TinyML4D

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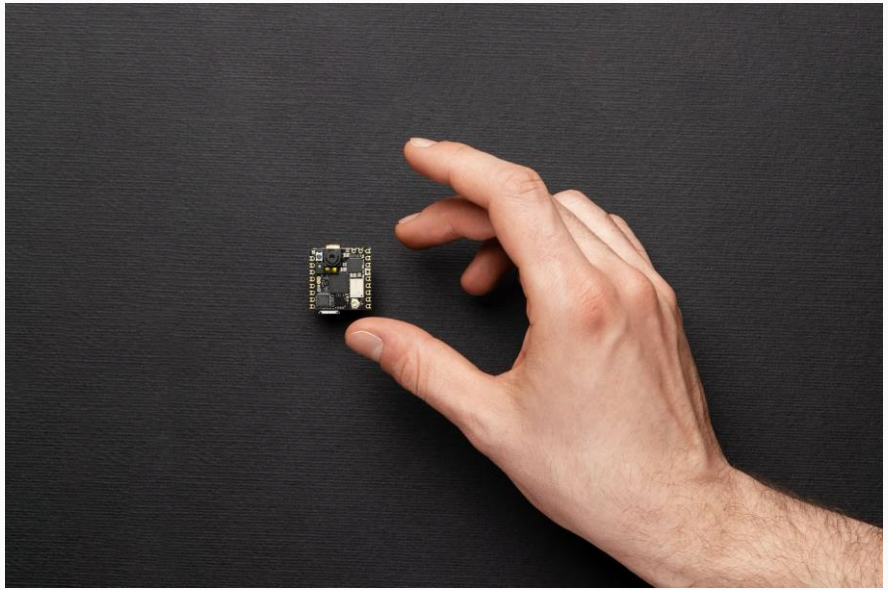
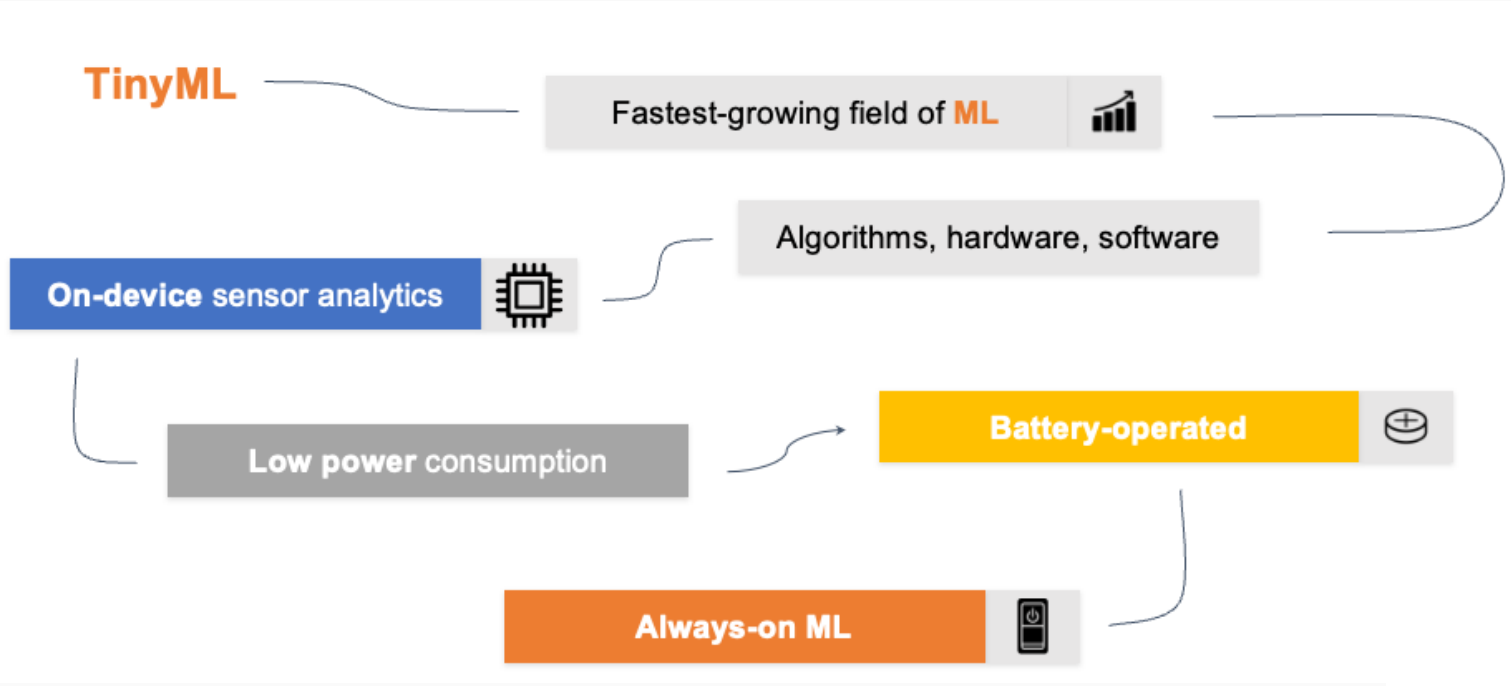
What is TinyML



What is TinyML



Orders of Magnitude

250 Billion
MCUs today

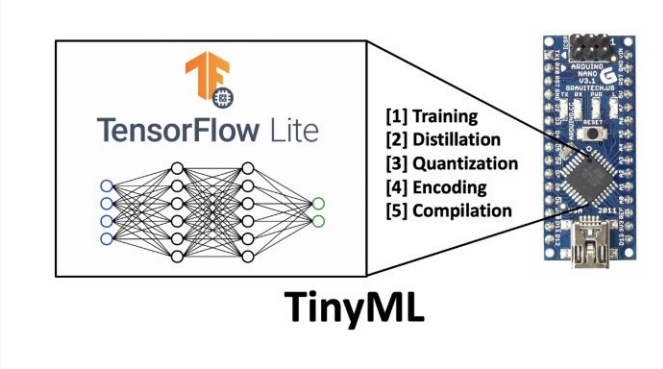
	Microprocessor	>	Microcontroller
Platform			
Compute	1GHz–4GHz	~10X	1MHz–400MHz
Memory	512MB–64GB	~10000X	2KB–512KB
Storage	64GB–4TB	~100000X	32KB–2MB
Power	30W–100W	~1000X	150µW–23.5mW

TinyML optimizations… How?

Problem: Less Compute Power, Less Memory, High Accuracy

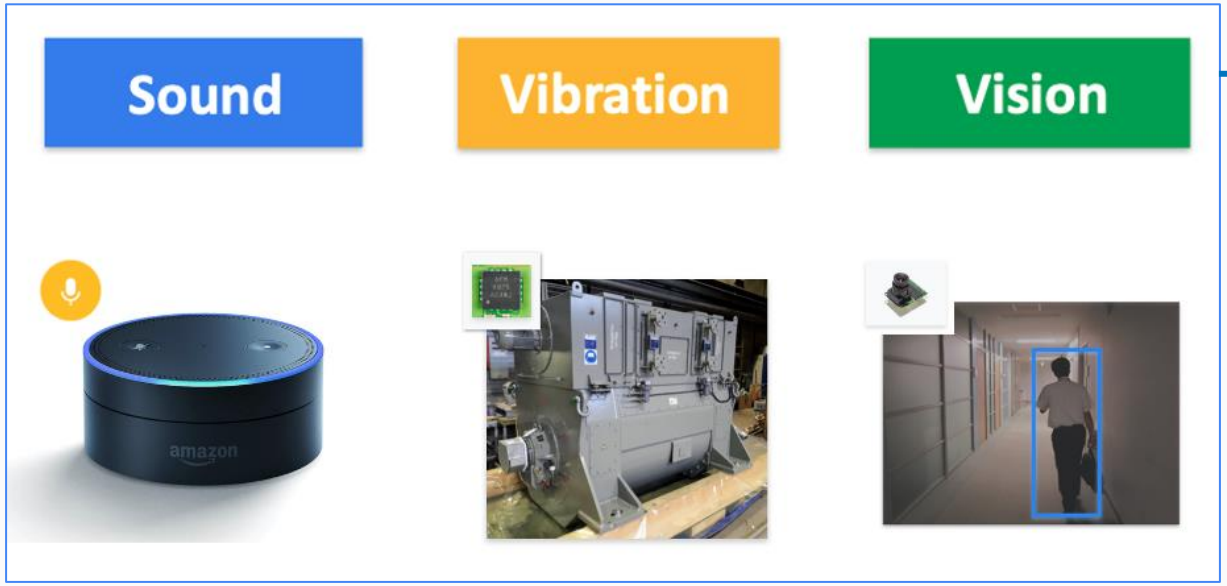
Some optimizations: Quantization and Pruning

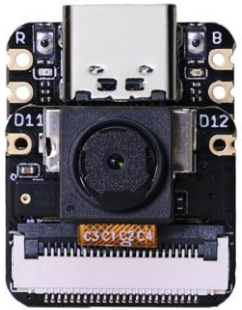
..and Separable Convolutions, Knowledge Distillation



TinyML is already here!

TinyML applications





TinyML applications: sound

Classifying mosquito wingbeat sound using TinyML

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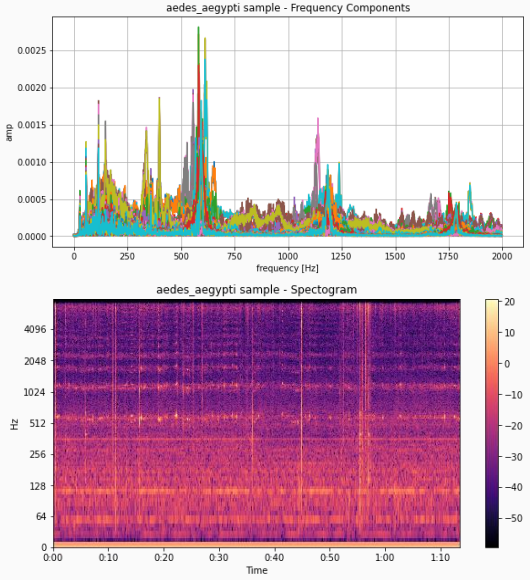
ABSTRACT

Every year more than one billion people are infected and more than one million people die from vector-borne diseases including malaria, dengue, zika and chikungunya. Mosquitoes are the best known disease vector and are geographically spread worldwide. It is important to raise awareness of mosquito proliferation by monitoring their incidence, especially in poor regions. Acoustic detection of mosquitoes has been studied for long and ML can be used to automatically identify mosquito species by their wingbeat. We present a prototype solution based on an openly available dataset, on the Edge Impulse platform and on three commercially-available TinyML devices. The proposed solution is low-power, low-cost and can run without human intervention in resource-constrained areas. This insect monitoring system can reach a global scale.

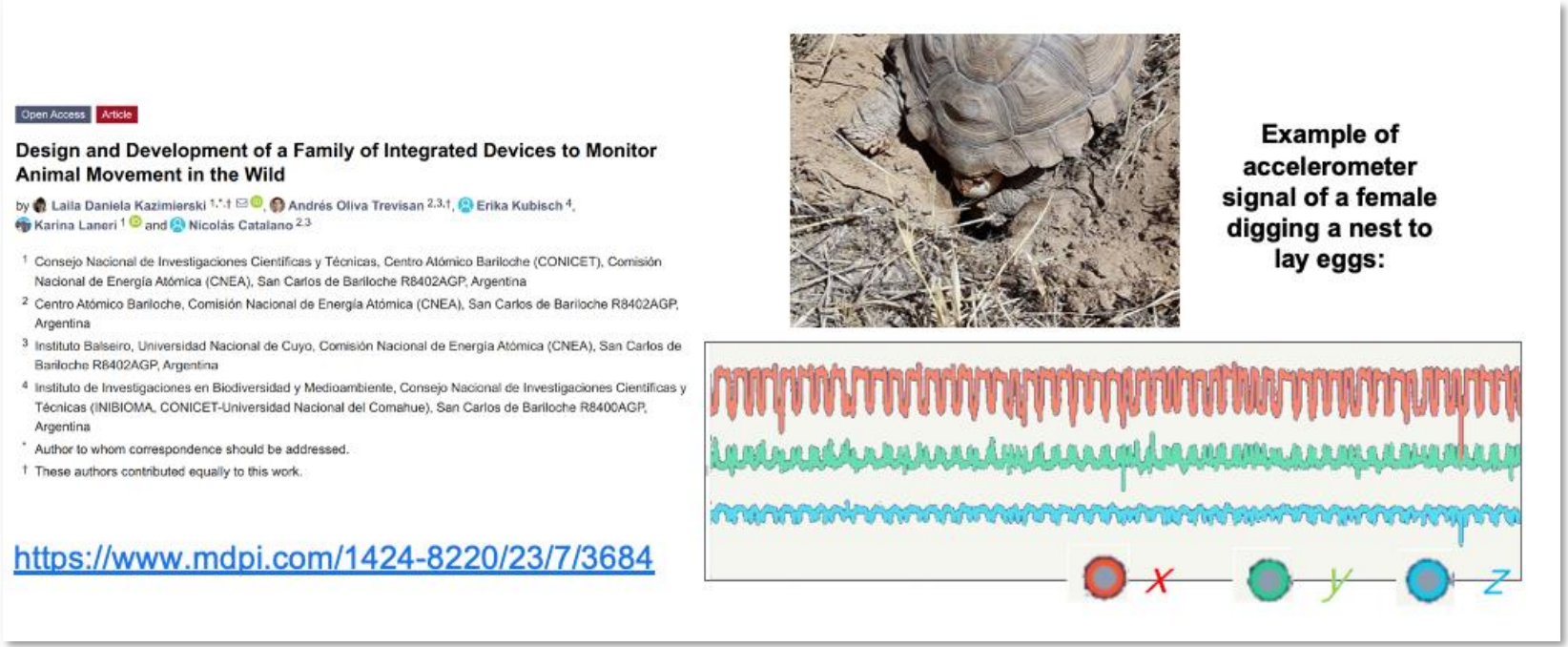
affected. People from poor communities with little access to health care and clean water sources are also at risk. Although anti-malarial drugs exist, there's currently no malaria vaccine.

Vector-borne diseases also exacerbate poverty. Illness prevent people from working and supporting themselves and their families, impeding economic development. Countries with intensive malaria have much lower income levels than those that don't have malaria.

Countries affected by malaria turn to control rather than eradication. Vector control means decreasing contact between humans and disease carriers on an area-by-area basis. It is therefore crucial to be able to detect the presence of mosquitoes in a specific area. This paper presents an approach based on TinyML and on low power embedded devices.



TinyML applications: vibration



Open Access Article

Design and Development of a Family of Integrated Devices to Monitor Animal Movement in the Wild

by Laila Daniela Kazimierski [1,*,†], Andrés Oliva Trevisan [2,3,†], Erika Kubisch [4], Karina Laneri [1] and Nicolás Catalano [2,3]

[1] Consejo Nacional de Investigaciones Científicas y Técnicas, Centro Atómico Bariloche (CONICET), Comisión Nacional de Energía Atómica (CNEA), San Carlos de Bariloche R8402AGP, Argentina
[2] Centro Atómico Bariloche, Comisión Nacional de Energía Atómica (CNEA), San Carlos de Bariloche R8402AGP, Argentina
[3] Instituto Balseiro, Universidad Nacional de Cuyo, Comisión Nacional de Energía Atómica (CNEA), San Carlos de Bariloche R8402AGP, Argentina
[4] Instituto de Investigaciones en Biodiversidad y Medioambiente, Consejo Nacional de Investigaciones Científicas y Técnicas (INIBIOMA, CONICET-Universidad Nacional del Comahue), San Carlos de Bariloche R8400AGP, Argentina
* Author to whom correspondence should be addressed.
† These authors contributed equally to this work.

https://www.mdpi.com/1424-8220/23/7/3684

Example of accelerometer signal of a female digging a nest to lay eggs:

TinyML applications: vision

TinyML: why?

5 Quintillion

bytes of data produced every day by IoT

<1%

of unstructured data is analyzed or used at all

Source: Harvard Business Review, What's Your Data Strategy?, April 18, 2017
Cisco, Internet of Things (IoT) Data Continues to Explode Exponentially. Who Is Using That Data and How?, Feb 5, 2018

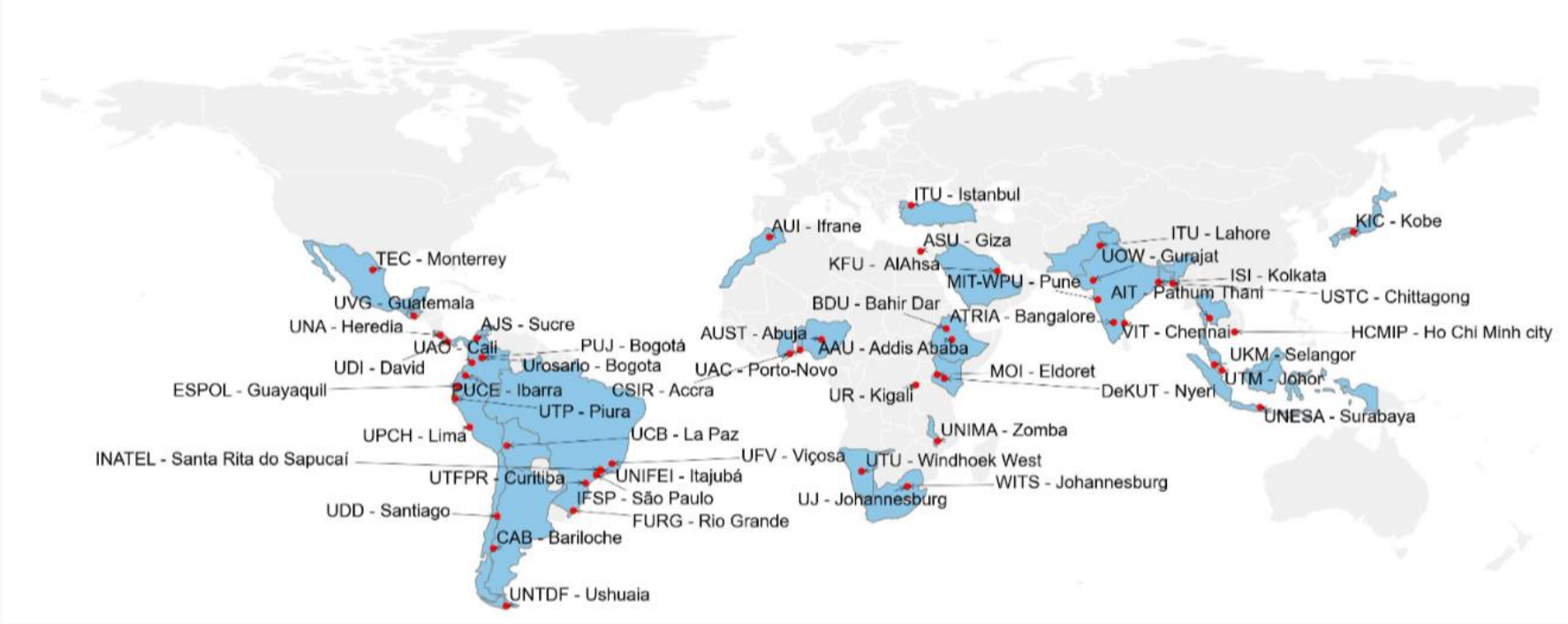
TinyML4D

ICT4D researchers claim that there are four technological requirements for an ICT4D project to be successful:

- **Autonomous Connectivity** ✔
- **Low-cost equipment** ✔
- **Power resilience** ✔
- **Appropriate User Interface** ✔

Brewer, Eric, et al. "The case for technology in developing regions." *Computer* 38.6 (2005): 25-38.

TinyML4D Academic Network - May 2025



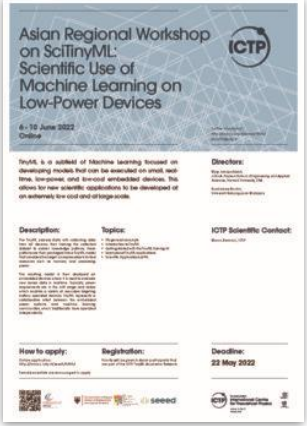
The Abdus Salam International Centre for Theoretical Physics

Harvard John A. Paulson School of Engineering and Applied Sciences

EDGE IMPULSE

ARDUINO

seeed studio



More than 2000 people trained!

Timothy Kudzanayi Kuhamba

Thanx Marisa[a*], Munyaradzi Munochiveyi[a*], Wadzanai Julius Zondai[a*], Ramson Munyaradzi Nyamukondiwa[a] , Isheanesu Newengo[b]

Case Study Zimbabwe

A DEEP LEARNING BASED APPROACH FOR FOOT AND MOUTH DISEASE DETECTION

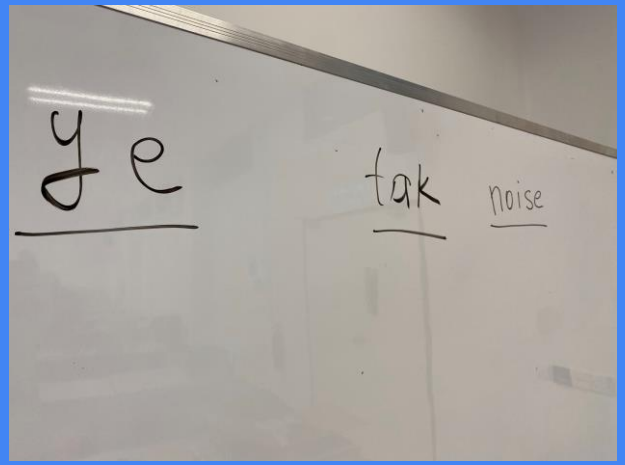
VEGETABLE DISEASE AND INSECT PEST RECOGNITION BASED ON TINYML:
Cotton Case in Benin

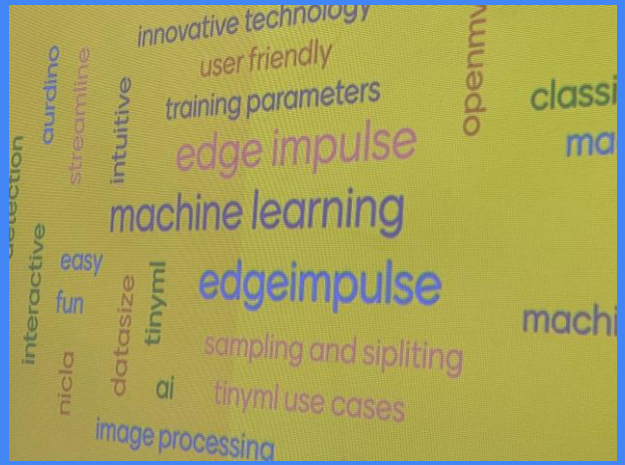
James O. ADEOLA
IMSP - UAC

Dr Marco Zenaro
ICTP Italy

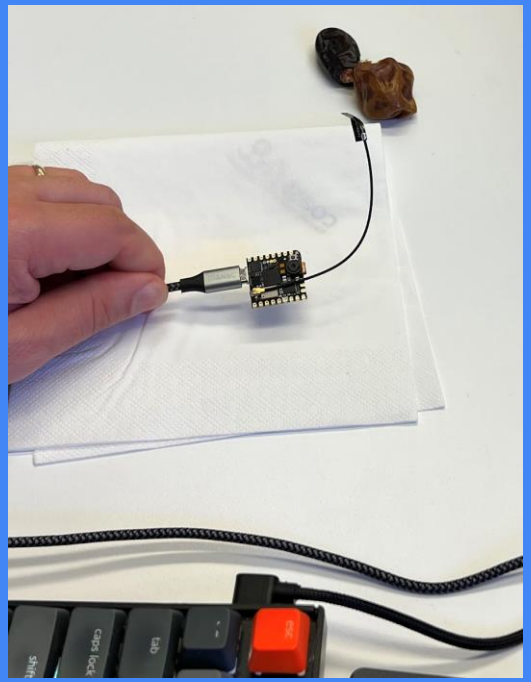
Dr Jules DEGILA
IMSP Benin

Malaysia 2023



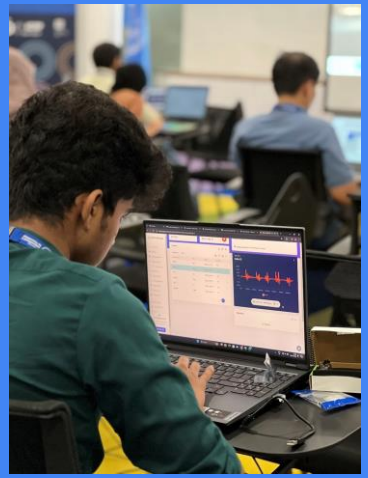


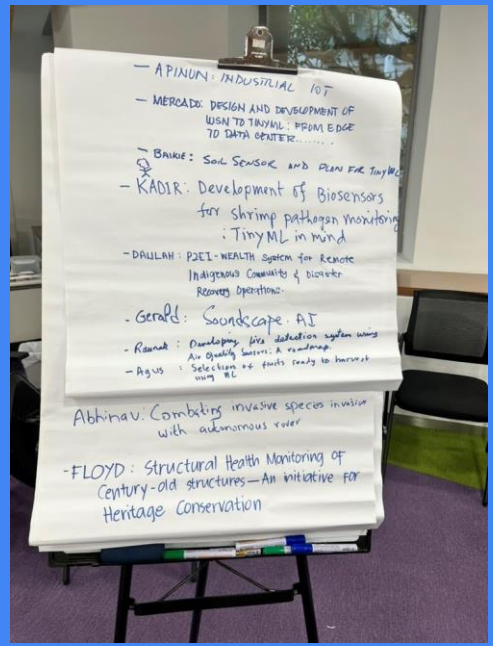

إتالة @talakutt · Mar 6
اليوم المنتظر قرب
ويكرا عرض مشاريع الـTinyML
بالرغم من العواقب بالطريق الا اني فخورة بالنتيجة وسعيده باللي وصلت له
دعواتكم للكل بالتوفيق
KEYWORD-SPOTTING SYSTEM FOR VIDEO GAMES
START
DESCRIBE THE IDEA



KAUST 2023

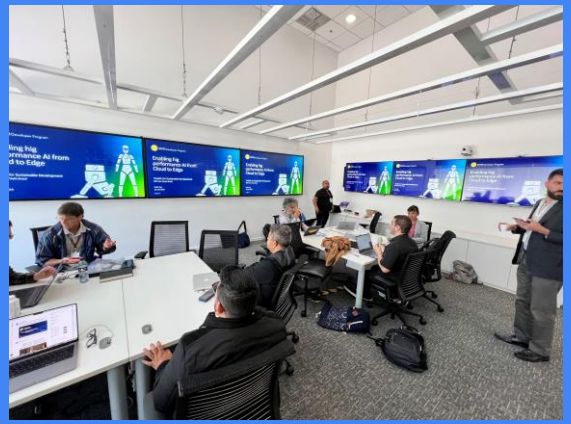
Macau 2024




— APINUN: INDUSTRIAL IOT
— MERCADO: DESIGN AND DEVELOPMENT OF WSN TO TINYML: FROM EDGE TO DATA CENTER.....
— BAIKIE: SOIL SENSOR AND PLAN FOR TinyML
— KADIR: Development of Biosensors for Shrimp pathogen monitoring : TinyML in mind
- DAULAH: PJEI- WEALTH System for Remote Indigenous Community & Disaster Recovery Operations
- Gerald: Soundscape AI
- Ramah: Developing fire detection system using Air Quality Sensors: A roadmap
- Agus: Selection of fruits ready to harvest using ML
Abhinav: Combating invasive species invasion with autonomous rover
-FLOYD: Structural Health Monitoring of Century-old structures—An initiative for Heritage Conservation


Where we are so far
(AND)
// elbows above shoulders
// wrists above elbows
// wrists above head
// wrists closer than elbows
// wrists very close or overlapping

Brazil 2024

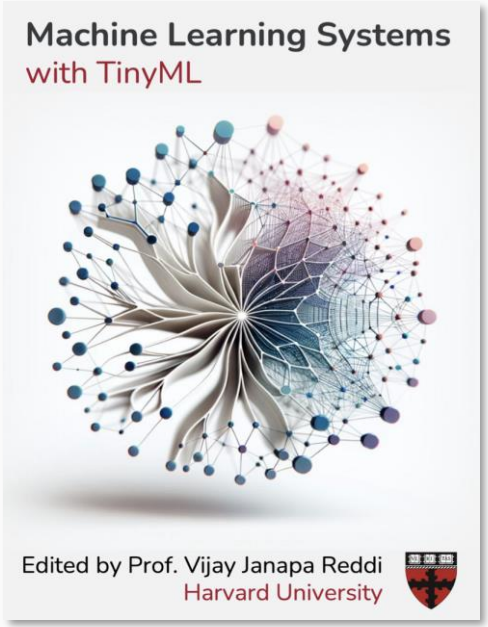



TinyML in Space
José Antonio Bagur Nájera


HASTA
LA VISTA,
BABY
ARDUINOPRO

Malawi 2025

Learning and Teaching



https://github.com/harvard-edge/cs249r_book

TinyML4D on Science!

FEATURES

CUTTING AI DOWN TO SIZE

A $34 chip incorporating tinyML AI models, actual size shown

Many artificial intelligence models are power hungry and expensive. Researchers in the Global South are increasingly embracing low-cost, low-power alternatives

By **Sandeep Ravindran**

The small drone circles the cashew tree, its rotor arms splayed out from its compact body like a water strider's. As it rises, its camera captures a bird's-eye view of the foliage, which shades from a dark glossy green at the tree's bottom to a purplish green at the top. Meanwhile an artificial intelligence (AI) model built into the drone determines whether the leaves are diseased—based on telltale black or brown spotches—or healthy. If needed, the system can one day direct other drones toward individual sick plants to treat their disease with a spritz of pesticide.

This system is the handiwork of Bala Murugan, a computer scientist at the Vellore Institute of Technology in Chennai, India. Murugan comes from a family of cashew farmers, including his father and uncle. "They apply a lot of pesticides on the cashew," he says. "I wanted to build a so-

https://www.science.org/doi/epdf/10.1126/science.adw7713

UN Policy Briefs

Science-Policy Brief for the Multistakeholder Forum on Science, Technology and Innovation for the SDGs, May 2022

TinyML: Applied AI for Development

Marco Zennaro (ICTP/UNESCO), Brian Plancher (Harvard University), Vijay Janapa Reddi (Harvard University)

Abstract

Artificial intelligence (AI) will likely be an instrumental part of progress towards the United Nations' Sustainable Development Goals (SDGs). However, its adoption and impact are limited by the immense power consumption, strong connectivity requirements and high costs of cloud-based deployments. TinyML is a new technology that allows machine learning (ML) models to run on low-cost, low-power microcontrollers, circumventing many of these issues. We believe that TinyML has a significant role to play in achieving the SDGs and facilitating scientific research in areas such as environmental monitoring, physics of complex systems and energy management. To broaden access and participation and increase the impact of this new technology, we present an initiative that is creating and supporting a global network of academic institutions working on TinyML in developing countries. We suggest the development of additional open educational resources, South–South academic collaboration and pilot projects of at-scale TinyML solutions aimed at addressing the SDGs.

Challenges with Machine Learning in Developing Countries

Machine learning has a huge potential to tackle societal issues in diverse fields that include agriculture, conservation and healthcare. A recent study [1] highlights the influence of AI on all aspects of

main energy consumer component of an embedded system.

3. **Privacy:** Applications that send data from the point of collection to the cloud may leak private information as data must be transmitted over the internet.

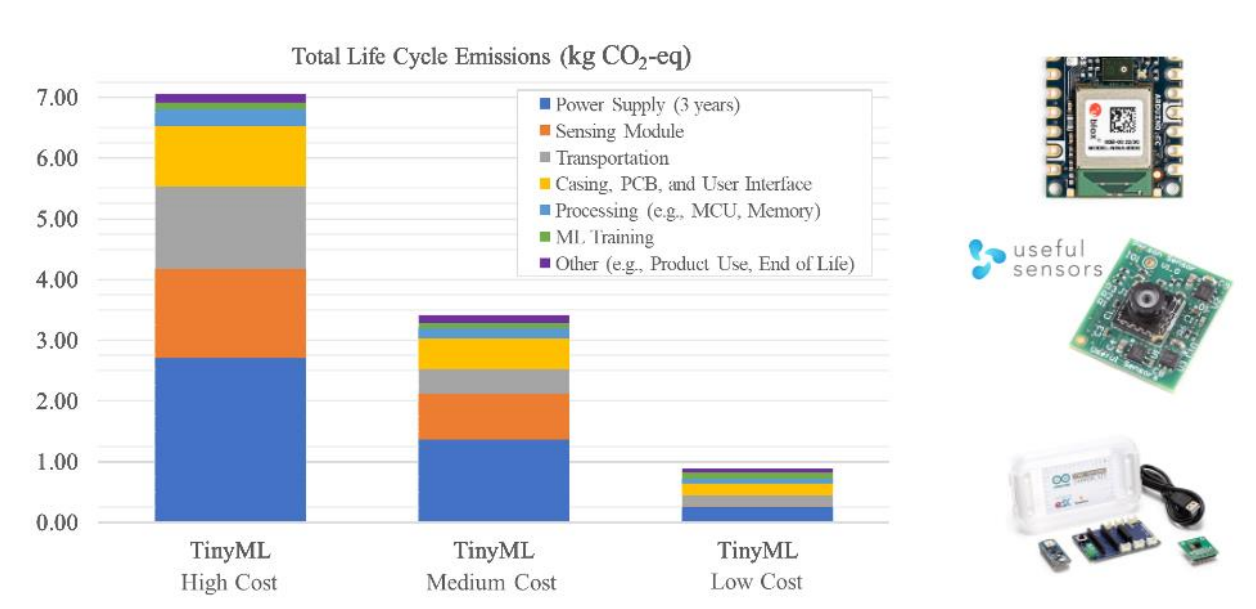
Bridging the Digital Divide: the Promising Impact of TinyML for Developing Countries

Marco Zennaro (ICTP/UNESCO), Brian Plancher (Barnard College, Columbia University), Vijay Janapa Reddi (Harvard University)

Abstract

The rise of TinyML has opened up new opportunities for the development of smart, low-power devices in resource-constrained environments. This technology has particular relevance for developing countries, where access to energy and computing resources is often limited. In light of this, a network of 40 universities has been established over the past two years with the goal of promoting the use of TinyML in developing regions. The members of this network have taught courses at their home institutions and have completed their first research projects covering topics ranging from the diagnosis of respiratory diseases in Rwanda to assistive technology development in Brazil, bee population monitoring in Kenya and estimating the lifespan of the date palm fruit in Saudi Arabia. These initial projects demonstrate the potential for TinyML to make a real impact on the Sustainable Development Goals. They hold great promise for a new generation of devices that could help to bridge the digital divide and bring the benefits of technology to those who need it most. Lastly, we suggest three policy recommendations to increase the future impact: first, training and research activities in STI should focus on regional networks; second, the ethics of artificial intelligence must be covered in all activities; and third, we need to support local champions better.

TinyML Sustainability



arxiv.org/abs/2301.11899

Thanks!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