21. April 2025

Curriculum Vitæ

"Profound study of nature is the most fertile source of mathematical discoveries. " – Joseph Fourier

Personal information

Name	Aras Bacho
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Citizenship	German

Positions

10/2024 – present **Postdoctoral Scholar**, *In the group "Applied and Computational Mathematicsand Control and Dynamical Systems" under Prof. Dr. Houman Owhadi*, California Institute of Technology.
Conducting research on Kernel- and Gaussian Processes Methods for Partial Differential Equations.

12/2021 – 09/2024 **Postdoctoral Scholar**, *In the group "Mathematical Foundations of Artificial Intelligence" under Prof. Dr. Gitta Kutyniok*, Ludwig-Maximilians-Universität München.
Conducting research in the field of Partial Differential Equations and Machine Learning. Furthermore, I hold lectures in Deep Learning, Partial Differential, and Programming.

01/2024 – 04/2024 **Visiting Scholar**, *In the group "Seminar for Applied Mathematics" under Prof. Dr. Siddhartha Mishra*, ETH Zurich.
Conducting research in Operator Learning.

04/2017 – 06/2021 **Research and Teaching Assistant**, *In the group "Partial Differential Equations" under Prof. Dr. Etienne Emmrich*, Technische Universität Berlin.
Conducting research on abstract nonsmooth doubly nonlinear evolution equations of first and second order and teach students in the field of partial differential equations.

07/2012 – 09/2012 **Internship**, *Process Dynamics and Operation Group under Prof. Dr.-Ing. habil. Prof. h.c. Dr. h.c. Günter Wozny*, Technische Universität Berlin.
Researching a special class of potential raw materials and the development of effective methods for refinement. Performed lab tests, numerical experiments, and presented results.

Education

2021 **PhD**, *Partial Differential Equations*, Technische Universität Berlin, Berlin.
Thesis: "On the Nonsmooth Analysis of Doubly Evolution Inclusions of First and Second Order with Applications"
Supervisor: Prof. Dr. Etienne Emmrich,
Reviewer: Prof. Dr. Etienne Emmrich (TU Berlin), Prof. Dr. Eduard Feireisl (Czech Academy of Sciences), Prof. Dr. Alexander Mielke (WIAS/HU Berlin), Prof. Dr. Martin Skutella (TU Berlin)

2016 **M.Sc.**, *Mathematics*, Technische Universität Berlin, Berlin.
Thesis: "Gradient Flows in Metric spaces and Applications"

2015 **M.Sc.**, *Mathematics*, Université Pierre et Marie Curie, Paris.
Exchange program ERASMUS+

2013 **B.Sc.**, *Technomathematics*, Technische Universität Berlin, Berlin.
Thesis: "Application of the mountain pass lemma to a certain class of semilinear elliptic equations", Technomathematics focuses on technical-mathematical methods used at the intersection of mathematics and engineering.

Research Interests

- My research centers on the theoretical foundations of machine learning—both supervised and unsupervised methods—with a strong emphasis on deep learning architectures such as physics-informed neural networks, operator learning frameworks, and random feature models. A key focus is to develop rigorous analytical insights into the representational capacity and training dynamics of these networks, particularly for applications involving partial differential equations (PDEs). In this vein, I investigate graph neural networks to uncover their theoretical properties, spectral analysis, and algorithmic complexity in both graph-based and manifold settings. Furthermore, my work addresses the mathematical underpinnings of PDEs, including existence, uniqueness, and stability results, with a special interest in employing machine learning methods for inverse problems. By leveraging physics-informed and domain knowledge, I aim to enhance stability, accuracy, and interpretability in solving and inverting PDEs, especially in data-scarce regimes. Finally, my research also extends to the study of complexity theory, algorithmic computability, and how both digital and analog computing architectures can be effectively harnessed for large-scale learning tasks. Overall, I strive to integrate physical principles and theoretical rigor into machine learning frameworks, thereby advancing robust, high-performance models for scientific and engineering applications. In recent years, I am also interested in developing a interpretable machine learning based framework for Theorem Proving.

Honors and Awards

2008/2009 First Prize in the first round and Second Prize in the second round of the Nationwide Mathematics Competition in Germany (Bundeswettbewerb Mathematik).

2009 DPG Prize for special achievements in physics issued by the German Physical Society (Deutsche Physikalische Gesellschaft).

2009 DMV Prize for special achievements in mathematics issued by the German Mathematical Society (Deutsche Mathematiker Vereinigung).

2012 Perfect score in the Math Advent Calendar organized by the DFG (German Research Foundation) Research Center MATHEON.

2014-2015 Erasmus+ Scholarship issued by the European Union for studies at Université Pierre et Marie Curie.

2017 PhD-Scholarship issued by TU Berlin. (4 Months)

2021-2024 Mentoring Program: Young researchers are supported on their way to an academic career financially and through advanced trainings.

2024 Long-Term Visiting Scholar at ETH Zurich (4 Months)

2024 Walter-Benjamin Fellowship from the German Research Foundation (~100.000 Euros)

Mentoring/Supervision

LMU Munich

PhD Students **Adalbert Fono**, LMU Munich, Mentoring, Topic: Computability theory (2022-2024)

Vit Fojtik, LMU Munich, Mentoring, Topic: Quantum Computing (2022-present)

Sohir Maskey, LMU Munich, Mentoring, Topic: Graph Neural Networks (2022-2024)

Phillip Scholl, LMU Munich, Mentoring, Topic: Physical Law Learning (2021-2024)

Jonghyeon Lee, Caltech, Mentoring, Topic: PDE Discovery (2024-present)

Master Students **Beatrice Lorenz**, LMU Munich, Supervison, Thesis: Error Estimation for Physics-informed Neural Networks Approximating Semilinear Wave Equations (2022-2023)

Sean Disaro, LMU Munich, Supervison, Thesis: Domain decomposition methods for Physics-informed Neural Networks (2024-present)

Bachelor Students **Helen Zwölfer**, LMU Munich, Supervison, Thesis: Deep Learning Methods for Physical Systems (2023-present)

Intern **Pritika Barshilia**, National Institute of Technology, India. Supervison, Topic: Deep Learning for the Kelvin-Voigt model (2023)

Caltech

Graduate Students **Jonghyeon Lee**, Caltech, Mentoring, Topic: PDE Discovery (2024-present)

Edgar Larios, Tecnológico de Monterrey, Mexico. Mentoring, Topic: Discovery and Parameter Estimation of PDEs for the Jupiter Radiation Environment Using Physics-Informed Neural Networks (2025)

Lennart Scholz, Leibniz University Hannover, Germany. Mentoring, Topic: Hybrid Models for Solving Navier-Stokes Equation (2025)

WAVE Students **Christian Pena**, Florida Atlantic University, Mentoring the WAVE Fellowship (a program for underrepresented students) Project, Topic: Experimental Design for Space Missions (2025)

Organization of Conferences and Workshops

11/2025 Minisymposium on "Kernel-based surrogate modelling for PDEs I,IIät SIAM Conference on Analysis of Partial Differential Equations (PD25), Pittsburgh, Pennsylvania, U.S.

Invited Talks and Posters

11/2025 SIAM Conference on Analysis of Partial Differential Equations (PD25), Pittsburgh, Pennsylvania, U.S.

08/2025 Mathematical and Scientific Machine Learning (MSML 2025), Naples, Italy.

05/2025 SIAM Conference on Applications of Dynamical Systems (DS25), Denver, Colorado, U.S.

12/2024 Franca Hoffmann Group Seminar, Caltech, California, U.S.

8/2024 Workshop on Machine Learning in Infinite Dimensions, Bath University, England. (Poster)

6/2024 CRUNCH Seminar Series hosted by Professor George Em Karniadakis, Brown University, Providence, United States.(Online Talk)

8/2023 International Council for Industrial and Applied Mathematics (ICIAM) 2023, Tokyo, Japan (Minisymposium)

8/2023 Lothar-Collatz-Seminar, University of Hamburg, Germany. (Online Talk)

6/2023 Scientific Machine Learning, Banff international Research Station (BIRS), Banff, Cananda (Talk)

6/2023 MCMP-MCML-Workshop, LMU Munich, Germany (Talk)

01/2023 TU-LMU-KU Joint Seminar on Mathematics and Data Science, LMU Munich, Germany (Online Talk)

10/2019 Winter school on Gradient Flows and Variational Methods in PDEs, University of Ulm, Germany (Poster)

10/2019 Workshop 1st Austrian Calculus of Variations Day, University of Vienna, Austria (Talk)

09/2019 Hausdorffschool on Modeling and analysis of evolutionary problems in materials science, HCM Bonn, Germany (Talk)

12/2018 Berlin-Prague workshop on PDE, stochastics and related problems, TU Berlin, Germany (Talk)

09/2018 International Conference on Control of Self-Organizing Nonlinear Systems, Warnemünde, Germany (Poster).

04/2018 Workshop on Nonlinear and Nonlocal Evolution Equations and Stochastic Methods, Stralsund, Germany (Talk)

08/2017 Workshop on Control of Self-Organizing Nonlinear Systems, Lutherstadt Wittenberg, Germany (Poster)

Referee for journals and Conferences

Qeios

IMA Journal of Numerical Analysis

ICALP 2024 - 51st EATCS International Colloquium on Automata, Languages and Programming

Discrete and Continuous Dynamical Systems (DCDS) - American Institute of Mathematical Sciences (AIMS)

IMA Journal of Numerical Analysis

Teaching Experience

Summer term 2024 Lecturer, Deep Learning for Partial Differential Equations

Summer term 2023 Lecturer, Deep Learning for Partial Differential Equations

Winter term 2022 Lecturer, Computergestützte Mathematik: Einführung in Python

Summer term 2022 T.A., Mathematics of Artificial Intelligence Seminar

Summer term 2022 Tutor, Funktionentheorie, Lebesguetheorie und gewöhnliche Differentialgleichungen

Summer term 2021 Teaching Assistant and Tutor, Partial Differential Equations III: Evolutionsgleichungen

Winter term 2020	Teaching Assistant and Tutor, Differentialgleichungen II B: Nichtlineare stationäre partielle Diffferentialgleichungen
Summer term 2020	Teaching Assistant and Tutor, Differentialgleichungen II A: Lineare stationäre partielle Diffferentialgleichungen
Winter term 2019	Teaching Assistant and Tutor, Differentialgleichungen I: gewöhnliche Diffferentialgleichungen
Summer term 2019	Teaching Assistant, Analysis II
Winter term 2018	Teaching Assistant, Differentialgleichungen I
Summer term 2018	Teaching Assistant, Differentialgleichungen II A
Summer term 2018	Tutor, Differentialgleichungen für Ingenieure
Winter term 2017	T.A. and Tutor, Differentialgleichungen I: gewöhnliche Diffferentialgleichungen
Summer term 2017	Teaching Assistant, Differentialgleichungen III
Summer term 2017	Tutor, Stochastik für Informatiker

Administrative Experience

Konrad-Zuse School for AI	I helped designing the master's program in artificial intelligence for the Konrad Zuse School of Excellence in Reliable AI (2022)
DFG-Proposal	I actively contributed to the Deutsche Forschungsgemeinschaft (DFG) grant application focused on the topic of 'Computability'. (2022 - 2023)
Seminar Leadership:	Demonstrated organizational leadership in the coordination of a weekly seminar series, titled 'Absolventenseminar'. The series featured diverse speakers originating both from within the institution and esteemed guest lecturers from external academic institutions. The seminars predominantly emphasized the exploration of various topics related to Partial Differential Equations (PDEs). (2019 - 2021)
Project Coordination:	Project Coordination: Serving as a project coordinator, where my responsibilities include organizing and facilitating group meetings within the research theme of 'Quantum Computing and Computability'. This role commenced in 2022 and continues to date, facilitating in-depth discussions and collaborative efforts within the group. (2022 - 2023)
Seminar Leadership:	I have also been managing another weekly seminar series, involving speakers from our university and distinguished external academics. The seminar series aims to provide a platform for knowledge exchange on various aspects of Artificial Intelligence, demonstrating my versatility in facilitating interdisciplinary academic discussions. (2023 - 2023)

Membership in Professional Societies

2023-present	SIAM (Society for Industrial and Applied Mathematics)
2023-present	SIAM Activity Group on Data Science
2023-present	SIAM Activity Group on Analysis of Partial Differential Equations
2023-2024	GAMM (Gesellschaft für Angewandte Mathematik und Mechanik)

Technical skills

Programming: Python, Java, Matlab, Latex, Git, Microsoft Office

Patents

[1] Vadia, S. and Förste, J. and Baimuratov, A. S., Bacho, A., and Maly, J., **Wavefront Analog Instruction Set and Architecture**, 2024. Ludwig-Maximilians-Universität München.

Languages

German: Native

Englisch: Fluent

French: Intermediate

Extramural Activity

IT Security and Cryptography: Reading about IT security and cryptography

Sports: Jogging in nature, hiking in the mountains, and swimming.

List of Publications

Bachelor's Thesis: [1] Anwendung des Mountainpass-Lemmas auf eine Klasse von semilinearen elliptischen Randwertproblemen. 2013. *Technische Universität Berlin.*

Master's Thesis: [2] Gradientenflüsse in metrischen Räumen und Anwendungen. *Technische Universität Berlin.* 2016.

PhD Thesis: [3] On the Nonsmooth Analysis of Doubly Nonlinear Evolution Inclusions of First and Second Order with Applications. *Doctoral Thesis, Technische Universität Berlin.* 2021. https://doi.org/10.14279/depositonce-12327.

Conference Contributions: [4] Scholl, P., **Bacho, A.**, Boche, H., Kutyniok, G. The Uniqueness Problem of Physical Law Learning. *2023 IEEE International Conference on Acoustics, Speech and Signal Processing.* **2023**. https://ieeexplore.ieee.org/document/10095017 **(Published)**

[5] Maskey, S., Paolino, R., **Bacho, A.**, Kutyniok, G. A Fractional Graph Laplacian Approach to Oversmoothing. *NeurIPS 2023.* **2023**. https://openreview.net/forum?id=kS7ED7eE74.

Peer-Reviewed Journals: [6] **Bacho, A.** Emmrich, E., Mielke, A. An existence result and evolutionary Γ-convergence for perturbed gradient systems. *Journal of Evolution Equations.*, *19*(2), 479–522, **2019**. https://doi.org/10.1007/s00028-019-00484-x.

[7] **Bacho, A.** Abstract Nonlinear Evolution Inclusions of Second Order with Applications in Visco-Elasto-Plasticity. *Journal of Differential Equations,* 363, 126–169, **2023**. https://doi.org/10.1016/j.jde.2023.03.008.

[8] **Bacho, A.** A generalization of the Moreau-Yosida regularization. *Journal of Mathematical Analysis and Applications.*, *524*(2), Paper No. 127139, 15, **2023**. https://doi.org/10.1016/j.jmaa.2023.127139.

[9] **Bacho, A.** Well-Posedness of a Fully Nonlinear Evolution Inclusion of Second Order. *Journal of Elliptic and Parabolic Equations.* **2024**. https://doi-org.emedien.ub.uni-muenchen.de/10.1007/s41808-024-00270-y

[10] **Bacho, A.** Nonsmooth Analysis of Doubly Nonlinear Evolution Inclusions of Second Order with Non-Convex Energy Functional. *Advances in Nonlinear Analysis, De Gruyter*. **2025**.

[11] Scholl, P., Iskandar, M., Wolf, S., Lee, J., **Bacho, A.**, Dietrich, A., Albu-Schäffer, A., Kutyniok, G. Learning-based adaption of robotic friction models. *Robotics and Computer-Integrated Manufacturing* . **2024**.

Preprint

[12] **Bacho, A.**, Boche, H., Kutyniok, G. Reliable AI: Does the Next Generation Require Quantum Computing? *Quantum Machine Intelligence.* **2023**. ArXiv.2307.01301.

[13] **Bacho, A.**, Boche, H., Kutyniok, G. Complexity Blowup for Solutions to the Laplace and the Diffusion Equation. **2022**. ArXiv.2212.00693.

[14] Scholl, P., **Bacho, A.**, Boche, H., Kutyniok, G. Well-definedness of Physical Law Learning: The Uniqueness Problem. **2022**. ArXiv.2210.08342.

[15] Lorenz, B., **Bacho, A.**, Kutyniok, G. Error Estimation for Physics-informed Neural Networks Approximating Semilinear Wave Equations **2024**. ArXiv.2402.07153.

[16] Phan, L., Gatti, A., Han, Z., Li, N., Hu, J. Zhang, H., ...**Bacho, A.**. ... and Hendrycks, D. et al.: Humanity's Last Exam. **2025**. ArXiv.2501.14249.