Philippe Bich

PhD Candidate in Electrical, Electronics and Communications Engineering - Politecnico di Torino (IT)

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Experience

PhD Student (Politecnico di Torino)

Turin, Italy

Supervisor: Professor Gianluca Setti

10/2021 – ongoing

- I am in the third (and final) year of my PhD. My research focuses on **low-energy Deep Neural Networks** (DNNs) and on **low-power sensing**. I am particularly interested in the optimization of large Deep Neural Networks (DNNs) for **Computer Vision** and in **Event-based cameras**.
- My PhD is in collaboration with the **Boston University Robotics Lab**.
- I have published papers in several prestigious conferences and journals, including **ICRA**, **CVPR** and I am a **finalist of the CVPR 2024 Event-based Eye-tracking Challenge**.

Master's thesis (Boston University)

Supervisor: Professor John Baillieul

09/2020 – 05/2021

- Developed an algorithm for **bio-inspired visual navigation** in unknown environments that relies solely on the output of a monocular camera and utilizes sparse optical flow.
- Part of this work has been summarized in a paper which has been accepted at the IEEE 2022 International Conference on Robotics and Automation (**ICRA**).

Education

Bachelor's Degree in Computer Engineering

Turin, Italy

Politecnico di Torino | Evaluation: 109/110 (GPA: 3.96)

2015-2018

Master's Degree in Mechatronics Engineering

Turin, Italy

Politecnico di Torino | Evaluation: 110 cum laude/110 (GPA: 4.0)

2018-2020

Most Relevant Exams:
-Event-based Cameras, Neuromorphic Hardware and Optimized Execution of Neural Networks at the Edge (Evaluation: 30/30 cum laude)
-Robotics (Evaluation: 30/30 cum laude)
-Computer Vision (Evaluation: 30/30 cum laude)

Relevant publications

-[C7] Memory in Motion: Exploring Leaky Integration of Time Surfaces for Event-based Eye Tracking (2024) In: IEEE Biomedical Circuits and System Conference (BioCAS)
-[J2] A Multiply-And-Max/min Neuron Paradigm for Aggressively Prunable Deep Neural Networks (2024) Under minor revision: IEEE Transactions on Neural Networks and Learning Systems (IEEE TNNLS)
-[J1] On the Universal Approximation Properties of MAM Neurons (2024) Under minor revision: IEEE Transactions on Pattern Analysis and Machine Intelligence (IEEE TPAMI)
-[C6] Event-based Eye Tracking: AIS 2024 Challenge Survey (2024) In: IEEE/CVF Computer Vision and Pattern Recognition Conference (CVPR)
-[C5] Optimizing Vision Transformers: Leveraging Max and Min Operations for Efficient Pruning (2024) In: IEEE International Conference on Artificial Intelligence Circuits and Systems (AICAS)
-[C4] PEDRo: an Event-based Dataset for Person Detection in Robotics (2023) In: IEEE/CVF Computer Vision and Pattern Recognition Conference (CVPR)
-[C3]Aggressively prunable MAM^2-based Deep Neural Oracle for ECG acquisition by Compressed Sensing (2022) In: IEEE Biomedical Circuits and System Conference (BioCAS)
-[C2] Visual Navigation Using Sparse Optical Flow and Time-to-Transit (2022) In: IEEE International Conference on Robotics and Automation (ICRA)
-[C1] Multiply-And-Max/min Neurons at the Edge: Pruned Autoencoder Implementation (2023) In: IEEE International Midwest Symposium on Circuits and Systems (MWSCAS)

Skills

Main interests	**Low-energy Computer Vision, Event-based cameras**, Robotics
Programming Languages and Softwares	**Python, C, C++, ROS/Gazebo**
Libraries	**Pytorch, Tensorflow, TensorRT**, NumPy, CuPy, Pandas, Scikit-learn, Matplotlib
Languages	**Italian** (native), **English** (C1: IELTS), **French** (C1: DALF)

Conferences and Talks

-From 24/06/2024 to 26/06/2024: **TinyML Foundation EMEA Innovation Forum**, Milan (IT) – **Speaker** (Low-energy ViTs)

-From 17/06/2024 to 21/06/2024: **IEEE / CVF Computer Vision and Pattern Recognition Conference (CVPR)**, Seattle (US) – Paper presentation

-From 22/04/2024 to 25/04/2024: **IEEE International Conference on Artificial Intelligence Circuits and Systems (AICAS)**, Abu Dhabi (UAE) – Paper presentation

-From 06/08/2023 to 09/08/2023: **IEEE International Midwest Symposium on Circuits and Systems (MWSCAS)**, Phoenix (US) – Paper presentation

-From 18/05/2023 to 22/05/2023: **IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)**, Vancouver (CAN) – Paper presentation

-From 13/10/2022 to 15/10/2022: **IEEE Biomedical Circuits and Systems Conference (BioCAS)**, Taipei (TW) – Paper presentation

-From 06/10/2022 to 15/10/2022: **IEEE/DEI Summer Ph.D. School of Information Engineering "Silvano Pupolin" (SSIE)**, Brixen (IT)

-From 23/05/2022 to 27/05/2022: **IEEE International Conference on Robotics and Automation (ICRA)**, Philadelphia (US) – Paper presentation

Activities

My research activity mainly focuses on the **optimization of large Deep Neural Networks (DNNs) for Computer Vision**. The goal is to allow their implementation on resource-constrained and low-energy/low-power devices, emphasizing the increasing importance of performing on-device inference which is becoming more and more important also because of the escalating costs associated with the server-side inference for large models. In order to achieve this, I have developed an in-depth expertise in pruning and quantization techniques. In addition to my work on low-energy DNNs, I delve into the realm of low-power sensing with **event-based cameras** and neuromorphic computing as well as of **robotics**, applying bio-inspired navigation principles to enhance the capabilities of autonomous systems. Here are some key points of my research activity in more detail:

- **Low-energy Computer Vision:** My experience in the optimization of DNNs is about the design of alternative approaches to substitute the typical Multiply and Accumulate (MAC) paradigm. Given that DNNs can be regarded as non-linear structures capable of learning, the idea is to find an alternative trainable non-linear structure that can be more aggressively pruned than a classical MAC neuron to reduce the size of the neural model. A novel Multiply-and-Max/min (MAM) map-reduce paradigm [J2] for neurons in DNNs has been researched in the attempt of developing a structure that can be naturally prone to pruning, i.e., many weights can be removed as not necessary, with a huge reduction in memory requirements. In particular, MAM has been proven to work with different classical computer vision tasks (MNIST, FashionMNIST, CIFAR-10, CIFAR-100 and ImageNet-1k) with very promising pruning performances on different DNNs [C1, C3] including large Vision Transformers models [C5, J2].
- **Event-based Vision:** My interest in strategies for low-energy sensing led me to explore the world of event-based cameras, both as standalone sensors and as enhancements to traditional cameras. In [C4], I presented PEDRo, an event-based dataset for person detection, which includes 43,259 manually labeled bounding boxes and is, to date, the largest manually annotated event-based dataset for person detection in the literature (>400 downloads). In [C6], the techniques used in the *2024 CVPR Event-based Eye-Tracking Challenge* are described, where the team I led reached the finals, ranking first in the public Kaggle leaderboard. In [C7], I explored the leaky integration of time surfaces for lightweight, non-recurrent event-based eye-tracking.
- **Deep Learning Theory**: To maintain the promise of MAM neurons [J2] in low-energy DNNs, the assumption that MAC&MAM architectures have the same expressive power as MAC-only ones must be proved. To concretize such a cornerstone, in [J1] I take a step in the theoretical characterization of the capabilities of mixed MAM&MAC networks. I prove, with two theorems, that two hidden MAM layers followed by a MAC neuron with possibly a normalization stage are still a universal approximator.
- **Bio-inspired Robotics Navigation:** Drawing inspiration from biology, the way in which visual sensing with a monocular camera can provide a reliable signal for navigation of mobile robots has been studied. Taking inspiration from the behavioral strategy pursued by diving sea birds which is based on a visual cue called time-to-contact, a closely related concept of time-to-transit has been defined. It has been shown how it can be estimated from the output of a monocular camera and how it can be used to guide a robot in unknown environments. The introduction of the concept of Eulerian Optical Flow and a simple theory of robust vision-based steering control has been developed together with ROS-Gazebo simulations as well as experiments with a camera-equipped Jackal robot [C2].