



# Ibrahim ALJabea, PhD candidate

*Topological Deep Learning, Higher-Order Neural Networks, and Dynamical Systems*

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## Education

- 2019 – now **Ph.D in Mathematics**, *Louisiana State University (LSU)*.
- 2022 – now **Graduate Minor in Computer Science and Engineering**, *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*.

## Research Experience (Projects)

- To access my research statement, please click [here](#).
- 1- TopoX: Developer of three transformative 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. Explore the packages on GitHub: <https://github.com/pyt-team>.
- 2- 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.
- 3- Approximations of Koopman Operator Semigroups. In progress.
- 4- Deep Learning Approach for Frog Egg Qualification: This project was a collaboration between the Mathematics Department at LSU and the AGGRC (Aquaculture Genetics and Genomics Research Center), <https://aggrc.com/>. The primary goal was to develop a new model based on the Stardist machine learning package, which uses image segmentation and star-convex polygons to count eggs by detecting cell nuclei.

## Open Source

- 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.

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## Ph.D. Dissertation

Title Approximation of Koopman Operator Semigroups.

Supervisor Dr. Frank Neubrandner, *LSU* & Dr. Mustafa Hajji, *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. This approach enables the application of linear semigroup methods to nonlinear systems by focusing on the dynamics of state observables rather than directly analyzing the dynamics of the states themselves. Specifically, we investigate how the eigenvalues and eigenfunctions of the linear Koopman operator, which generates the observations of the underlying nonlinear system, can serve as useful tools for approximating and studying the qualitative properties of the underlying nonlinear flow.

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## 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](#).

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## Teaching Experience

- To access my teaching philosophy statement, please click [here](#).
- David Oxley Graduate Student Teaching Award: This prestigious award recognizes excellence in teaching by graduate students and is presented each semester to at most one outstanding graduate student. Please click [here](#) for more details.
- To access the Certificate of Teaching Excellence, please click [here](#).
- To access recent feedback on my classes, including course evaluations, please click [here](#).

2020 - present **Teaching Assistant**, *Louisiana State University*.

- 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 **Teaching Assistant**, *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*.

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## 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.neurreprs.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.

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## Publications

- 1- **TopoX**: A Suite of Python Packages for Machine Learning on Topological Domains. Accepted to Journal of Machine Learning Research (JMLR).
- 2- Generalizing Graph Embedding Algorithms to Topological Spaces: Behind the Scenes of TopoEmbedX. In preparation.
- 3- An Introduction to Topological Neural Networks. In preparation.
- 4- A User's Guide to Topological Deep Learning. In preparation.
- 5- Cohomology of GKM-sheaves. Preprint, <https://arxiv.org/abs/1806.01761>

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## 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.

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## 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 In progress.*
- **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

- 2023 Organization committee for the student colloquium, *Department of Mathematics, LSU.*
- 2023 Mentor (senior researcher), *SIAM TX-LA 2023 SIAM Texas-Louisiana Sectional Meeting.*
- Fall 2023 Volunteered for a capstone course project in machine learning, *Department of Mathematics, LSU.*

## Honors and Awards

- Fall 2023 Certificate of Teaching Excellence, *LSU.*
- Spring 2020 Comprehensive Exam - PhD, *Distinction in Analysis, LSU*
- Spring 2017 Awarded a certificate for participating in a workshop on writing a review article, *MUN.*
- Spring 2017 A certificate for course completion in Teaching Skills Enhancement Program. *Center for Innovation in Teaching and Learning (CITL), MUN.*

## Talks

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

## Memberships

- 2021 - present SIAM.
- 2019 - present American Mathematical Society (AMS).

## References

- 1- Dr. Frank Neubrandner (Academic Advisor), *LSU, Department of Mathematics*, [neubrand@math.lsu.edu](mailto:neubrand@math.lsu.edu)
- 2- Dr. Mustafa Hajij (Co-advisor), *USFCA, Department of Computer Science*, [mhajij@usfca.edu](mailto:mhajij@usfca.edu)
- 3- Dr. James Oxley (Teaching Advisor), *LSU, Department of Mathematics*, [oxley@math.lsu.edu](mailto:oxley@math.lsu.edu)
- 4- Dr. Theodore Papamarkou, *Zhejiang Normal University (ZJNU), College of Mathematical Medicine*, [theo@zjnu.edu.cn](mailto:theo@zjnu.edu.cn)
- 5- Julia Ledet (Calculus Coordinator), *LSU, Department of Mathematics*, [ledet@lsu.edu](mailto:ledet@lsu.edu)