WALC 2023
Applied AI

Applied AI Track Wrap-up

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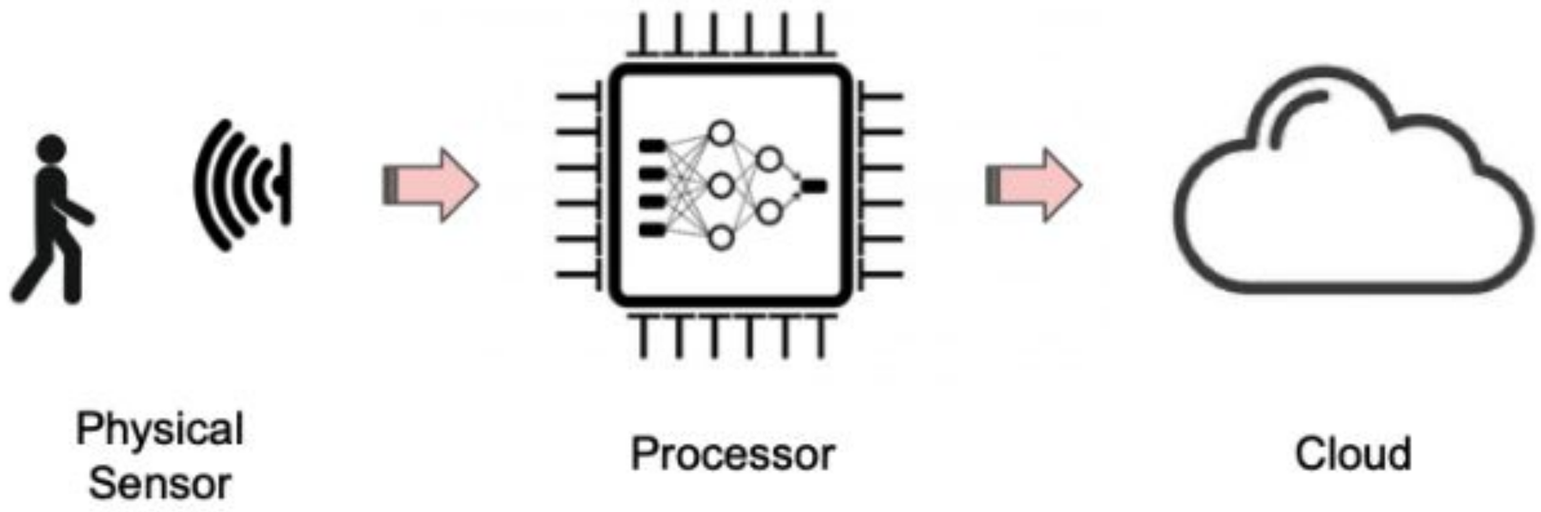
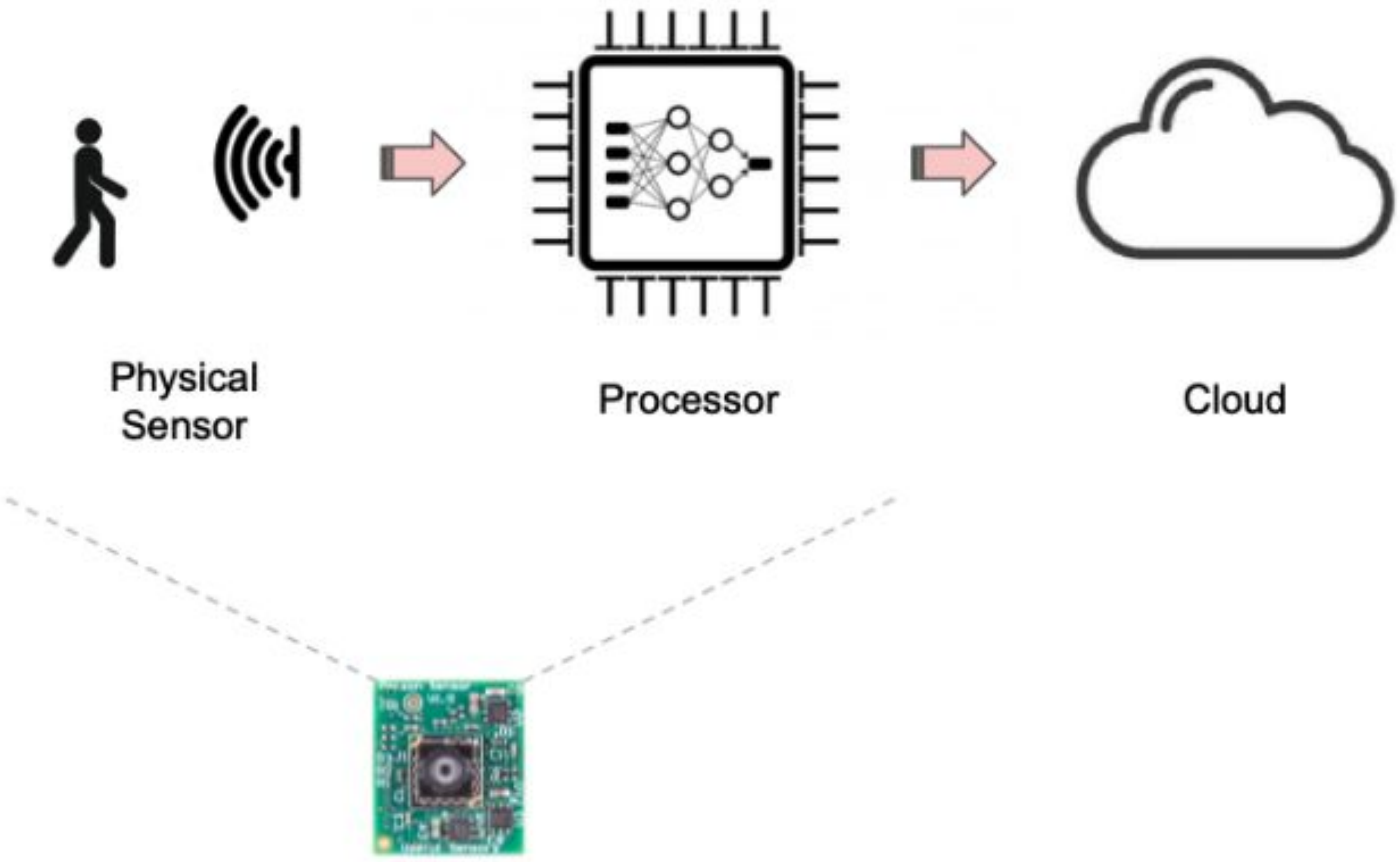
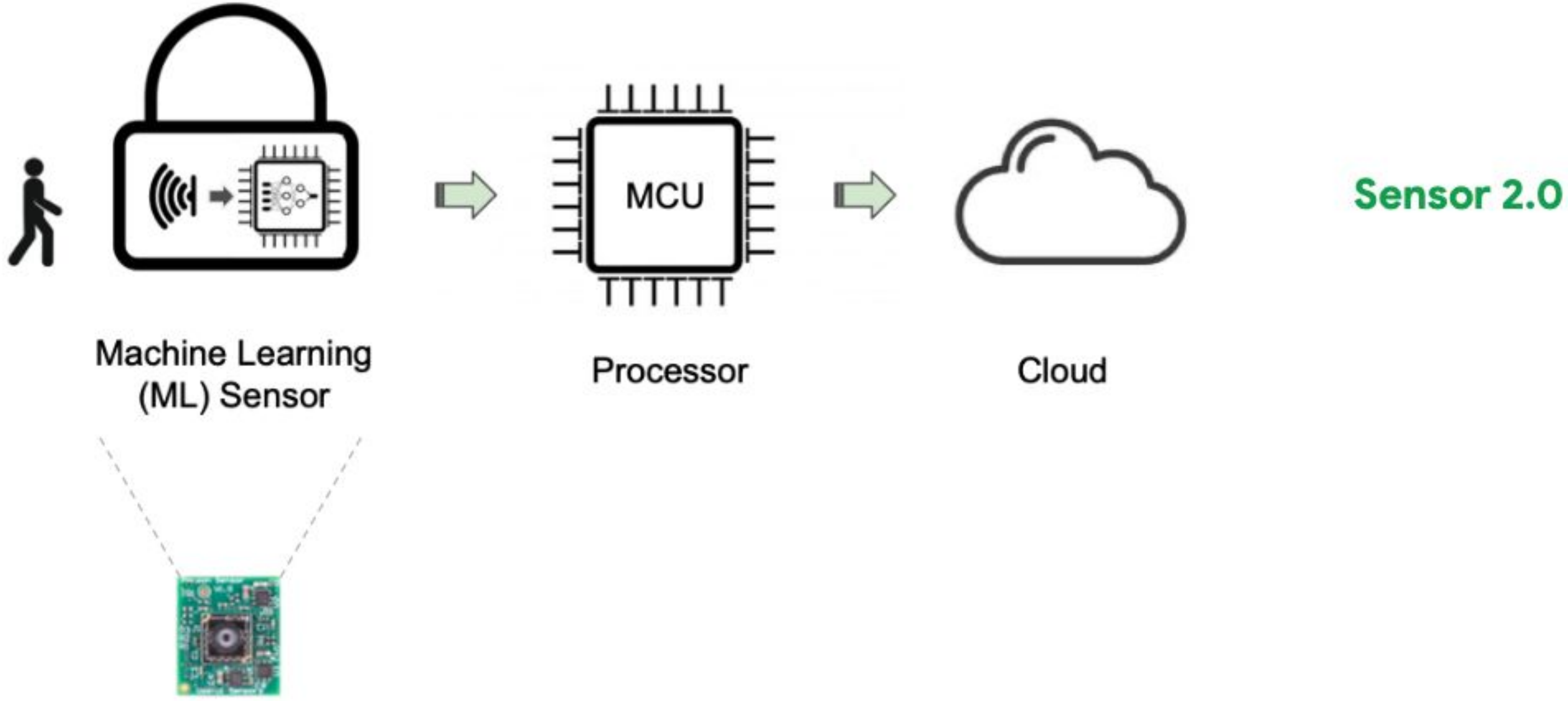
UNIFEI - Federal University of Itajuba, Brazil
TinyML4D Academic Network Co-Chair

The Future of the EdgeAI



Sensor 1.0


Physical
Sensor
Processor
Cloud


MCU
Machine Learning
(ML) Sensor
Processor
Cloud
Sensor 2.0

useful sensors

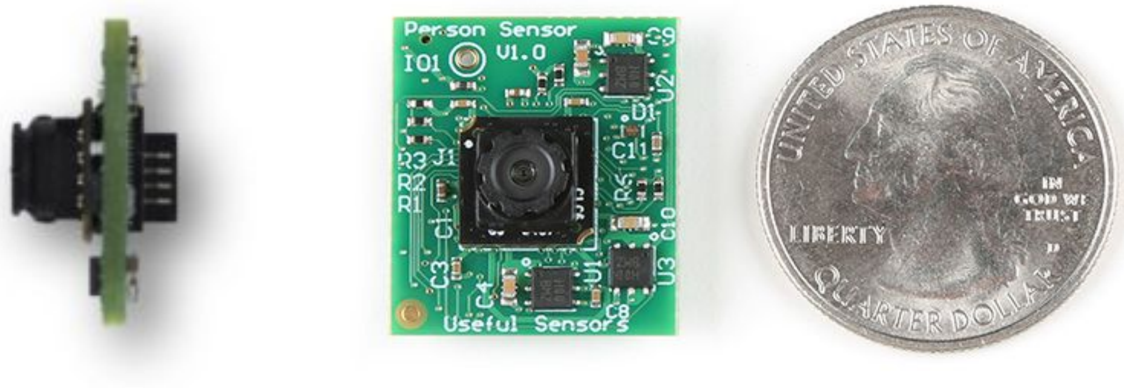
Person detector

Gaze sensor

Voice command

Text recognizer

...

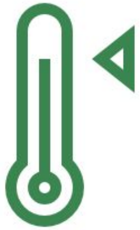


The Person Sensor has built in facial recognition and determines how many people there are, as well as their relative position.

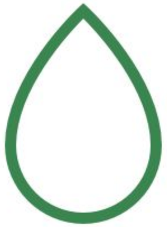
[USD 10 -> https://www.sparkfun.com/products/21231](https://www.sparkfun.com/products/21231)

Bosch BME688 - Environmental sensing with AI

Relative humidity barometric pressure



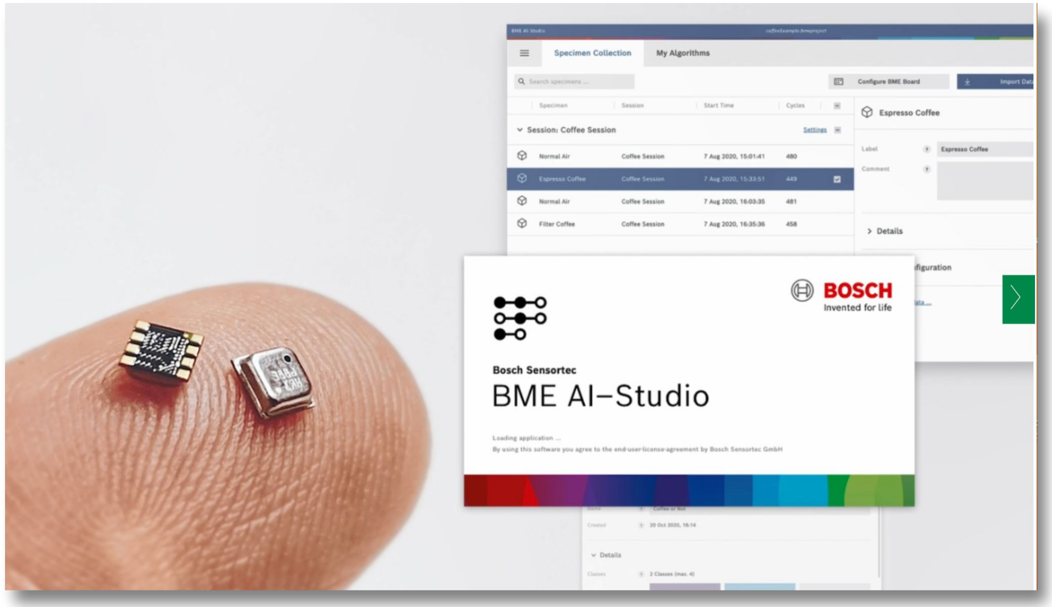
Excellent temperature stability



Humidity

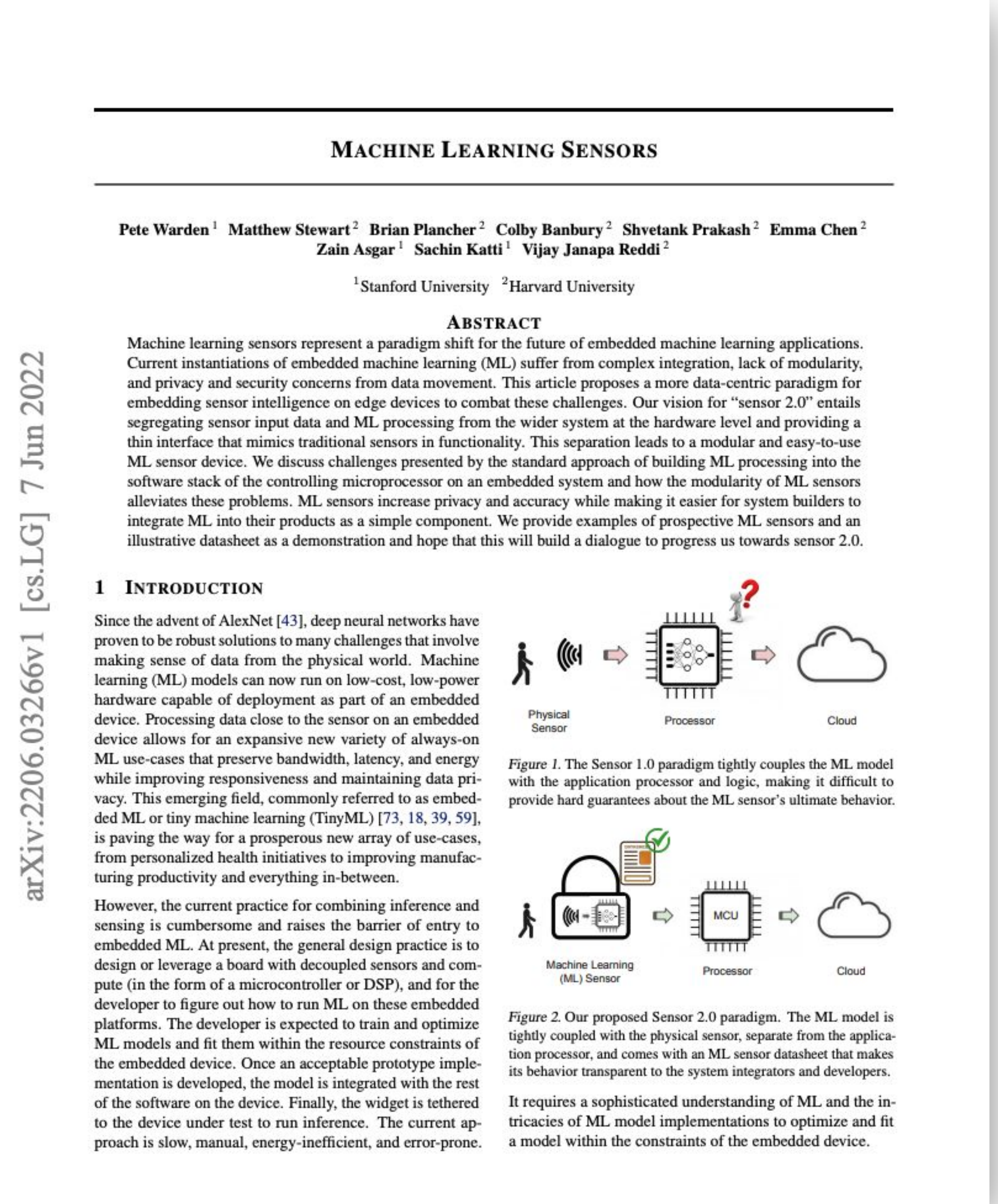
Gas sensing

https://www.bosch-sensortec.com/products/environmental-sensors/gas-sensors/bme688/



mlsensors.org

https://github.com/harvard-edge/ML-Sensors



arXiv:2206.03266v1 [cs.LG] 7 Jun 2022

Machine Learning Sensors

Pete Warden [1] Matthew Stewart [2] Brian Plancher [2] Colby Banbury [2] Shvetank Prakash [2] Emma Chen [2] Zain Asgar [1] Sachin Katti [1] Vijay Janapa Reddi [2]

[1] Stanford University [2] Harvard University

Abstract

Machine learning sensors represent a paradigm shift for the future of embedded machine learning applications. Current instantiations of embedded machine learning (ML) suffer from complex integration, lack of modularity, and privacy and security concerns from data movement. This article proposes a more data-centric paradigm for embedding sensor intelligence on edge devices to combat these challenges. Our vision for "sensor 2.0" entails segregating sensor input data and ML processing from the wider system at the hardware level and providing a thin interface that mimics traditional sensors in functionality. This separation leads to a modular and easy-to-use ML sensor device. We discuss challenges presented by the standard approach of building ML processing into the software stack of the controlling microprocessor on an embedded system and how the modularity of ML sensors alleviates these problems. ML sensors increase privacy and accuracy while making it easier for system builders to integrate ML into their products as a simple component. We provide examples of prospective ML sensors and an illustrative datasheet as a demonstration and hope that this will build a dialogue to progress us towards sensor 2.0.

1 Introduction

Since the advent of AlexNet [43], deep neural networks have proven to be robust solutions to many challenges that involve making sense of data from the physical world. Machine learning (ML) models can now run on low-cost, low-power hardware capable of deployment as part of an embedded device. Processing data close to the sensor on an embedded device allows for an expansive new variety of always-on ML use-cases that preserve bandwidth, latency, and energy while improving responsiveness and maintaining data privacy. This emerging field, commonly referred to as embedded ML or tiny machine learning (TinyML) [73, 18, 39, 59], is paving the way for a prosperous new array of use-cases, from personalized health initiatives to improving manufacturing productivity and everything in-between.

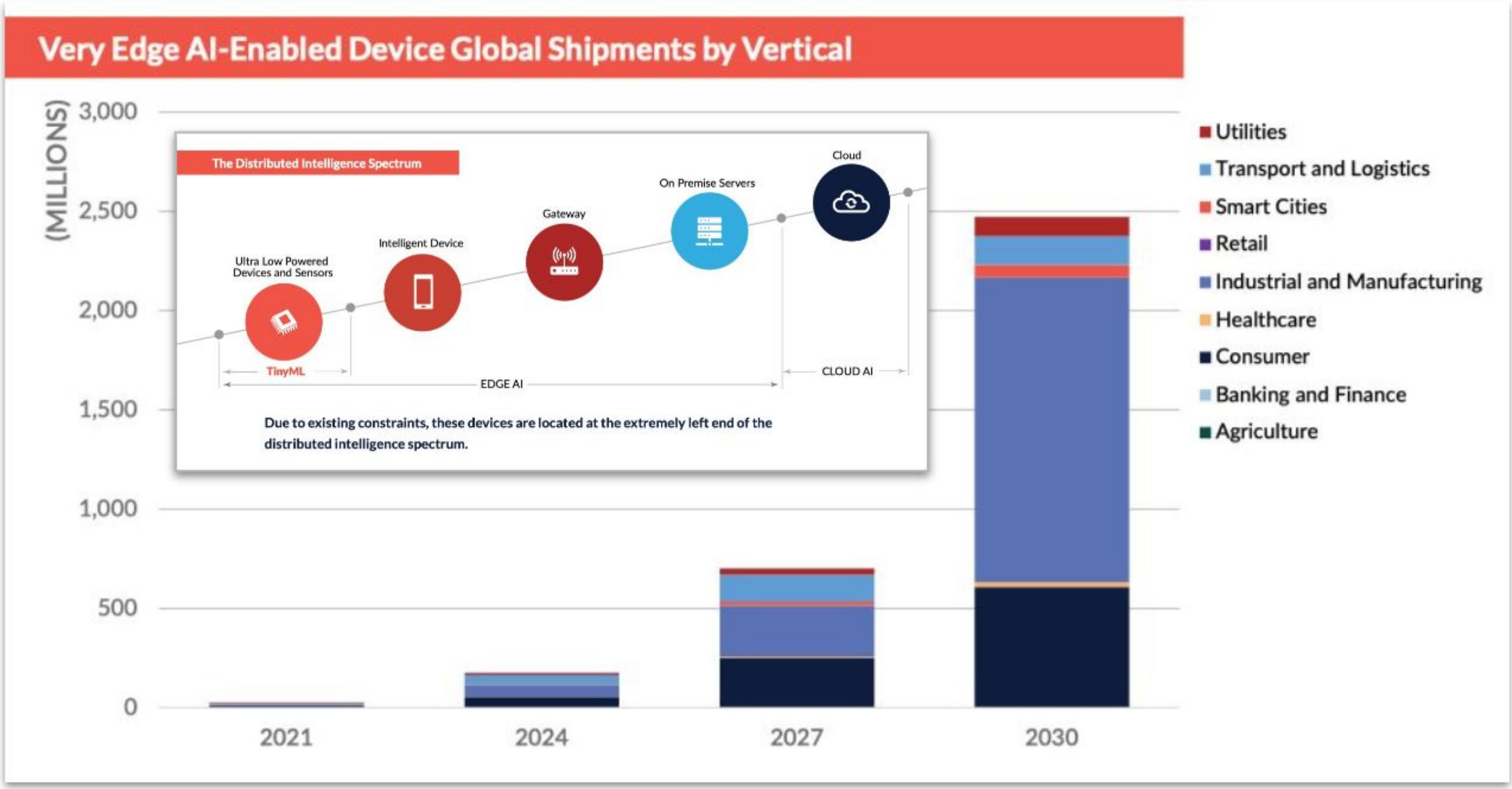
However, the current practice for combining inference and sensing is cumbersome and raises the barrier of entry to embedded ML. At present, the general design practice is to design or leverage a board with decoupled sensors and compute (in the form of a microcontroller or DSP), and for the developer to figure out how to run ML on these embedded platforms. The developer is expected to train and optimize ML models and fit them within the resource constraints of the embedded device. Once an acceptable prototype implementation is developed, the model is integrated with the rest of the software on the device. Finally, the widget is tethered to the device under test to run inference. The current approach is slow, manual, energy-inefficient, and error-prone.

Figure 1. The Sensor 1.0 paradigm tightly couples the ML model with the application processor and logic, making it difficult to provide hard guarantees about the ML sensor's ultimate behavior.

Figure 2. Our proposed Sensor 2.0 paradigm. The ML model is tightly coupled with the physical sensor, separate from the application processor, and comes with an ML sensor datasheet that makes its behavior transparent to the system integrators and developers.

It requires a sophisticated understanding of ML and the intricacies of ML model implementations to optimize and fit a model within the constraints of the embedded device.

Massive Potential for Impact



Source: ABI Research: TinyML

Edge AI has a very high impact potential, and it is for now!

Conclusion

The Future of ML is Tiny and Bright

***Vijay Janapa Reddi**, Ph. D. | Associate Professor |*
John A. Paulson School of Engineering and Applied Sciences | Harvard University |

Responsible AI

Suzan Kennedy, Ph.D.

Santa Clara University

[SciTinyML Seminar - Slides]

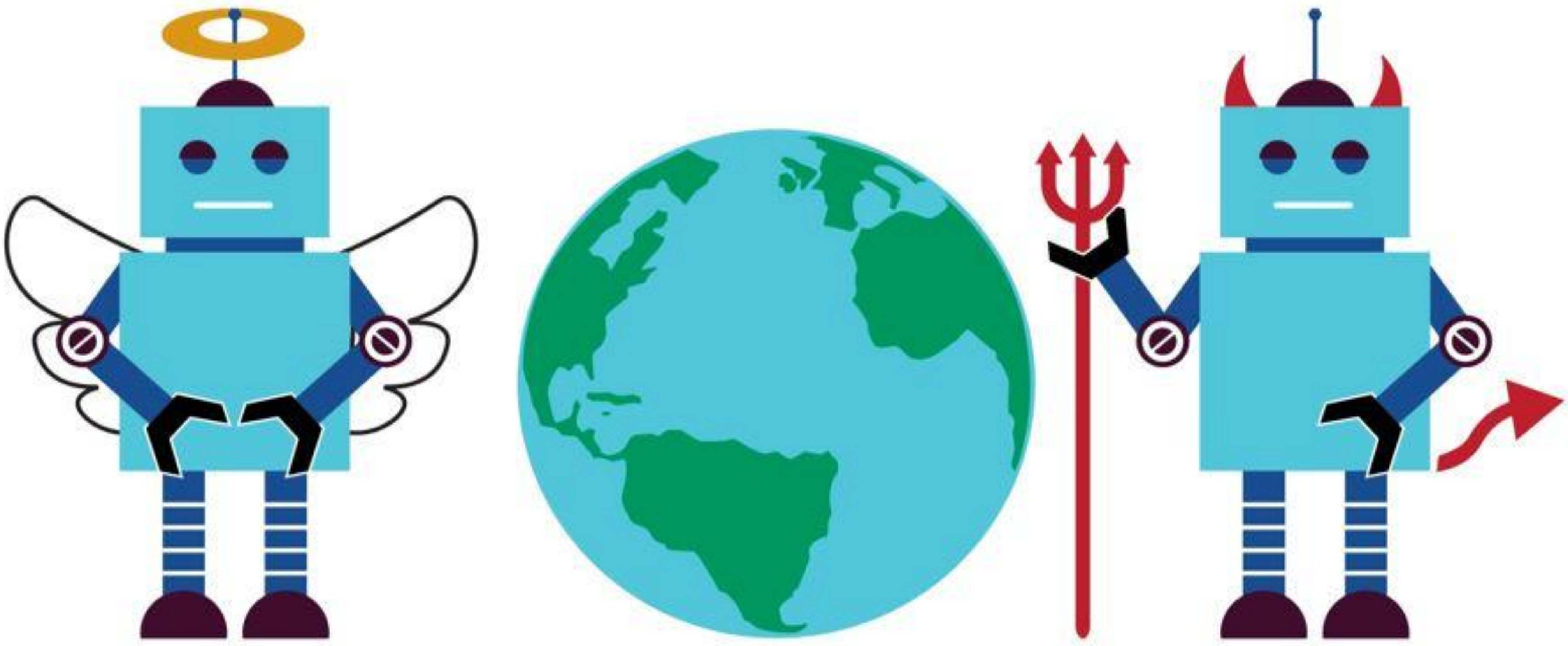
[SciTinyML Seminar - Video]

SciTinyML

Scientific Use of Machine Learning on Low-Power Devices

October 18-22 2021

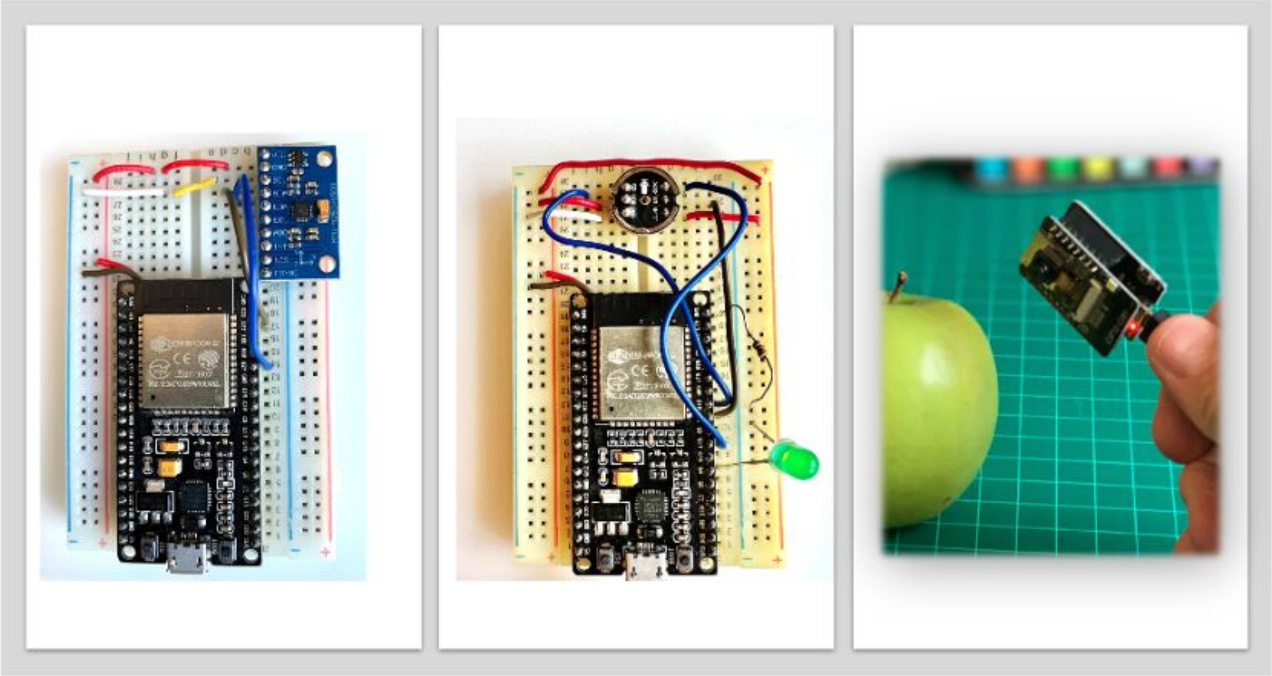
Responsible AI



To learn more …

ESP32-TinyML

Exploring TinyML with ESP32 MCUs.



Seeed-XIAO-BLE-Sense

KWS, Anomaly Detection & Motion Classification and Micropython - Exploring the Seeed XIAO BLE Sense.

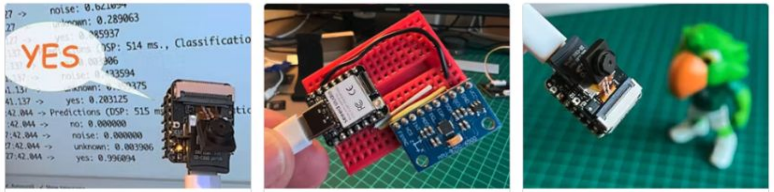
Programming Tiny devices with MicroPython. The easiest way!
MJRoBot (Marcelo Rovai)

Sensor DataLogger
MJRoBot (Marcelo Rovai)

TinyML Made Easy: Anomaly Detection & Motion Classification
MJRoBot (Marcelo Rovai)

TinyML Made Easy: Sound Classification (KWS)
MJRoBot (Marcelo Rovai)

XIAO-ESP32S3-Sense



TinyML Made Easy: KeyWord Spotting (KWS)
MJRoBot (Marcelo Rovai)

Exploring Machine Learning with the new XIAO ESP32S3
MJRoBot (Marcelo Rovai)

TinyML Made Easy: Image Classification
MJRoBot (Marcelo Rovai)

To learn more …

- IESTI01 TinyML - Machine Learning for Embedding Devices (Videos: Pt)
- WALC 22 – Applied AI - TinyML (Videos in Spanish)
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- "Deep Learning with Python" book by François Chollet
- "TinyML" book by Pete Warden, Daniel Situnayake
- "TinyML Cookbook" by Gian Marco Iodice
- "AI at the Edge" book by Daniel Situnayake, Jenny Plunkett
- “MACHINE LEARNING SYSTEMS for TinyML” Collaborative effort
- Edge Impulse Expert Network

TinyML4D **Show&Tell** Presentations

Date	Thread	Video
August 31st, 2023	TBD	Video here when ready
May 25th, 2023	Thread here	Video here when ready
April 20th, 2023	Thread here	https://youtu.be/uoM_IjXjDFY
March 30th, 2023	thread here	https://youtu.be/UQ0l-SwBwUY
February 23rd, 2023	thread here	https://youtu.be/BAEdil7X68Y
January 26th, 2023	thread here 17	https://youtu.be/-0xRZ-5UYUc 9
December 1st, 2022	thread here 2	https://youtu.be/e49pkjnIMlQ 8
October 27th, 2022	thread here 2	https://youtu.be/s8_hKpOWUwY 1

TinymML4D Academic Network Show and Tell Main Index.

The TinyML4D Academic Network Students should use this form to sign up for the latest presentations.
https://forms.gle/ic52HZMqVv4pBrkP7 2

The Show and Tell are typically held at 2 pm UTC on the last Thursday of each month and will take place in this Zoom room.
https://zoom.us/j/95229860797 1
Meeting ID: 952 2986 0797
Passcode: 141278

Projects by Students (UNIFEI – IESTI01)

- **Sound:**
  - Earthquake detection
  - Covid Detection (cough)
  - Key Detection
  - Pulmonary Disease
  - Snore Detection
  - Bionic Hand Control
- **Image:**
  - Mask Detection
  - Forest Fire Detection
  - Helmet Detection
  - Water Consumption (hydrometer)
  - Sign Language
  - Coffee Disease Classification
  - Bee Counting
- **Other Sensors:**
  - Bionic Hand – Finger Detection
  - Electric Charges
  - ECG – Fibrial Atrilation detection
- **Vibration:**
  - Personal Trainer
  - Bearing – Anomaly Detection

UNIFEI IESTI01 2021.1 – Final Projects   UNIFEI IESTI01 2021.2 – Final Projects   UNIFEI IESTI01 2022.1 – Final Projects

Thanks

TINYML4D