Tiny Robot Learning: Expanding Access to Edge ML as a Step Towards Accessible Robotics

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***Abstract*—The high barriers to entry associated with robotics, in particular its high cost, has rendered it inaccessibility for many. In this poster we present our early efforts to begin to address these challenges through edge machine learning (ML). We show how ultra-low-cost robot and computational hardware paired with open-source software and courseware can be leveraged for hands-on education globally and the beginnings of a globally diverse research community.**

I. The Motivating Challenge

We are currently at a transformative moment in history, where the convergence of artificial intelligence and robotics holds immense potential to revolutionize various aspects of our lives. To ensure that these advancements benefit society as a whole, it is essential to foster a diverse community of researchers and educators in this field. However, the high barriers to entry associated with robotics, in particular its high cost, has rendered it inaccessibility for many. As such, we need to develop techniques to run sophisticated algorithms on ultra-low-cost computational and robot hardware.

II. Tiny Robot Learning as a Possible Solution

One approach to lowering the cost of robotics, is to leverage recent advances in edge ML using low-cost microcontrollers, also known as TinyML [1], to enable modern ML powered robotics stacks to run on ultra-low-cost tiny robots. This new paradigm is referred to as tiny robot learning [2] and has recently gained increased attention.

Figure 1 shows an example of promising early results of sim-to-real transfer of RL models for locomotion deployed onto such low cost computational (e.g., a $15 Raspberry Pi Zero 2W) and robotics hardware (e.g., the $299 Petoi Bittle) [3]. Other recent papers have also successfully leveraged TinyML for autonomous driving [4] and drone navigation [5]. As such, we believe that the future of tiny robot learning is both bright and ultra-low-cost.

III. Expanding Access through Open-Source Courseware and Academic Networks

Even if we can design systems that leverage ultra-low-cost computational and robot hardware, without educational materials to get a global audience trained on the requisite topics, and networks to foster collaborations and provide support, tiny robot learning will remain inaccessible.

*Brian Plancher is the primary contact and will present this poster virtually.

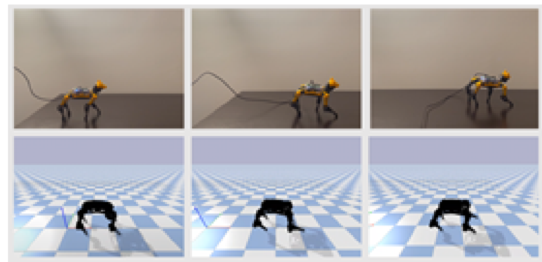

Fig. 1: Sim-to-real transfer of a locomotion policy for the $299 Petoi Bittle quadruped using a $15 Raspberry Pi Zero 2W [3].

As a step in that direction, and to expand access to the fundamentals of edge machine learning needed for tiny robots, we formed a global academic-industry partnership in 2021 which we called the Tiny Machine Learning Open Education Initiative (tinyMLedu.org) [6].

We started by developing and releasing open-source, hands-on course materials. This began with our edX course series that has now be taken by over 90,000 students from over 170 countries [7], leveraged a low-cost (<$50) kit we co-developed with Arduino (see Figure 2), and whose courseware we released open-source. **Feedback from students and educators reported that the low-cost of the kit paired with the availabiity of the open-source courseware was a major motivator for deciding to take and teach TinyML**.

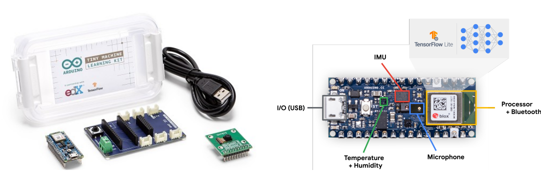

Fig. 2: The Arduino TinyML Kit (left) includes the Arduino Nano 33 BLE Sense (with key sensors detailed on the right), an Arducam OV7675 camera module, and a TinyML shield that simplifies sensor integration [8].

Requests for a shorter form version of the course also led to the development of a seminar series and a flagship synchronous virtual global workshop, SciTinyML, attended by hundreds of students and educators from over 50 countries, many from groups traditionally underrepresented in robotics.

To aid educators in launching their own courses, we now have materials posted on our website from over 10 MOOC and university courses as well as 9 one day to one week workshops in English, Spanish, and Portugese.

To further catalyze these efforts, we built a global academic network of over 40 universities spanning the Global South (see Figure 3). TinyML courses and workshops have been or are planned to be run by most network members, many of which have been collaborative efforts. Excitingly, these events have occurred in multiple languages and many more events and activities are planned for this coming year.

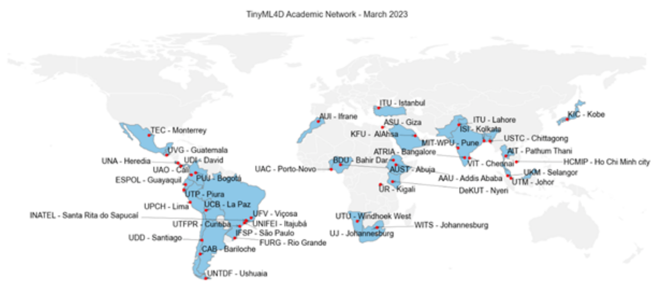

Fig. 3: The TinyML4D Academic Network now has over 40 countries spanning the Global South.

This network has has also catalyzed a growing global research community. Network members have already published 11 papers in international journals and conference proceedings[1], as well as a series of student projects that have been presented in our new "TinyML Show & Tell" seminar series. Highlights in robotics include a voice activated robotic hand as well as a gesture controlled RC car (see Figure 4).

We will be hosting our first in-person convening of the network this summer and will be working on a white paper to further document our approach and grow our impact.

Fig. 4: Left: the voice activated robotic hand from a student team in Brazil [9]. Right: the gesture controlled RC car from a student team in Kenya [10].

IV. Conclusion and Future Work

In this poster we present our early efforts to reduce the cost and increase the globally accessibility of robotics through edge ML. We show how ultra-low-cost hardware paired with open-source software and courseware can be leveraged for hands-on edge ML education globally and can lead to the initiation of a globally diverse research community.

Many future challenges exist in this exciting field including overcoming imperfect sensor information and actuator limitations on low-cost hardware, as well as finding ways to support increasingly larger and more powerful ML models on constrained edge hardware.

[1] The full list can be found at https://tinyMLedu.org/research.

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Biography

Brian Plancher is an assistant professor of computer science at Barnard College, Columbia University. His robotics research explores the intersection of AI, ML, and optimization with computer systems and architecture. He has hosted workshops and published in both top robotics (e.g., RSS, ICRA, iROS) as well as systems and architecture venues (e.g., ASPLOS, MICRO, MLSYS). He is also focused on improving the accessibility of STEM education and research both through the design of new interdisciplinary, project-based, open-access courses, as well as through the development of modern robotics stacks on ultra-low-cost computational and robot hardware. Brian co-chairs TinyMLedu and is an associate co-chair for the IEEE RAS TC on Model Based Optimization for Robotics.

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