

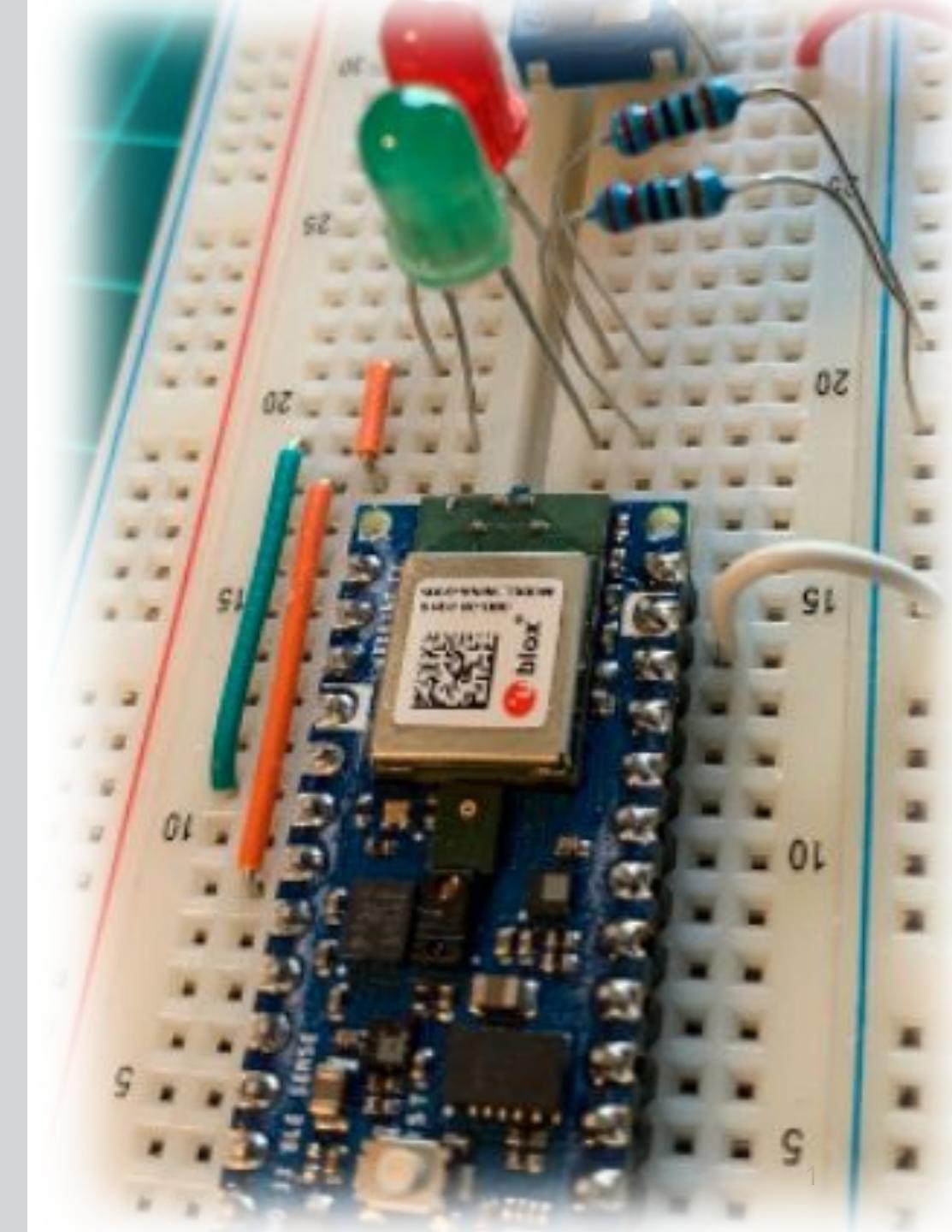
IESTI01 – TinyML

Embedded Machine Learning

25. Collecting Data with Edge Impulse Studio



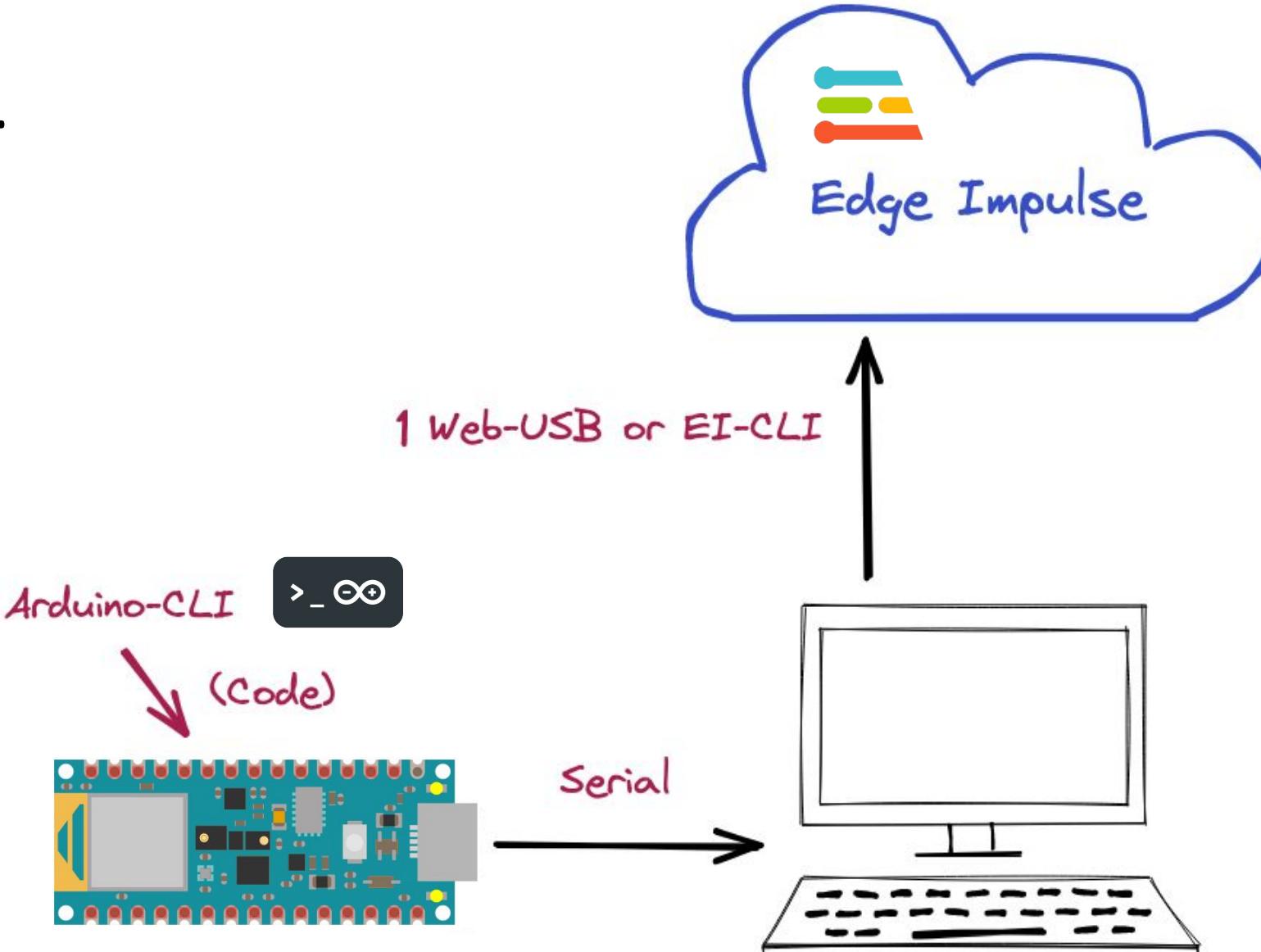
Prof. Marcelo Rovai
UNIFEI



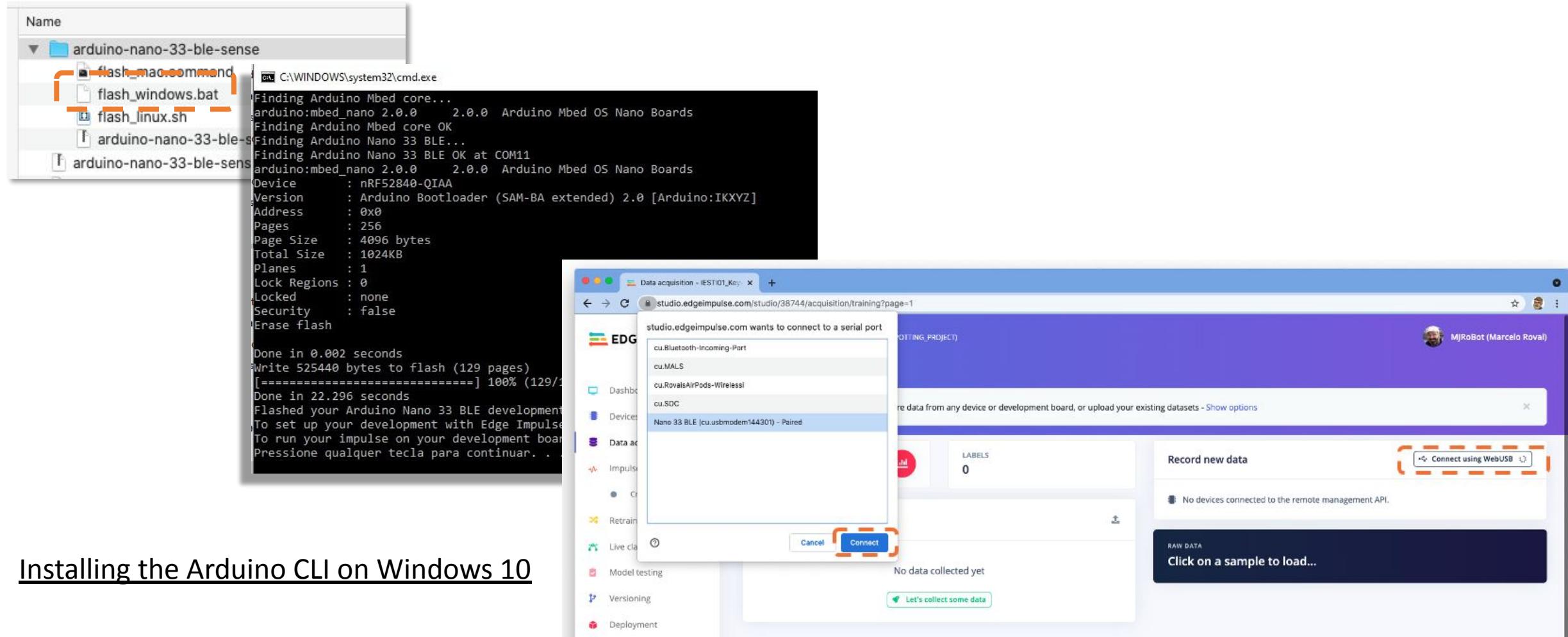
Sensor Data – EI Studio Ingestion

Alternative methods

1.

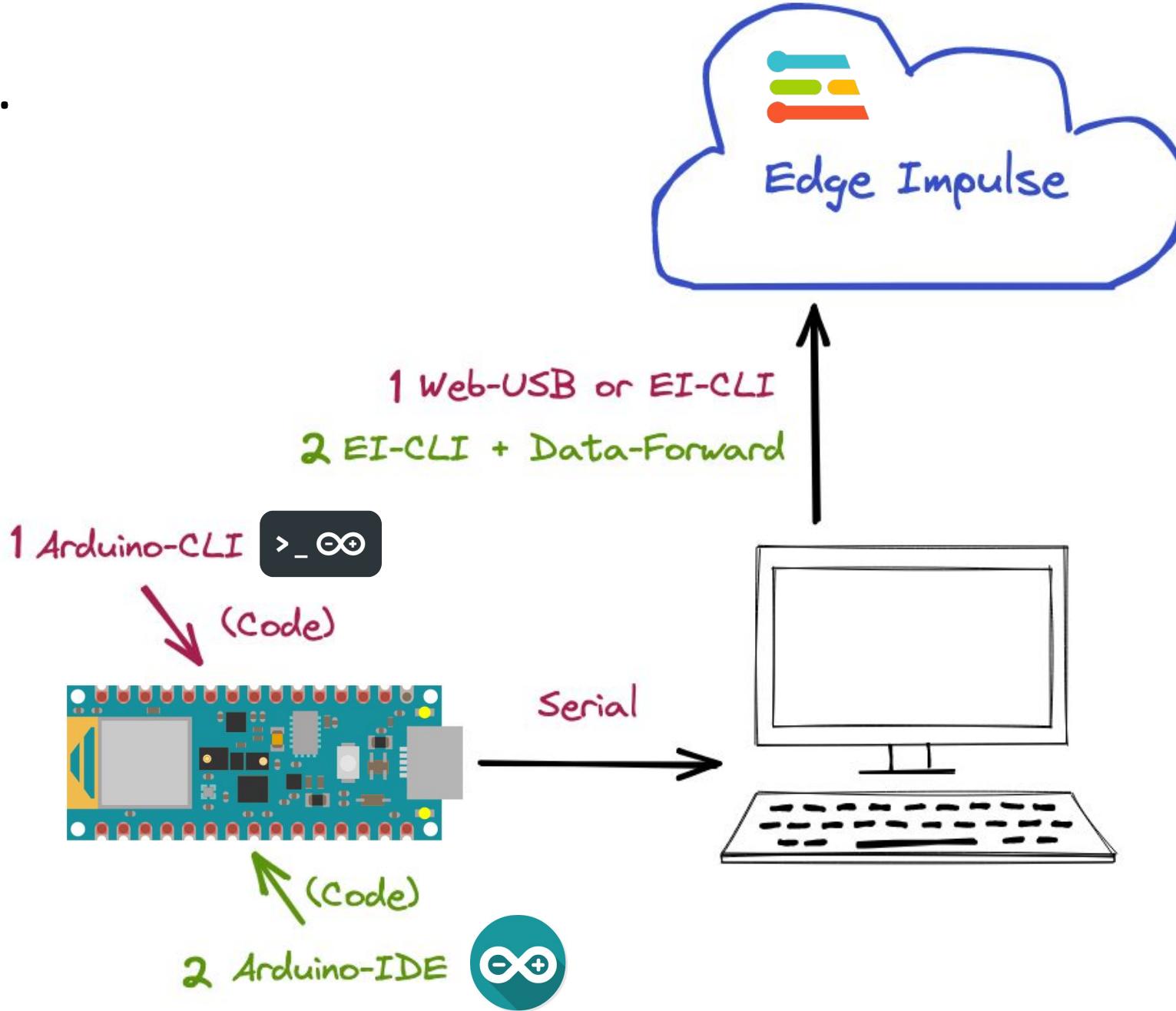


1. Data Ingestion using Arduino-Cli + Web-USB (or EI-CLI)



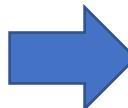
Installing the Arduino CLI on Windows 10

2.



2. Data Ingestion using El-Cli + Data Forward

```
Capture_Ardub33_Sense_IMU_Acc
1 #include <Arduino_LSM9DS1.h>
2
3 #define CONVERT_G_TO_MS2 9.80665f
4 #define FREQUENCY_HZ 50
5 #define INTERVAL_MS (1000 / (FREQUENCY_HZ + 1))
6
7 void setup() {
8     Serial.begin(115200);
9     while (!Serial);
10    Serial.println("Started");
11
12    if (!IMU.begin()) {
13        Serial.println("Failed to initialize IMU!");
14        while (1);
15    }
16 }
17
18 void loop() {
19     static unsigned long last_interval_ms = 0;
20     float x, y, z;
21
22     if (millis() > last_interval_ms + INTERVAL_MS) {
23         last_interval_ms = millis();
24
25         IMU.readAcceleration(x, y, z);
26
27         Serial.print(x * CONVERT_G_TO_MS2);
28         Serial.print(',');
29         Serial.print(y * CONVERT_G_TO_MS2);
30         Serial.print(',');
31         Serial.println(z * CONVERT_G_TO_MS2);
32     }
33 }
```



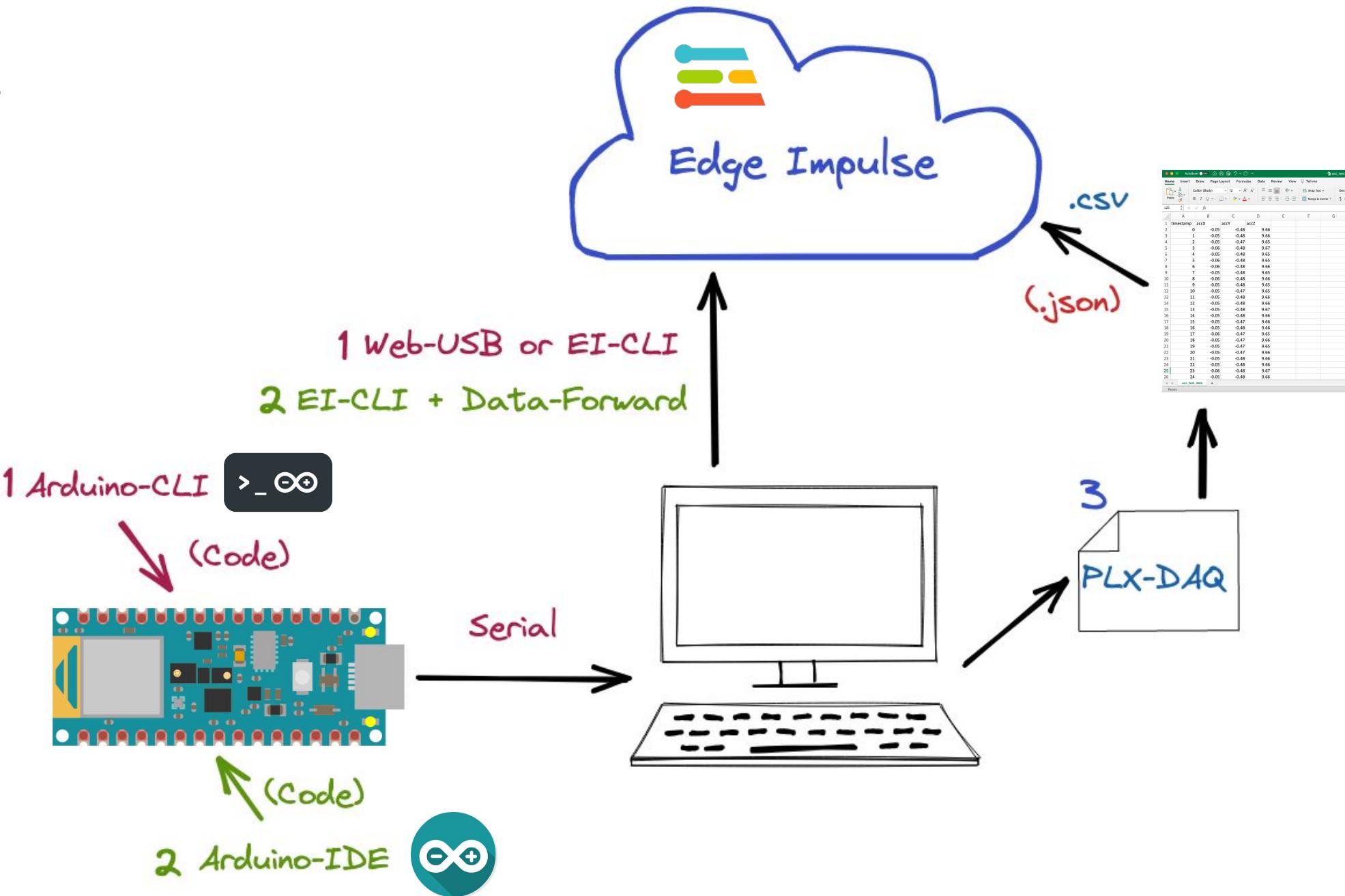
```
$ edge-impulse-data-forwarder --clean
```

```
mjrovai — bash — 80x41
(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

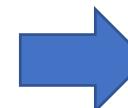
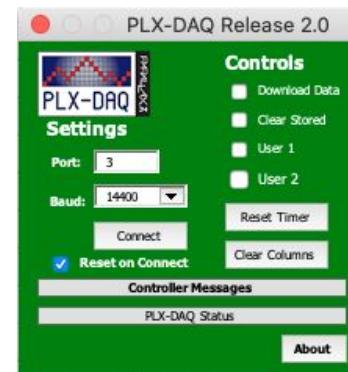
? To which project do you want to connect this device? MJRoBot (Marcelo Rovai) / IESTI01_Input_Data_Test
[SER] Detecting data frequency...
[SER] Detected data frequency: 51Hz
[?] 3 sensor axes detected (example values: [-0.08,-0.34,9.82]). What do you want to call them? Separate the names with ',': accX, 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)'
```

3.



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

```
Capture_Ard33_Sense_IMU_Acc
1 #include <Arduino_LSM9DS1.h>
2
3 #define CONVERT_G_TO_MS2 9.80665f
4 #define FREQUENCY_HZ 50
5 #define INTERVAL_MS (1000 / (FREQUENCY_HZ + 1))
6
7 void setup() {
8     Serial.begin(115200);
9     while (!Serial);
10    Serial.println("Started");
11
12    if (!IMU.begin()) {
13        Serial.println("Failed to initialize IMU!");
14        while (1);
15    }
16 }
17
18 void loop() {
19     static unsigned long last_interval_ms = 0;
20     float x, y, z;
21
22     if (millis() > last_interval_ms + INTERVAL_MS) {
23         last_interval_ms = millis();
24
25         IMU.readAcceleration(x, y, z);
26
27         Serial.print(x * CONVERT_G_TO_MS2);
28         Serial.print(',');
29         Serial.print(y * CONVERT_G_TO_MS2);
30         Serial.print(',');
31         Serial.println(z * CONVERT_G_TO_MS2);
32     }
33 }
```



	A	B	C	D	E	F	G
1	timestamp	accX	accY	accZ			
2		0	-0.05	-0.48	9.66		
3		1	-0.05	-0.48	9.66		
4		2	-0.05	-0.47	9.65		
5		3	-0.06	-0.48	9.67		
6		4	-0.05	-0.48	9.65		
7		5	-0.06	-0.48	9.65		
8		6	-0.06	-0.48	9.66		
9		7	-0.05	-0.48	9.65		
10		8	-0.06	-0.48	9.66		
11		9	-0.05	-0.48	9.65		
12		10	-0.05	-0.47	9.65		
13		11	-0.05	-0.48	9.66		
14		12	-0.05	-0.48	9.66		
15		13	-0.05	-0.48	9.67		
16		14	-0.05	-0.48	9.66		
17		15	-0.05	-0.47	9.66		
18		16	-0.05	-0.48	9.66		
19		17	-0.06	-0.47	9.65		
20		18	-0.05	-0.47	9.66		
21		19	-0.05	-0.47	9.65		
22		20	-0.05	-0.47	9.66		
23		21	-0.05	-0.48	9.66		
24		22	-0.05	-0.48	9.66		
25		23	-0.06	-0.48	9.67		
26		24	-0.05	-0.48	9.66		

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

The screenshot shows the Arduino IDE interface. The top menu bar includes 'Arquivo', 'Editar', 'Sketch', 'Ferramentas', and 'Ajuda'. The title bar says 'IMU_excel | Arduino 1.8.15'. The code editor contains the following sketch:

```
#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(9600);
  while (!Serial)
  {
    // do nothing
  }
  //limpa todos os dados do sheet incluindo os labels
  Serial.println("CLEARSHHEET");
  Serial.println("CLEARDATA");
  //delay para dar o tempo suficiente para excluir os labels originais a fim de substitui-los
  delay(300);
  //escrevendo os nomes das colunas da planilha. É sempre necessário escrever o nome LABEL com o objetivo de sinalizar de que se quer nomear as colunas.
  //Após isso, basta colocar os nomes das colunas, sempre separando-as por vírgulas.
  //O nome "timestamP" para representar o horário pelo qual foram adicionados os dados é escolhido pensando na possibilidade de subir esses dados no EdadImpulse.
}

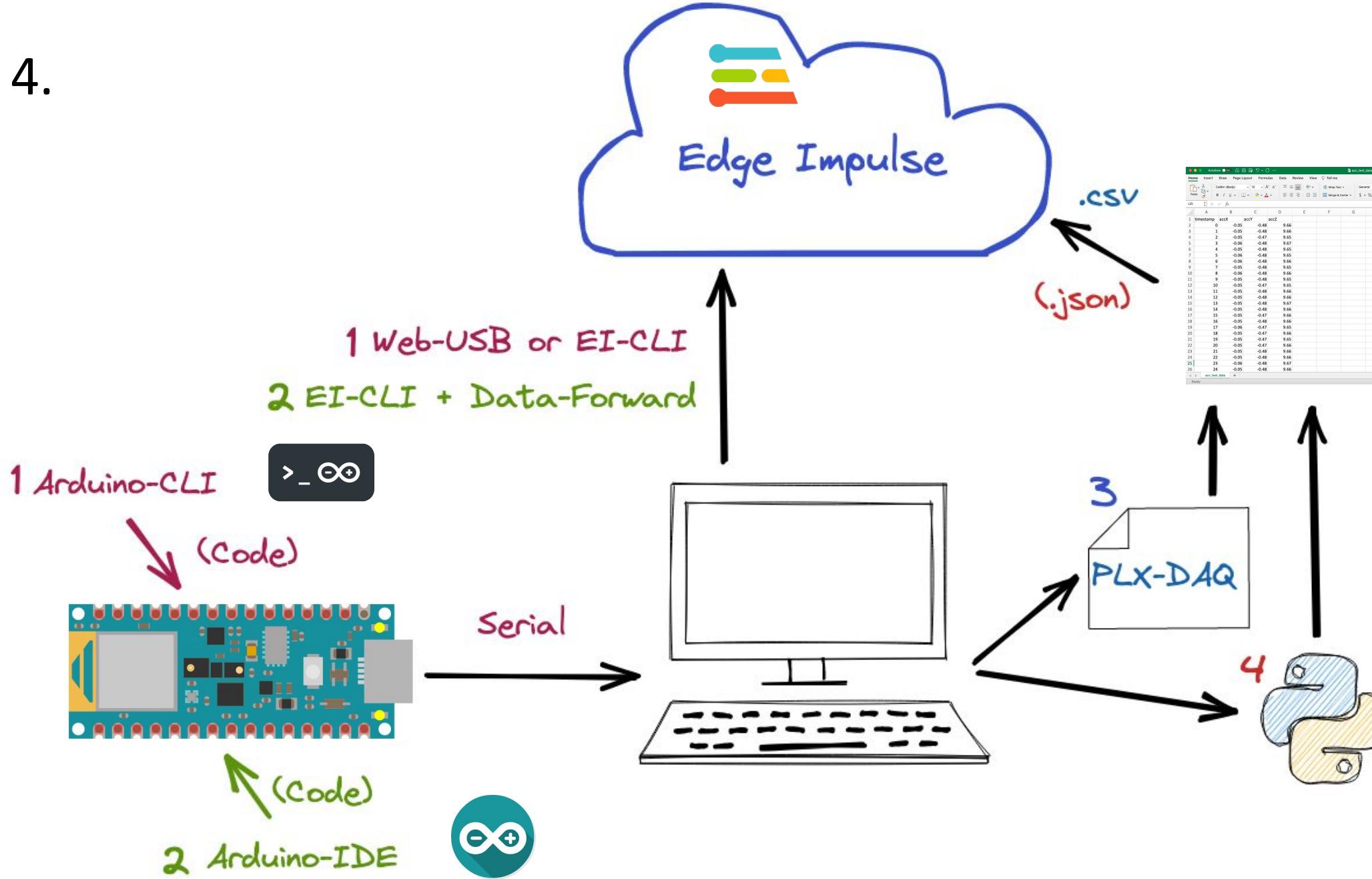
Carregado:
writeBuffer(scr_addr=0x34, dst_addr=0x14000, size=0x1000)
[=====] 87% (21/24 pages) write(addr=0x34, size=0x1000)
writeBuffer(scr_addr=0x34, dst_addr=0x15000, size=0x1000)
[=====] 91% (22/24 pages) write(addr=0x34, size=0x1000)
writeBuffer(scr_addr=0x34, dst_addr=0x16000, size=0x1000)
[=====] 95% (23/24 pages) write(addr=0x34, size=0x1000)
writeBuffer(scr_addr=0x34, dst_addr=0x17000, size=0x1000)
[=====] 100% (24/24 pages)
Done in 3.995 seconds
reset()

48
```

The serial monitor window shows the progress of writing data to a file, indicating 100% completion after 3.995 seconds. The status bar at the bottom right shows 'Arduino Nano 33 BLE em COM10', '10°C Pred. limpo', '02:35', and the date '14/07/2021'.

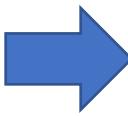
<https://www.youtube.com/watch?v=BwbmNle2CZo>

4.



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

```
Capture_Ardub33_Sense_IMU_Acc
1 #include <Arduino_LSM9DS1.h>
2
3 #define CONVERT_G_TO_MS2    9.80665f
4 #define FREQUENCY_HZ        50
5 #define INTERVAL_MS          (1000 / (FREQUENCY_HZ + 1))
6
7 void setup() {
8     Serial.begin(115200);
9     while (!Serial);
10    Serial.println("Started");
11
12    if (!IMU.begin()) {
13        Serial.println("Failed to initialize IMU!");
14        while (1);
15    }
16 }
17
18 void loop() {
19     static unsigned long last_interval_ms = 0;
20     float x, y, z;
21
22    if (millis() > last_interval_ms + INTERVAL_MS) {
23        last_interval_ms = millis();
24
25        IMU.readAcceleration(x, y, z);
26
27        Serial.print(x * CONVERT_G_TO_MS2);
28        Serial.print(',');
29        Serial.print(y * CONVERT_G_TO_MS2);
30        Serial.print(',');
31        Serial.println(z * CONVERT_G_TO_MS2);
32    }
33 }
```

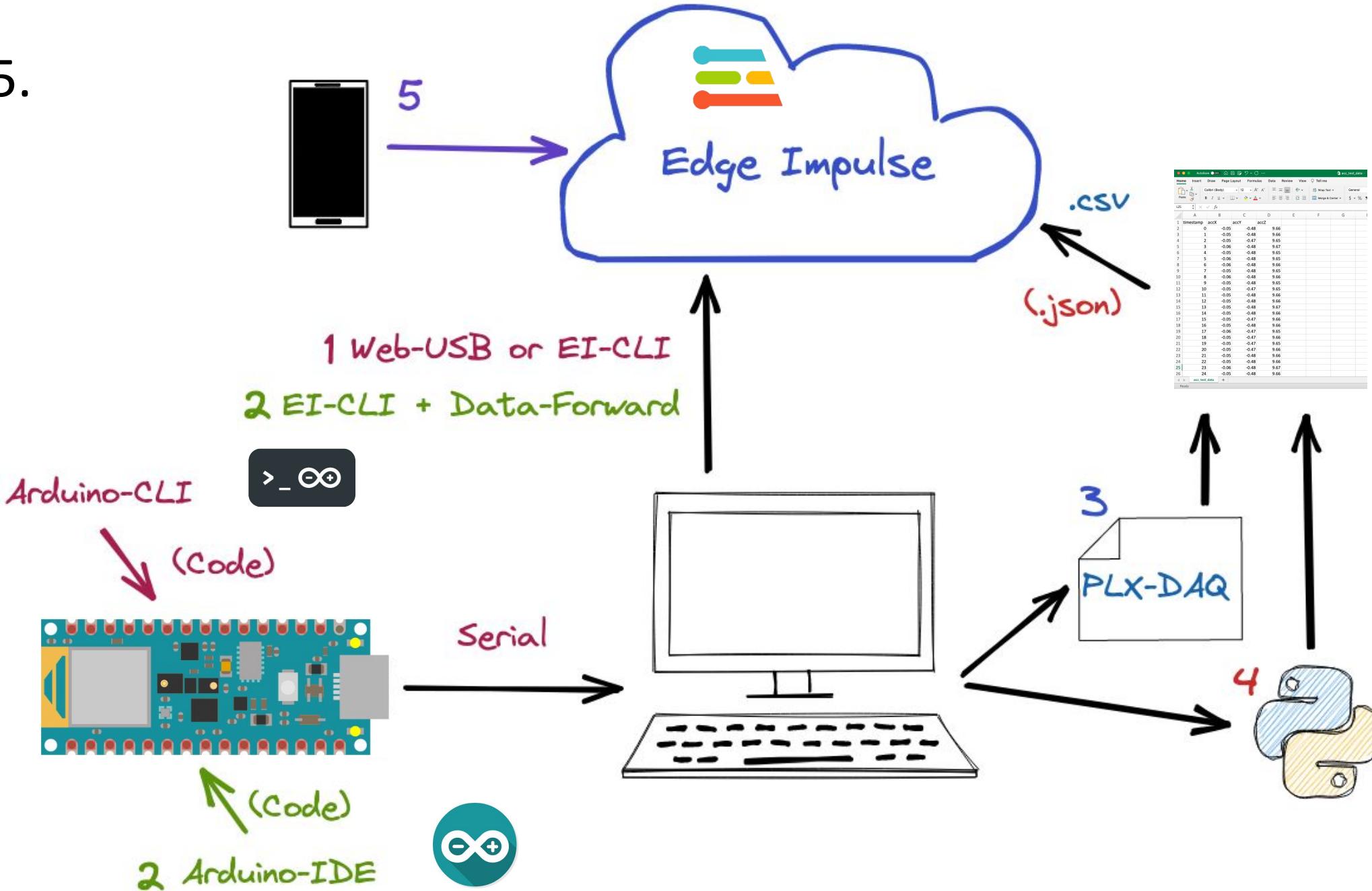


```
1 # Sensor data Logger (CSV)
2 # by Marcelo Rovai @ 13July21
3
4 import serial
5
6 arduino_port = '/dev/tty.usbmodem144301'
7 baud_rate = 115200
8 ser = serial.Serial(port=arduino_port, baudrate=baud_rate)
9
10 fileName = "acc_test_data.csv" # name of the CSV file generated
11
12 first_line = 'timestamp,accX,accY,accZ'
13 file = open(fileName, "w")
14 file.write(first_line + "\n") # write data with a newline
15 file.close()
16
17 Freq_hz = 50
18 num_seconds = 10 # number of seconds collecting data
19 samples = num_seconds * Freq_hz # number of samples to collect
20
21 sample = 0
22 while sample <= samples:
23     getData = str(ser.readline())
24     data = getData[2:][:-5]
25     print(data)
26
27     file = open(fileName, "a")
28     file.write(str(sample) + "," + data + "\n")
29     sample = sample+1
30 print("Data collection complete!")
31 file.close()
```



L25	A	B	C	D	E	F	G
1	timestamp	accX	accY	accZ			
2	0	-0.05	-0.48	9.66			
3	1	-0.05	-0.48	9.66			
4	2	-0.05	-0.47	9.65			
5	3	-0.06	-0.48	9.67			
6	4	-0.05	-0.48	9.65			
7	5	-0.06	-0.48	9.65			
8	6	-0.06	-0.48	9.66			
9	7	-0.05	-0.48	9.65			
10	8	-0.06	-0.48	9.66			
11	9	-0.05	-0.48	9.65			
12	10	-0.05	-0.47	9.65			
13	11	-0.05	-0.48	9.66			
14	12	-0.05	-0.48	9.66			
15	13	-0.05	-0.48	9.67			
16	14	-0.05	-0.48	9.66			
17	15	-0.05	-0.47	9.66			
18	16	-0.05	-0.48	9.66			
19	17	-0.06	-0.47	9.65			
20	18	-0.05	-0.47	9.66			
21	19	-0.05	-0.47	9.65			
22	20	-0.05	-0.47	9.66			
23	21	-0.05	-0.48	9.66			
24	22	-0.05	-0.48	9.66			
25	23	-0.06	-0.48	9.67			
26	24	-0.05	-0.48	9.66			

5.



5. Data Ingestion using Smart Phone

The screenshot shows the Edge Impulse Studio interface on a web browser. The URL in the address bar is `studio.edgeimpulse.com`. The main title of the project is "MJRoBot (Marcelo Rovai) / IESTI01 - Gesture Classification". The left sidebar contains a navigation menu with the following items:

- EDGE IMPULSE
- Dashboard
- Devices
- Data acquisition
- Impulse design
- Create impulse
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

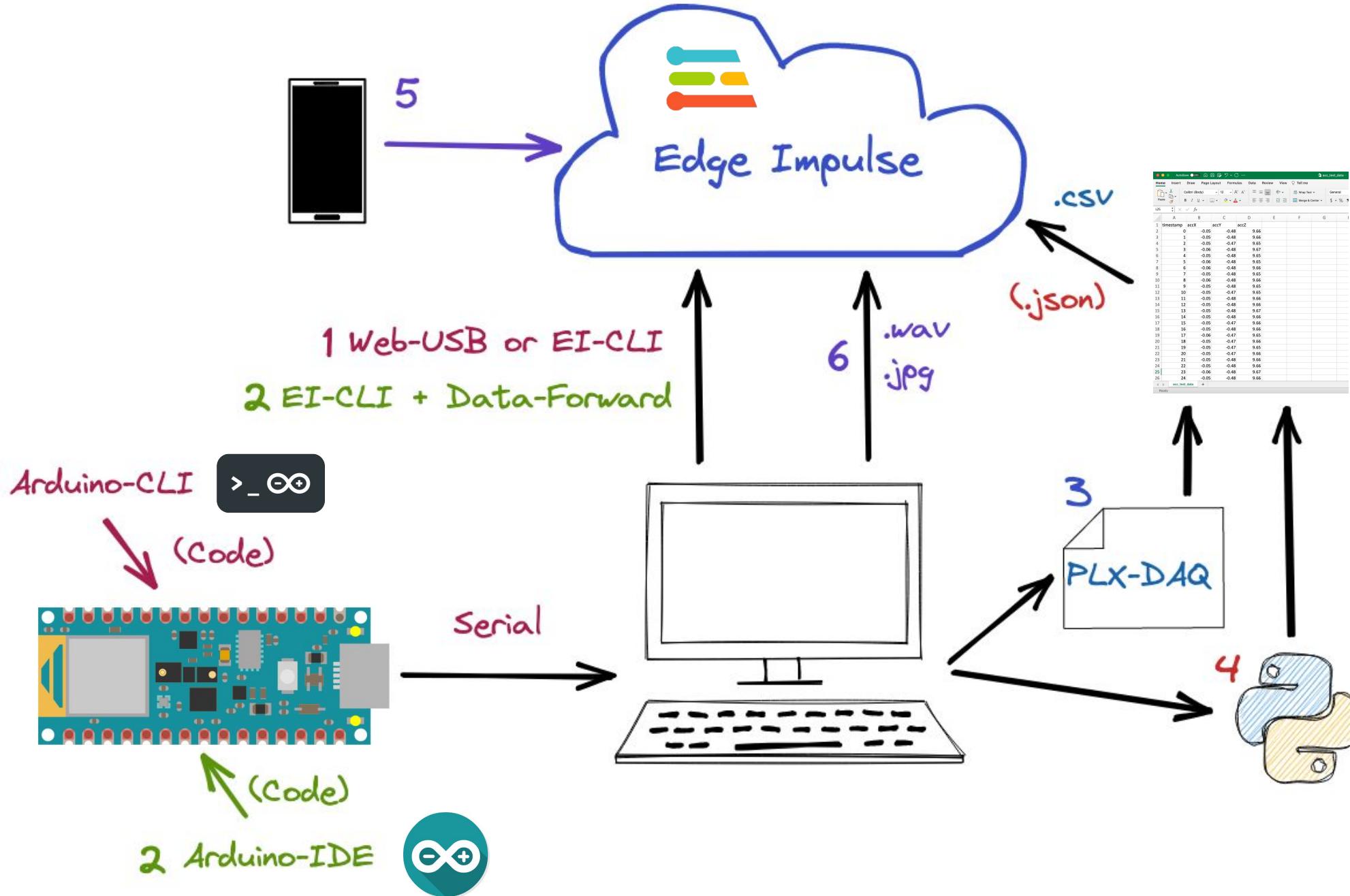
Below this, under "GETTING STARTED", are links for Documentation and Forums.

The central area displays a "Collect data" modal window. The title of the modal is "Creating your first impulse (0)". It contains three sections: "Acquire data", "Design an impulse", and "Deploy".

- Acquire data:** Text: "You can collect data from any smartphone. From your smartphone go to [this URL](#), or scan the QR code below." Below this is a large QR code.
- Design an impulse:** Text: "Teach the model to interpret new data. Use this to categorize new readings." Below this are three buttons: "LET'S COLLECT SOME DATA", "GETTING STARTED: CONTINUOUS", and "GETTING STARTED: RESPONDING".
- Deploy:** Text: "Package the complete impulse up, from signal processing code to trained model, and deploy it on your device. This ensures that the impulse runs with low latency and without requiring a network connection." Below this is a button: "DEPLOY YOUR MODEL".

On the right side of the screen, there is a "Sharing" section which says "Your project is private." and a "Make this project public" button. Below that is a "Summary" section showing "DEVICES CONNECTED: 0" and "DATA COLLECTED: -". The "Collaborators" section lists "MjRoBot (Marcelo Rovai) OWNER". At the bottom is a "Project info" section.

6.



6. Data Ingestion using Upload existing Data

The screenshot illustrates the DataRobot interface for data ingestion. On the left, the 'LABELS' panel shows 5 labels. The main interface features a central 'Upload existing data' button. Below it, a tree view displays a folder structure: 'data' containing 'cool' and 'hot' subfolders, which further contain numerous .wav files. A blue arrow points from the 'hot' folder to the 'Upload existing data' button. To the right, a detailed 'UPLOAD DATA (ICTP_PSYCHOACOUSTICS_TEMPERATURE_DEPENDENCE)' dialog box is open. It contains fields for 'Choose Files' (no file chosen), 'Upload into category' (set to 'Training'), 'Label' (set to 'hot'), and a 'Begin upload' button. To the right of the dialog, a progress bar shows 'Uploading 14 files...' with a list of 14 successful uploads. The message 'Done. Files uploaded successful: 14. Files that failed to upload: 0.' is displayed, followed by 'Job completed'. The top right corner shows a user profile for 'MJRoBot (Marcelo Rova)'. The overall interface is clean with a light blue and white color scheme.

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

LABELS
5

Upload existing data

ADDED LENGTH

data

cool

hot

20210710-125854.wav

20210710-125930.wav

20210710-125956.wav

20210710-130010.wav

20210710-130041.wav

20210710-130100.wav

20210710-130119.wav

20210710-130129.wav

20210710-130142.wav

20210710-130200.wav

20210710-130212.wav

20210710-130224.wav

20210710-130236.wav

20210710-130246.wav

20210710-130256.wav

20210710-130304.wav

20210710-130315.wav

20210710-130329.wav

20210710-130348.wav

20210710-130358.wav

20210710-130408.wav

20210710-130416.wav

UPLOAD DATA (ICTP_PSYCHOACOUSTICS_TEMPERATURE_DEPENDENCE)

Upload existing data

You can upload existing data to your project in the Data Acquisition Format (CBOR, JSON, CSV), or as WAV, JPG or PNG files.

Select files

Choose Files No file chosen

Upload into category

Automatically split between training and testing

Training

Testing

Label

Infer from filename

Enter label:

hot

Begin upload

Upload output

Uploading 14 files...

[1/14] Uploading 20210710-130535.wav OK

[2/14] Uploading 20210710-130603.wav OK

[3/14] Uploading 20210710-130544.wav OK

[4/14] Uploading 20210710-130553.wav OK

[5/14] Uploading 20210710-130738.wav OK

[6/14] Uploading 20210710-130718.wav OK

[7/14] Uploading 20210710-130649.wav OK

[8/14] Uploading 20210710-130700.wav OK

[9/14] Uploading 20210710-130630.wav OK

[10/14] Uploading 20210710-130621.wav OK

[11/14] Uploading 20210710-130709.wav OK

[12/14] Uploading 20210710-130611.wav OK

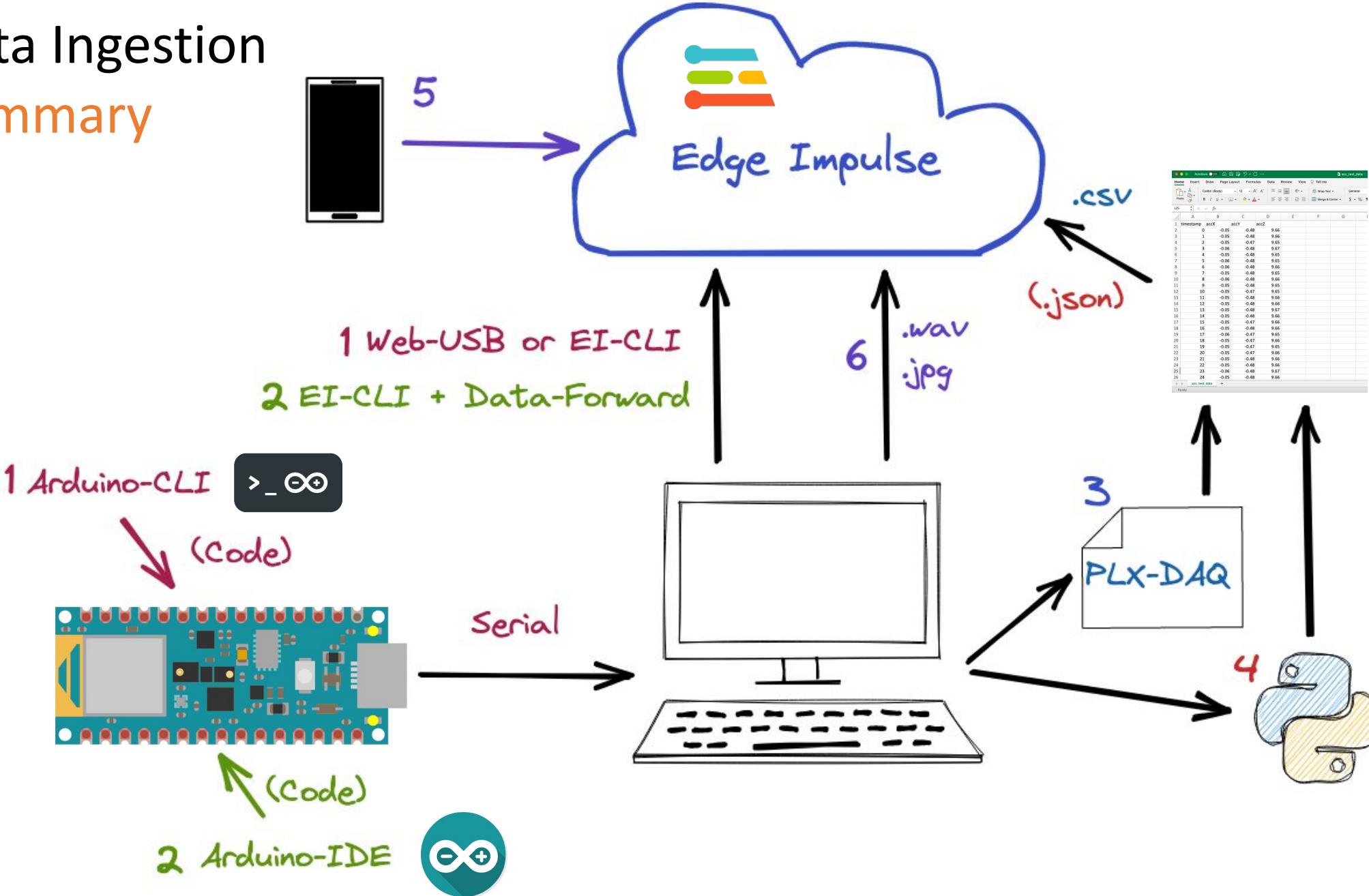
[13/14] Uploading 20210710-130728.wav OK

[14/14] Uploading 20210710-130639.wav OK

Done. Files uploaded successful: 14. Files that failed to upload: 0.

Job completed

Data Ingestion Summary



Temperature Dependence Psychoacoustics

Simple TinyML Proof-of-concept



<https://www.hackster.io/mjrobot/listening-temperature-with-tinyml-7e1325>



Audio Engineering Society

Convention e-Brief 473

Presented at the 145th Convention
2018 October 17 – 20, New York, NY, USA

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Why can you hear a difference between pouring hot and cold water? An investigation of temperature dependence in psychoacoustics.

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²Queen Mary University of London

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[http://www.eecs.qmul.ac.uk/~josh/
documents/2018/19737.pdf](http://www.eecs.qmul.ac.uk/~josh/documents/2018/19737.pdf)

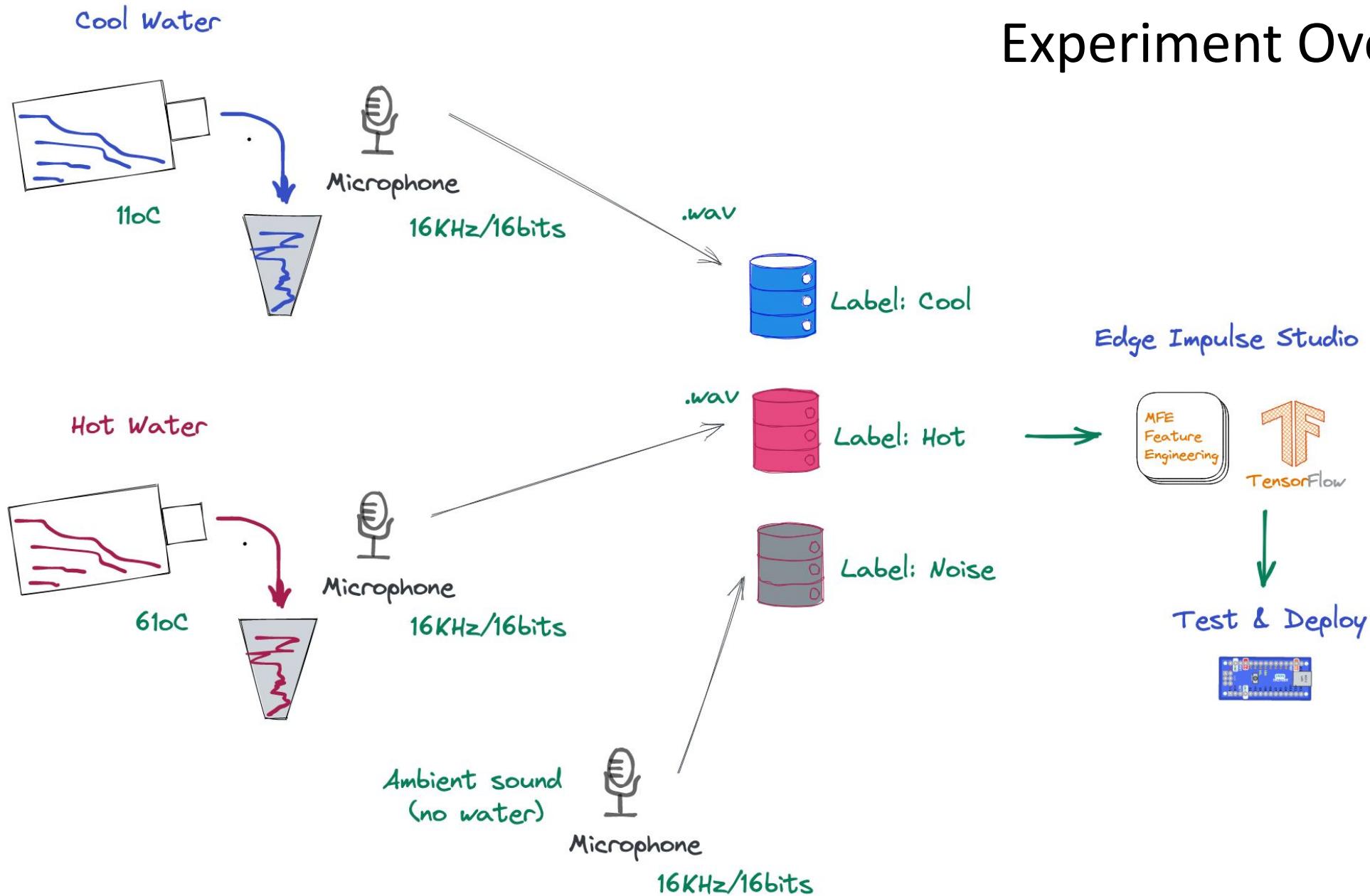


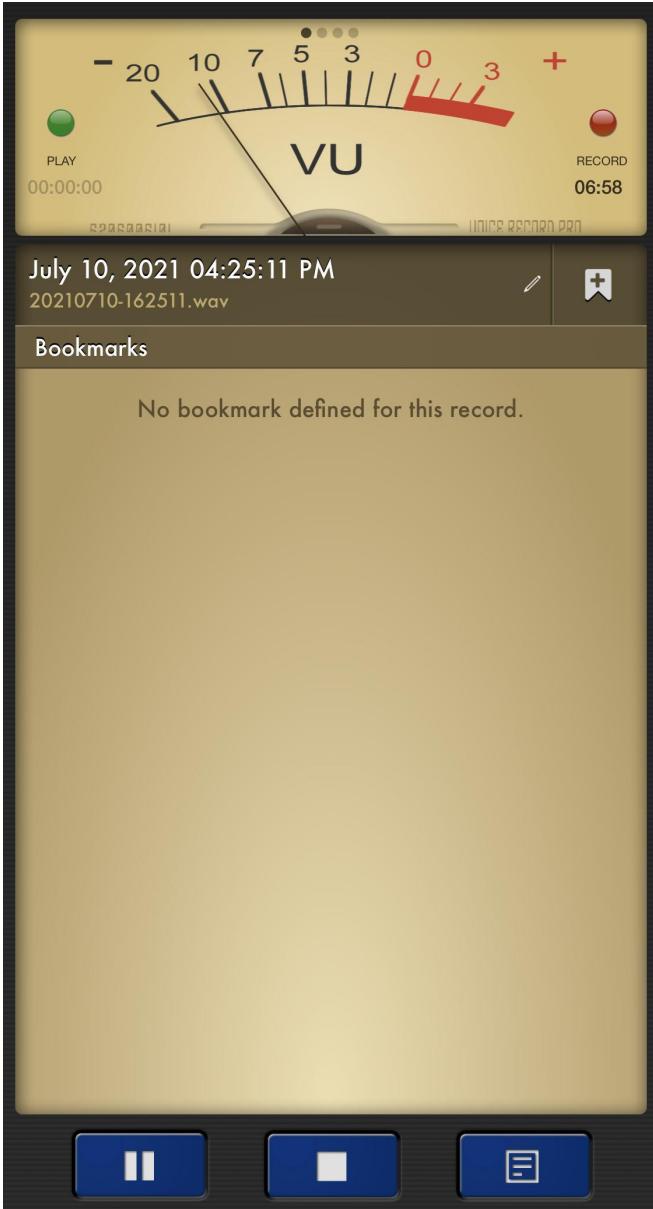
You Can Hear The Difference Between Hot and Cold W...

Tom Scott

[\(min: 0.17 => min 2:37\)](https://www.youtube.com/watch?v=Ri_4dDvcZeM)

Experiment Overview





Voice Recorder



Sample Sound:

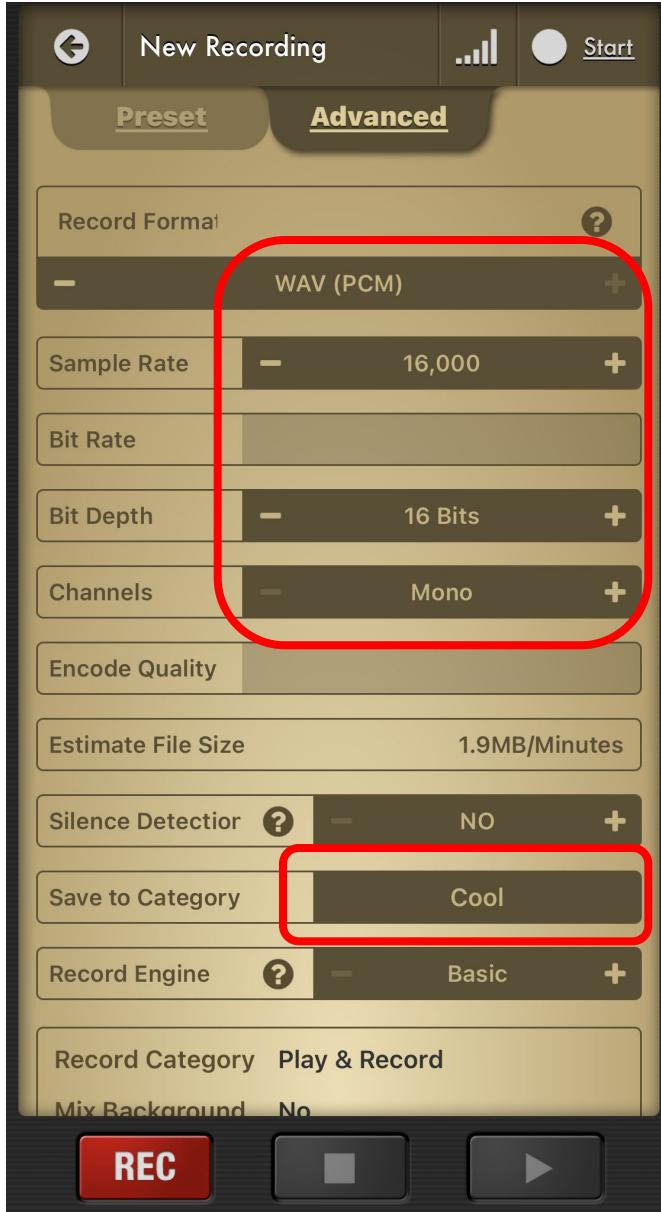
- 16KHz
- PCM – 16bits
- Mono

Classes:

- Hot
- Cool
- Noise



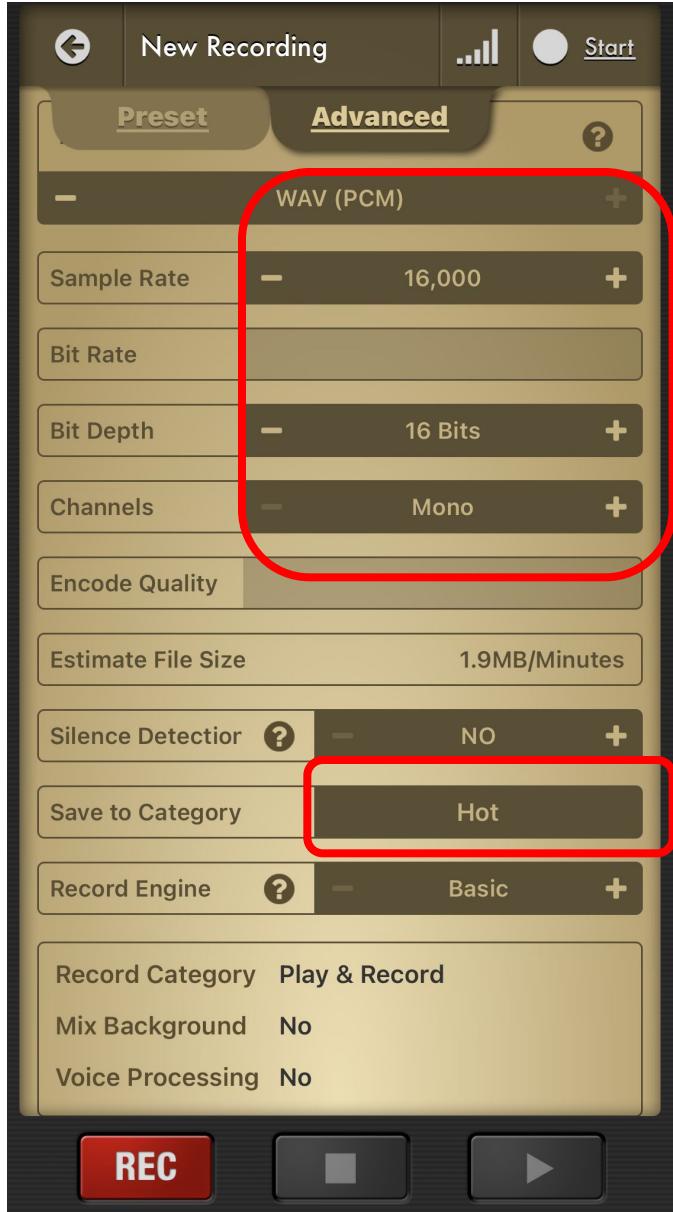
Ambient Temperature: 19°C 20



Class: Cool



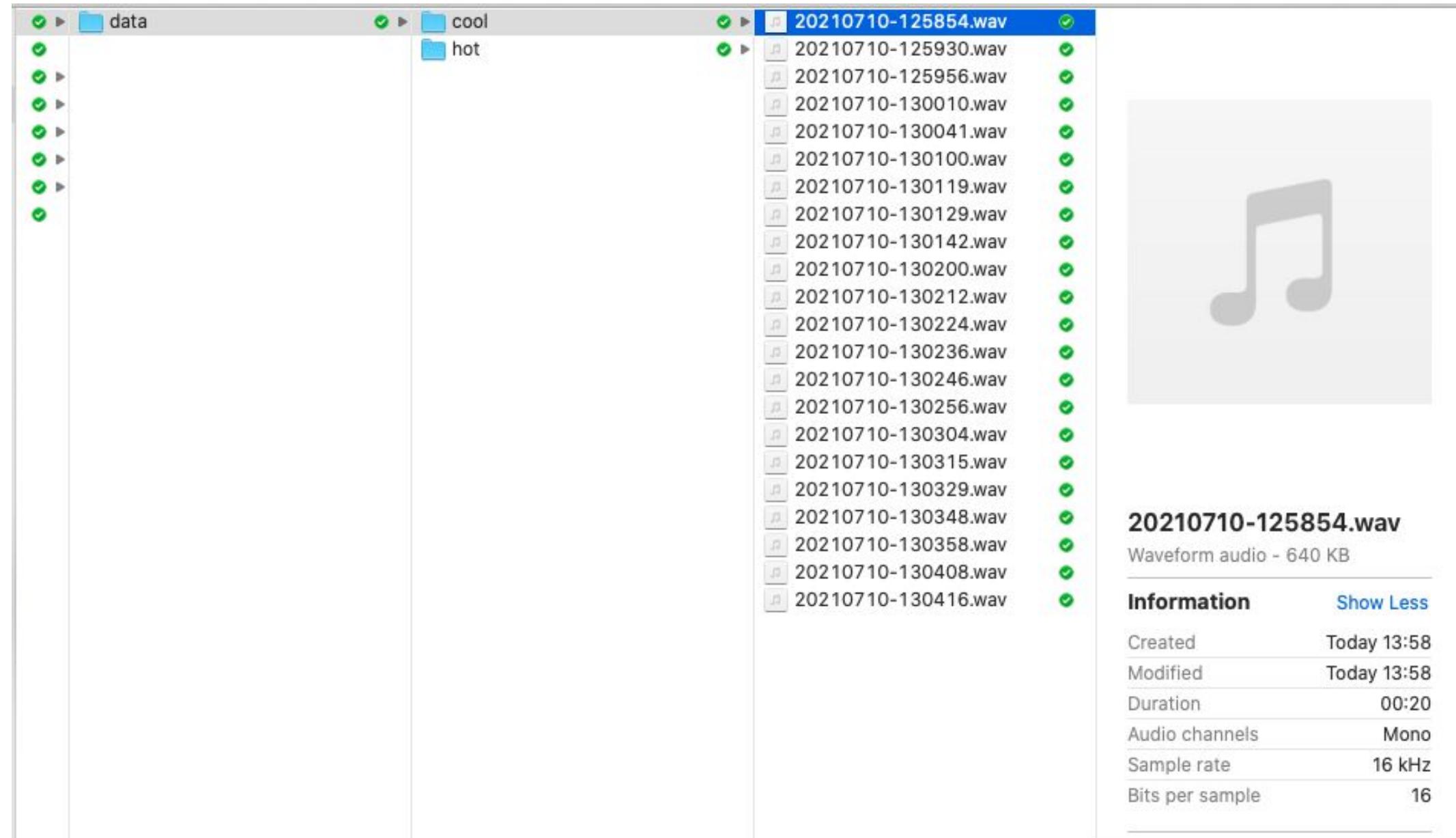
Cool Water Temperature: 11°C



Class: Hot



Hot Water Temperature: 61°C



The screenshot shows a file explorer window with three main directories: 'data', 'cool', and 'hot'. The 'cool' directory contains a sub-directory 'hot' which holds 24 waveform audio files named from '20210710-125854.wav' to '20210710-130416.wav'. Each file has a green checkmark icon next to it. On the right side of the window, there is a detailed view for the selected file, '20210710-125854.wav'. This view includes a large gray musical note icon, the file name, its type ('Waveform audio - 640 KB'), and an 'Information' table with the following details:

Information	Show Less
Created	Today 13:58
Modified	Today 13:58
Duration	00:20
Audio channels	Mono
Sample rate	16 kHz
Bits per sample	16

Data captured using app Voice Recorder and uploaded to Computer



Upload existing data

You can upload existing data to your project in the [Data Acquisition Format](#) (CBOR, JSON, CSV), or as WAV, JPG or PNG files.

Select files

No file chosen

Upload into category

- Automatically split between training and testing ?
- Training
- Testing

Label

- Infer from filename ?
- Enter label:

hot

Upload output

Uploading 14 files...

```
[ 1/14] Uploading 20210710-130535.wav OK
[ 2/14] Uploading 20210710-130603.wav OK
[ 3/14] Uploading 20210710-130544.wav OK
[ 4/14] Uploading 20210710-130553.wav OK
[ 5/14] Uploading 20210710-130738.wav OK
[ 6/14] Uploading 20210710-130718.wav OK
[ 7/14] Uploading 20210710-130649.wav OK
[ 8/14] Uploading 20210710-130700.wav OK
[ 9/14] Uploading 20210710-130630.wav OK
[10/14] Uploading 20210710-130621.wav OK
[11/14] Uploading 20210710-130709.wav OK
[12/14] Uploading 20210710-130611.wav OK
[13/14] Uploading 20210710-130728.wav OK
[14/14] Uploading 20210710-130639.wav OK
```

Done. Files uploaded successful: 14. Files that failed to upload: 0.

Job completed

Raw Data uploaded to Edge Impulse Studio as .wav



Did you know? You can capture data from any device or development board, or upload your existing datasets - [Show options](#)



DATA COLLECTED
2m 49s



LABELS
2



Collected data



SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
20210710-130621.wav.2a5e0...	hot	Today, 14:02:55	4s	⋮
20210710-130630.wav.2a5e0...	hot	Today, 14:02:54	3s	⋮
20210710-130700.wav.2a5e0...	hot	Today, 14:02:52	4s	⋮
20210710-130649.wav.2a5e0...	hot	Today, 14:02:52	5s	⋮
20210710-130718.wav.2a5e0...	hot	Today, 14:02:52	5s	⋮
20210710-130738.wav.2a5e0...	hot	Today, 14:02:51	5s	⋮
20210710-130553.wav.2a5e0...	hot	Today, 14:02:51	4s	⋮
20210710-130544.wav.2a5e0...	hot	Today, 14:02:51	4s	⋮
20210710-130603.wav.2a5e0...	hot	Today, 14:02:51	3s	⋮
20210710-130535.wav.2a5e0...	hot	Today, 14:02:48	5s	⋮
20210710-130416.wav.2a5dv...	cool	Today, 14:02:12	4s	⋮
20210710-130408.wav.2a5dv...	cool	Today, 14:02:11	4s	⋮

Record new data

Connect using WebUSB

No devices connected to the remote management API.

RAW DATA

20210710-130621.wav.2a5e0r33



0 393 787 1180 1574 1967 2361 2755 3148 3542



▶ 0:03 / 0:03 ━ ━ ━ ━ ━



Raw Data cleaned as split in 1 second samples

Split sample '20210710-130621.wav.2a5e0r33'

x

[+ Add Segment](#)[Remove segment](#)

is.):

1000

[Apply](#)15000
10000
5000
0
-5000
-10000
-15000
-20000

0 379 758 1138 1517 1896 2276 2655 3035 3414

audio

0:01 / 0:01

[Cancel](#)

Raw Data cleaned as split in 1 second samples

 Shift samples [Split](#)



⚡ An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

Time series data

Axes
audio

Window size 1000 ms.

Window increase 500 ms.

Zero-pad data

Audio (MFE)

Name

Input axes audio

Neural Network (Keras)

Name

Input features MFE

Output features
3 (cool, hot, noise)

Output features

3 (cool, hot, noise)

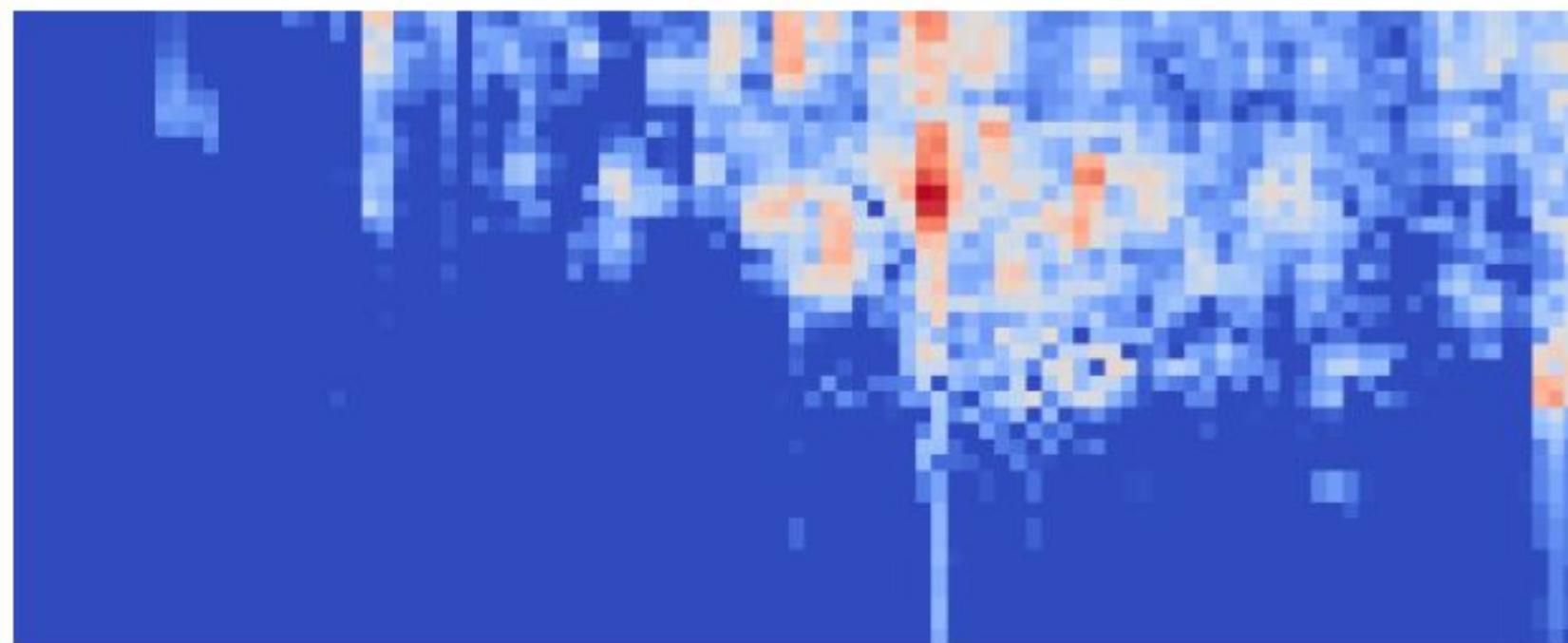
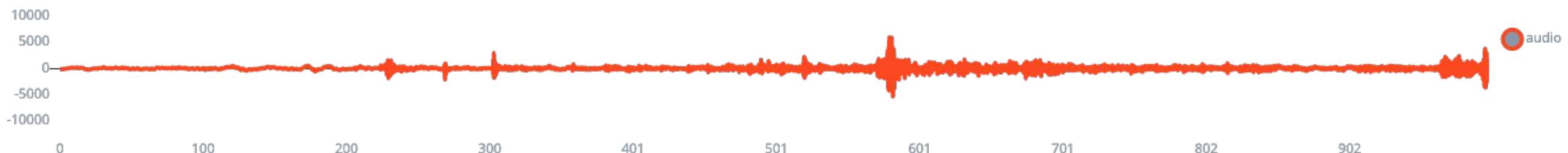
Save Impulse

Add a processing block

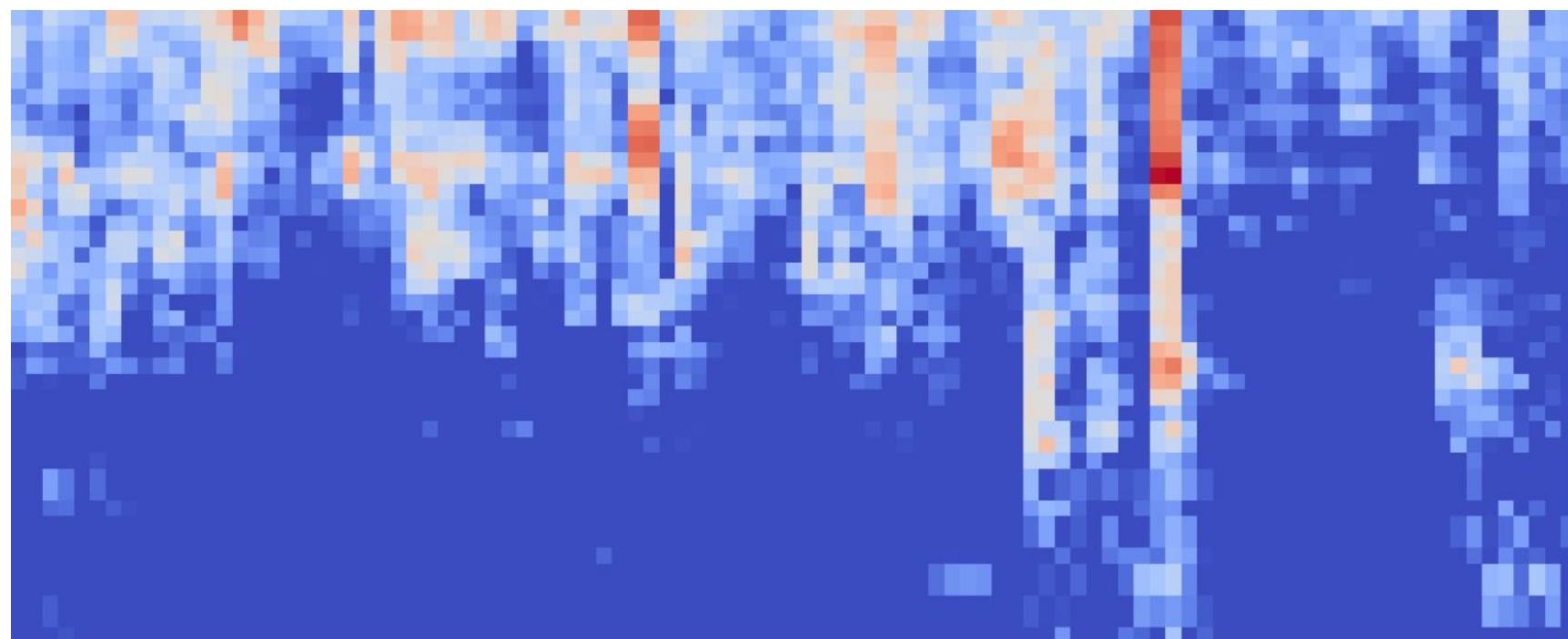
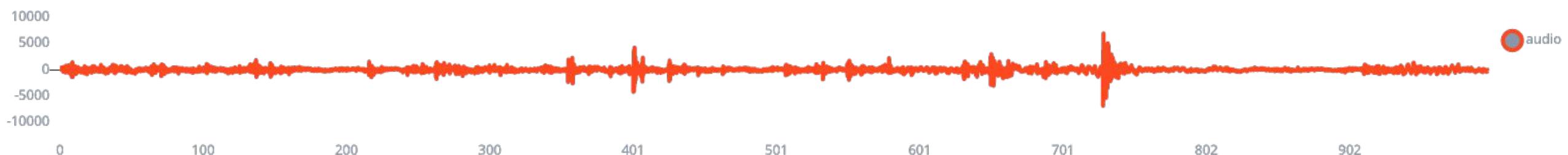
Add a learning block

Audio (MFE)
Extracts a spectrogram from audio signals using **Mel-filterbank energy features**, great for non-voice audio.

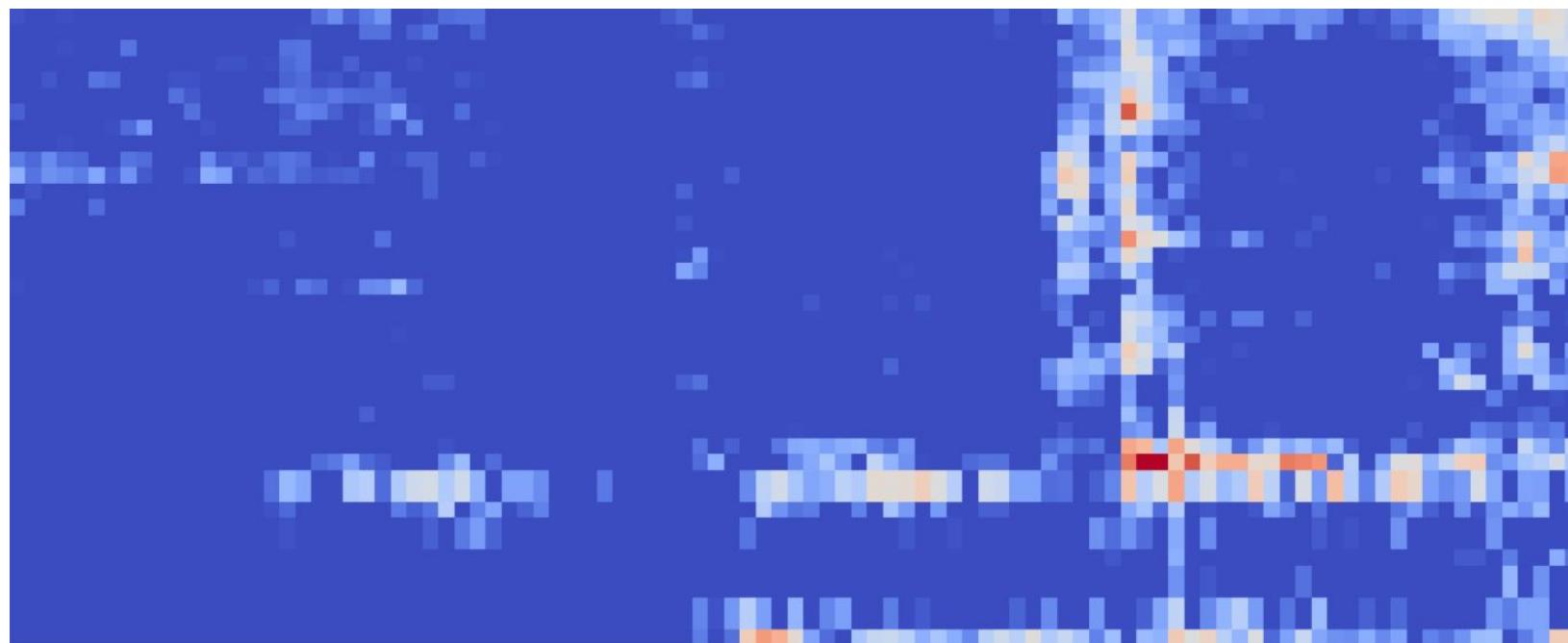
Cool Water 1 second sample



Hot Water 1 second sample



Noise 1 second sample



Parameters Generate features

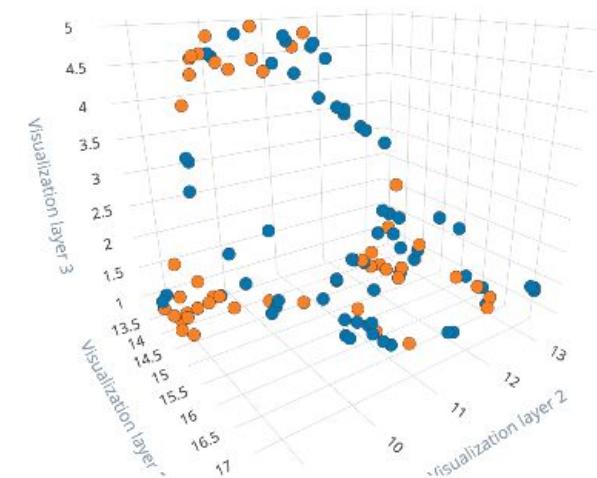
Training set

Data in training set	2m 35s
Classes	3 (cool, hot, noise)
Window length	1000 ms.
Window increase	500 ms.
Training windows	155

Generate featuresFeature explorer (155 samples) ?

X Axis Y Axis Z Axis
Visualization layer 1 Visualization layer 2 Visualization layer 3

- cool
- hot
- noise



20210710-125930.wav.2a5dv05j.s2

Label: cool

[View sample](#)[View features](#)▶ 0:00 / 0:01 ◀ ⋮On-device performance ?

PROCESSING TIME
250 ms.



PEAK RAM USAGE
25 KB

#1 ▾ Click to set a description for this version

Neural Network settings

Training settings

Number of training cycles ②

Learning rate ②

Minimum confidence rating ②

Audio training options

Data augmentation ②

Neural network architecture

Architecture presets ② 1D Convolutional (Default) 2D Convolutional

Input layer (3,960 features)

Reshape layer (40 columns)

1D conv / pool layer (8 neurons, 3 kernel size, 1 layer)

Dropout (rate 0.25)

1D conv / pool layer (16 neurons, 3 kernel size, 1 layer)

Dropout (rate 0.25)

Flatten layer

Add an extra layer

Output layer (3 features)

Training output

Model

Model version: ② Quantized (int8) ▾

Last training performance (validation set)

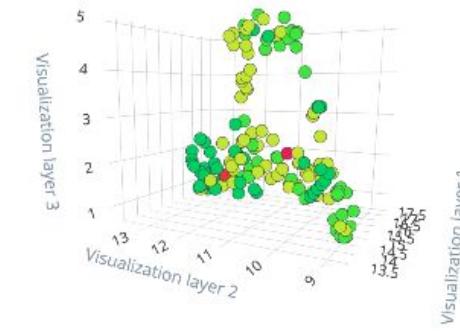
 ACCURACY 93.5%	 LOSS 0.13
---	--

Confusion matrix (validation set)

	COOL	HOT	NOISE
COOL	92.9%	7.1%	0%
HOT	16.7%	83.3%	0%
NOISE	0%	0%	100%
F1 SCORE	0.93	0.83	1.00

Feature explorer (full training set) ②

- cool - correct
- hot - correct
- noise - correct
- cool - incorrect
- hot - incorrect



On-device performance ②

 INFERENCING TIME 17 ms.	 PEAK RAM USAGE 10.9K	 FLASH USAGE 31.4K
--	---	--



This lists all test data. You can manage this data through [Data acquisition](#).

Test data

[Classify all](#)

Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse.

SAMPLE NAME	EXPECTED OUTCOME	LENGTH	ACCURACY	RESULT	...
20210710-130728.wav	hot	1s	100%	1 hot	...
20210710-130639.wav	hot	1s	100%	1 hot	...
20210710-130553.wav	hot	1s	100%	1 hot	...
20210710-130535.wav	hot	1s	100%	1 hot	...
20210710-130535.wav	hot	1s	100%	1 hot	...
20210710-130224.wav	cool	1s	0%	1 noise	...
20210710-130304.wav	cool	1s	100%	1 cool	...
20210710-130236.wav	cool	1s	100%	1 cool	...
20210710-130256.wav	cool	1s	100%	1 cool	...
20210710-130224.wav	cool	1s	100%	1 cool	...
20210710-130142.wav	cool	1s	0%	1 noise	...
20210710-130100.wav	noise	1s	100%	1 noise	...
20210710-130041.wav	noise	1s	100%	1 noise	...
20210710-125854.wav	noise	1s	100%	1 noise	...
20210710-125854.wav	noise	1s	100%	1 noise	...

Model testing output

Model testing results

ACCURACY

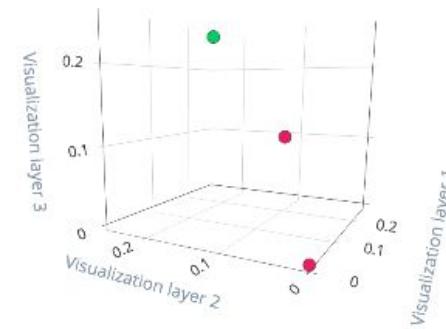
86.67%

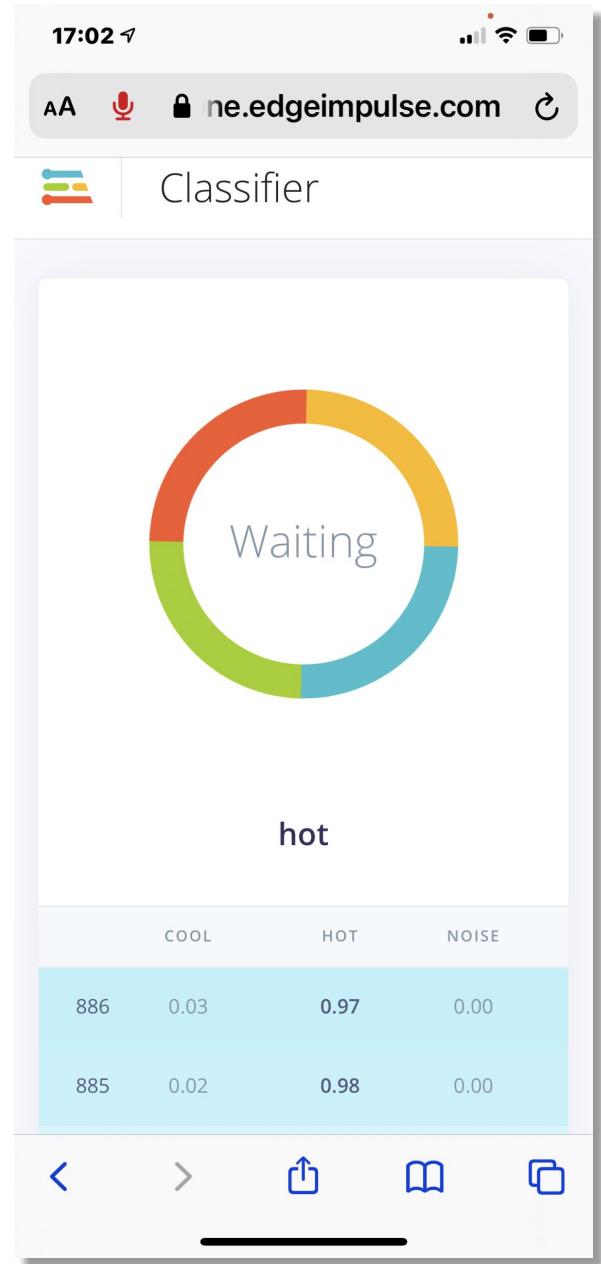
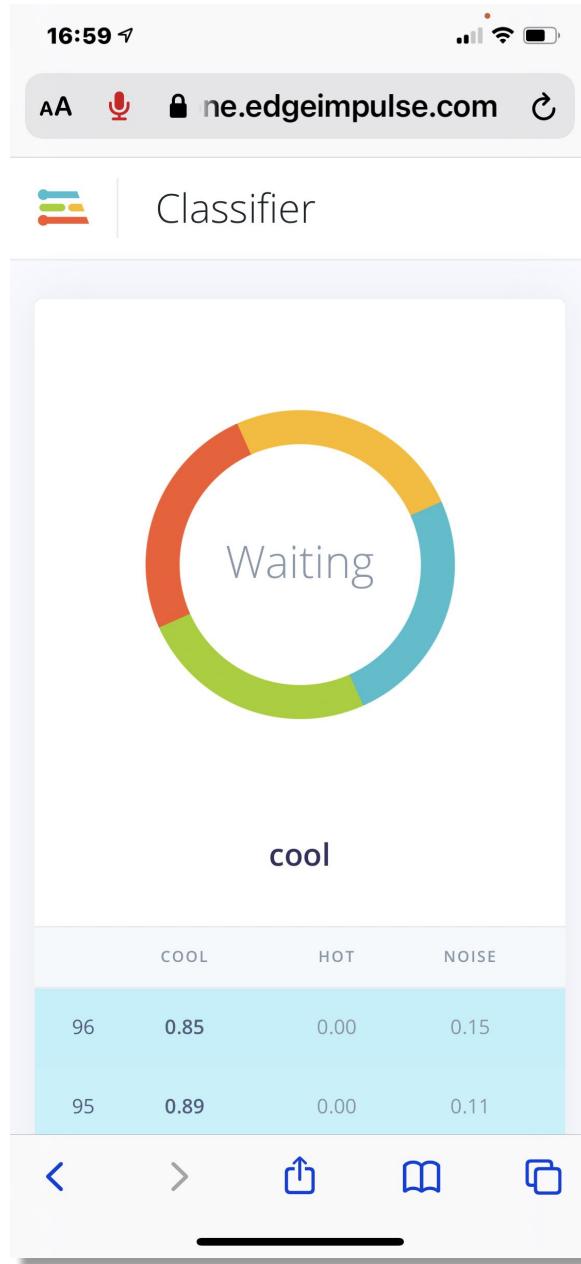
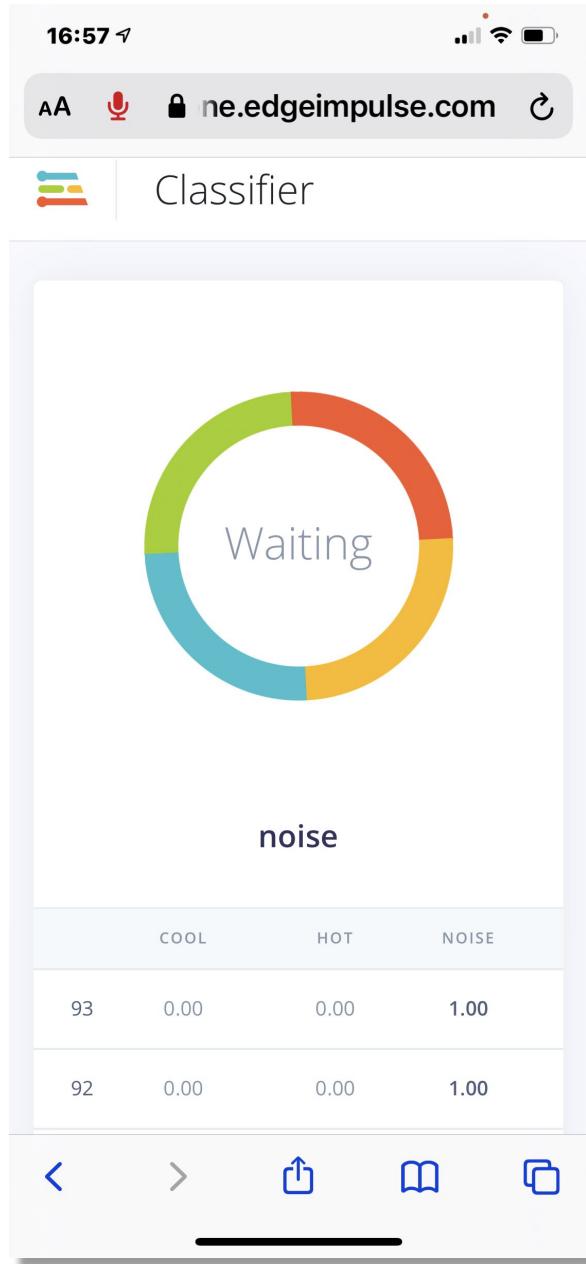


	COOL	HOT	NOISE	UNCERTAIN
COOL	66.7%	0%	33.3%	0%
HOT	0%	100%	0%	0%
NOISE	0%	0%	100%	0%

Feature explorer

- cool - correct
- hot - correct
- noise - correct
- cool - incorrect





Select optimizations (optional)

Model optimizations can increase on-device performance but may reduce accuracy. Click below to analyze optimizations and see the recommended choices for your target. Or, just click Build to use the currently selected options.



Enable EON™ Compiler

Same accuracy, up to 50% less memory. Open source.



Available optimizations for NN Classifier

Quantized (int8)	RAM USAGE	LATENCY	CONFUSION MATRIX			
	10.9K	17 ms	66.7	0	33.3	0
Currently selected	FLASH USAGE	ACCURACY	0	100	0	0
	31.4K	86.67%	0	0	100	0
Unoptimized (float32)	RAM USAGE	LATENCY	CONFUSION MATRIX			
	33.9K	78 ms	66.7	0	33.3	0
Click to select	FLASH USAGE	ACCURACY	0	100	0	0
	38.0K	86.67%	0	0	100	0

Estimate for Cortex-M4F 80MHz (ST IoT Discovery Kit)

Arduino File Edit Sketch Tools Help

nano_ble33_sense_microphone_continuous_LED | Arduino 1.8.15

/dev/cu.usbmodem144301

ICTP - PSYCOACOUSTICS TEMPERATURE Project

Inferencing settings:

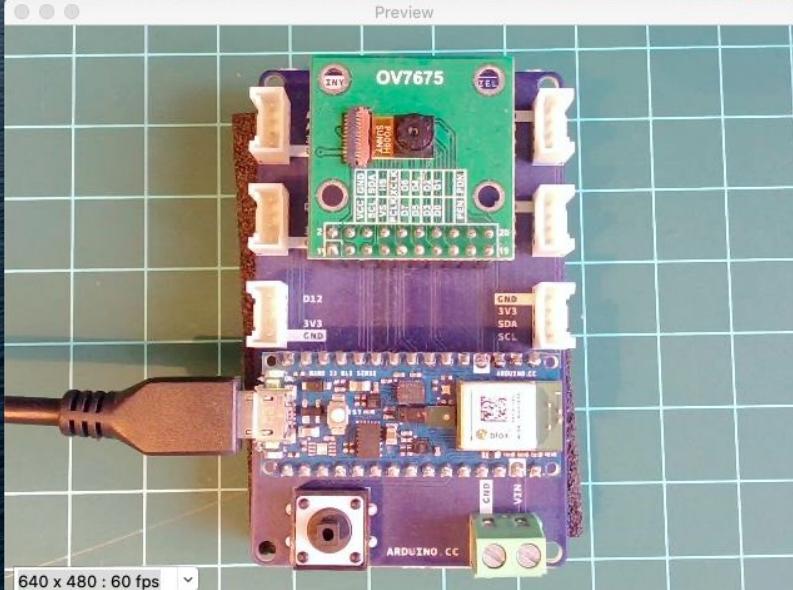
- Interval: 0.06 ms.
- Frame size: 16000
- Sample length: 1000 ms.
- No. of classes: 3

Predictions (DSP: 126 ms., Classification: 21 ms., Anomaly: 0 ms.):

:
 PREDICTION: ==> noise with probability 1.00
 :
 Predictions (DSP: 126 ms., Classification: 21 ms., Anomaly: 0 ms.):
 :
 PREDICTION: ==> noise with probability 1.00
 :
 Predictions (DSP: 126 ms., Classification: 20 ms., Anomaly: 0 ms.):
 :
 PREDICTION: ==> noise with probability 1.00

Autoscroll Show timestamp Both NL & CR 115200 baud Clear output

Preview



Done uploading.
 writeBuffer(scr_addr=0x34, dst_addr=0x44000, size=0x1000)
 [=====] 95% (69/72 pages) write(addr=0x34, size=0x1000)
 writeBuffer(scr_addr=0x34, dst_addr=0x45000, size=0x1000)
 [=====] 97% (70/72 pages) write(addr=0x34, size=0x1000)

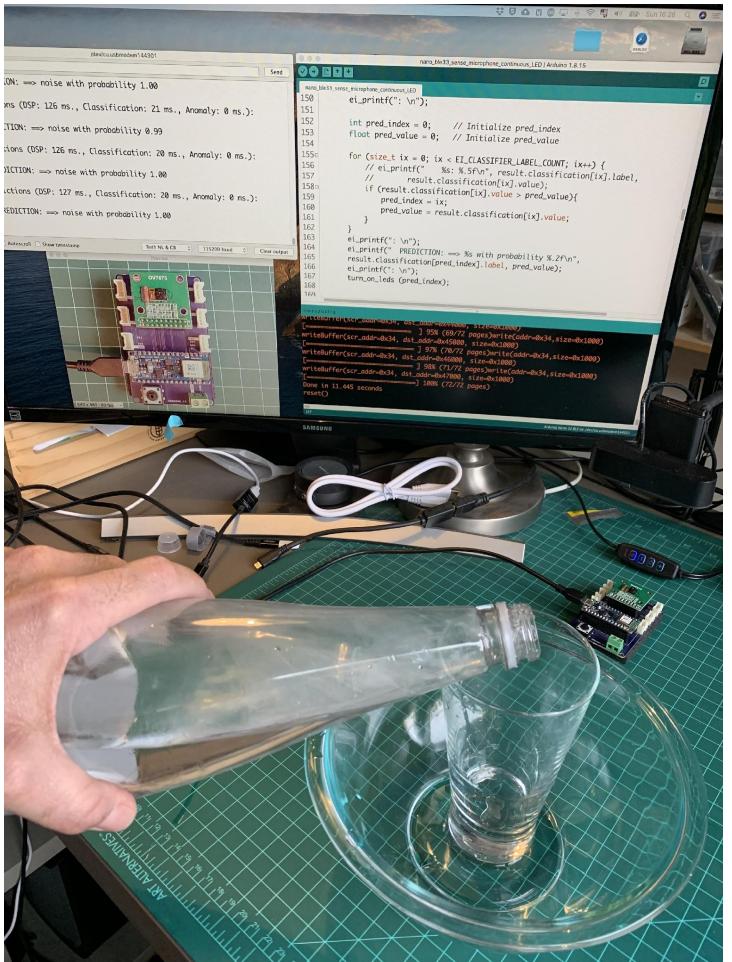
Arduino Nano 33 BLE on /dev/cu.usbmodem144301

```

88 /**
89 * @brief      Special Postprocess function for RGB LEDs
90 */
91
92 void turn_off_leds(){
93     digitalWrite(LED_R, HIGH);
94     digitalWrite(LED_G, HIGH);
95     digitalWrite(LED_B, HIGH);
96 }
97
98 /*
99 * cool: [0] ==> Blue ON
100 * hot: [1] ==> Red ON
101 * noise: [2] ==> ALL OFF
102 */
103
104 void turn_on_leds(int pred_index) {
105     switch (pred_index)
106     {
107     case 0:
108         turn_off_leds();
109         digitalWrite(LED_B, LOW);
110         break;
111
112     case 1:
113         turn_off_leds();
114         digitalWrite(LED_R, LOW);
115         break;
116
117     case 2:
118         turn_off_leds();
119         break;
120     }
121 }
122

```

87



```

Serial.println("noise with probability 1.00");
...
PREDICTION: ==> noise with probability 0.99
...
PREDICTION: ==> noise with probability 1.00
...
PREDICTION: ==> noise with probability 0.99
...
PREDICTION: ==> noise with probability 1.00
...
PREDICTION: ==> noise with probability 0.99
...
PREDICTION: ==> noise with probability 1.00
...
PREDICTION: ==> cool with probability 0.96
...

```

The screenshot shows a terminal window with a blue border. A red box highlights the line "PREDICTION: ==> cool with probability 0.96". Below the terminal is a camera view showing the Arduino Uno and OV7675 module setup. A blue arrow points to the OV7675 module, and a red box highlights the blue LED on its PCB.

```

PREDICTION: ==> noise with probability 1.00
...
PREDICTION: ==> noise with probability 0.99
...
PREDICTION: ==> cool with probability 0.68
...
PREDICTION: ==> cool with probability 1.00
...
PREDICTION: ==> cool with probability 1.00
...
PREDICTION: ==> hot with probability 0.99
...

```

The screenshot shows a terminal window with a blue border. A red box highlights the line "PREDICTION: ==> hot with probability 0.99". Below the terminal is a camera view showing the Arduino Uno and OV7675 module setup. A red arrow points to the OV7675 module, and a red box highlights the blue LED on its PCB.

Reading Material

Main references

- [Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning](#)
- [Professional Certificate in Tiny Machine Learning \(TinyML\) – edX/Harvard](#)
- [Introduction to Embedded Machine Learning \(Coursera\)](#)
- [Text Book: "TinyML" by Pete Warden, Daniel Situnayake](#)

I want to thank Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google, and especially Harvard professor Vijay Janapa Reddi, Ph.D. student Brian Plancher and their staff for preparing the excellent material on TinyML that is the basis of this course at UNIFEI.

The IESTI01 course is part of the TinyML4D, an initiative to make TinyML education available to everyone globally.

Thanks
And stay safe!



UNIFEI