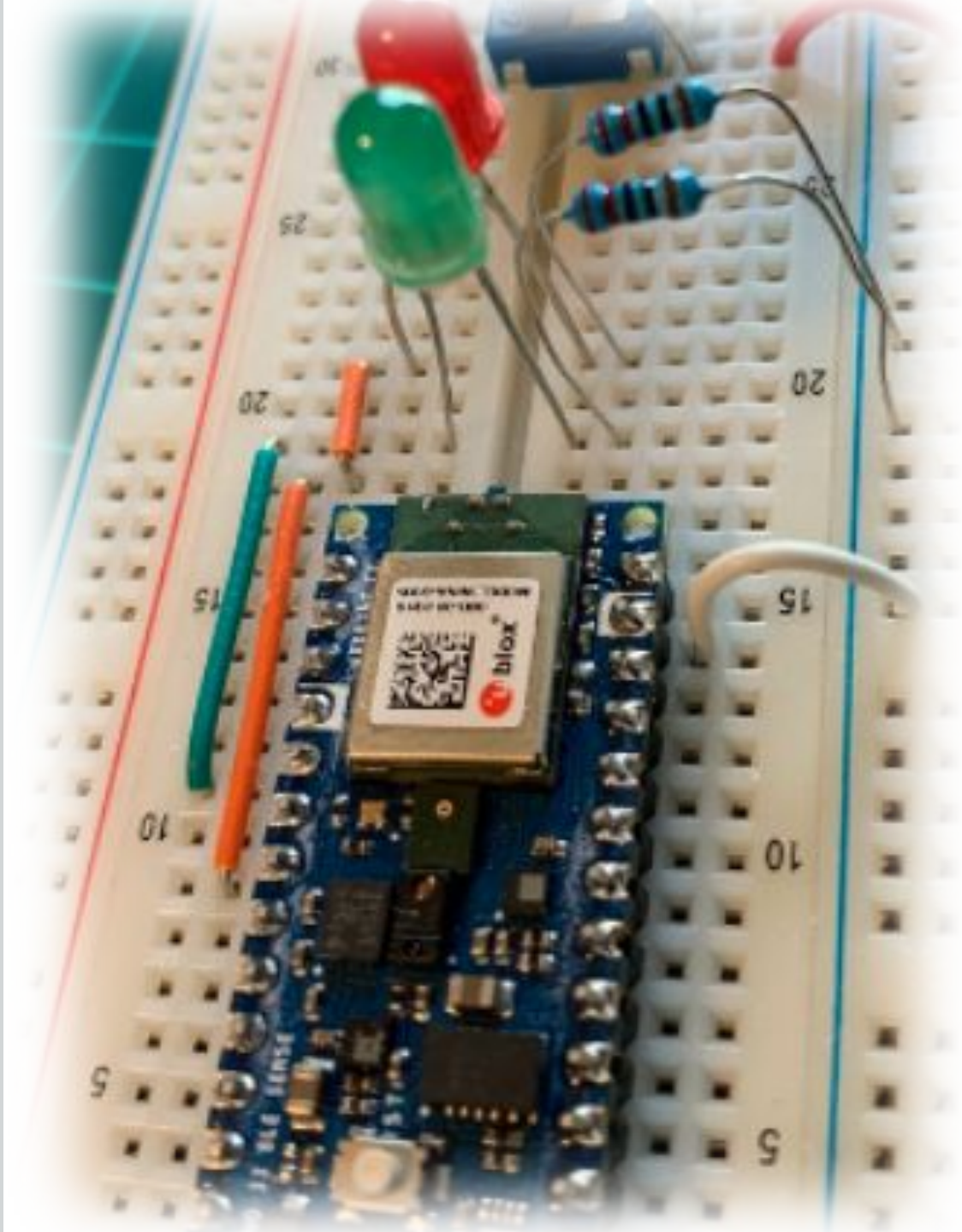
IESTI01 – TinyML

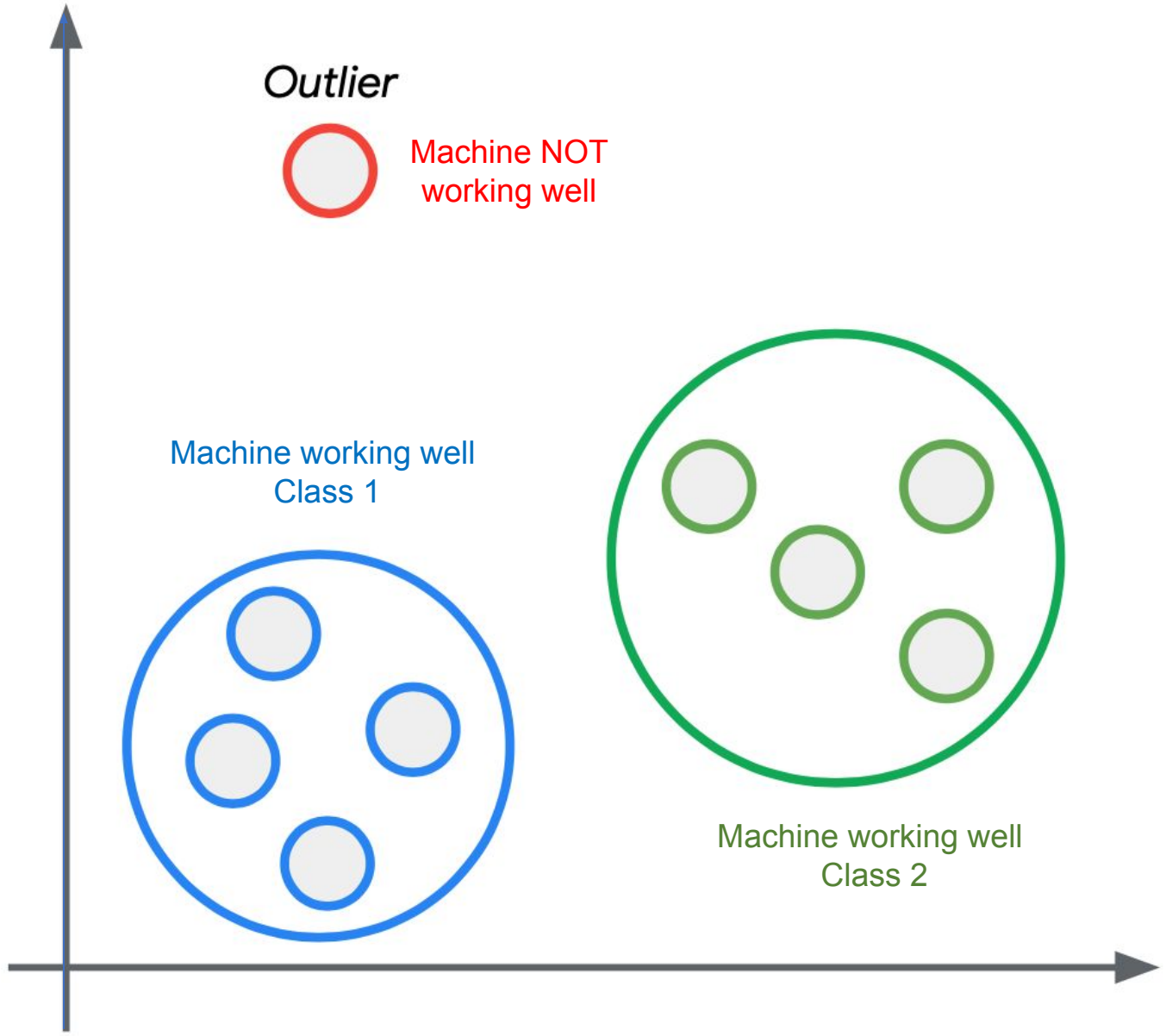
Embedded Machine Learning

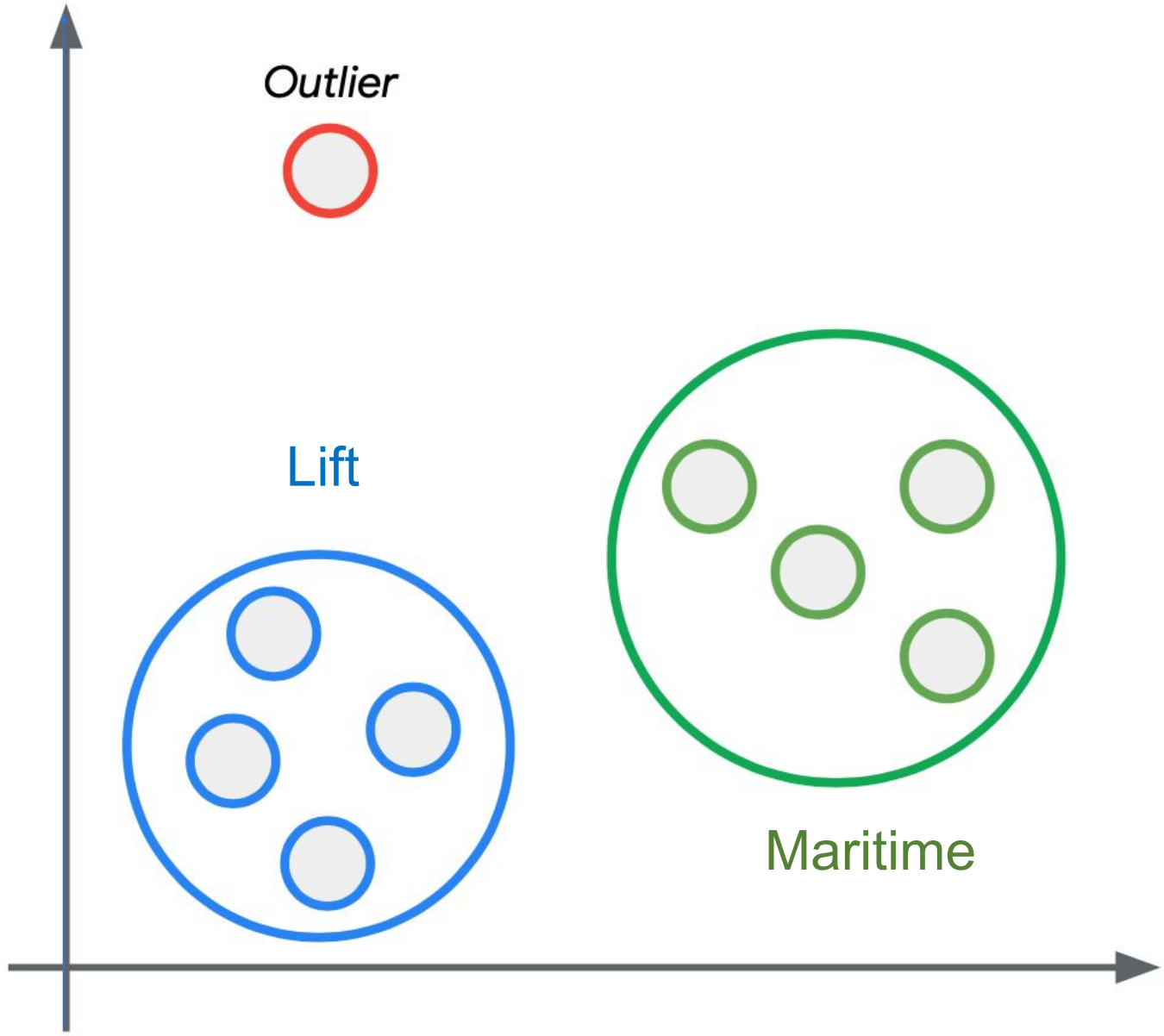
22. Anomaly Detection Hands-On Lab & Pos-Processing

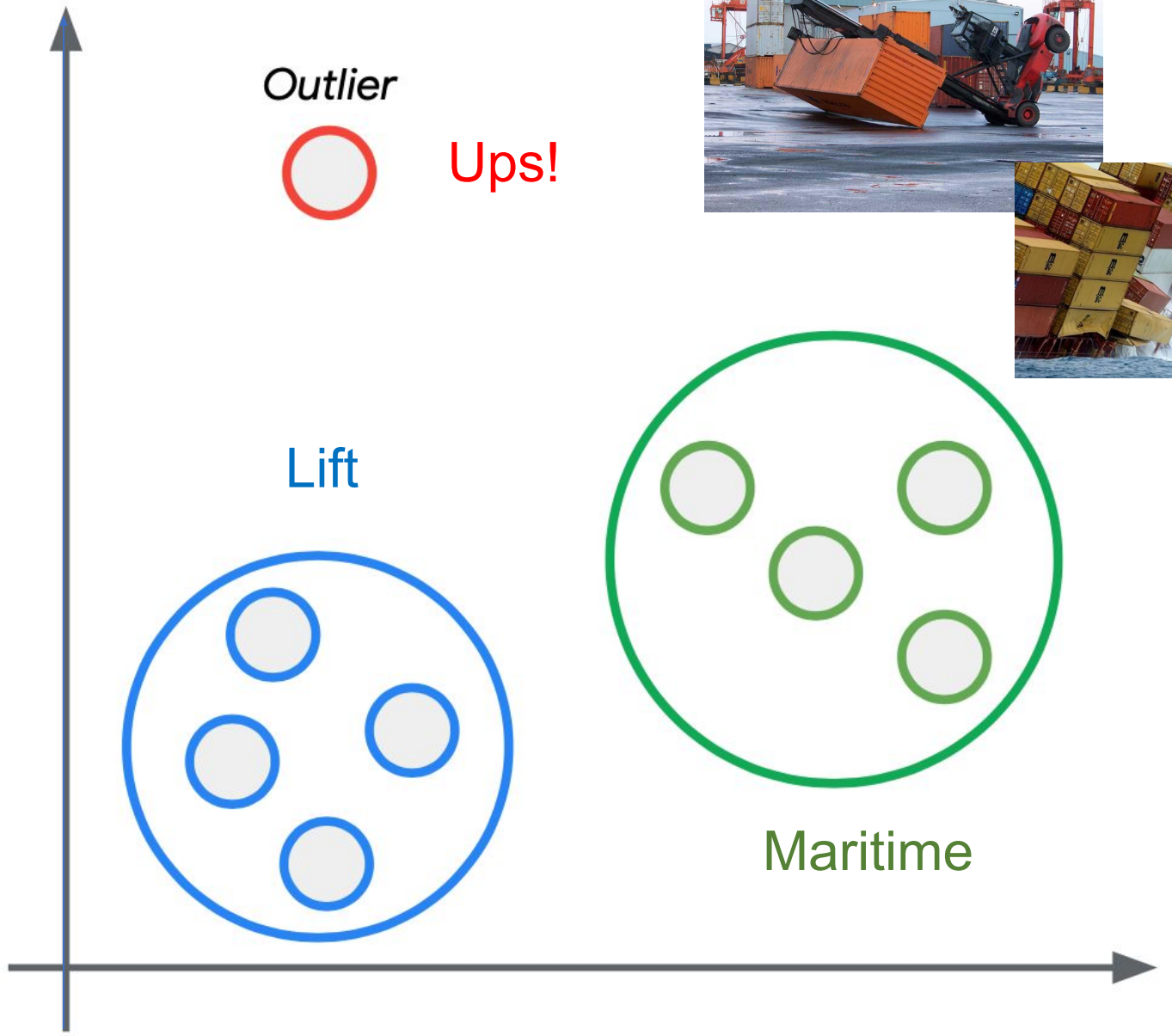


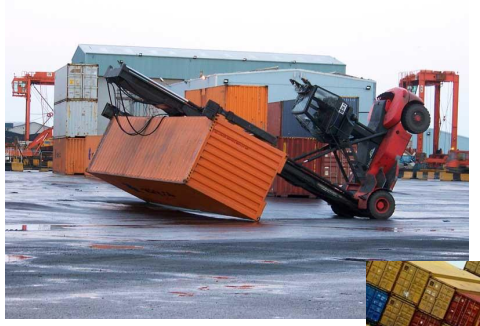
Prof. Marcelo Rovai
UNIFEI

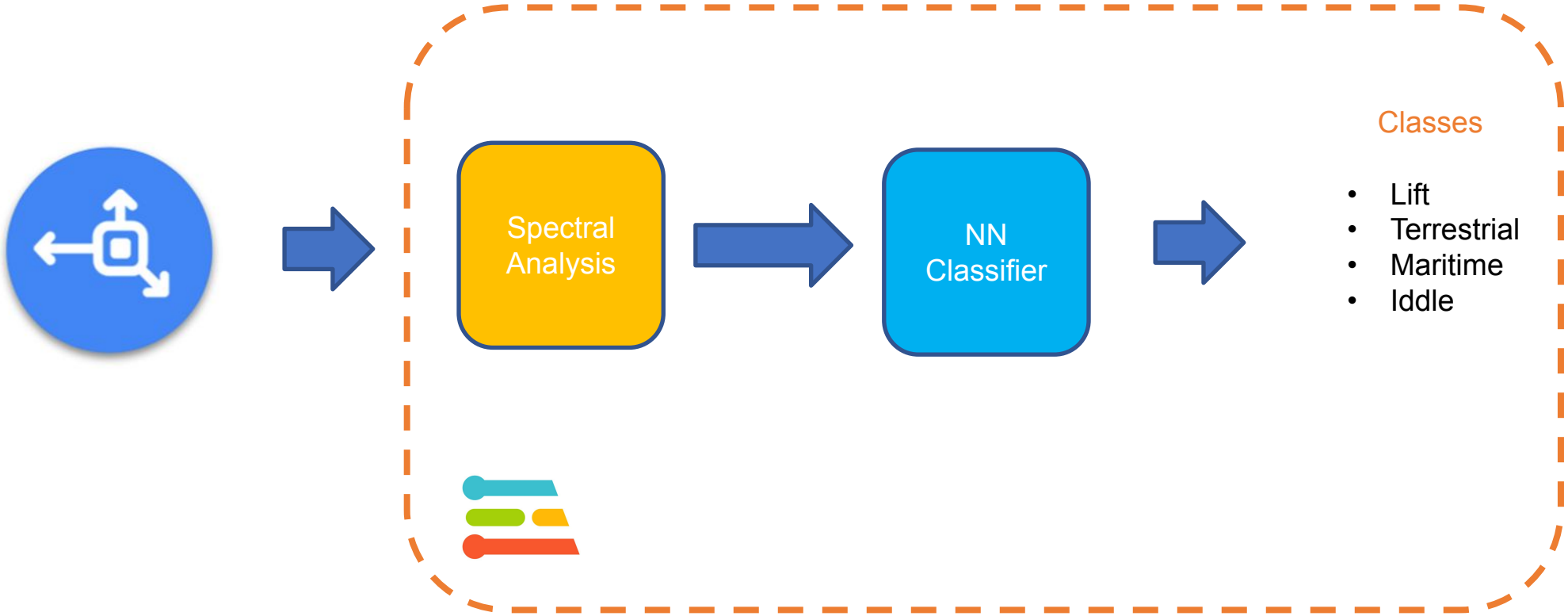
Anomaly Detection Hands-On

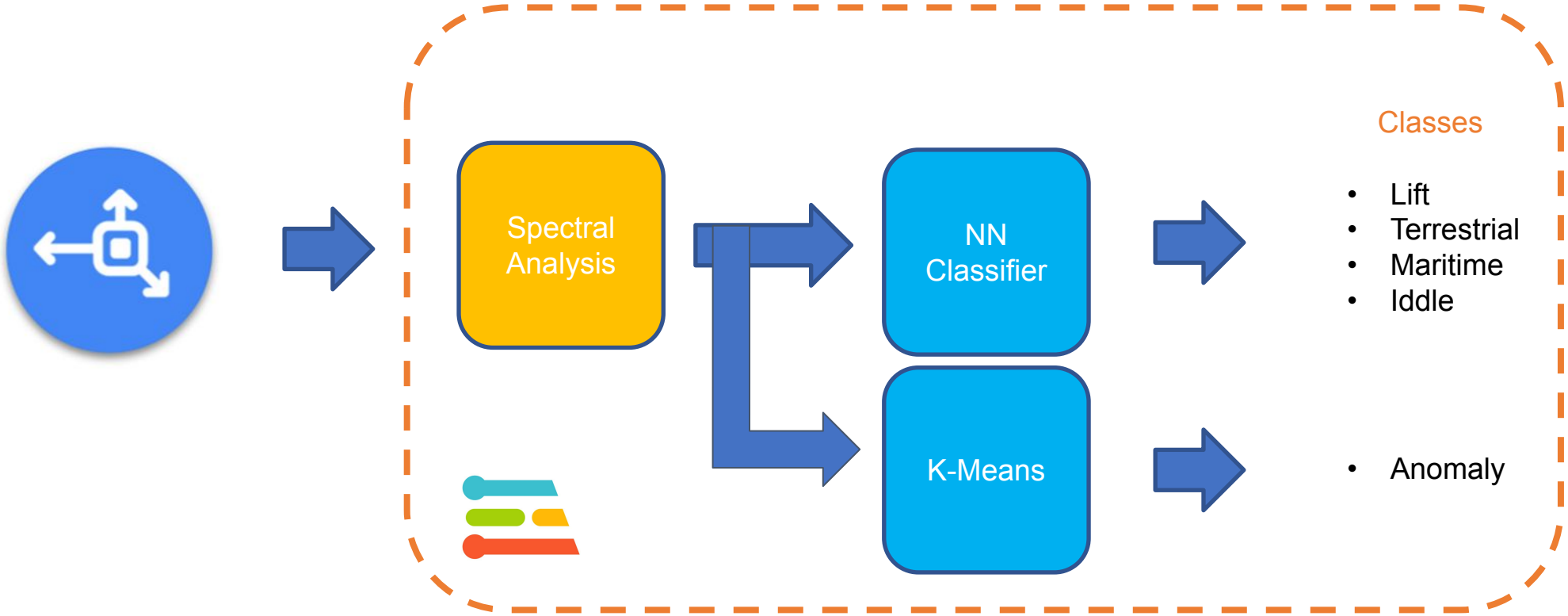

Outlier
Machine NOT working well
Machine working well Class 1
Machine working well Class 2

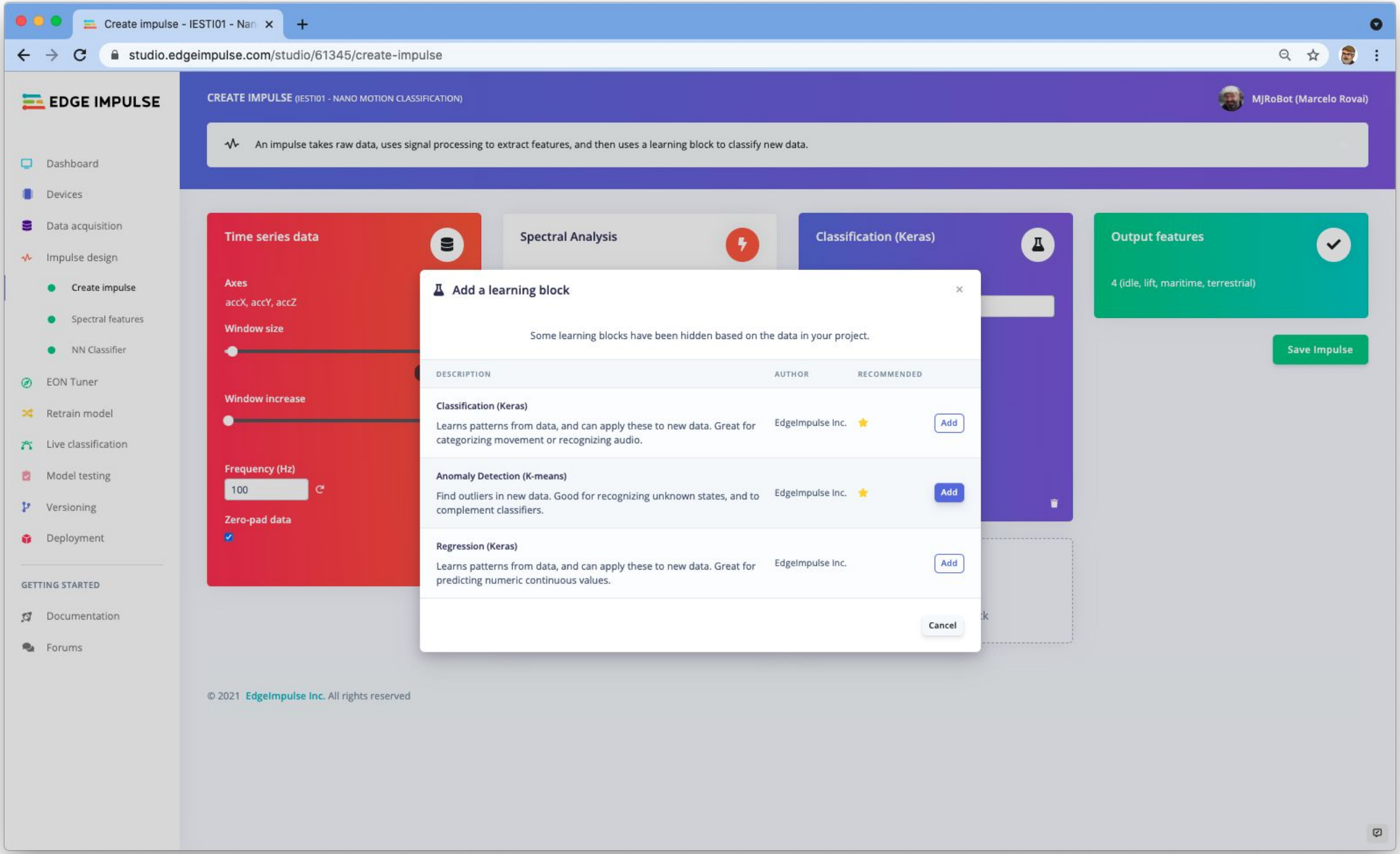

Outlier
Lift
Maritime

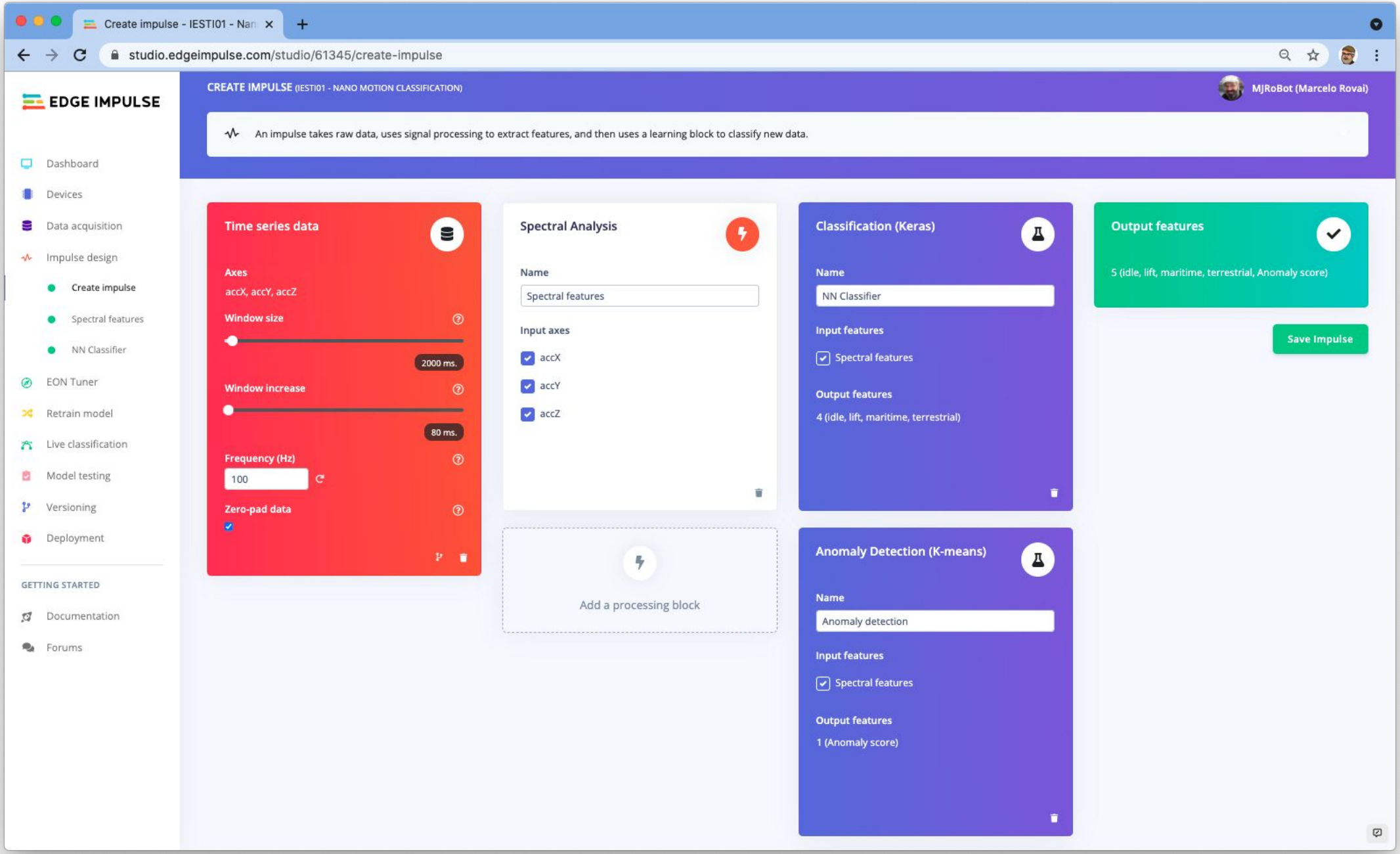

Outlier
Ups!
Lift
Maritime




Spectral Analysis
NN Classifier
Classes
Lift
Terrestrial
Maritime
Iddle


Spectral Analysis
NN Classifier
K-Means
Classes
Lift
Terrestrial
Maritime
Iddle
Anomaly


Create impulse - IESTI01 - Nan
studio.edgeimpulse.com/studio/61345/create-impulse
EDGE IMPULSE
CREATE IMPULSE (IESTI01 - NANO MOTION CLASSIFICATION)
MJRoBot (Marcelo Rovai)
An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
Spectral features
NN Classifier
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
Time series data
Axes
accX, accY, accZ
Window size
Window increase
Frequency (Hz)
100
Zero-pad data
Spectral Analysis
Classification (Keras)
Output features
4 (idle, lift, maritime, terrestrial)
Save Impulse
Add a learning block
Some learning blocks have been hidden based on the data in your project.
DESCRIPTION
AUTHOR
RECOMMENDED
Classification (Keras)
Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio.
EdgeImpulse Inc.
Add
Anomaly Detection (K-means)
Find outliers in new data. Good for recognizing unknown states, and to complement classifiers.
EdgeImpulse Inc.
Add
Regression (Keras)
Learns patterns from data, and can apply these to new data. Great for predicting numeric continuous values.
EdgeImpulse Inc.
Add
Cancel
© 2021 EdgeImpulse Inc. All rights reserved


Create impulse - IESTI01 - Nan
studio.edgeimpulse.com/studio/61345/create-impulse
EDGE IMPULSE
Dashboard
Devices
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Deployment
GETTING STARTED
Documentation
Forums
CREATE IMPULSE (IESTI01 - NANO MOTION CLASSIFICATION)
MJRoBot (Marcelo Rovai)
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
accX, accY, accZ
Window size
2000 ms.
Window increase
80 ms.
Frequency (Hz)
100
Zero-pad data
Spectral Analysis
Name
Spectral features
Input axes
accX
accY
accZ
Add a processing block
Classification (Keras)
Name
NN Classifier
Input features
Spectral features
Output features
4 (idle, lift, maritime, terrestrial)
Anomaly Detection (K-means)
Name
Anomaly detection
Input features
Spectral features
Output features
1 (Anomaly score)
Output features
5 (idle, lift, maritime, terrestrial, Anomaly score)
Save Impulse

Anomaly detection - IESTI01 -

studio.edgeimpulse.com/studio/61345/learning/anomaly/15

EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
  - Create impulse
  - Spectral features
  - NN Classifier
  - Anomaly detection
- EON Tuner
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

GETTING STARTED

- Documentation
- Forums

ANOMALY DETECTION (IESTI01 - NANO MOTION CLASSIFICATION)

#1 Click to set a description for this version

MJRoBot (Marcelo Rovai)

Anomaly detection settings

Cluster count

32

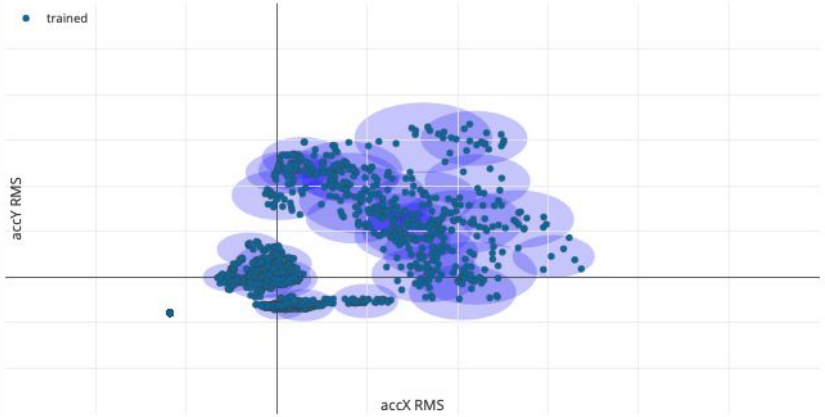
Axes — Select all axes

- [x] accX RMS
- [ ] accX Peak 1 Freq
- [ ] accX Peak 1 Height
- [ ] accX Peak 2 Freq
- [ ] accX Peak 2 Height
- [ ] accX Peak 3 Freq
- [ ] accX Peak 3 Height
- [ ] accX Spectral Power 0.1 - 0.5
- [ ] accX Spectral Power 0.5 - 1.0
- [ ] accX Spectral Power 1.0 - 2.0
- [ ] accX Spectral Power 2.0 - 5.0
- [x] accY RMS
- [ ] accY Peak 1 Freq
- [ ] accY Peak 1 Height
- [ ] accY Peak 2 Freq
- [ ] accY Peak 2 Height
- [ ] accY Peak 3 Freq
- [ ] accY Peak 3 Height
- [ ] accY Spectral Power 0.1 - 0.5
- [ ] accY Spectral Power 0.5 - 1.0
- [ ] accY Spectral Power 1.0 - 2.0
- [ ] accY Spectral Power 2.0 - 5.0
- [x] accZ RMS
- [ ] accZ Peak 1 Freq
- [ ] accZ Peak 1 Height
- [ ] accZ Peak 2 Freq
- [ ] accZ Peak 2 Height
- [ ] accZ Peak 3 Freq
- [ ] accZ Peak 3 Height
- [ ] accZ Spectral Power 0.1 - 0.5
- [ ] accZ Spectral Power 0.5 - 1.0
- [ ] accZ Spectral Power 1.0 - 2.0
- [ ] accZ Spectral Power 2.0 - 5.0

Start training

Anomaly explorer (3,400 samples)

X Axis: accX RMS | Y Axis: accY RMS | Test data: -- No test data

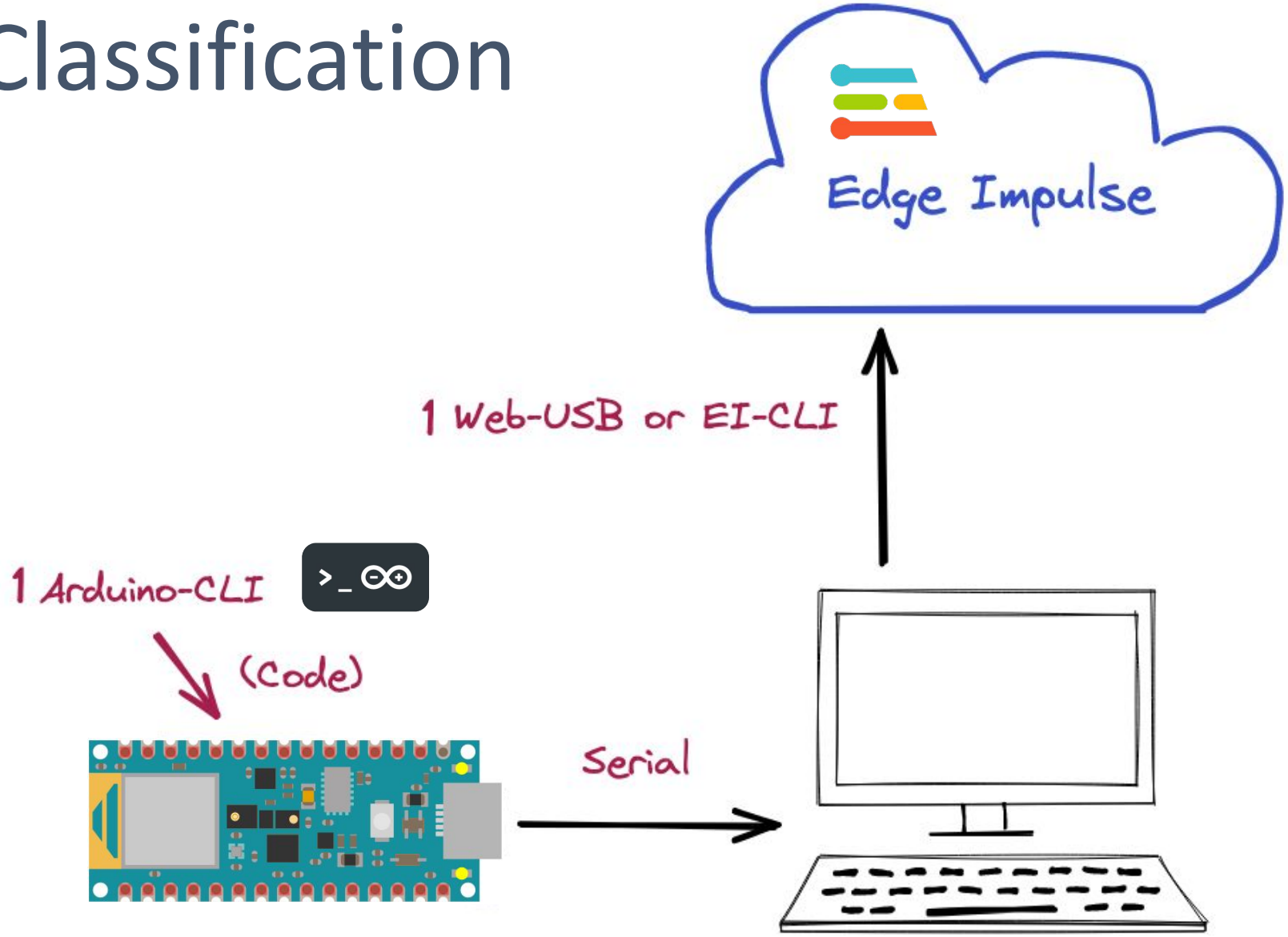


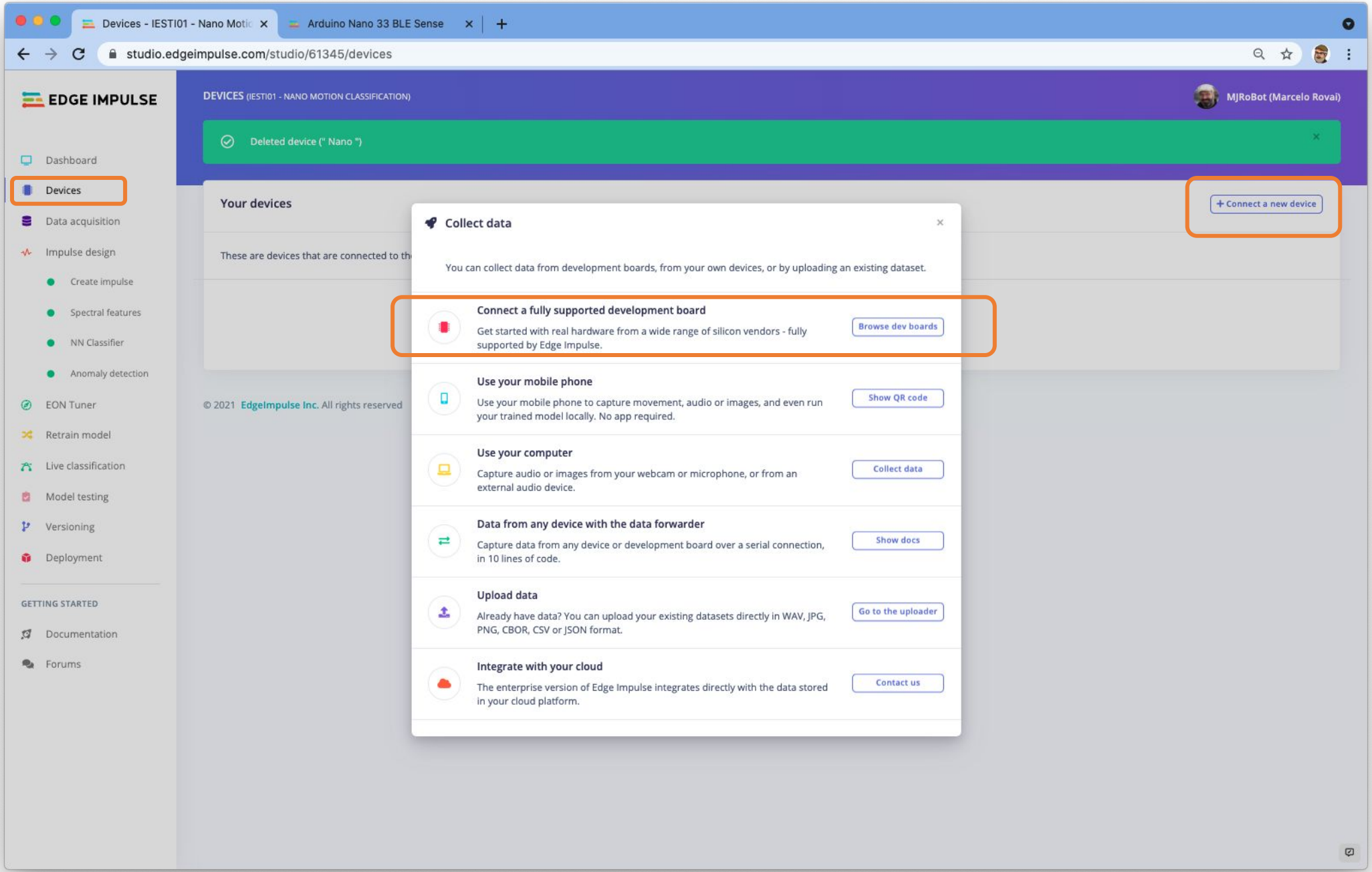
Training output

```
0.6082163453102112, 0.25316372513771057], 'max_error': 0.34954408210594134}, {'center':
[-0.5115050673484802, -0.004735563416033983, 0.709574282169342], 'max_error': 0.2947459724666345},
{'center': [2.031501531600952, 1.2126123905181885, 1.129497766494751], 'max_error': 0.6769873962564943},
{'center': [1.391443133354187, 0.9029868841171265, 0.8108663558959961], 'max_error': 0.5210900944982784},
{'center': [0.035471659153699875, 1.796299695968628, 1.2969461679458618], 'max_error':
0.5249936584588187}, {'center': [0.10634401440620422, 2.2963626384735107, 0.7528809905052185],
'max_error': 0.44105256183930464}, {'center': [1.6457377672195435, 1.7475732564926147,
1.4299843311309814], 'max_error': 0.5520137297917197}, {'center': [2.219975709915161, 2.0978941917419434,
0.7476416230201721], 'max_error': 0.5746162180430946}, {'center': [0.032550420612096786,
-0.03719609975814819, 1.590340256690979], 'max_error': 0.4070282568799601}, {'center':
[0.2832728922367096, 2.612391710281372, 1.1812870502471924], 'max_error': 0.43737044666248764},
{'center': [1.6214791536331177, 3.0532443523406982, 1.385027527809143], 'max_error': 0.7516882902121258},
{'center': [0.97445040941238 4, 1.6822280883789062, 1.557731032371521], 'max_error': 0.7167072825903013},
{'center': [3.062652111053467, 0.4566035866737366, 0.4609105587005615], 'max_error': 0.4446181809668133}]

Job completed
```

Live Classification




Devices - IESTI01 - Nano Motic
Arduino Nano 33 BLE Sense
studio.edgeimpulse.com/studio/61345/devices
EDGE IMPULSE
DEVICES (IESTI01 - NANO MOTION CLASSIFICATION)
MJRoBot (Marcelo Rovai)
Deleted device (" Nano ")
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
Spectral features
NN Classifier
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EON Tuner
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Live classification
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Your devices
These are devices that are connected to th
+ Connect a new device
Collect data
You can collect data from development boards, from your own devices, or by uploading an existing dataset.
Connect a fully supported development board
Get started with real hardware from a wide range of silicon vendors - fully supported by Edge Impulse.
Browse dev boards
Use your mobile phone
Use your mobile phone to capture movement, audio or images, and even run your trained model locally. No app required.
Show QR code
Use your computer
Capture audio or images from your webcam or microphone, or from an external audio device.
Collect data
Data from any device with the data forwarder
Capture data from any device or development board over a serial connection, in 10 lines of code.
Show docs
Upload data
Already have data? You can upload your existing datasets directly in WAV, JPG, PNG, CBOR, CSV or JSON format.
Go to the uploader
Integrate with your cloud
The enterprise version of Edge Impulse integrates directly with the data stored in your cloud platform.
Contact us
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Devices - IESTI01 - Nano Moti | Arduino Nano 33 BLE Sense

docs.edgeimpulse.com/docs/arduino-nano-33-ble-sense

Press RESET twice quickly to launch the bootloader on the Arduino Nano 33 BLE Sense.

2. Update the firmware

The development board does not come with the right firmware yet. To update the firmware:

1. Download the latest Edge Impulse firmware, and unzip the file.
2. Open the flash script for your operating system (`flash_windows.bat` , `flash_mac.command` or `flash_linux.sh`) to flash the firmware.
3. Wait until flashing is complete, and press the RESET button once to launch the new firmware.

3. Setting keys

From a command prompt or terminal, run:

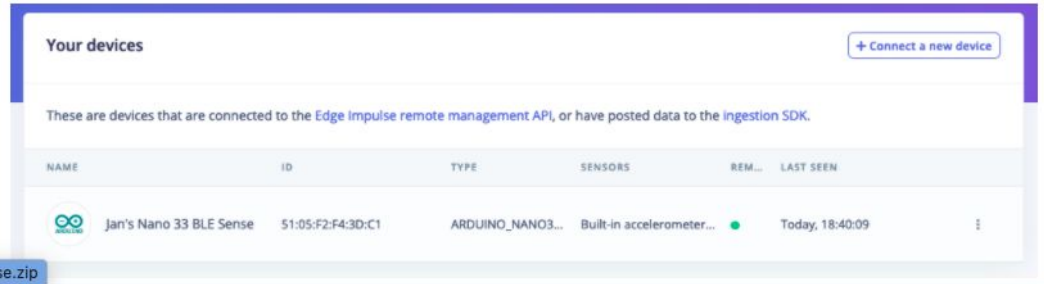
```
edge-impulse-daemon
```

This will start a wizard which will ask you to log in, and choose an Edge Impulse project. If you want to switch projects run the command with `--clean` .

Alternatively, recent versions of Google Chrome and Microsoft Edge can collect data directly from your development board, without the need for the Edge Impulse CLI. See this blog post for more information.

4. Verifying that the device is connected

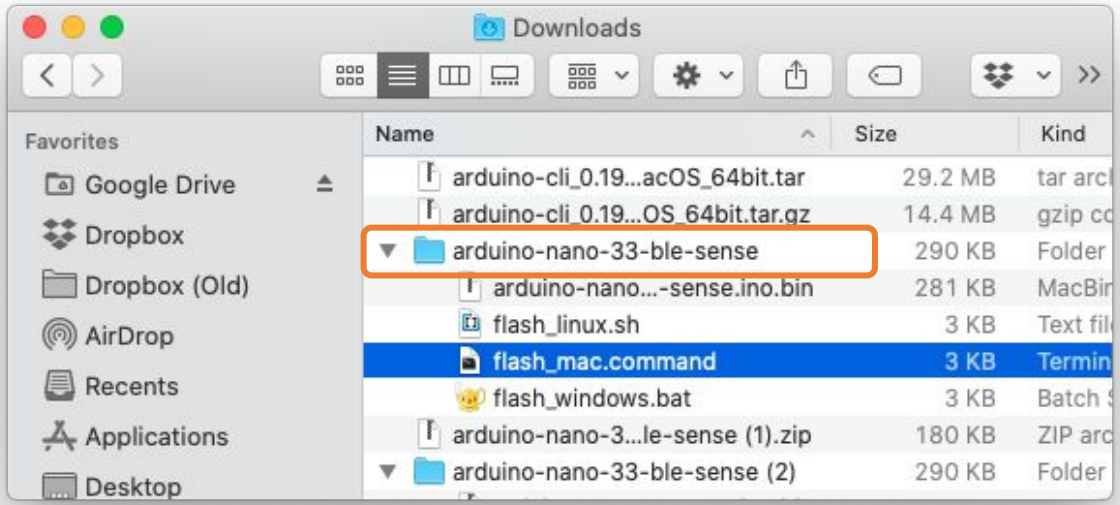
That's all! Your device is now connected to Edge Impulse. To verify this, go to your Edge Impulse project, and click **Devices**. The device will be listed here.



https://cdn.edgeimpulse.com/firmware/arduino-nano-33-ble-sense.zip

arduino-nano-33....zip

Show All



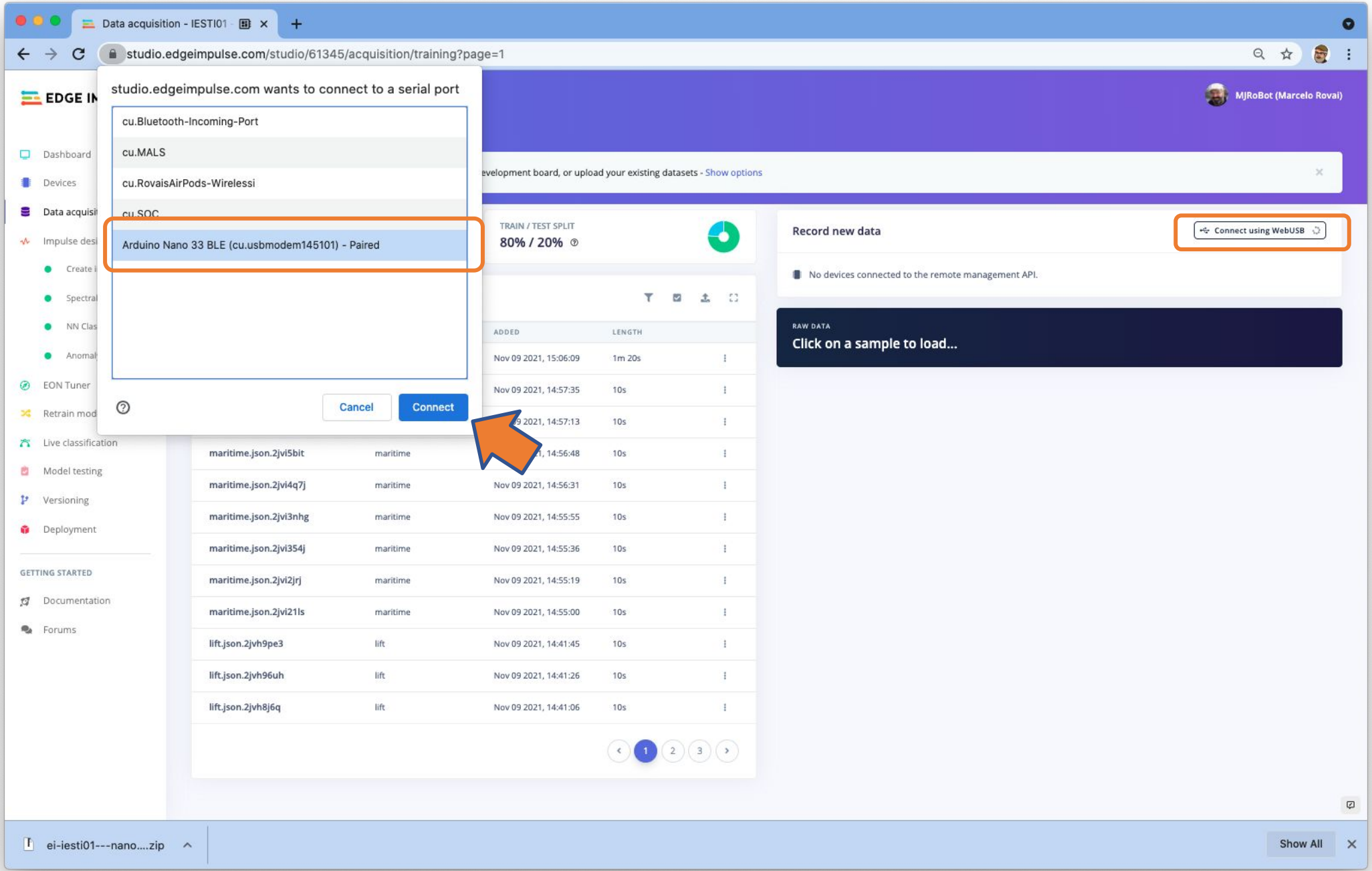

```
mjrovai — flash_mac.command — 80×43
Last login: Thu Nov 11 14:24:32 on ttys000
You have new mail.
/Users/mjrovai/Downloads/arduino-nano-33-ble-sense/flash_mac.command ; exit;

The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
(base) MacBook-Pro-de-Marcelo:~ mjrovai$ /Users/mjrovai/Downloads/arduino-nano-3
3-ble-sense/flash_mac.command ; exit;
Finding Arduino Mbed core...
Finding Arduino Mbed OK
Finding Arduino Nano 33 BLE...
Finding Arduino Nano 33 BLE OK
Flashing board...
Device        : nRF52840-QIAA
Version       : Arduino Bootloader (SAM-BA extended) 2.0 [Arduino:IKXYZ]
Address       : 0x0
Pages         : 256
Page Size     : 4096 bytes
Total Size    : 1024KB
Planes        : 1
Lock Regions : 0
Locked        : none
Security      : false
Erase flash

Done in 0.001 seconds
Write 280848 bytes to flash (69 pages)
[==============================] 100% (69/69 pages)
Done in 10.982 seconds

Flashed your Arduino Nano 33 BLE development board.
To set up your development with Edge Impulse, run 'edge-impulse-daemon'
To run your impulse on your development board, run 'edge-impulse-run-impulse'
logout
Saving session...
...copying shared history...
...saving history...truncating history files...
...completed.
Deleting expired sessions...none found.

[Process completed]
```


Data acquisition - IESTI01
studio.edgeimpulse.com/studio/61345/acquisition/training?page=1
studio.edgeimpulse.com wants to connect to a serial port
cu.Bluetooth-Incoming-Port
cu.MALS
cu.RovaisAirPods-Wirelessi
cu.SOC
Arduino Nano 33 BLE (cu.usbmodem145101) - Paired
Cancel
Connect
MJRoBot (Marcelo Rovai)
Dashboard
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Impulse desi
EON Tuner
Retrain mod
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GETTING STARTED
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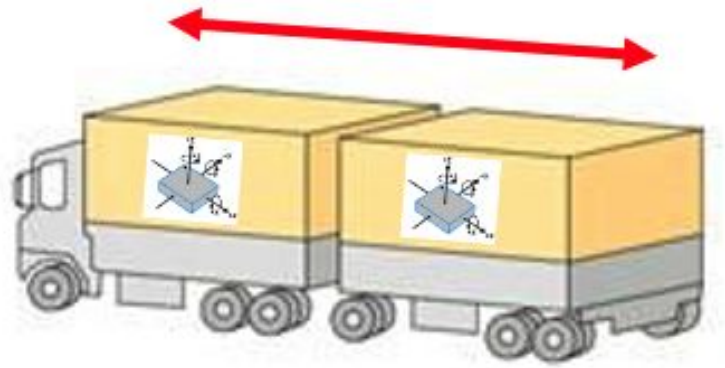
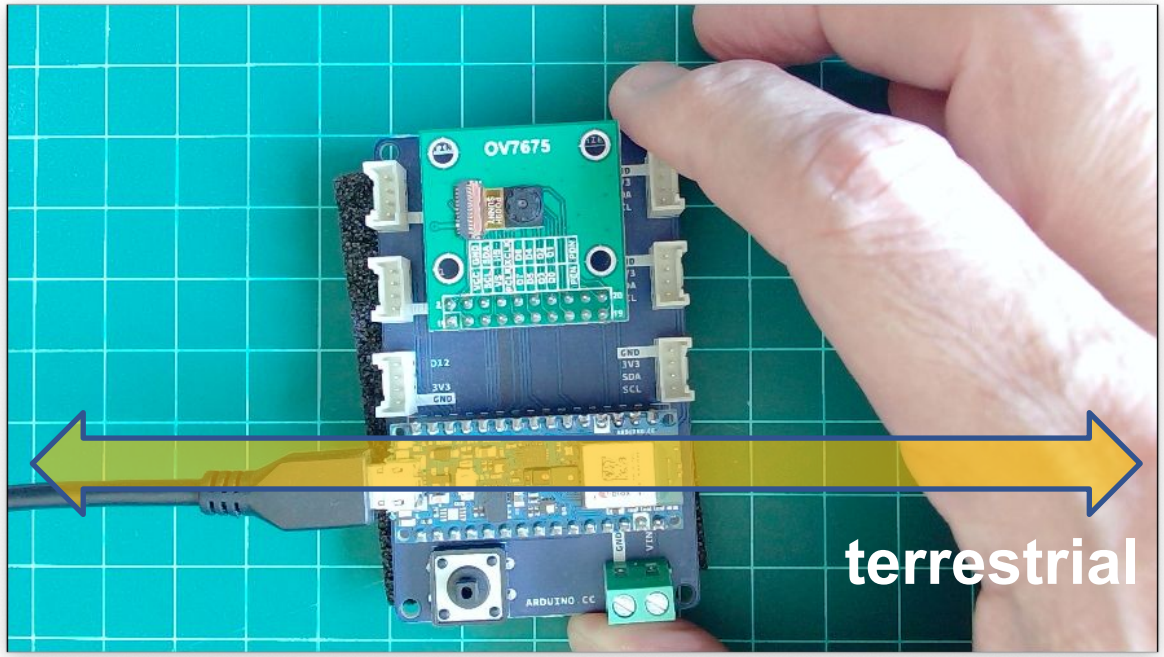
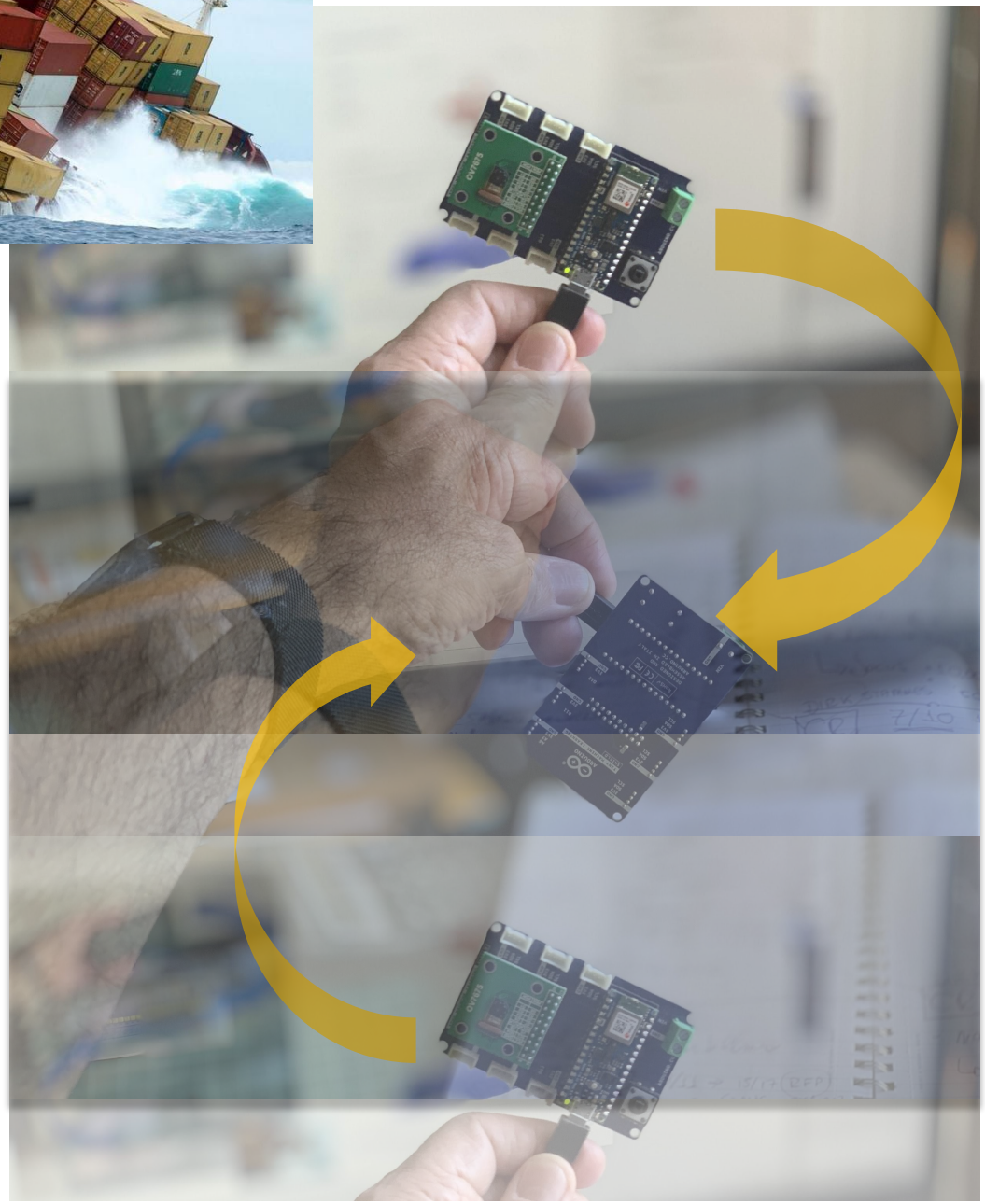
development board, or upload your existing datasets - Show options
TRAIN / TEST SPLIT
80% / 20%
Record new data
Connect using WebUSB
No devices connected to the remote management API.
RAW DATA
Click on a sample to load...
ADDED
LENGTH
Nov 09 2021, 15:06:09 1m 20s
Nov 09 2021, 14:57:35 10s
Nov 09 2021, 14:57:13 10s
maritime.json.2jvi5bit maritime Nov 09 2021, 14:56:48 10s
maritime.json.2jvi4q7j maritime Nov 09 2021, 14:56:31 10s
maritime.json.2jvi3nhg maritime Nov 09 2021, 14:55:55 10s
maritime.json.2jvi354j maritime Nov 09 2021, 14:55:36 10s
maritime.json.2jvi2jrj maritime Nov 09 2021, 14:55:19 10s
maritime.json.2jvi21ls maritime Nov 09 2021, 14:55:00 10s
lift.json.2jvh9pe3 lift Nov 09 2021, 14:41:45 10s
lift.json.2jvh96uh lift Nov 09 2021, 14:41:26 10s
lift.json.2jvh8j6q lift Nov 09 2021, 14:41:06 10s
1
2
3
ei-iesti01---nano....zip
Show All

Test: terrestrial







Classification result

Summary

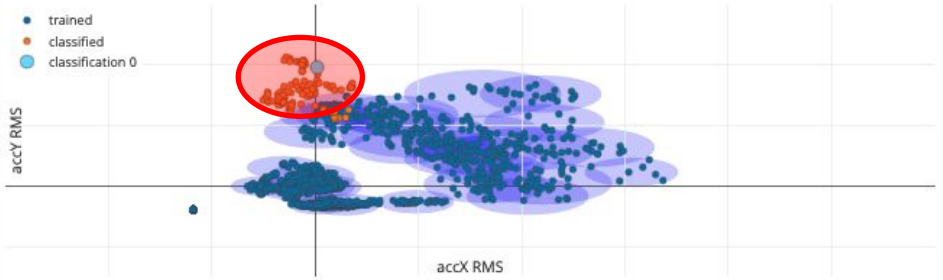
Name	testing.2kfaokbr
Expected outcome	testing

CATEGORY	COUNT
idle	0
lift	0
maritime	7
terrestrial	0
uncertain	0
anomaly	94

Anomaly explorer (3,501 samples)

X Axis: accX RMS

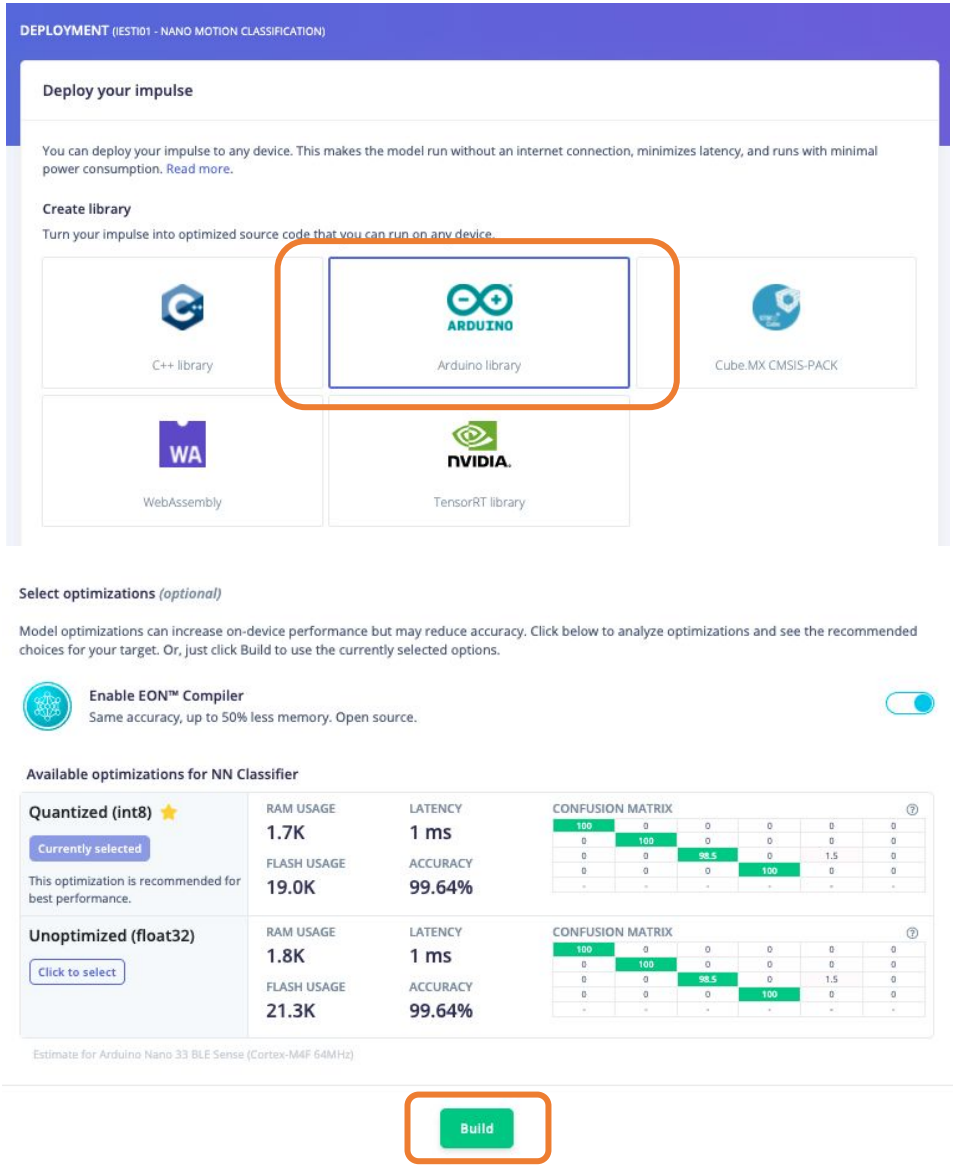
Y Axis: accY RMS

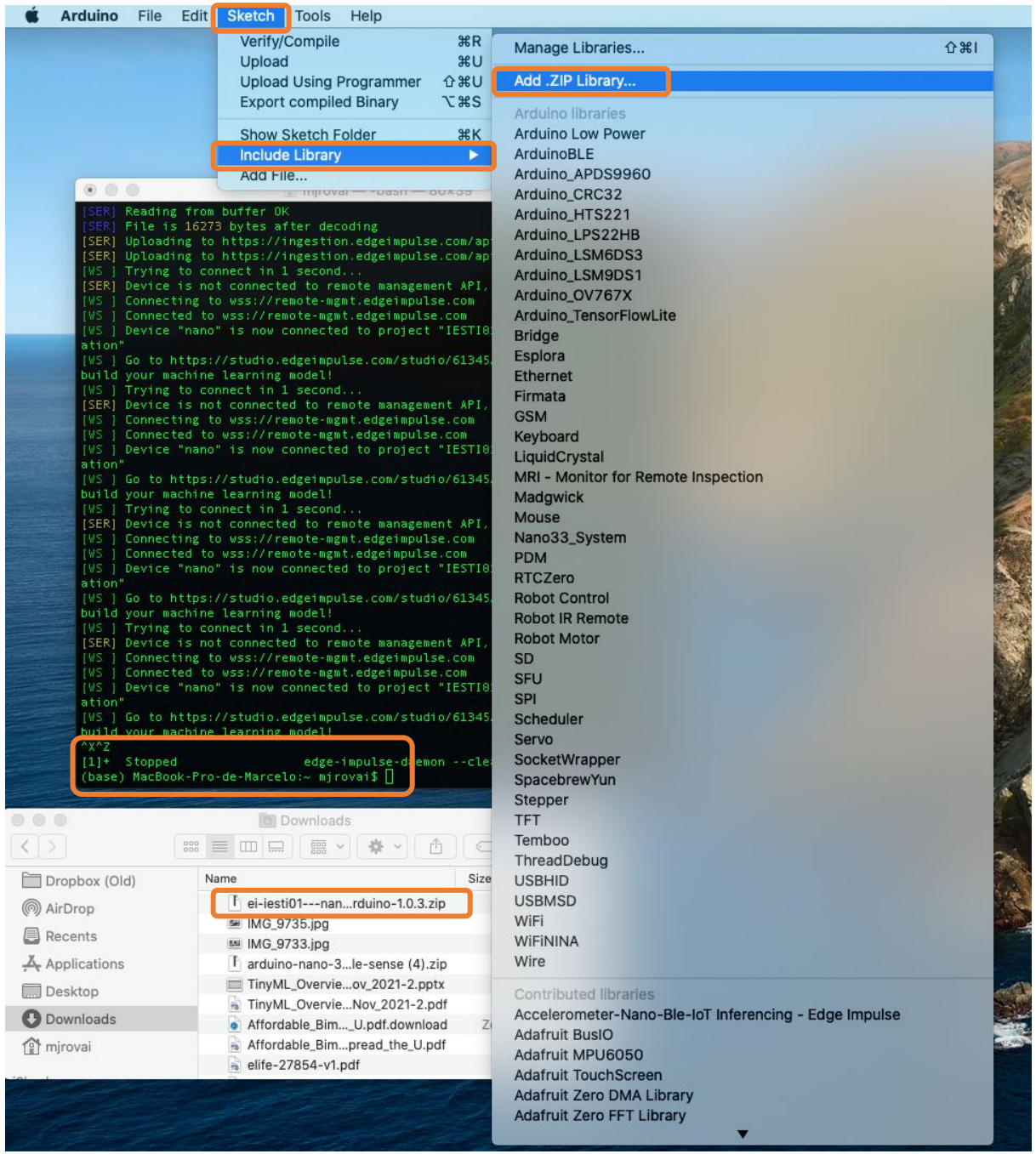


Distance from closest cluster

accX RMS: 0.2653, accY RMS: 1.3105, accZ RMS: 0.8946

Deploy


DEPLOYMENT (IESTI01 - NANO MOTION CLASSIFICATION)
Deploy your impulse
You can deploy your impulse to any device. This makes the model run without an internet connection, minimizes latency, and runs with minimal power consumption. Read more.
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
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)
Currently selected
This optimization is recommended for best performance.
RAM USAGE
1.7K
LATENCY
1 ms
FLASH USAGE
19.0K
ACCURACY
99.64%
CONFUSION MATRIX
Unoptimized (float32)
Click to select
RAM USAGE
1.8K
LATENCY
1 ms
FLASH USAGE
21.3K
ACCURACY
99.64%
CONFUSION MATRIX
Estimate for Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz)
Build


Arduino File Edit Sketch Tools Help
Verify/Compile ⌘R
Upload ⌘U
Upload Using Programmer ⇧⌘U
Export compiled Binary ⌥⌘S
Show Sketch Folder ⌘K
Include Library
Add File...
Manage Libraries... ⇧⌘I
Add .ZIP Library...
Arduino libraries
Arduino Low Power
ArduinoBLE
Arduino_APDS9960
Arduino_CRC32
Arduino_HTS221
Arduino_LPS22HB
Arduino_LSM6DS3
Arduino_LSM9DS1
Arduino_OV767X
Arduino_TensorFlowLite
Bridge
Esplora
Ethernet
Firmata
GSM
Keyboard
LiquidCrystal
MRI - Monitor for Remote Inspection
Madgwick
Mouse
Nano33_System
PDM
RTCZero
Robot Control
Robot IR Remote
Robot Motor
SD
SFU
SPI
Scheduler
Servo
SocketWrapper
SpacebrewYun
Stepper
TFT
Temboo
ThreadDebug
USBHID
USBMSD
WiFi
WiFiNINA
Wire
Contributed libraries
Accelerometer-Nano-Ble-IoT Inferencing - Edge Impulse
Adafruit BusIO
Adafruit MPU6050
Adafruit TouchScreen
Adafruit Zero DMA Library
Adafruit Zero FFT Library
[SER] Reading from buffer OK
[SER] File is 16273 bytes after decoding
[SER] Uploading to https://ingestion.edgeimpulse.com/ap
[SER] Uploading to https://ingestion.edgeimpulse.com/ap
[WS] Trying to connect in 1 second...
[SER] Device is not connected to remote management API,
[WS] Connecting to wss://remote-mgmt.edgeimpulse.com
[WS] Connected to wss://remote-mgmt.edgeimpulse.com
[WS] Device "nano" is now connected to project "IESTI0
ation"
[WS] Go to https://studio.edgeimpulse.com/studio/61345
build your machine learning model!
^X^Z
[1]+ Stopped edge-impulse-d
(base) MacBook-Pro-de-Marcelo:~ mjrovai$
Downloads
Dropbox (Old)
AirDrop
Recents
Applications
Desktop
Downloads
mjrovai
Name
Size
ei-iesti01---nan...rduino-1.0.3.zip
IMG_9735.jpg
IMG_9733.jpg
arduino-nano-3...le-sense (4).zip
TinyML_Overvie...ov_2021-2.pptx
TinyML_Overvie...Nov_2021-2.pdf
Affordable_Bim..._U.pdf.download
Affordable_Bim...pread_the_U.pdf
elife-27854-v1.pdf

/dev/cu.usbmodem145101

Send

```
Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 1 ms.):
    idle: 0.00000
    lift: 0.00000
    maritime: 0.99609
    terrestrial: 0.00000
    anomaly score: 0.620

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 2 ms.):
    idle: 0.00000
    lift: 0.00000
    maritime: 0.99609
    terrestrial: 0.00000
    anomaly score: 1.470
```

Autoscroll Show timestamp Both NL & CR 115200 baud Clear output

Pos-processing

Turn on/off LEDS

- Idle : ==> All OFF
- lift: ==> **Green ON**
- maritime: ==> **Red ON**
- terrestrial: ==> **Blue ON**
- Anomaly ==> **LED_BUILTIN ON**

motion_classification_nano_ble33_sense_accelerometer | Arduino 1.8.16

motion_classification_nano_ble33_sense_accelerometer §

```
36 void setup()
37 {
38     Serial.begin(115200);
39     while (!Serial);
40
41     Serial.println("IESTI01 - Nano Motion Classification - Inferencing Test");
42
43     pinMode(LED_BUILTIN, OUTPUT);
44     pinMode(LEDR, OUTPUT);
45     pinMode(LEDG, OUTPUT);
46     pinMode(LEDB, OUTPUT);
47
48     // Ensure the LED is off by default.
49     digitalWrite(LED_BUILTIN, LOW);
50     digitalWrite(LEDR, HIGH);
51     digitalWrite(LEDG, HIGH);
52     digitalWrite(LEDB, HIGH);
53
54     if (!IMU.begin()) {
55         ei_printf("Failed to initialize IMU!\r\n");
56     }
57     else {
58         ei_printf("IMU initialized\r\n");
59     }
60
61     if (EI_CLASSIFIER_RAW_SAMPLES_PER_FRAME != 3) {
62         ei_printf("ERR: EI_CLASSIFIER_RAW_SAMPLES_PER_FRAME should be equal to 3 (t
63         return;
64     }
65 }
66
```

Done Saving.

```
[==============================] 100% (39/39 pages)
Done in 6.193 seconds
reset()
```

136 Arduino Nano 33 BLE on /dev/cu.usbmodem145101

motion_classification_nano_ble33_sense_accelerometer | Arduino 1.8.16

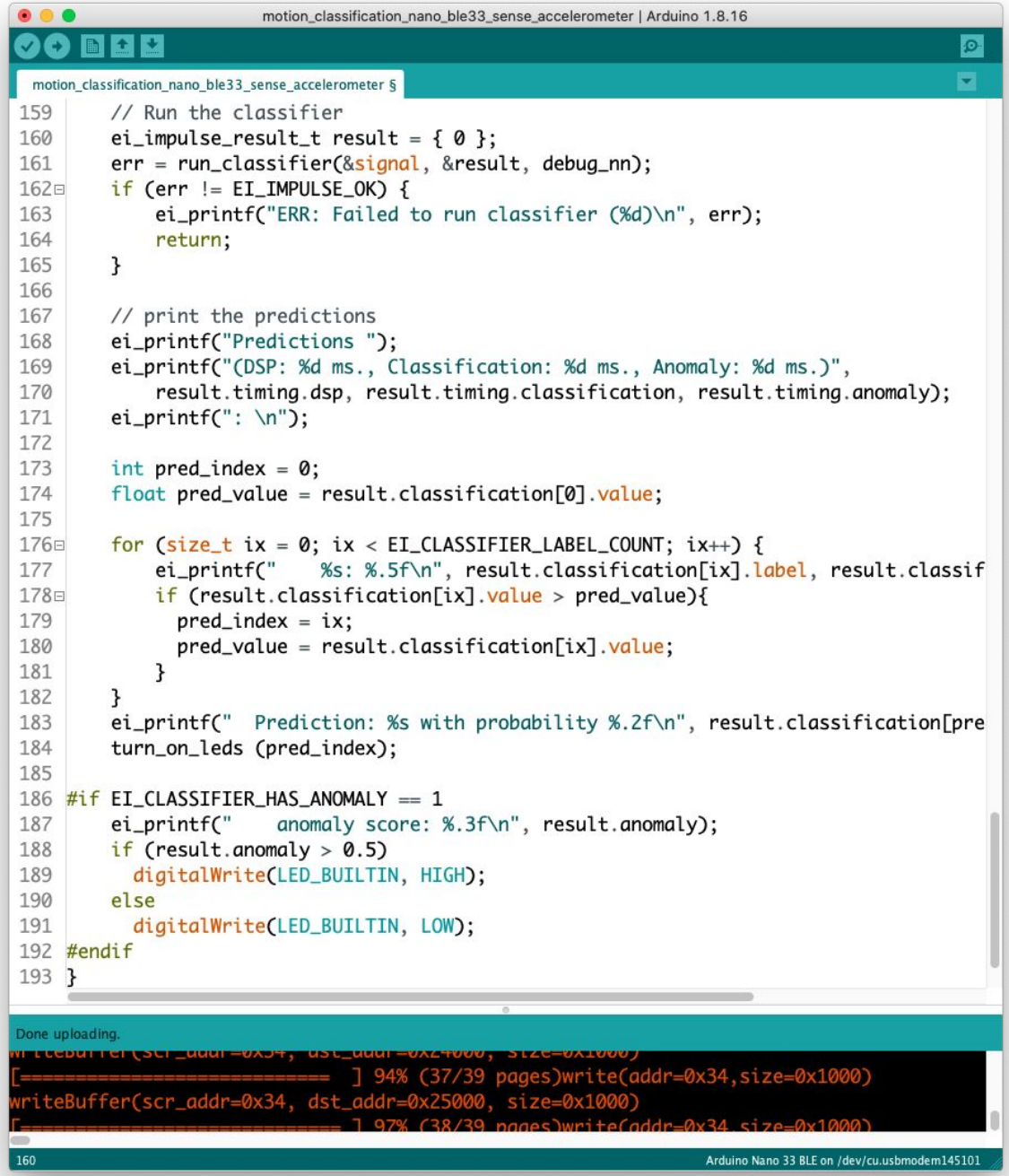
motion_classification_nano_ble33_sense_accelerometer §

```
66
67 void turn_off_leds(){
68     digitalWrite(LEDR, HIGH);
69     digitalWrite(LEDG, HIGH);
70     digitalWrite(LEDB, HIGH);
71 }
72 /*
79
80 void turn_on_leds(int pred_index) {
81   switch (pred_index)
82   {
83     case 0:     // Iddle:      [0] ==> All OFF
84       turn_off_leds();
85       break;
86
87     case 1:     // lift:       [1] ==> Green ON
88       turn_off_leds();
89       digitalWrite(LEDG, LOW);
90       break;
91
92     case 2:     // maritime:   [2] ==> Red ON
93       turn_off_leds();
94       digitalWrite(LEDR, LOW);
95       break;
96
97     case 3:     //terrestrial:[3] ==> Blue ON
98       turn_off_leds();
99       digitalWrite(LEDB, LOW);
100      break;
101  }
```

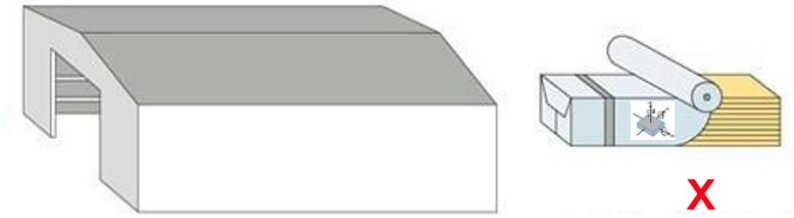
Done Saving.

```
[==============================] 100% (39/39 pages)
Done in 6.193 seconds
reset()
```

97 Arduino Nano 33 BLE on /dev/cu.usbmodem145101


motion_classification_nano_ble33_sense_accelerometer | Arduino 1.8.16
motion_classification_nano_ble33_sense_accelerometer §
// Run the classifier
ei_impulse_result_t result = { 0 };
err = run_classifier(&signal, &result, debug_nn);
if (err != EI_IMPULSE_OK) {
ei_printf("ERR: Failed to run classifier (%d)\n", err);
return;
}
// print the predictions
ei_printf("Predictions ");
ei_printf("(DSP: %d ms., Classification: %d ms., Anomaly: %d ms.)",
result.timing.dsp, result.timing.classification, result.timing.anomaly);
ei_printf(": \n");
int pred_index = 0;
float pred_value = result.classification[0].value;
for (size_t ix = 0; ix < EI_CLASSIFIER_LABEL_COUNT; ix++) {
ei_printf("   %s: %.5f\n", result.classification[ix].label, result.classif
if (result.classification[ix].value > pred_value){
pred_index = ix;
pred_value = result.classification[ix].value;
}
}
ei_printf(" Prediction: %s with probability %.2f\n", result.classification[pre
turn_on_leds (pred_index);
#if EI_CLASSIFIER_HAS_ANOMALY == 1
ei_printf("   anomaly score: %.3f\n", result.anomaly);
if (result.anomaly > 0.5)
digitalWrite(LED_BUILTIN, HIGH);
else
digitalWrite(LED_BUILTIN, LOW);
#endif
}
Done uploading.
[========================] 94% (37/39 pages)write(addr=0x34,size=0x1000)
writeBuffer(scr_addr=0x34, dst_addr=0x25000, size=0x1000)
160
Arduino Nano 33 BLE on /dev/cu.usbmodem145101

label: idle



/dev/cu.usbmodem145101

Send

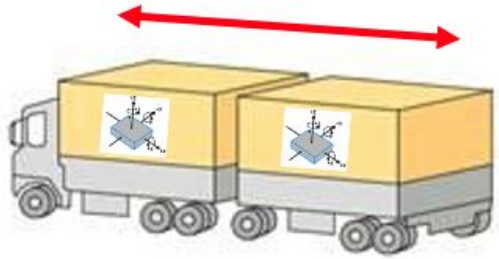
```
IESTI01 - Nano Motion Classification - Inferencing Test
IMU initialized

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 2 ms.):
    idle: 0.99219
    lift: 0.00391
    maritime: 0.00391
    terrestrial: 0.00000
  Prediction: idle with probability 0.99
    anomaly score: 0.001

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 1 ms.):
    idle: 0.99219
    lift: 0.00391
    maritime: 0.00391
    terrestrial: 0.00000
  Prediction: idle with probability 0.99
    anomaly score: -0.001
```

Autoscroll Show timestamp Both NL & CR 115200 baud Clear output

label: terrestrial



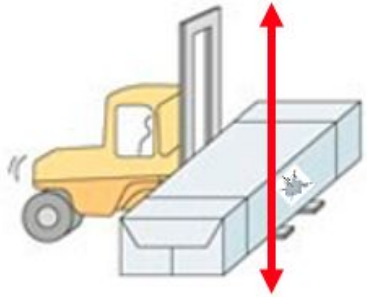
```
/dev/cu.usbmodem145101

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 1 ms.):
    idle: 0.00000
    lift: 0.00000
    maritime: 0.00000
    terrestrial: 0.99609
  Prediction: terrestrial with probability 1.00
    anomaly score: -0.190

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 2 ms.):
    idle: 0.00000
    lift: 0.00000
    maritime: 0.00000
    terrestrial: 0.99609
  Prediction: terrestrial with probability 1.00
    anomaly score: -0.096

Autoscroll  Show timestamp   Both NL & CR   115200 baud   Clear output
```

label: lift

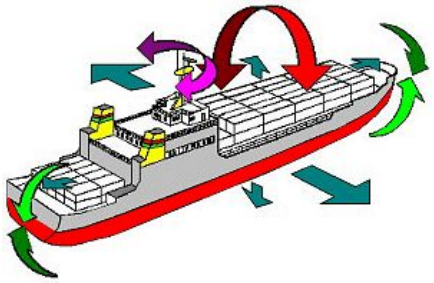


```
/dev/cu.usbmodem145101

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 2 ms.):
    idle: 0.00000
    lift: 0.99609
    maritime: 0.00000
    terrestrial: 0.00000
  Prediction: lift with probability 1.00
    anomaly score: 0.047

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 1 ms.):
    idle: 0.76172
    lift: 0.12500
    maritime: 0.10547
    terrestrial: 0.00781
  Prediction: idle with probability 0.76
    anomaly score: 0.874
```

label: maritime



/dev/cu.usbmodem145101

Send

```
Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 2 ms.):
    idle: 0.00391
    lift: 0.29297
    maritime: 0.40625
    terrestrial: 0.29297
  Prediction: maritime with probability 0.41
    anomaly score: 0.431

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 1 ms.):
    idle: 0.95312
    lift: 0.03516
    maritime: 0.00781
    terrestrial: 0.00391
  Prediction: idle with probability 0.95
    anomaly score: 0.247
```

Autoscroll Show timestamp Both NL & CR 115200 baud Clear output

label: anomaly

```
/dev/cu.usbmodem145101

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 1 ms.):
    idle: 0.00781
    lift: 0.12109
    maritime: 0.87109
    terrestrial: 0.00000
  Prediction: maritime with probability 0.87
    anomaly score: 0.902

Starting inferencing in 2 seconds...
Sampling...
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 1 ms.):
    idle: 0.89453
    lift: 0.08984
    maritime: 0.01172
    terrestrial: 0.00781
  Prediction: idle with probability 0.89
    anomaly score: 0.248
```

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/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- Fundamentals textbook: “Deep Learning with Python” by François Chollet
- Applications & Deploy textbook: “TinyML” by Pete Warden, Daniel Situnayake
- Deploy textbook “TinyML Cookbook” by Gian Marco Iodice

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

Thanks

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