Workshop on TinyML for Sustainable Development | (SMR 3961)

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T01

Development of an algorithm that predicts hand movement in the game rock, paper and scissors with the use of TinyML and arduino nano BLE 33

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In the game of rock, paper, scissors, your hands are one of the key elements. This popular game involves hand gestures representing these iconic figures. With the aim to develop a TinyML algorithm capable of predicting three categories (rock, paper or scissors) during the game, we collect kinetic data from an accelerometer, a gyroscope, and a magnetometer with 3-axis using the Arduino Nano BLE with the LSM9DS1 IMU. For the experiment, two opponents wearing a glove equipped with the microcontroller played the hand game[1]. In each round was captured the kinetic signals over a 10-second period, the movement category and the winner motion. Additionally, the Edge Impulse platform was used as a data collection tool for the database [2].

For the prediction of hand gestures, a comparison between two models was proposed: one based on dense neural networks and the other based on 1D convolutional networks. The evaluation of the performance for classification and deployment was considered. With this work it was possible to recognize the advantage to use TinyML technology using low-power devices in a resource-limited environment [3].

[1] Arduino, “Nano 33 BLE - Arduino Documentation”, Arduino.cc, (2024). Disponible en: docs.arduino.cc/hardware/nano-33-ble.

[2] Edge Impulse, “Documentation for ML Professionals - Edge Impulse”, EdgeImpulse.com, (2024). Available at: docs.edgeimpulse.com/docs/readme/for-ml-practitioners.

[3] Khalife, R., Mrad, R., Dabbous, A., Ibrahim, A. (2024). Real-Time Implementation of Tiny Machine Learning Models for Hand Motion Classification. In: Bellotti, F., et al. Applications in Electronics Pervading Industry, Environment and Society. ApplePies 2023. Lecture Notes in Electrical Engineering, vol 1110. Springer, Cham. https://doi.org/10.1007/978-3-031-48121-5-70

T02

Integrating TinyML into Nanosatellite Operations for Enhanced Image Decision-Making

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Tiny Machine Learning (TinyML) is revolutionizing how we approach machine intelligence in severely resource-constrained environments, such as nanosatellites. This talk discusses the implementation of TinyML algorithms on nanosatellites to autonomously determine the viability of transmitting images based on real-time analysis, primarily focusing on environmental conditions such as cloud coverage. This capability is critical for optimizing data management and transmission costs, which are significant constraints in satellite operations.

Our approach utilizes TinyML to process and analyse images onboard before deciding whether they meet the criteria for transmission. This method significantly reduces the bandwidth and energy consumed during data transmission, vital for sustainable satellite operations. We will present findings from recent deployments that demonstrate the effectiveness of TinyML in reducing unnecessary transmissions and ensuring that only pertinent data is sent back to Earth.

The application of TinyML in nanosatellites exemplifies a significant step forward in making space technology more sustainable and efficient. By minimizing the resources required for data transmission, we not only enhance satellites' operational capabilities but also open new avenues for environmental monitoring from space.

T03

Enabling TinyML Training on Low-Power Devices Through Local Feature Alignment

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Artificial neural networks, as pivotal components of artificial intelligence, are increasingly present in the daily life through applications ranging from natural language processing to search engines. These networks, central to machine learning, necessitate extensive data for training, traditionally demanding substantial computational resources. This is primarily due to their reliance on backpropagation for parameter optimization, a process that constructs a computational graph requiring significant memory and energy.

However, resource-efficient neural networks have the potential to revolutionize this landscape by enabling the deployment of machine learning on low-power devices [1, 2]. This advancement can significantly reduce energy and computational requirements, presenting an ideal solution for remote and resource-constrained environments. Consequently, these technologies enable the application of sophisticated algorithms in diverse sectors, driving sustainable development by making intelligent systems accessible where they are most needed.

One approach to achieving more efficient neural networks involves modifying the training rule. Instead of relying on backpropagation, which requires extensive memory for a differentiable graph encompassing the entire network, one could employ local training algorithms [3, 4]. These algorithms focus on restricting the differentiable graph to local operations within the network. By segmenting the network into self-contained blocks that can be dynamically loaded and unloaded from memory as needed, the overall memory demand decreases significantly. Consequently, this method enables the training of neural networks on low-powered devices, making it a practical solution for enhancing computational efficiency in resource-constrained settings.

In this work, we explore the concept of local feature alignment [4, 5], a modification of a technique aimed at approximating the reversibility of neural networks, specifically tailored for local training approaches. This technique operates by predicting the input of a specific local region within the network based on its output. Such a predictive mechanism facilitates the training of network parameters using solely local information. This process effectively emulates the capability of a network to invert its outputs, thereby enabling a more efficient approximation of reversible computing in the context of neural networks.

We demonstrate the feasibility of this technique through its application to a regression problem in computer vision. By employing an encoder-only network configuration, the neural network is optimized to reconstruct images from the output of the latent vector, which is represented as the last layer of the network. Utilizing local training, the neural network successfully learns to predict the images, effectively reducing memory consumption. This practical application not only showcases the technique's effectiveness for solving a problem but also highlights its potential to run machine learning on low-powered devices.

[1] A. Goel, C. Tung, Y. -H. Lu, G. K. Thiruvathukal, 2020 IEEE 6th WF-IoT, pp. 1-6 (2020)
[2] S. Kuninti, S. Rooban, Journal of Physics: Conference Series, 012169 (2021).
[3] P. Baldi,P. Sadowski, Neural networks : the official journal of the International Neural Network Society. **83**, 51-74 (2015).
[4] T. de S. Farias, PhD's thesis, UFSM (2023).
[5] T. de S. Farias, J. Maziero, Frontiers in Artificial Inteligence. Vol. **5** (2023).

T04

Experiences using TinyML tools in teaching biomedical engineering at the Universidad Peruana Cayetano Heredia

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The integration of TinyML tools in the teaching of biomedical engineering represents a significant advancement in student education. This presentation describes the educational experiences in university courses offered by Universidad Peruana Cayetano Heredia, emphasizing the use of TinyML tools under a flipped learning approach. TinyML, or Tiny Machine Learning, is a rapidly growing field that brings the transformative power of machine learning to the realm of embedded systems **[1].** By incorporating TinyML tools into biomedical engineering courses, students are exposed to cutting-edge technologies that are increasingly relevant in the healthcare industry. This approach not only enhances their theoretical understanding but also provides them with hands-on experience in applying machine learning algorithms to real-world problems. Through a series of case studies and projects, students at Universidad Peruana Cayetano Heredia have had the opportunity to work with TinyML tools to develop innovative solutions for biomedical applications **[2]**. These projects have ranged from developing algorithms for early disease detection to creating smart devices for patient monitoring, as an example I will present The Development of an electrocardiographic signal classifier for bundle branch blocks that was presented at international conferences **[3]**. The hands-on experience gained through these projects has been invaluable in preparing students for careers in the rapidly evolving field of biomedical engineering.

References

[1] Ramon Sanchez-Iborra, Abdeljalil Zoubir, Abderahmane Hamdouchi, Ali Idri, Antonio Skarmeta, *Intelligent and Efficient IoT Through the Cooperation of TinyML and Edge Computing*, Informatica 34(2023), no. 1, 147-168, DOI 10.15388/22-INFOR505

[2] L. De La Cruz, M. Meza-Rodriguez, J. A. Cáceres-DelAguila and P. Vela-Anton, "The didactic experience in a biomedical engineering course at a Peruvian university," 2023 IEEE 3rd International Conference on Advanced Learning Technologies on Education & Research (ICALTER), Chiclayo, Peru, 2023, pp. 1-4, doi: 10.1109/ICALTER61411.2023.10372910.

[3] M. Meza-Rodriguez, L. De La Cruz and J. A. Cáceres-DelAguila, "Development of an electrocardiographic signal classifier for bundle branch blocks, applying Tiny Machine Learning," 2023 IEEE XXX International Conference on Electronics, Electrical Engineering and Computing (INTERCON), Lima, Peru, 2023, pp. 1-6, doi: 10.1109/INTERCON59652.2023.10326046.