

IESTI01 - TinyML

Collecting Data Alternative ways

Prof. Marcelo Rovai

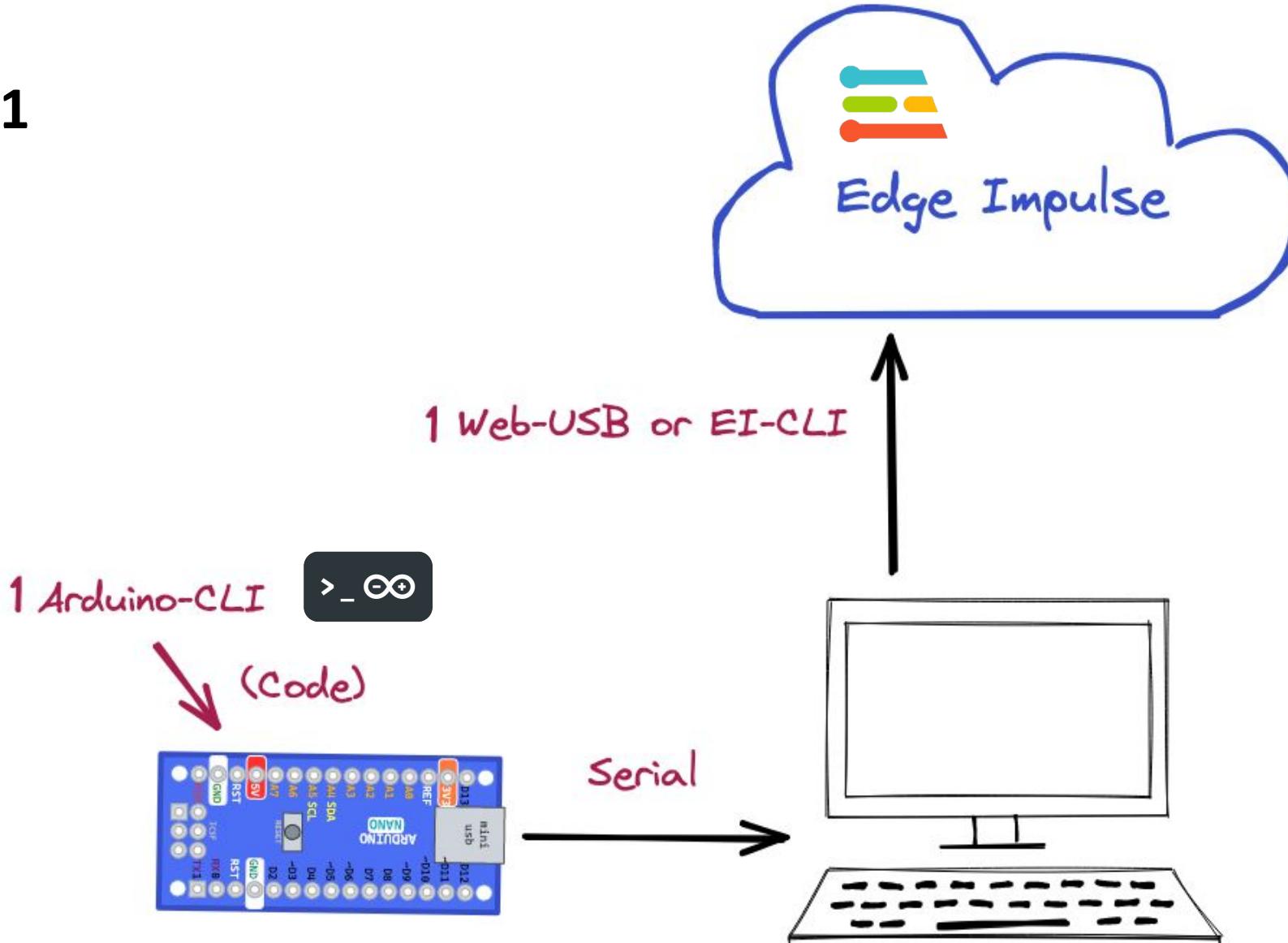
July 14th, 2021



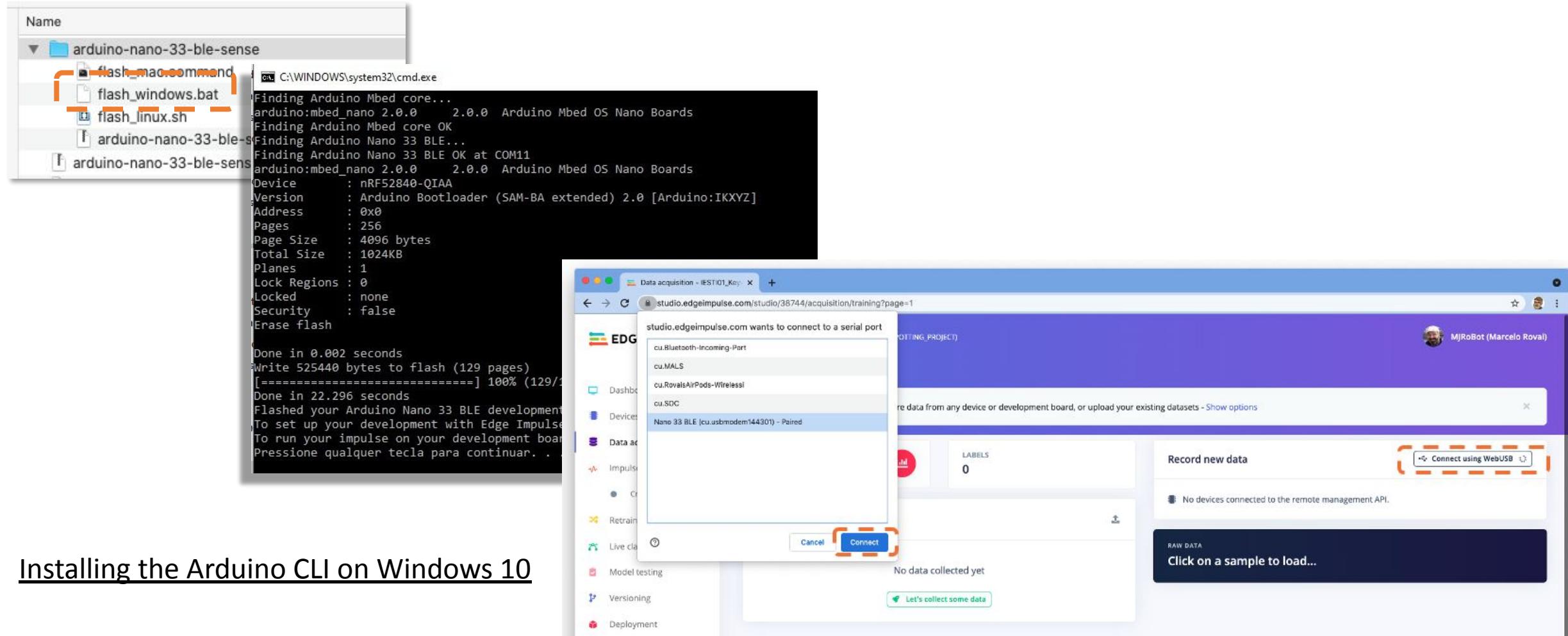
Sensor Data – EI Studio Ingestion

Alternative methods

1

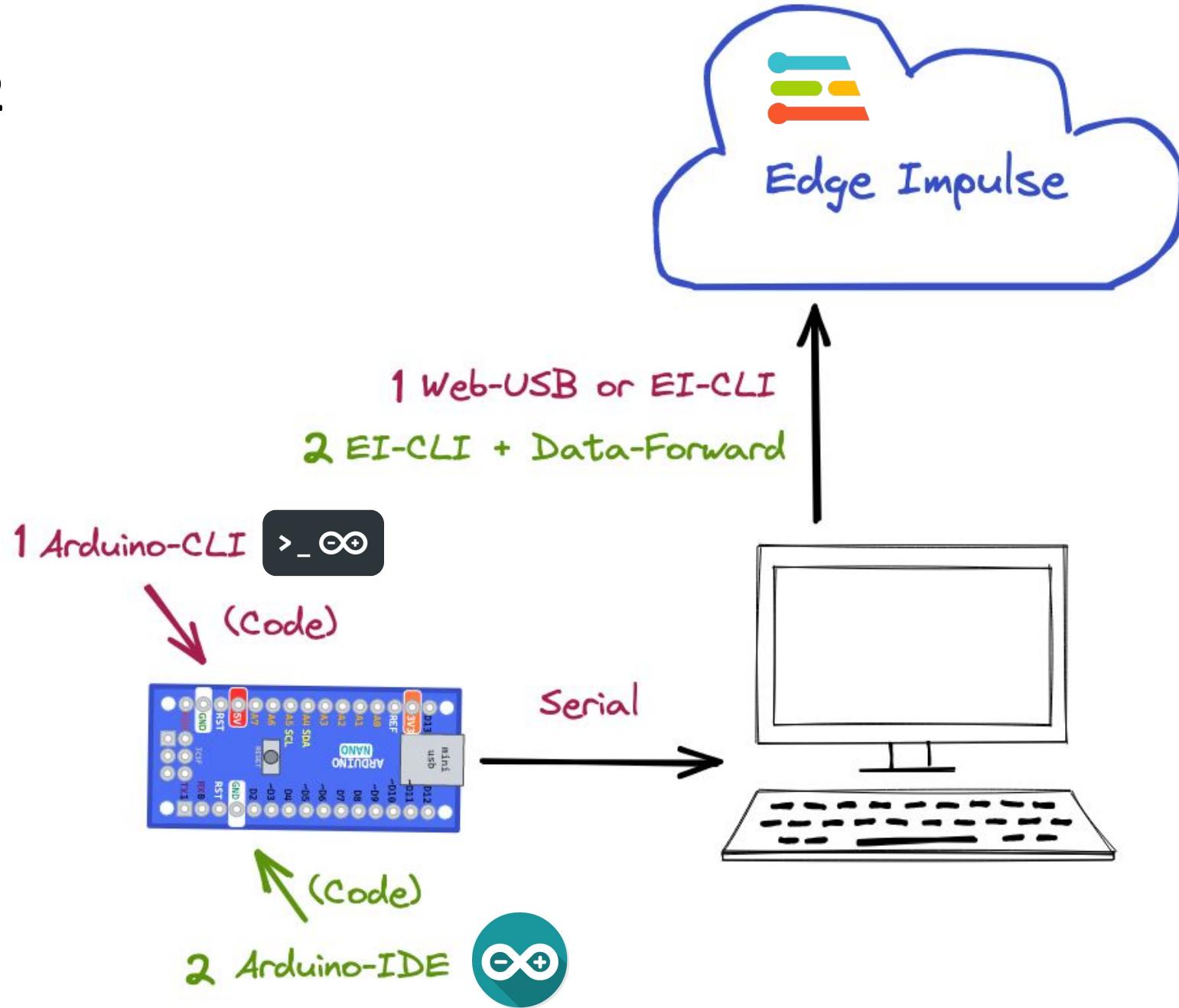


1. Data Ingestion using Arduino-Cli + Web-USB (or EI-CLI)



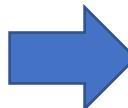
Installing the Arduino CLI on Windows 10

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 }
```



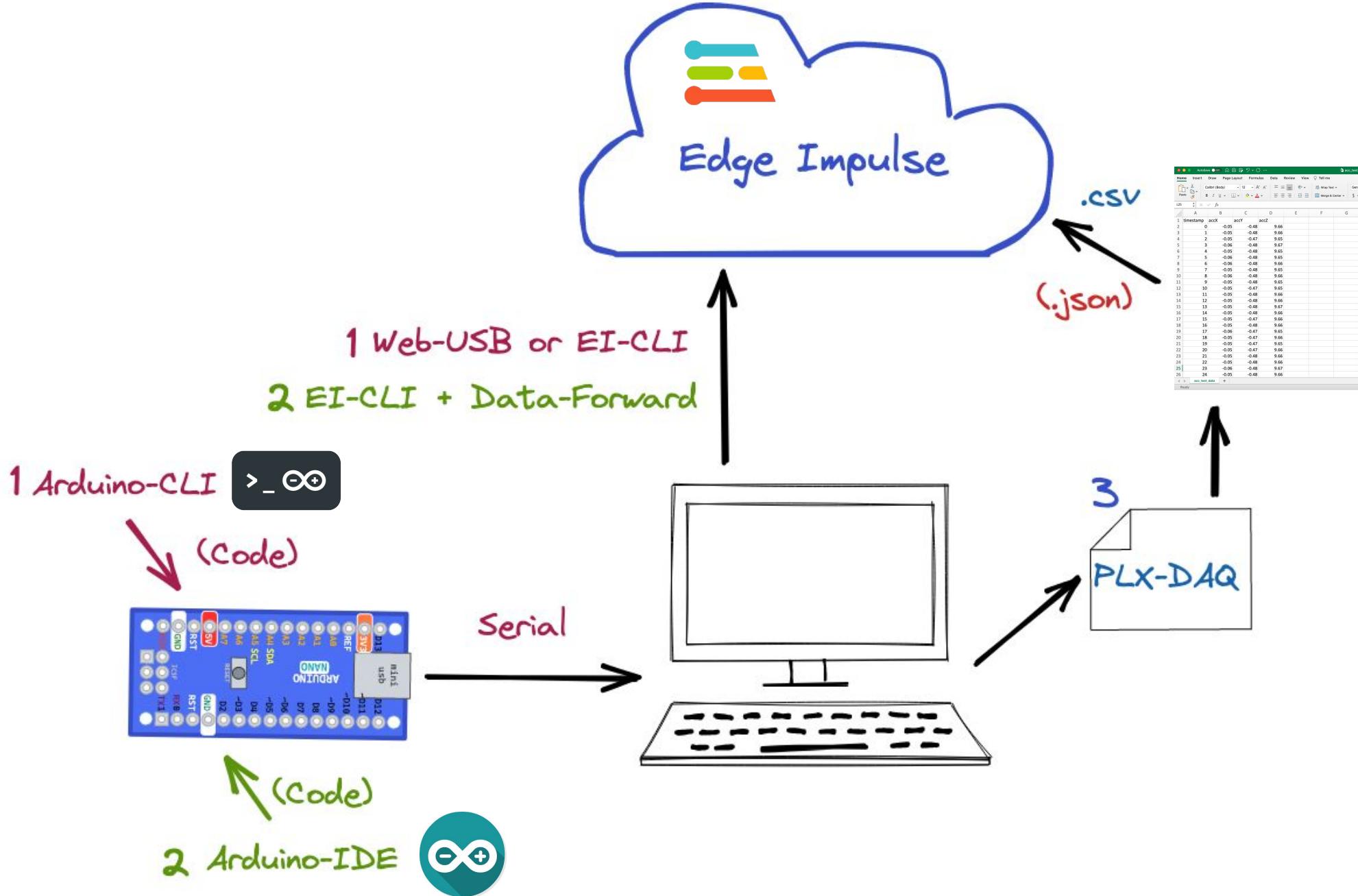
```
$ edge-impulse-data-forwarder --clean
```

```
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

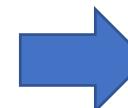
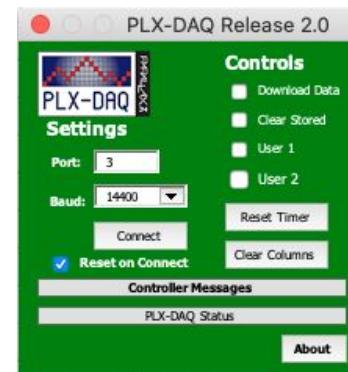
? To which project do you want to connect this device? MJRoBot (Marcelo Rovai) / IESTI01_Input_Data_Test
[SER] Detecting data frequency...
[SER] Detected data frequency: 51Hz
[?] 3 sensor axes detected (example values: [-0.08,-0.34,9.82]). What do you want to call them? Separate the names with ',': accX,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

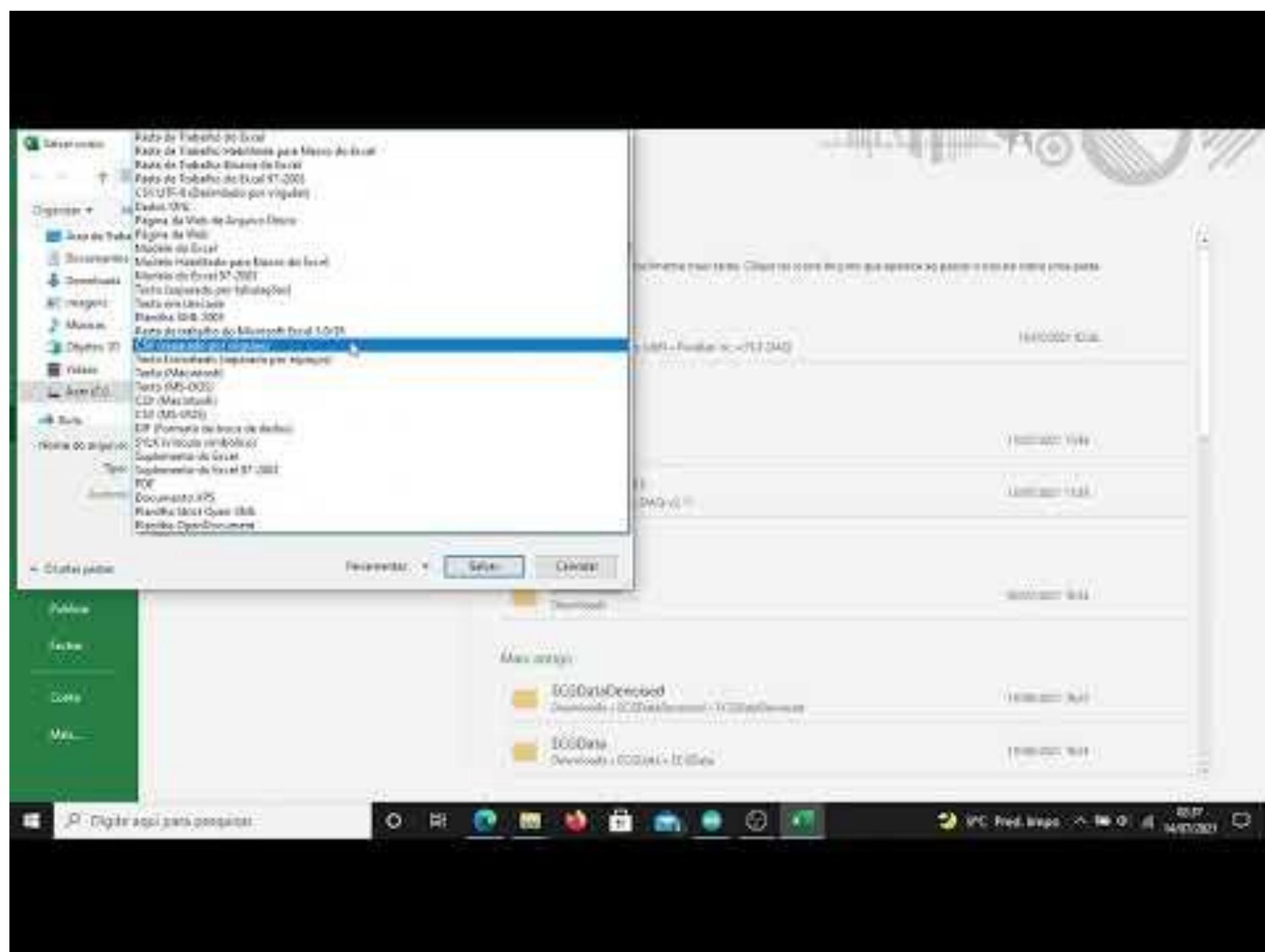


3. Data Ingestion using PLX-DAQ (Windows) => Final Format: .csv

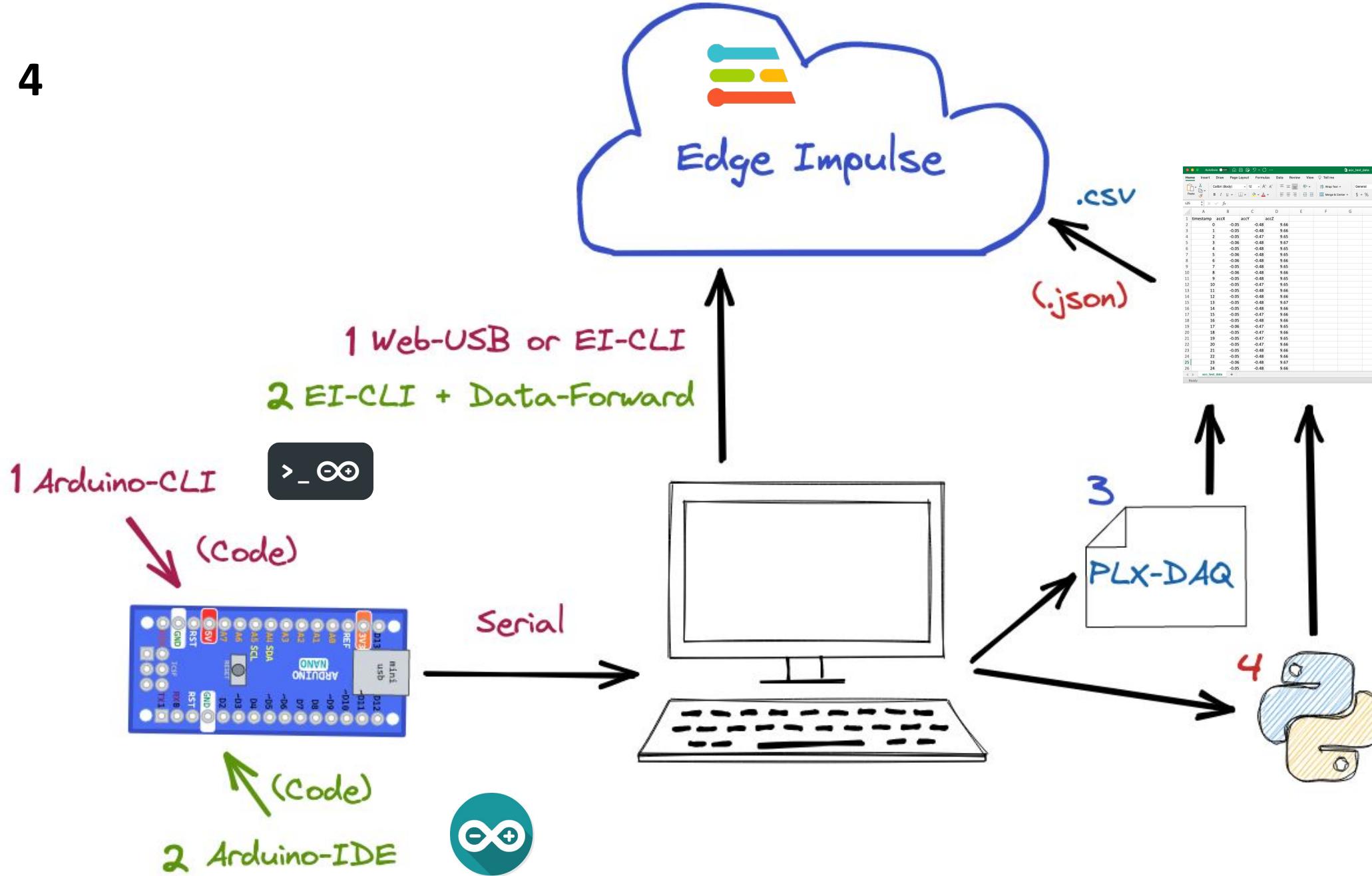
```
Capture_Ard33_Sense_IMU_Acc
1 #include <Arduino_LSM9DS1.h>
2
3 #define CONVERT_G_TO_MS2 9.80665f
4 #define FREQUENCY_HZ 50
5 #define INTERVAL_MS (1000 / (FREQUENCY_HZ + 1))
6
7 void setup() {
8     Serial.begin(115200);
9     while (!Serial);
10    Serial.println("Started");
11
12    if (!IMU.begin()) {
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		

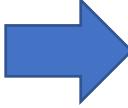


4



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

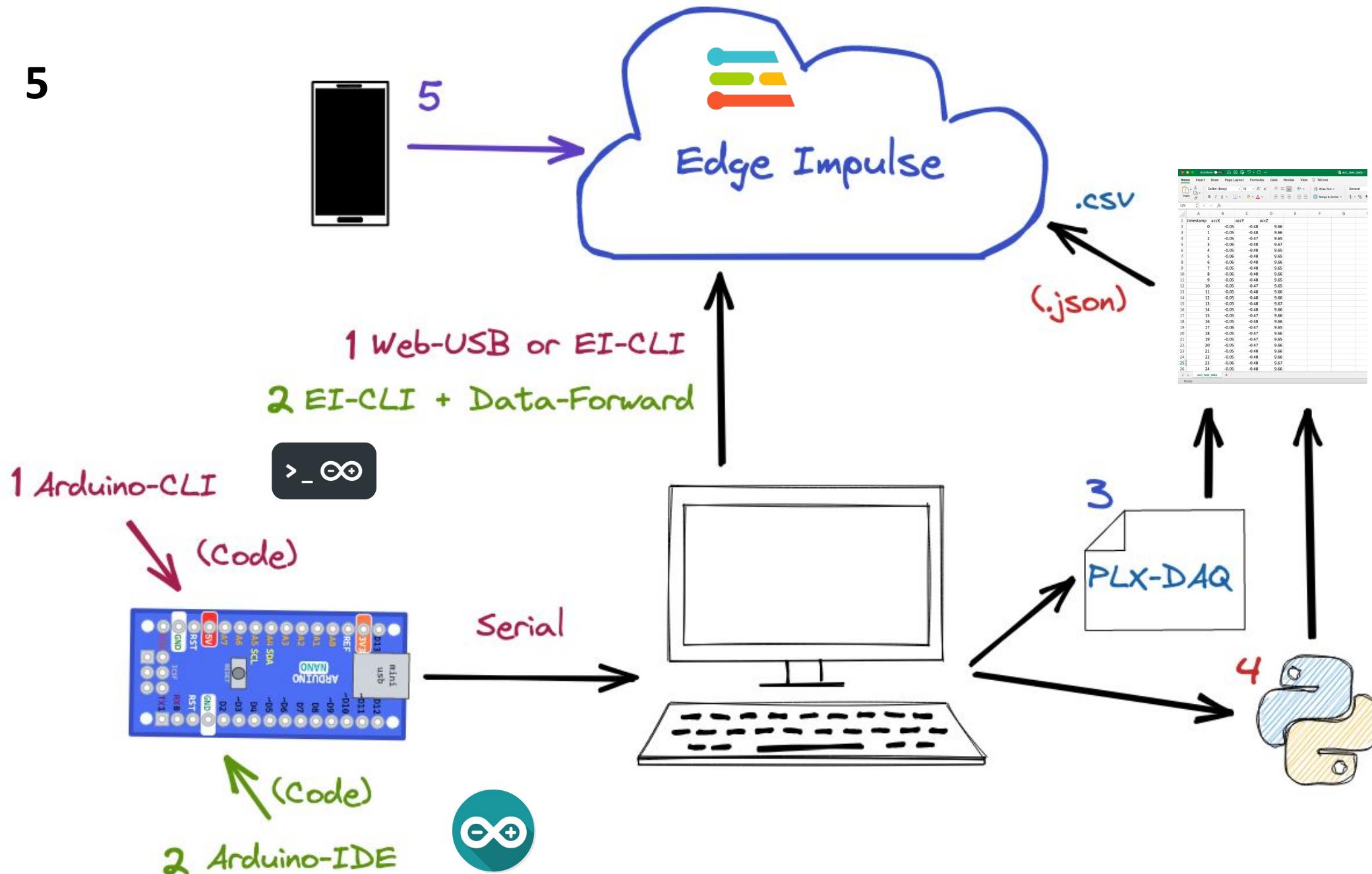
```
Capture_Ardub33_Sense_IMU_Acc
1 #include <Arduino_LSM9DS1.h>
2
3 #define CONVERT_G_TO_MS2    9.80665f
4 #define FREQUENCY_HZ        50
5 #define INTERVAL_MS          (1000 / (FREQUENCY_HZ + 1))
6
7 void setup() {
8     Serial.begin(115200);
9     while (!Serial);
10    Serial.println("Started");
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 }
```



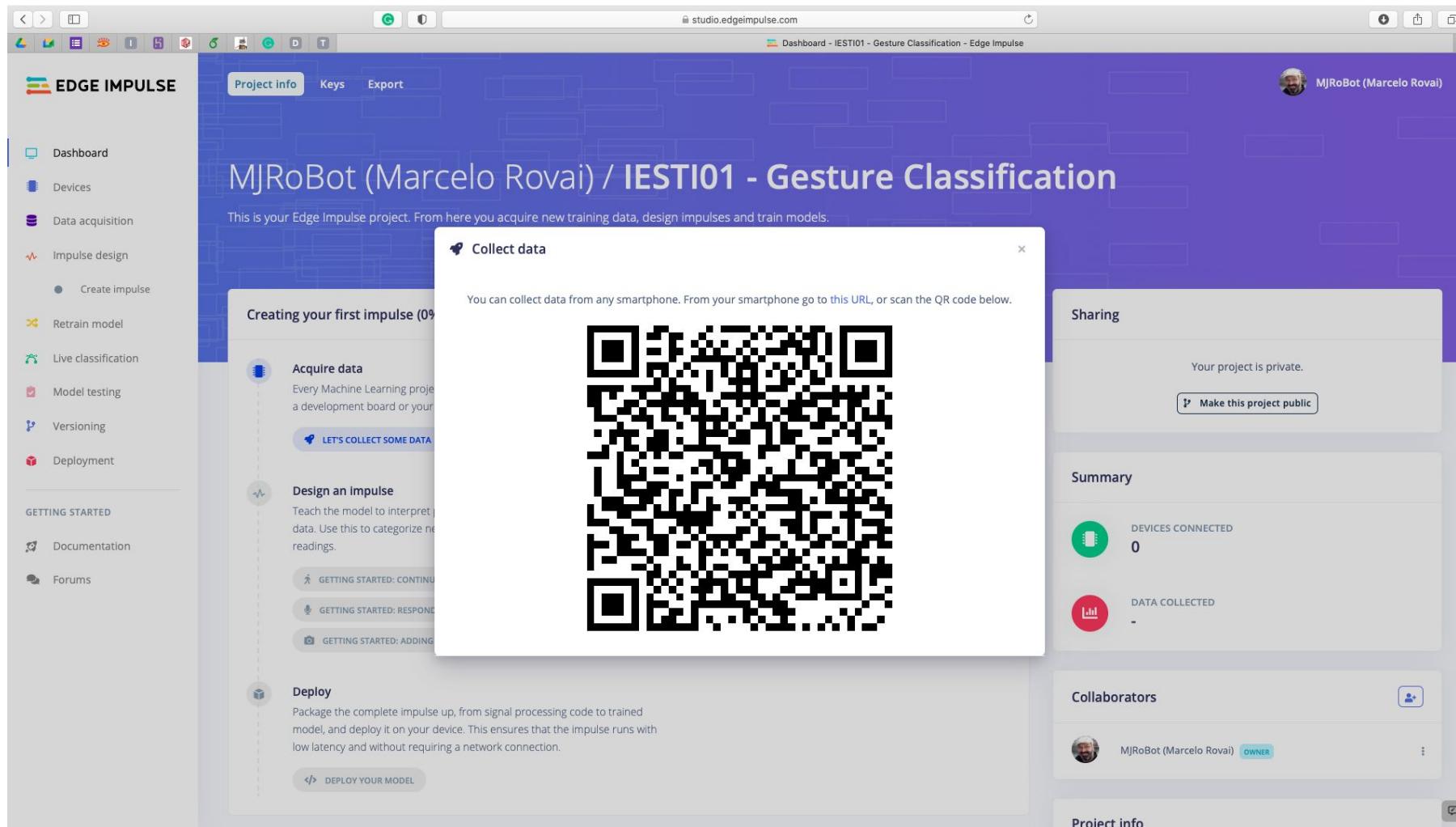
```
1 # Sensor data Logger (CSV)
2 # by Marcelo Rovai @ 13July21
3
4 import serial
5
6 arduino_port = '/dev/tty.usbmodem144301'
7 baud_rate = 115200
8 ser = serial.Serial(port=arduino_port, baudrate=baud_rate)
9
10 fileName = "acc_test_data.csv" # name of the CSV file generated
11
12 first_line = 'timestamp,accX,accY,accZ'
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()
```



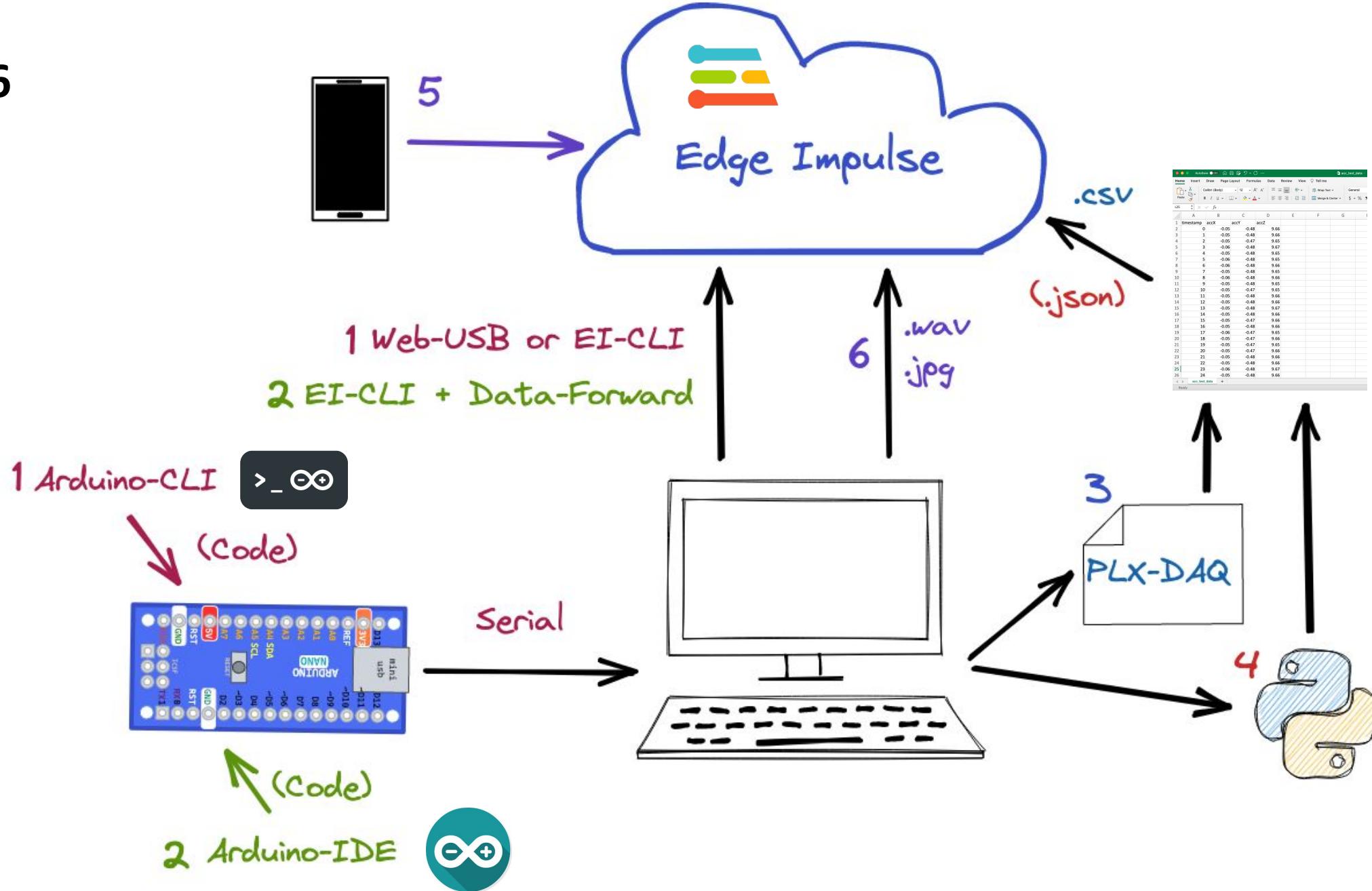
L25	A	B	C	D	E	F	G
1	timestamp	accX	accY	accZ			
2	0	-0.05	-0.48	9.66			
3	1	-0.05	-0.48	9.66			
4	2	-0.05	-0.47	9.65			
5	3	-0.06	-0.48	9.67			
6	4	-0.05	-0.48	9.65			
7	5	-0.06	-0.48	9.65			
8	6	-0.06	-0.48	9.66			
9	7	-0.05	-0.48	9.65			
10	8	-0.06	-0.48	9.66			
11	9	-0.05	-0.48	9.65			
12	10	-0.05	-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. Data Ingestion using Smart Phone



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. 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 progress bar concludes with 'Done. Files uploaded successful: 14. Files that failed to upload: 0.' and 'Job completed'. The top right corner of the interface shows a user profile for 'MJRoBot (Marcelo Rova)'.

(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

Temperature Dependence Psychoacoustics

Simple TinyML Proof-of-concept





Audio Engineering Society

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

He Peng¹ and Joshua D. Reiss²

¹Tianjin University

²Queen Mary University of London

Correspondence should be addressed to He Peng, Joshua Reiss (hepeng2018@hotmail.com, joshua.reiss@qmul.ac.uk)

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

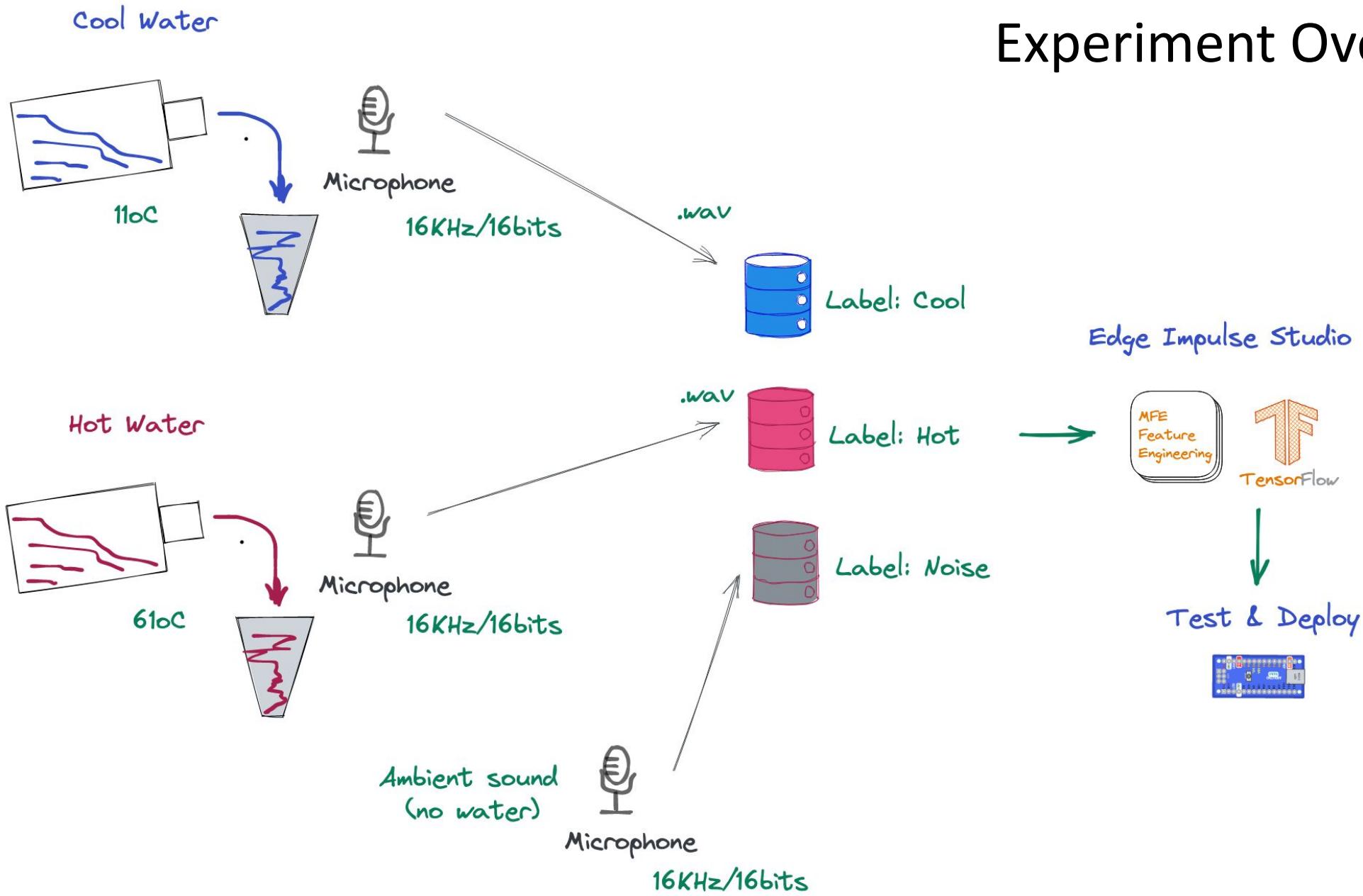


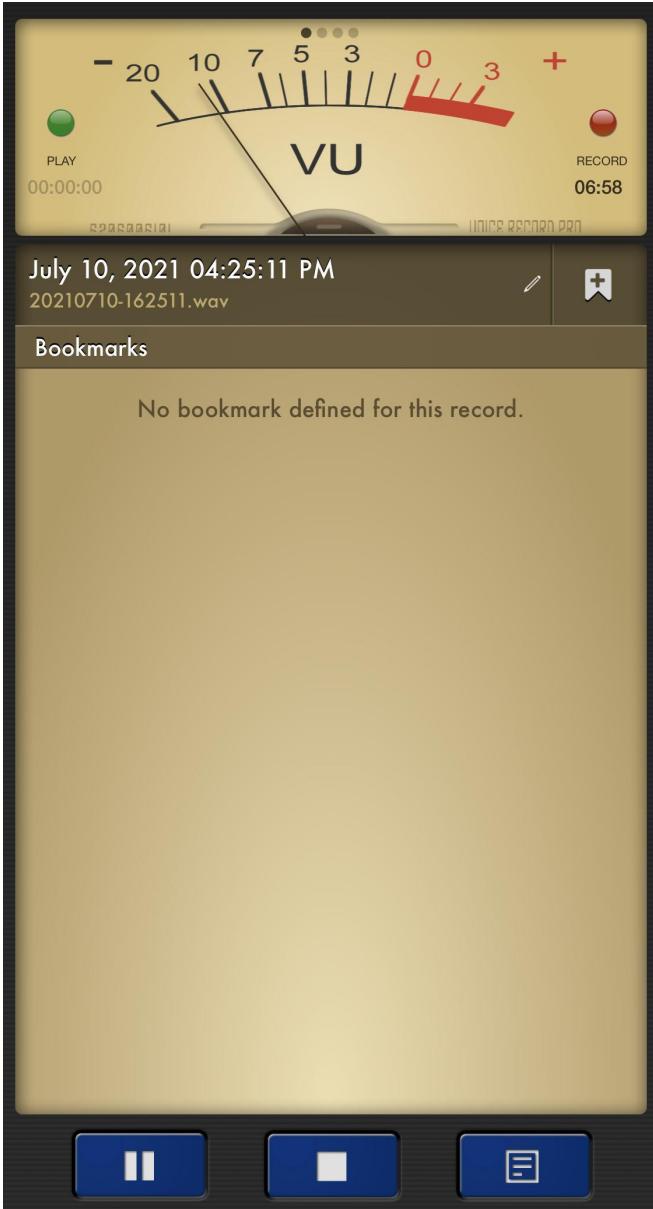
You Can Hear The Difference Between Hot and Cold W...

Tom Scott

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

Experiment Overview





Voice Recorder



Sample Sound:

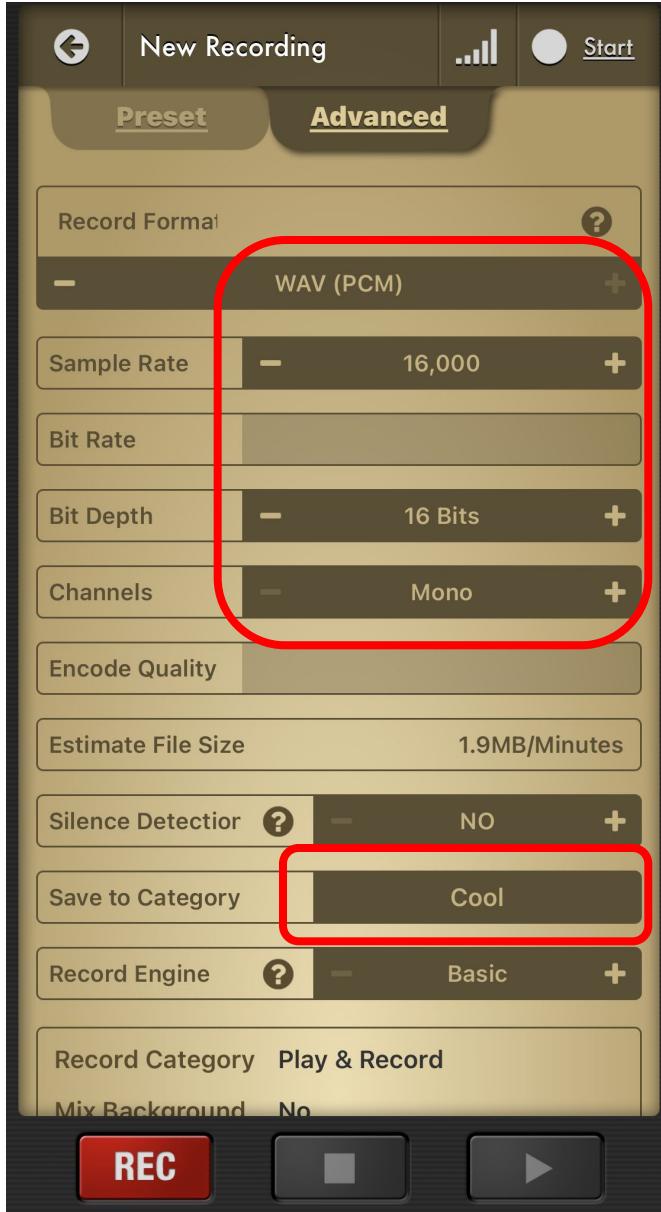
- 16KHz
- PCM – 16bits
- Mono

Classes:

- Hot
- Cool
- Noise



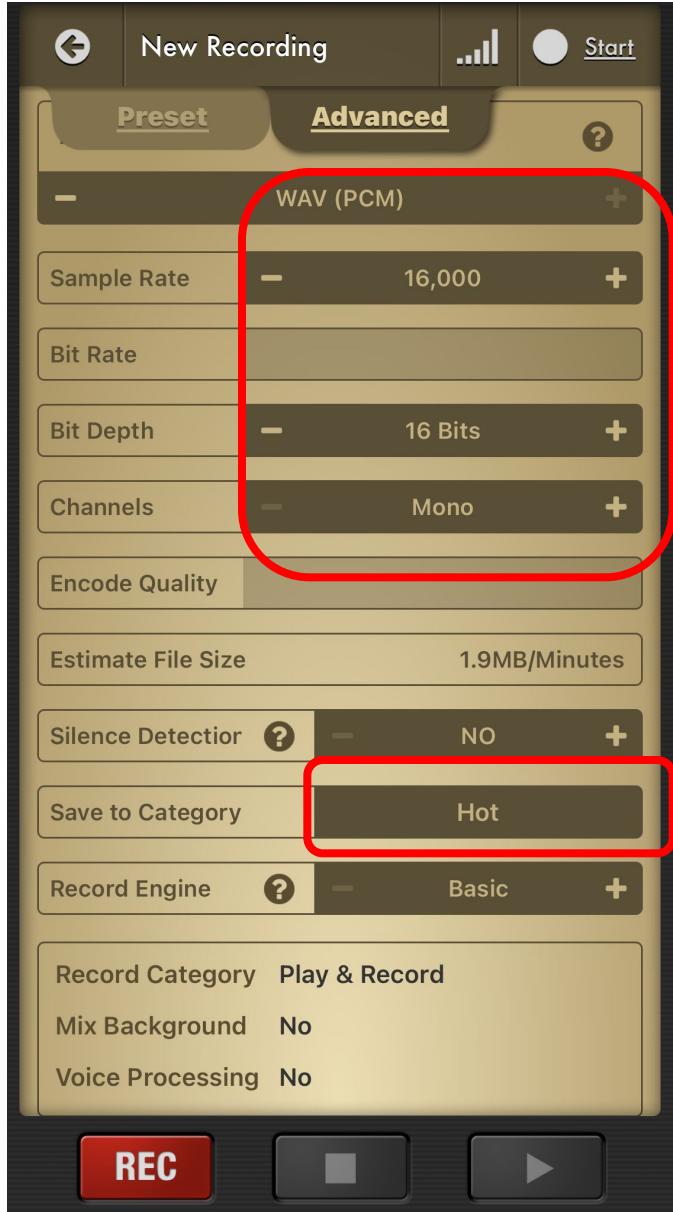
Ambient Temperature: 19°C 19



Class: Cool



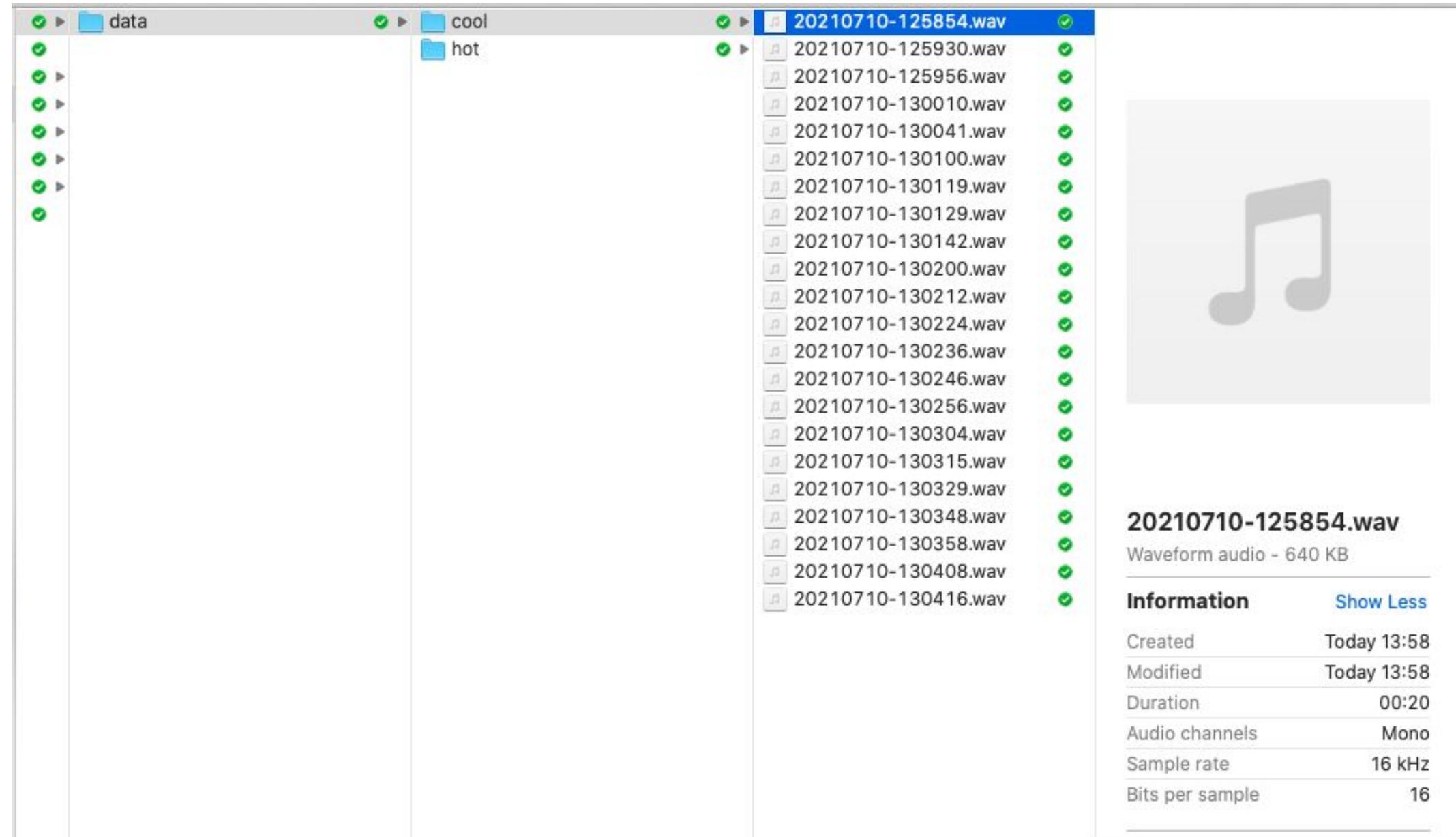
Cool Water Temperature: 11°C



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 of 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](#)

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)

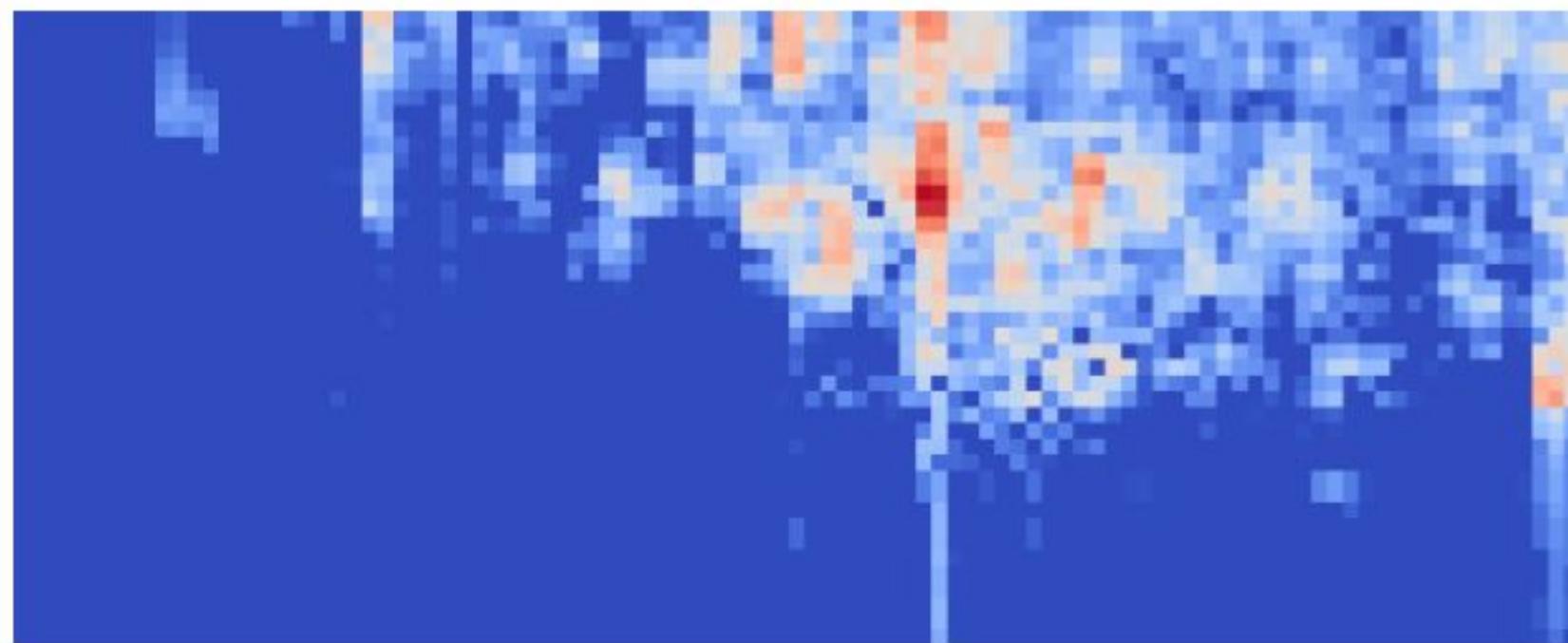
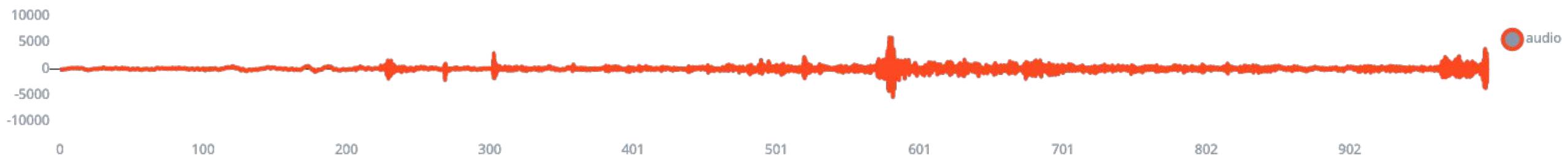
Save Impulse

Add a processing block

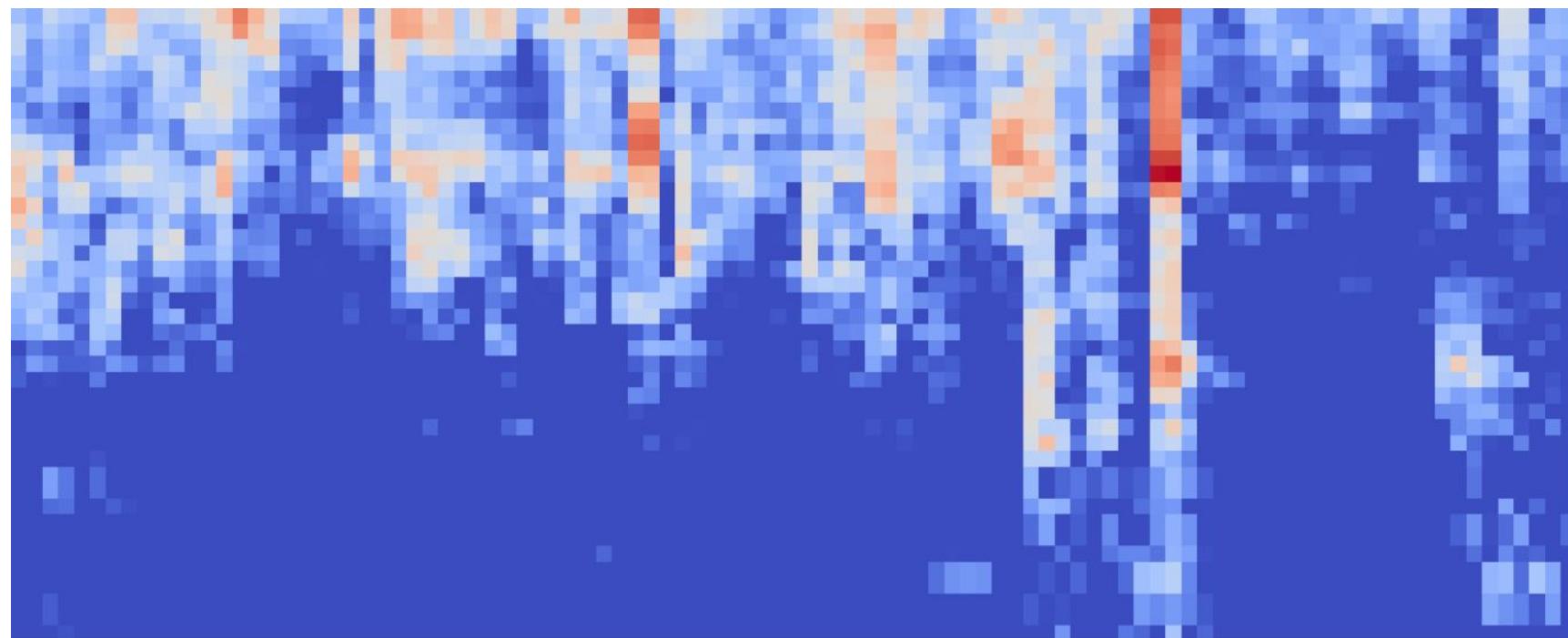
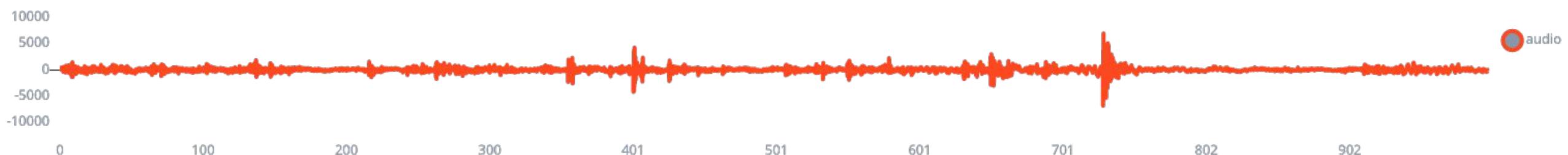
Add a learning block

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

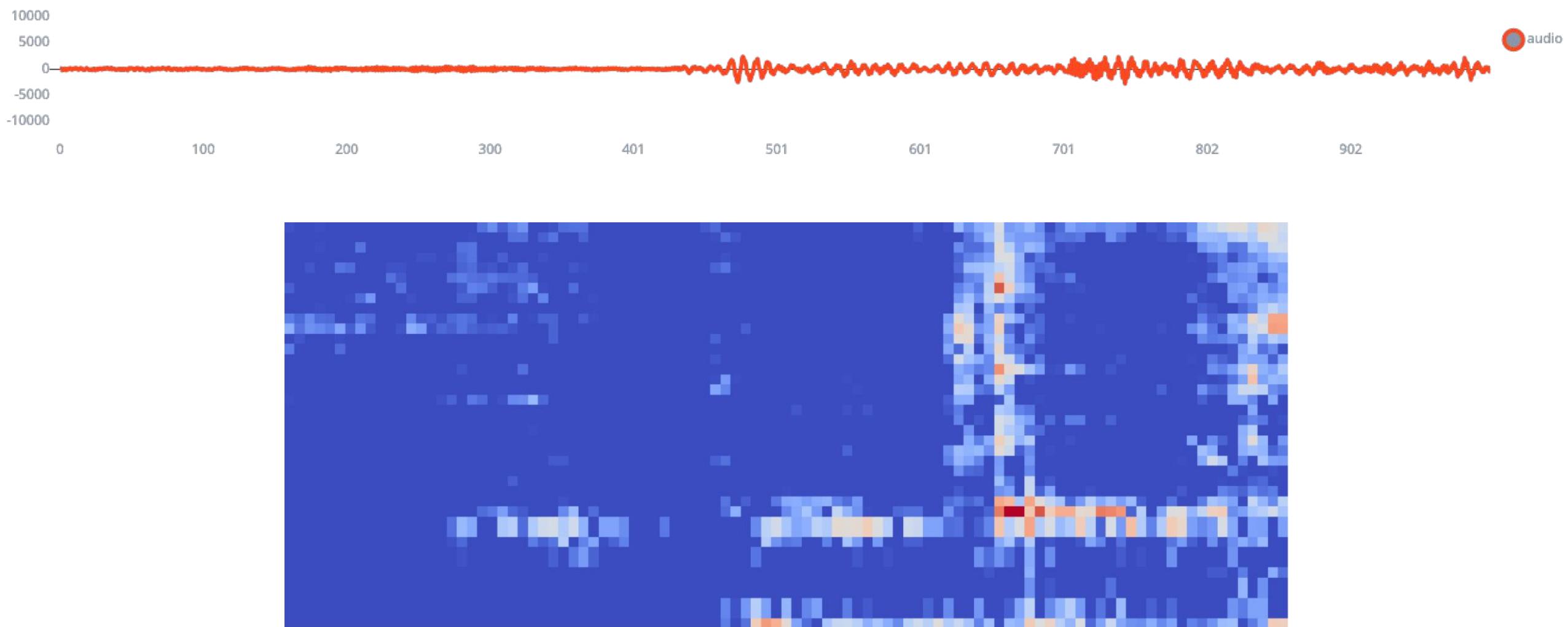
Cool Water 1 second sample



Hot Water 1 second sample



Noise 1 second sample



Parameters Generate features

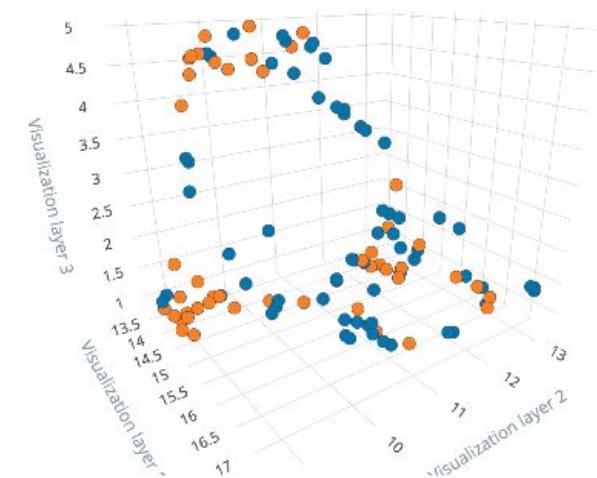
Training set

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

Learning rate

Minimum confidence rating

Audio training options

Data augmentation

Neural network architecture

Architecture presets 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

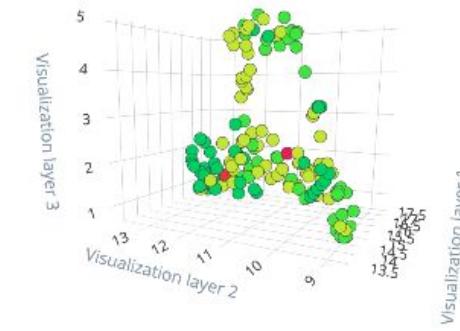
Model version:

Last training performance (validation set)

	COOL	HOT	NOISE
ACCURACY	93.5%	7.1%	0%
LOSS	0.13	83.3%	0%
CONFUSION MATRIX			
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)

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



On-device performance

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

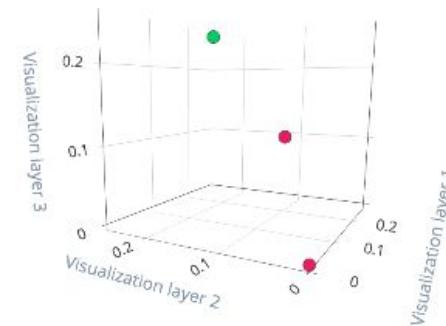
86.67%

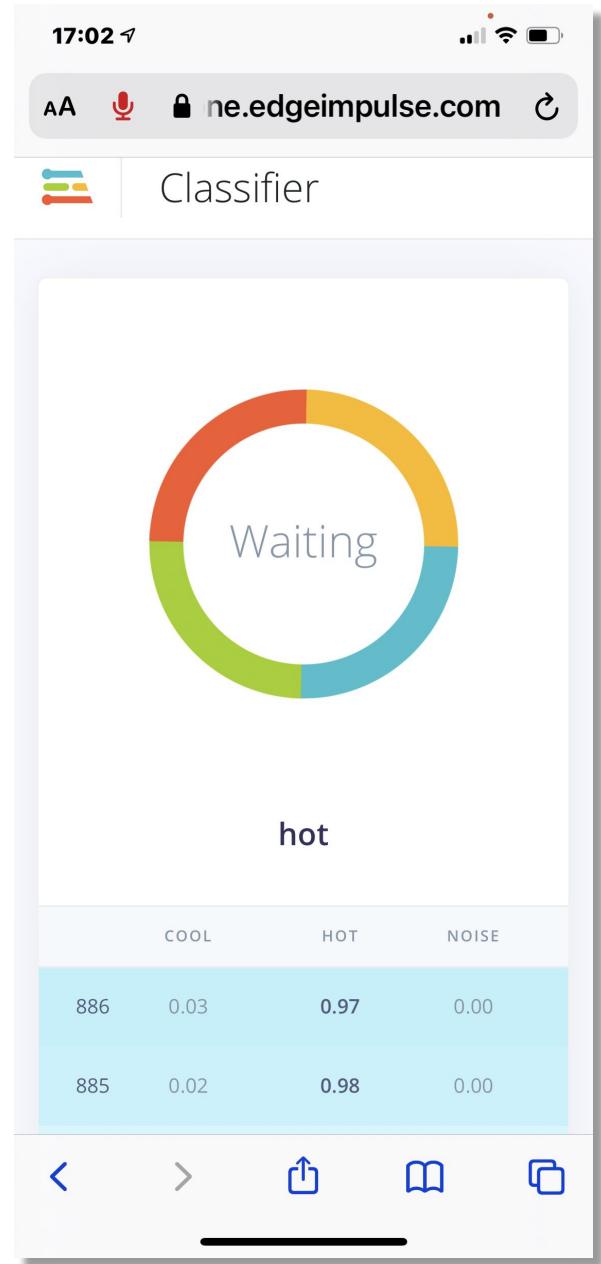
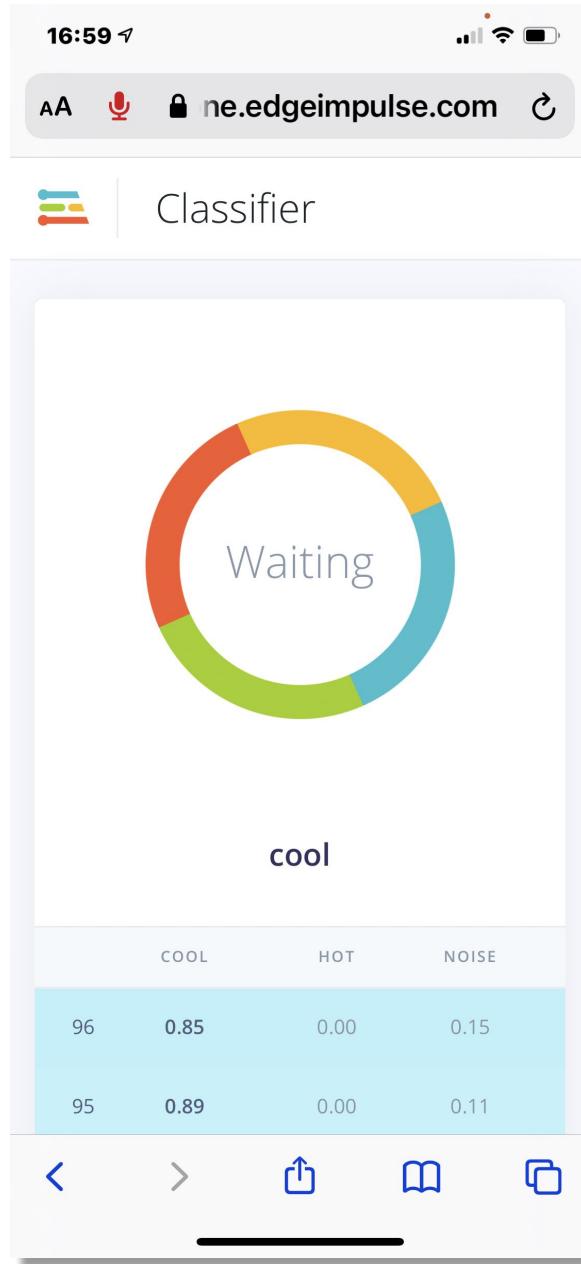
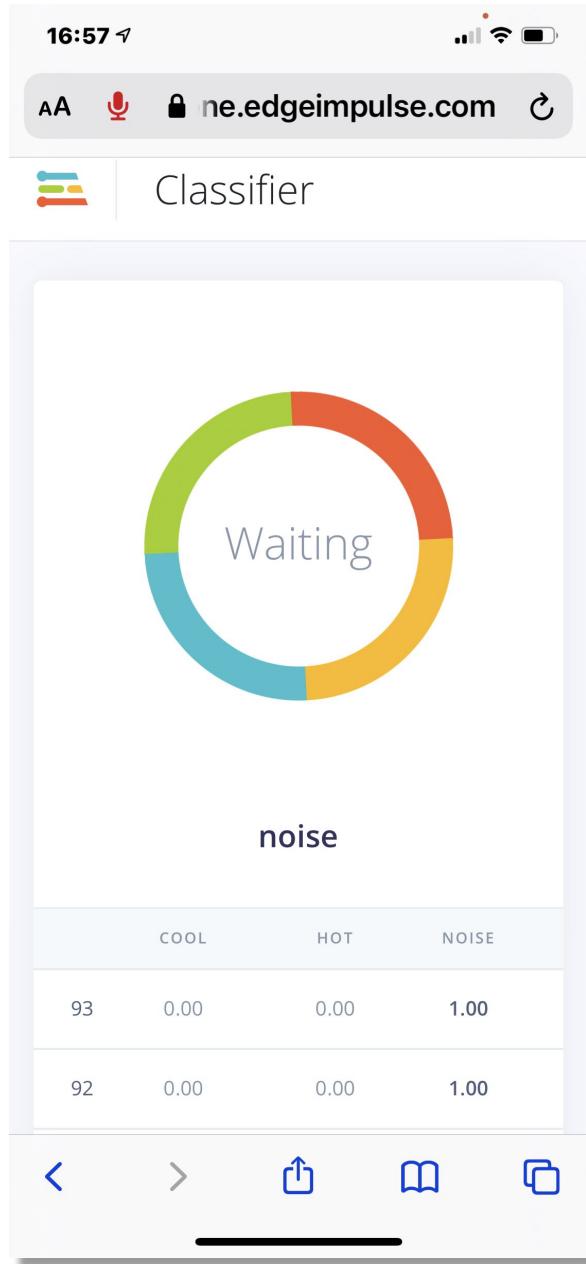


	COOL	HOT	NOISE	UNCERTAIN
COOL	66.7%	0%	33.3%	0%
HOT	0%	100%	0%	0%
NOISE	0%	0%	100%	0%

Feature explorer

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





Live Classifier (Off line) using iphone

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

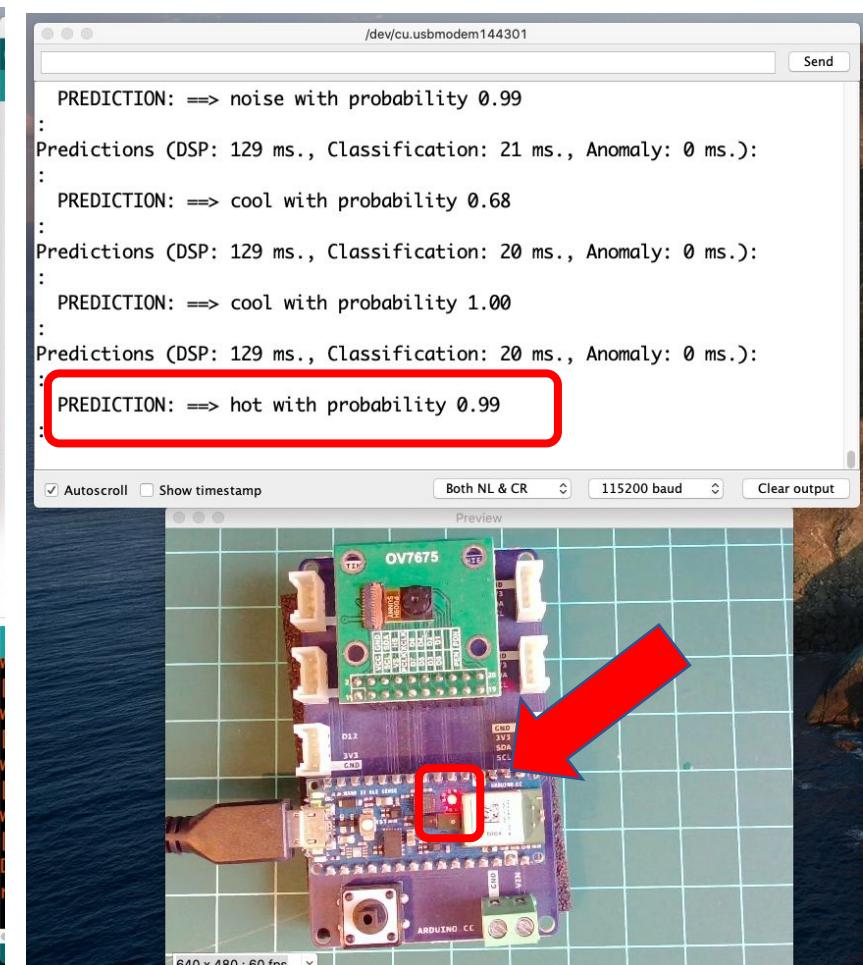
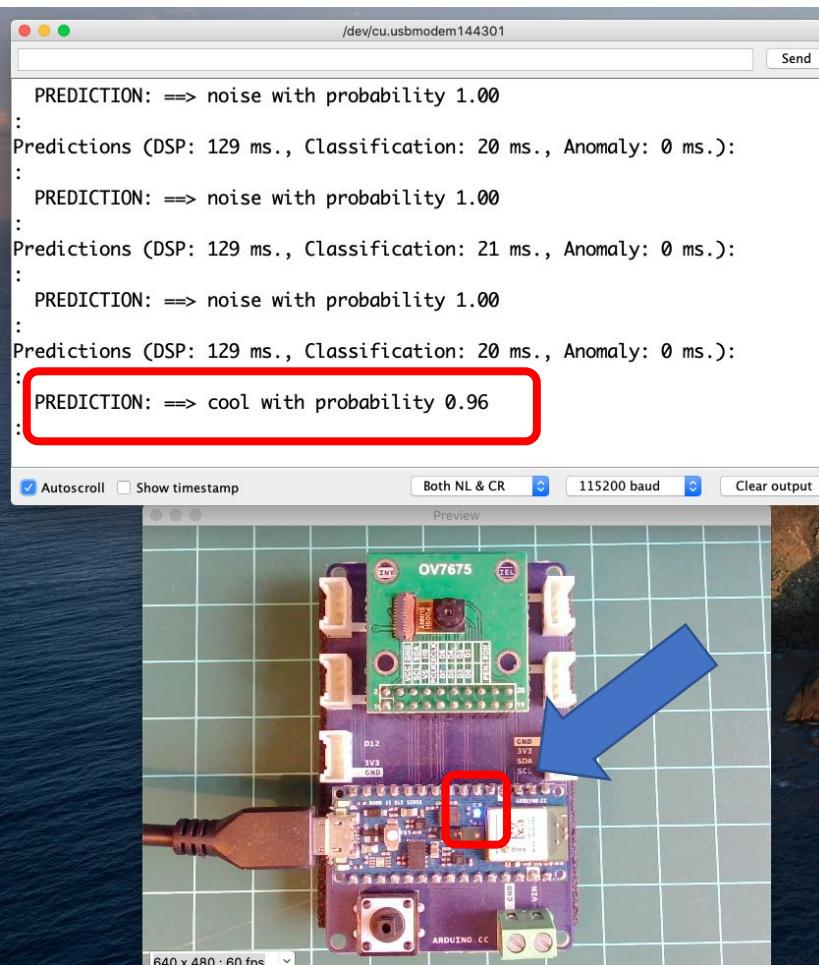
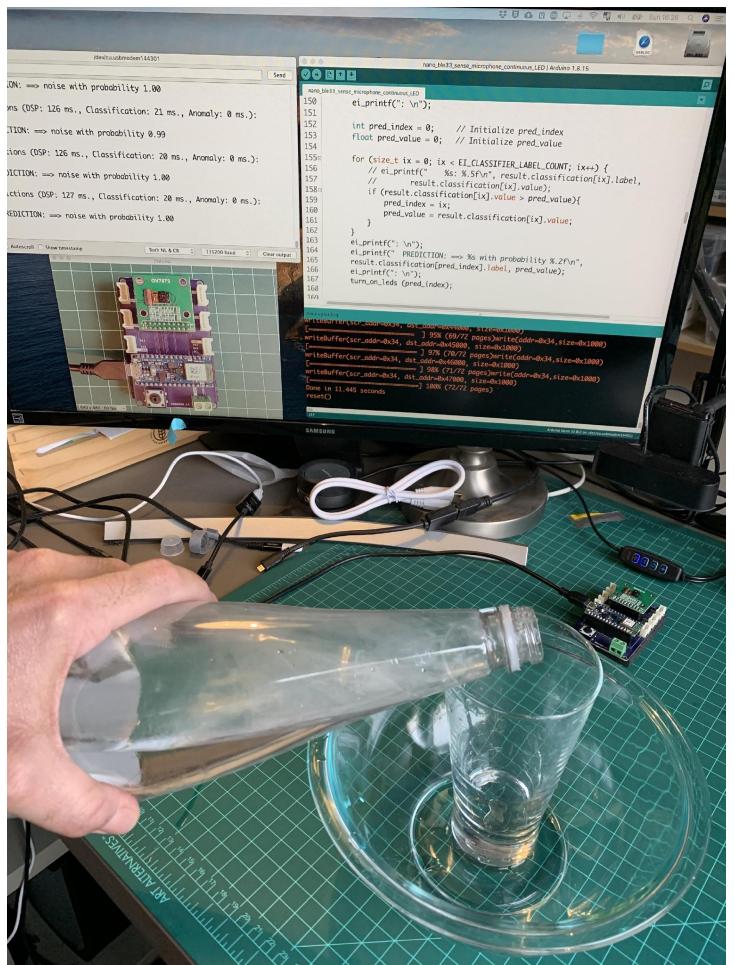
Preview

640 x 480 : 60 fps

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

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



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 specially 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!

