Bradley Z. Vigil, Ph.D.

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Research Interests

I build topological theory for objects that classical topological data analysis does not reach: data that is *time-transient*, lives on a *network*, and carries no meaningful metric. My work moves between three registers: **theory** (filtrations, nerve theorems, functoriality, stability and interleaving), **computation** (provably lossless reductions, efficient discrete homotopy algorithms, open-source software) and **application** (propagation on networks in neuroscience and oncology).

Theory — Persistent homology and stability; nerve and Dowker complexes; choice functions and arborizations; discrete homotopy theory of graphs; cellular sheaves and sheaf Laplacians; category theory.

Computation — Algorithms for persistent homology and discrete homotopy; input reduction with homotopy guarantees; scalable topological software.

Application — Propagation and contagion on networks; mathematical neuroscience; neurodegenerative disease; mathematical oncology; complex systems.

Education

2021–2026 **Ph.D., Mathematics**, *Texas Tech University*, *Lubbock, TX*.
Dissertation: *Topological Methods for Complex Systems Dynamics*. Advisor: Dr. Travis B. Thompson.

2021–2022 **M.Sc., Mathematics**, *Texas Tech University*, *Lubbock, TX*.

2019–2021 **B.Sc., Mathematics** (Minor: Economics), *Texas Tech University*, *Lubbock, TX*.

Academic Appointments

2026–Present ***Charles S. Peirce Postdoctoral Fellow***, *Institute for Studies in Pragmaticism, Texas Tech University*.
- Sheaf-theoretic models of feature binding (*discourse complexes*) and combinatorial criteria for when pairwise constraints suffice
- Category-theoretic semantics for Peirce's existential (Beta) graphs
- Topological analysis of neural time series; agentic AI models

2021–2026 ***Distinguished Graduate Research Assistant***, *Dept. of Mathematics & Statistics, Texas Tech University*.
- Developed a local theory of TDA via choice functions and arborizations, recovering classical constructions
- Introduced the restricted nerve and propagation complexes (NPC, GPC, coGPC), with functoriality and stability theorems
- Characterized discrete homotopy distance and implemented a faster algorithm

2021–2026 ***Graduate Instructor of Record***, *Dept. of Mathematics & Statistics, Texas Tech University*.
Calculus II; Ordinary Differential Equations; Linear Algebra. Large-lecture and online sections.

Selected Results

Restricted nerve — The restricted nerve $\mathrm{Nrv}_\bullet(\mathcal{U})$, which records cardinalities of intersections, is a functor $(0,\infty)^{\mathrm{op}} \to \mathbf{Cplx}$. For any finite family of finite sets, discarding non-maximal sets preserves homotopy type at every scale, and the maximal subfamily is the minimal such set: a provably lossless preprocessing step.

Propagation — Graph and co-Graph Propagation Complexes built from activation times on a universal complex; a structure theorem for H_0 of the Nerve Propagation Complex on cycle graphs; bottleneck stability of the GPC for complexes in $\mathbb{R}^3$, resolving a conjecture on the stability of the radial filtration for tumor vasculature.

Choice functions — Vietoris–Rips, Witness and Alpha constructions are m-fold covariant choice functions; Vietoris–Rips choice functions on isomorphic universal complexes yield ϵ-interleaved persistence modules for $\epsilon > d_{\mathrm{GH}}$, giving stability for a whole family of constructions.

Discrete homotopy — A characterization of the discrete homotopy distance between trajectories on networks, attaining its lower bound exactly when trajectories are interleaved, with a substantially faster algorithm.

Publications & Preprints

Topology

Sub. **B. Z. Vigil**. *A characterization of discrete homotopy distance in complex networks.* Submitted. , code

Prep. **B. Z. Vigil**, S. Ranasinghe, A. Solodukina, T. B. Thompson. *Filtering complexity: A topological construction for activity and flow across scales.* Code available on request.

Prep. **B. Z. Vigil**, A. Solodukina, S. Ranasinghe, T. B. Thompson. *Making a complex choice.*

Sub. **B. Z. Vigil**. *Discourse complexes: A sheaf model of feature binding and a combinatorial criterion for the sufficiency of pairwise constraints.*

Mathematical modeling

2026 T. B. Thompson, A. Shin, B. Decourt, Y. Wang, **B. Z. Vigil**, A. Solodukina, S. Ranasinghe, R. Young, V. Hegde, N. Moustaïd-Moussa. *Linking dietary patterns to Alzheimer's disease biomarkers with network mathematical modeling could enable new approach methodologies preventative AD research: A narrative interdisciplinary review.* Frontiers in Nutrition, 12:1673533, 2026. doi:10.3389/fnut.2025.1673533

2024 T. B. Thompson, **B. Z. Vigil**, R. S. Young. *Alzheimer's disease and the mathematical mind.* Brain Multiphysics, 6:100094, 2024. doi:10.1016/j.brain.2024.100094

Sub. B. Awoyemi, R. S. Young, **B. Z. Vigil**, T. B. Thompson, K. Palle, S. Almodovar, A. Laubmeier. *Computational methods enable hybrid dynamical systems applications in cancer research.* Submitted to Mathematical Biosciences.

Invited Talks & Presentations

Apr. 2026 **Sandia National Laboratories**, *Albuquerque, NM*.
Invited talk: *Complexity Takes Shape*.

Sep. 2025 **SIAM TX–LA Section, University of Texas**, *Austin, TX*.
Invited talk: *Getting on Your Nerves: A Restricted View of Intersections*; mini-symposium organizer.

Oct. 2024 **SIAM TX–LA Section, Baylor University**, *Waco, TX*.
Invited talk: *Making a Complex Choice*; mini-symposium organizer.

Nov. 2023 **SIAM TX–LA Section, Univ. of Louisiana at Lafayette**, *Lafayette, LA*.
Invited talk: *Networks, Topology, Data and Pathology*; mini-symposium organizer.

Mar. 2023 **Groups and Dynamics Conference, UT Austin**, *Austin, TX*.
Talk: *Dynamics, Dysfunction and Degeneration: The Mathematics of Alzheimer's Disease*.

May 2025 **Quad Fellowship Spring Symposium**, *Virtual*.
Syndemics: An Analysis of Factors Using Machine Learning Techniques. code

Oct. 2024 **Institute for Studies in Pragmaticism**, *Lubbock, TX*.
Invited talk: *Understanding the Importance of Academic Outreach Across Societies and Cultures*.

Research Workshops

Aug. 2025 **The Geometric Realization of AATRN**, *Chicago, IL*.
Applied Algebraic Topology Research Network, Institute for Mathematical and Statistical Innovation (IMSI). (Accepted participant)

Oct. 2023 **Topology and Geometry in Neuroscience**, *Providence, RI*.
Institute for Computational and Experimental Research in Mathematics (ICERM), Brown University. (Accepted participant; travel grant)

Fellowships & Awards

2026–Present **Charles S. Peirce Postdoctoral Fellowship**, Texas Tech University

2025–2026 **Doctoral Completion Fellowship**, Texas Tech University

2024–2025 **Quad Fellowship**, Institute of International Education (TTU article)

2023–2025 **Charles S. Peirce Graduate Fellowship**, Texas Tech University

2023–2024 **Hildebrand Graduate Fellowship**, Texas Tech University

2023 **ICERM Travel Grant**, Brown University

2021–2026 **Distinguished Graduate Research Assistantship**, Texas Tech University

2019–2023 **Presidential Scholar**; **Merit Scholar**, Texas Tech University

Software & Computing

Packages `discrete-homotopy`: efficient discrete homotopy distance on networks. `neTDA`: Propagation-complex (NPC/GPC/coGPC) and restricted-nerve code (available on request). `nodes`: The Network Ordinary Differential EquationS Python library aims to make NODES easy to define easy to solve for the applied interdisciplinary researcher or scientist.TDA workshop notebooks.

Topology Python with GUDHI; persistent homology pipelines on simplicial and nerve complexes

General Python (NumPy/SciPy, scikit-learn, pandas, TensorFlow), MATLAB, C/C++, Mathematica, LaTeX

Interdisciplinary Collaborations

Neuroscience Network reaction–diffusion models of protein spreading on the connectome; discrete homotopy signatures of Alzheimer's subtypes.

Oncology Hybrid dynamical models of chemotherapy resistance.

Cognition Co-PI, NSF HCC proposal (in preparation): fNIRS study of human and AI collaborators, with TDA of neural time series (ordinal partition networks, sliding-window embeddings). CLF-Lab, TTU.

Service, Outreach & Mentoring

2023–2025 **Mini-symposium Organizer**, *SIAM TX–LA Section*.
Organized three mini-symposia on applied topology, networks and data.

2024 **Topological Data Analysis Workshops I & II**, *Institute for Studies in Pragmaticism, TTU*.
Designed and taught hands-on Python/TDA workshops for faculty and graduate students.

Math Circle & Math Club, *Texas Tech University*.
Problem-solving sessions for middle and high school students; mentoring undergraduates on graduate study.

Dream Center, *Lubbock, TX*.
Initiated community cooking classes on the links between diet and Alzheimer's disease.

Professional Memberships

American Mathematical Society (AMS); Society for Industrial and Applied Mathematics (SIAM); Mathematical Association of America (MAA); National Association of Mathematicians (NAM)