CHRISTIAN PEHLE

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Biographic Data

Born in Darmstadt, Germany. German citizen.

Academic Positions & Experience

Kirchhoff Institute for Physics, Heidelberg University   Heidelberg, Germany
PostDoc, STRUCTURES Excellence Cluster.   May 2021 - present

· Developing theory, algorithms and software for differentiable simulation and learning in physical systems, in particular detailed neuron models and networks, integrated with the machine-learning framework JAX.

· Developing theory and algorithms for closed-loop control of Quantum Experiments with Spiking Neural Networks.

· Architect and developer of "Norse", a software library for machine learning with Spiking Neurons.

· Supervising students implementing event-based learning algorithms for analog Neuromorphic Hardware.

PhD student in Physics.   August 2015 - February 2021

· Focussed on learning algorithms and plasticity in Spiking Neural Networks and analog Neuromorphic Hardware: Found a way to compute parameter gradients in networks of spiking neurons without approximations or assumptions on network topology, a long-standing open question.

· Worked on variational approximation of quantum density matrices and certain quantum operations by artificial and Spiking Neural Networks.

· Part of design team of a Neuromorphic Processor (BrainScaleS-2). Responsible for scale-up and verification of "plasticity processing unit" (an embedded processor with SIMD unit), evaluation and design of plasticity experiments.

Institute for Theoretical Physics, Heidelberg University   Heidelberg, Germany
Master Student.   October 2012 - February 2014

· Developed a novel method to count massless matter in String Theory (F-Theory).

Education

Heidelberg University   Heidelberg, Germany

August 2015 – February 2021	PhD in Physics
	Thesis: *Adjoint Equations of Spiking Neural Networks*
	Advisor: Karlheinz Meier[†], Johannes Schemmel
November 2011 – August 2015	Diplom Mathematics (incomplete, decided to proceed with PhD instead)
	finished majority of required and elective courses (among them: PDE, Optimization on Manifolds, Numerical Methods, Hodge Theory, Algebraic Topology, TQFT)
October 2010 – March 2014	MSc in Theoretical Physics (focus on Quantum Field Theory and String Theory)
October 2007 – November 2011	Vordiplom in Mathematics
October 2007 – August 2010	BSc in Physics

Edith-Stein-Schule   Darmstadt, Germany

July 2007	Abitur
	Recommended for German National Merit Foundation, received state-wide award for written physics exam.

Honors

2007–2014	Studienstiftung des Deutschen Volkes (German Academic Scholarship Foundation)
2007–2014	Evangelisches Studienwerk Villigst, based on academic excellence and social involvement

Publications & Preprints

1. Philipp Spilger, Elias Arnold, Luca Blessing, Christian Mauch, Christian Pehle, Eric Müller, and Johannes Schemmel. hxtorch. snn: Machine-learning-inspired spiking neural network modeling on brainscales-2. *arXiv preprint arXiv:2212.12210*, 2022

2. Christian Pehle and Christof Wetterich. Neuromorphic quantum computing. *Physical Review E*, 106(4):045311, 2022

3. Benjamin Cramer, Sebastian Billaudelle, Simeon Kanya, Aron Leibfried, Andreas Grübl, Vitali Karasenko, Christian Pehle, Korbinian Schreiber, Yannik Stradmann, Johannes Weis, et al. Surrogate gradients for analog neuromorphic computing. *Proceedings of the National Academy of Sciences*, 119(4), 2022

4. Eric Müller, Elias Arnold, Oliver Breitwieser, Milena Czierlinski, Arne Emmel, Jakob Kaiser, Christian Mauch, Sebastian Schmitt, Philipp Spilger, Raphael Stock, et al. A scalable approach to modeling on accelerated neuromorphic hardware. *Frontiers in neuroscience*, 16, 2022

5. Christian Pehle, Sebastian Billaudelle, Benjamin Cramer, Jakob Kaiser, Korbinian Schreiber, Yannik Stradmann, Johannes Weis, Aron Leibfried, Eric Müller, and Johannes Schemmel. The brainscales-2 accelerated neuromorphic system with hybrid plasticity. *Frontiers in Neuroscience*, 16, 2022

6. Timo C Wunderlich and Christian Pehle. Event-based backpropagation can compute exact gradients for spiking neural networks. *Scientific Reports*, 11(1):1–17, 2021

7. Christian Pehle and Jens Egholm Pedersen. Norse - a deep learning library for spiking neural networks, 2021

8. Sebastian Billaudelle, Yannik Stradmann, Korbinian Schreiber, Benjamin Cramer, Andreas Baumbach, Dominik Dold, Julian Göltz, Akos F Kungl, Timo C Wunderlich, Andreas Hartel, et al. Versatile emulation of spiking neural networks on an accelerated neuromorphic substrate. In *2020 IEEE International Symposium on Circuits and Systems (ISCAS)*, pages 1–5. IEEE, 2020

9. Philipp Spilger, Eric Müller, Arne Emmel, Aron Leibfried, Christian Mauch, Christian Pehle, Johannes Weis, Oliver Breitwieser, Sebastian Billaudelle, Sebastian Schmitt, et al. hxtorch: Pytorch for brainscales-2. In *IoT Streams for Data-Driven Predictive Maintenance and IoT, Edge, and Mobile for Embedded Machine Learning*, pages 189–200. Springer, Cham, 2020

10. Korbinian Schreiber, Timo C Wunderlich, Christian Pehle, Mihai A Petrovici, Johannes Schemmel, and Karlheinz Meier. Closed-loop experiments on the brainscales-2 architecture. In *Proceedings of the Neuro-inspired Computational Elements Workshop*, pages 1–3, 2020

11. Thomas Bohnstingl, Franz Scherr, Christian Pehle, Karlheinz Meier, and Wolfgang Maass. Neuromorphic hardware learns to learn. *Frontiers in neuroscience*, 13:483, 2019

12. Timo Wunderlich, Akos F Kungl, Eric Müller, Andreas Hartel, Yannik Stradmann, Syed Ahmed Aamir, Andreas Grübl, Arthur Heimbrecht, Korbinian Schreiber, David Stöckel, et al. Demonstrating advantages of neuromorphic computation: a pilot study. *Frontiers in neuroscience*, 13:260, 2019

13. Christian Pehle, Karlheinz Meier, Markus Oberthaler, and Christof Wetterich. Emulating quantum computation with artificial neural networks. *arXiv preprint arXiv:1810.10335*, 2018

14. Syed Ahmed Aamir, Yannik Stradmann, Paul Müller, Christian Pehle, Andreas Hartel, Andreas Grübl, Johannes Schemmel, and Karlheinz Meier. An accelerated lif neuronal network array for a large-scale mixed-signal neuromorphic architecture. *IEEE Transactions on Circuits and Systems I: Regular Papers*, 65(12):4299–4312, 2018

15. Martin Bies, Christoph Mayrhofer, Christian Pehle, and Timo Weigand. Chow groups, deligne cohomology and massless matter in f-theory. *arXiv preprint arXiv:1402.5144*, 2014

Invited Talks & Workshops

2023	Discussion Leader, "Lessons from Machine Learning", CapoCaccia workshop in Alghero, Italy.
2022	Fürberg Workshop, in Fürberg, Austria.
2021	SNUFA Workshop (online).
2021	Segev Lab Journal Club (online).
2020	CNRS-Thales, NIST (online). Talk: Adjoint Equations and Spiking Neural Networks.
2019	OCNS workshop on generative connectomics and plasticity in Barcelona, Spain.
2019	HBP L2L (learning to learn) workshop in Fürberg, Austria.
2018	HBP L2L (learning to learn) workshop in Fürberg, Austria.
2017	SP9 Fürberg Workshop, in Fürberg, Austria.
2016	SP9 Fürberg Workshop on Stochastic Computing, in Fürberg, Austria.
2016	EITN in Paris, France.

Supervision & Teaching

2021 – present	Co-Supervisor of two Master students.
2021 – present	Lead preparation of new teaching material for Neuromorphic Computing lab exercises.
2021	Graduate Teaching Assistant, Experimental Physics I (6-12 Students).
2017 – present	Supervised graduate students in lab exercises on Neuromorphic Computing (40+ Students).
2016	Taught Graduate Seminar: Brain Inspired Computing (6 Students).
2011 – 2012	Graduate Teaching Assistant, Linear Algebra, Heidelberg University (20-25 Students).
2009 – 2010	Teaching Assistant, Analysis, Heidelberg University (20-25 Students).

Research Funding

2019 – 2020   Participated in a second compute time proposal (3.4 million core-h) at JUWELS on LTL (learning to learn): successfully ran multi-node and multi-gpu deep-learning experiments with Spiking Neural Networks, contributed to the final report.

2018 – 2019   Participated in a successful collaborative compute time proposal on LTL (learning to learn), which resulted in 3.4 million core-h of compute time at JUWELS (FZ Jülich), the 8th fastest supercomputer in the world (as of November 2021), with participants from 5 international research labs: participated in and presented at planning workshop, wrote proposal for sub-project, ran feasibility study and contributed to the final report.

2017 – 2018   Assisted PhD supervisor with a successful collaborative bid (EXC 2181/1-390900948, the Heidelberg STRUCTURES Excellence Cluster) for 7-10 Million Euro per year in funding: did literature review, wrote draft for section in proposal, gave presentations at planning meetings, performed initial preparatory research.

Research Software Tools

2019 – present   **Norse** (*github.com/norse/norse*, > 400 stars on Github)

   · Library for gradient-based machine learning with Spiking Neural Networks in PyTorch.

   · Created initial architecture and implementation. Co-lead design and development.

   · In use by several external groups (European Space Agency, FZI & KIT Karlsruhe, KTH Stockholm).

   · Backends for neuromorphic chips (BrainScaleS-2, SpiNNaker-2) in development.

2020 – present   **aestream** (*github.com/norse/aestream*)

   · Library for streaming data from event-based cameras to deep-learning models in particular spiking neural network models.

   · Provided the initial C++ implementation and interface to PyTorch.

   · In use for closed-loop robotics experiments at KTH Stockholm.

Impact Activities

2023	Workshop on Norse at HBP Student Conference in Madrid, Spain.
2021	Held virtual workshop on Deep Learning with Spiking Neurons at the 5th HBP student conference (50+ participants).
2020	HBP Tea and Slides VII, online seminar for general scientific audience (30+ participants).
2017	2nd HBP Young Researchers Event in Geneva, Switzerland.

Training & Development

2018	CapoCaccia workshop in Alghero, Italy.
2017	HBP CodeJam in Lausanne, Switzerland.
2016	HBP CodeJam in Manchester, UK.
2016	CapoCaccia workshop in Alghero, Italy.

Languages

German (native), English (fluent), French (basic)

Technical Skills

I have seven years of experience working in a team of 5-8 hardware and 10-20 software developers and users. We practice sustainable software and hardware development principles. We have implemented an integrated software-hardware development flow, including Code Review, Continuous Integration, fully reproducible software-hardware deployment and dependency management.

· Machine Learning: PyTorch, JAX, algorithm design, optimal control, Neural ODE, Graph Neural Networks, HPC training

· Software Development: C/C++, Python, git, basic unix tools and environment, LaTeX, Functional Programming

· Hardware Development: Digital Design, FPGA (XilinX) and ASIC development: Contributed to three successful tapeouts of two prototype and one full-scale neuromorphic processor in TSMC 65 nm. Verilog/SystemVerilog, UVM, Verilator

· DevOps: Continuous Integration (Jenkins, Github workflows), Code Review (Gerrit), SLURM, Singularity, Spack

Other Interests

Programming Language Design and Type Theory, Long Distance Hiking (300 km+), Bouldering, Downhill Skiing

References

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