Leveraging any Microcontrollers & Data Collection at Edge Impulse Studio

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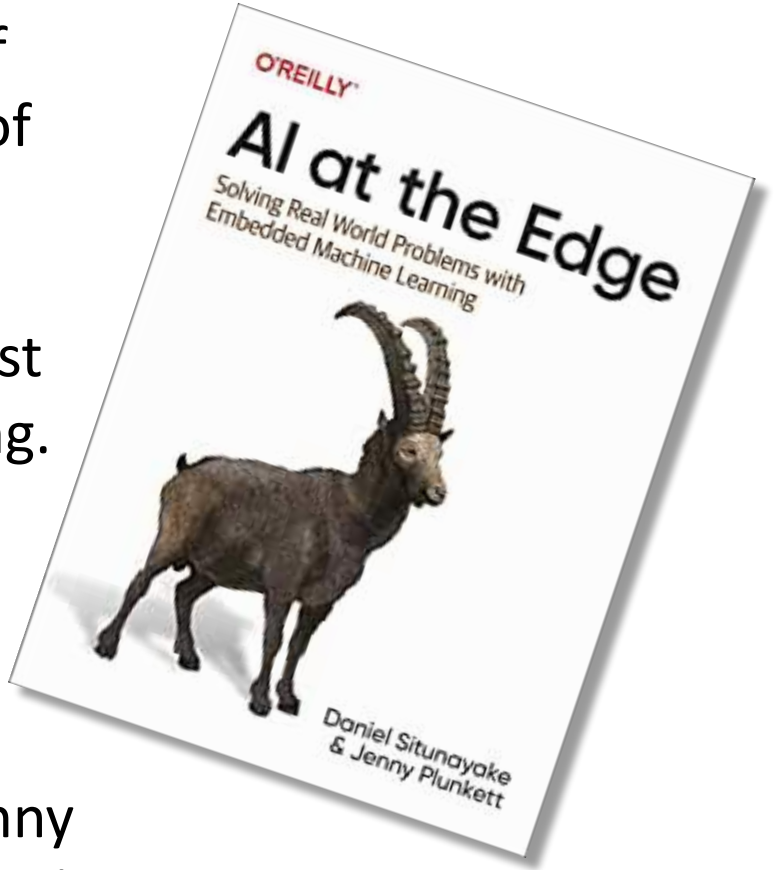
TinyML4D Academic Network Co-Chair

UNIFEI

"Edge AI is a truly complete technology. As a topic, it makes use of knowledge from everything from the physical properties of semiconductor electronics all the way up to the engineering of high-level architectures that span devices and the cloud. It demands expertise in the most cutting-edge approaches to artificial intelligence and machine learning along with the most venerable skills of bare-metal embedded software engineering. It makes use of the entire history of computer science and electrical engineering, laid out end to end."



Situnayake, Daniel; Plunkett, Jenny
AI at the Edge (pp. 215-216)
O'Reilly Media

Marcelo Rovai was born in São Paulo and holds a Master's degree in Data Science from the Universidad del Desarrollo (UDD) in Chile and an MBA from IBMEC (INSPER) in Brazil. He graduated in 1982 as an Engineer from UNIFEI, Federal University of Itajubá, with a specialization from Escola Politécnica de Engenharia of São Paulo University (USP), both institutions located in Brazil.

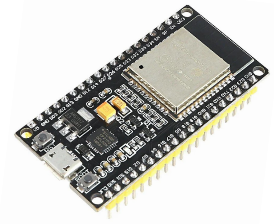
Rovai has experience as a teacher, engineer, and executive in several technology companies such as CDT/ETEP, AVIBRAS Aeroespacial, SID Informática, ATT-GIS, NCR, DELL, COMPAQ (HP), and more recently at IGT as a VP and a Senior Advisor for Latin America.

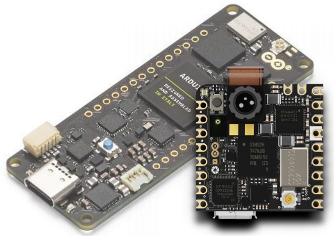
Marcelo Rovai publishes articles about electronics on websites such as MJRoBot.org, Hackster.io, Instructables.com, and Medium.com. Furthermore, he is a volunteer Professor at the UNIFEI in Brazil and a lecturer at several Congresses and Universities on IoT and TinyML. He is an active member and a Co-Chair of the TinyML4D group, an initiative to bring TinyML education to developing countries.

Hardware

Hardware

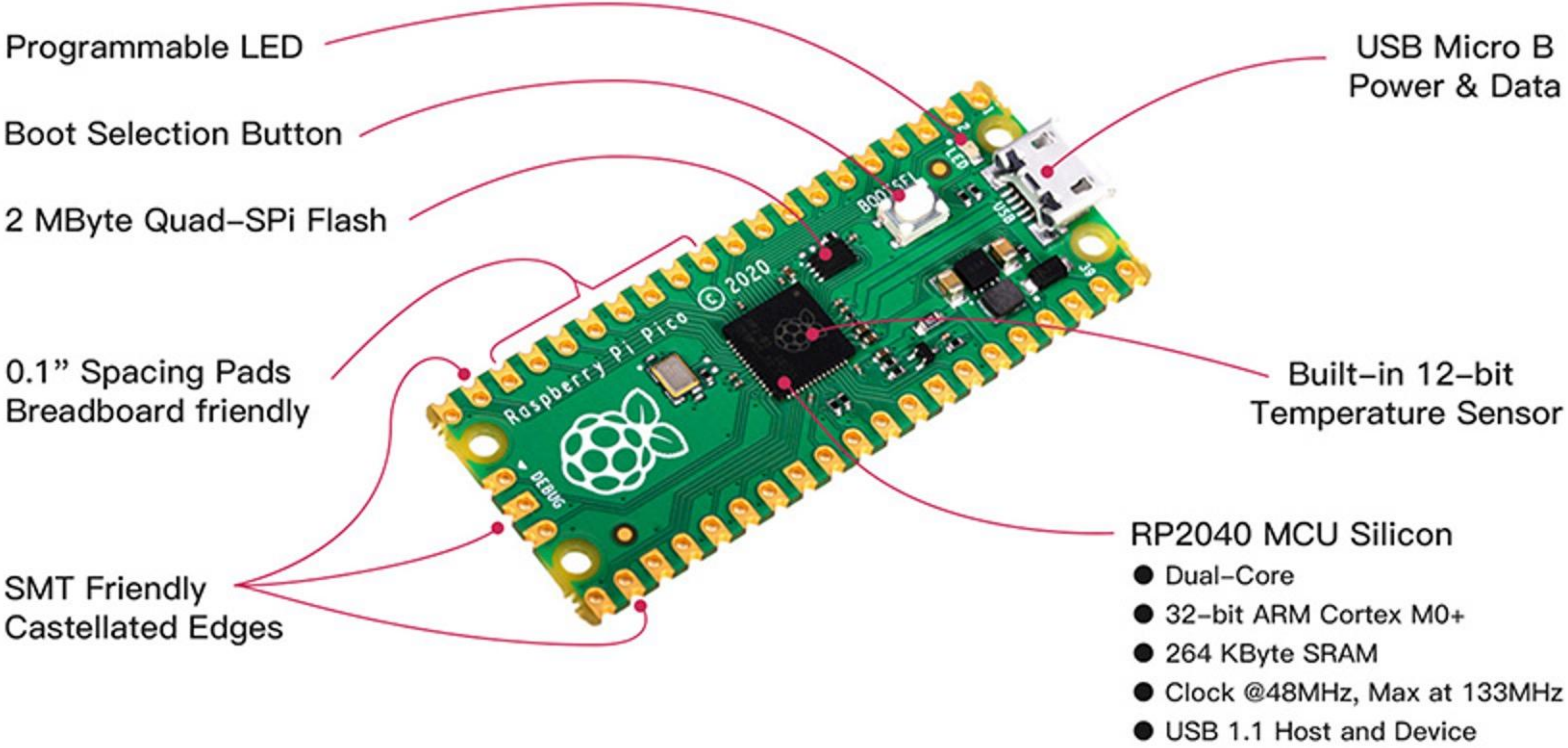






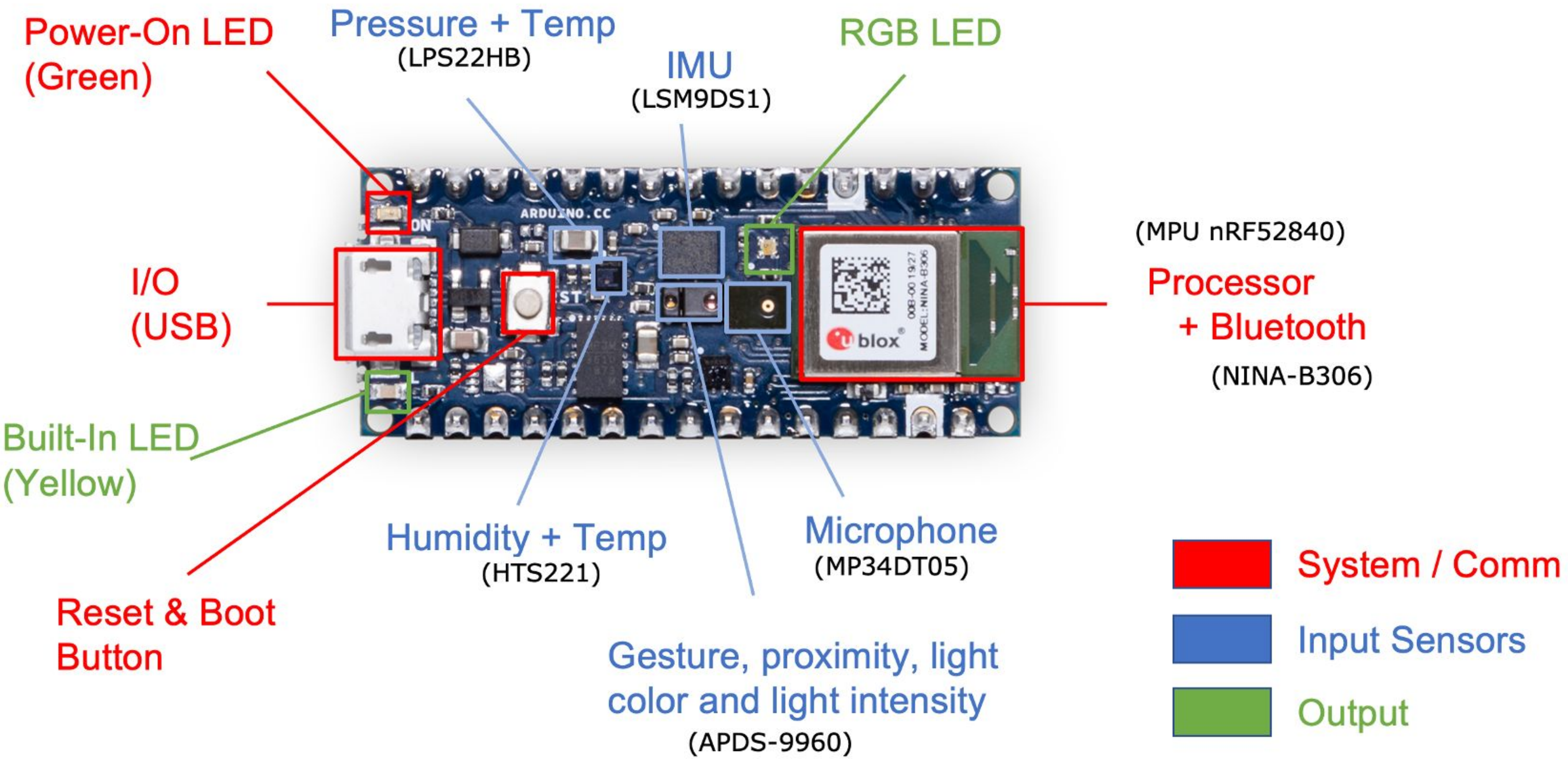
	Raspberry Pico (W)	Arduino Nano Sense	ESP 32	Seeed XIAO Sense / ESP32S3	Arduino Pro
32Bits CPU	Dual-core Arm Cortex-M0+	Arm Cortex-M4F	Xtensa LX6 Dual Core	Arm Cortex-M4F (BLE) Xtensa LX7 Dual Core	Dual Core Arm Cortex M7/M4
CLOCK	133MHz	64MHz	240MHz	64 / 240MHz	480/240MHz
RAM	264KB	256KB	520KB (part available)	256KB / 8MB	1MB
ROM	2MB	1MB	2MB	2MB / 8MB	2MB
Radio	(Yes for W)	BLE	BLE/WiFi	BLE / WiFi (ESP32S3)	BLE/WiFi
Sensors	No	Yes	No	Yes (Sense)	Yes (Nicla)
Bat. Power Manag.	No	No	No	Yes	Yes
Price	$	$$$	$	$$	$$$$$

https://media.digikey.com/Resources/Maker/the-original-guide-to-boards-2022.pdf

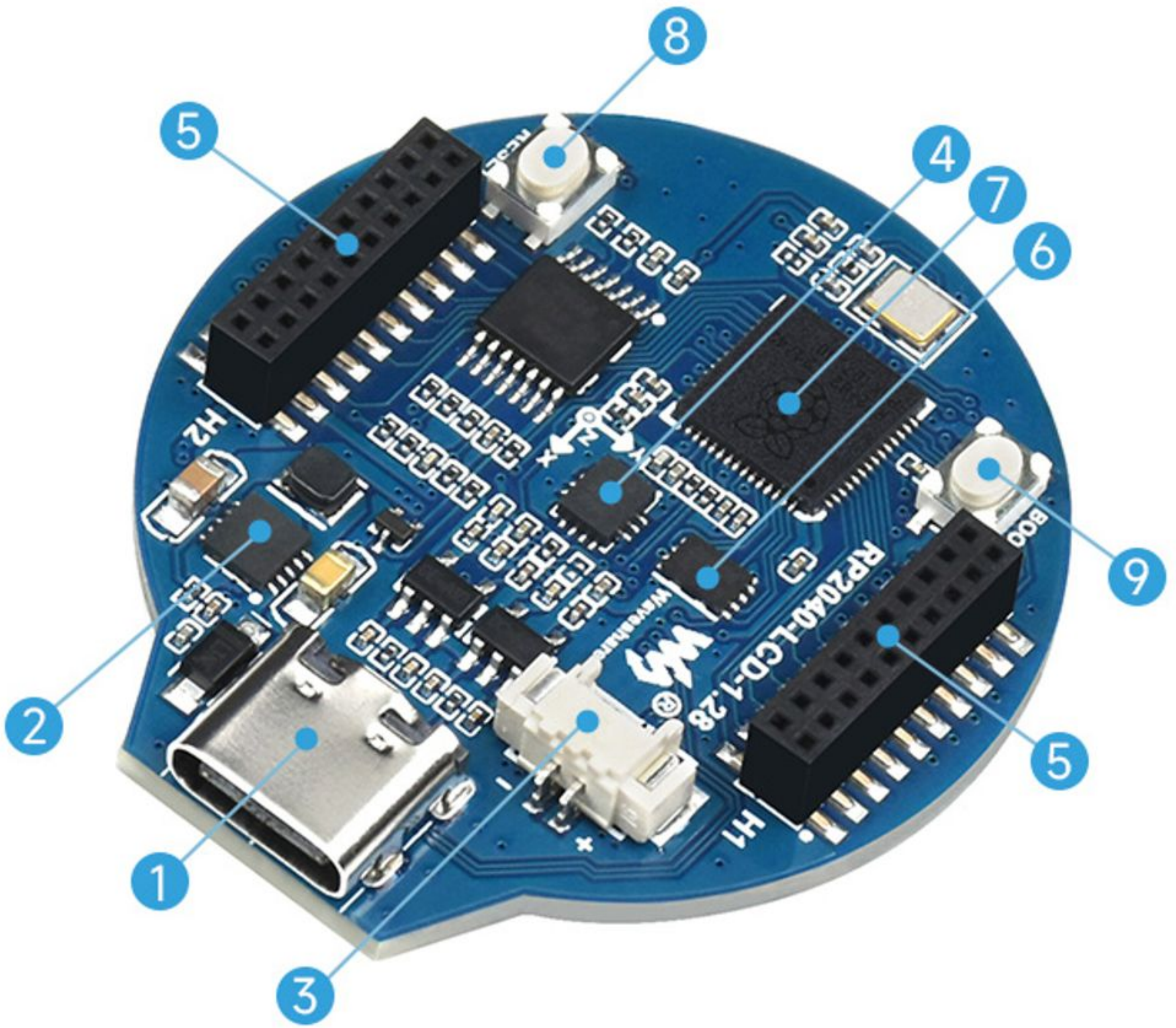


Programmable LED
Boot Selection Button
2 MByte Quad-SPi Flash
0.1" Spacing Pads
Breadboard friendly
SMT Friendly
Castellated Edges
USB Micro B
Power & Data
Built-in 12-bit
Temperature Sensor
RP2040 MCU Silicon
● Dual-Core
● 32-bit ARM Cortex M0+
● 264 KByte SRAM
● Clock @48MHz, Max at 133MHz
● USB 1.1 Host and Device

Nano 33 BLE Sense (Development board)

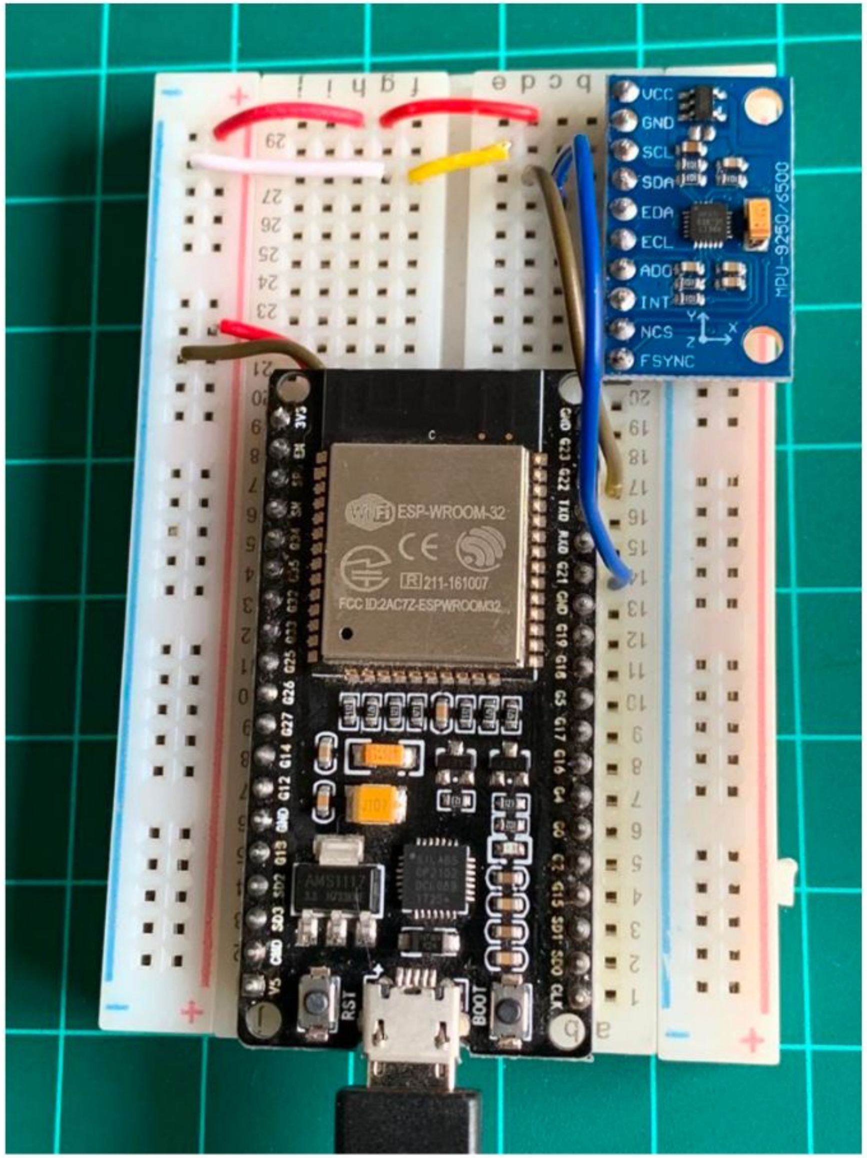


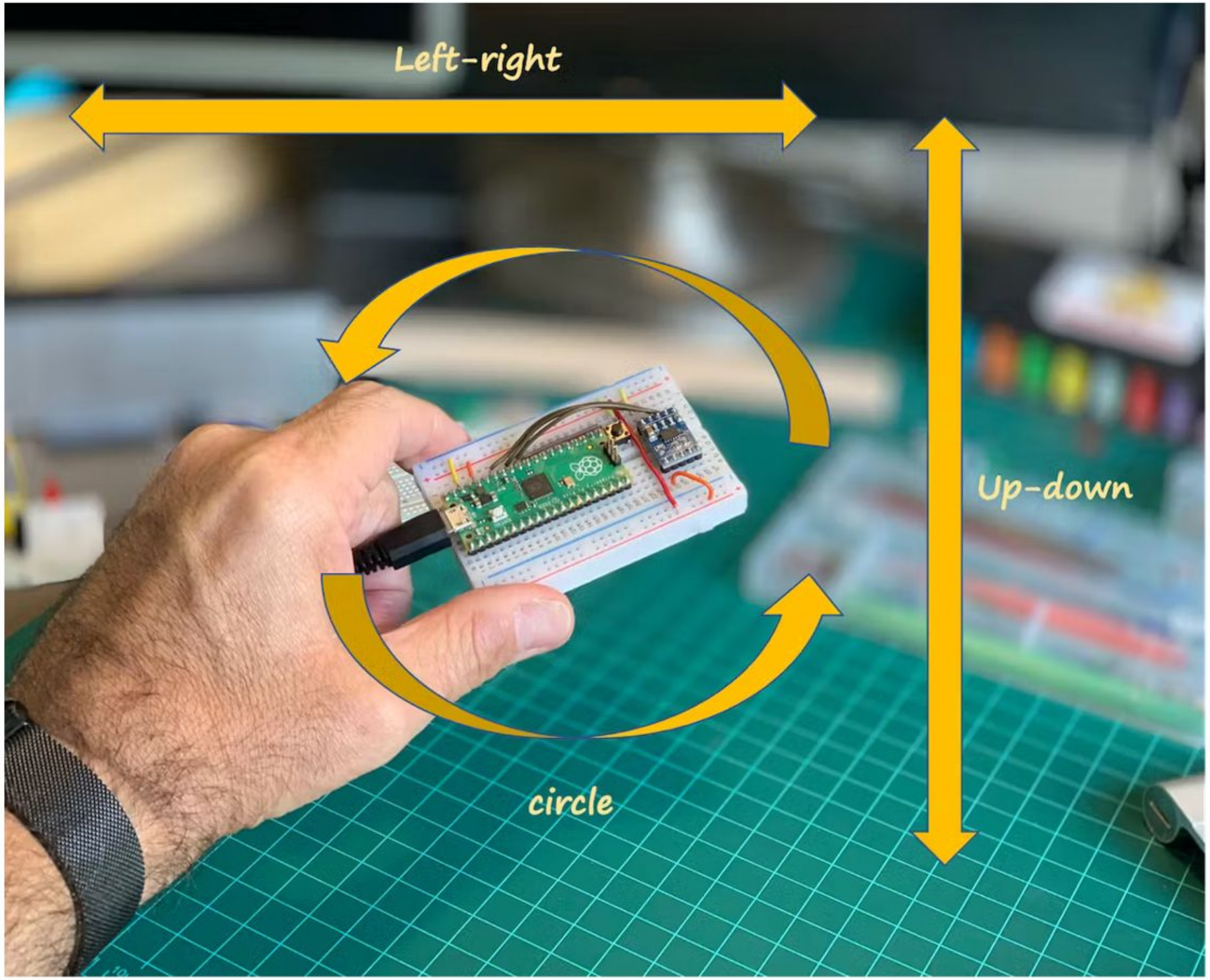
RP2040 MCU Board, with LCD, accelerometer, and gyroscope Sensor



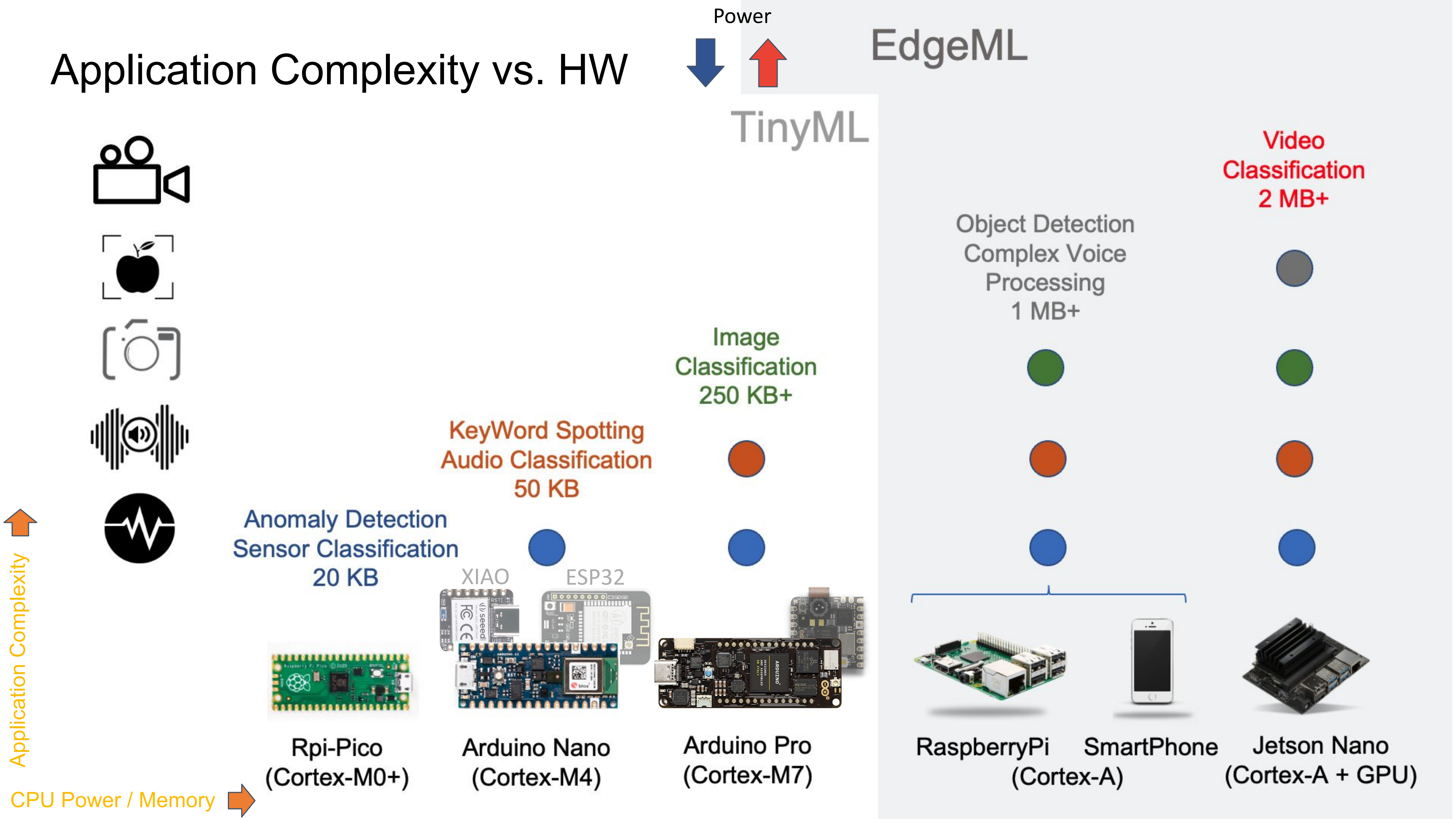
1. **USB Type-C connector**
   USB 1.1 with device and host support
2. **ETA6096**
   high efficiency Lithium battery recharge manager
3. **Battery Header**
   MX1.25 header, for 3.7V Lithium battery, allows recharging the battery and powering the board at the same time
4. **QMI8658C**
   IMU, includes a 3-axis gyroscope and a 3-axis accelerometer

5. **1.27mm pitch headers**
   Adapting all GPIO and Debug pins
6. **W25Q16JVUXIQ**
   2MB NOR-Flash
7. **RP2040**
   Dual-core processor, up to 133MHz operating frequency
8. **RESET Button**
9. **BOOT Button**
   press it when resetting to enter download mode

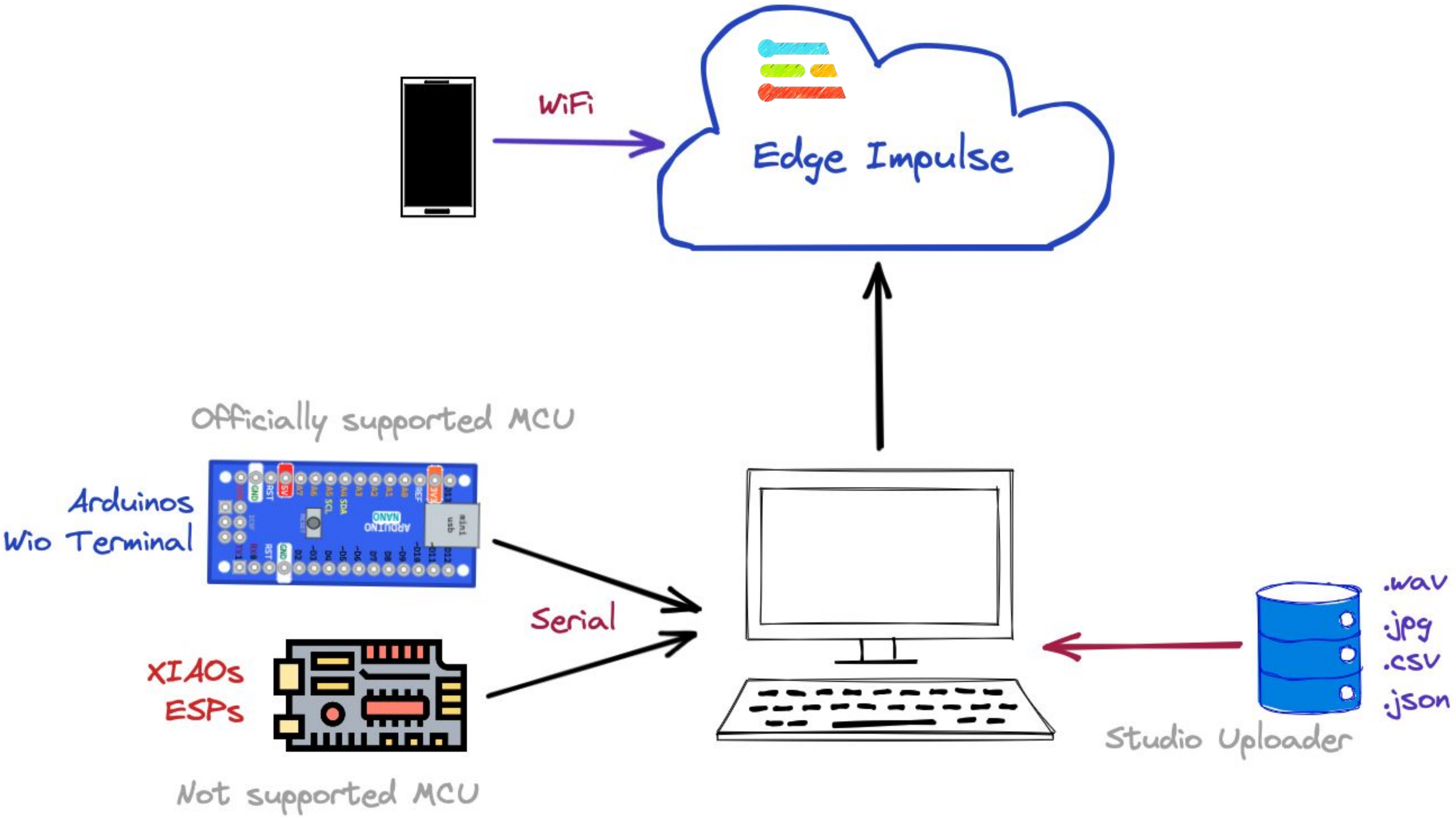

ESP-WROOM-32
VCC
GND
SCL
SDA
EDA
ECL
ADO
INT
NCS
FSYNC
MPU-9250/6500


Left-right
Up-down
circle

Application Complexity vs. HW

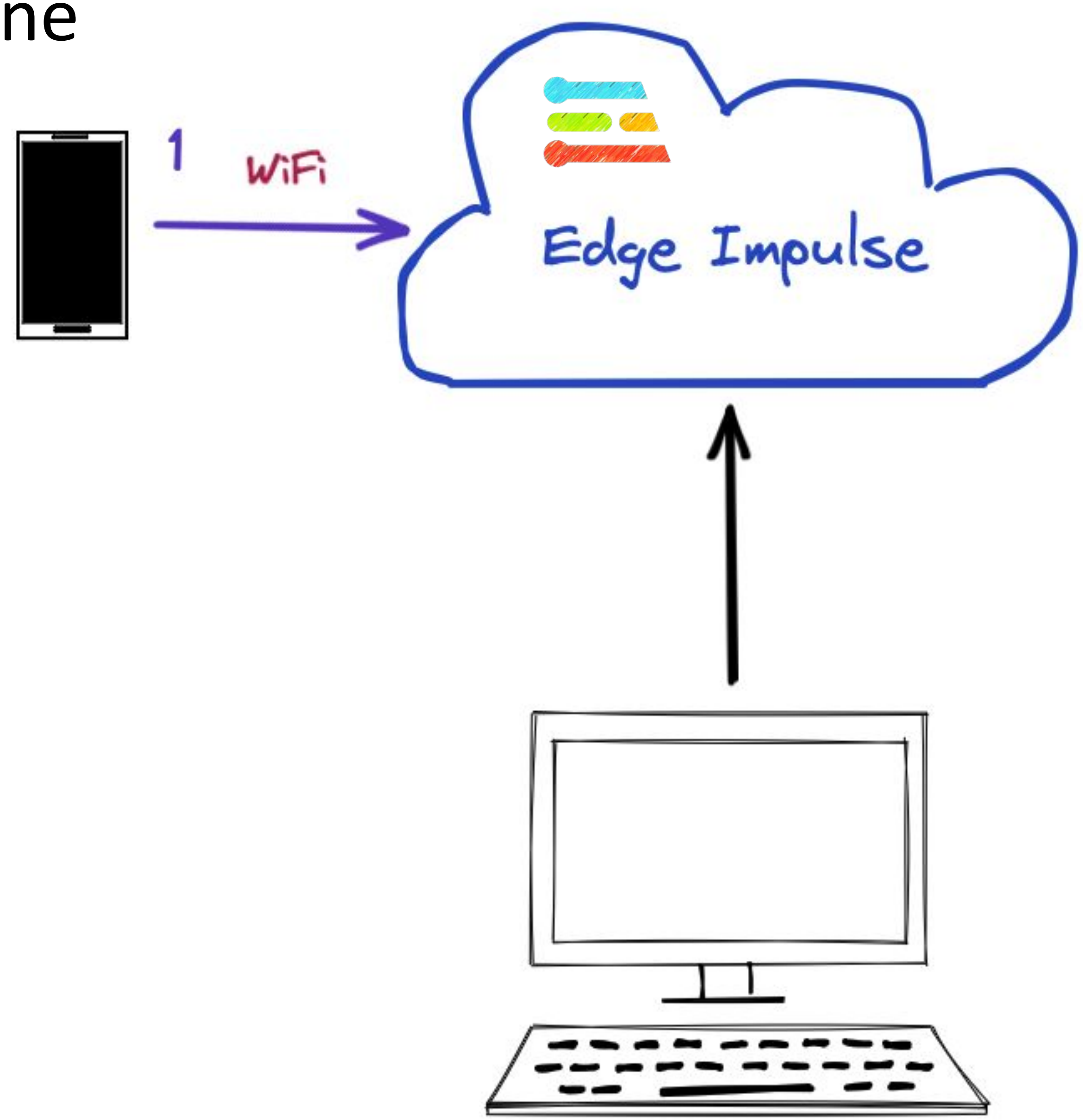


EI Studio Data Ingestion
Alternative methods

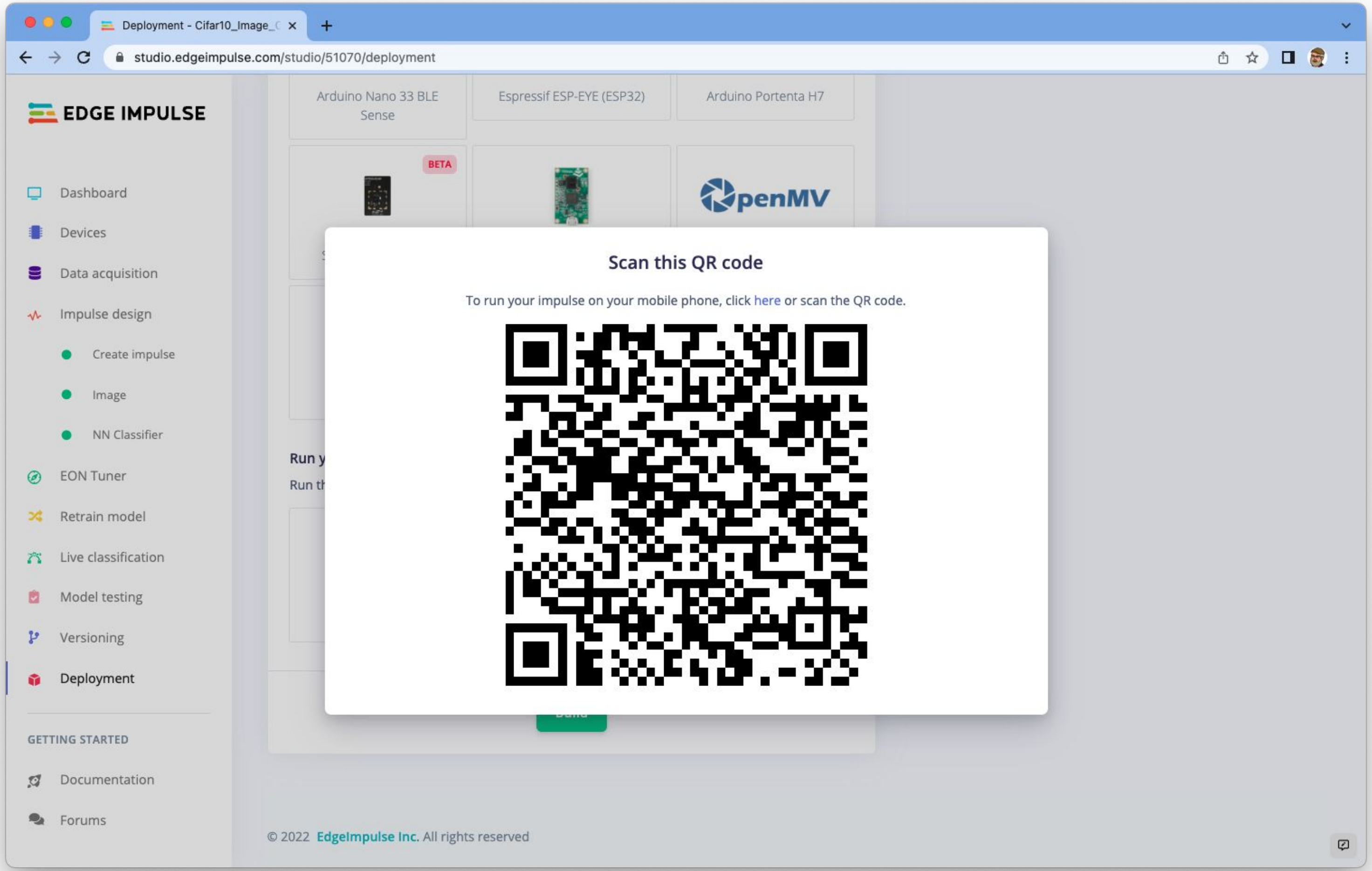


WiFi
Edge Impulse
Officially supported MCU
Arduinos
Wio Terminal
Serial
XIAOs
ESPs
Not supported MCU
.wav
.jpg
.csv
.json
Studio Uploader

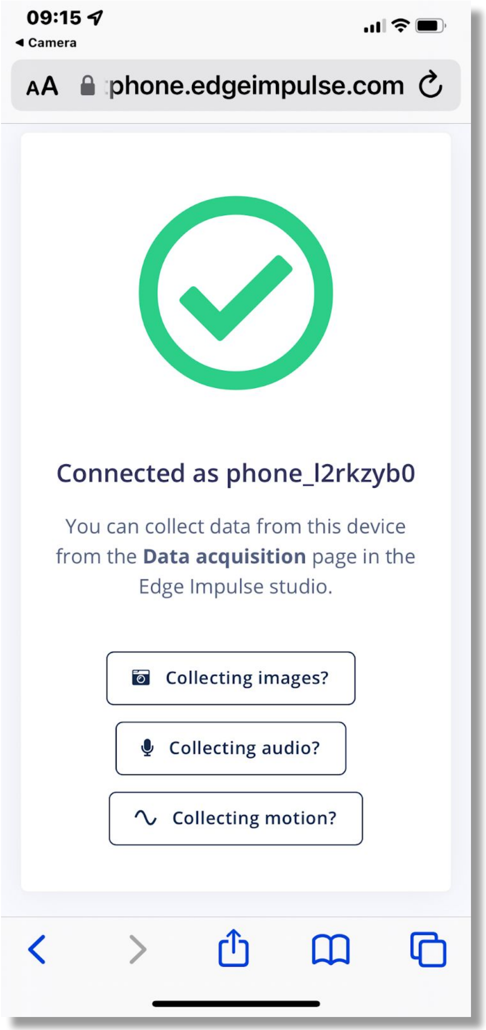
1. SmartPhone

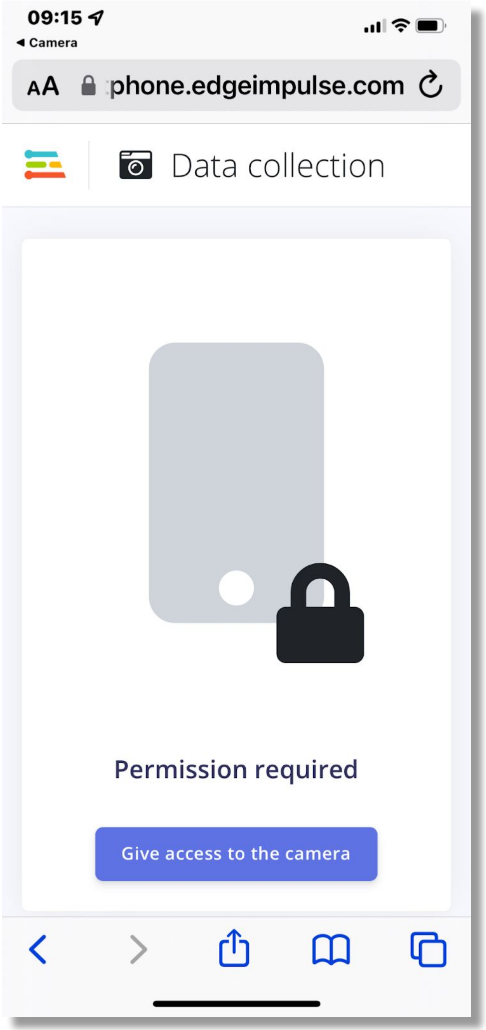


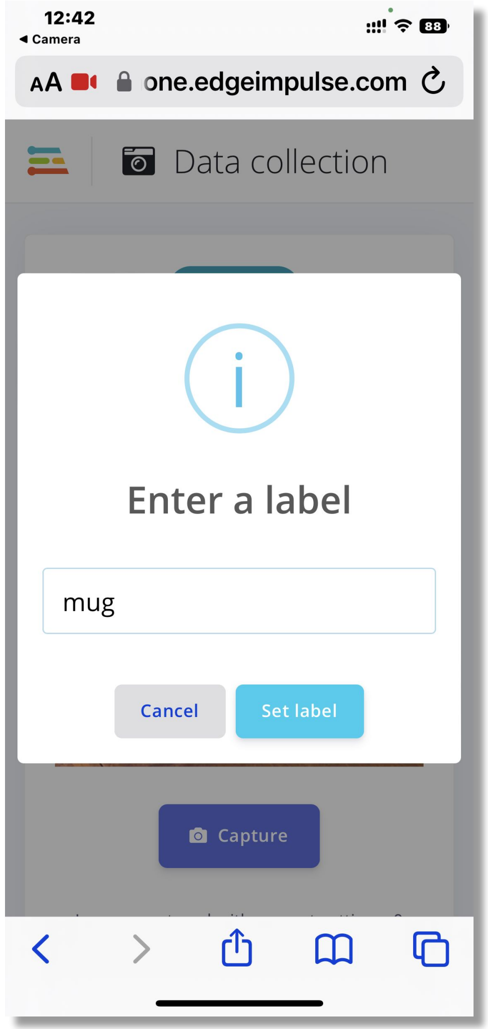
1. Data Ingestion using Smart Phone

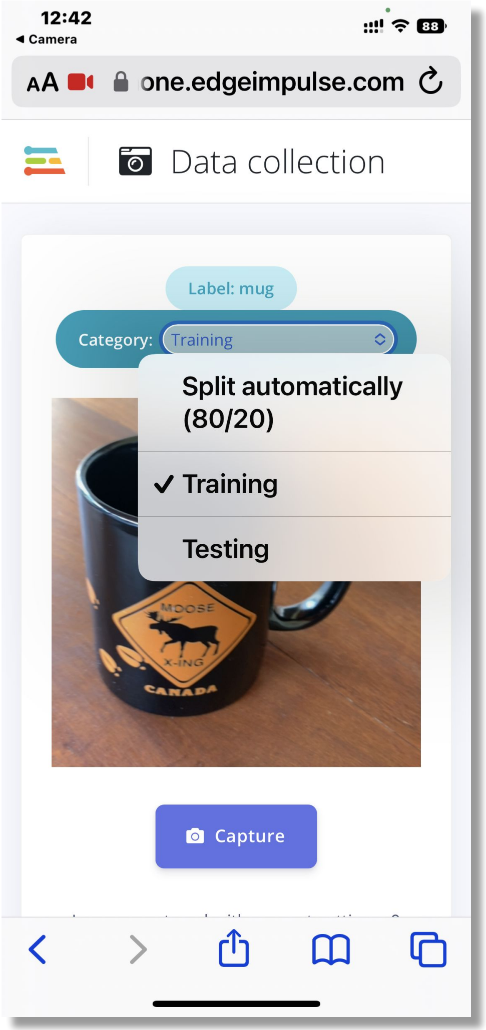


1. Data Capture and model Training

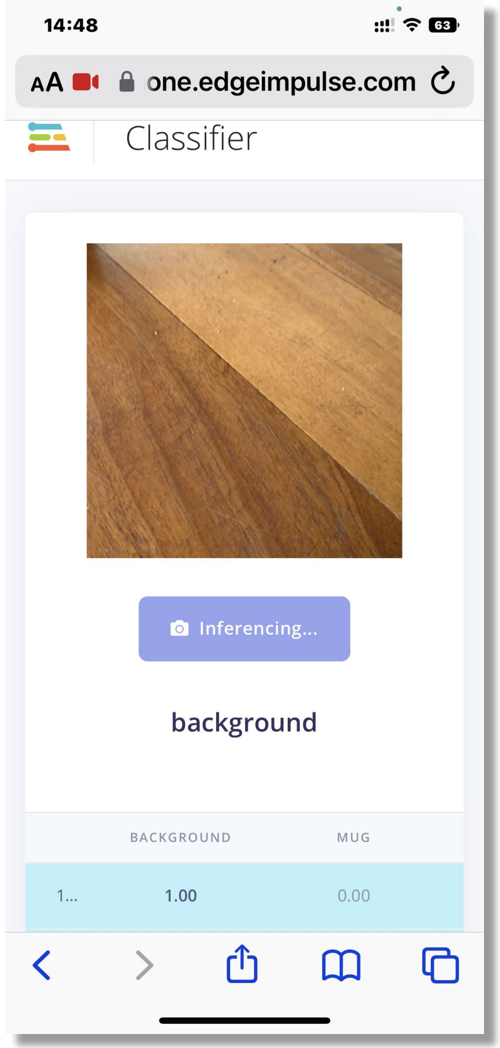


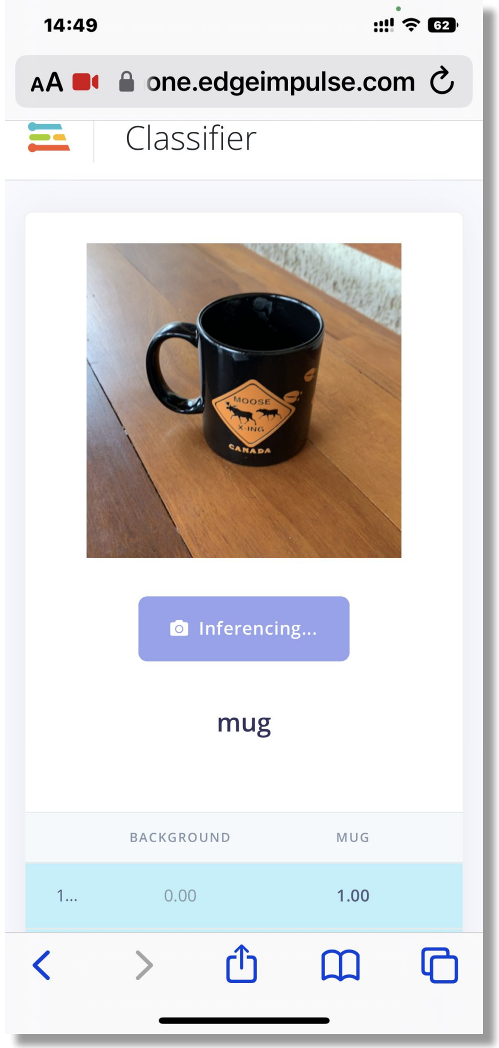


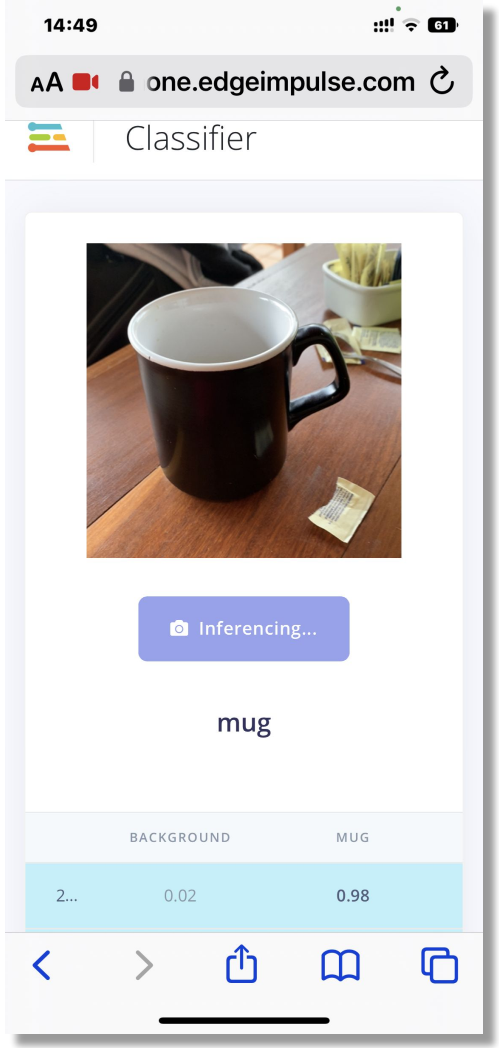


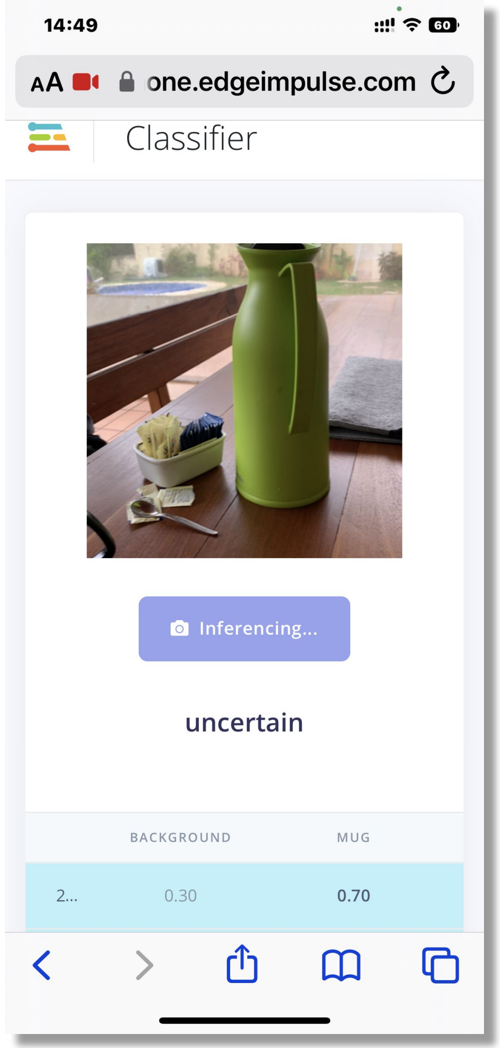


1. Off-Line Inference

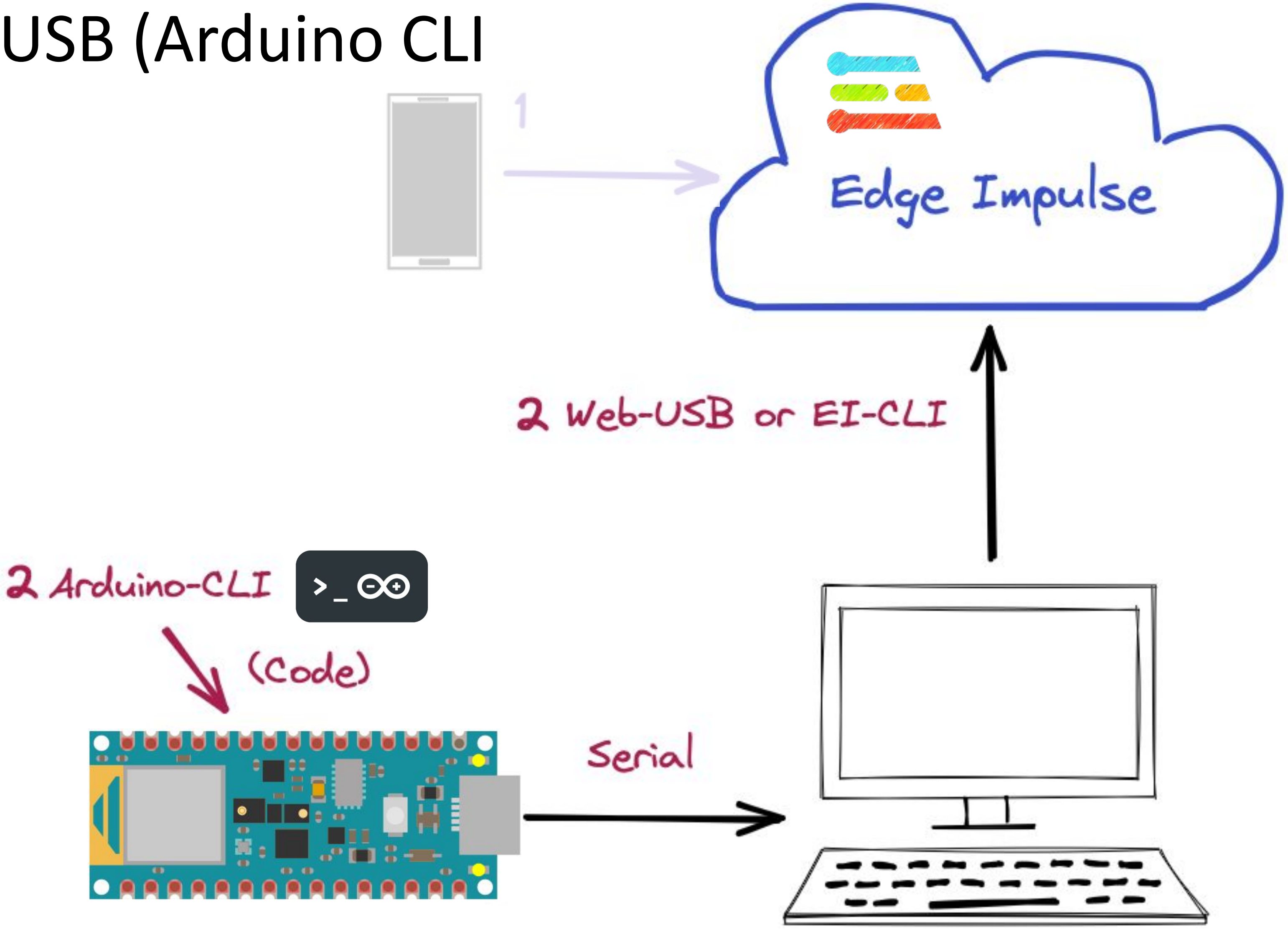




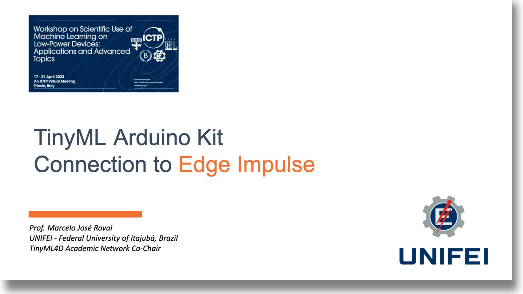




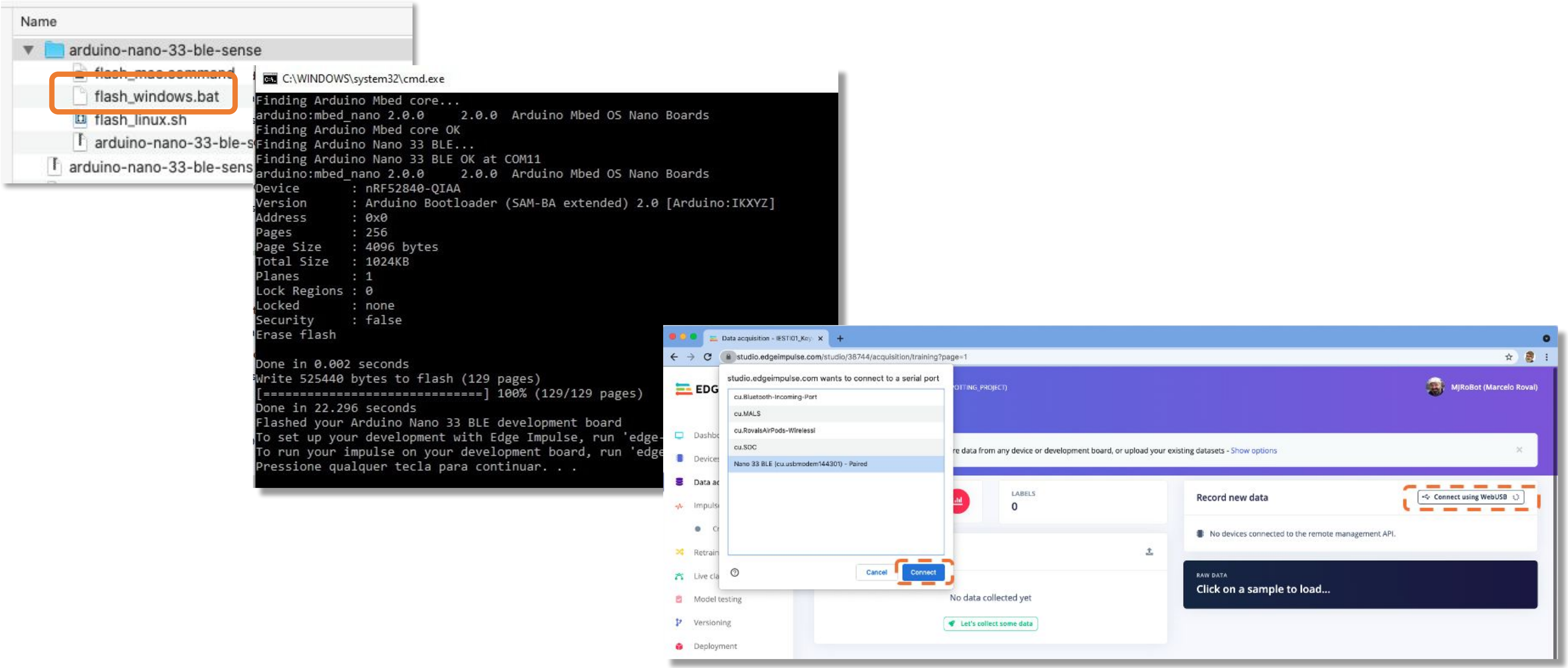
2. Web-USB (Arduino CLI



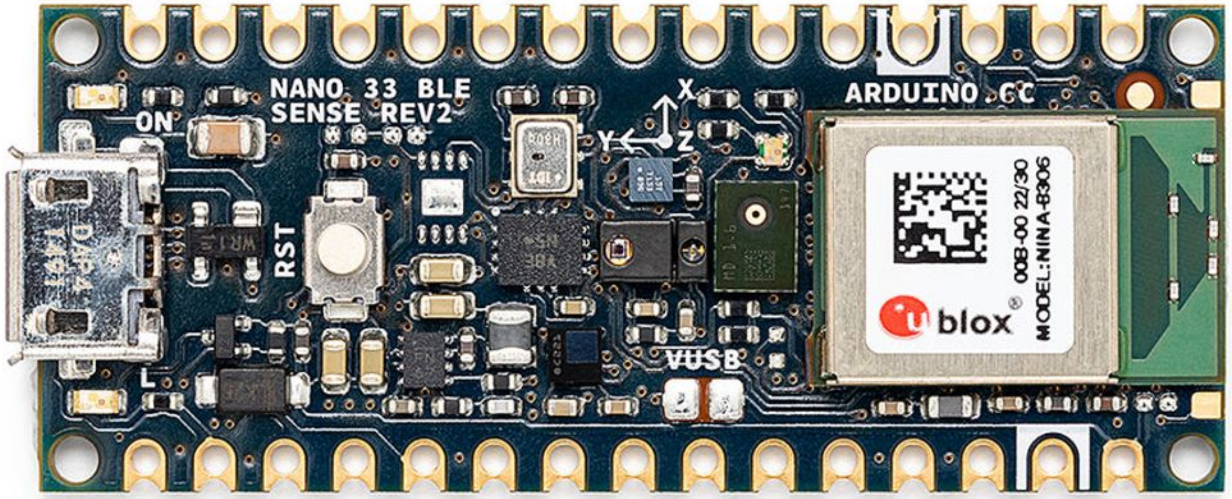
Issue: Limited MCU and sensors



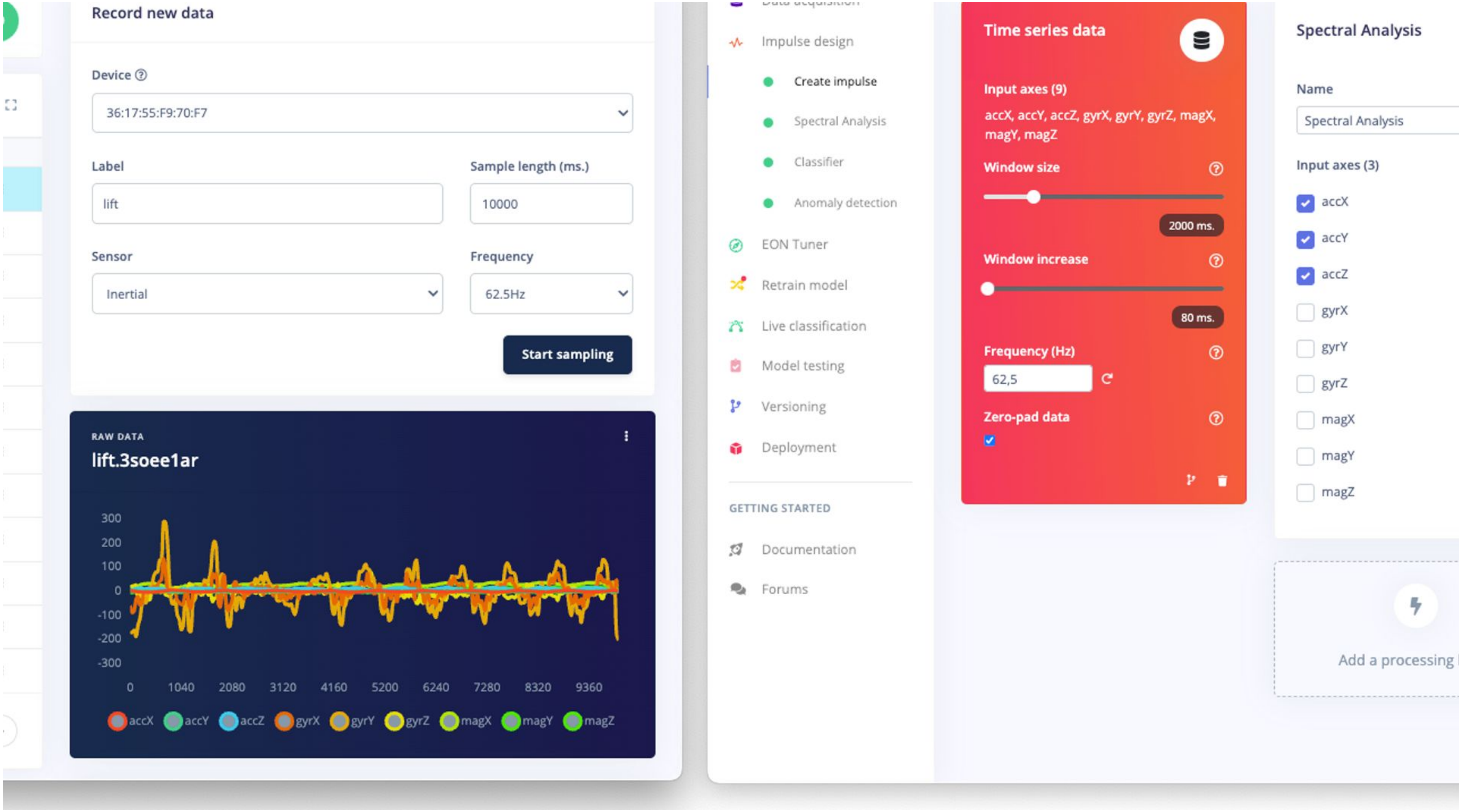
2. Data Ingestion using Arduino-Cli + Web-USB (or EI-CLI)



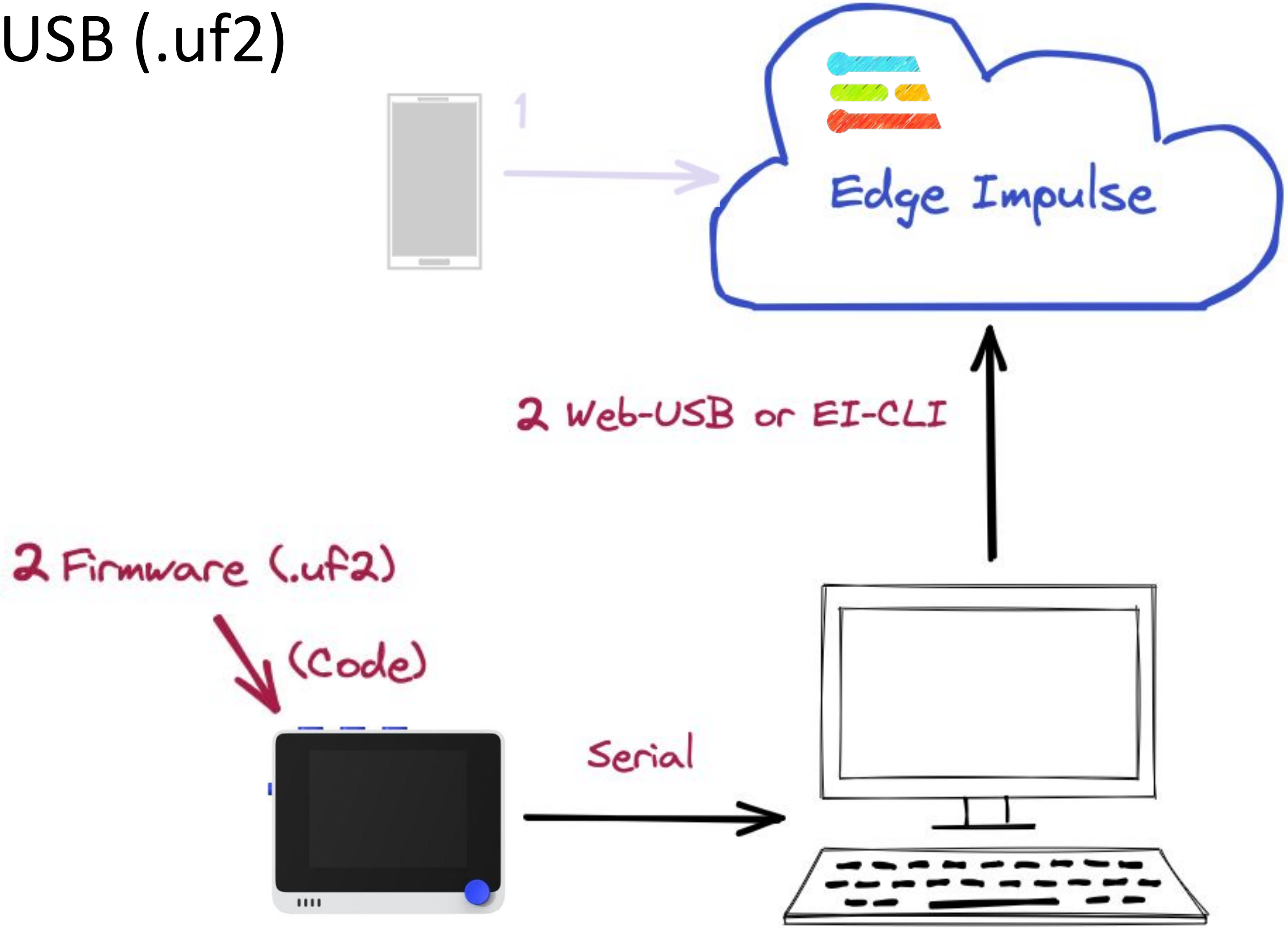
Arduino Nano 33 BLE Sense **Rev2**



- **IMU** - LSM9DS1 - 9 axis ➔ BMI270 – 6 axis + BMM150 - 3 axis
- **Temperature and humidity sensor -** HTS221 ➔ HS3003
- **Microphone -** MP34DT05 ➔ MP34DT06JTR.


Record new data
Device
36:17:55:F9:70:F7
Label
lift
Sample length (ms.)
10000
Sensor
Inertial
Frequency
62.5Hz
Start sampling
RAW DATA
lift.3soee1ar
300
200
100
0
-100
-200
-300
0
1040
2080
3120
4160
5200
6240
7280
8320
9360
accX
accY
accZ
gyrX
gyrY
gyrZ
magX
magY
magZ
Impulse design
Create impulse
Spectral Analysis
Classifier
Anomaly detection
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
Time series data
Input axes (9)
accX, accY, accZ, gyrX, gyrY, gyrZ, magX, magY, magZ
Window size
2000 ms.
Window increase
80 ms.
Frequency (Hz)
62,5
Zero-pad data
Spectral Analysis
Name
Spectral Analysis
Input axes (3)
accX
accY
accZ
gyrX
gyrY
gyrZ
magX
magY
magZ
Add a processing

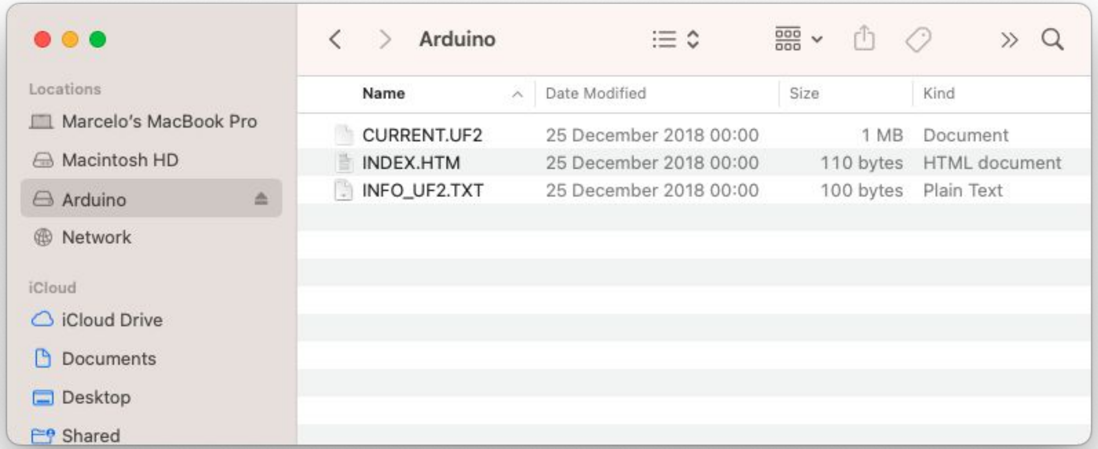
2. Web-USB (.uf2)

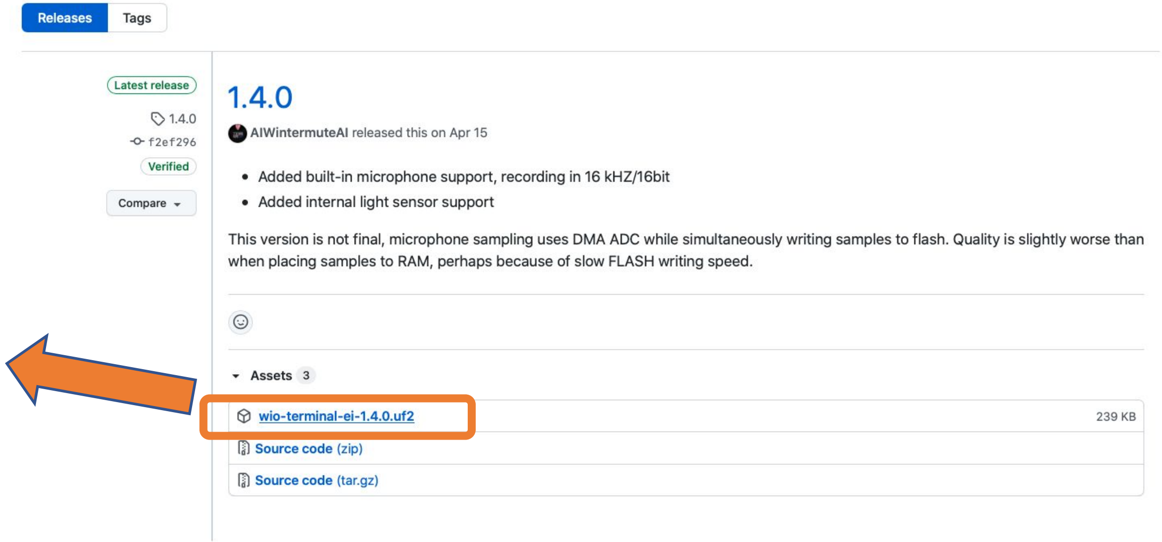


Issue: Limited MCU and sensors

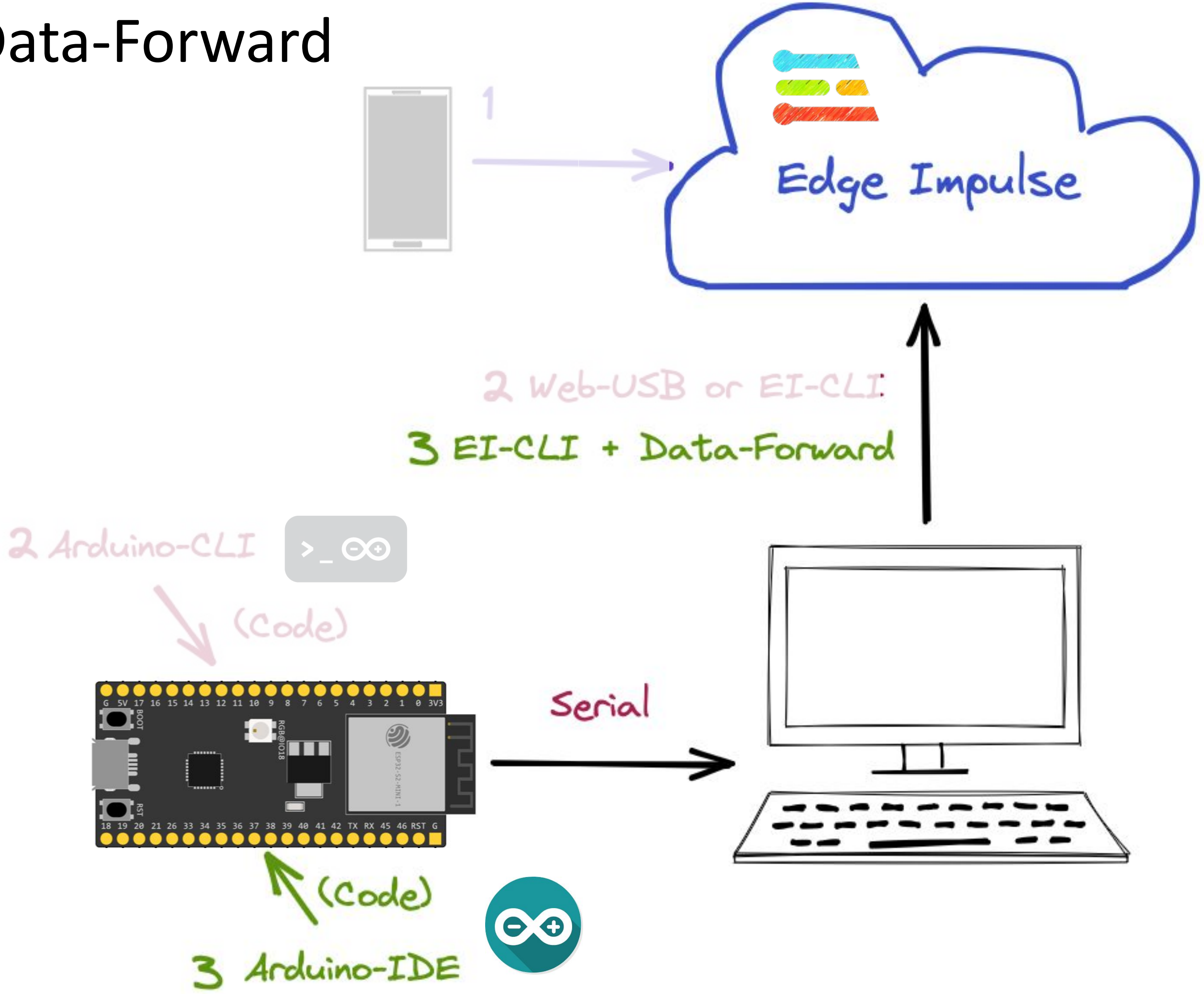
2. (.uf2) Firmware installation

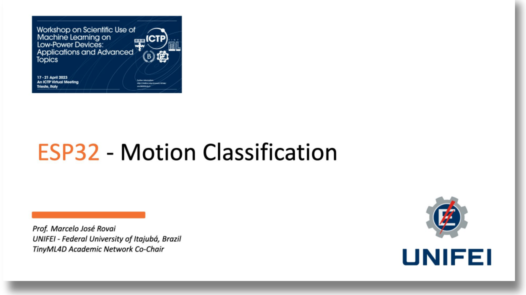
1. Connect Wio Terminal to your computer.
2. Entering the bootloader mode by sliding the power switch twice quickly.
3. An external drive named Arduino should appear in your PC.
4. Drag the the downloaded [Edge Impulse uf2 firmware files]() to the Arduino drive. Now, Edge Impulse is loaded on Seeeduino Wio Terminal!



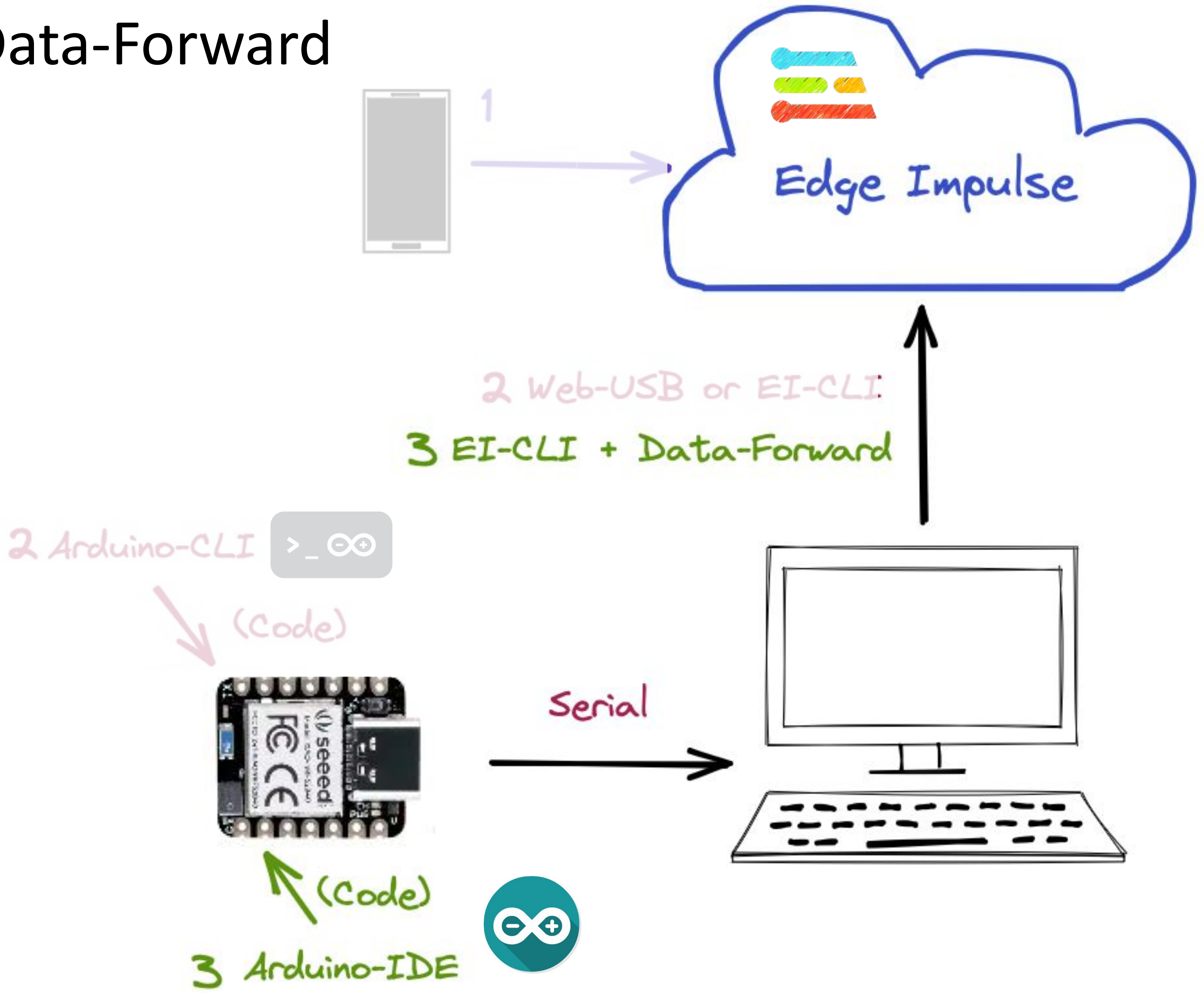


3. Data-Forward





3. Data-Forward



2. Data Ingestion using EI-Cli + Data Forward

XIAO_BLE_Sense_Accelerometer_Data_Forewarder | Arduino 1.8.19

XIAO_BLE_Sense_Accelerometer_Data_Forewarder §

```
  Marcelo Rovai @July2022
*/
#include "LSM6DS3.h"
#include "Wire.h"

//Create an instance of class LSM6DS3
LSM6DS3 xIMU(I2C_MODE, 0x6A);    //I2C device address 0x6A

#define CONVERT_G_TO_MS2    9.80665f
#define FREQUENCY_HZ        50
#define INTERVAL_MS         (1000 / (FREQUENCY_HZ + 1))
static unsigned long last_interval_ms = 0;

void setup() {
  Serial.begin(115200);
  while (!Serial);

  if (xIMU.begin() != 0) {
      Serial.println("Device error");
  } else {
      Serial.println("Device OK!");
  }
  Serial.println("Data Forwarder - Built-in IMU on the XIAO BLE Sense\n");
}

void loop() {
    float x, y, z;
    if (millis() > last_interval_ms + INTERVAL_MS) {
        last_interval_ms = millis();
        x = xIMU.readFloatAccelX();
        y = xIMU.readFloatAccelY();
        z = xIMU.readFloatAccelZ();

        Serial.print(x * CONVERT_G_TO_MS2);
        Serial.print('\t');
        Serial.print(y * CONVERT_G_TO_MS2);
        Serial.print('\t');
        Serial.println(z * CONVERT_G_TO_MS2);
    }
}
```

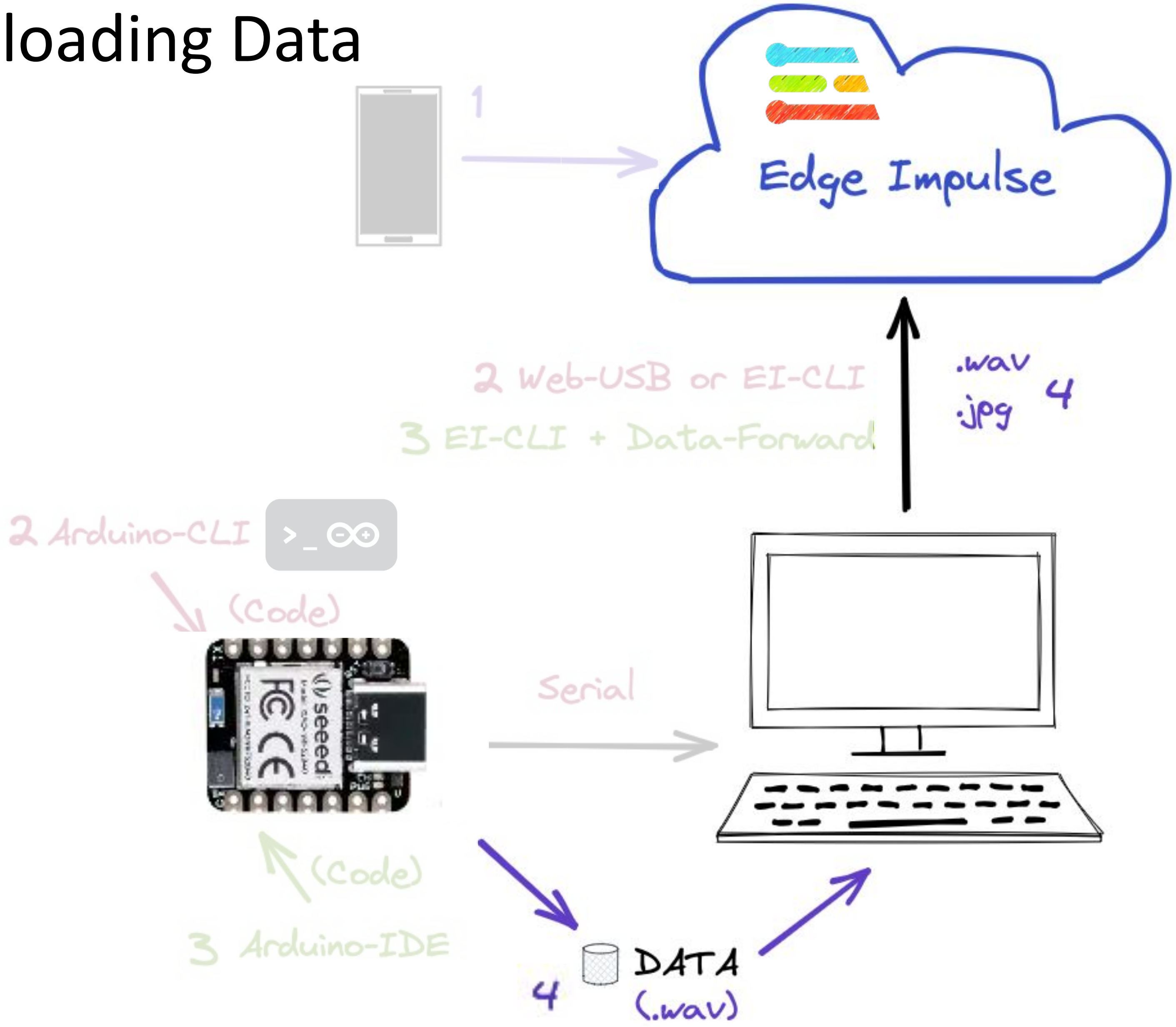
dio Wio Terminal, Master, Enabled, 120 MHz (standard), Small (-Os) (standard), 50 MHz (standard), Arduino, Off, On on /dev/cu.usbmodem1101

$ edge-impulse-data-forwarder --clean

mjrovai — -bash — 80×41

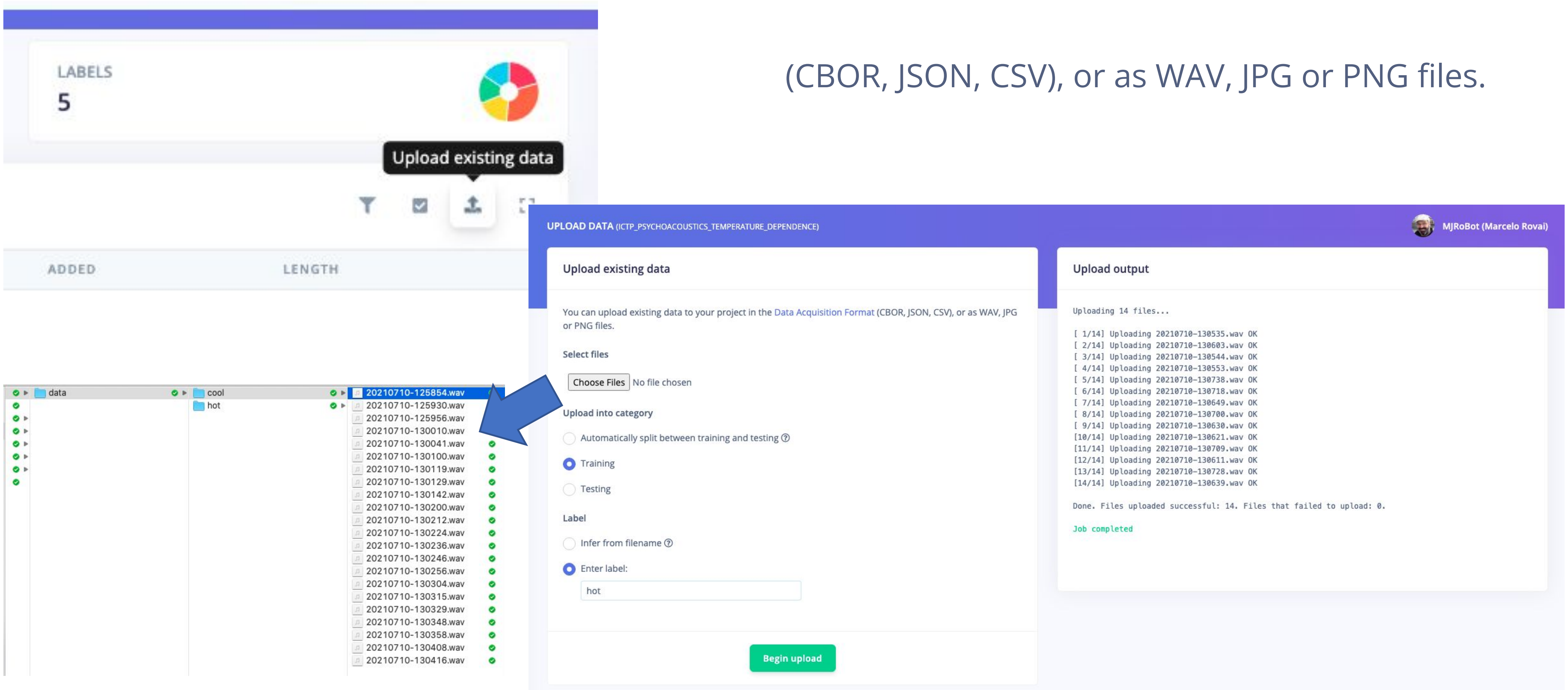
```
(base) MacBook-Pro-de-Marcelo:~ mjrovai$ edge-impulse-data-forwarder --clean
Edge Impulse data forwarder v1.12.2
? What is your user name or e-mail address (edgeimpulse.com)? rovai@mjrobot.org
? What is your password? [hidden]
Endpoints:
    Websocket: wss://remote-mgmt.edgeimpulse.com
    API:       https://studio.edgeimpulse.com/v1
    Ingestion: https://ingestion.edgeimpulse.com

[SER] Connecting to /dev/tty.usbmodem144301
[SER] Serial is connected (4A:5A:36:17:55:F9:70:F7)
[WS ] Connecting to wss://remote-mgmt.edgeimpulse.com
[WS ] Connected to wss://remote-mgmt.edgeimpulse.com

? To which project do you want to connect this device? MJRoBot (Marcelo Rovai) /
 IESTI01_Input_Data_Test
[SER] Detecting data frequency...
[SER] Detected data frequency: 51Hz
? 3 sensor axes detected (example values: [-0.08,-0.34,9.82]). What do you want
to call them? Separate the names with ',': accX, accY,
 accZ
? What name do you want to give this device? nano
[WS ] Device "nano" is now connected to project "IESTI01_Input_Data_Test"
[WS ] Go to https://studio.edgeimpulse.com/studio/39877/acquisition/training to
build your machine learning model!
[WS ] Incoming sampling request {
  path: '/api/training/data',
  label: 'left-right',
  length: 10000,
  interval: 19.607843137254903,
  hmacKey: '6ee929b90e563aa74517f505a3ecb9c8',
  sensor: 'Sensor with 3 axes (accX, accY, accZ)'
}
```

4. Uploading Data

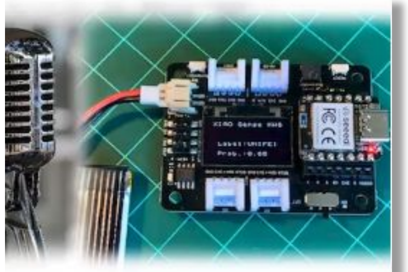


4. Data Ingestion using Upload existing Data

(CBOR, JSON, CSV), or as WAV, JPG or PNG files.

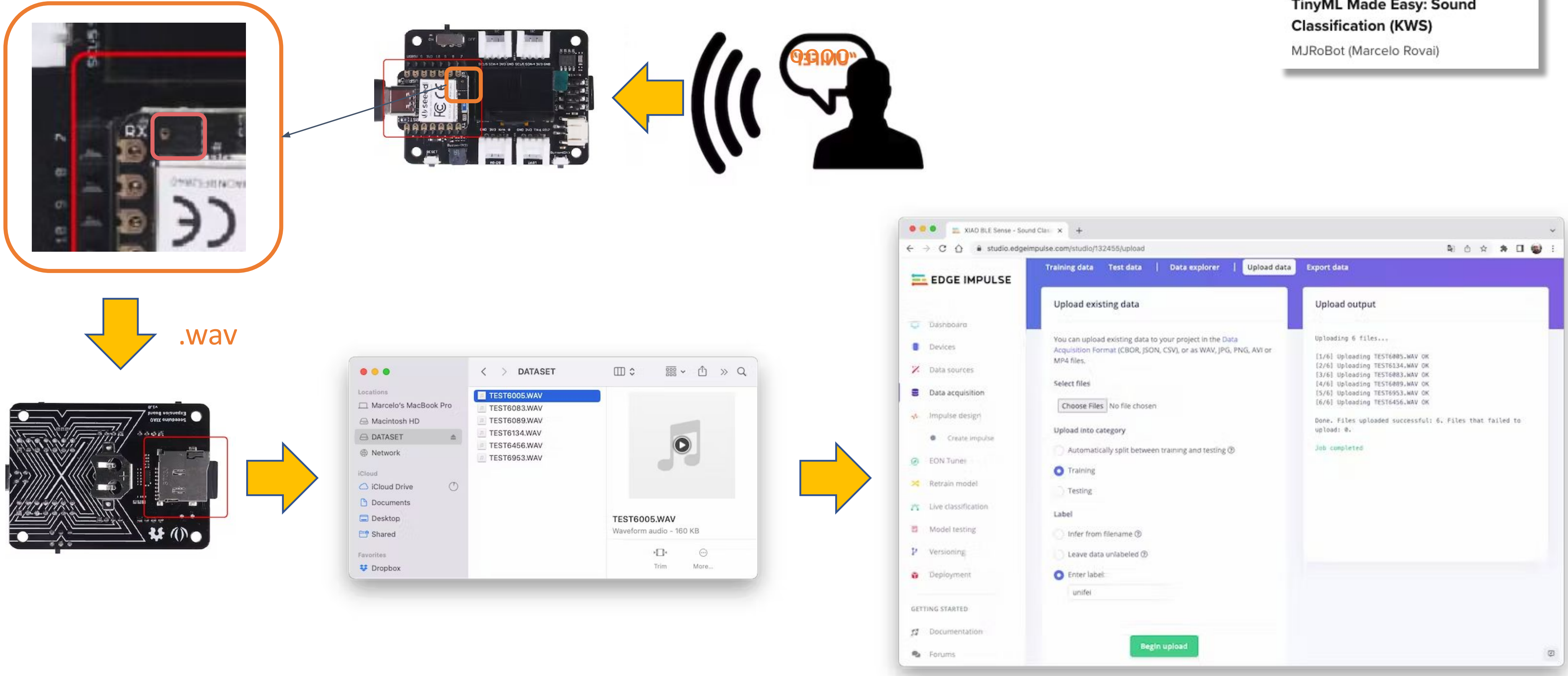


4. Uploading .wav data



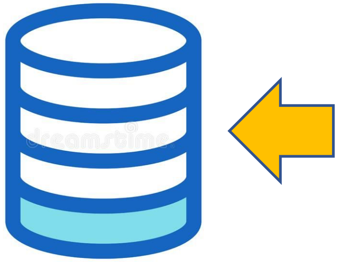
TinyML Made Easy: Sound Classification (KWS)

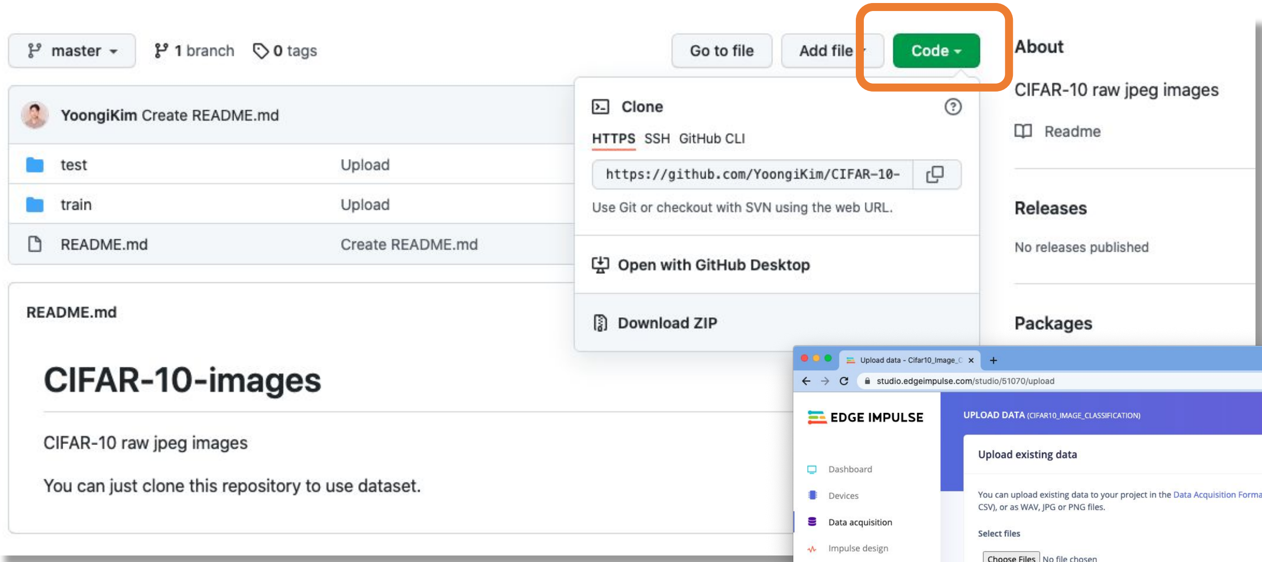
MJRoBot (Marcelo Rovai)

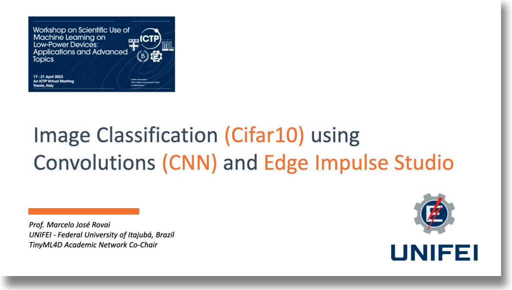


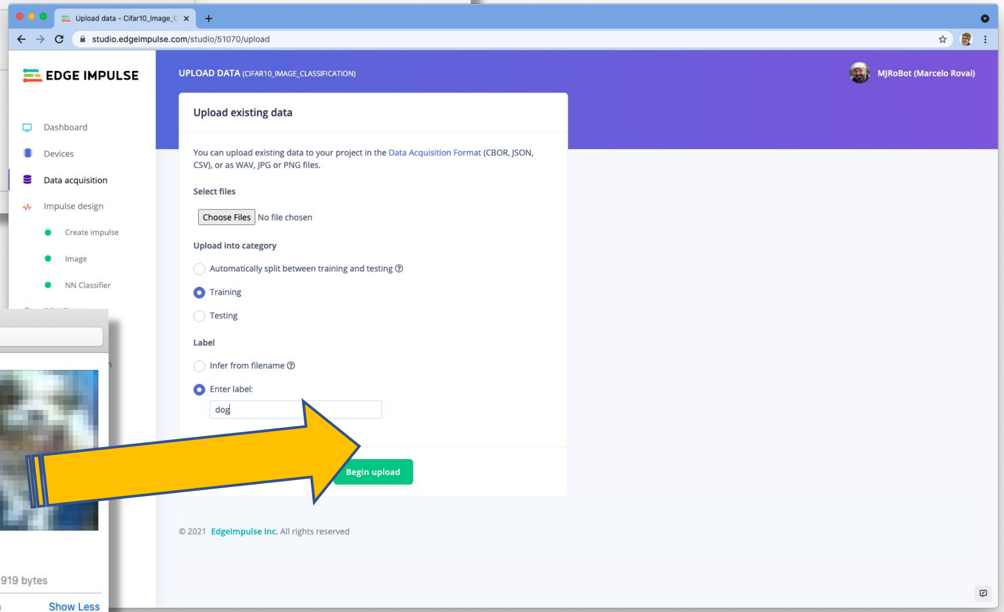
4. Uploading .jpg data

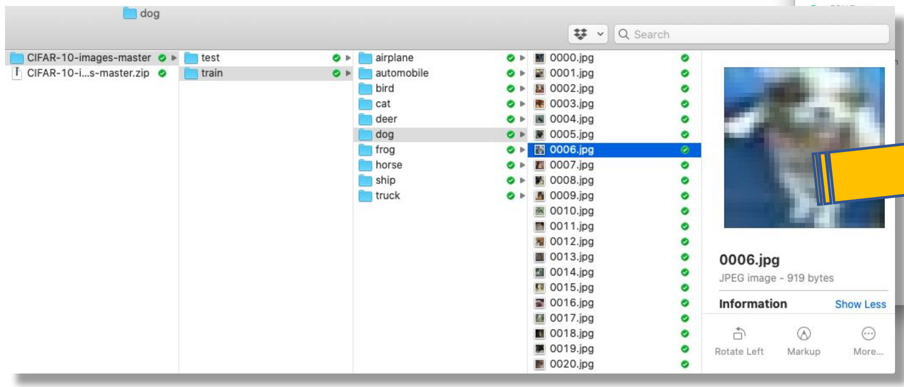
https://github.com/YoongiKim/CIFAR-10-images

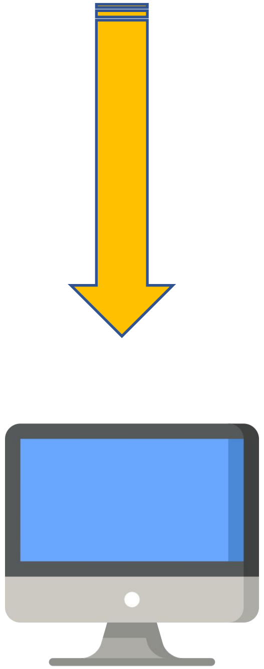




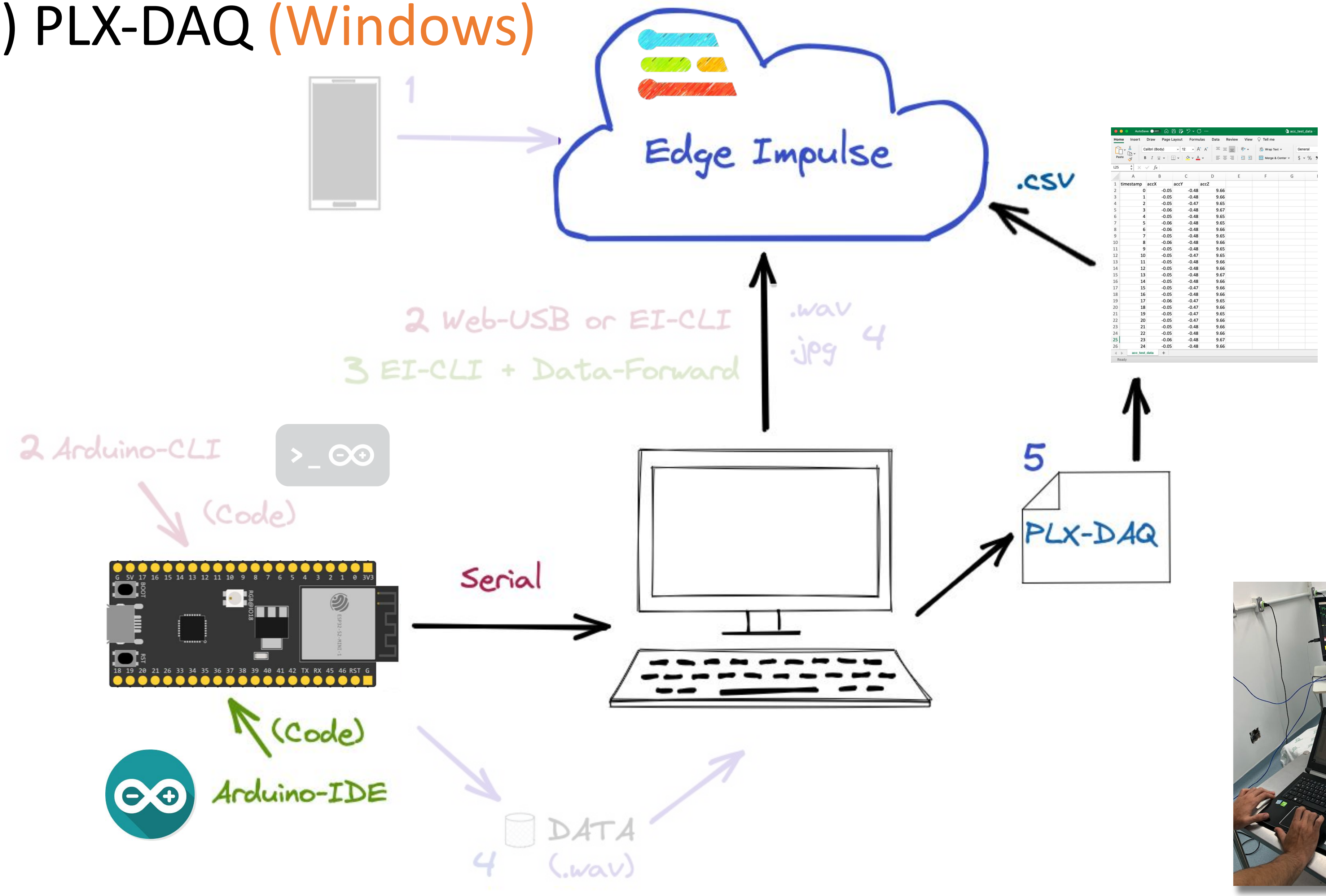


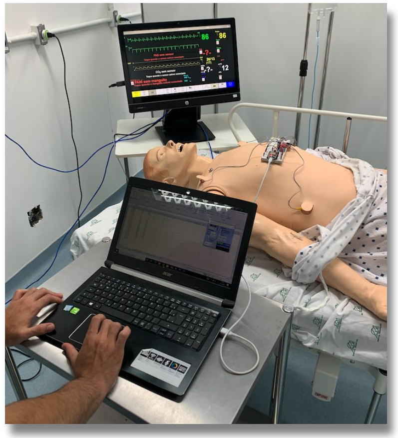






5. (.CSV) PLX-DAQ (Windows)





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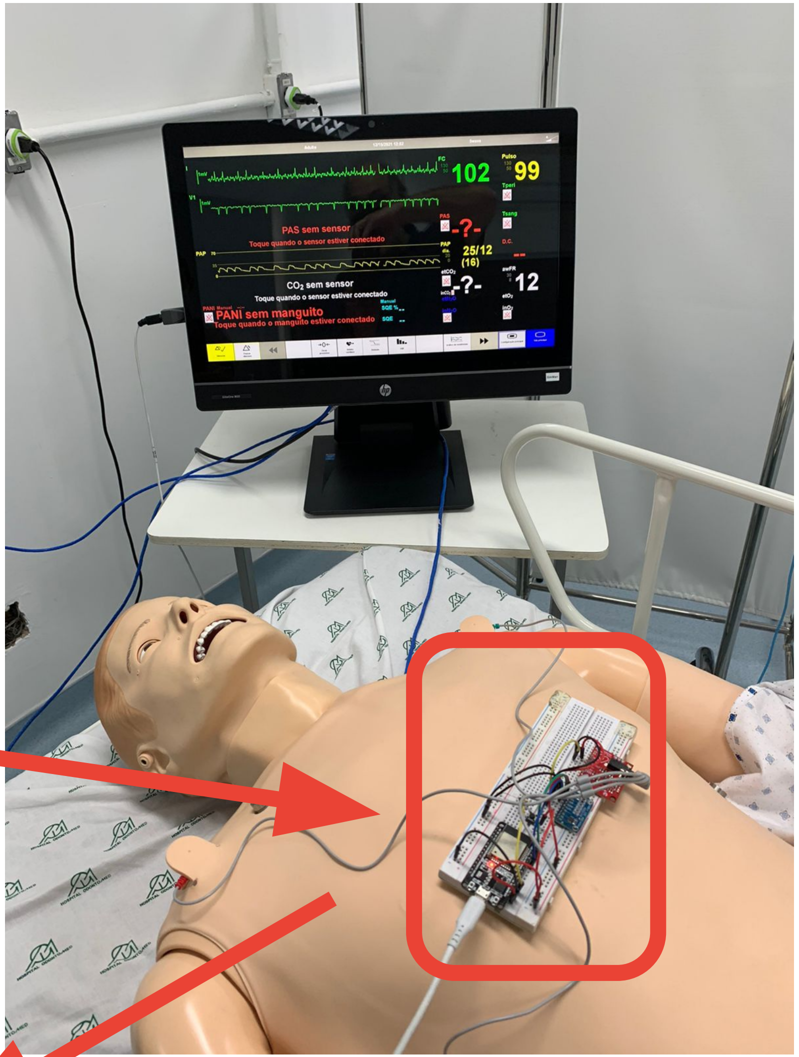
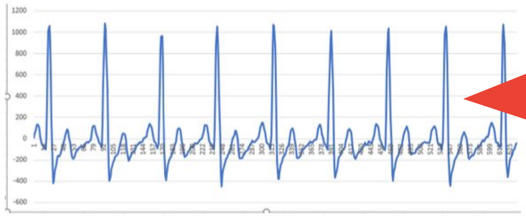
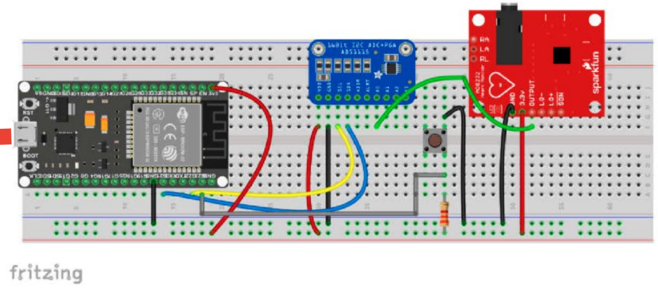






5. Data Ingestion using PLX-DAQ (Windows) => Final Format: .csv

Capture_Ardu33_Sense_IMU_Acc

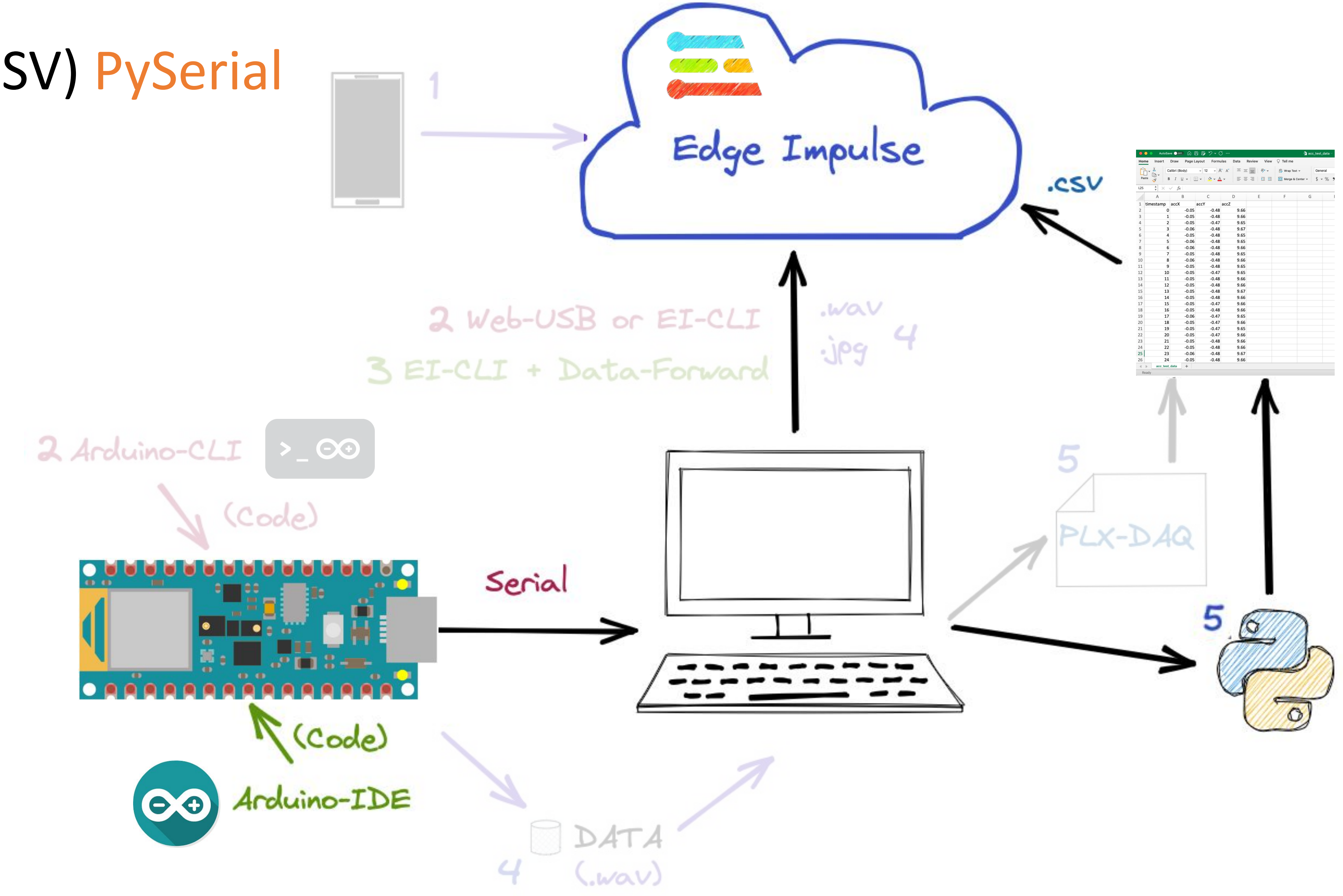
```
#include <Arduino_LSM9DS1.h>

#define CONVERT_G_TO_MS2    9.80665f
#define FREQUENCY_HZ        50
#define INTERVAL_MS         (1000 / (FREQUENCY_HZ + 1))

void setup() {
    Serial.begin(115200);
    while (!Serial);
    Serial.println("Started");

    if (!IMU.begin()) {
        Serial.println("Failed to initialize IMU!");
        while (1);
    }
}

void loop() {
    static unsigned long last_interval_ms = 0;
    float x, y, z;

    if (millis() > last_interval_ms + INTERVAL_MS) {
        last_interval_ms = millis();

        IMU.readAcceleration(x, y, z);

        Serial.print(x * CONVERT_G_TO_MS2);
        Serial.print(',');
        Serial.print(y * CONVERT_G_TO_MS2);
        Serial.print(',');
        Serial.println(z * CONVERT_G_TO_MS2);
    }
}
```

acc_test_data

timestamp	accX	accY	accZ
0	-0.05	-0.48	9.66
1	-0.05	-0.48	9.66
2	-0.05	-0.47	9.65
3	-0.06	-0.48	9.67
4	-0.05	-0.48	9.65
5	-0.06	-0.48	9.65
6	-0.06	-0.48	9.66
7	-0.05	-0.48	9.65
8	-0.06	-0.48	9.66
9	-0.05	-0.48	9.65
10	-0.05	-0.47	9.65
11	-0.05	-0.48	9.66
12	-0.05	-0.48	9.66
13	-0.05	-0.48	9.67
14	-0.05	-0.48	9.66
15	-0.05	-0.47	9.66
16	-0.05	-0.48	9.66
17	-0.06	-0.47	9.65
18	-0.05	-0.47	9.66
19	-0.05	-0.47	9.65
20	-0.05	-0.47	9.66
21	-0.05	-0.48	9.66
22	-0.05	-0.48	9.66
23	-0.06	-0.48	9.67
24	-0.05	-0.48	9.66

https://www.youtube.com/watch?v=BwbmNle2CZo

5. (.CSV) PySerial

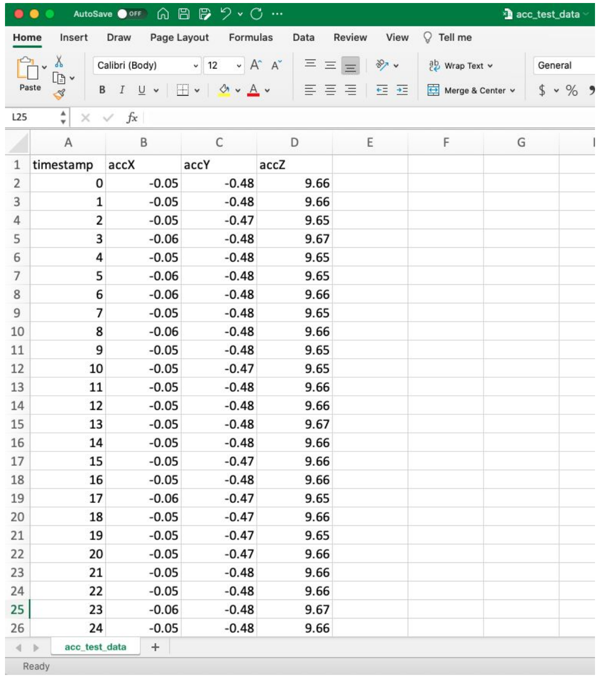


5. Data Ingestion using Python (PySerial) => Final Format: .csv

Capture_Ardu33_Sense_IMU_Acc

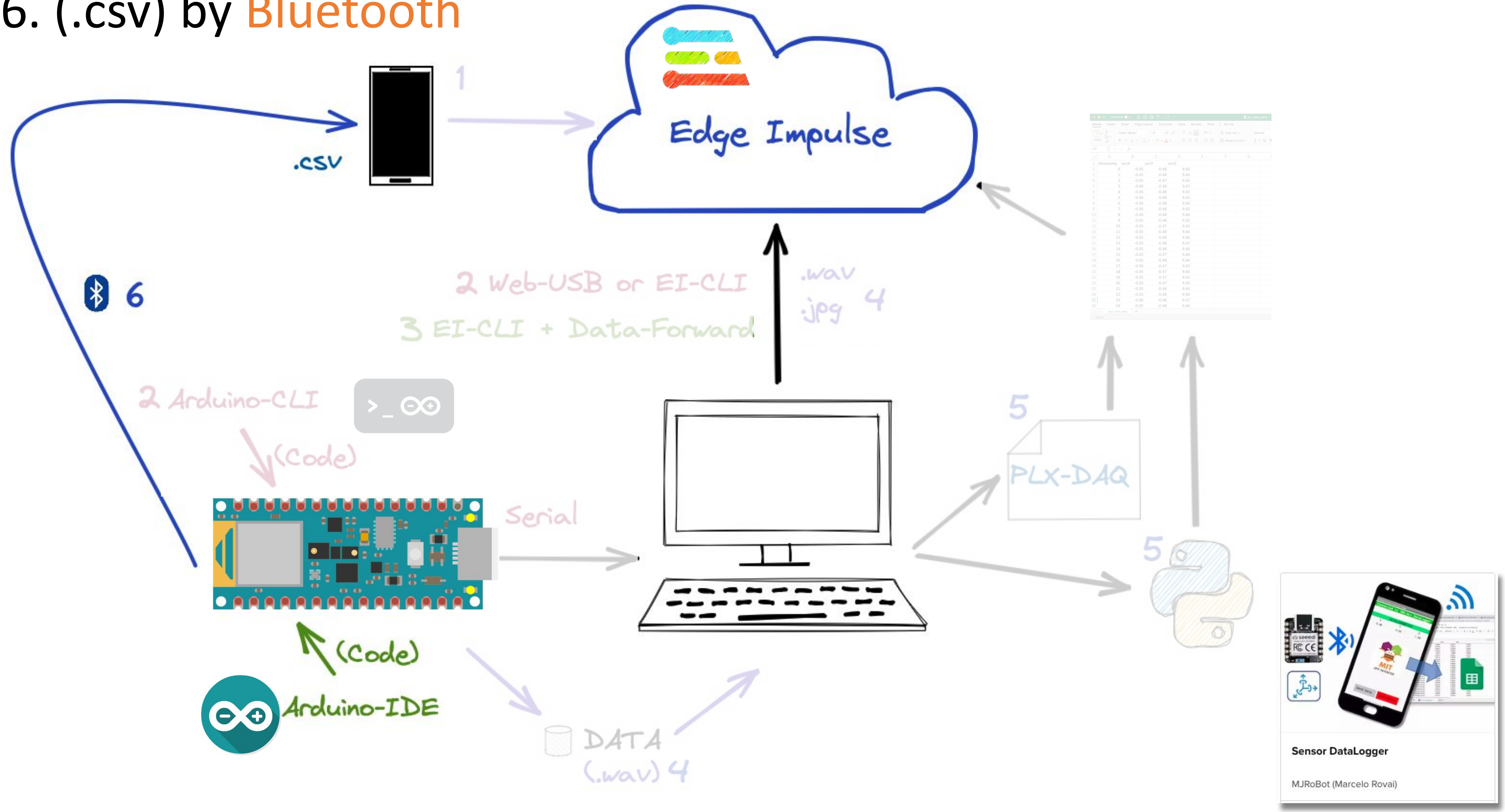
```
#include <Arduino_LSM9DS1.h>

#define CONVERT_G_TO_MS2    9.80665f
#define FREQUENCY_HZ        50
#define INTERVAL_MS         (1000 / (FREQUENCY_HZ + 1))

void setup() {
    Serial.begin(115200);
    while (!Serial);
    Serial.println("Started");

    if (!IMU.begin()) {
        Serial.println("Failed to initialize IMU!");
        while (1);
    }
}

void loop() {
    static unsigned long last_interval_ms = 0;
    float x, y, z;

    if (millis() > last_interval_ms + INTERVAL_MS) {
        last_interval_ms = millis();

        IMU.readAcceleration(x, y, z);

        Serial.print(x * CONVERT_G_TO_MS2);
        Serial.print(',');
        Serial.print(y * CONVERT_G_TO_MS2);
        Serial.print(',');
        Serial.println(z * CONVERT_G_TO_MS2);
    }
}
```

```python
# Sensor data Logger (CSV)
# by Marcelo Rovai @ 13July21

import serial

arduino_port = '/dev/tty.usbmodem144301'
baud_rate = 115200
ser = serial.Serial(port=arduino_port, baudrate=baud_rate)

fileName = "acc_test_data.csv"  # name of the CSV file generated

first_line = 'timestamp,accX,accY,accZ'
file = open(fileName, "w")
file.write(first_line + "\n")  # write data with a newline
file.close()

Freq_hz = 50
num_seconds = 10  # number of seconds collecting data
samples = num_seconds * Freq_hz # number of samples to collect

sample = 0
while sample <= samples:
    getData = str(ser.readline())
    data = getData[2:][:-5]
    print(data)

    file = open(fileName, "a")
    file.write(str(sample) + "," + data + "\n")
    sample = sample+1
print("Data collection complete!")
file.close()
```

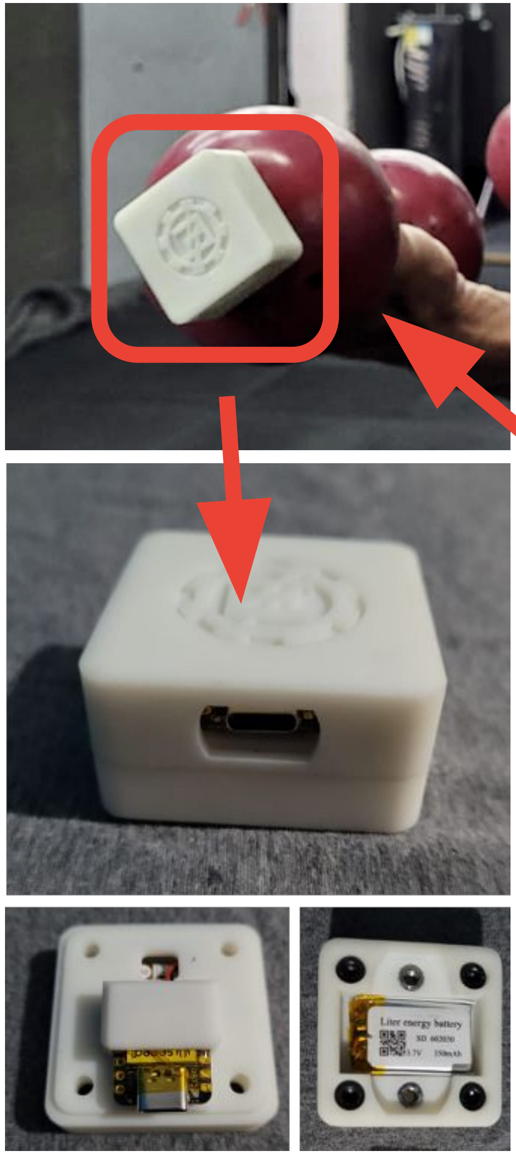


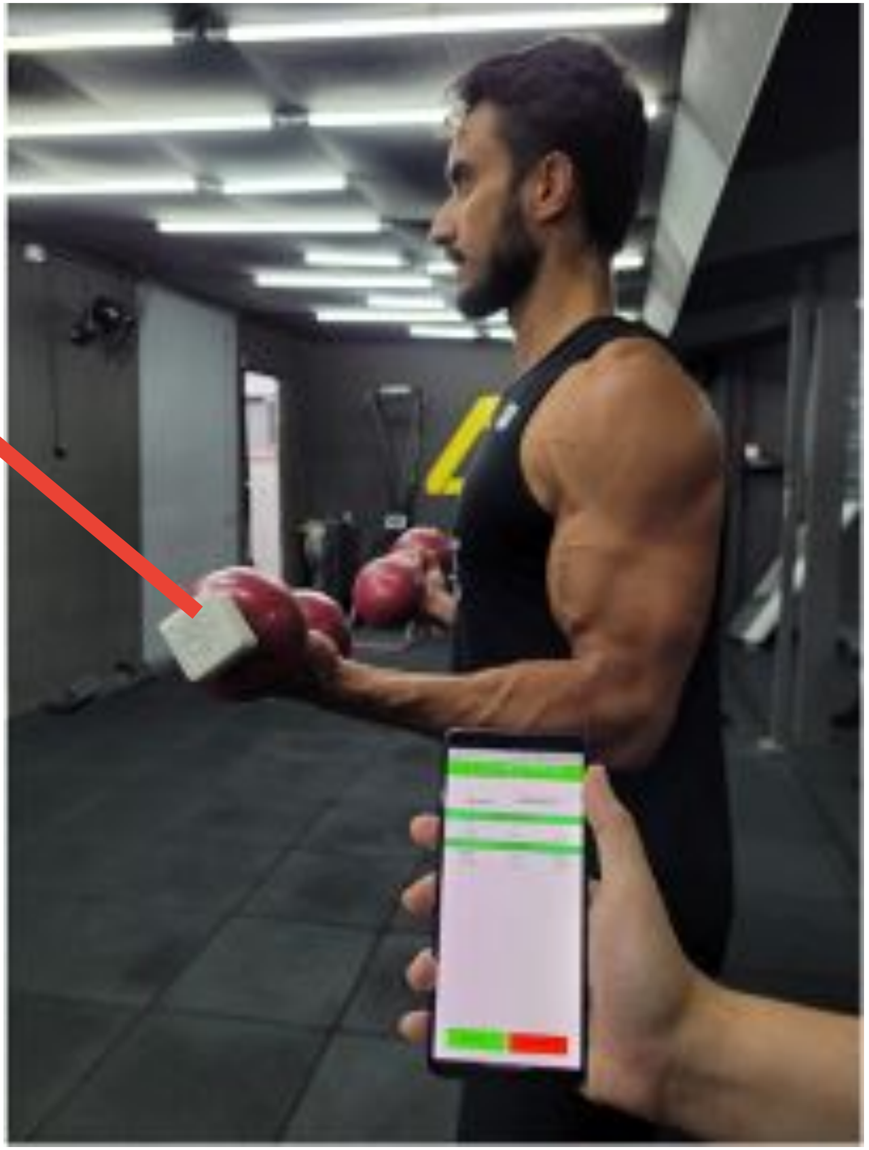
timestamp	accX	accY	accZ
0	-0.05	-0.48	9.66
1	-0.05	-0.48	9.66
2	-0.05	-0.47	9.65
3	-0.06	-0.48	9.67
4	-0.05	-0.48	9.65
5	-0.06	-0.48	9.65
6	-0.06	-0.48	9.66
7	-0.05	-0.48	9.65
8	-0.06	-0.48	9.66
9	-0.05	-0.48	9.65
10	-0.05	-0.47	9.65
11	-0.05	-0.48	9.66
12	-0.05	-0.48	9.66
13	-0.05	-0.48	9.67
14	-0.05	-0.48	9.66
15	-0.05	-0.47	9.66
16	-0.05	-0.48	9.66
17	-0.06	-0.47	9.65
18	-0.05	-0.47	9.66
19	-0.05	-0.47	9.65
20	-0.05	-0.47	9.66
21	-0.05	-0.48	9.66
22	-0.05	-0.48	9.66
23	-0.06	-0.48	9.67
24	-0.05	-0.48	9.66

6. (.csv) by Bluetooth



6. (.csv) by Bluetooth





CNPq

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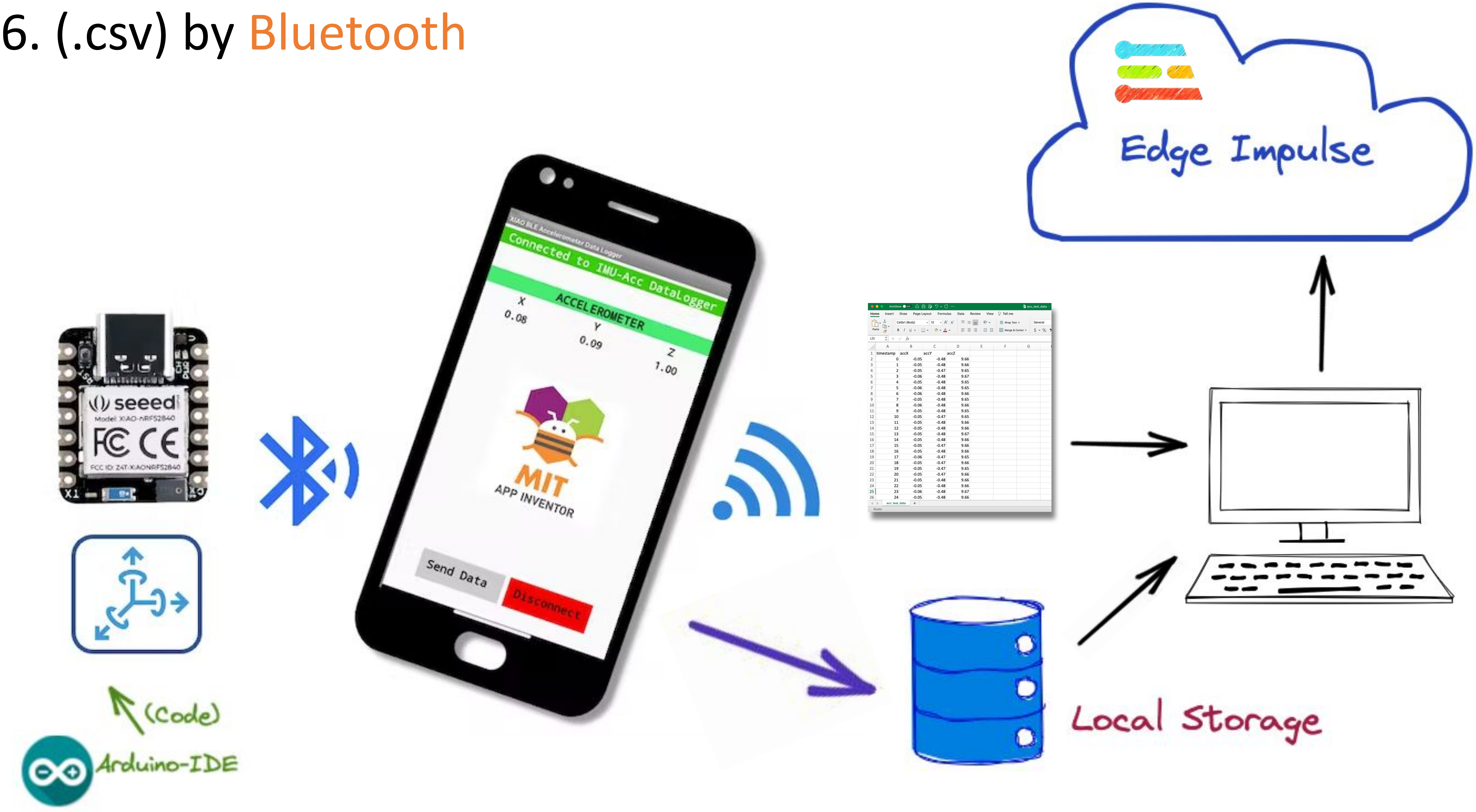
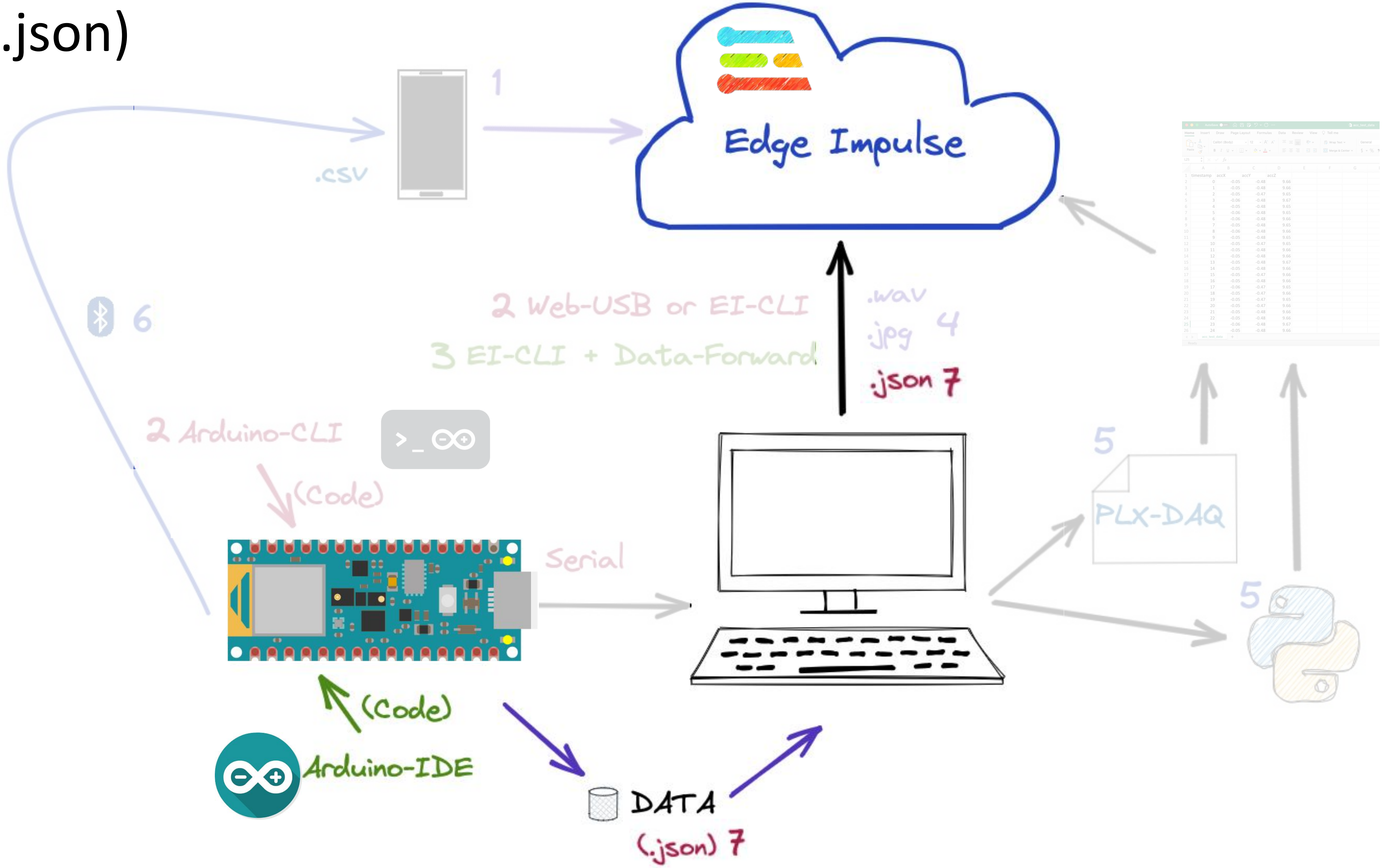
6. (.csv) by Bluetooth



7. (.json)



Edge Impulse
1
.csv
6
2 Web-USB or EI-CLI
3 EI-CLI + Data-Forward
.wav
.jpg
4
.json 7
2 Arduino-CLI
(Code)
Serial
5
PLX-DAQ
5
(Code)
Arduino-IDE
DATA
(.json) 7

7. Raw Uploader (.json files)

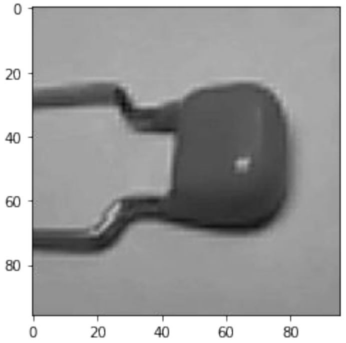
Image Classification: Raw Uploader

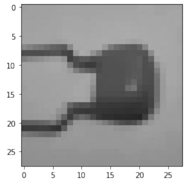
Open in Colab

Run this notebook to convert images to a single row of raw, normalized values (between 0 and 1) and upload them to Edge Impulse as raw samples. Note that pixel values will be normalized to be between 0 and 1.

Create a folder named "dataset" in the /content directory and upload your images there. The images should be divided into their respective classes, where each class has its own folder with the name of the class. For example:

```
/content
    |- dataset
        |- background
        |- capacitor
        |- diode
        |- led
        |- resistor
```





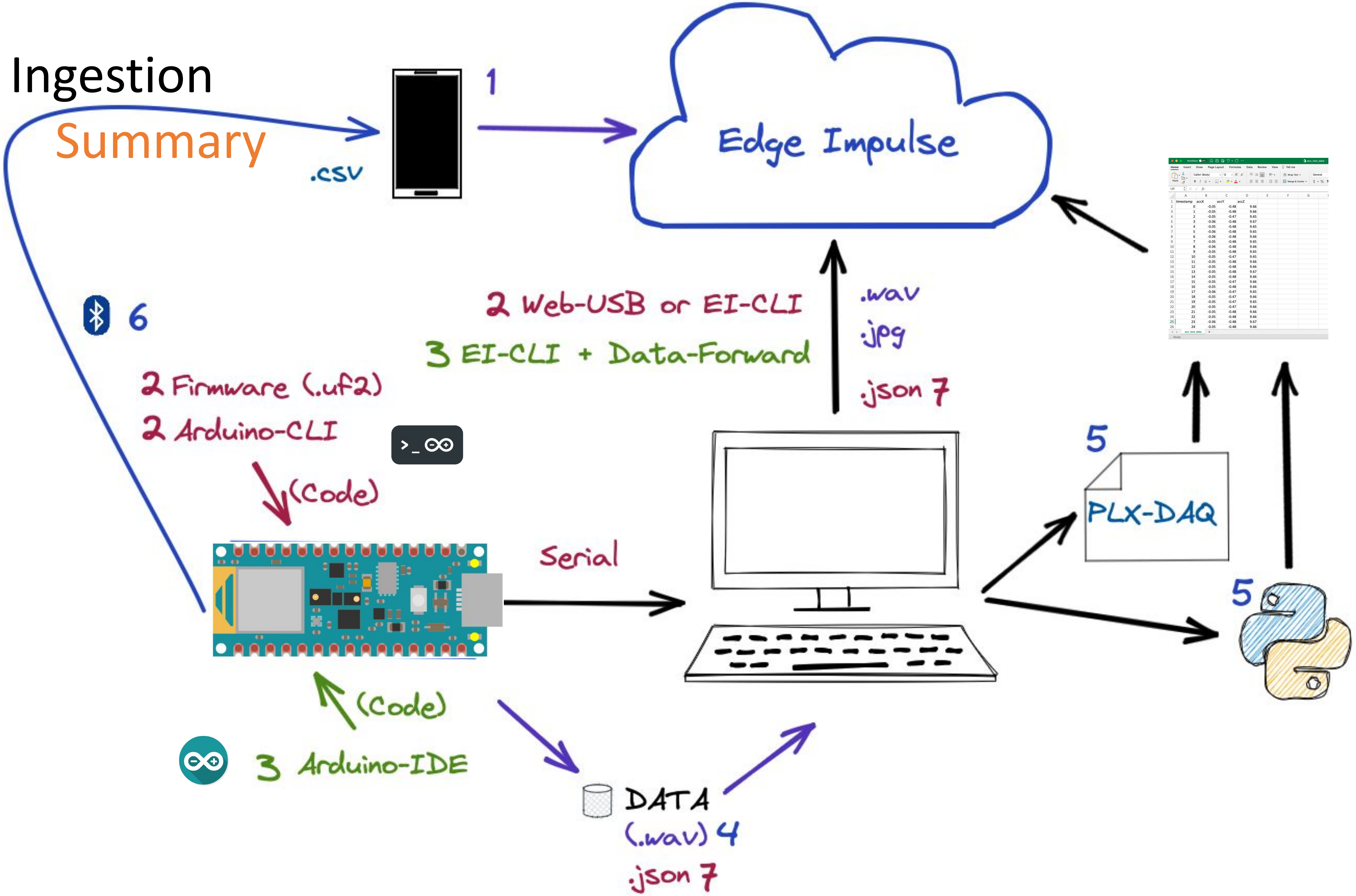
.json

EDGE IMPULSE
(Training as DNN)

Author: EdgeImpulse, Inc.
Date: June 6, 2021
License: Apache-2.0

TinyML Made Easy: Exploring Regression - White Wine Quality
MJRoBot (Marcelo Rovai)

Data Ingestion
Summary



To learn more …

- IESTI01 TinyML - Machine Learning for Embedding Devices (Videos: Pt)
- WALC 22 – Applied AI - TinyML (Videos in Spanish)
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- "Deep Learning with Python" book by François Chollet
- "TinyML" book by Pete Warden, Daniel Situnayake
- "TinyML Cookbook" by Gian Marco Iodice
- "AI at the Edge" book by Daniel Situnayake, Jenny Plunkett

On the **TinyML4D** website, You can find lots of educational materials on TinyML. They are all free and open-source for educational uses – we ask that if you use the material, please cite them! TinyML4D is an initiative to make TinyML education available to everyone globally.

Thanks

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