Ibrahem AlJabea, Ph.D.

Topological Deep Learning (TDL), and dynamical systems

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Education

2019 – 2025 **Ph.D in Applied Mathematics, GPA: 3.98** , *Louisiana State University (LSU).*
2022 – 2025 **Graduate Minor in Computer Science and Engineering, GPA: 4.09** , *LSU.*
2019 – 2021 **M.S. in Mathematics, GPA: 4.0**, *LSU.*
2015 – 2018 **M.S. in Mathematics**, *Memorial University of Newfoundland (MUN), Canada.*
2005 – 2008 **M.S. in Mathematics**, *Jordan University of Science and Technology, Jordan.*
2002 – 2005 **B.S. in Mathematics**, *Al Al-Bayt University, Jordan.*

Ph.D. Dissertation

Title **Approximation of Koopman Operator Semigroups**.
Supervisors Dr. Frank Neubrander, *LSU* & Dr. Mustafa Hajij, *University of San Francisco (USFCA).*
Description The main purpose of my dissertation is to study approximation methods for nonlinear systems using Bernhard Koopman's Global Linearization Method, see.

Master Thesis

Title **Equivariant Cohomology and GKM Theory with Applications**.
Supervisor Dr. Thomas Baird, *MUN.*
Description I studied GKM theory and GKM sheaves, focusing particularly on the higher cohomology of GKM sheaves. Additionally, I extended the theory to compact T-manifolds, where $H_T^*(X)$ is reflexive, see.

Honors and Awards

Spring 2025 **University College Alumni Association Teaching Assistant Award**: LSU's highest teaching award for graduate students.. This award recognizes outstanding teaching ability and service to students and acknowledges and emphasizes the important role teaching assistants play in providing quality academic instruction, please click here
Fall 2024 **David Oxley Graduate Student Teaching Award**: This is the department's highest teaching award for graduate students. The prestigious award recognizes excellence in teaching by graduate students and is presented each semester to at most one outstanding graduate student. Please click here
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Fall 2023 **Certificate of Teaching Excellence**, *LSU.*
Spring 2020 **Qualifying Exam - PhD**, *Distinction in Analysis*, *LSU*
Spring 2017 **A certificate for course completion in Teaching Skills Enhancement Program**. *Center for Innovation in Teaching and Learning (CITL), MUN.*

Teaching Experience

- To access my **teaching philosophy**, please click here.
- To access **recent feedback** on my classes, including course evaluations, please click here.

Summer 2025 **Lead Educator – AI Foundations for Students**, *Gordon A. Cain Center for STEM Literacy*, *LSU.*

- I will coordinate an introductory AI course for high school students, focusing on the fundamentals of how AI works and its real-world applications. The course combines hands-on activities and conceptual lessons to explore topics such as data, algorithms, machine learning, and AI ethics, providing students with a strong foundation for future study in technology and computer science.

2020 -2025 **Instructor of Record**, *LSU.*

- MATH 1550 (Calculus I), MATH 1530 (Differential Calculus), and MATH 1552 (Calculus II): Duties include preparing syllabi, teaching classes, setting and grading tests, and assigning final grades. These courses have been taught both in person and online.
- MATH 1020/1021 (College Algebra): Responsibilities include preparing and teaching all classes and providing support to students in the math lab, where they are required to spend three hours working each week.
- MATH 2070 and MATH 2065 (Elementary Differential Equations and Linear Algebra): Responsibilities include grading tests and assignments and managing the gradebook in Moodle.
- MATH 7510 (Topology, Ph.D. level): Responsibilities include grading assignments and managing the gradebook in Moodle.

2019 - 2020 **Tutoring**, *Academic Center for Student-Athletes*, *LSU.*

- MATH 1431 (Calculus with Business and Economic Applications), MATH 1029 (Introduction to Contemporary Mathematics), MATH 1530 (Differential Calculus), and MATH 1540 (Integral Calculus): Responsibilities include preparing lecture notes, teaching classes, and evaluating student performance.

2018 - 2019 **Academic Quality Control - SABIS® Network**, *United Arab Emirates.*

- College Algebra and Differential Calculus: Responsibilities include preparing syllabi, teaching, and preparing students for the SAT. Instruction incorporates technology, including smart boards and videos, to enhance learning.

2013 - 2018 **Research Assistant**, *MUN.*

Research Experience (Projects)

To access my **research statement**, please click here.

- **Topo-Rec: Modeling Higher-Order Connectivity in Social Recommendation**
  TDL framework designed for social recommendation tasks. By leveraging topological structures in social networks, Topo-Rec captures higher-order interactions and complex user-item relationships, leading to more accurate and robust recommendations. In progress.
- **Topo-Detect: A Topological Deep Learning Framework for Anomaly Detection in Industrial Control systems (ICS)**
  We introduce Topo-Detect, a novel security framework that leverages algebraic topology to model ICS for enhanced anomaly detection and localization. Our framework utilizes Combinatorial Complexes (CC), an advanced mathematical structure that extends traditional graphs, hypergraphs, and simplicial complexes, see: *Topo-Detect.*
- **TopoX: Topological Deep Learning**
  Python packages for Topological Deep Learning, designed to enable fast and robust deep learning computations for graph generalizations, including hypergraphs, simplicial complexes, and cellular complexes. Highlighted project : *TopoX: A Suite of Python Packages for Machine Learning on Topological Domains.*
- **SOM: Splitting Operator Method**
  Applied splitting methods to efficiently approximate Koopman operator semigroups for nonlinear dynamical systems, enabling improved analysis and prediction in complex systems. Highlighted Project: Splitting Methods to Approximate Koopman Operator Semigroups.

- **TRL: Topological Representation Learning**
  The purpose of this project is to investigate methods for topological representation learning in *TopoEmbedX* (TEX) and explore how it can be applied to represent elements of a topological domain within a Euclidean space. In progress.
- **Optimizing Pricing Strategies and Customer Quote Selection at C.H. Robinson using Machine Learning**
  Collaborating with a team under the guidance of a data scientist at C.H. Robinson to analyze customer quote selection and pricing strategies. Our project began with a dataset of approximately 400,000 quote entries from C.H. Robinson's website, which required extensive data cleaning and preprocessing. Using a variety of machine learning models, including XGBoost, CatBoost, KNN, and Neural Networks, we worked to predict customer quote preferences. These models were crucial for constructing yield surfaces, allowing us to develop optimal pricing strategies aimed at maximizing the company's expected value (EV) of profit, https://cse.umn.edu/ima/events/math-industry-boot-camp-vii.

Publications

1- TopoX: A Suite of Python Packages for Machine Learning on Topological Domains. Journal of Machine Learning Research (JMLR).

2- TopoDetect: A Topological Deep Learning Framework for Anomaly Detection and Localization in ICS Networks. Submitted.

3- Splitting Methods to Approximate Koopman Operator Semigroups. Under reveiw.

4- Generalizing Graph Embedding Algorithms to Topological Spaces: Behind the Scenes of TopoEmbedX. In progress.

5- Cohomology of GKM-sheaves. Preprint, https://arxiv.org/abs/1806.01761

Open Source

Developer of three transformative Python packages in the area of topological deep learning: TopoNetX, TopoModelX, and TopoEmbedX.

2022 - now *TopoNetX* (TNX), Developer.
- A Python package for modeling entities and relationships in higher-order networks, such as meshes and simplicial complexes.

2022 - now *TopoModelX* (TMX), Developer.
- A Python package designed for efficient deep learning models on topological domains, such as simplicial and cell complexes.

2022 - now *TopoEmbedX* (TEX), Developer.
- A Python package for efficient representation learning on relational systems within topological domains, such as social networks and protein structures.

Conferences and Workshops

- **Society for Industrial and Applied Mathematics (SIAM)**, *Conference on Mathematics of Data Science (MDS24), Oct 20-25, 2024.*

  I presented my recent work on the forthcoming article, Introduction to Topological Neural Networks, along with the accompanying Python package, TopoX.
- **Neural Information Processing Systems (NeurIPS)**, *Dec 11-16, 2023.*

  I participated in the NeurReps workshop on Symmetry and Geometry in Neural Representations https://www.neurreps.org/about, where we presented our work on Topological Deep Learning and the TopoX package.
- **SIAM**, *The 6th Annual Meeting of the SIAM Texas Louisiana Section, Nov 3-5, 2023.*
- **Summer School in Mathematics of Machine Learning**, *Mathematical Sciences Research Institute (MSRI), Jul 25 - Aug 5, 2022.*

  This summer school is offered in partnership with the Istituto Nazionale di Alta Matematica Francesco Severi (INdAM) and the Courant Institute of Mathematical Sciences. Its purpose is to introduce graduate students to foundational results in deep learning techniques, with applications spanning vision, natural language processing, and reinforcement learning.

- **IMA Math-to-Industry Boot Camp participant**, *University of Minnesota*, *Jun 20 – Jul 29, 2022.*

  This Boot Camp consisted of two parts: (i) completing courses in Applied Statistics, Data Science, Machine Learning, Optimization, and Stochastic Modeling, and (ii) collaborating with a team under the guidance of a data scientist at C.H. Robinson to analyze customer quote selection and pricing strategies. Our project began with a dataset of approximately 400,000 quote entries from C.H. Robinson's website, which required extensive data cleaning and preprocessing. Using a variety of machine learning models, including XGBoost, CatBoost, KNN, and Neural Networks, we worked to predict customer quote preferences. These models were crucial for constructing yield surfaces, allowing us to develop optimal pricing strategies aimed at maximizing the company's expected value (EV) of profit, https://cse.umn.edu/ima/events/math-industry-boot-camp-vii.
- **4th LBRN-LONI Scientific Computing Bootcamp**, *High Performance Computing*, *LSU*, *May 2021.*
- **Combinatorics of Group Actions and its Application**, *MUN*, *Aug 2017.*
- **19th Annual Aldrich Multidisciplinary**, *Graduate Research Conference*, *Mar 2017.*
- **Student Leadership Conference**, *MUN*, *Jan 2017.*
- **Hopf Algebras and Algebraic Groups**, *International Workshop*, *MUN*, *Jun 2016.*

Skills and Qualification

- Developer of three transformative Python packages in the area of topological deep learning: TopoNetX, TopoModelX, and TopoEmbedX.
- Experienced in collaborating with researchers of varying expertise and effectively communicating complex research concepts to diverse audiences and large groups.
- Strong teamwork skills and a willingness to contribute to various committees and groups.
- Able to quickly understand and explain complex ideas.

Programming Experience

- **Programming Languages:** Python, C# Programming, LaTeX and Beamer.
- **Tools:** Tensorflow, Pytorch, Geometric Pytorch, scikit-learn, NetworkX, Numpy, Scipy, TopoModelX, TopoNetX, TopoEmbedX, Git.

Certificates and Achievements

- **IBM Data Science**, *LSU Degree and Certificate Students Academy, 2024.*
- **Graph Neural Network**, *LSU, 2023.*
- **Machine Learning and Deep Learning**, *LSU, 2023.*
- **Training course in Python and R programming**, *LSU, 2021.*
- **Improving Deep Neural Networks: Hyperparameters Tuning, Regularization and Optimization**, *Coursera, 2021.*

Leadership, Services and Volunteering

Spring 2025 Directed Reading Program Graduate Mentor: Met weekly with an undergraduate student to explore problems in topological deep learning, culminating in a final presentation at the end of the semester.

2023-2024 Communicating Mathematics Mentor: Worked one-on-one with a first-year graduate student preparing for a guest lecture in my course. Provided guidance beforehand and constructive feedback afterward to enhance their teaching experience.

2023 Organization committee for the student colloquium, *Department of Mathematics*, *LSU*.

2023-2024 Mentor (senior researcher), *SIAM TX-LA 2023 SIAM Texas-Louisiana Sectional Meeting*.

Spring 2023 Louisiana State Literary Rally Proctor: Proctored exams for high school students participating in the Louisiana State Rally academic competition, ensuring a fair and organized testing environment.

Fall 2023 Volunteered for a capstone course project in machine learning, *Department of Mathematics*, *LSU*.

Invited Talks

1- Topological Deep Learning Framework for Anomaly Detection in Industrial Control Systems, *Texas-Louisiana Section of SIAM 8th Annual Meeting*, *Sep 2025.*

2- Higher Order Neural Networks and Applications, *CCT*, *LSU*, *April 2025.*
3- Splitting Methods to Approximate Koopman Operator, *LSU*, *March, 2025.*
4- Topological Neural Networks, *SIAM Conference on Mathematics of Data Science (MDS24)*, *October 2024.*
5- Koopman Operator and Approximation of Semigroups by Using Splitting Methods, *LSU*, *April 2023.*
6- Morse Theory, *LSU*, *May 2020.*
7- Equivariant Cohomology and Fibre Bundles, *MUN*, *Jan 2018.*
8- Introduction to Sheaf Theory and GKM-sheaves, *MUN*, *May 2017.*
9- Free Group, *MUN*, *Mar 2013.*
10- De Rham cohomology, *MUN*, *April 2013.*

Memberships

2020 - present SIAM.
2019 - present American Mathematical Society (AMS).

References

1- Dr. Frank Neubrander (Academic Advisor), *LSU*, *Department of Mathematics*, neubrand@math.lsu.edu
2- Dr. Mustafa Hajij (Academic Advisor), *USFCA*, *Department of Computer Science*, mhajij@usfca.edu
3- Dr. James Oxley (Teaching Advisor), *LSU*, *Department of Mathematics*, oxley@math.lsu.edu
4- Dr. Christin Bibby (Teaching Advisor), *LSU*, *Department of Mathematics*, bibby@math.lsu.edu
5- Julia Ledet (Calculus Coordinator), *LSU*, *Department of Mathematics*, ledet@lsu.edu