technische universität dortmund

computer science 12

Master Thesis

Energy analysis of machine learning algorithms on ultra-low power embedded devices

Dr.-Ing. Mojtaba Masoudinejad
Prof. Dr. Jian-Jia Chen
Otto-Hahn Str. 16
Technische Universität Dortmund
mojtaba.masoudinejad@tu-dortmund.de
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Edge computing with the use of Machine Learning (ML) is gaining momentum and is considered as a hot research topic. One of major challenges in this field has been reliable porting solutions which enable code generation for embedded edge devices. These systems mostly have limited *memory*, *computation power* and *energy*. However, introduction of TensorFlow Lite [1] by Google provides a solution mainly for Arm Cortex-M Series and some limited microcontrollers such as Arduino and ESP.

Although most available Arm Cortex-M Series and microcontrollers require less energy than their alternatives, they are not in the energy scale of ultra-low power (ULP) solutions. On the contrary, while ULP devices such TI MSP430 series [2] demand limited energy, their NV-memory limitations and ISA design make porting ML solution very limited, tedious and non systematic. Introduction of ULP Arm based 32-Bit processors such as Apollo series [3] from Ambiq provides a combination of both worlds. Their Arm Cortex-M design enables a straightforward porting which also can be stored in their roughly large memory. Meanwhile they demand a very small energy footprint in the scale of 6 µA/MHz and lower. In addition, availability of multiple periphery connections (ADC, I/O, UART) enable connection of diverse sensors such as camera and microphones to build real-world edge devices.

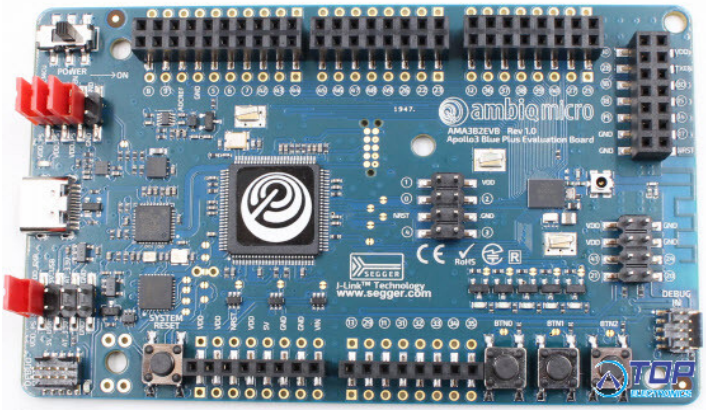

Figure 1: An evaluation board for Apollo3 Blue Plus from Ambiq.

Some initial trials such as [3] have integrated this device to build a face recognition prototype in a battery-less manner. However, an optimal design requires a systematic analysis of the ML program, key parameters finding and their effect on the overall energy demand.

In this thesis: student first should get familiar with the available hardware and build a toolchain for porting ML algorithms to it. In addition, a structure for energy measurement and analysis of the board has to be set. Next, a common image processing problem has to be selected with a survey on its common ML solutions with possibility of porting to this specific hardware considering computation, memory and so on. This has to be followed with the identification and analysis of possible factors on the energy demand such as the ML design, image size and resolution, etc.

Other suggestions and related topics are also welcome. Please do not hesitate to make an appointment.

Required Skills:

- Knowledge of C and/or C++ programming
- Basic know-how on ML and image processing
- Basics of electronic (power measurement)

Acquired Skills after the thesis:

- Knowledge about optimized ML for ULP edge computing.
- Knowledge about energy optimized system design.

[1] `https://www.tensorflow.org/lite/`
[2] `https://www.ti.com/microcontrollers/msp430-ultra-low-power-mcus/overview.html`
[3] `https://ambiq.com/mcu-soc/`
[4] M. Giordano, P. Mayer, and M. Magno; *A Battery-Free Long-Range Wireless Smart Camera for Face Detection*. DOI:https://doi.org/10.1145/3417308.3430273