RISC-V based Embedded Systems For Always-on Energy Efficient Smart Sensing with TinyML

Lukas Schulthess
Dep. Of Information technology and Electrical Engineering
ETH Zurich
Zurich, Switzerland

Tommaso Polonelli
Dep. Of Information technology and Electrical Engineering
ETH Zurich
Zurich, Switzerland

Michele Magno
Dep. Of Information technology and Electrical Engineering
ETH Zurich
Zurich, Switzerland

POSTER ABSTRACT

Technology advancements in electronics, sensors, processors, and wireless communication enable the design and implementation of energy-efficient and intelligent low power devices. Most of those miniaturized IoT "smart" devices have limited intelligence or even they only acquire/store the data and send them wirelessly to a smartphone or more intelligent device or download them off-line. Today, machine learning on IoT devices is applied with the traditional cloud computing paradigm where the whole data processing is performed in the cloud, and the IoT devices stream the data out in the raw form or possibly after simple filtering and/or compression. However, the number of IoT devices is expanding rapidly, and the massive amount of collected data is hard to manage by central clouds. The new trend of IoT devices is to be “smart” to make decisions on their own, without streaming all the raw data to the cloud.

Tiny machine learning is very promising for low-power IoT devices to address the major challenge of extracting relevant information close to the many sensors and data spread in the physical world. Lots of research efforts toward specialized hardware and optimized inference algorithms to run such NNs on power-constrained devices have been made over the last few years. Today’s most IoT devices host microcontrollers (MCUs), especially from the ARM Cortex-M family, which can achieve power consumption in the order of milliwatt and computational resources in the order of hundreds of MOPS. The power consumption in the range of milliwatts is required for battery-operated devices to avoid frequent battery recharges. On the other hand, RISC-V the open standard instruction set architecture (ISA) is an exciting and rapidly emerging technology. based on established reduced instruction set computer (RISC) principles. Very recently the microprocessors RISC-V based that target milliwatts of power consumption are finally available both as research platforms (such as the ETH Zurich PULP processor) or the very promising ESP32-C3 that included even a Wifi and BTLE communication interface and a RISC-V core with only 20mA current consumption at 160MHz.

This work presents a branch of novel embedded systems and smart sensors with a milliwatt power budget that has a RISC-V processor as the main core. The designed prototypes are done with energy efficiency and tinyML in mind. With the same concept as RISC-V, the hardware and software design will be soon realized open, including some TinyML algorithms to evaluate the potentiality of machine learning with low power cores. Moreover, they are embedding novel sensors that are recently realized on the market or will be in the next few months, such as the 8x8 Time of Flights matrix, novel inertial sensors with analog-front end for capacitive sensing, and many others. In particular, among other low-power smart sensors systems we will present the following: **MicroBeanRISC-V**: A miniaturized RISC-V bases multi-sensor multi-radio sensor tile. **CrazyToF [1]**: A CrazyFly for camera-free autonomous navigation: **SelfEdgeEye[2]:** A self-sustaining long-range energy-efficient vision node for long-term edge computing. The work presents open RISC-V sensors platforms to achieve truly smart and always-on sensors for the next generation of IoT. The poster will present more experimental preliminary results, on power consumption, tinyML, MACs per Cycle, etc. will be presented.

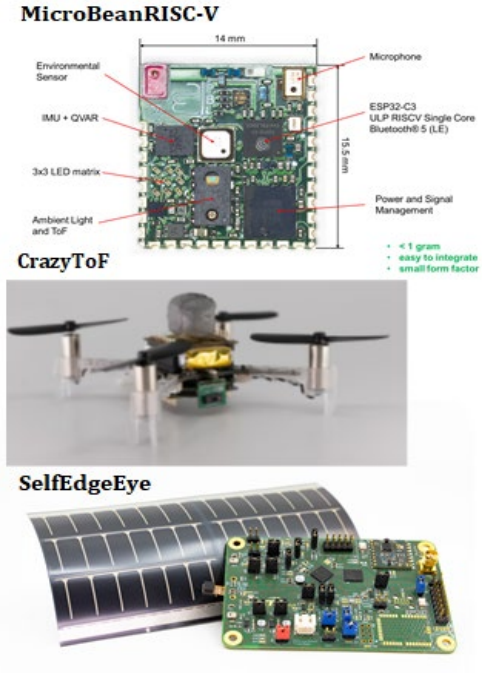

Figure 1: Three embedded systems for always-on smart sensing with novel sensors and TinyML

REFERENCES

[1] V. Niculescu , H. Mueller, I. Ostovar, T. Polonelli, M. Magno , and L Benini “Towards a Multi-Pixel Time-of-Flight Indoor Navigation System for Nano-Drone, Proceedings, 39nd IEEE International Instrumentation and Measurement Technology Conference (I2MTC 2022).

[2] Benninger, Simon, Michele Magno, Andres Gomez, and Luca Benini. "Edgeeye: A long-range energy-efficient vision node for long-term edge computing." In 2019 Tenth International Green and Sustainable Computing Conference (IGSC), pp. 1-8. IEEE, 2019.-