Marissa Masden

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Education

Ph.D., Mathematics (Applied Toplogy) University of Oregon, Eugene, OR *June 2023*

- Dissertation: Accessing the Topological Properties of Neural Network Functions
- Advisor: Dev Sinha

Bachelor's of Science, majors in **Mathematics and Chemistry** Walla Walla University, College Place, WA *June 2015*

- With honors: *summa cum laude*
- Honors program general studies
- WA State teaching certification

Papers

- **Automated Grain Boundary (GB) Segmentation and Microstructural Analysis in 347H Stainless Steel Using Deep Learning and Multimodal Microscopy.** Shoieb Ahmed Chowdhury, M. F. N. Taufique, Jing Wang, Marissa Masden, Madison Wenzlick, Ram Devanathan, Alan L Schemer-Kohrn, Keerti S Kappagantula (2023). See https://arxiv.org/abs/2305.07790. To appear, *Integrating Materials and Manufacturing Innovation*.
- **Algorithmic Determination of the Combinatorial Structure of the Linear Regions of ReLU Neural Networks**. Marissa Masden (2022). See https://arxiv.org/abs/2207.07696.
- **Local and global topological complexity measures of ReLU neural network functions.** J. Elisenda Grigsby, Kathryn Lindsey and Marissa Masden (2022). See https://arxiv.org/abs/2204.06062.
- **Linear discriminant intitialization for feedforward neural networks.** Marissa Masden and Dev Sinha (2019). See arxiv.org/abs/2007.12782.

Research Experience

Brown University Providence, RI *September 2023-May 2024*

Postdoctoral Fellow at the Institute for Computational and Experimental Research in Mathematics (ICERM).

- Semester program *Math + Neuroscience: Strengthening the Interplay Between Theory and Mathematics*, Fall 2023.
- Institute Postdoctoral Fellow, Spring 2023.

University of Oregon Eugene, OR *September 2017 - June 2023*

Graduate research Advisor: Dev Sinha

- Researched geometric and topological properties of neural network functions using applied topology.
- Discovered and proved a combinatorial description of ReLU neural networks' linear regions which encodes the face poset of the canonical polyhedral complex of a ReLU neural network by recording sign sequence information about its vertices.
- Developed and optimized code in Python to compute the face poset of the canonical polyhedral complex of fully-connected feedforward ReLU neural networks as implemented in PyTorch.
- Created Sage scripts computing the homology groups of subcomplexes of the canonical polyhedral complex by combinatorially-defined cochain complexes, allowing for measuring topological invariants of the decision boundaries of neural networks.
- Observed the topological generalization properties of neural networks by measuring statistics about neural networks' decision boundaries at initialization and during training on synthetic datasets.

Research Experience (continued)

Pacific Northwest National Laboratory Richland, WA (remote) *Summer 2021*
NSF Math Sciences Graduate Intern (ORISE) Ram Devanathan lab

- Proposed and implemented topological data analytic methods to improve neural network segmentation of microscope images, including training a PyTorch model with modified topological loss function.
- Compared scikit-learn to custom ridge detection algorithms' performance for post-processing deep neural network output with classical accuracy metrics.

Washington State University Pullman, WA *Summers 2013-2014*
Undergraduate Research Intern Aurora Clark lab

- Implemented a C algorithm for finding polyhedral structure in xyz data from molecular dynamics simulations and incorporated it into preexisting ChemNetworks software, with some extensions (2014)
- Created utility software in R to visualize data output and optimize hyperparameters for the C software (2014)
- Performed literature search on the Markov Clustering algorithm, gave an expository talk on its properties, and helped the research group efficiently implement it by manipulating data structure (2013)

Loma Linda University Loma Linda, CA *Summer 2013*
Biomedical Undergraduate Research Program Intern Jonathan Neihdigh lab

- Investigated organic pathways for synthesizing selectively methylated amino acids for use in constructing artificially modified proteins.
- Performed and recorded possible synthetic pathways and evaluated success using thin layer chromatography (TLC), high pressure liquid chromatography with UV/Vis and mass spectrometry (HPLC-UV/Vis, HPLC-MS), and nuclear magnetic resonance (NMR).

Teaching Experience

Mathematics Department University of Oregon, Eugene OR *2017-2023*
Instructor of Record for the following courses:

- Math 111 (College Algebra)
- Math 112 (Elementary Functions)
- Math 231 (Elements of Discrete Mathematics I)
- Math 243 (Intro. to Methods of Probability and Statistics)
- Math 251 (Calculus I)
- Math 281 (Multivariate Calculus I)
- Math 282 (Multivariate Calculus II)
- Math 341 (Linear Algebra I)

Teaching Assistant and Grader for the following courses:

- Math 243 (Intro. to Methods of Probability and Statistics)
  - Lead TA, Fall 2021
- Math 461 (Intro. to Mathematical Methods of Statistics I)
- Math 635-636 (Algebraic Topology)

Teaching Experience (continued)

Henrietta Lacks Health and Bioscience High School Vancouver, WA *2015-2017*
Certificated Teacher.

- Geometry. Developed curriculum meeting state standards to balance the needs of a diverse student population.
- AP Statistics. Designed post-exam interdisciplinary project alongside epidemiology teacher, introducing advanced methods for statistical analysis. Increased course enrollment by over 50% between first and second year.
- Faculty sponsor of Math Club and supervisor of after-school tutoring.

Walla Walla University, College Place, WA *2011-2015*

- Contract Instructor, Developmental Geometry *Fall terms 2013 and 2014*
- Teaching Assistant, Introductory Statistics Lab *Winter 2013-2015*
- Mathematics Tutor, Teaching Learning Center *2011-2015*

Teaching portfolio at https://mmasden.github.io/teaching.

Select Presentations

Research and Invited Talks

- Tracking Topological Properties of Neural Networks as they Train. Spring Topology and Dynamical Systems Conference (STDC), March 2023.
- Topological properties of ReLU network functions, at initialization and during training. JMM 2023 Special Session *Mathematical Methods in Machine Learning and Optimization*.
- Precise computation of cellular topology of neural network functions. JMM 2023 Special Session *Applied Topology: Theory and Implementation*.
- Geometric Duality, Neural Networks, and Decision Boundaries. Cascade Topology Seminar, Portland State University, November 2022.
- Exact Combinatorial and Topological Data for ReLU Networks' Linear Regions. Northeastern University Topology Seminar, May 2022.
- Persistent Homology for Machine Learning in Microstructure Analysis. NSF Math Sciences Graduate Internship 2021 Summer Presentations, Summer 2021.
- Neural Networks at Initialization. Boston College Math and Machine Learning Seminar, Boston College, Fall 2020.

Expository Talks and Posters

- Piecewise Linear Morse theory: An overview. Geometry-Topology Seminar, Oregon State University, Fall 2021.
- Understanding ReLU Activation Patterns through the Sign Sequence Cubical Complex. Poster at Applied Algebraic Topology Network Poster Session, Fall 2021.
- Using Persistence Signatures in Machine Learning. Geometry-Topology Seminar, Oregon State University, Spring 2020.
- Understanding Neural Networks through Geometry. 1st Midwest Graduate Student Conference: Geometry and Topology Meet Data Analysis and Machine Learning, The Ohio State University, 2019

Leadership, Service and Outreach

Association for Women in Mathematics, UO Student Chapter

- President, AY 2020-2021 and 2022-2023
- Secretary, AY 2019-2020

UO AWM K-12 Outreach Committee member 2018-2023; co-chair 2019-2023.
Coordinated teams of two-six volunteers and budgeted materials. Established post-pandemic chapter involvement in:

- Girls' Science Adventure Days, Eugene Science Center, with Women in Graduate Sciences (WiGS). Co-designed and led *Math Games* (2023) and *Mathemagic and Maps* (2022), two three-hour enrichment programs for 10-15 girls in grades 4-6.
- Eugene Math Festival (2023). Independently developed two activity booths, *Math Doodling* and *Mystery Shadows*.
- Willagillespie Math and Science Night (2023). Selected activities and coordinated volunteers for three math-focused activity booths at a local elementary school's math and science night.

Directed Reading Program Mentor, University of Oregon Mathematics Department AY 2021-2022

- Lead an undergraduate through a 12-week directed reading on finite-state Markov chains and stochastic processes. Selected readings and appropriate problems, designed code exercises in Jupyter notebooks, and met 1-2 hours weekly.
- Guided the undergraduate through preparing a 10-minute academic mathematics talk about Markov chains and absorbing states to their peers.

American Mathematical Society, UO Student Chapter

- Departmental Liaison (elected position), 2021-2022

Graduate Affairs Committee, UO Mathematics Department

- Graduate student representative (nominated position), 2018-2020
- Graduate Student Peer Mentor, 2019-2023

Graduate Student Mathematics Teaching Seminar, UO Mathematics Department

- Co-organizer, 2019-2023

Professional Affiliations

American Mathematical Society (AMS) member 2021-present

Association for Women in Mathematics (AWM) member 2019-present

Technical Skills

Programming, scripting, and markup:

- *Proficient* in Python, C/C++, SageMath, R, LaTeX, Git
- *Some Experience* with HTML/CSS/JavaScript, Ruby/Jekyll, Bash

Python-specific proficiencies:

- Machine Learning: PyTorch and TensorFlow/Keras
- Topological Data Analysis: Ripser, GUDHI, scikit-tda
- Network Analysis: NetworkX, igraph
- Data Analysis: scikit-learn, scikit-image, scipy, numpy, pandas
- Application and GUI Development: Pygame
- Environment Control: Anaconda, Jupyter, venv

Scientific Computing Experience:

- Comfort with distributed computing using SLURM workload management system.
- Light experience performing molecular dynamics simulations using NWChem and Visual Molecular Dynamics (VMD)

Select Conferences and Workshops

- Joint Mathematics Meetings. Boston, Massachusetts, January 2023. *Invited to speak at AMS Special Session on Mathematical Methods in Machine Learning and Optimization* and *AMS Special Session on Applied Topology: Theory and Implementation.*
- Cascade Topology Seminar. Fariborz Maseeh Department of Mathematics and Statistics, Portland State University, Portland OR, November 2022. *Invited to speak, awarded travel funding*.
- Institute of Advanced Studies 2022 Women and Mathematics program: The Mathematics of Machine Learning. Princeton, NJ, May 2022.
  One of 50 attendees to a program focused on interpretable and distributed machine learning.
- Oxford Applied Topology School. University of Oxford, Oxford, UK, March 2020.
  Awarded travel funding. Cancelled due to COVID-19.
- Neural Information Processing Systems (NeurIPS). Vancouver, BC, Canada, December 2019.
- FRG Workshop on Discrete Shapes. University of California, Davis, 2019.
  Awarded travel funding.
- The 1st Midwest Graduate Student Conference: Geometry and Topology meet Data Science and Machine Learning. The Ohio State University, 2019. *Speaker, awarded travel funding.*

Honors and Awards

University of Oregon

- *NSF Research Training Grant*, UO Mathematics Department — Summer 2022
- *Johnson Fellowship*, UO Mathematics Deparatment — Summer 2019
- *Dean's First Year Merit Award*, UO Mathematics Department — AY 2017-2018

Walla Walla University

- *Schofield Memorial Scholarship*, WWU Education Department — 2015
- *Honors Program Scholarship*, WWU Honors General Studies Program — 2015
- *Schottlauer Math Scholarship*, WWU Mathematics Department — 2015
- *M&I Johnstone Scholarship*, WWU Mathematics Department — 2014-2015
- *President's Scholarship for National Merit Scholars*, WWU — 2010-2014
- *C&L Jones Chemistry Scholarship*, WWU Chemistry Department — 2010-2011

Boeing National Merit Scholarship — 2010-2011