# YİĞİT DEMİRAĞ


**Contact Information**

Brunnwiesenstrasse 40, 8049, Zürich, Switzerland
yigit@ini.ethz.ch, https://github.com/YigitDemirag, +41 78 772 23 13


**Research Interests**

Brain-inspired computing, on-chip learning, mixed-signal accelerators, memristors

**Education**

***Institute of Neuroinformatics, ETH Zurich and UZH*** *July 2019 - Present*
*Joint Ph.D. in Neuroscience and Electrical Engineering*
*Marie Skłodowska Curie ITN Fellow*

***Bilkent University**, Turkey* *Sept 2015 - July 2018*
*M.S. in Electrical and Electronics Engineering*

***Bilkent University**, Turkey* *Sept 2011 - July 2015*
*B.S. in Electrical and Electronics Engineering*

**Research Experience**

***Google Research, Zürich*** *July 2023 - April 2024*
*Student Researcher*

- *Developed local attention-based neural cellular automata as a microcolumn-inspired self-organizing architecture.*
- *Investigated layerwise local learning optimization of Vision Transformers.*
- *Benchmarked few-shot learning of PaLM 2 on the ARC visual reasoning dataset using randomized alphabets.*
- *Investigated stacked autoencoders and training schemes for generalization.*

***Institute of Neuroinformatics, ETH Zurich and UZH*** *July 2019 - Present*
*Ph.D. Candidate with Giacomo Indiveri and Melika Payvand*

- Developed effective training techniques for the neuromorphic Mosaic chip, a systolic array of modular analog compute cores with unique locally dense and globally sparse connectivity matrix.
- Engineered a 130 nm mixed-signal circuit utilizing PCM drift for long-lasting synaptic eligibility traces, achieving over 11x smaller silicon area enabling scalable learning rule implementations *(Patented)*.
- Characterized 4,000 $HfO_2$-based binary RRAMs and developed a programming scheme increasing bit-resolution (to $\sim$ 6-bits) for robust on-chip learning.
- Analyzed the effects of various memristor programming methods on the learning efficiency of spiking recurrent networks trained with bio-plausible e-prop learning rule. Collaborated with IBM Research to validate findings on 14nm CMOS and PCM-based in-memory computing cores.
- Investigated novel halide perovskite materials for dual-use as volatile and non-volatile memory elements, based on the programming scheme.
- Developed a meta-learning based training approach to address key challenges in analog hardware, i.e., bit resolution, programming noise, and update non-linearity for enhanced edge adaptation in spiking analog neuromorphic systems.

***MILA - Quebec AI Institute, Montreal*** March 2023 - May 2023
*Visiting Ph.D. researcher with Blake Richards*

- Implemented 4-bit quantized training for ResNet models with exponentiated gradients in log number system for on-chip learning, drawing connections between multiplicative weight updates and synapses in the biological brain.

***Samsung Electronics, Seoul*** Oct 2017 - Apr 2018
*Intern at Advanced Technology Development Group*

- Developed a time and temperature dependent physics model that predicts electrical resistance drift of OTS selectors for the next generation NVM devices.

***École Polytechnique Fédérale de Lausanne (EPFL)*** Aug 2017 - Sept 2017
*Intern at Microelectronic Systems Laboratory*

- Worked on various supervised local learning rules for multilayer spiking neural networks that optimized for crossbar arrays of memristive devices.
- Developed a measurement analysis tool for investigating multi-level switching behavior of bilayer ReRAM devices.

***Bilkent University Nanotechnology Research Center*** Sept 2015 - 2018
*M.Sc. Student with Ekmel Özbay*

- Developed a multiphysics COMSOL simulator for PCM-based synaptic devices, encompassing electrical, thermal, crystallization, and growth dynamics across diverse READ/WRITE scenarios, tailored for brain-inspired applications.
- Performed thermal simulations on COMSOL for optimizing the geometry of GaN/AlGaN high-electron-mobility transistors.
- Developed a spectrum classification algorithm for a THz-TDS system using PCA and multivariate GMM, implemented in MATLAB and LabVIEW.

***Google*** Summer 2015
*Google Summer of Code Student*

- Developed ARM NEON extension of Vector Class Library in C++.
- Performed SIMD optimization on Philox and Threefry CBRNGs for Intel's AVX512 and AVX2 ISA.

***CERN, European Organization for Nuclear Research*** Summer 2014
*Undergraduate Openlab Summer Student*

- Performed SIMD optimization of CBRNGs using Intel's Haswell Architecture.
- The throughput of Philox CBRNG increased >3x, deployed in Monte Carlo simulations of GEANT4, ROOT and FLUKA frameworks at CERN.

***Middle East Technical University, Physics Dept.*** *Oct 2013 - June 2014*
*Undergraduate Researcher*

- Designed trigger circuit of a particle (Muon) detector using thyristor that operates at 12kV DC and provides 1kA peak current in 150 ns to discharge parallel transition plates.

**Skills** JAX, PyTorch, Brian2, SystemVerilog, C/C++, COMSOL, MATLAB, LTSpice

**Projects**

***Spike: TPU accelerated SNN library***
Spike is a JAX-based library for TPU-optimized training of spiking neural networks using surrogate-gradient and evolutionary strategies.

***Dynap-SE Simulator***
A Brian2-based SNN library that emulates underlying mixed-signal physical circuit dynamics of Dynap-SE1 neuromorphic processor. This library is being actively used for research and for teaching neuromorphic classes at ETH Zürich.

***pcbMaster: Chip Testing Framework***
pcbMaster is a Python-based framework to systematically program and monitor neuromorphic chips via OpalKelly FPGA using FrontPanel Python API. This library has been used for benchmarking three different brain-inspired chips designed at the ETH.

***Arduino Simulator***
Programmable simulator of the Arduino Uno with 3D GUI in Java. Its onboard 8-bit Atmel ATmega328p CPU with 131 instructions, EEPROM, registers are emulated. It can be programmed by Arduino IDE.

**Teaching**

Spiking Neural Networks on Neuromorphic Processors (Designed, TA) ETH Zürich
Neuromorphic Intelligence (TA) University of Zürich
Analog Electronics (TA) Bilkent University
EEE Design II (TA) Bilkent University

**Honors & Awards**

Google TPU Research Cloud Fellow, 2022
Marie Skłodowska Curie ITN Fellow, 2019
The Best Researcher Award for Class of 2015
Prof. Engin Arık Scholarship, 2014
Excellence in Research Scholarship from NANOTAM, 2013
Full-Tuition Waiver and Scholarship From Bilkent University
First Lego League Turkey The Best Volunteer Award, 2012

**On the News**

My interview on brain-inspired chips on The Brightest Young AI Researchers by NZZ.
ETH News and UZH News coverage on our reconfigurable analog devices.
Our PCM-trace work is highlighted by EE Times Europe.
PCM-trace and Mosaic chips on ICML coverage of The TWIML AI Podcast.

**co-Supervision**

Anja Šurina - MS student at IBM Research, now PhD with Yoshua Bengio at Mila
Karthik Raghunathan - MS student, now PhD with Melika Payvand at ETH
Maxime Fabre - MS student at IBM Research, now PhD with Emre Neftci at FZJ

**Invited Talks**

Google Research Talk, In memory accelerated training on analog substrates, Sep 2023
Mila, In memory accelerated training of neural networks, Apr 2023
Forschungszentrum Jülich, On-chip training of recurrent neural networks, Nov 2022
SNUFA Seminar, Online Training of SRNNs With Memristive Synapses, Jul 2022
CapoCaccia Workshop, Mixed-signal implementation of scalable e-traces, Apr 2022
COSYNE Tutorial TA, Spiking Neural Network Models in Neuroscience, Apr 2022
NICE Workshop, Dynap-SE1 Neuromorphic Chip Simulator, March 2021

**Publications & Patents**

1. D'Agostino S.*, Moro F.*, Torchet T.*, Demirağ Y et al. DenRAM: Neuromorphic Dendritic Architecture with RRAM for Efficient Temporal Processing with Delays. Nature Communications (In Review, 2024)
2. Demirağ Y., Indiveri G. Network of biologically plausible neuron models can solve complex tasks without synaptic plasticity. COSYNE (2024)
3. Dalgaty T.*, Moro F.*, Demirağ Y.*, et al. The neuromorphic Mosaic: in-memory computing and routing for small-world graphs. Nature Communications (2023).
4. John R.A.*, Demirağ Y.*, Shynkarenko Y. et al. Reconfigurable halide perovskite nanocrystal memristors for neuromorphic computing. Nature Communications (2022).
5. Demirağ Y., Dittmann R., Indiveri G. et al. Overcoming phase-change material non-idealities by meta-learning for adaptation on the edge. NeuMatDeCas (Best run up oral contribution, 2023)
6. Bohnstingl T. et al. Biologically-inspired training of spiking recurrent neural networks with neuromorphic hardware. AICAS (2022).
7. Dalgaty T., Vianello E., Indiveri G., Payvand M., Demirağ Y., Filippo M. Synapse circuit for three-factor learning. US Patent App. 17/454,435. May 12, 2022.
8. Demirağ Y., Frenkel C., Payvand M. et al. Online Training of Spiking Recurrent Neural Networks with Phase-Change Memory Synapses. Arxiv (2021).
9. Demirağ Y., Moro F., Dalgaty T. et al. PCM-trace: Scalable Synaptic Eligibility Traces with Resistivity Drift of Phase-Change Materials. ISCAS (2021).
10. Payvand M., Demirağ Y., Dalgaty T., et al. Analog weight updates with compliance current modulation of binary ReRAMs for on-chip learning. Special Session, ISCAS (2020).
11. Yu Z, Bégon-Lours L, Demirağ Y. et al. BEOL compatible cross-bar array of ferroelectric synapses. ICONS (2021).
12. Demirağ Y., Ozbay E. & Leblebici Y. Modeling Electrical Resistance Drift with Ultrafast Saturation of OTS Selectors. Arxiv (2019).
13. Ghobadi A., Demirağ Y., Hajian H. et al. Spectrally Selective Ultrathin Photodetectors Using Strong Interference in Nanocavity Design. IEEE Electron Device Letters (2019).
14. Demirağ Y. Multiphysics Modeling of Ge2Sb2Te5 Based Synaptic Devices for Brain Inspired Computing. Bilkent University. (2018)
15. Hajian H., Serebryannikov A., E. Ghobadi A., Demirağ Y. et al. Tailoring far-infrared surface plasmon polaritons of a single-layer graphene using plasmon-phonon hybridization in graphene-LiF heterostructures. Scientific Reports (2018)
16. Demirağ Y., Funke D. & Wenzel S. Vectorization Studies of Random Number Generators on Intel's Haswell Architecture. ZENODO (2014).

* — equal contributions