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

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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.

What is TinyML?

Embedded Machine Learning (also known as TinyML) brings the transformative power of machine learning (ML) to the performance and power-constrained domain of embedded systems. This opens new opportunities for a smarter and cheaper internet of things (IoT).

The primary goal of TinyML is to enable intelligent decision-making capabilities on the edge, without requiring cloud or remote computing resources. This is achieved by deploying lightweight machine learning models that can operate on resource-constrained devices while maintaining high levels of accuracy and performance.

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, conservation and smart homes.

What is the TinyML Academic Network?

TinyML is a great educational tool, as it explores topics from across the computer science curriculum. However, access to this technology is currently limited in many parts of the world, particularly in the Global South. The Tiny Machine Learning Open Education Initiative [1] involves an international group of global academics and industry professionals who are boosting access to low-cost embedded machine learning education and research.

In the last two years, we have run a series of virtual global workshops with hundreds of attendees from over 50 countries [2]. Through these events, we have built a global academic network spanning the Global South [3] and released open-source course materials to teach TinyML courses and support additional workshops and outreach activities [4]. We have also partnered with the private sector to expand the reach of our network and now have over 40 institutional network members across the Global South.

Network Impact Stages

We have continuously broadened the impact of our network through a five-stage plan:

1) Providing **equipment** to network members. To launch the network, we began by providing equipment to network members in 2021. Selected universities received a kit with 10 TinyML devices. We identified the difficulty in acquiring equipment as being one of the main barriers to the early adoption of this new technology.

2) **Online training**. In the last two years, we have trained more than 500 participants in online workshops. Most participants came from institutions that had received the equipment but we opened participation to other applicants as well. We learned that

regional workshops provided a great platform for regional cooperation, as participants can work together on locally relevant applications.

3) **Advanced online training**. Once network members are knowledgeable of the basic concepts of ML and TinyML, more advanced topics can be covered in online workshops. We are holding an advanced TinyML workshop in April 2023 that will be open to network members and a series of "Show and Tell" talks highlighting network accomplishments throughout 2022 and 2023.

4) **In-person regional events**. In 2022, we organised three online regional events for Africa, Latin America and Asia. Coordinators from these three regions have proposed in-person events in their regions for 2023. As these training events have a strong lab component, meeting in person will allow us to cover more topics and deepen our global collaborations.

5) **TinyML University Programme**. To augment these efforts, we are planning to hold additional in-person workshops in 2023 to bridge the gap between having course materials and developing a full integrated university programme in embedded machine learning. We will bring together the most active participants in our network and open up the event to other educators. We will cover the application of our open-source course materials to local contexts and explore the development of university research programmes centred around embedded machine learning. This will enable students and faculty to develop new technologies and publications in the field of embedded machine learning.

Promising Initial Results

Our network has already accomplished much, especially since its existence has coincided with the global pandemic. Beyond our workshops and training activities, we have launched a series of regional collaborations, outreach activities and virtual 'show and tell' events to share best practices and augment our network's impact. This has also led to academic papers that support the SDGs through new technological developments [5].

Regional Collaborations:
Following the 2022 online regional activities, joint in-person regional activities have been organised. For example, Marcelo Rovai of UNIFEI in Brazil has run a five-day workshop with 46 remote and 16 on-site participants at the Universidad del Istmo in Panama. Held in Spanish, the workshop highlighted projects and opportunities that are relevant to the region to help jumpstart network activities in Panama.

Outreach activities:
The network has also supported several outreach activities for researchers and the general public. Two examples are a seminar for the Colombian IEEE chapter in Bogota on "Pushing Intelligence to the Edge of IoT: a New Paradigm Enabling Next-generation Smart Systems of Systems," and the article on hackster.io on the research carried out in Bariloche, Argentina, on the TinyML system to monitor the behaviour of turtles.

Show and Tell:
To make our network more inclusive, we asked young researchers, graduate students and practitioners to present their projects in an informal setting. We have found this format to be more inclusive than traditional academic conferences and have received contributions from less represented communities of researchers as well as more than 50 participants at our first four events (October and December 2022, January and February 2023). A sample of the projects presented includes: Hand Gesture Recognition for Mute People from Algeria, Monitoring Bees from Kenya, Irrigation Prediction from Colombia, Non-Invasive Anaemia Detection from Peru, Shelf Life Estimation of Date Palms from Saudi Arabia and Cashew Nut Disease Detection from India.

Papers:
Lastly, our network has produced more than 10 scientific, peer-reviewed papers [5]. Many of these papers have had a strong focus on accomplishing the SDGs. This includes research from Moulay Ismail University of Meknes in Morocco which surveys how TinyML can be used to solve environmental issues [6]. This supports **Sustainable Development Goal 13: Climate Action**. Research from UNIFEI in Brazil presents a low-cost solution to monitor atrial fibrillation and sinus rhythm that can be used to extend health coverage in poor regions of the world

[7]. A collaborative paper led by researchers from the University of Khartoum in Sudan and the ICTP presents the use of a low-cost device based on TinyML to detect mosquito species, which could lead to a more efficient malaria eradication campaign [8]. Both of these projects support **Sustainable Development Goal 3: Good Health and Wellbeing**. Lastly, a second paper from UNIFEI in Brazil develops a low-cost method of detecting diseases in coffee plants [9]. **Agriculture is the common thread which holds the 17 SDGs together**. Investing in the agricultural sector can address not only hunger and malnutrition but also other challenges including poverty; water and energy use; climate change; and unsustainable production and consumption.

Policy Recommendations

From our three-year experience of coordinating the network, we have learned a few lessons that can become policy recommendations:

Training and research activities in STI should focus on regional networks. The regional approach, when adopting a new technology, is key. People living in the same region face the same challenges and can share technical solutions. More importantly, the language barrier can be overcome when working in the same region. As such, learning happens faster and ideas spread more quickly, increasing the impact.

The ethics of artificial intelligence must be covered in all activities. TinyML provides many unique opportunities to expand the application of machine learning at the edge. This raises new challenges, as AI will become a more pervasive and ever-present technology. As such, considerations of privacy, security and bias will become more pronounced. As the *UNESCO Recommendation on the Ethics of Artificial Intelligence* (2021) has been an extremely useful tool for tackling this challenge through its unified, internationally recognized framework, we suggest that the Recommendation be used as a guideline when considering embedded machine learning and related additional challenges and opportunities.

We need to support local champions better. Networks are as strong as the people who champion them. We have had the greatest impact in those parts of the world where we have strong local champions who make sure that activities are carried out in their communities. Public–private partnerships are needed to ensure that these champions have the financial and institutional support to develop their local activities and bring about change in all corners of the world.

References

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