Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Syllabus

Kursbeschreibung

Titel der Lehrveranstaltung	Physics Informed Neural Networks
Code der Lehrveranstaltung	71082
Zusätzlicher Titel der Lehrveranstaltung	
Wissenschaftlich-disziplinärer Bereich	IINF-05/A
Sprache	Englisch
Studiengang	Doktoratsstudium in Informatik
Andere Studiengänge (gem. Lehrveranstaltung)	
Dozenten/Dozentinnen	Dottore di ricerca Alessandro Bombini, Alessandro.Bombini@unibz.it https://www.unibz.it/en/faculties/engineering/academic-staff/person/53352
Wissensch. Mitarbeiter/Mitarbeiterin	
Semester	Alle Semester
Studienjahr/e	2025-2026
KP	2
Vorlesungsstunden	20
Laboratoriumsstunden	0
Stunden für individuelles Studium	50
Vorgesehene Sprechzeiten	0
Inhaltsangabe	The course introduces the concept of Physics Informed Deep Neural Networks (PINN), discuss its implementation from scratch in PyTorch and using advanced ad-hoc developed open-source libraries such as Nvidia PhysicsNemo for addressing real-world problems in various fields (engineering, physics, petroleum reservoir). We discuss recent topics such as Mixture-of-Models, Neural Operators, Physics-Informed Kolmogorov-Arnold Networks

	and Physics-Informed Computer Vision.
Themen der Lehrveranstaltung	• General Introduction to the Course: PDEs, Functional Analysis, Monte Carlo Integration • An Introduction to numerical resolution of PDEs • Finite Difference Methods to solve PDEs with Python • Introduction to PINNs: forward problems, inverse problems and parametric PINNs • Solving Heat equation with PINN in PyTorch (lightning) • Advanced PINNs methods - Learning strategies, Architectures, Losses, and other approaches • Introduction to PhysicsNemo-SYM to solve PDEs with PINNs • Advanced methods for PINNs in PhysicsNemo • PIKANs and Neural Operators • Solving Darcy Flow with DeepONets and FNOs in PhysicsNemo
Stichwörter	Deep Learning; Physics-Informed Neural Networks
Empfohlene Voraussetzungen	Basics of Python; Real Analysis; Numerical Methods; Machine Learning
Propädeutische Lehrveranstaltungen	Basics of Python; Real Analysis; Numerical Methods; Machine Learning
Unterrichtsform	Each lecture will consist of a frontal lecture (using presentation materials) and an hands-on section (using Google Colab, Jupyter Lab)
Anwesenheitspflicht	Attendance is not compulsory, but non-attending students have to contact the lecturers at the start of the course to agree on the modalities of the independent study.
Spezifische Bildungsziele und erwartete Lernergebnisse	The goal of the course is to introduce the concept of Physics Informed Deep Neural Networks (PINN), discuss its implementation from scratch in PyTorch and using advanced ad-hoc developed open-source libraries such as nvidia-modulus for addressing real-world problems in various fields (engineering, physics, petroleum reservoir). We discuss recent topics such as Mixture-of-Models, Neural Operators, Physics-Informed Kolmogorov-Arnold Networks and Physics-Informed Computer Vision. Knowledge and understanding • D1.1 – Ability to analyse and solve complex problems in computational science by integrating physics-informed neural

	networks with advanced numerical methods. • D1.2 – Ability to read, understand, and critically evaluate state-of-the-art scientific literature on PINNs, Neural Operators, and Physics-Informed Computer Vision. Applying knowledge and understanding • D2.1 – Ability to design and implement PINNs from scratch, demonstrating mastery of both theoretical and practical aspects. • D2.2 – Ability to apply innovative architectures (e.g. Mixture-of-Models, Kolmogorov-Arnold Networks) to extract knowledge from complex, high-dimensional physical systems. Making judgements • D3.1 – Ability to autonomously select and integrate specialist documentation, libraries, and datasets to advance research in physics-informed AI. • D3.2 – Ability to work with broad autonomy in multidisciplinary projects, taking responsibility for the design and validation of computational experiments. Communication skills • D4.1 – Ability to present PINN-based research results clearly and effectively to both specialist and non-specialist audiences, including through scientific publications. Learning skills • D5.1 – Ability to independently extend knowledge in emerging areas of physics-informed machine learning, keeping pace with rapid developments in AI and computational science.
Spezifisches Bildungsziel und erwartete Lernergebnisse (zusätzliche Informationen)	
Art der Prüfung	Option a: Discussion of a research work on the topic, selected by the student and accepted by the instructor; it must be presented orally with a presentation and with a Git repo offering the students implementation of the code Option b: Resolution of a small research problem discussed jointly with the instructor; presented either orally with a brief presentation or a written essay, and a git repo.

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Bewertungskriterien	The exam is pass/fail and no marks are awarded. Relevant for the assessment are the following: clarity of exposition, ability to summarize, evaluate, and establish relationships between topics, ability to present scientific notions, ability to evaluate research results by others.
Pflichtliteratur	All the required reading material including slides and lecture notes will be provided during the course and will be available in electronic format. Materials for hands-on sessions will be made available on the course github repository.
Weiterführende Literatur	Maziar Raissi, Paris Perdikaris, George Em Karniadakis. Physics Informed Deep Learning (Part I): Data-driven Solutions of Nonlinear Partial Differential Equations. arXiv 1711.10561 Maziar Raissi, Paris Perdikaris, George Em Karniadakis. Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. J. Comp. Phys. 378 pp. 686-707 DOI: 10.1016/j.jcp.2018.10.045 Toscano, Juan Diego et al. “From PINNs to PIKANs: Recent Advances in Physics-Informed Machine Learning.” (2024). arXiv:2410.13228 Chayan B., Kien N., Clinton F., and Karniadakis G.. 2024. Physics-Informed Computer Vision: A Review and Perspectives. ACM Comput. Surv. (August 2024). https://doi.org/10.1145/3689037 Cuomo, S., Cola, V.S., Giampaolo, F., Rozza, G., Raissi, M., & Piccialli, F. (2022). Scientific Machine Learning Through Physics–Informed Neural Networks: Where we are and What’s Next. Journal of Scientific Computing, 92. ArXiV 2201.05624
Weitere Informationen	Python, PyTorch, Nvidia PhysicsNemo 2504, JupyterLab/Hub
Ziele für nachhaltige Entwicklung (SDGs)	Hochwertige Bildung