ISSN 1454 - 8003
Proceedings of 2023 International Conference on Hydraulics and Pneumatics - HERVEX
November 8-10, Băile Govora, Romania

ASPECTS OF THE USE OF AI (ARTIFICIAL INTELLIGENCE) TECHNOLOGY IN CONSTRUCTION EQUIPMENT MANAGEMENT

Mihail Ioan SAVANIU[1], Oana TONCIU[1], Radu PANAITESCU – LIESS[1], Cristina SESCU- GAL[1], Magdalena CULCEA[2], Anca Ruxandra SASU[1]

[1] Technical University of Civil Engineering Bucharest (UTCB) – Faculty of Mechanical Engineering and Robotics in Constructions

mihai.savaniu@utcb.ro; oana.tonciu@utcb.ro; liess.panaitescu@utcb.ro; cristina.sescu-gal@utcb.ro; anca-ruxandra.sasu@utcb.ro

[2] Technical University of Civil Engineering Bucharest (UTCB) – Faculty of Building Services Engineering

magdalena.culcea@utcb.ro

Abstract: *In this paper, the authors want to present some aspects related to the use of AI technology for continuous monitoring of technological processes in a construction site. The authors present preliminary experimental studies undertaken in the implementation of AI technology in the field of construction machinery through the realization of a low-cost hardware platform. The platform allows the development of preliminary tests on the optimization of construction equipment trajectories. The envisaged platform involves the use of affordable equipment such as the Arduino Nano 33 development platform and a small drone for aerial filming. The paper presents the preliminary tests carried out with in defining trajectories for construction equipment.*

Keywords: *Construction equipment, drone, artificial intelligence, optimal trajectory*

1. Introduction

The use of AI technology for continuous monitoring of technological processes on the construction site leads to improved working conditions and thus to higher levels of occupational safety and health on construction sites. At the same time, it increases the productivity of the entire construction process, reduces costs, improves supply chain management, reduces resource consumption and waste generation on construction sites. From a cultural point of view, the introduction of AI technologies on a construction site contributes decisively to raising the technical cultural level of human resources working in the construction sector.
The integration of artificial intelligence (AI) technology into construction equipment management has the potential to significantly improve efficiency, safety, project outcomes. In the case of construction equipment, AI technology can be integrated, for:

- Predictive maintenance: AI can analyze sensor data and equipment performance history to predict when construction equipment is likely to fail. This enables proactive maintenance, reducing downtime and avoiding costly repairs.
- Condition monitoring: Real-time monitoring via AI allows the condition of construction equipment to be assessed. Sensors and data analytics can detect anomalies or the onset of wear, allowing timely intervention before major problems occur.
- Optimized equipment management: AI technology can analyze the work sequences of the adopted construction technology project, check resource availability and equipment capabilities to optimize the layout of construction equipment. This ensures that equipment is used efficiently, reducing downtime and maximizing productivity.
- Automated operation and control: Artificial intelligence can enable autonomous or semi-autonomous operation of construction equipment. This includes technologies such as automated levelling systems, robotic construction equipment and autonomous systems that can increase accuracy, productivity and operational safety.

- Energy efficiency: Artificial intelligence algorithms can be used to optimise the energy consumption of construction equipment. This includes intelligent scheduling of equipment operation and energy efficient use, contributing to cost reduction and environmental sustainability.
- Ensuring personnel safety: AI-driven cameras and sensors can monitor construction sites for safety compliance. This includes detecting potential hazards, ensuring the use of personal protective equipment and alerting operators to unsafe conditions.
- Inventory management and resource management: AI can help manage construction equipment fleets, track equipment location, enforce maintenance schedules. This helps to allocate resources efficiently, reducing the costs associated with over- or under-use of construction equipment.

As the construction industry continues to embrace digital transformation, the integration of AI in equipment management holds the potential to revolutionize how construction projects are planned, executed, and maintained. However, it's essential to address challenges such as data privacy, security, and workforce training when implementing AI technologies in construction [1,2].

According to reference [3] robotics, AI, and the Internet of Things can reduce building costs by up to 20 percent. Companies are using AI to develop safety systems for worksites. AI is being used to track the real-time interactions of workers, machinery, and objects on the site and alert supervisors of potential safety issues, construction errors, and productivity issues. Despite the predictions of massive job losses, AI is unlikely to replace the human workforce. Instead, it will alter business models in the construction industry, reduce expensive errors, reduce worksite injuries, and make building operations more efficient. Leaders at construction companies should prioritize investment based on areas where AI can have the most impact on their company's unique needs. Early movers will set the direction of the industry and benefit in the short and long term.

The research aims to develop a hardware platform for implementing AI technology in the field of low-cost construction machinery. This approach requires the use of low-cost and affordable equipment. Thus for aerial filming of work processes we will use a drone with a mass of less than 250 grams and for the interpretation of images in order to define trajectories we will use a specialized open-source platform such as Arduino Nano 33 BLE. The paper presents how to define trajectories of construction equipment using this type of microcontroller.

Microcontrollers implemented on Arduino development boards, are compact integrated circuits developed to perform a specific operation. They are basically small computers that consist of a processor, memory and input/output (I/O) peripherals, all on a single chip.

Also called MCUs, they are embedded in billions of gadgets such as cars, robots, medical devices, home appliances, drones, 3D printers, toys, smart plugs. These miniature personal computers that have no operating system were developed to control larger entities. In addition, the current trend is to connect these devices, creating what is called the Internet of Things (IoT) [4,5].

Arduino is on the one hand an open-source platform, and on the other a community focused on making microcontroller application development accessible to everyone. There are several practical reasons for wanting to implement Machine Learning ML on microcontrollers. One of these would be that we want a smart device to be able to operate quickly regardless of whether the internet is present or not. Another reason is cost - these hardware devices are simple and low cost. We also want privacy, i.e. not to share all our data outside. Last but not least, these devices are energy efficient.

2. Hardware and software resources used

TinyML (Tiny Machine Learning) is a field of machine learning, dedicated integrated circuits, algorithms and software that have the ability to perform data analysis using sensors (video, audio, IMU, etc.) with extremely low power consumption. [6]. Arduino Nano 33 BLE Sense rev2 with connectors is a board used for Machine Learning from Arduino, having a small form factor and comes equipped with a set of sensors.

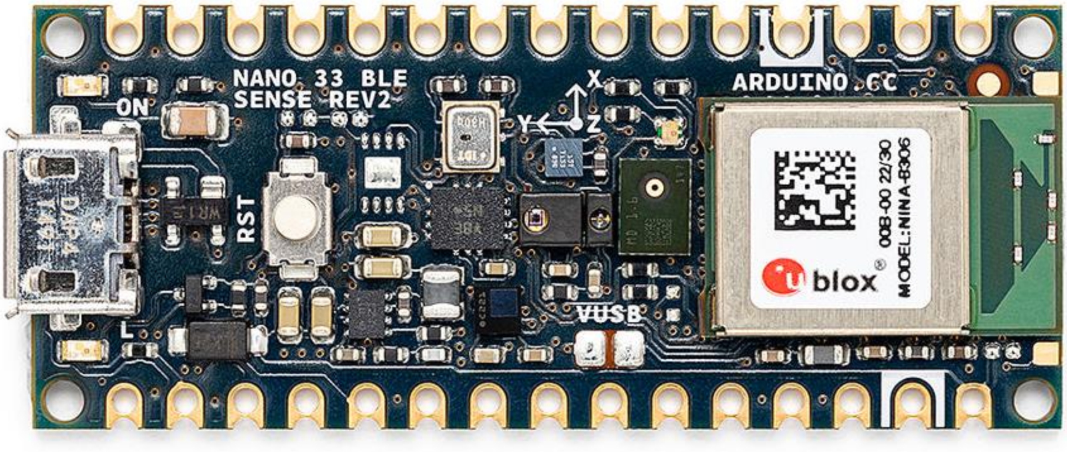

Fig. 1. Arduino Nano 33 BLE Sense Arduino Board [4]

The main feature of this board, in addition to on-board sensors, is the ability to run Edge Computing (AI) applications using TinyML. The features are shown in the table 1.

Table 1

Microcontroller	nRF52840 (Arm Cortex-M4)
Operating voltage	3.3V
Maximum input voltage	21 V
DC current at I/O pins	15 mA
Clock Speed	64MHz
CPU flash memory	1MB (nRF52840)
SRAM	256KB (nRF52840)
Digital Input/Output Pines	14
PWM pins	14
UART	1
SPI	1
I2C	1
Analogue input pines	8 (ADC 12 bit 200 k samples)
Analogue output pines	Only through PWM

External Interrupts	All digital pins
LED_BUILTIN	13
USB	Native in nRF52840 CPU
IMU	BMI270 and BMM150
Microphone	MP34DT06JTR
Motion, vibration and orientation sensor	APDS9960
Pressure sensor	LPS22HB
Temperature and humidity sensor	HS3003

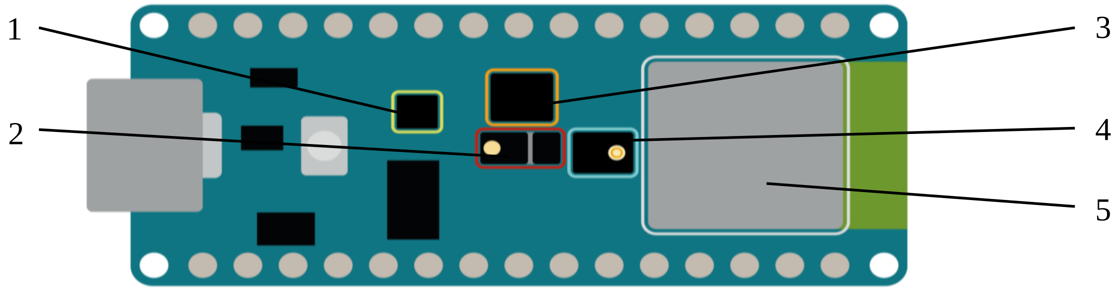

Fig. 2. Arduino Nano 33 BLE Sense board schematic [6]

Figure 2 shows the Arduino Nano 33 BLE, as follows:
1 Temperature, humidity and pressure sensor;
2 Colour, brightness, proximity and gesture sensor;
3 Motion, vibration and orientation sensor;
4 Digital microphone;
5 Arm-Cortex-M4 microcontroller

3. Implementation

The productivity of a construction machine depends, among other things, on the path it takes during the working process. It is clear in this respect that a desideratum is to optimise the mechanisation scheme so that it tends towards a maximum possible value.
For this purpose, we filmed a construction equipment aerial filming a job to move a landfill. The filming was done with a DJI MINI 3 drone which filmed the equipment from a fixed point about 7 meters away during the work process. In fig. We present the drone used and a sequence of the working process of the equipment in an aerial filming.

Fig. 3. Drone used in aerial filming (left). Aerial filming with the equipment (right)

To define the trajectories, we have approached Machine learning technology is a subset of artificial intelligence. Machine learning is an area of artificial intelligence that uses statistical techniques to provide computer systems with the ability to "learn" from previously collected data without being explicitly programmed. An ML becomes more efficient at understanding and providing information as it is exposed to more data-the better trained it is. This can be achieved through ML technology using an Arduino Nano 33 BLE Sense board installed on the shield for ease of use as shown in Fig. 4.

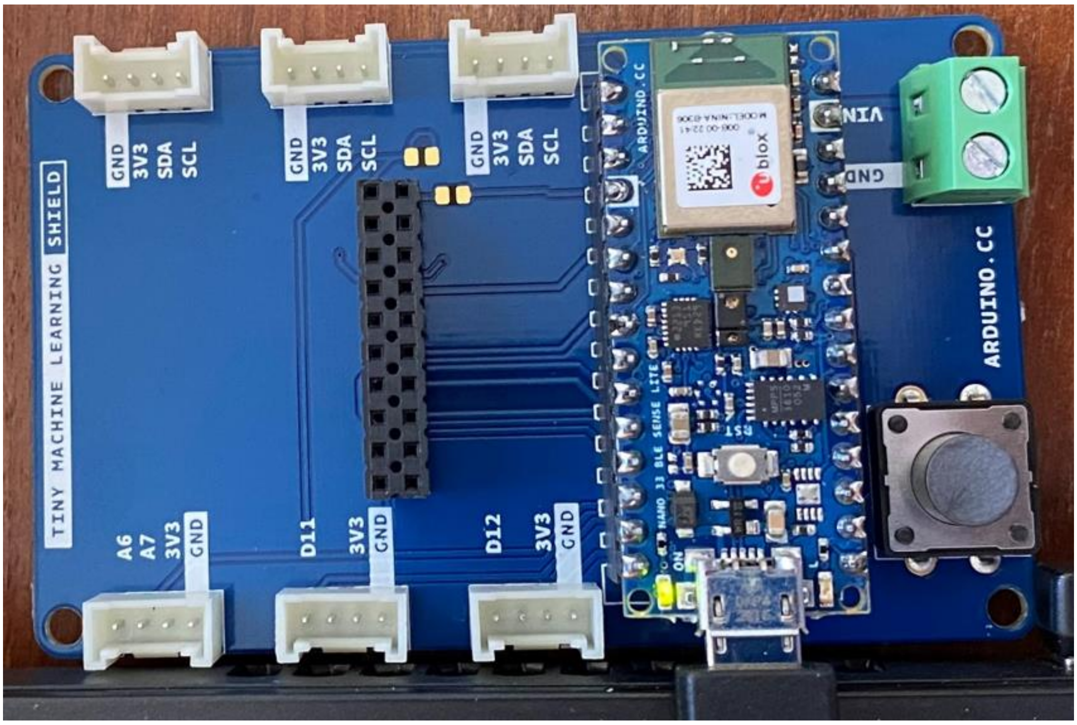

Fig. 4. Shield Arduino Arduino Nano 33 BLE Sense

In order to implement the Ardunino Nano 33 BLE board for our application, there are several steps we plan to take. For example, for the generation of the trajectory we have:

- Install the plate on a mechanized model (mock-up) to generate in the laboratory different trajectories that we will save on https://tinyml.seas.harvard.edu/magic_wand/
- Training the ML model
- Carry out experiments on site

The first step was to generate trajectories via the Arduino Nano 33 BLE Sense board. For this we ran the Magic Wand code (default) from the Arduino IDE examples. After connecting the board via the Bluetooth button in the https://tinyml.seas.harvard.edu/magic_wand/ app, the trajectories were uploaded (an example is shown in Figure 5).

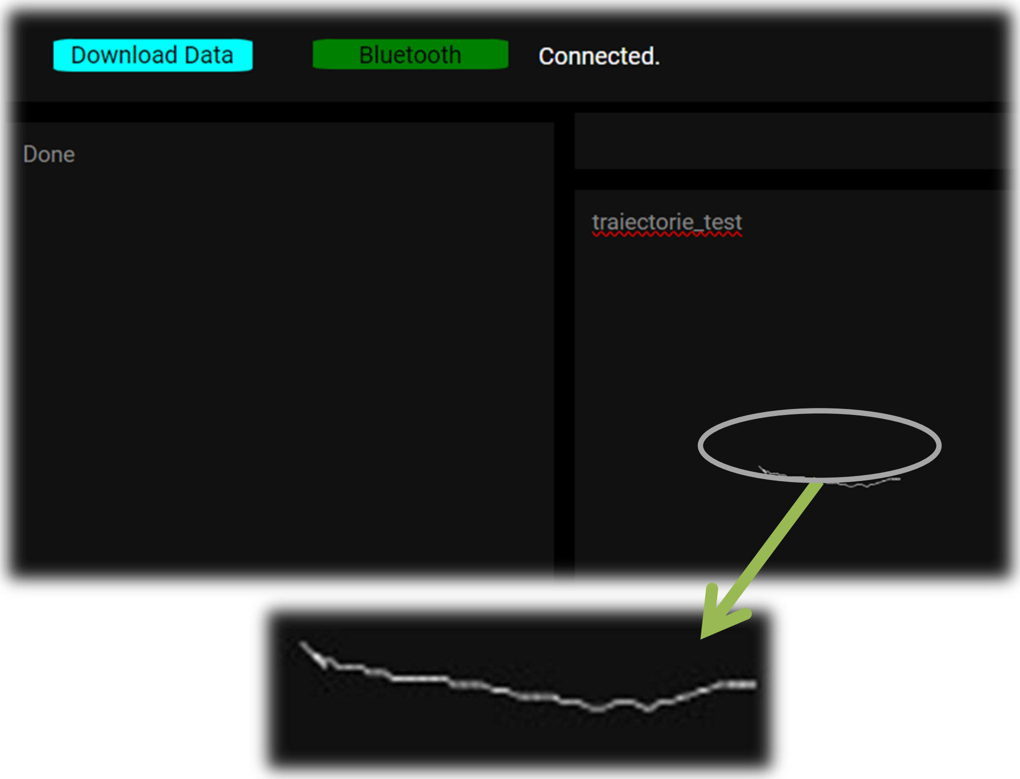

Fig. 5. Recording made by moving the Arduino Nano 33 BLE Sense board

4. Conclusions

Following the aerial drone filming experiment and the tests carried out with the Arduino 33 BLE Sense development board, the possibility of realizing a low-cost hardware platform to be used for implementing AI in construction equipment management is assured.
While early tests are encouraging, one challenge will be to see how the Arduino 33 BLE Sense board performs when generating large trajectories. However, the authors aim to move to the next steps by making multiple trajectories and training the ML model to obtain an optimal trajectory for construction equipment.

Acknowledgments

This work is part of the ARUT Competition Program for the financing of the scientific research in UTCB, project title Optimising mechanisation processes in construction using artificial intelligence project acronym OPTIMEC, code $GnaC_{2023}^{ARUT}$-UTCB-20.

References

[1] Abioye, Sofiat O., Lukumon O. Oyedele, Lukman Akanbi, Anuoluwapo Ajayi, Juan Manuel Davila Delgado, Muhammad Bilal, Olugbenga O. Akinade, and Ashraf Ahmed. "Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges." *Journal of Building Engineering* 44 (December 2021): 103299.

[2] Skycatch, Inc. ″Data Analytics Package (DAP). Our Construction Solution: The only automated drone data solution for construction enterprises.” Accessed October 10, 2023. https://skycatch.com/drone-photogrammetry.
[3] Rao, Sumana. ″The Benefits of AI In Construction.” *Trimble. Construction*, April 6, 2022. Accessed October 10, 2023. https://constructible.trimble.com/construction-industry/the-benefits-of-ai-in-construction.
[4] Mistry, Sandeep, and Dominic Pajak. ″Get Started With Machine Learning on Arduino.” *Arduino Documentation*. Accessed October 10, 2023. https://docs.arduino.cc/tutorials/nano-33-ble-sense/get-started-with-machine-learning.
[5] Lutkevich, Ben. ″microcontroller (MCU).” *TechTarget*. Accessed October 10, 2023. https://www.techtarget.com/iotagenda/definition/microcontroller.
[6] tinyML Foundation. ″About tinyML Foundation.” Accessed October 10, 2023. https://www.tinyml.org/about/.
[7] Arduino S.r.l. ″Arduino Nano 33 BLE Sense Rev2.” Accessed October 10, 2023. https://store.arduino.cc/products/nano-33-ble-sense-rev2.
[8] Ardushop S.R.L. ″Arduino® Nano 33 BLE Sense Rev2 with headers.” / ″Arduino® Nano 33 BLE Sense Rev2 cu pini.” *ArduShop*. Accessed October 10, 2023. https://ardushop.ro/ro/electronica/2730-arduino-nano-33-ble-sense-rev2-with-headers.html.
[9] Ramírez, Lorenzo. ″Physics with Arduino nano 33 BLE Sense and Phyphox: all sensors in one.” / ″Física amb Arduino nano 33 BLE Sense i Phyphox: tots els sensors en un.” *Free experimentation. A resource block for Experimental Sciences / Experimentació lliure. Un bloc de recursos per a les Ciències Experimentals*, May 9, 2021. Accessed October 10, 2023. https://experimentaciolliure.com/2021/05/09/fisica-amb-arduino-nano-33-ble-sense-i-phyphox-tots-els-sensors-en-un/.