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.