VU-ANH LE

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Personal Website • **Google Scholar** • **ORCID**

RESEARCH INTERESTS

My research focuses on developing reliable and explainable AI models and applying them to climate science. Drawing on techniques from applied topology, graph theory, and statistics, I investigate the structural properties that ensure robustness, scalability, and efficiency in machine learning systems. I then translate these theoretical results into designing explainable AI models that help climate scientists predict natural hazards and strengthen community resilience, particularly in coastal regions.

EDUCATION

Beloit College Beloit, Wisconsin
Bachelor of Science, Mathematics, GPA: 3.58/4.00 *Aug 2021 - May 2025*
Relevant Coursework: Mathematical Statistics, Differential Equations, Complex Analysis, Topology, Algorithm Design and Analysis, Data Mining

SELECTED RESEARCH EXPERIENCES

Vietnam Academy of Science and Technology Hanoi, Vietnam
Researcher, Institute of Information Technology *June 2023 – Present*

- Proved eigenvalue-level robustness for persistent Laplacians: a uniform Lipschitz bound showing any single up-persistent Laplacian eigenvalue shifts by at most $2\|\partial\sigma\|_2^2$ under one-simplex insertion. This result closes an open gap in spectral Topological Data Analysis (TDA) stability and enables error control for spectral features in dynamic complexes.
- Designed a boundary-weighted graph filter for δ-hyperbolic graphs using Busemann functions; established a closed-form spectral-norm contraction (curvature-controlled energy decay per pass), giving a lightweight, parameter-free stability mechanism for hierarchical networks.
- Co-designed **Residual Noise-Fingerprinting (RN-F)**, a residual-noise fingerprinting framework for Large Language Models' contamination detection that operates in a semi–black-box regime via layer-wise FP16–INT4 activation residuals; provided distributional guarantees and single-pass detection with minimal compute.
- Developed spectral–topological operators for graphs and complexes: Lipschitz-stable persistent spectra for robust feature extraction; curvature-aware filters for message passing; and theory-driven constraints for safe graph pipelines in foundation model pretraining.
- Results include two arXiv preprints on graph spectral stability and hyperbolic filtering; one *ICML 2025 DIG-BUGS workshop* paper on contamination detection; one *Maltepe Journal of Mathematics* article on topology-preserving scaling for augmentation.

Ministry of Agriculture and Environment Hanoi, Vietnam
Research Intern, National Remote Sensing Department *Aug 2021 – May 2025*

- Derived physics-informed convergence guarantees for neural operators solving PDEs via contraction mappings; analyzed stability regions and step-to-solution error decay under operator compositions.
- Engineered a differential-operator solver with provable exponential convergence and achieved **15% faster training** than DeepONet while maintaining reliability bounds (theory-first design; ablations across discretizations).
- Built evaluation harnesses for stiffness regimes and boundary conditions; profiled compute/performance trade-offs for mixed-precision inference on sequence-to-operator workloads.
- Published journal article formalizing scaling-robust augmentation with optimization over Δs under a TDA stability constraint; two papers published in *Maltepe Journal of Mathematics* and Chapter 23 in the book issue *Advances in Quantum Calculus and Functional Analysis, CRC Press.*

PREPRINTS

1. Le, Vu Anh, Dik, Mehmet, Nguyen, Viet Anh, and Le, Hai Khoi, "Lipschitz Bounds for Persistent Laplacian Eigenvalues under One-Simplex Insertions," available on *Arxiv*.
2. Le, Vu Anh, Dik, Mehmet, and Nguyen, Viet Anh, "Spectral Contraction of Boundary-Weighted Filters on delta-Hyperbolic Graphs," available on *Arxiv*.

PUBLICATIONS

1. Le, Vu Anh and Dik, Mehmet, "A Mathematical Analysis of Neural Operator Behaviors," Chapter 23 in *Advances in Quantum Calculus and Functional Analysis, Taylor & Francis Group, July 2025*
2. Le, Vu Anh, Nguyen, Dinh Duc Nha, Nguyen, Phi Long, and Sood, Keshav, "RN-F: A Novel Approach for Mitigating Contaminated Data in Large Language Models," in *International Conference on Machine Learning Workshop on Data in Generative Models, June 2025*
3. Le, Vu Anh and Dik, Mehmet, "Topology-Preserving Scaling in Data Augmentation," in *Maltepe Journal of Mathematics, April 2025*
4. Le, Vu Anh and Dik, Mehmet, "How Analysis Can Teach Us the Optimal Way to Design Neural Operators," in *Proceedings of International Mathematical Sciences, December 2024*
5. Le, Vu Anh and Dik, Mehmet, "The Stability of Persistence Diagrams Under Non-Uniform Scaling," in *Boletim da Sociedade Paranaense de Matemática, Nov 2024*
6. Vu Thi Phuong Thao, Dang Truong Giang, and **Le, Vu Anh**, "Reliability Assessment of Land Subsidence Monitoring Results Using PSI Technique in Ho Chi Minh City, Vietnam," in *International Journal of Environmental Studies, Routledge, Volume 81, Issue 2, pp. 881–895, March 2024*

SELECTED PRESENTATIONS

1. "RN-F: A Novel Approach for Mitigating Contaminated Data in Large Language Models."
- Workshop on Data in Generative Models, *International Conference on Machine Learning*, July 2025

2. "Mathematical Foundations of Neural Operators."
- Infinite Possibilities Conference, *University of Chicago*, April 2025
- National Conference on Undergraduate Research 2025, *Pittsburgh*, April 2025

SELECTED AWARDS AND HONORS

Cum Laude, Beloit College — *May 2025*
Presidential Scholarship, Beloit College, Awards 48,000 USD annually — *Aug 2021 - May 2025*
Board of Trustees Grant, Beloit College, Awards 10,000 USD annually — *Aug 2021 - May 2025*
Dean's list, Beloit College — *Every semester*
MIT Summer Research Program, Massachusetts Institute of Technology, Fully funded — *June 2024*
Weissberg Human Rights Grant, Weissberg Foundation, Awards 1,000 USD — *March 2024*
Semifinalist, InSPiR2eS Global Pitching Research Competition 2023 (IGPRC 2023) — *Jan 2024*
Station1 Frontiers Fellowship, Station1, Awards 13,500 USD — *June 2023*
Friends of UTokyo Scholarship, University of Tokyo, Awards 4,000 USD — *April 2022*

OTHER EXPERIENCES

GEOHUB.ai (Remote Sensing Startup) — Remote
AI Advisor — *Dec 2024 – Present*
- Advised on geospatial ML pipelines (STAC-compliant ETL, tiling, reprojection) and physics-informed modules with uncertainty and drift monitoring.
- Introduced data governance and traceable evaluation protocols for robust and reproducible scientific workflows.