


# Workshop on TinyML for Sustainable Development

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# Thanks!



**Bruno Flach**  
**Raquel Zarattini Chebabi**  
**Rodrigo Neumann Barros Ferreira**  
**The whole IBM Brazil team!**



**Harvard** John A. Paulson  
**School of Engineering**  
and Applied Sciences



# TinyML Academic Network

<http://tinymledu.org>

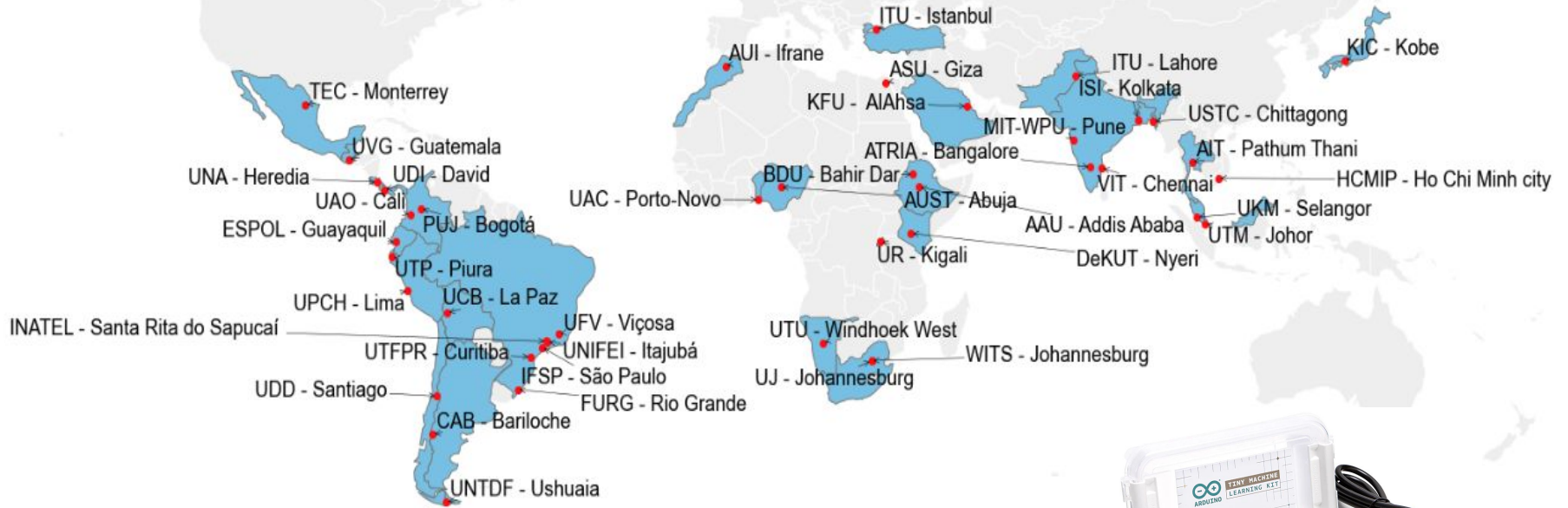


We aim to develop a **community** of researchers and practitioners focused on both **improving access** to TinyML education and enabling **innovative solutions** for the unique challenges faced by Developing Countries.

Joint workshops and seminars on TinyML

An online forum to consolidate the TinyML community

Open exchange of student projects, lesson plans, real-world deployments and outreach materials



# SciTinyML: Scientific Use of Machine Learning on Low-Power Devices

18 - 22 October 2021  
An ICFP Virtual Meeting  
Trieste, Italy

SciML enables machine learning technologies to perform on device analysis of sensor data or inferently use power. This allows for new scientific applications to be developed at an extremely low cost and at large scale.

In recent years, hardware advancements have made it possible for microcontrollers to perform calculations much faster. Improved hardware has made it easier for developers to build programs on these devices. Perhaps the most important benefit for scientists has been the rise of tiny machine learning or tinyML.

Between hardware advancements and the tinyML community's recent innovation in machine learning, it is now possible to run increasingly complex deep learning models directly on microcontrollers. tinyML represents a collaborative effort between the embedded power systems and machine learning communities, which traditionally have operated independently.

**Topics:**

- ML general concepts
- Scientific applications of ML
- Introduction to tinyML
- Examples of tinyML applications

**How to apply:**  
<https://www.eurocongress.com/2021/10/18-22-october-2021>

**Registration:**  
<https://www.eurocongress.com/2021/10/18-22-october-2021>

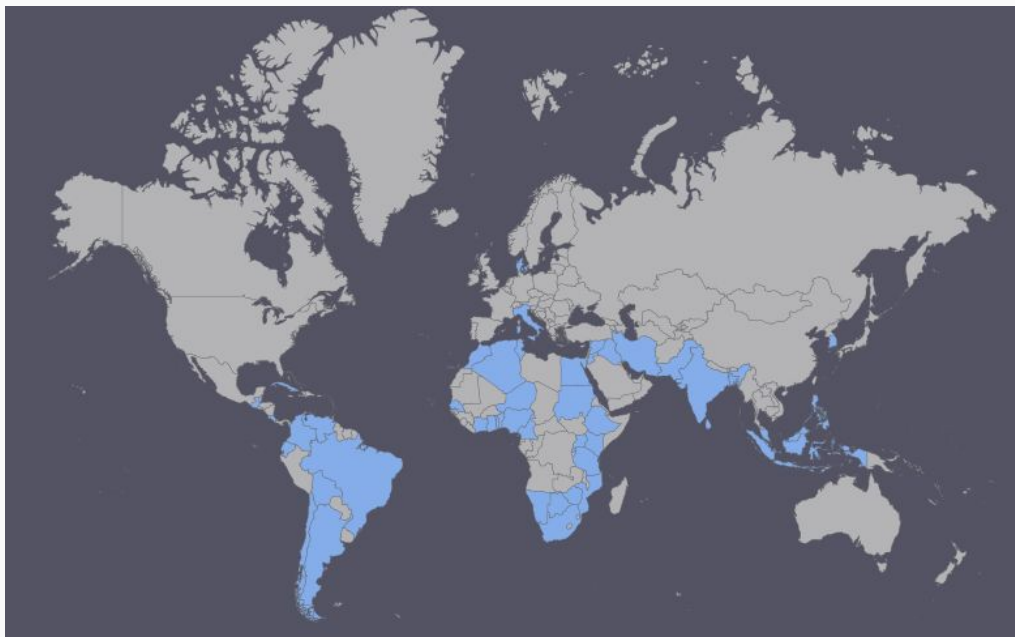












2021: 210 participants from  
48 countries

## African Regional Workshop on SciTinyML: Scientific Use of Machine Learning on Low-Power Devices

25 - 29 April 2022  
Online

TinyML is a subset of Machine Learning focused on developing models that can be executed on small, real-time, low-power, and low-cost embedded devices. This allows for new scientific applications to be developed at an extremely low cost and of large scale.

**Description:**  
The TinyML course will introduce participants to the field of Machine Learning on Low-Power Devices. The course will cover the fundamentals of Machine Learning on Low-Power Devices, including the hardware and software aspects of the field.

**Topics:**  

- Introduction to Machine Learning on Low-Power Devices
- Hardware and Software Aspects of Machine Learning on Low-Power Devices
- Applications of Machine Learning on Low-Power Devices

**How to apply:**  
[Apply here](#)

**Deadline:**  
15 April 2022

**Organized by:**  









2022: 187 participants  
29 African countries

## Asian Regional Workshop on SciTinyML: Scientific Use of Machine Learning on Low-Power Devices

6 - 10 June 2022  
Online

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**Description:**  
The TinyML course will introduce participants to the field of Machine Learning on Low-Power Devices. The course will cover the fundamentals of Machine Learning on Low-Power Devices, including the hardware and software aspects of the field.

**Topics:**  

- Introduction to Machine Learning on Low-Power Devices
- Hardware and Software Aspects of Machine Learning on Low-Power Devices
- Applications of Machine Learning on Low-Power Devices

**How to apply:**  
[Apply here](#)


**Registration:**  
[Register here](#)

**Deadline:**  
22 May 2022

**Organized by:**  









2022: 100 participants  
8 Asian countries

## Latin American Regional Workshop on SciTinyML: Scientific Use of Machine Learning on Low-Power Devices

11 - 15 July 2022  
An ICSTP Special Meeting  
Prague, Czechia

The workshop will be held in English (English only).

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**Description:**  
The TinyML course will introduce participants to the field of Machine Learning on Low-Power Devices. The course will cover the fundamentals of Machine Learning on Low-Power Devices, including the hardware and software aspects of the field.

**Topics:**  

- Introduction to Machine Learning on Low-Power Devices
- Hardware and Software Aspects of Machine Learning on Low-Power Devices
- Applications of Machine Learning on Low-Power Devices

**How to apply:**  
[Apply here](#)

**Registration:**  
[Register here](#)

**Deadline:**  
29 June 2022

**Organized by:**  









2022: 183 participants  
17 LatAm countries

# Workshop on Scientific Use of Machine Learning on Low-Power Devices: Applications and Advanced Topics

**17 - 21 April 2023**  
An ICTP Virtual Meeting  
Trieste, Italy

**Further Information:**  
<http://indico.ictp.org/event/13184/>  
www.ictp.int

**Directors:**  
G. FLAMIGLI, *Barnard College, USA*  
L. J. SHARPE, *Barnard University, USA*  
M. RIZZO, *Barnard University of Tripoli, BAH*

**Description:**  
ICTPP, researchers in collaborative effort between the embedded power systems and Machine Learning communities, which traditionally have operated independently. ICPTP has a significant role to play in achieving the SDGs and facilitating scientific research in areas such as environmental monitoring systems of complex systems and energy management.

**Local Organiser:**  
Dr. STEFANO, *ICTP, Italy*

**Topics:**

- Introduction to TinyML
- Getting Started with the TinyML Kit
- Examples of TinyML Applications
- The TinyML Development Workflow
- Scientific Applications of ML
- Special Research and Advanced Topics in TinyML

**Registration:**  
https://indico.ictp.org/event/13184/

**Deadline:**  
7 April 2023

Remote activities are encouraged to support:









2023: 418 participants  
from 72 countries



**ICTP-UNU Workshop on TinyML for Sustainable Development**  
 AN ICTP 60<sup>th</sup> ANNIVERSARY SATELLITE EVENT

**Description:**  
 TinyML is a new technology that allows machine learning models to run on low-cost, low-power microcontrollers. This technology has a significant role to play in achieving the Sustainable Development Goals (SDGs) and in facilitating scientific research in areas such as environmental monitoring and the physics of complex systems.

**DATE:** 25 - 30 April 2024  
**LOCATION:** Macau, SAR of China  
**Deadline:** 15 March 2024

**MORE DETAILS:**  
 The new TinyML technology offers opportunities for developing intelligent low-power devices in resource-constrained environments in recent years. TinyML has gained significant attention from researchers, developers, and industries due to its potential for enabling new applications in fields such as healthcare, agriculture, transportation, communication, and transportation. TinyML is a great educational tool as it employs topics from across the computer science and engineering curricula.

**THE TECHNOLOGY HAS A SIGNIFICANT ROLE TO PLAY IN ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS (SDGs) AND IN ENABLING NEW APPLICATIONS IN FIELDS SUCH AS HEALTHCARE, AGRICULTURE, TRANSPORTATION, MONITORING AND COMMUNICATION.**

**TOPICS:**

- Introduction to TinyML
- Sensor and Data Collection
- Energy Efficiency
- Environmental Monitoring
- Health Monitoring
- Agriculture Monitoring
- Smart Cities
- Ethical and Machine Learning

**GRANTS:**  
 A limited number of grants are available to support the attendance of participants from developing countries. Please see the application form.

**DIRECTORS:**  
 L. DI LUCA (ICTP) and S. CHEN (UNU) will be the main contacts for this event.

**ICTP SCIENTIFIC CONTACT:**  
 S. CHEN (UNU)

**FURTHER INFORMATION:**  
 Email: [unu2024@ictp.itp](mailto:unu2024@ictp.itp)  
 Web: <https://indico.ictp.it/event/11946/>  
 Female scientists are encouraged to apply.

**REGISTRATION:**  
 There is no registration fee.

**SPONSORS:**  
 UNU Macau, seed studio, BARNARD, IBM, UNIFEI

Macau  
April 2024



**Workshop on Machine Learning on Low-Power Devices: Applications and Advanced Topics**

**Description:**  
 TinyML empowers machine learning technologies to conduct on-device analytics of sensor data with remarkably low power consumption. This opens the door for the development of novel applications at an exceptionally affordable cost and on a large scale.

**DATE:** 6 - 10 May 2024  
**LOCATION:** Online  
**Deadline:** 26 April 2024

**MORE DETAILS:**  
 The emergence of TinyML has created new possibilities for building smart, ultra-low-power devices that fit into resource-limited settings. In these past, TinyML has attracted significant interest from researchers, developers, and industries for its potential to enable new applications in healthcare, agriculture, transportation, communication, smart homes, and more. TinyML technology has the potential to enable machine learning models to be deployed on low-cost, low-power microcontrollers, opening up new possibilities for scientific research and applications in resource-constrained environments.

**THE TECHNOLOGY HAS A SIGNIFICANT ROLE TO PLAY IN ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS (SDGs) AND IN ENABLING NEW APPLICATIONS IN FIELDS SUCH AS HEALTHCARE, AGRICULTURE, TRANSPORTATION, MONITORING AND COMMUNICATION.**

**TOPICS:**

- Introduction to TinyML
- The TinyML Development Workflow
- TinyML Applications
- Scientific Applications of ML
- Recent Research and Advanced Topics in TinyML

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 A limited number of grants are available to support the attendance of participants from developing countries. Please see the application form.

**DIRECTORS:**  
 S. CHEN (UNU) and L. DI LUCA (ICTP) will be the main contacts for this event.

**LOCAL ORGANISER:**  
 S. CHEN (UNU)

**FURTHER INFORMATION:**  
 Email: [unu2024@ictp.itp](mailto:unu2024@ictp.itp)  
 Web: <https://indico.ictp.it/event/11946/>  
 Female scientists are encouraged to apply.

**REGISTRATION:**  
 There is no registration fee.

**SPONSORS:**  
 BARNARD, IBM, UNIFEI

Online,  
May 2024



**Workshop on TinyML for Sustainable Development**

**Description:**  
 TinyML enables machine learning on low-power microcontrollers, allowing access to performance at an incredibly resource-constrained settings. This revolutionary technology unlocks new possibilities for sustainable development and scientific research by accessing available access to on-device intelligence worldwide.

**DATE:** 22 - 26 July 2024  
**LOCATION:** São Paulo, Brazil  
**Deadline:** 6 May 2024

**MORE DETAILS:**  
 The emergence of TinyML has created new possibilities for building smart, ultra-low-power devices that fit into resource-limited settings. In these past, TinyML has attracted significant interest from researchers, developers, and industries for its potential to enable new applications in healthcare, agriculture, transportation, communication, smart homes, and more. TinyML technology has the potential to enable machine learning models to be deployed on low-cost, low-power microcontrollers, opening up new possibilities for scientific research and applications in resource-constrained environments.

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**TOPICS:**

- Introduction to TinyML
- Sensor and Data Collection
- Energy Efficiency
- Environmental Monitoring
- Health Monitoring
- Agriculture Monitoring
- Smart Cities
- Ethics and TinyML

**GRANTS:**  
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**DIRECTORS:**  
 L. DI LUCA (ICTP) and S. CHEN (UNU) will be the main contacts for this event.

**ICTP SCIENTIFIC CONTACT:**  
 S. CHEN (UNU)

**FURTHER INFORMATION:**  
 Email: [unu2024@ictp.itp](mailto:unu2024@ictp.itp)  
 Web: <https://indico.ictp.it/event/11946/>  
 Female scientists are encouraged to apply.

**REGISTRATION:**  
 There is no registration fee.

**KEYNOTE SPEAKER:**  
 S. CHEN (UNU) will be the keynote speaker for this event.

**SPONSORS:**  
 BARNARD, IBM, UNIFEI

Brazil,  
July 2024



# Timothy Kudzanayi Kuhamba

Thanx Marisa<sup>a</sup>, Munyaradzi Munochiveyi<sup>a</sup>, Wadzanai Julius Zondai<sup>b</sup>, Ramson Munyaradzi Nyamukondiwa<sup>a</sup>, Isheanesu Newengo<sup>b</sup>

## Case Study Zimbabwe

A DEEP LEARNING BASED APPROACH FOR FOOT AND MOUTH DISEASE DETECTION



AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

UNIVERSITY OF ZIMBABWE

THE WORLD BANK

# TinyML Based Self Diagnostic Kit for Respiratory Diseases

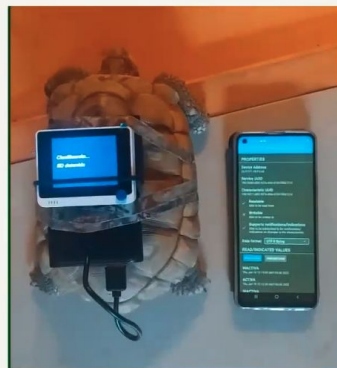
Samson Otieno Ooko

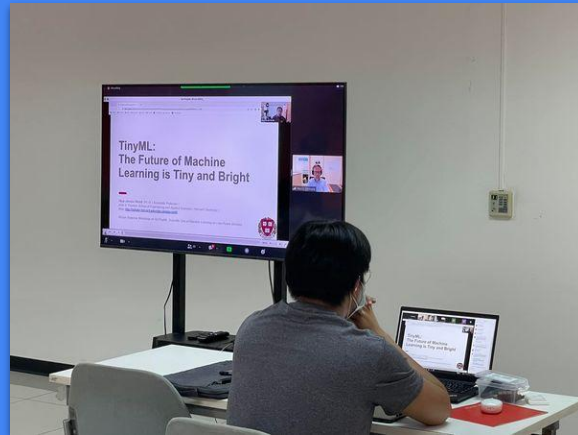
# VEGETABLE DISEASE AND INSECT PEST RECOGNITION BASED ON TINYML: Cotton Case in Benin

James O. ADEOLA  
IMSP - UAC

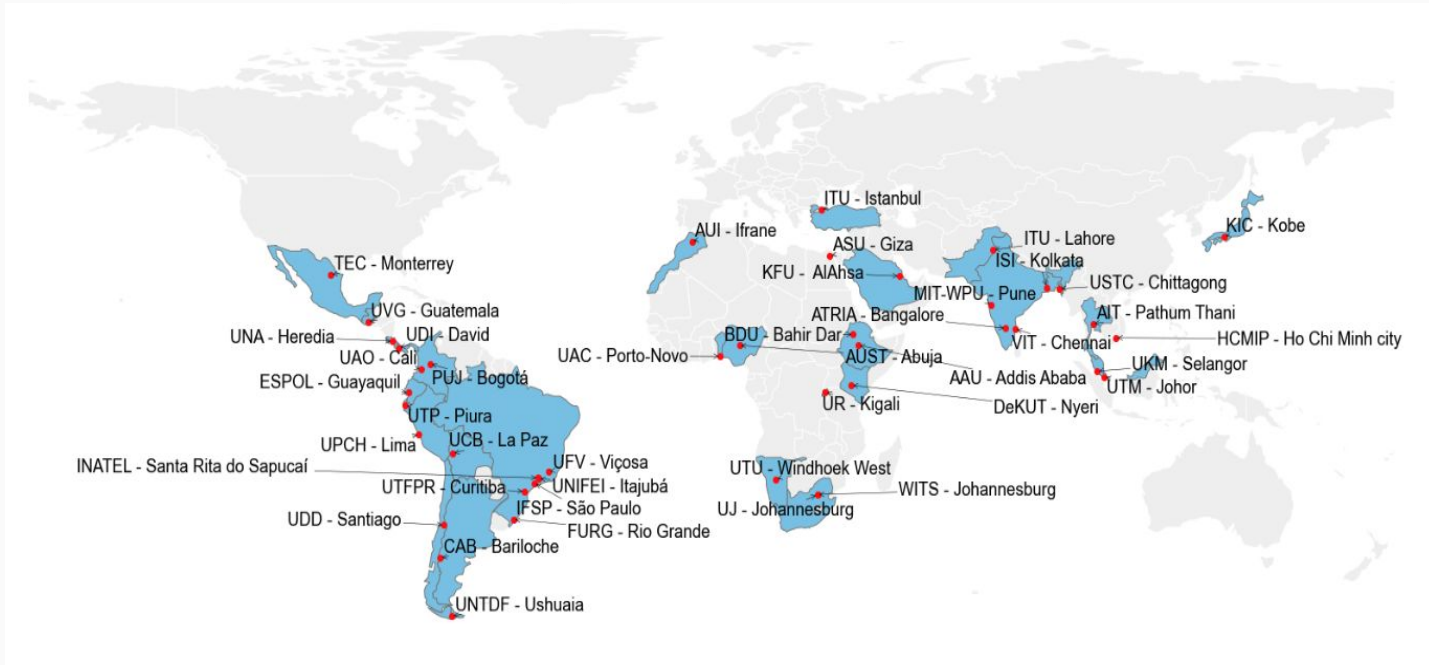
Dr Marco Zenaro  
ICTP Italy

Dr Jules DEGILA  
IMSP Benin





# Networking



# Opportunities

- 1) Join the TinyML Academic Network: [edu@tinymml.org](mailto:edu@tinymml.org)
- 2) Please join Discord by following this link:  
<https://discord.gg/zKWgwhSAEY> if you haven't already done so!

We will post **news, opportunities, workshops** only on Discord.

# Learning and Teaching

If you want to learn more about TinyML:



<https://tinyMLedu.org/learn>



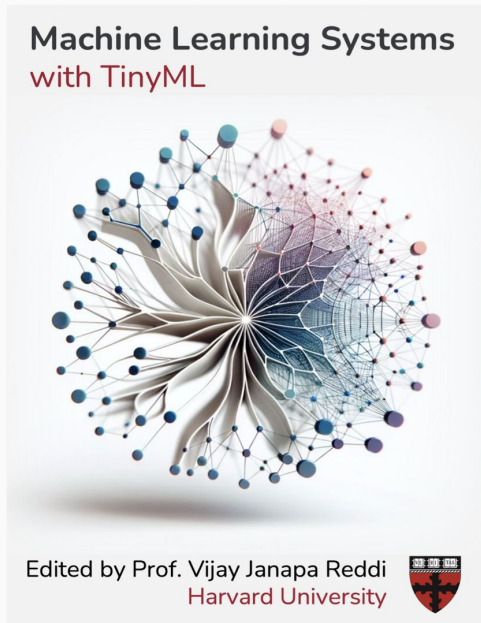
**coursera**

If you want to teach a course on TinyML:

<https://tinyMLedu.org/teach>

 edX tinyML Specialization	Launched 2020-2022	Everyone	English	English	<a href="#">Course 1-3 Website</a> <a href="#">Course 4 Website</a> <a href="#">All Materials</a> <a href="#">All Colabs</a> <a href="#">Arduino Library</a>
 UNIFEI IESTIO1 TinyML - Machine Learning for Embedding Devices	Jan 2021 - Present	Undergraduate Students	Portuguese	English	<a href="#">2022.1 Website and Materials</a> <a href="#">2021.2 Website and Materials</a> <a href="#">2021.1 Website and Materials</a>

# Learning and Teaching















[https://github.com/harvard-edge/cs249r\\_book](https://github.com/harvard-edge/cs249r_book)

# Research

## View Our Research

Explore our Academic Publications.

### Journal Articles

Lead Organizations	Title	Author(s)	Publication	Date	Links
  	Machine Learning Sensors: A Design Paradigm for the Future of Intelligent Sensors	Pete Warden, Matthew Stewart, Brian Plancher, Sachin Katti, Vijay Janapa Reddi	Communications of the ACM (CACM)	Coming 2023	<a href="#">Webpage</a> <a href="#">Technical Report</a>
	Coffee Disease Classification at the Edge using Deep Learning	João Vitor Yukio Bordin Yamashita, João Paulo R.R. Leite	Smart Agricultural Technology	August 2023	<a href="#">DOI</a>
 	A TinyML Deep Learning Approach for Indoor Tracking of Assets	Diego Avellaneda, Diego Mendez, Giancarlo Fortino	Sensors	January 2023	<a href="#">DOI</a>
  	On-Device IoT-Based Predictive Maintenance Analytics Model: Comparing TinyLSTM and TinyModel from Edge Impulse	Irene Niyonambaza Mihigo, Marco Zennaro, Alfred Uwitonze, James Rwigema, Marcelo Rovai	Sensors	June 2022	<a href="#">DOI</a>
  	Widening Access to Applied Machine Learning with TinyML	Vijay Janapa Reddi, Brian Plancher, Susan Kennedy, Laurence Moroney, Pete Warden, Anant Agarwal, Colby Banbury, Massimo Banzì, Matthew Bennett, Benjamin Brown, Sharad Chitlangia, Radhika Ghosal, Sarah Grafman, Rupert Jaeger, Srivatsan Krishnan, Maximilian Lam, Daniel Leiker, Cara Mann, Mark Mazumder, Dominic Pajak, Dhilan Ramaprasad, J. Evan Smith, Matthew Stewart, Dustin Tingley	Harvard Data Science Review	January 2022	<a href="#">DOI</a>

<https://tinyMLedu.org/research/>

# Research

Mihigo, Irene Niyonambaza, et al. "**On-Device IoT-Based Predictive Maintenance Analytics Model: Comparing TinyLSTM and TinyModel from Edge Impulse.**" Sensors 22.14 (2022): 5174.

Altayeb, Moez, Marco Zennaro, and Marcelo Rovai. "**Classifying mosquito wingbeat sound using TinyML.**" Proceedings of the 2022 ACM Conference on Information Technology for Social Good. 2022.

Bamoumen, Hatim, et al. "**How TinyML Can be Leveraged to Solve Environmental Problems: A Survey.**" 2022 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT). IEEE, 2022.

João Vitor Yamashita et al.. "**Coffee disease classification at the edge using deep learning**". Smart Agricultural Technology Volume 4, August 2023, 100183

G. Silva, M.D. Lima, J.A.F. Filho and M.J. Rovai "**Atrial Fibrillation and Sinus Rhythm detection using TinyML (Embedded Machine Learning).**" "IX Latin American Congress on Biomedical Engineering" and "XXVIII Brazilian Congress on Biomedical Engineering"



# Research

- **[DeepPicarMicro]:** Applying TinyML to Autonomous Cyber Physical Systems | [\[pdf\]](#)
- Incremental Online Learning Algorithms Comparison for Gesture and Visual Smart Sensors | [\[pdf\]](#) -**[Protean]:** An Energy-Efficient and Heterogeneous Platform for Adaptive and Hardware-Accelerated Battery-free Computing | [\[pdf\]](#)
- IN-SENSOR & NEUROMORPHIC COMPUTING ARE ALL YOU NEED FOR ENERGY EFFICIENT COMPUTER VISION | [\[pdf\]](#)
- Energy Efficient Hardware Acceleration of Neural Networks with Power-of-Two Quantisation | [\[pdf\]](#)
- Enabling ISP-less Low-Power Computer Vision | [\[pdf\]](#)
- Rethinking Vision Transformers for MobileNet Size and Speed | [\[pdf\]](#)
- Neuromorphic Computing and Sensing in Space | [\[pdf\]](#)
- Joint Data Deepening-and-Prefetching for Energy-Efficient Edge Learning | [\[pdf\]](#)
- PreMa: Predictive Maintenance of Solenoid Valve in Real-Time at Embedded Edge-Level | [pdf\]](#)

[▲ Top](#)

## 2023

- Exploring Automatic Gym Workouts Recognition Locally On Wearable Resource-Constrained Devices | [\[pdf\]](#)
- **[MetaLDC]:** Meta Learning of Low-Dimensional Computing Classifiers for Fast On-Device Adaption | [\[pdf\]](#)
- Faster Attention Is What You Need: A Fast Self-Attention Neural Network Backbone Architecture for the Edge via Double-Condensing Attention Condensers | [\[pdf\]](#)

<https://github.com/gigwegbe/tinyml-papers-and-projects>

# Research



## Call For Papers

Special Issue on “tinyML – The ecosystem for next generation ML systems.”

### Aim and Scope

tinyML encapsulates and nurtures the fast-growing branch of ultra-low power machine learning technologies and approaches dealing with machine intelligence at the very edge of the cloud. These integrated “tiny” machine learning applications require “full-stack” (hardware, system, software, and applications) solutions including machine learning architectures, techniques, tools, benchmarks, and approaches capable of performing on-device analytics. A variety of sensing modalities (vision, audio, motion, environmental, human health monitoring, etc.) are used with extreme energy efficiency, typically in the single milliwatt (and below) power range, to enable machine intelligence right at the boundary of the physical and digital worlds. We see a new world with trillions of distributed intelligent devices enabled by energy efficient machine learning technologies that sense, analyze, and autonomously act together to create a healthier and more sustainable environment for all! The tinyML ecosystem is fueled by (i) emerging commercial applications and new systems concepts on the horizon; (ii) significant progress on algorithms, networks, and models down to 100 kB and below; and (iii) current low-power applications in vision and audio that are already becoming mainstream and commercially available. Over the last few years, the tinyML ecosystem has grown significantly in terms of research, innovation and products. Several stakeholders from academia, industry and policymakers emerged as key leaders in this field. The objective therefore of this special issue, is to bring together the key stakeholders of the tinyML ecosystem, in presenting the state of the art in tinyML research and innovation, through a set of contributed manuscripts that detail advancements in research and innovation, identifying

# Show and Tell

- Addressed to young researchers, students, practitioners
- Informal → not academic

## **TinymML4D Academic Network 2nd Show and Tell on October 27th, 2022.**

The First TinyML4D Show and Tell of student projects was October 27th, 2022. The recorded video is at this Youtube link [https://youtu.be/s8\\_hKpOWUwY](https://youtu.be/s8_hKpOWUwY) <sup>2</sup>

Presenting is:

1. Samson Otieno Ooko, University of Rwanda, TinyML Based Self Diagnostic Kit for Respiratory Diseases, 10 minutes. Video starts at 4:37
2. Mateus Faria Delangélica, Universidade Federal de Itajubá (UNIFEI), The Impact of TinyML on an Assistive Technology Project in Brazil, 15 minutes. Video starts at 13:48
3. Ezzeldin Ayman Ibrahim Ismail, Universiti Teknologi Malaysia, Anomaly Detection in the Temperature of an AC Motor Using Embedded Machine Learning, 10 minutes. Video starts at 31:12

## **TinymML4D Academic Network 2nd Show and Tell on December 1st 2022.**

The full video is at this Youtube address <https://youtu.be/e49pkjnIMQ> <sup>1</sup>

Presenters in the order of presentation are:

1. Wong Khai Chiuan, Universiti Teknologi Malaysia Malaysia, Smart Switch Based on Embedded Machine Learning, 10 minutes. Video at 0s [here](#) <sup>1</sup>
2. Laila Daniela Kazimierski, Centro Atómico Bariloche, Argentina, Study of animal movement: using the TinyML kits for monitoring, 15 minutes Video Starting at 11:13 [here](#).
3. Slimane Larabi, Usthb University, Algérie, Human-Computer Interaction: Hand Gesture Recognition for Mute People Using Tiny Machine Learning, 10 minutes Video at 29:39 [here](#)
4. Md Sharif Ahmed and Prabha Sundaravadeivel, The University of Texas at Tyler, United States, Automated American Sign Language (ASL) using TinyML, 5 minutes. Video at 44:13 [here](#)
5. Jackline Tum, Dedan Kimathi University of Technology, Kenya, Using TinyML to Monitor Bees, 10 minutes. Video at 47.58 [here](#)

# What do you need more?

Hardware?Books?

Open training material?

Seminars on specific topics? Introductory seminars?

In-person workshops in your country?

How should we stay in touch?

New sensors for the Nicla?