

# Max Horn

MACHINE LEARNING IN HEALTHCARE · DEEP LEARNING · INTERPRETABLE ML  
TIME SERIES · PROBABILISTIC MODELLING

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## EDUCATION

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- MAR. 2018 – NOV. 2021<sup>1</sup>    **PH.D. IN MACHINE LEARNING AND COMPUTATIONAL BIOLOGY**    ETH ZÜRICH, SWITZERLAND  
I develop **deep learning** methods for real world **medical time series data** where I focus on the property of **irregular sampling**. Furthermore, I am interested in **dimensionality reduction** using methods from **topology** in order to preserve the underlying manifold structure of the data. I also use probabilistic modelling to gain insights into real world biological and chemical problems.  
**Supervisor:** Prof. Dr. Karsten M. Borgwardt
- OCT. 2015 – OCT. 2017    **M.Sc. IN MOLECULAR BIOSCIENCES: SYSTEMS BIOLOGY**    HEIDELBERG UNIVERSITY, GERMANY  
**Thesis title:** “Fully Bayesian Modelling of Covariate Effects on the Gut Microbiome Using Horseshoe Priors for Sparsity Induction”  
**Supervisors:** Prof. Dr. Ursula Kummer, Dr. Frederik Graw & Prof. Eran Elinav  
**Final grade:** 1.0/very good
- OCT. 2012 – OCT. 2015    **B.Sc. MOLECULAR BIOTECHNOLOGY**    HEIDELBERG UNIVERSITY, GERMANY  
**Thesis title:** “Clustering and Scoring the Druggability of Transient Protein Pockets”  
**Supervisor:** Prof. Dr. Rebecca Wade  
**Final grade:** 1.5/very good
- OCT. 2004 – JUL. 2012    **GENERAL UNIVERSITY ENTRANCE QUALIFICATION (ABITUR)**    GYMANSIUM GERABRONN, GERMANY  
**Final grade:** 1.5/very good, awards for excellent performance in mathematics and physics

## PUBLICATIONS

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Authors who equally contributed to a publication are marked with a †.

### CONFERENCE AND JOURNAL PUBLICATIONS

1. **Max Horn**, Michael Moor, Christian Bock, Bastian Rieck, and Karsten Borgwardt. Set Functions for Time Series. In *Proceedings of the 37<sup>th</sup> International Conference on Machine Learning (ICML)*, 2020
2. Michael Moor<sup>†</sup>, **Max Horn**<sup>†</sup>, Bastian Rieck, and Karsten Borgwardt. Topological Autoencoders. In *Proceedings of the 37<sup>th</sup> International Conference on Machine Learning (ICML)*, 2020
3. Caroline Weis<sup>†</sup>, **Max Horn**<sup>†</sup>, Bastian Rieck<sup>†</sup>, Aline Cuénod, Adrian Egli, and Karsten Borgwardt. Topological and kernel-based microbial phenotype prediction from MALDI-TOF mass spectra. In *Bioinformatics* 36, 2020
4. Stephanie L. Hyland<sup>†</sup>, Martin Faltys<sup>†</sup>, Matthias Hüser<sup>†</sup>, Xinrui Lyu<sup>†</sup>, Thomas Gumbsch<sup>†</sup>, Cristóbal Esteban, Christian Bock, **Max Horn**, Michael Moor, et al. Machine learning for early prediction of circulatory failure in the intensive care unit. In *Nature Medicine* 26 (3), 2019
5. Michael Moor, **Max Horn**, Bastian Rieck, Damian Roqueiro, and Karsten Borgwardt. Early Recognition of Sepsis with Gaussian Process Temporal Convolutional Networks and Dynamic Time Warping. In *Proceedings of the 4<sup>th</sup> Machine Learning for Healthcare Conference (MLHC)*, 2019
6. Bastian Rieck<sup>†</sup>, Matteo Togninalli<sup>†</sup>, Christian Bock<sup>†</sup>, Michael Moor, **Max Horn**, Thomas Gumbsch, and Karsten Borgwardt. Neural Persistence: A Complexity Measure for Deep Neural Networks Using Algebraic Topology. In *Proceedings of the 7<sup>th</sup> International Conference on Learning Representations (ICLR)*, 2019

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<sup>1</sup> Expected graduation date

7. Jotham Suez, Niv Zmora, Gili Zilberman-Schapira, Uria Mor, Mally Dori-Bachash, Stavros Bashiardes, Maya Zur, Dana Regev-Lehavi, Rotem Ben-Zeev Brik, Sara Federici, **Max Horn**, et al. Post-Antibiotic Gut Mucosal Microbiome Reconstitution Is Impaired by Probiotics and Improved by Autologous FMT. In *Cell* 174.6, 2018
8. Antonia Stank, Daria Kokh, **Max Horn**, Elena Sizikova, Rebecca Neil, Joanna Panecka, Stefan Richter, and Rebecca C Wade. TRAPP webserver: predicting protein binding site flexibility and detecting transient binding pockets. In *Nucleic acids research* 45. W1, 2017
9. Max C. Waldhauer, Silvan N. Schmitz, Constantin Ahlmann-Eltze, Jan G. Gleixner, Carolin C. Schmelas, Anna G. Huhn, Charlotte Bunne, Magdalena Büscher, **Max Horn**, et al. Backbone circularization of *Bacillus subtilis* family 11 xylanase increases its thermostability and its resistance against aggregation. In *Molecular BioSystems* 11 (12), 2015

#### WORKSHOPS AND PREPRINT PUBLICATIONS

10. Michael Moor, Max Horn, Karsten Borgwardt, Bastian Rieck. Challenging Euclidean Topological Autoencoders. In *TDA and Beyond Workshop, NeurIPS*, 2020
11. Michael Moor, **Max Horn**, Christian Bock, Karsten Borgwardt, Bastian Rieck. Path Imputation Strategies for Signature Models. In *Artemiss Workshop, ICML*, 2020
12. Caroline Weis<sup>†</sup>, **Max Horn**<sup>†</sup>, Bastian Rieck<sup>†</sup>, Aline Cuenod, Adrian Egli, Karsten Borgwardt. Kernel-based antimicrobial resistance prediction from MALDI-TOF mass spectra. In *Machine Learning for Global Health Workshop, ICML*, 2020
13. Stefan Ganscha, Vincent Fortuin, **Max Horn**, Eirini Arvaniti, and Manfred Claassen. Supervised learning on synthetic data for reverse engineering gene regulatory networks from experimental time-series. In *bioRxiv* 356477, 2018

#### HONORS AND AWARDS

|                       |   |   |
|-----------------------|---|---|
| APR. 2017 – JUN. 2017 | PROMOS SCHOLARSHIP  | GERMAN ACADEMIC EXCHANGE SERVICE                                |
|                       | for master's thesis project in the group of Prof. Eran Elinav, Weizmann Institute of Science, Israel  |   |
| SEP. 2016 – JAN. 2017 | PROMOS SCHOLARSHIP  | GERMAN ACADEMIC EXCHANGE SERVICE                                |
|                       | for research project in the group of Prof. Manfred Claassen, ETH Zürich, Switzerland  |   |
| JUN. 2016             | MINT EXCELLENCE FINALIST  | WIESLOCH, GERMANY   |
|                       | Participated in the assessment center of the MINT Excellence Fellowship and was rated as one of the top 300 applicants  |   |
| NOV. 2014             | GRAD PRIZE WINNER   | INTERNATIONAL GENETICALLY ENGINEERED MACHINE (iGEM) COMPETITION |
|                       | as participant in the Heidelberg 2014 team we won the Grand Prize and Special Prizes of the categories: Best Foundational Advance Project, Best Supporting Software, iGEMer's prize |   |

#### PRESENTATIONS

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|-----------|---|---|
| JUL. 2020 | SET FUNCTIONS FOR TIME SERIES   | 37 <sup>TH</sup> INTERNATIONAL CONFERENCE ON MACHINE LEARNING |
|           | I presented our work on "Set Functions for Time Series" which proposes a novel way to handle irregularly-sampled time series by treating them as sets of observation tuples.  |   |
| JUL. 2020 | UNDERSTANDING NEURONS WITH NEURONS  | MACHINE LEARNING SUMMER SCHOOL 2020                           |
|           | I presented my work on "Understanding Neurons with Neurons – Tackling Spike Sorting with Amortized Variational Inference" where I combine techniques from object recognition and object-centric representations with simulation-based inference to tackle the inverse problem of spike-sorting in neuroscience. |   |
| MAR. 2020 | PREDICTING STABILITY OF FOSSIL-EMBEDDED DNA   | MLCB GROUP SEMINAR  |
|           | In this presentation I showed how probabilistic models can be used to model the stability of DNA in a Fossil-Embedded state. This research is part of an effort to improve long-term data storage in DNA.   |   |

|           |   |                            |
|-----------|---|----------------------------|
| Nov. 2019 | TOPOLOGICAL AUTOENCODERS  | SWISS MACHINE LEARNING DAY |
|           | I presented our work on “Topological Autoencoders” which utilize concepts from topological data analysis in order to derive topology-preserving low-dimensional representations of high dimensional data.                                       |                            |
| AUG. 2019 | CLASSIFYING THE IRREGULAR   | BAYER AG, BERLIN           |
|           | In “Classifying the Irregular – Learning with Sporadically Sampled Medical Time Series” I presented multiple efforts on how to design machine learning methods for irregularly-sampled time series which are omnipresent in the medical domain. |                            |
| JUL. 2019 | SCALABLE CLASSIFICATION OF IRREGULAR-SAMPLED TIME SERIES  | MLCB GROUP SEMINAR         |
|           | Here I presented preliminary results on our research into the application of set functions as a model for irregularly-sampled time series.  |                            |
| DEC. 2018 | DENSITY ESTIMATION IN MULTIMODAL TIME SERIES  | MLCB GROUP SEMINAR         |
|           | In “Density Estimation in Multimodal Time Series – A Joint Venture of Neural Processes and Normalizing Flows” I presented research on combining Neural Processes with Normalizing Flows for anomaly detection in time series.                   |                            |








## SKILLS

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|-------------------------|--|
| Python                  | Excellent knowledge in Python, in the creation of packages and in the utilization of NumPy, pandas, Dask and JAX <sup>2</sup> .  |
| C++                     | Good knowledge of C++ and experienced in the implementation of CUDA kernels for accelerating computations using GPUs <sup>3</sup> .                                      |
| Deep Learning           | Excellent experience in the development and application of Deep Learning models in both TensorFlow and PyTorch <sup>4</sup> .  |
| Probabilistic Modelling | Excellent experience in probabilistic modelling, in particular in the utilization of probabilistic programming frameworks such as PyMC3 <sup>5</sup> .                   |
| Linux, HPC              | Excellent technical skills in the maintenance of network infrastructures and Linux server environments and in setting up computation clusters using the SLURM scheduler. |
| LaTeX                   | Good knowledge of LaTeX and experienced in the design of figures using TikZ.   |

## SOFTWARE

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|-----------------------|---|
| simple-gpu-scheduler  | Command line tool for handling and distributing a queue of jobs among GPUs.<br> ExpectationMax/simple_gpu_scheduler $\approx$ 300 downloads/month  |
| SeFT                  | Implementation of Set Function for Time Series model in TensorFlow and Keras.<br> BorgwardtLab/Set_Functions_for_Time_Series $\approx$ 30 users  |
| TopoAE                | Implementation of <b>Topological Autoencoders</b> model in PyTorch.<br> BorgwardtLab/topological-autoencoders $\approx$ 25 users   |
| sklearn-jax-kernels   | Composable kernels for scikit-learn classes implemented in JAX.<br> ExpectationMax/sklearn-jax-kernels $\approx$ 100 downloads/month   |
| medical-ts-datasets   | Medical time series datasets for deep learning implemented using TensorFlow Datasets.<br> ExpectationMax/medical_ts_datasets   |
| HorseshoeDMRegression | Models for analysing microbiome-covariate effects using hierarchical Dirichlet-Multinomial regression models with sparsity inducing Horseshoe priors.<br> ExpectationMax/HorseshoeDMRegression |
| uea-ucr-datasets      | Time series datasets of the UEA and UCR repository for deep learning frameworks.<br> BorgwardtLab/uea_ucr_datasets   |

<sup>2</sup> See projects simple-gpu-scheduler, sklearn-jax-kernels, and uea-ucr-datasets.

<sup>3</sup> See project bactSim.

<sup>4</sup> See projects SeFT, medical-ts-datasets and topological-autoencoders.

<sup>5</sup> See project HorseshoeDMRegression.

bastSim C++ Library for large-scale simulations of interacting bacterial populations using GPUs.  
 ExpectationMax/bactSim

## SERVICE TO THE SCIENTIFIC COMMUNITY

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### REVIEWING

TDA and Beyond NeurIPS Workshop (2020), NeurIPS (2020), AAAI (2021), MLHC (2020, 2019), ISMB (2020), Swiss Machine Learning Day (2019), ECML-PKDD (2019), Springer Machine Learning (2019)

### TEACHING

Teaching assistant in Data Mining I – ETH Zürich (2019)

### CONTRIBUTIONS TO OPEN SOURCE SOFTWARE

 tensorflow/tensorflow,  tensorflow/datasets,  hyperopt/hyperopt,  
 palantir/python-language-server,  PyTorchLightning/pytorch-lightning,  
 IDSIA/sacred

## EXTRACURRICULAR ACTIVITIES

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|------|--|
| 2020 | <p><b>MACHINE LEARNING SUMMER SCHOOL 2020</b> <span style="float: right;">ONLINE</span></p> <p>Accepted as a full participant after competitive selection process (acceptance rate of <math>\approx 13\%</math>). Presented work on “Understanding Neurons with Neurons – Tackling Spike Sorting with Amortized Variational Inference”. Participated in two weeks of lectures and discussion rounds with many core players in the field of Machine Learning.</p> |
| 2019 | <p><b>MLFPN SUMMER SCHOOL 2019</b> <span style="float: right;">MUTTENZ, SWITZERLAND</span></p> <p>Accepted as participant of the Machine Learning Frontiers in Precision Medicine summer school which consisted of one week of lectures and discussions with experts at the intersection of machine learning and precision medicine.</p>   |

## PERSONAL

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|---------------------|---|
| Blogging            | <p>One of the most important aspects of this internet is that it allows us to share experiences and information with people of similar interests. I use my blog to help others who need to deal with similar issues and to share thoughts and summaries about research I am interested in.</p>  |
| NeoVim              | <p>As a passionate programmer, I optimized my editor to fit my needs and be compatible with the projects I am working on. NeoVim has become an essential tool of my day-to-day life. I write my lab book, papers, presentations and code in NeoVim and occasionally blog about how to extend it into a full-fledged IDE using modern approaches such as language servers.</p> |
| Reverse Engineering | <p>In my free time I enjoy working on small electronics projects, often involving reverse engineering old devices and making them function again or adapting their use case. In my most recent project I obtained an old Flip-dot display built in the 1970’s, reverse engineered it in order to understand how to display digits and repurposed it as a minimal clock.</p>   |
| Recreational        | <p>As recreational activities I enjoy reading popular science and science fiction books and bouldering.</p>   |