Joshua Michael Roldan

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BIO

I am a freelance researcher interested in the intersection of 1) computational neuroscience, and 2) machine learning. My role is to make theoretical and algorithmic contributions. I apply shape analysis - topology/geometry/graph theory, and dynamical systems for the theory and design of spiking neural networks. Inversely, I use graph neural networks to represent and classify neural data. Clinical applications of my work include autism and epilepsy.

Interests: Network/Topological Neuroscience; Geometric Deep Learning; Neural Computation; Complex Systems; Spiking Neural Networks; Brain Organoids

EDUCATION

Bachelor of Science| Major in Mathematics| Minor in Philosophy.
University of California, San Diego. Graduated March 2018.

AWARDS

Microsoft Research Fellowship Award. August 2018 - March 2023.

RESEARCH EXPERIENCE

Visiting Researcher (*upcoming*), March 2024 - May 2024.
Fakultät für Mathematik und Informatik, Universität Leipzig, Germany
Center of Scalable Data Analytics and Artificial Intelligence.
PI: Prof. Érika Roldán. *Stochastic Topology and its applications.* https://www.erikaroldan.net/.

AI and Machine Learning for Combinatorial (Topological and Geometrical) Problems

- Utilize a **graph neural network** to solve graph coloring problems.

Visiting Researcher, May 2023 - present.
Department of Epidemiology and Biostatistics, University of South Carolina
PI: Prof. Yuan Wang. *TDA-Brain lab*. https://www.tda-brain.com/.

GNN4Epilepsy: Post-Surgical Outcome Prediction via Graph NNs

- *Hypothesis*: There exists local graph structures indicative of an epileptic brain.
- Constructed **graph neural networks** to detect brain structural abnormalities and predict post-surgical outcomes with ROI-level diffusion tensor imaging data.

Research Assistant, March 2018 - March 2023.
Department of Bioengineering, University of California, San Diego
Mathematical Neuroscience Lab at the Center for Engineered Natural Intelligence.
PI: Prof. Gabriel Silva. http://www.silva.ucsd.edu/.

Topological Analysis of Spiking Neural Network Dynamics

- *Hypothesis*: *Emergent properties reflect a high level perspective of hierarchies of computed information passed across scales of organization.*
- Lead effort in determining how the geometric and temporal constraints of the neural network shape the geometric properties of the **neural manifold**.
- Analyzed the topological structure of simulated neuronal population dynamics via **Topological Data Analysis** (*persistent homology*, *Mapper*).
- Detected the emergent property of **object manifold separability**.
- Tuned **spike-timing-dependent-plasticity** learning rule informed by the manifold topology.

Graphlet-Based Analysis of Spiking Neural Network Dynamics

- *Hypothesis*: *There exists overrepresented small, induced subgraphs (graphlets) acting as a signature of the signal dynamics.*
- Extended directed graphlets to edge-ordered, multi-directed graphlets to be used in a latent space embedding.

- Analyzed time series of local connectivity via graphlet-orbit transitions.
- Developed a graphlet-based technique for real-time analysis with a vector space parameterization.

MEA Effective Network Analysis of Cortical Brain Organoids

- *Method*: *Utilize network patterns in the spatio-temporal evolution of cortical brain organoids to understand and treat autism.*
- Performed spectral graph theory (*omnibus embedding*), network analysis method (*graphlets*), and topological data analysis (*persistent homology*) on multi-electrode array data.
- Performed **graph time series analyses** (*network alignment*, *change point detection*)

TEACHING EXPERIENCE

Teaching Assistant, August 2023 - September 2023.
UCSD Summer Bridge Accelerating to Calculus.

Calculus and Art Tutor, March 2018 - May 2018.
Preuss High School, San Diego.

COMMUNITY SERVICE

Summer Intern, July 2018 - August 2018.
Hub Basic Needs Center at University of California, San Diego.
Supervisor: Alicia Magallanes, Director of UCSD the HUB Basic Needs Center

Affordable Grocery Store Map

- Created a map featuring a bus **transportation network** and store affordability
- Collected data on proximity and accessibility to grocery stores
- Classified the affordability and cultural reflection of stores
- https://basicneeds.ucsd.edu/food-security/map/index.html

PAPERS

Roldan J., Pardo S., George V., Silva G. (2020) *Construction of edge-ordered multidirected graphlets for comparing dynamics of spatial temporal neural networks*. arXiv:2006.15971

INVITED TALKS

Roldan J. "Tightening the knot between Biological and Artificial Neural Networks via Shape Analysis of Spiking Neural Networks". Institute of Geometry, Graz University of Technology. November 2023.

POSTERS

Roldan J., Mikhael A., Zhang X. "Topological Data Analysis on Phoneme Neural Signals". UCSD Brain Machine Interface Workshop and Hackathon. September 2023.

- Participated in a 48-hour Hackathon competition
- Used a topology-based distance to measure the similarity between neural signal spike trains derived from different phonemes.
- **Awarded** "Best Communication"

Roldan J., Silva G. "Topology of dynamic perceptrons". Center for Engineered Natural Intelligence (CENI) 2018 Research Review Symposium. December 2018.

CODING SKILLS

Coding Languages: Python, Matlab
Graph Neural Network: PyTorch
Topological Data Analysis: giotto-tda, Gudhi, JavaPlex, Ripser

FOREIGN LANGUAGES

English (Native), Spanish (B2), Italian (A2)