning."*PMLR Volume on Topology, Algebra, and Geometry in Learning*, 2022.
* **Balwani A.**\*, Miano J.\*, Liu R., Kitchell L., Prasad J., Johnson E., Gray-Roncal W., & Dyer E. “Multi-Scale Modeling of Neural Structure in X-ray Imagery” *IEEE International Conference on Image Processing (ICIP)*, 2021.
* **Balwani, A.**, & Dyer E. "Modeling variability in brain architecture with deep feature learning." *2019 53rd Asilomar Conference on Signals, Systems, and Computers. IEEE*, 2019.

**Workshop Papers & Peer Reviewed Abstracts**

* Zhou W., **Balwani A.**, Chung S., Schneider D., "Motor-sensory Experience Reshapes Neural Manifolds in Auditory Cortex to Reflect Acoustic Expectations." Advances and Perspectives in Auditory Neuroscience 2023.
* **Balwani A.**, Choi H. "On the Architectural Biases of the Canonical Cortical Microcircuit." (Talk, Top 3.2% of submissions), COSYNE 2023.
* **Balwani A.**, Krzyston J. "Zeroth-order Topological Insights into Magnitude-based Neural Network Pruning."(Spotlight, Top 9.8% of submissions), *Topology, Algebra, and Geometry in Machine Learning, ICML*, 2022.
* **Balwani A.**, & Dyer E. "Modeling Brain Microarchitecture with Deep Representation Learning." (Poster), *ML Interpretability for Scientific Discovery, ICML*, 2020.

# Relevant Research & Work Experience

* **Summer Research Associate**, Center for Computational Neuroscience, Flatiron Institute, Simons Foundation (Summer 2022)
  + Areas of Research: Bio-plausible learning rules for training deep neural networks; Representational Geometry (Supervisor: Dr. SueYeon Chung)
  + Developed a three-factor Hebbian learning rule that operates on non-negative neural networks with a recurrent structure.
  + Theoretically and empirically showed that the learning rule typically updates weights in the same direction as the loss gradient. Provided exact conditions under which the updates would always be sign-matched with the loss gradient.
  + Analyzed data from the auditory cortex of mice and generated insightful low-dimensional visualizations of their neuronal trajectories, quantified disentanglement between neuronal trajectories and task-relevant separating hyperplanes, found neuronal coordinates that encoded meaningful directions with respect to the experimental task.
* **Graduate Research Assistant**, Georgia Institute of Technology
  + Architectural biases in cortical microcircuits and their effects on sequence learning, Predictive coding, Dimensionality of representations in neural networks across learning and brain areas, RNN training with biological constraints.
  + Representation learning, Transfer/Meta and Multi-task learning, Sparse and low-rank representations of data, Models of brain structure and organization.

# Selected Teaching & Mentoring Experience

**Teaching Assistant**

* Linear Algebra, Georgia Tech (Spring 2024)
* Data Analytics for Engineers, Georgia Tech (Fall 2019, 2018)
* Mathematical Foundations for Data Science, Georgia Tech (Spring 2018)

# Selected Honours & Awards

**Academic Awards & Fellowships**

* ECE Coulter MS Fellowship, Georgia Institute of Technology, 2016-2017

**Registration & Travel Awards**

* COSYNE Presenters Travel Award, 2023.
* ICML Diversity and Inclusion Fellowship, 2020.