Sunia Tanweer

FINAL YEAR DUAL PHD CANDIDATE

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Executive Summary

PhD in computational mathematics with expertise in time series analysis, developing and deploying ML models, stochastic simulations, and data-driven algorithms for real-world applications. Skilled in Python and experienced in integrating machine/deep learning techniques into production.

Education

Michigan State University   *East Lansing, MI, USA*

Dual PhD in Mechanical Engineering, and Computational Mathematics   *Sept 2022 - May 2026*

- CGPA: 4.0/4.0 | Advisor: Dr Firas A. Khasawneh
- Awarded NSF Frontera Computational Science Fellowship for 2025-2026—worth ∼ *$50000* to use Frontera supercomputer at TACC UT Austin.
- Thesis: Analyzing Dynamical Systems with Topological Data Analysis, Stochastic Theory and Machine Learning.
- Main courses: Numerical Methods of Differential Equations, Numerical Linear Algebra, Mathematical Foundations of Data Science, Stochastic Processes, Analysis of Stochastic Processes, Nonlinear Dynamics, Parallel Computing, Scientific Machine Learning, Computational Statistics, Deep Learning, Data Structures, MLOps, Computational Optimization

National University of Sciences and Technology (NUST)   *Islamabad, Pakistan*

Bachelors in Mechanical Engineering   *Sept 2017 - May 2021*

- CGPA: 3.95/4.00 – Summa Cum Laude (awarded President's Gold Medal for Academic Excellence)
- US State Department's fully funded merit-based Global UGRAD Semester Exchange Scholarship for 6th semester at University of Wyoming (Laramie, WY, USA)—worth over *$25000*. Selected out of 14000+ applicants from all over Pakistan. Mentioned in President's Honor Roll.

Research and Work Experience

Georgia Tech Research Institute   *Atlanta, GA, USA*

Deep Learning Applied Research Intern (Part Time)   *Aug 2025 - ongoing*

- Genome modeling with large-language models and deep neural networks for classification and pathogen environment identification.

PhD Machine Learning Research Intern - Cybersecurity Lab   *June 2025 - Aug 2025*

- Exploring chaos and stochasticity in activation functions for improved robustness against adversarial attacks in neural networks.
- Empirically established a correlation between loss curve and TDA betti vectors of the polyhedral decomposition of feature space for ReLU-based Neural Networks and investigated grokking behaviour in deep neural networks with the change in topology of feature space.

Michigan State University   *East Lansing, MI, USA*

Research and Teaching Assistant   *Sep 2022 - May 2026*

- Solved a longstanding 50-year-old problem in stochastic dynamics by introducing novel algorithms for detecting bifurcations in stochastic time series from density estimates using topological data analysis, Bayesian spatial modelling, and statistical methods.
- Exploring topology of directed graphs derived from climate models using asymmetric filtrations to explore weather regimes.
- Developed data pipelines and fine-tuned machine learning classifiers like SVM, Logistic Regression, and Random Forests to predict epileptic seizures with topological machine learning, achieving over 99% accuracy for single-channel data. Exploring data fusion techniques to enhance performance with multi-channel classification beyond the current 75% accuracy.
- Modelling epidemics using stochastic compartmental models to compare effects of white, Ornstein-Uhlenbeck and lognormal noise, and provide data-driven predictions of disease spread through bifurcation parameter estimation.
- Taught *Computational Modeling and Data Analysis* to sophomores, guiding in Python, time series analysis, graph theory and machine learning (with emphasis on Pandas, Seaborn, and Statsmodels) Overall teaching performance rated 18% above average.
- Cleaned, packaged, and documented code into an open-source Python package, `teaspoon`, using Jupyter Notebook, GitHub and Sphinx with unit-tests.

Publications

- **Tanweer, S.**[*], Bosca, V.[*], Rask, T.[*], Tawfeek, A.R.[*], & Stone, B. (*2025*). Topological Signatures of ReLU Neural Network Activation Patterns. *Preprint*. https://arxiv.org/abs/2510.12700. [*]Equal contribution.
- **Tanweer, S.** & Khasawneh, FA. (*under review*). Unsupervised Learning of Kernel Density Estimates with Topology Optimization.
- **Tanweer, S.**, Khasawneh, FA. & Mamis, K. (*2025*, April). TDA for Detection of Phenomenological Bifurcations in Stochastic Epidemiological Models. https://doi.org/10.48550/arXiv.2504.13215.
- Khasawneh, FA., Munch, E., **Tanweer, S.**, et al. (*2025*, March). Teaspoon: A Python Package for Topological Signal Processing. Journal of Open Source Software. https://doi.org/10.21105/joss.07243.
- **Tanweer, S.** & Khasawneh, FA. (*2024*, May). Topological detection of phenomenological bifurcations with unreliable kernel densities. Probabilistic Engineering Mechanics. https://doi.org/10.1016/j.probengmech.2024.103634.
- **Tanweer, S.**, Khasawneh, FA., & Munch, E. (*2024*, March). Robust Zero-crossings Detection in Noisy Signals using Topological Signal Processing. Foundations of Data Science. https://doi.org/10.3934/fods.2024006.
- **Tanweer, S.**, Khasawneh, FA., Munch, E. et al. (*2024*, February). A topological framework for identifying phenomenological bifurcations in stochastic dynamical systems. Nonlinear Dyn. https://doi.org/10.1007/s11071-024-09289-1
- Zhao, C., **Tanweer, S.**, Li, J., Lin, M., Zhang, X., & Liu, Y. (*2021*, August). Nonlinear Guided Wave Tomography for Detection and Evaluation of Early-Life Material Degradation in Plates. Sensors, 21(16), 5498.
- Zhao, C., **Tanweer, S.**, Li, J., Lin, M., Zhang, X., & Liu, Y. (*2021*, July). Early Fatigue Damage Evaluation of Nonlinear Guided Wave Imaging in Hyperelastic Materials. In Quantitative Nondestructive Evaluation (Vol. 85529, p. V001T11A009). American Society of Mechanical Engineers.

Presentations

- **Invited conference talk**: "TDA for Nonlinear Dynamical Systems", Joint Mathematics Meetings (JMM), Washington, DC, January 2026.
- "Phenomenological Bifurcations in Compartmental Stochastic SIS and SIR Models for Epidemiology", SIAM Conference on Applications of Dynamical Systems (DS25). Denver, CO, May 2025.
- "Dynamics-Aware Filtrations-II", Joint Mathematics Meetings (JMM), Seattle, WA, January 2025.
- "Homological Bifurcations in Probabilistic descriptions of dynamical systems", Joint Mathematics Meetings (JMM), Seattle, WA, January 2025.
- **Invited one-hour talk**: "A comprehensive guide to detecting phenomenological bifurcations in stochastic systems using TDA", TDA Seminar, MSU, East Lansing, April 2024.
- "Establishing a Topology-Driven Framework for Phenomenological Bifurcations in Stochastic Systems", Regional Mathematics and Statistics Conference (RMSC), Greensboro, NC, November 2023.
- "A Topological Approach to Quantify Phenomenological Bifurcations in Stochastic Dynamical Systems", SIAM Great Lakes Meeting, East Lansing, MI, October 2023.
- "Exploring Topological Data Analysis for Identifying Phenomenological Stochastic Bifurcations", SIAM Conference on Applications of Dynamical Systems (DS23). Portland, OR, May 2023.
- "Robust Zero-Crossing Detection with Persistent Homology", 2nd MSU CMSE Data Science Student Conference (DISC). Michigan State University, East Lansing, MI, December 2022.

Selected Semester Projects

- *Reinforcement Learning*: Implemented a PPO-based reinforcement learning agent for algorithmic stock trading using stable-baselines3 and gymnasium, which achieved a 3000+% ROI in a historical backtest on AAPL data by learning an effective buy-and-hold strategy.
- *Machine Learning*: Implemented the Random Feature Map-based Machine Learning algorithm for time series forecasting, achieving 5x speedup.
- *Data Science*: Predicted stock price for Crowdstrike using methods like ARIMA, stochastic modeling and LSTM neural network, with stochastic model showing 40% and LSTM showing 80% less error than ARIMA.
- *Data Management SQL*: Used PostgreSQL to filter out unicorn companies for investment by manipulating and inner joining multiple dataframes.
- *Numerical Differential Equations*: Comparative analysis of discretization level for a McCormack compressible shock tube solver.
- *Parallel Computing*: Parallelized n Bayesian Point Processes using OpenMP and MPI for n times speedup.
- *Deep Learning:* Built an e-commerce multiclass clothing classifier using CNN with PyTorch, achieving 89% accuracy.
- *Theory of Vibrations*: Validation of closed-form expressions for crossing rate in narrow-band processes.

Skills

Programming	Python, C++, MATLAB / Octave, Fortran, R, SQL, AWS Cloud Computing, HPC SLURM, Parallel Computing (MPI, OpenMP)
Data Science	Statsmodels, PyMC3, scikit-learn, PyTorch, TensorFlow, Machine Learning, Deep Learning, Time Series Analysis Forecasting, Hypothesis Testing, Stochastic Modelling, Markov Chains
Software Development	Sphinx, Markdown, Git/Github, Unit Testing, LaTeX, MLFlow

Awards and Achievements

- Awarded NSF Frontera Computational Science Fellowship for 2025-2026—worth $\sim$ *$50000*.
- Awarded AMS graduate student travel grant to present at JMM 2025—worth *$1400*.
- 1 of 30 participants for AMS' Mathematics Research Communities conference 2024—awarded funding worth *$2000* by NSF.
- Received the Graduate Leadership Fellowship (College of Engineering) worth *$3000* for 2024.
- Awarded *$700* travel and accommodation fund for presenting at RMSC by NSF.
- Awarded a laptop in Prime Minister's merit-based laptop scheme (Pakistan).
- Awarded NESCOM's undergraduate fellowship (Pakistan) of 2019 from the entire batch of 110 students.
- Nationwide first position in NUST entrance test 2017 out of 70000+ students achieving Chancellor's scholarship in 1st semester.
- Among the top 25 participants in National Round (Pakistan) of International Physics Olympiad (IPhO) 2017 (NPTC-21) out of 5000+ students.
- Special Mention in South Asia Model United Nation (SAMUN) 2017 for UN-Security Council.