Study of animal movement: using the TinyML kits for monitoring

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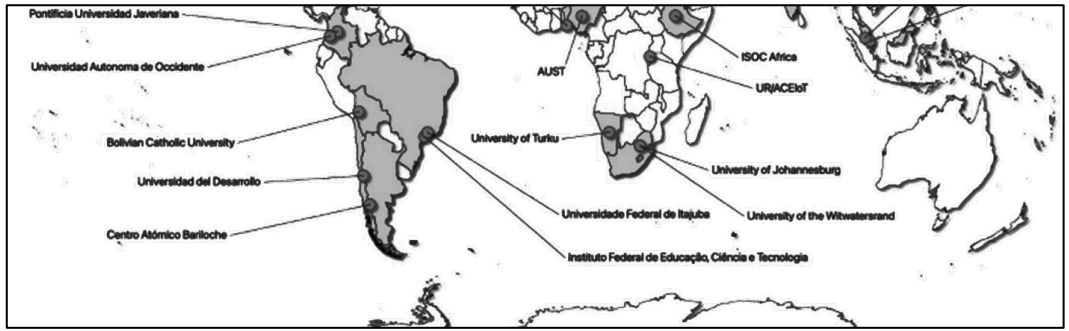
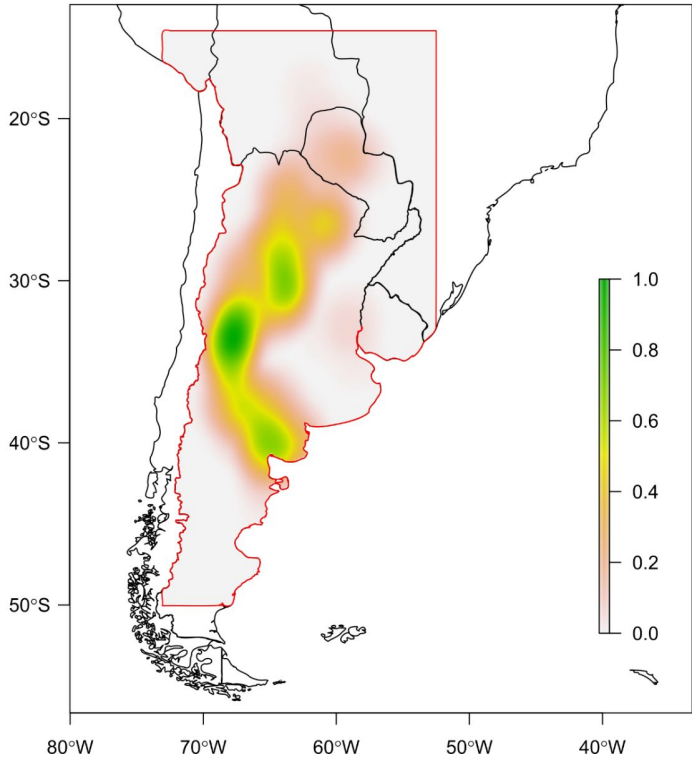
ICTP - Workshop on Widening Access to TinyML Network by Establishing Best Practices in Education - July 2023

The beginnings



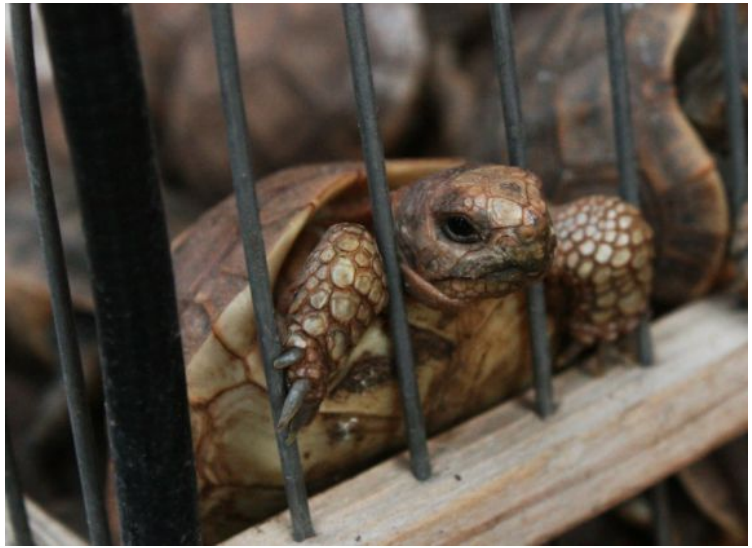
Tortoise *Chelonoidis chilensis*



Estimated distribution of *Chelonoidis chilensis*

Main threats for the species:

- Habitat fragmentation.
- Livestock.
- Illegal trade as a pet.



General objetives

Answer basic questions about the biology of animal species. **How?**

- Monitoring and characterizing animal behavior.
- Developing movement models.

Objectives with TinyML kits

Optimize the animal monitoring.

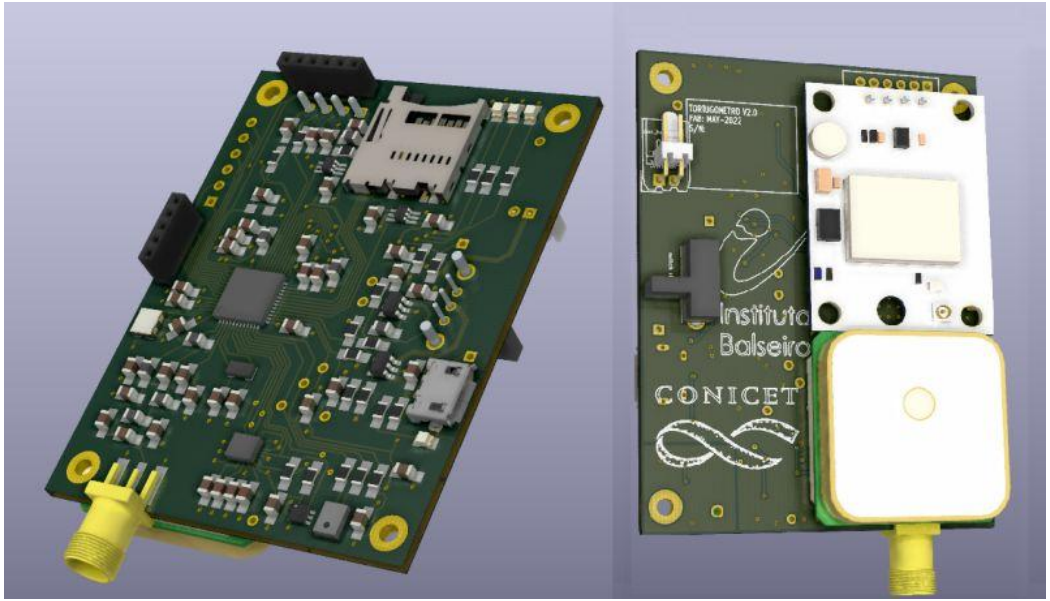
How?

- Automatically detecting, without direct observation, the activity carried out by animals.
- Automating the device operation based on the activity of the animals.

Our own design

- Custom hardware to improve energy efficiency and size.
- Flexible firmware to adapt to other species and hardware

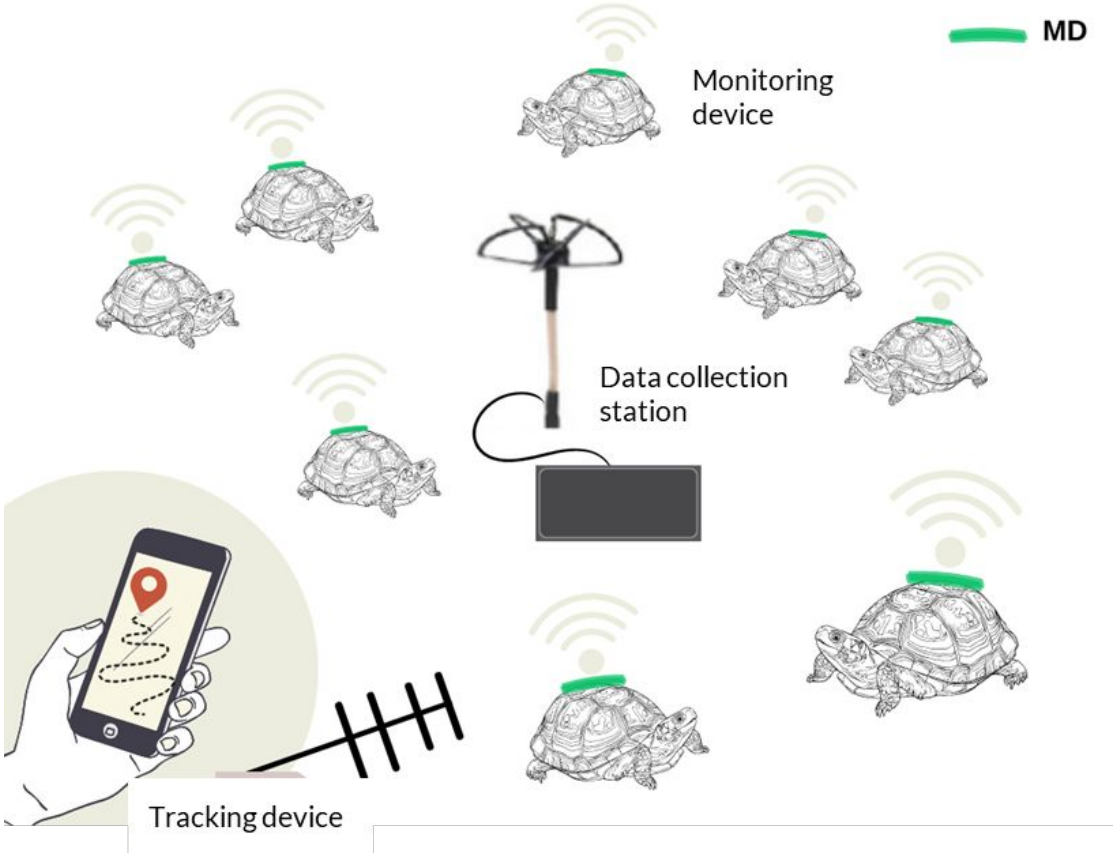
  .
- 150 MHz communication.
- **TinyML compatible**.



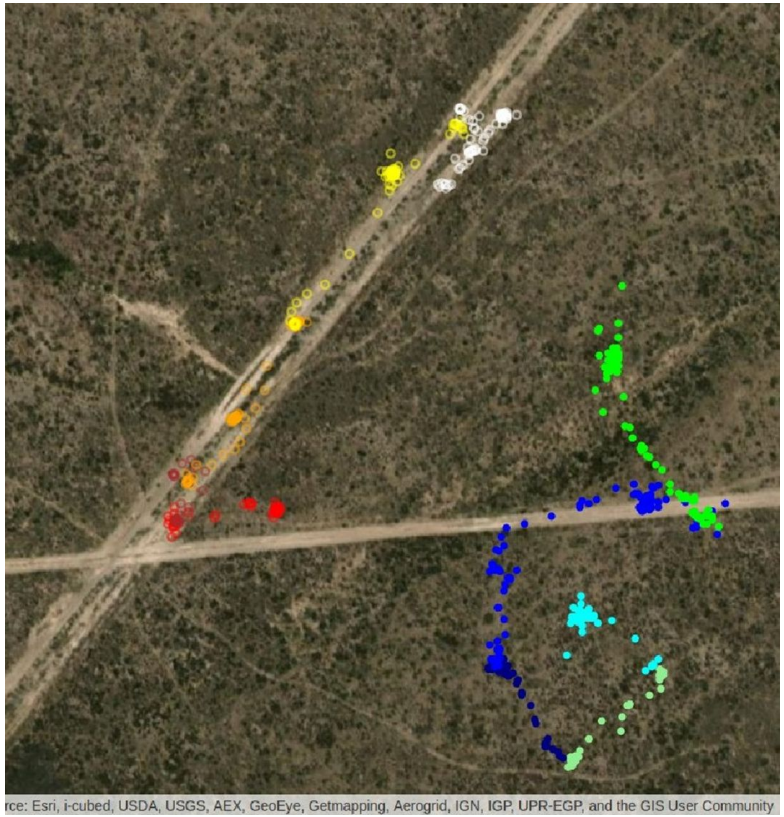
Kazimierski, L. D., Oliva Trevisan, A., Kubisch, E., Laneri, K., & Catalano, N. (2023). Design and Development of a Family of Integrated Devices to Monitor Animal Movement in the Wild. Sensors, 23(7), 3684.

Data collection

-Eight individuals.
-Spring 2020 and summer 2021.
-GPS, accelerometer data and visual observation of activities.

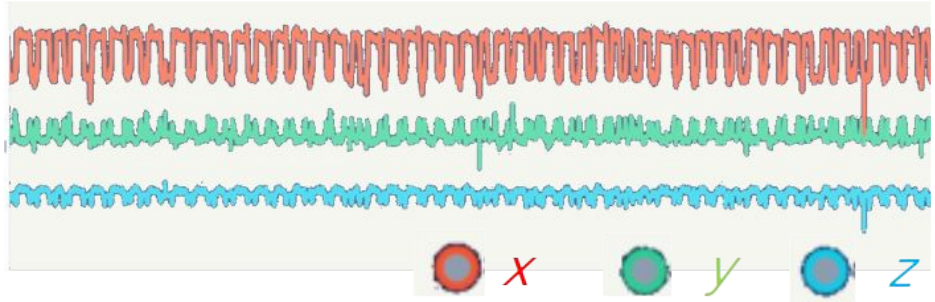


Data analysis

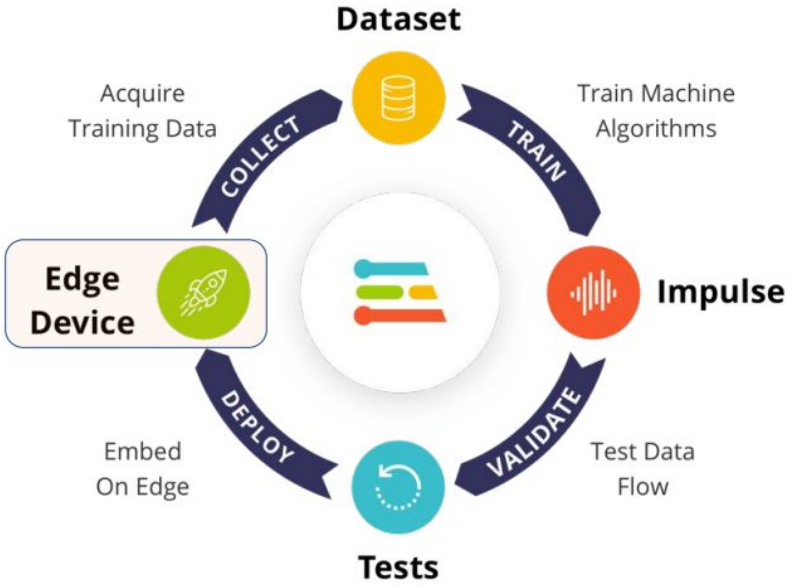


-Label signal segments using observed behaviors.
-Train a ML algorithm that recognizes between different activities.
-Classify behavior of the animal in real time.

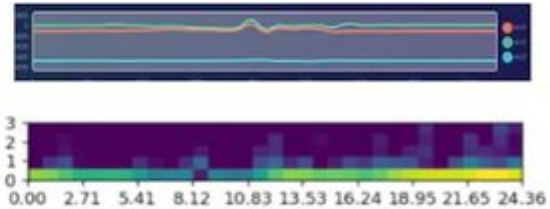
Example of accelerometer signal of a female digging a nest to lay eggs:

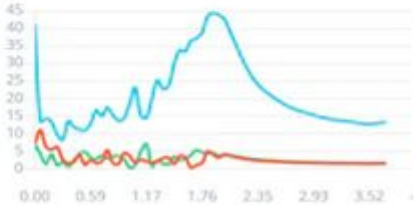


Machine Learning: movement or stillness



- Pre-Processing Data
- Design a Model
- Train a Model





	Datos crudos		Características espectrales		Espectrograma	
Versión	int 8	float 32	int 8	float 32	int 8	float 32
Aciertos movimiento	12.8 %	12.6 %	51.2 %	97.2 %	99.3 %	99.3 %
Aciertos quietud	0.5 %	99.9 %	0.1 %	99.7 %	99.9 %	99.9 %
Precisión	2.33 %	85.56 %	8.04 %	99.27 %	99.83 %	99.83 %
Pérdida	2.5	0.66	1.6	0.23	0.01	0.01
Tiempo de inferencia	2 ms	8 ms	1 ms	1 ms	3 ms	13 ms
Uso de memoria	2.1 kB	3.3 kB	1.7 kB	1.8 kB	5 kB	7.2 kB
Uso de RAM	26.5 kB	51.5 kB	19.2 kB	21.5 kB	34.7 kB	37.6 kB

ACCURACY

99.83%

	MOVIMIENTO	QUIETO	UNCERTAIN
MOVIMIENTO	99.3%	0.6%	0.1%
QUIETO	0.1%	99.9%	0.0%
F1 SCORE	0.99	1.00	

Machine Learning: movement or stillness

Create library

Turn your impulse into optimized source code that you can run on any device.

C++ library

Arduino library

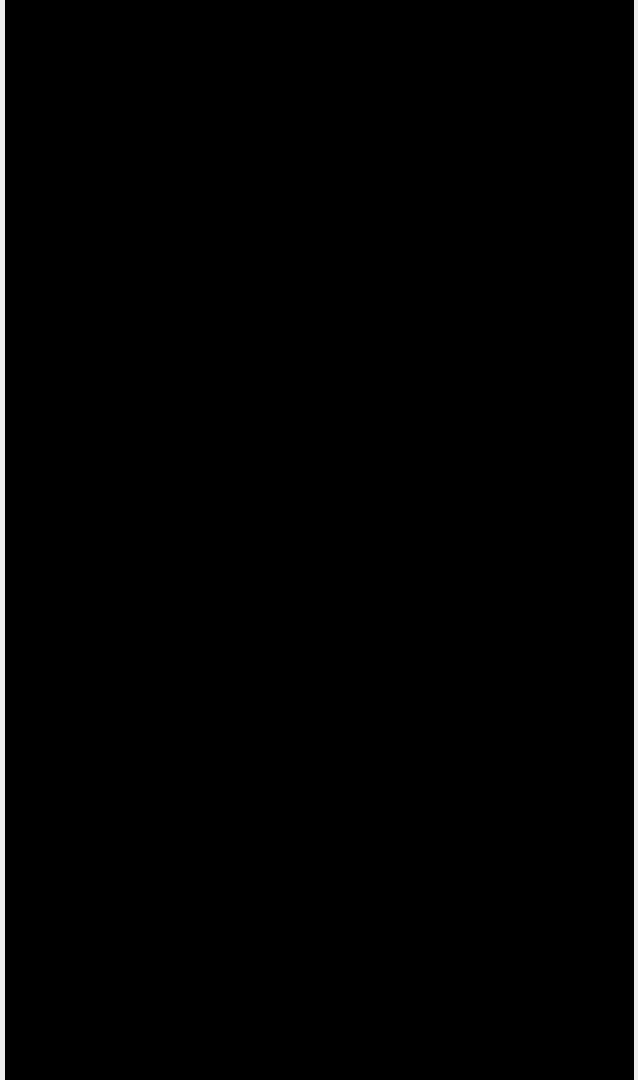
Cube.MX CMSIS-PACK

WebAssembly

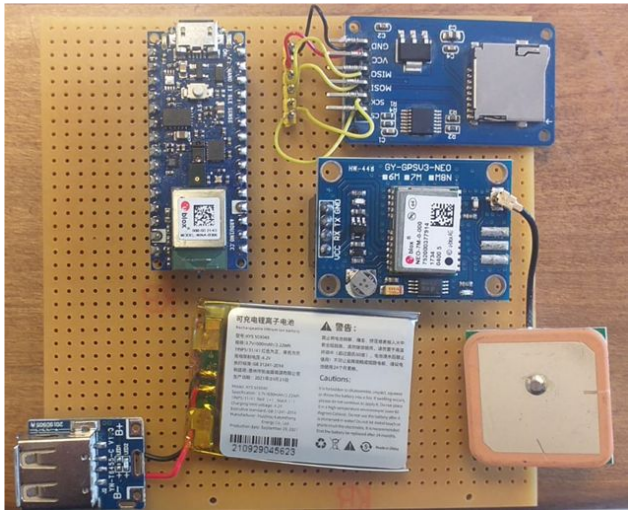
TensorRT library

Ethos-U library

Simplicity Studio Component



Using the TinyML kits as monitoring system



gps_logger | Arduino 1.8.19

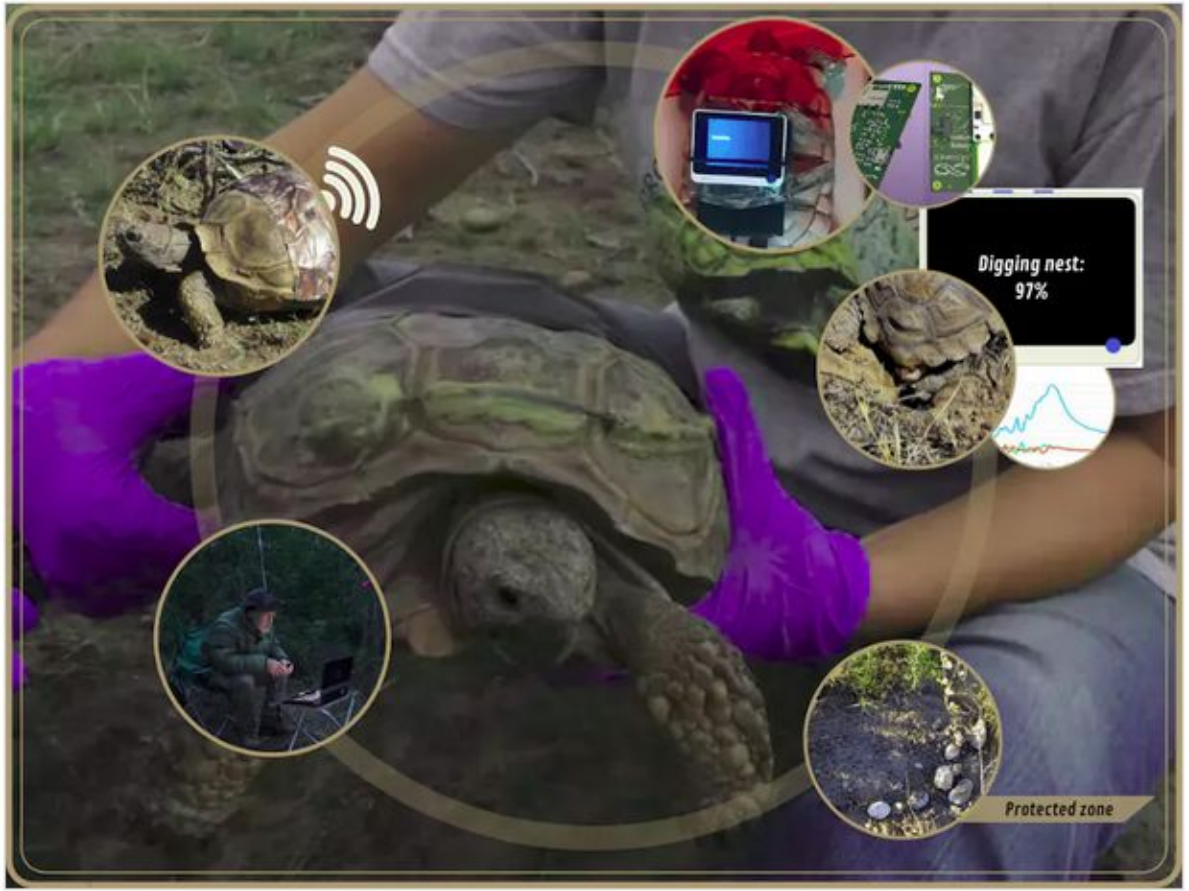
File Edit Sketch Tools Help

gps_logger

```
// include the SD library:
#include <SPI.h>
#include <SD.h>

// set up variables using the SD utility library funct
Sd2Card card;
SdVolume volume;
SdFile root;

// change this to match your SD shield or module;
// Arduino Ethernet shield: pin 4
// Adafruit SD shields and modules: pin 10
// Sparkfun SD shield: pin 8
// MKRZero SD: SDCARD_SS_PIN
const int chipSelect = 4; // Nano 33 ble pin digital
```

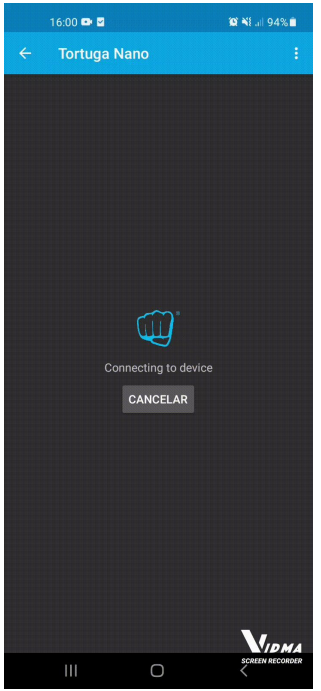


Using the TinyML kits as monitoring system

Step by step of a the data logger prototype with Arduino Nano 33 BLE Sense: https://github.com/droyktton/dataLoggerNano33BLE

Here is the arduino code to store the data: https://github.com/droyktton/dataLoggerNano33BLE/blob/main/gps_logger_ble/gps_logger_ble.ino

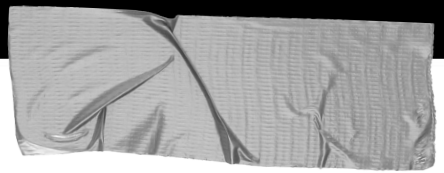
And here is the python code that processes them: https://colab.research.google.com/drive/1_9go_lZilCCMfnH9YfPFYoGr_VzLNvT9



Winners of the Innovative and Creative Project Award within the framework of the IoT Into the Wild Contest for Sustainable Planet 2022 with Seeed Studio

https://www.hackster.io/471203/study-of-animal-movement-equipment-design-and-development-febb17

seeed



Conclusions and future ideas

- We can classify movement and rest in tortoises. We want to expand the classification labels: digging nests, copulation, etc.
- Notify the users' cell phone of the activities of the animals. Use this classification to automate devices.
- Incorporate GPS and batteries to more kits to use them in the next campaign.
- Implement the kit's microphone to identify specific behaviors such as copulation and be able to contrast it with the accelerometer signals.
- Generalize the results to use the device in other species.
- Migrate the trained neural network to our own design.
- Incorporate the use of LoRa.
- More courses of TinyML in our institute.
- **Collaborate**.

Thank you!

Laila Daniela Kazimierski

(All this happens within the framework of an interdisciplinary group)

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