UNIVERSITÄT LEIPZIG

BuildMoNa

SCIENTIFIC AND METHOD MODULES

Module name	Methods of Scientific Computing: Deep Learning/Machine Learning
Number	2021-T7
Aims	The course aims at two aspects of machine learning. The first goal is an introduction to statistical mechanics of learning, which aims at describing the typical learning behavior of neural networks, discussion of the generalization performance of strongly overparametrized neural networks. Information field theoretic description of ultrawide neural networks. The second aim is to give an introduction to machine learning techniques and its applications in natural sciences. It will include fields of image recognition, time series analysis and reinforcement learning with examples and applications of neural networks in fluid mechanics.
Basics	Knowledge of statistical mechanics Basic Knowledge of Linear Algebra Programming knowledge is of advantage
Contents	1) Introduction to Machine Learning and Deep Learning Techniques 2) Deep Learning Statistical Physics: Mapping of ultrawide neural networks to Gaussian processes, description of neural networks with the help of functional integrals 3) Machine Learning Applications: Image Segmentation, Tracking and Feature Extraction with Convolutional Neural Networks 4) Time Series Analysis with Recurrent Neural Networks 5) Applications of Reinforcement Learning in Physics 6) Machine Learning for Fluid Mechanics
Methods	Theoretical methods of modern statistical mechanics Image Processing Methods Time Series Analysis Programming
Type	Online Course
Date (month/year)	16 – 17 September 2021
Time	See page 2
Work load	15 hours presence / 45 hours self-study
Examination	Written examination
Credit points	2
Responsible scientists	B. Rosenow, F. Cichos
Industrial partners	-

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Recommendations for literature, e-learning	• Statistical Mechanics of Learning, A. Engel and C. Van den Broeck, Cambridge University Press (2001). • Theory Of Neural Information Processing Systems, Anthony C.C. Coolen, Peter Sollich, and Reimer Kühn, Oxford University Press (2009). • Neural Networks and Deep Learning, Michael A. Nielsen, Determination Press (2015). • Sutton, R. S. & Barto, A. G. Reinforcement Learning: An Introduction. *MIT Press, Cambridge* (1998). • Deep Learning with Python. F. Chollet, *Manning* (2017). • Neural Networks and Deep Learning: A Textbook. C. C. Agarwal, *Springer* (2018). • Deep Learning. I. Goodfellow, Y. Bengio & A. Courville, *MIT Press* (2016). • Brunton, S., Noack, B. & Koumoutsakos, P. Machine learning for fluid mechanics. *arXiv preprint arXiv:1905.11075* (2019). • Brunton, S. L., Proctor, J. L. & Kutz, J. N. Discovering governing equations from data by sparse identification of nonlinear dynamical systems. *Proc National Acad Sci* **113**, 3932--3937 (2016). • Cichos, F., Gustavsson, K., Mehlig, B. & Volpe, G. Machine learning for active matter. *Nat Mach Intell* **2**, 94--103 (2020).

SCHEDULE for Module 2021-T7

Time	Lecturer	Program	Location
Thursday, 16 September 2021			
9:30-10:00		Introductory Overview of Deep Learning	
10:00-11:00	Peter Sollich (Universtität Göttingen)	Introduction to statistical machine learning	
11:15-12:15	Giovanni Volpe (Gothenburg)	Introduction to Timeseries Analysis with Recurrent Neural Networks	
14:00-15:00	Giovanni Volpe (Gothenburg)	Introduction to Image Processing in Physics with Machine Learning	
15:15-16:00	Kristian Gustavsson (Gothenburg)	Introduction to Reinforcement Learning	
Friday, 17 September 2021			
10:00-11:00	Peter Sollich (Universtität Göttingen)	Gaussian processes for machine learning	
11:15-12:15	Zohar Ringel (Hebrew University)	Deep learning theory - an approach from the over-parametrized limit	
14:00-15:30	Zohar Ringel (Hebrew University)	Deep learning theory - an approach from the over-parametrized limit	
15:45-16:45	Steven Brunton (Washington University)	Machine Learning in Fluid Mechanics	
Online	Hands-on (F. Cichos)	*A few online Examples on Machine Learning in Python*	
Online	*Hands-on (B. Rosenow)*	*A few problems in the Statistical Mechanics of Learning*	