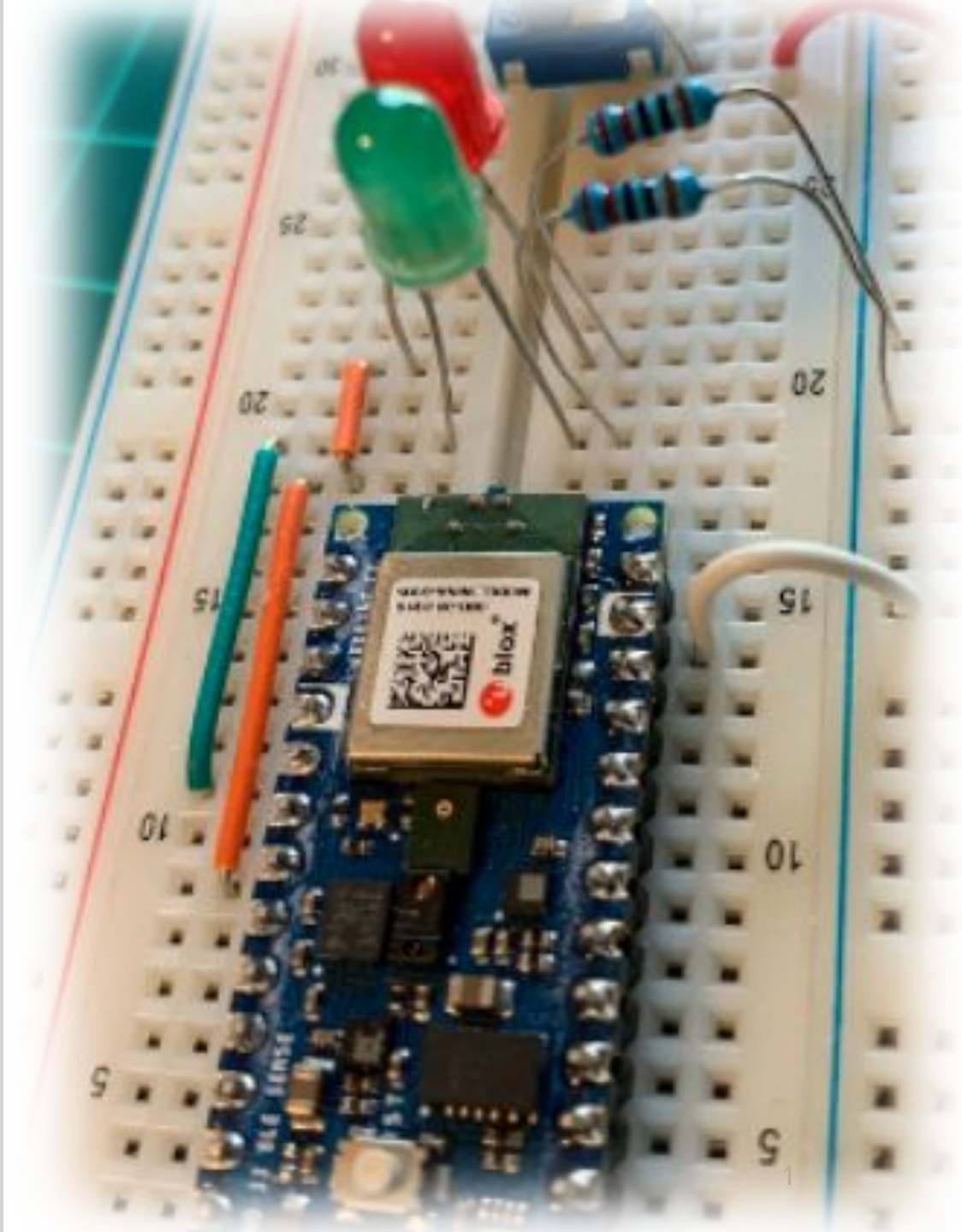
IESTI01 – TinyML

Embedded Machine Learning

- TinyML Kit Overview
- HW and SW installation & Test
- Connection with EI Studio
- Motion Classification

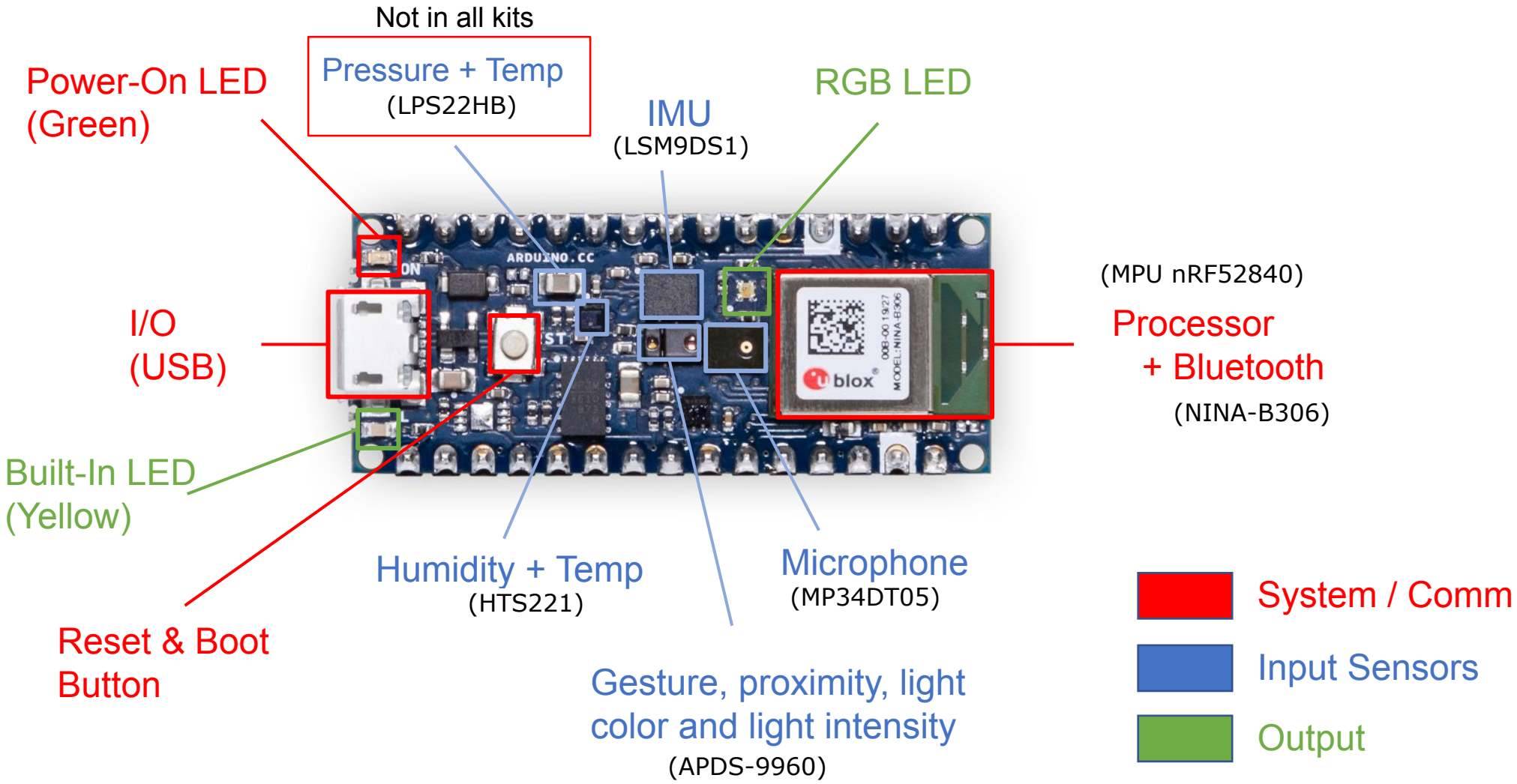


Prof. Marcelo Rovai
UNIFEI

TinyML Kit Overview


ARDUINO
TINY MACHINE
LEARNING KIT
in partnership with:
edX
TensorFlow
OV7675

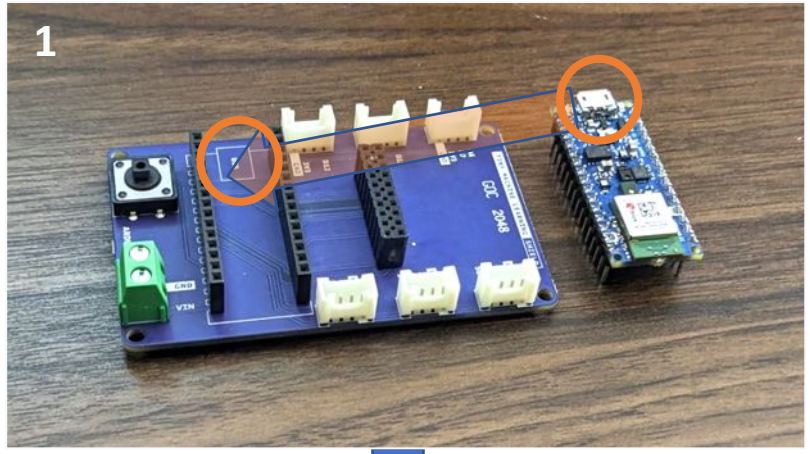
Nano 33 BLE Sense (Development board)

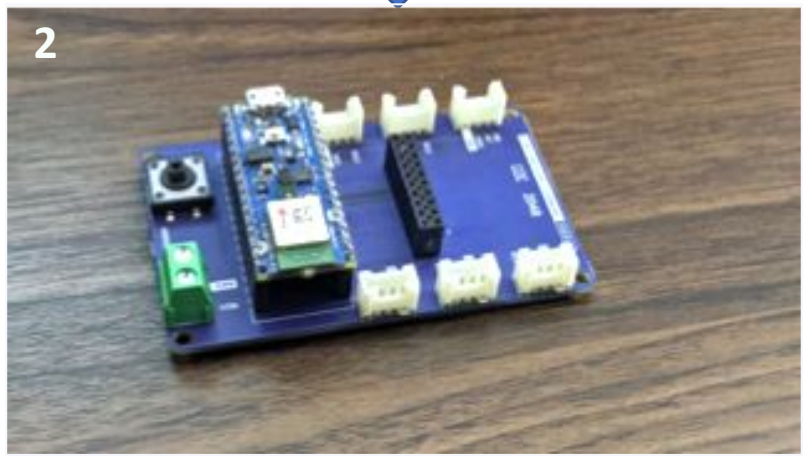


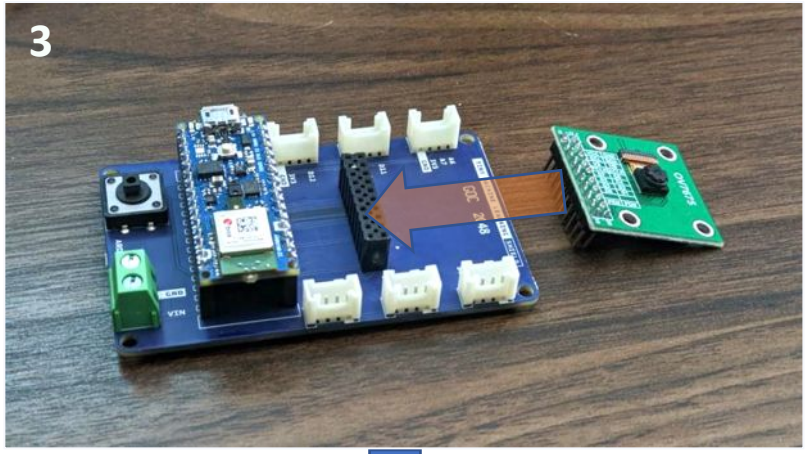
TinyML Kit Installation

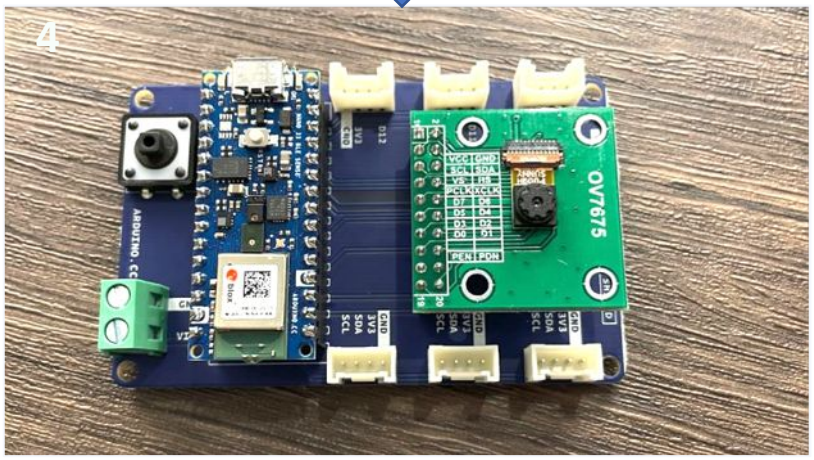
- Hardware Set-up
- Software Set-up

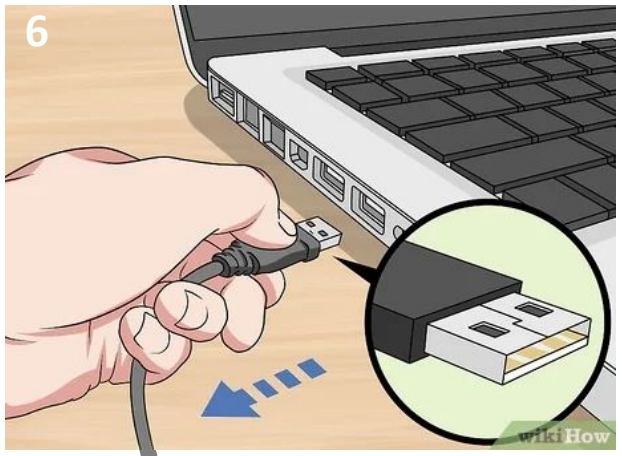
Installing the Hardware



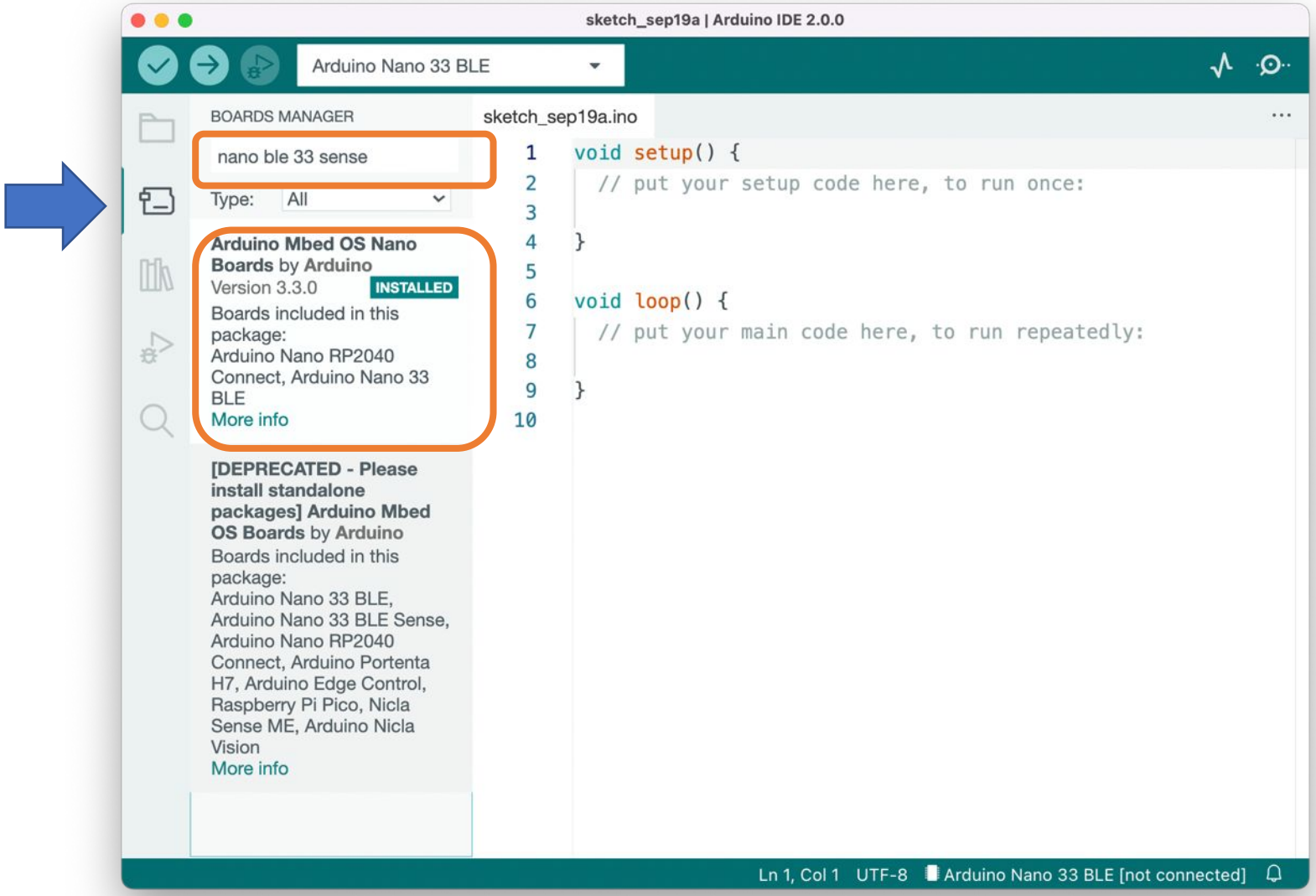




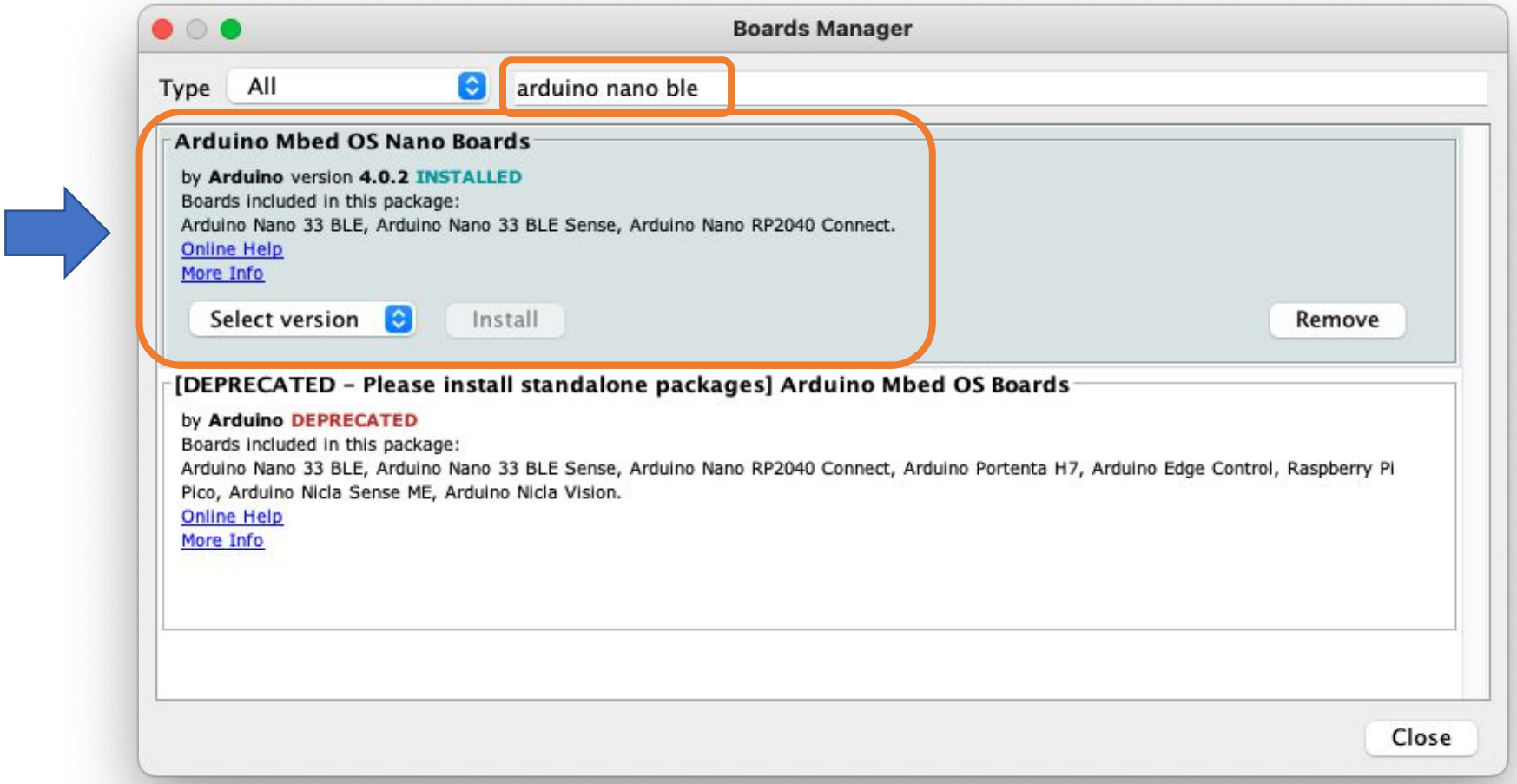




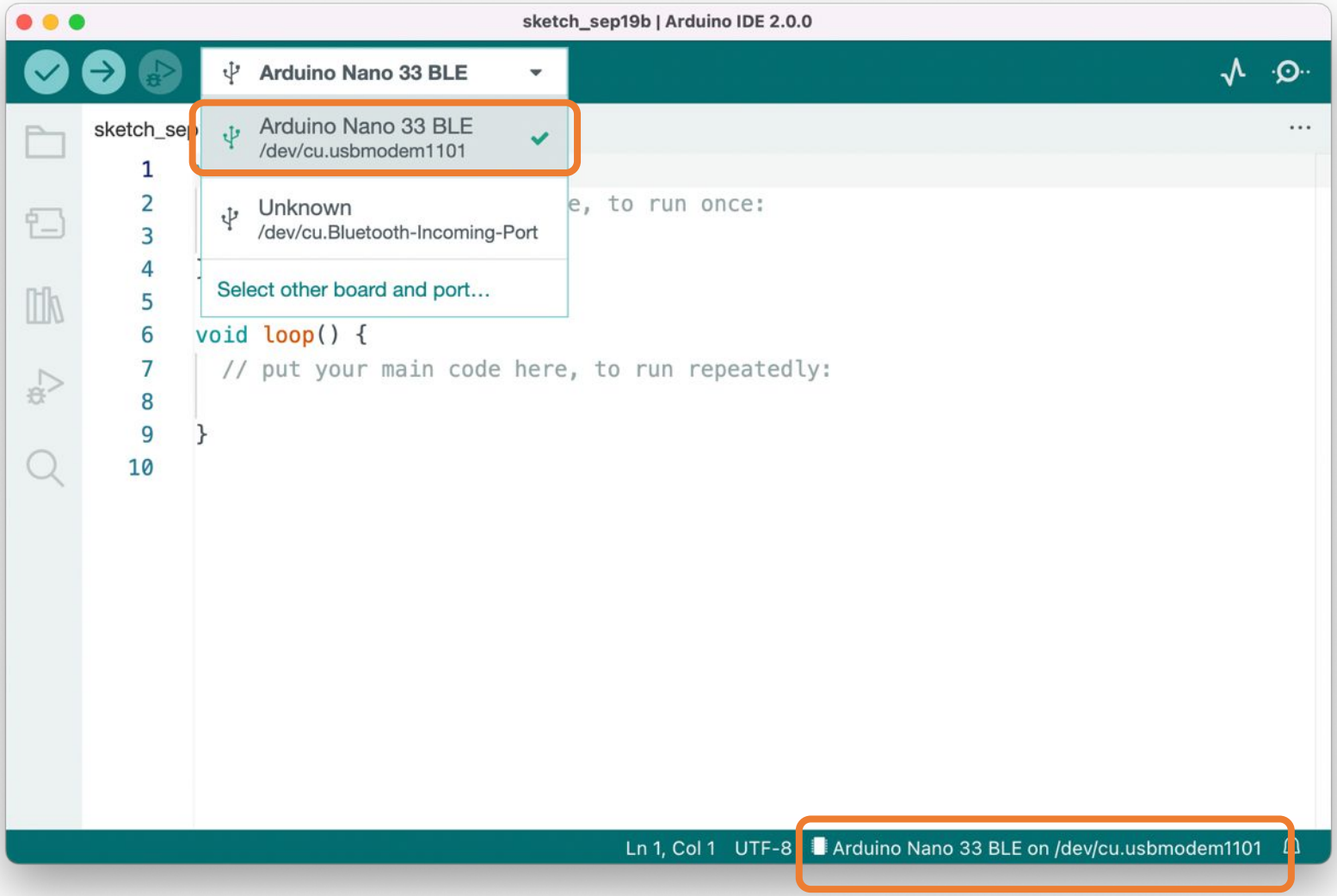
Installing the Board Files



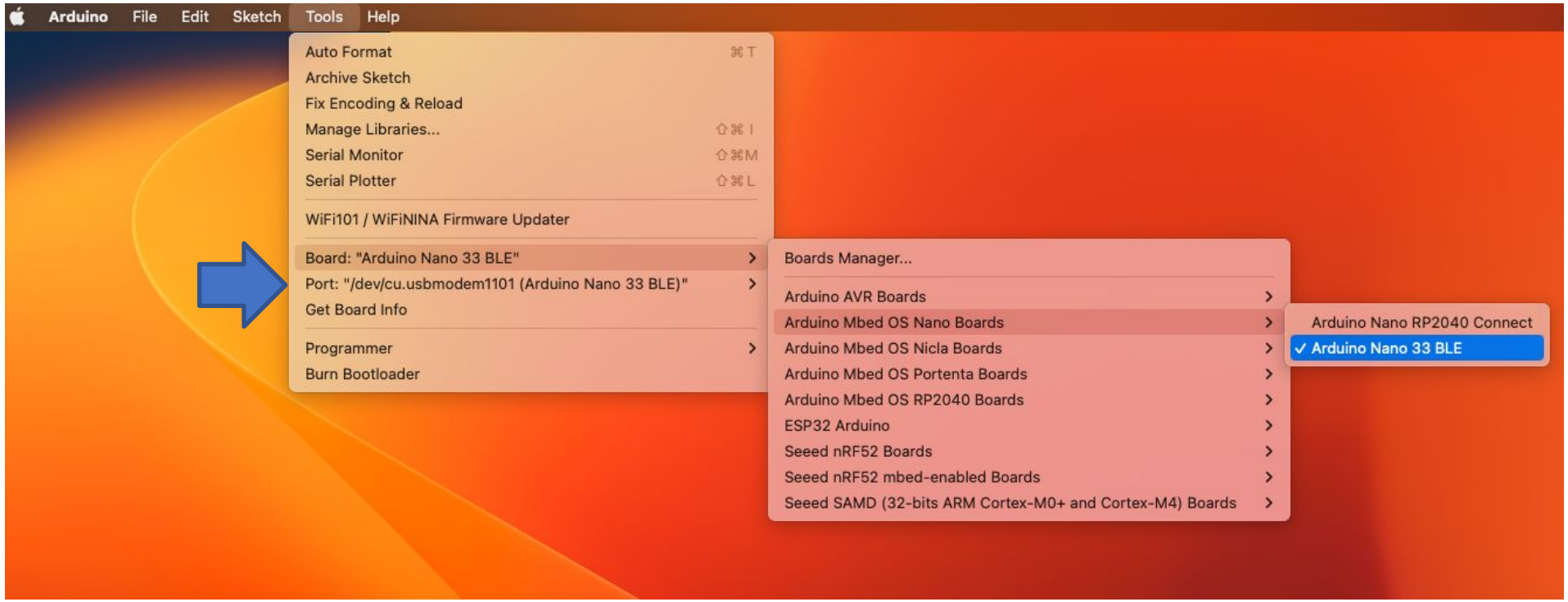
Installing the Board Files (IDE 1.8.19)



Select Board and Port



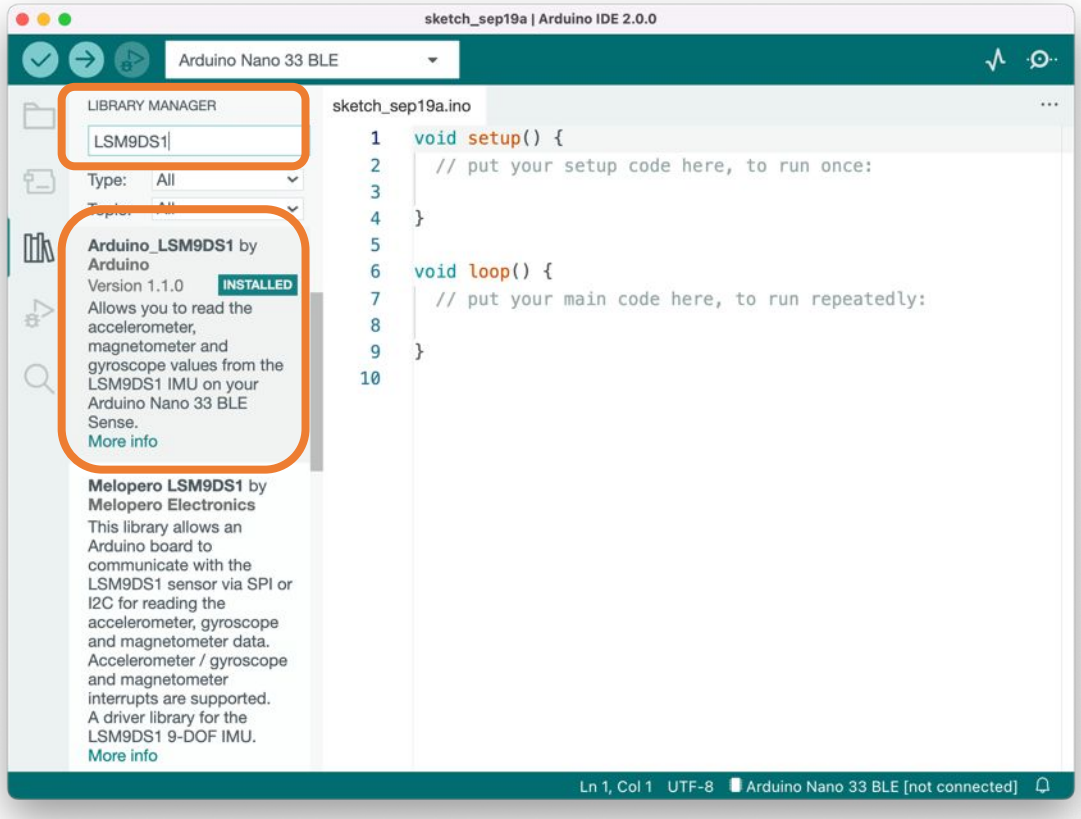
Select Board and Port (IDE 1.8.19)

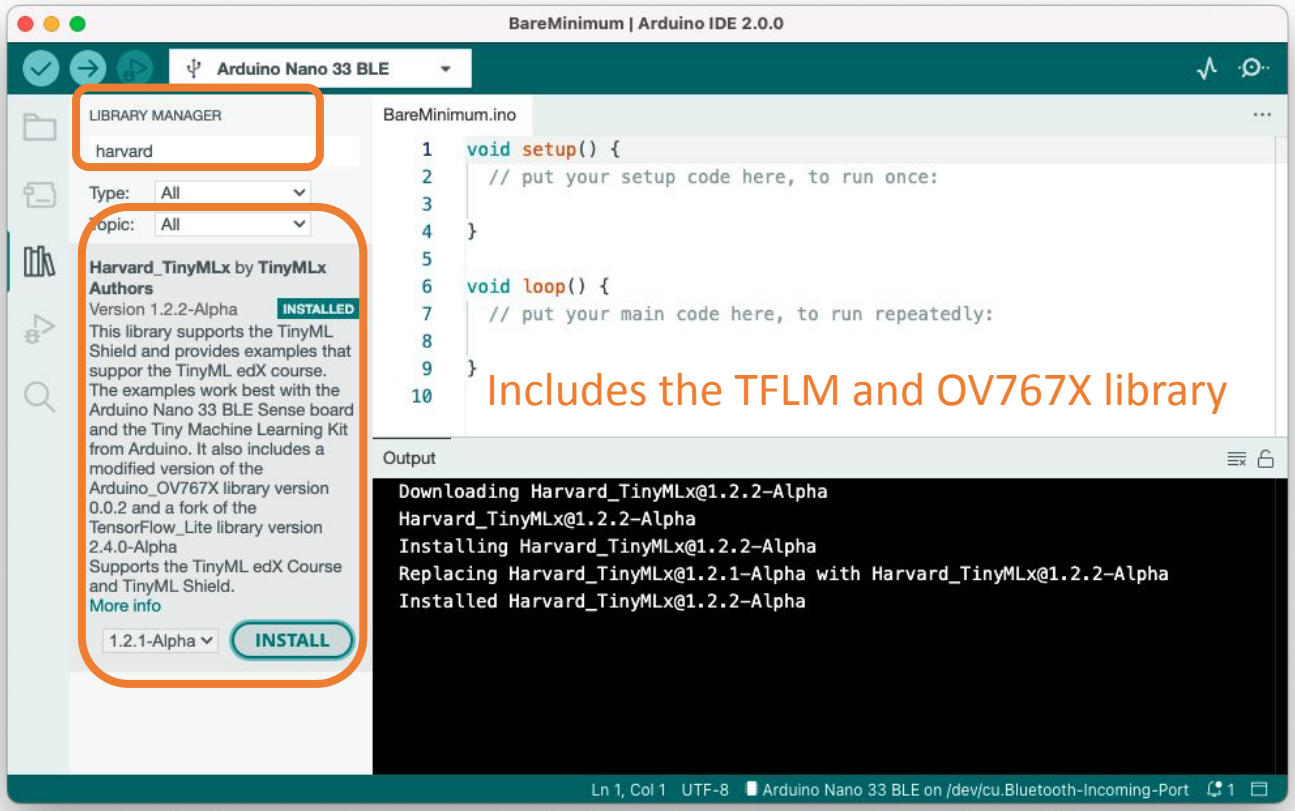


Installing Sensor and Auxiliary Libraries

IMU library

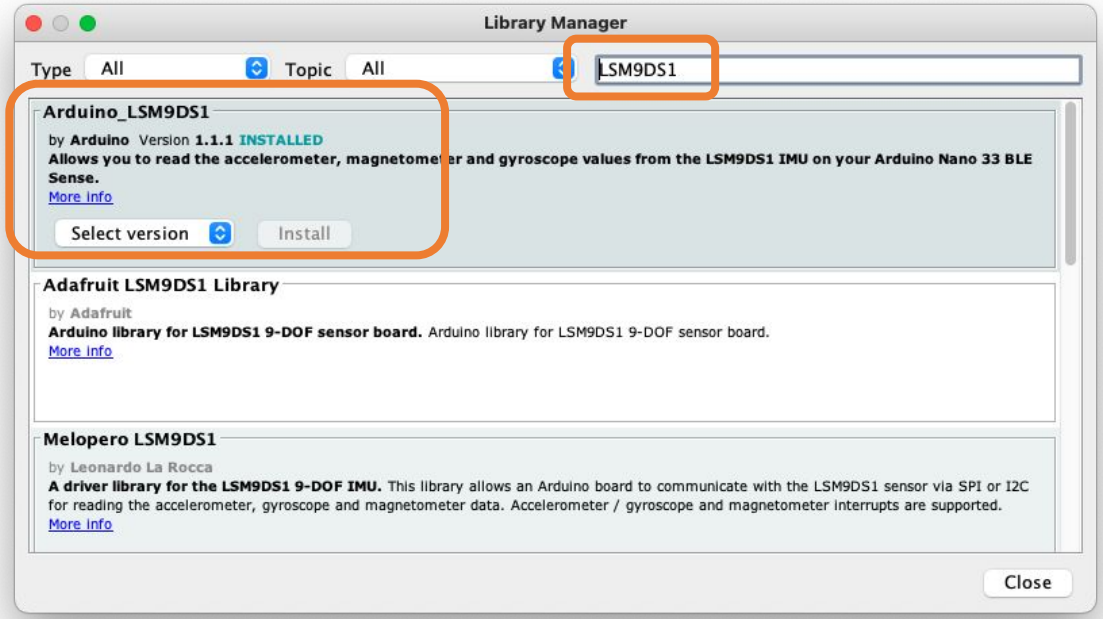
Shield, TFLM and Camera libraries



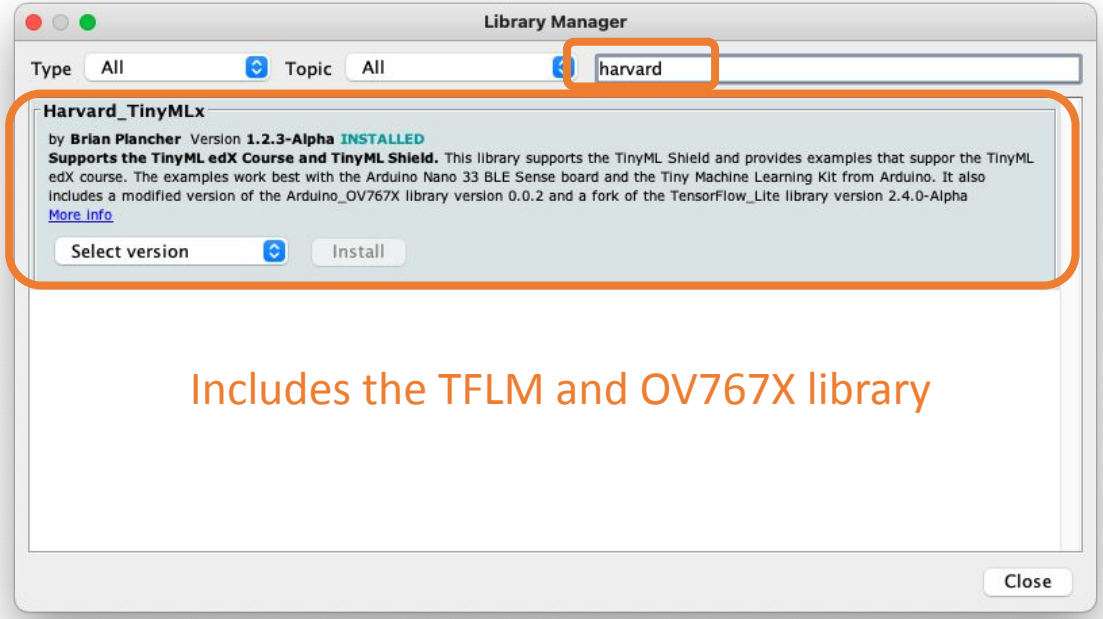


Installing Sensor and Auxiliary Libraries (IDE 1.8.19)

IMU library (LSM9DS1)

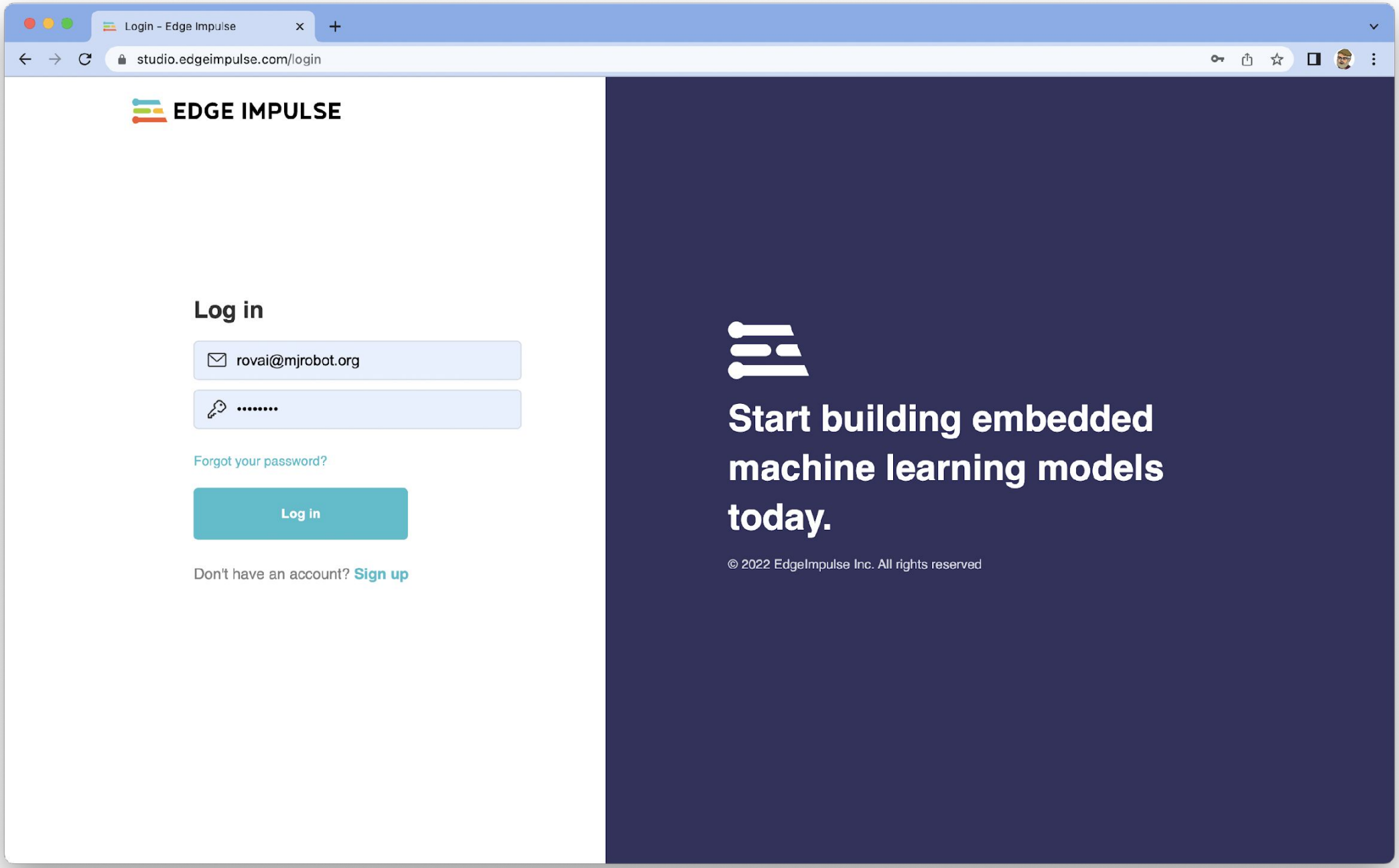


Shield, TFLM, and Camera libraries (Harvard)



Includes the TFLM and OV767X library

Set up connection between Arduino Nano and Edge Impulse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rovai@mjrobot.org
Forgot your password?
Log in
Don't have an account? Sign up
Start building embedded machine learning models today.
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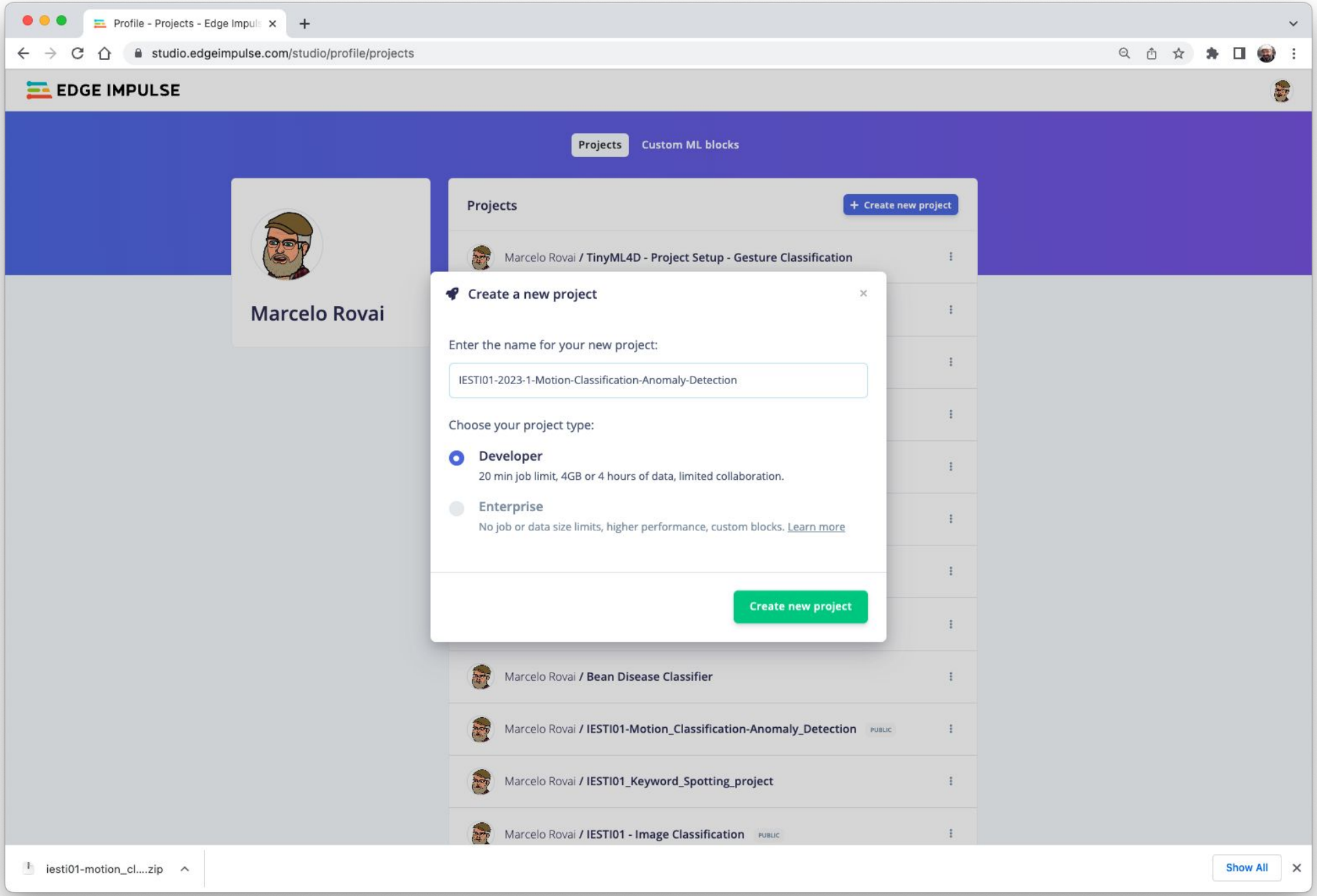
Profile - Projects - Edge Impuls
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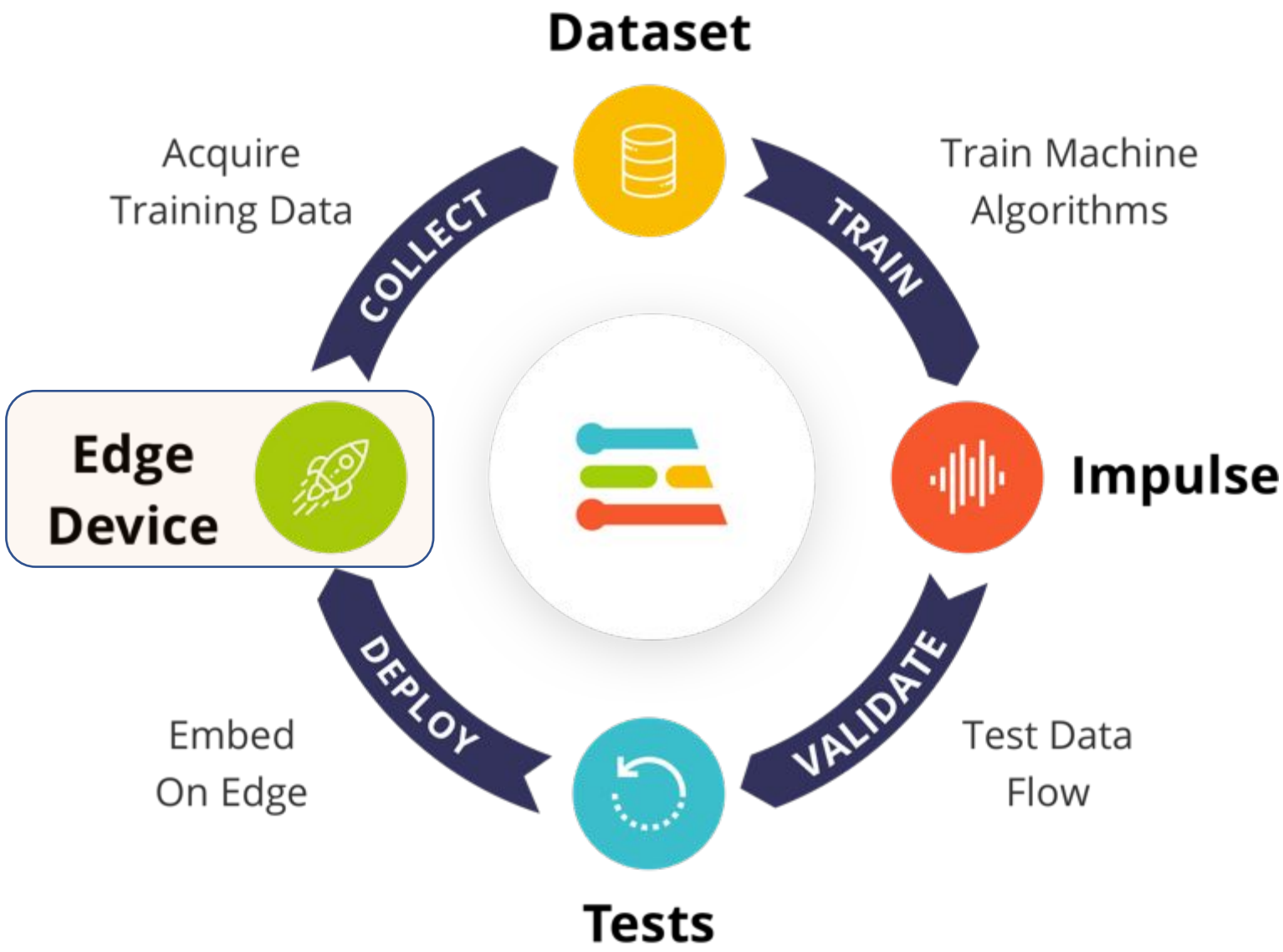
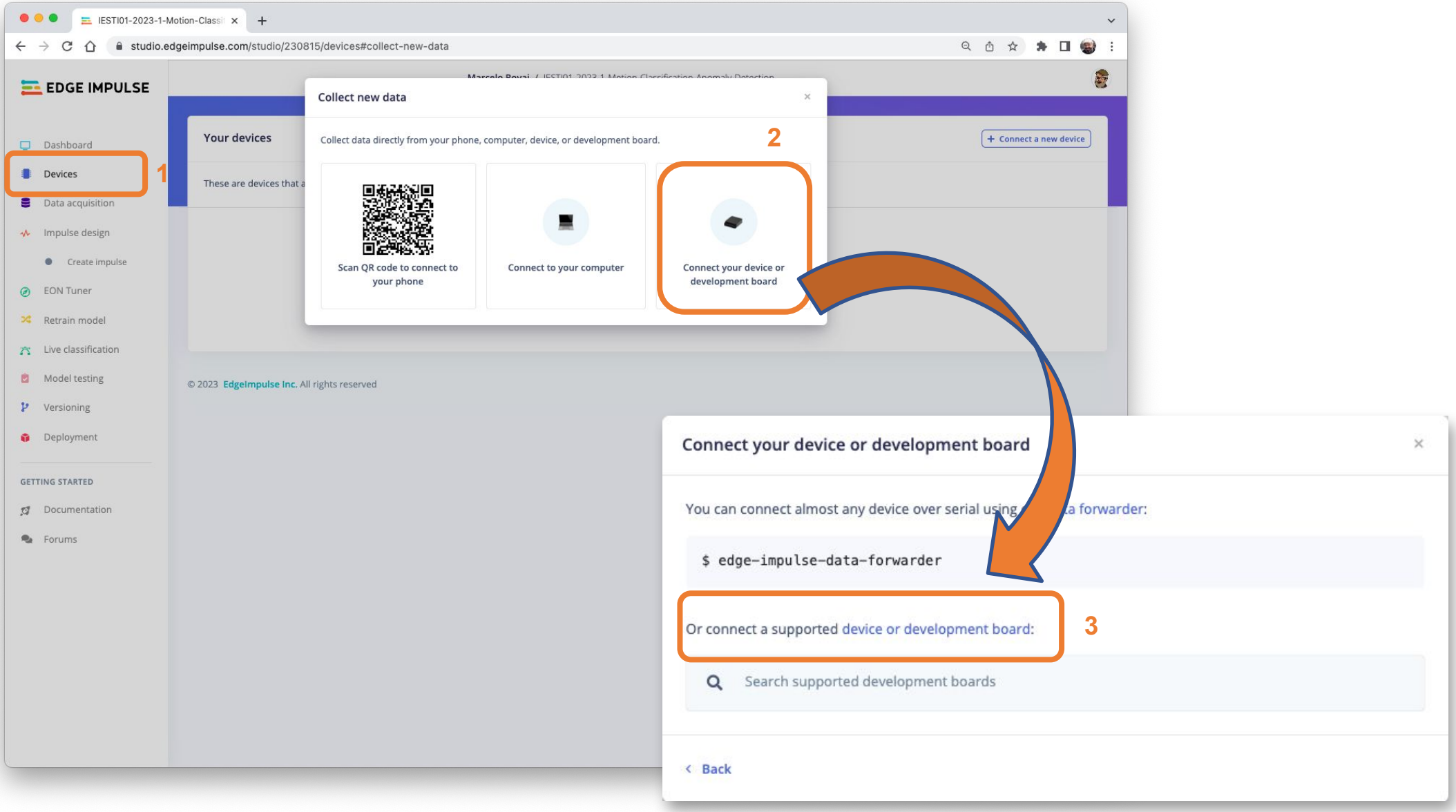
EDGE IMPULSE
Projects
Custom ML blocks
Marcelo Rovai
Projects
+ Create new project
Marcelo Rovai / TinyML4D - Project Setup - Gesture Classification
Create a new project
Enter the name for your new project:
IESTI01-2023-1-Motion-Classification-Anomaly-Detection
Choose your project type:
Developer
20 min job limit, 4GB or 4 hours of data, limited collaboration.
Enterprise
No job or data size limits, higher performance, custom blocks. Learn more
Create new project
Marcelo Rovai / Bean Disease Classifier
Marcelo Rovai / IESTI01-Motion_Classification-Anomaly_Detection PUBLIC
Marcelo Rovai / IESTI01_Keyword_Spotting_project
Marcelo Rovai / IESTI01 - Image Classification PUBLIC
iesti01-motion_cl....zip
Show All



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


IESTI01-2023-1-Motion-Classi
studio.edgeimpulse.com/studio/230815/devices#collect-new-data
EDGE IMPULSE
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
1
Your devices
+ Connect a new device
Collect new data
Collect data directly from your phone, computer, device, or development board.
2
Scan QR code to connect to your phone
Connect to your computer
Connect your device or development board
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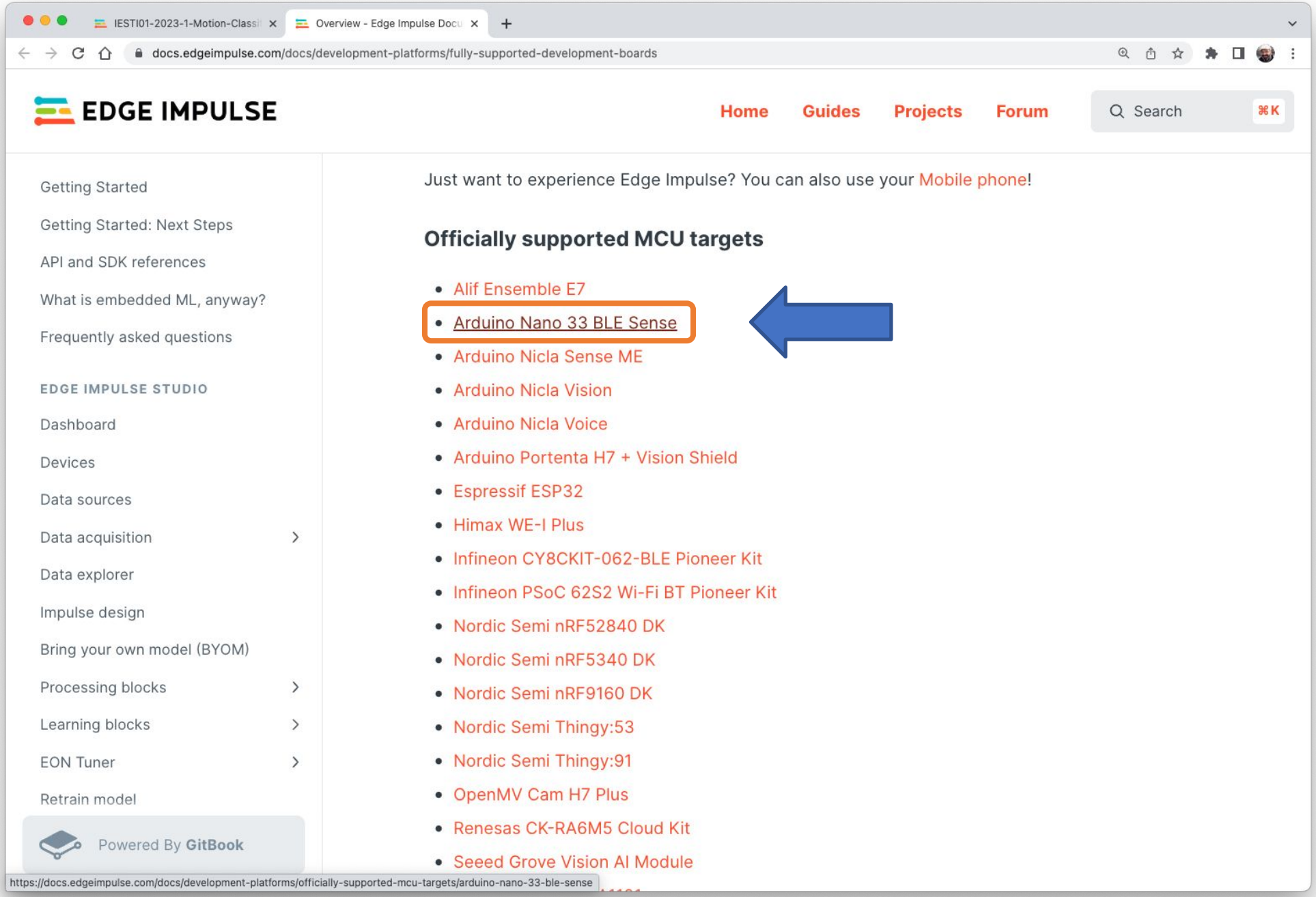
Connect your device or development board
You can connect almost any device over serial using
a forwarder:
$ edge-impulse-data-forwarder
Or connect a supported device or development board:
3
Search supported development boards
Back


IESTI01-2023-1-Motion-Classi
Overview - Edge Impulse Docu
docs.edgeimpulse.com/docs/development-platforms/fully-supported-development-boards
EDGE IMPULSE
Home
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What is embedded ML, anyway?
Frequently asked questions
EDGE IMPULSE STUDIO
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Data sources
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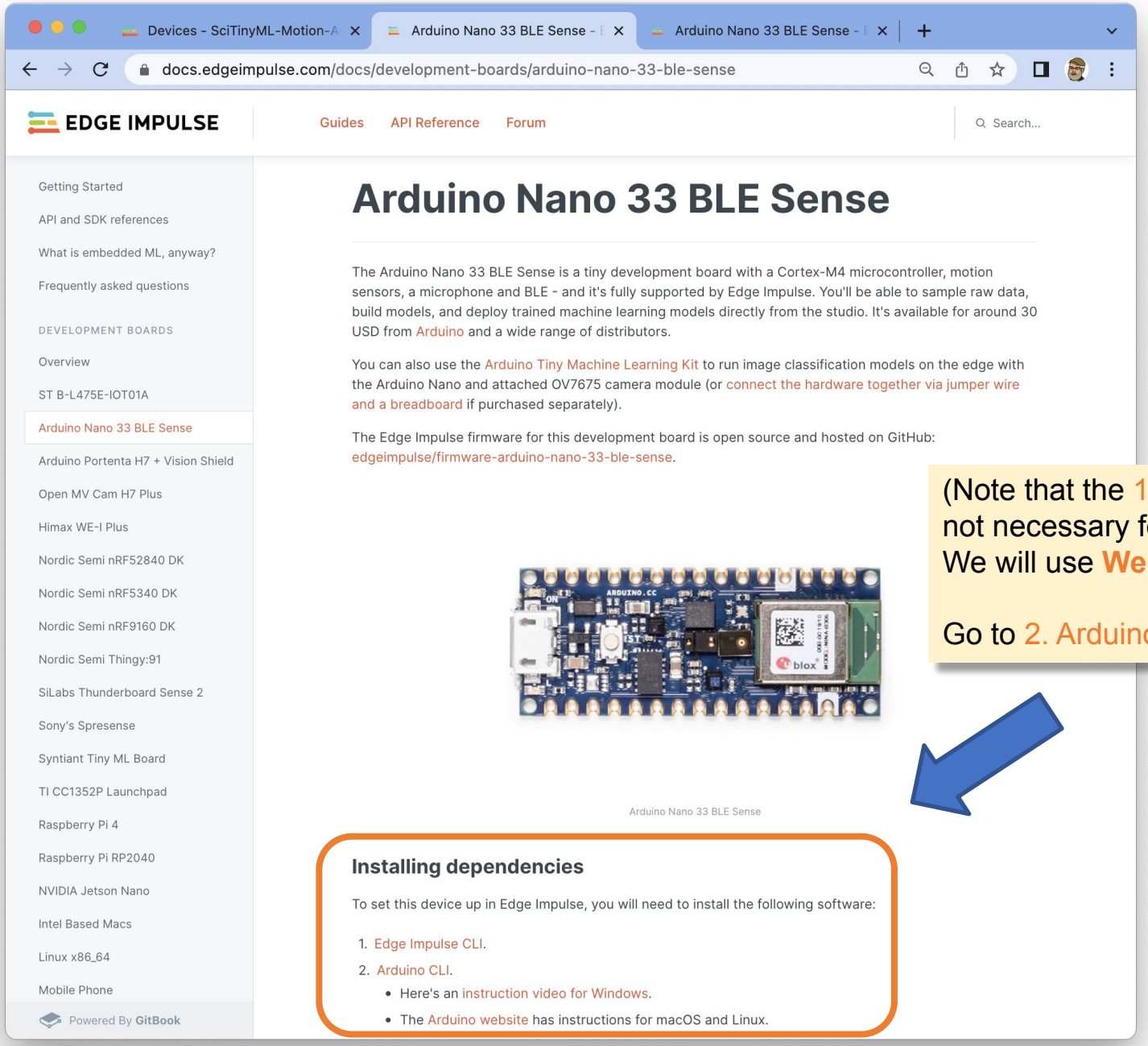
Data explorer
Impulse design
Bring your own model (BYOM)
Processing blocks
Learning blocks
EON Tuner
Retrain model
Powered By GitBook
Just want to experience Edge Impulse? You can also use your Mobile phone!
Officially supported MCU targets
Alif Ensemble E7
Arduino Nano 33 BLE Sense
Arduino Nicla Sense ME
Arduino Nicla Vision
Arduino Nicla Voice
Arduino Portenta H7 + Vision Shield
Espressif ESP32
Himax WE-I Plus
Infineon CY8CKIT-062-BLE Pioneer Kit
Infineon PSoC 62S2 Wi-Fi BT Pioneer Kit
Nordic Semi nRF52840 DK
Nordic Semi nRF5340 DK
Nordic Semi nRF9160 DK
Nordic Semi Thingy:53
Nordic Semi Thingy:91
OpenMV Cam H7 Plus
Renesas CK-RA6M5 Cloud Kit
Seeed Grove Vision AI Module
https://docs.edgeimpulse.com/docs/development-platforms/officially-supported-mcu-targets/arduino-nano-33-ble-sense

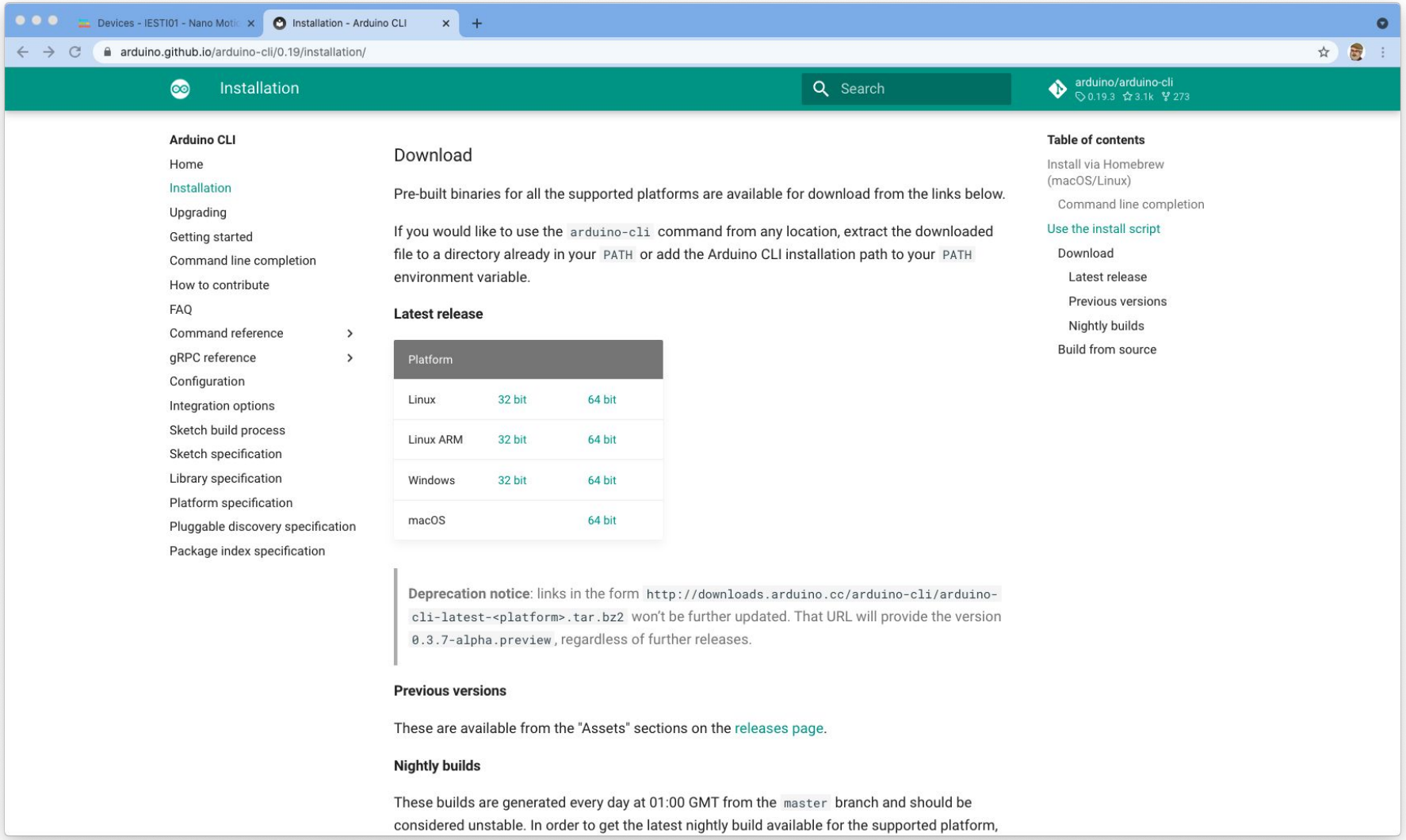
EI/Arduino CLI

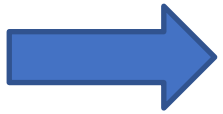


(Note that the 1. Edge Impulse CLI is not necessary for Arduino Nano-33. We will use **WebUSB** insteady)

Go to 2. Arduino CLI

Arduino CLI





[See this video for Windows installation: https://www.youtube.com/watch?v=1jMWsFER-Bc](https://www.youtube.com/watch?v=1jMWsFER-Bc)

Arduino CLI Installation Summary

If you're on Windows:

- Unzip the .zip file to C:\Program Files\arduino-cli
- Open System Properties > Advanced > Environment Variables
- Path under "user variables" > Edit
- Add C:\Program Files\arduino-cli

If you're on macOS:

- I recommend using the curl method or homebrew shown on the installation page: https://arduino.github.io/arduino-cli/0.21/installation/
- if you use the curl method, it likely installs arduino-cli to ~/bin. That might not be on your path. So, you might need to run: `export PATH=$PATH:~/bin`

IESTI01-2023-1-Motion-Classi | Arduino Nano 33 BLE Sense -

docs.edgeimpulse.com/docs/development-platforms/officially-supported-mcu-targets/arduino-nano-33-ble-sense

EDGE IMPULSE

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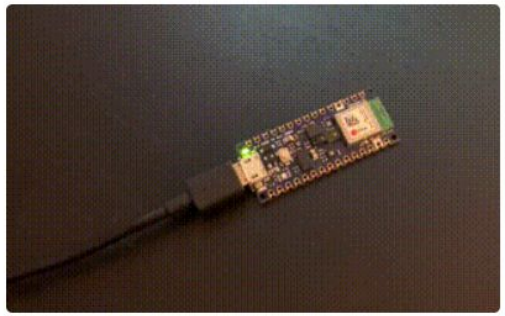
Powered By GitBook

1

1. Connect the development board to your computer

Use a micro-USB cable to connect the development board to your computer. Then press RESET twice to launch into the bootloader. The on-board LED should start pulsating to indicate this.



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

2

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.

arduino-nano-33....zip

3

Show All

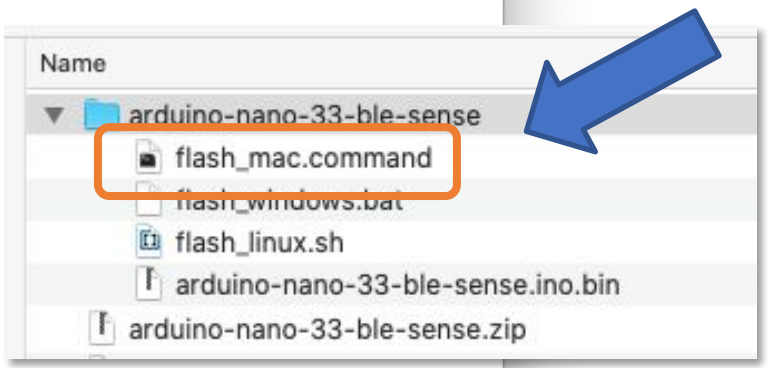
MacOS

marcelo_rovai — flash_mac.command — 138×42

```
Last login: Tue May 23 15:47:55 on console
/Users/marcelo_rovai/Downloads/arduino-nano-33-ble-sense\ \(18\)/flash_mac.command ; exit;
(base) marcelo_rovai@Marcelos-MacBook-Pro ~ % /Users/marcelo_rovai/Downloads/arduino-nano-33-ble-sense\ \(18\)/flash_mac.command ; exit;
You're using an untested version of Arduino CLI, this might cause issues (found: 0.31.0, expected: 0.18.x)
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 352560 bytes to flash (87 pages)
[==============================] 100% (87/87 pages)
Done in 13.971 seconds


A new release of Arduino CLI is available: 0.31.0 → 0.32.2
https://arduino.github.io/arduino-cli/latest/installation/#latest-packages

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'

Saving session...
...copying shared history...
...saving history...truncating history files...
...completed.

[Process completed]
```

3.Nano-33 LED Stop Flashing

1. Press Nano-33 Reset button Twice
2. With Nano-33 LED Flashing:

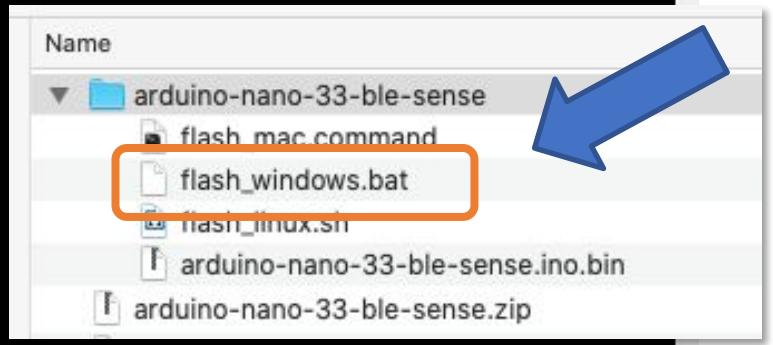


Windows 10

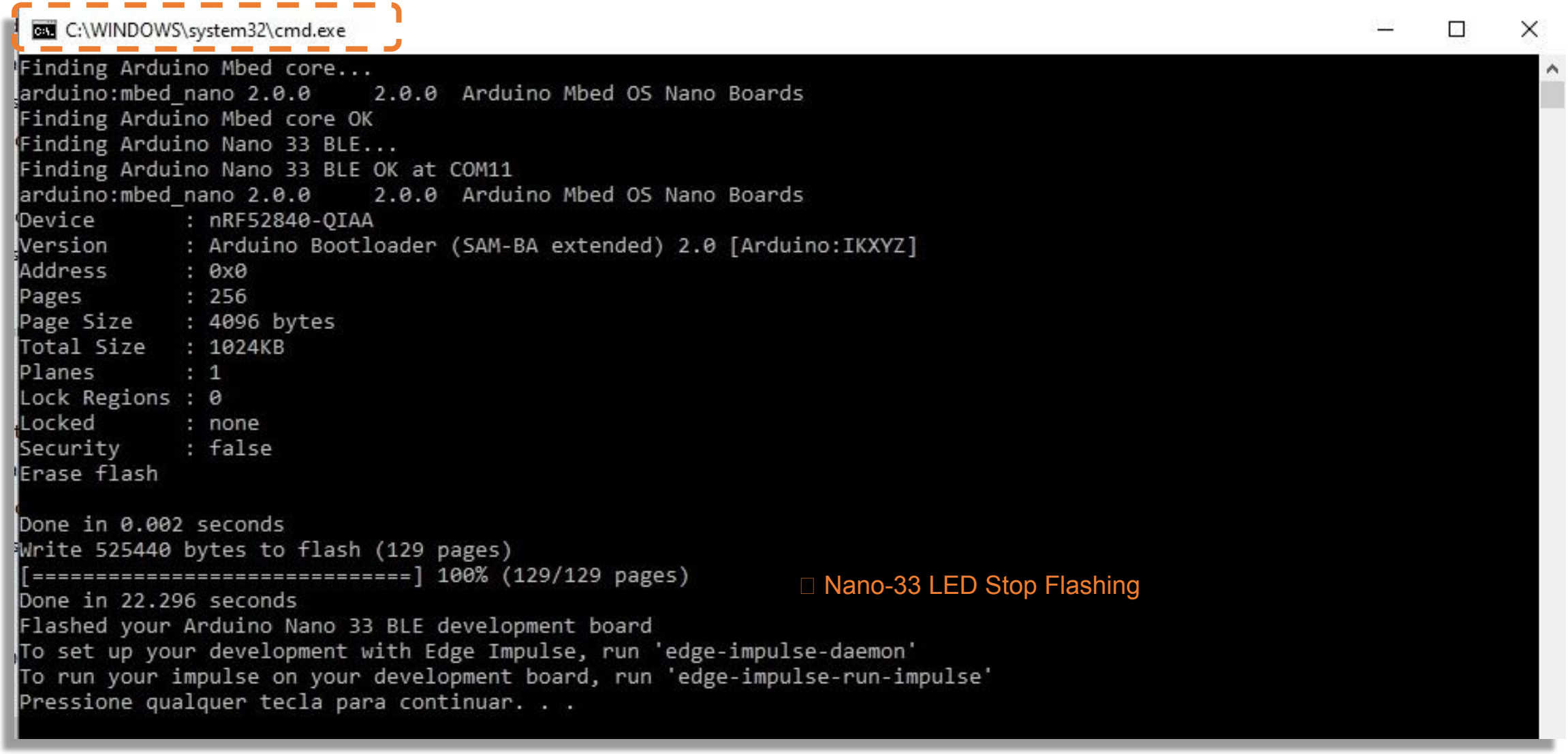
Prompt de Comando

```
Microsoft Windows [versão 10.0.19041.1052]
(c) Microsoft Corporation. Todos os direitos reservados.

C:\Users\GUILH>arduino-cli
Arduino Command Line Interface (arduino-cli).

Usage:
  arduino-cli [command]

Examples:
  arduino-cli <command> [flags...]

Available Commands:
  board           Arduino board commands.
  burn-bootloader Upload the bootloader.
  cache           Arduino cache commands.
  compile         Compiles Arduino sketches.
  completion      Generates completion scripts
  config          Arduino configuration commands.
  core            Arduino core operations.
  daemon          Run as a daemon on port 50051
  debug           Debug Arduino sketches.
  help            Help about any command
  lib             Arduino commands about libraries.
  outdated        Lists cores and libraries that can be upgraded
  sketch          Arduino CLI sketch commands.
  update          Updates the index of cores and libraries
  upgrade         Upgrades installed cores and libraries.
  upload          Upload Arduino sketches.
  version         Shows version number of Arduino CLI.
```

1. Press Nano-33 Reset button Twice
2. With Nano-33 LED Flashing:

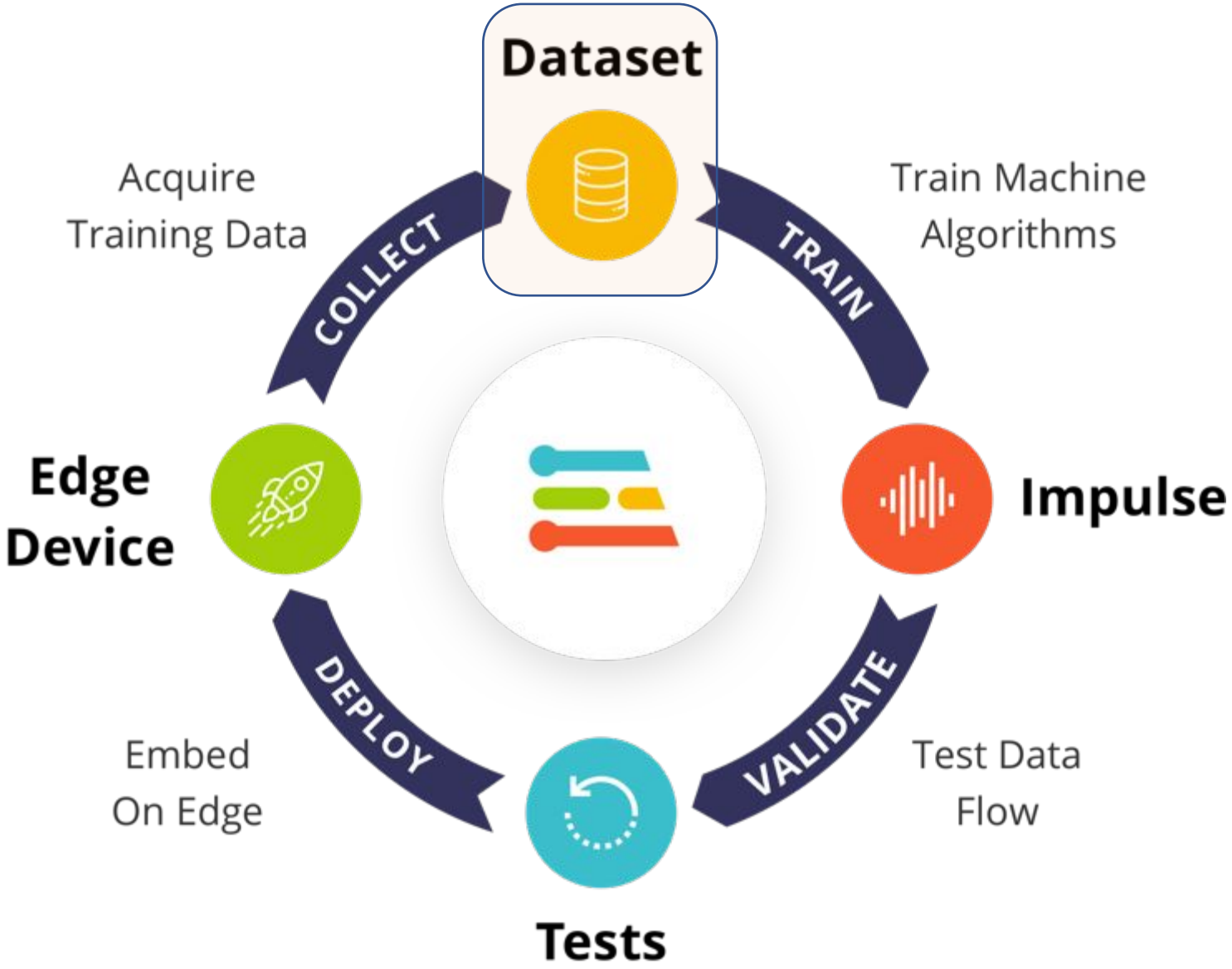


Windows 10

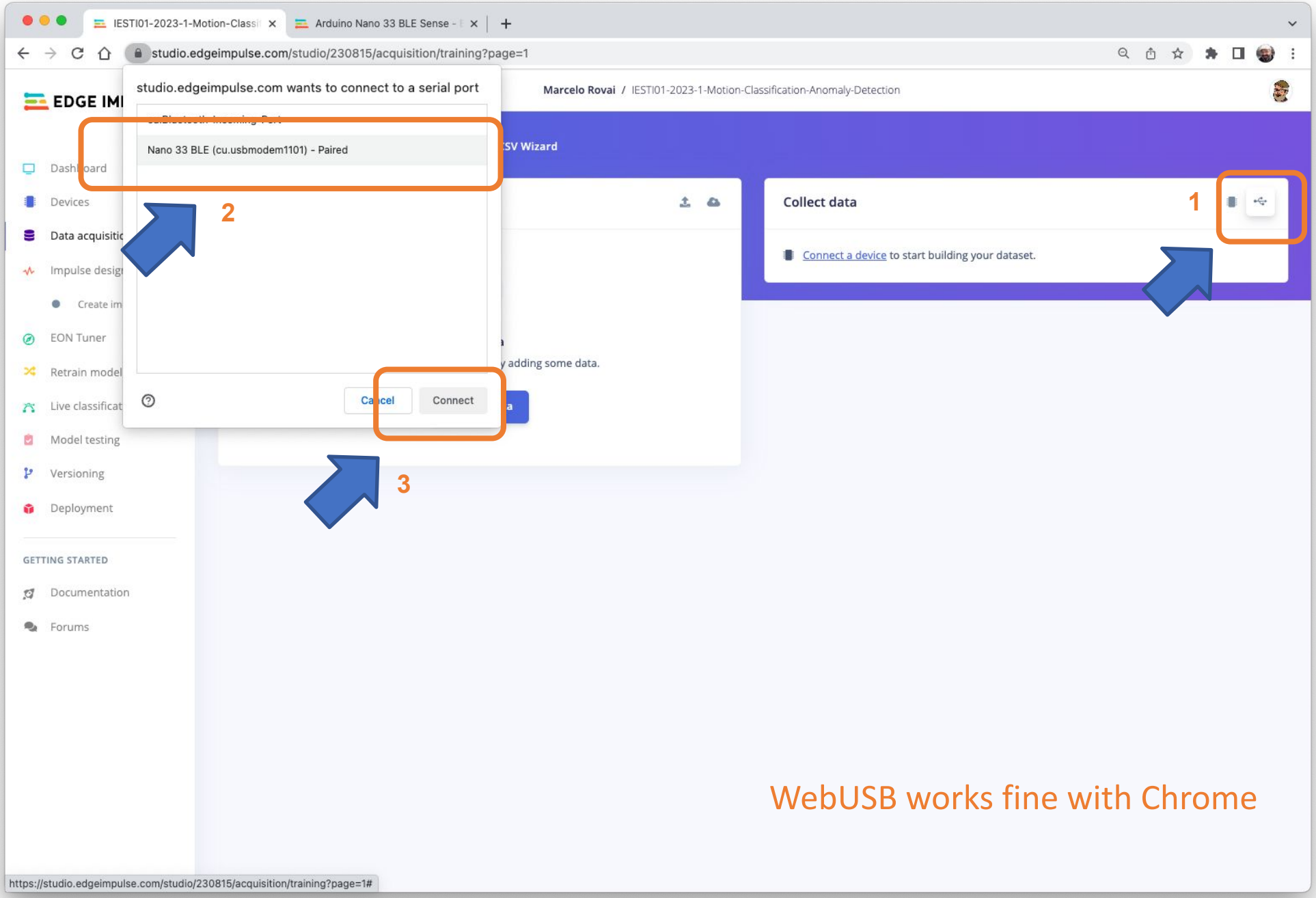


 Nano-33 LED Stop Flashing

Sensor’s Test

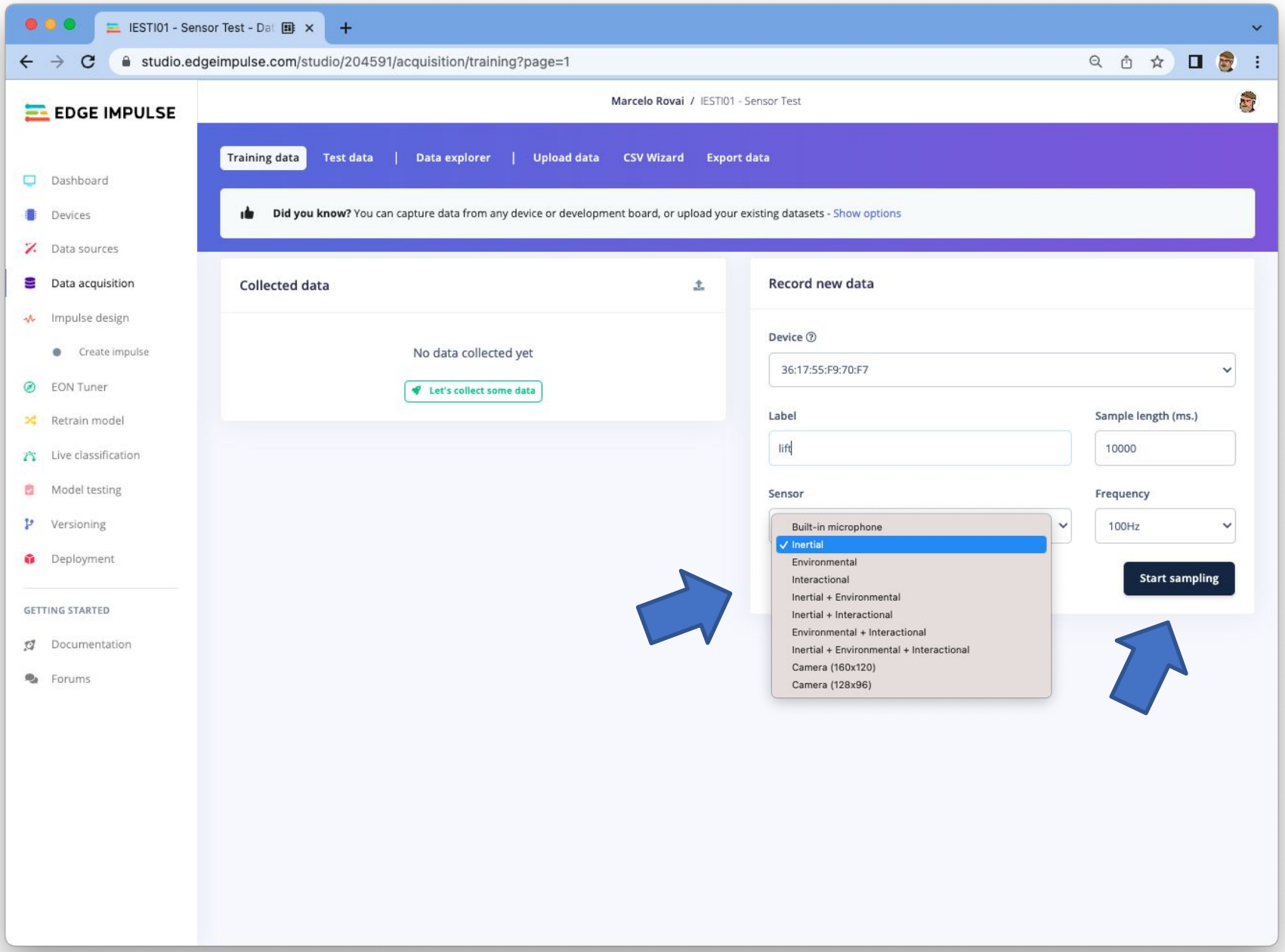


- Pre-Processing Data
- Design a Model
- Train a Model

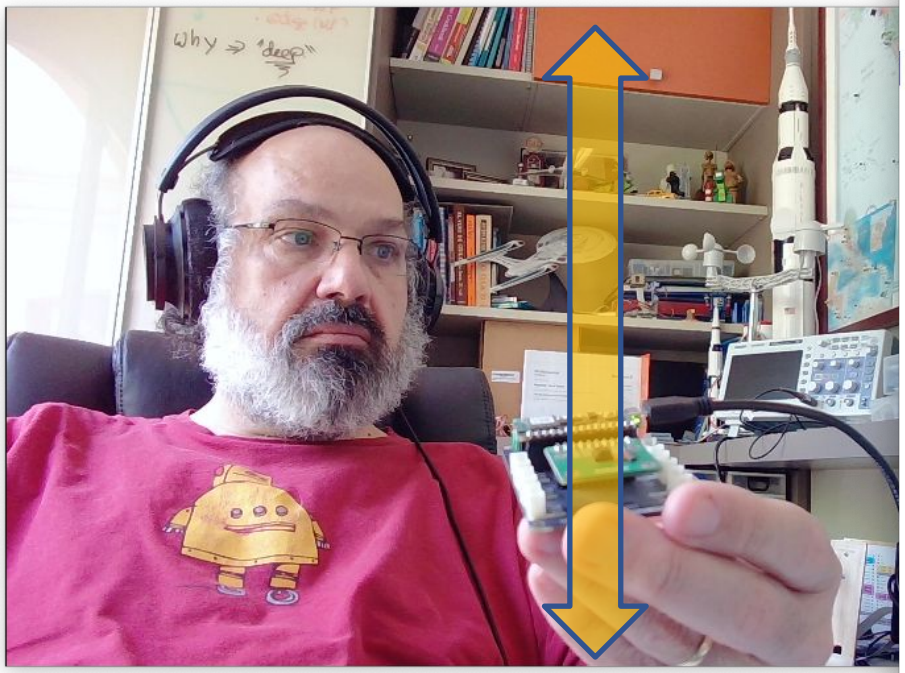


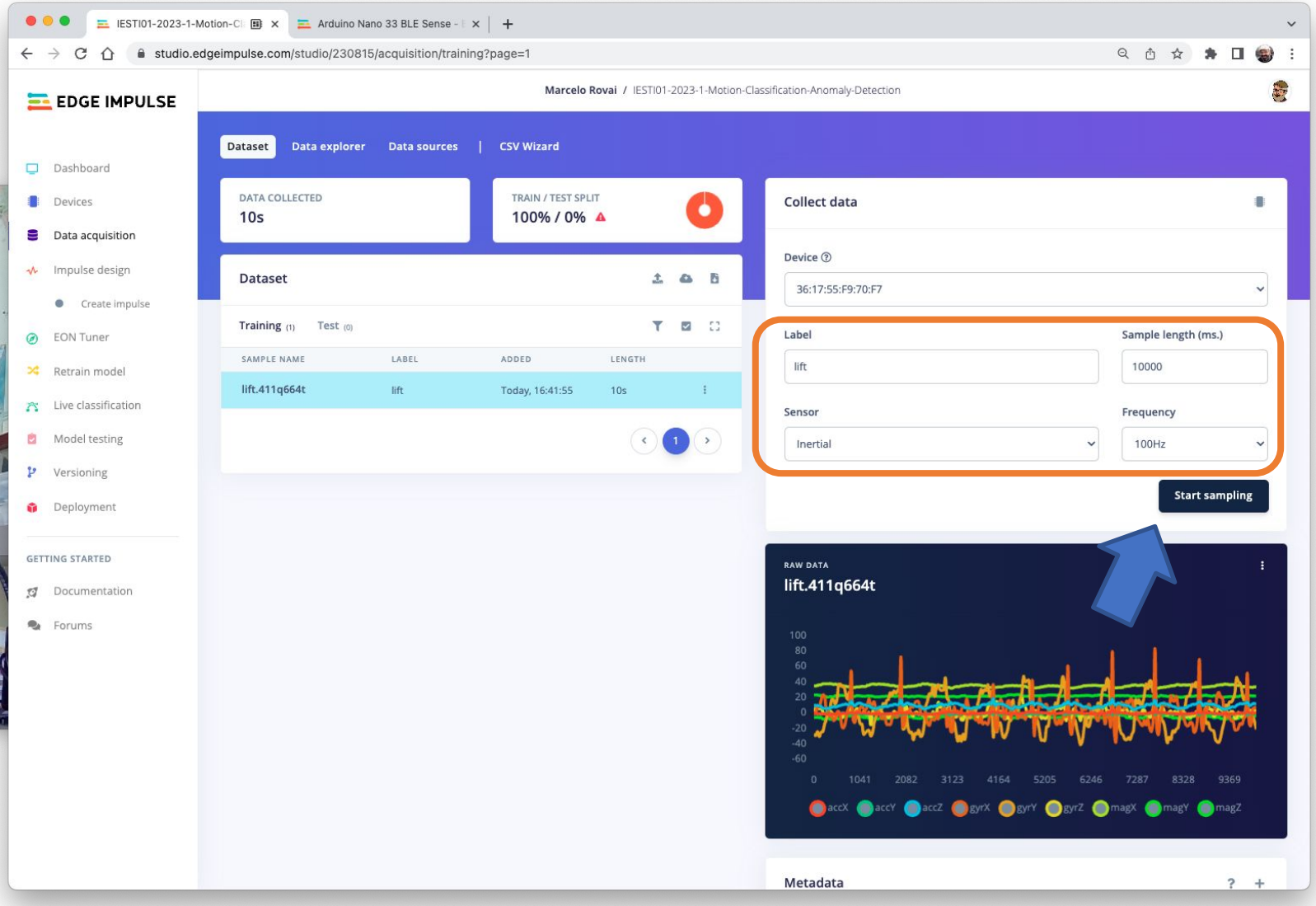
WebUSB works fine with Chrome

Select the sensor that you want to capture data from. For example, to capture accelerometer data, select *Inertial*. Then, enter with a label, for example, *lift,* and the sample length, for example, 10s (*10,000* ms). And Start Sampling. The sampling frequency is automatically captured from the MCU'' code.



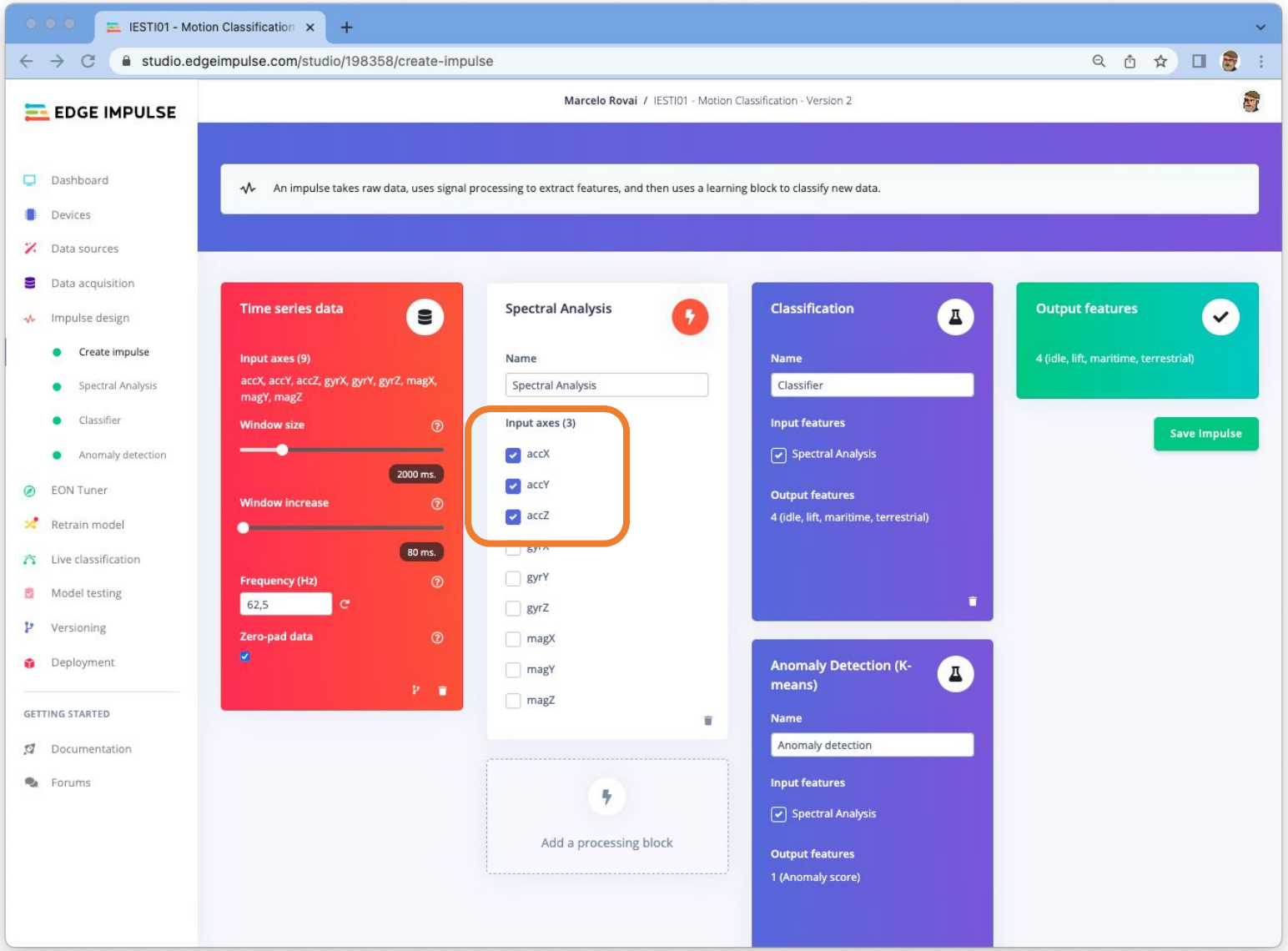
IMU sensor (Inertial)





Accelerometer

Note that on capturing data from the IMU (Inertial Measurement Unit) sensor, now with the Studio, all nine axes will be captured simultaneously (from the accelerometer, gyroscope, and magnetron). Therefore, if you need only the accelerometer data, select it in the Create Impulse section.



Data acquisition - IESTI01

studio.edgeimpulse.com/studio/38744/acquisition/training?page=1

EDGE IMPULSE

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

GETTING STARTED

- Documentation
- Forums

DATA COLLECTED
10s

LABELS
1

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
unifei.29js37tq	unifei	Today, 18:22:34	10s

1

Record new data

Device
36:17:55:F9:70:F7

Label
unifei

Sample length (ms.)
10000

Sensor
Built-in microphone

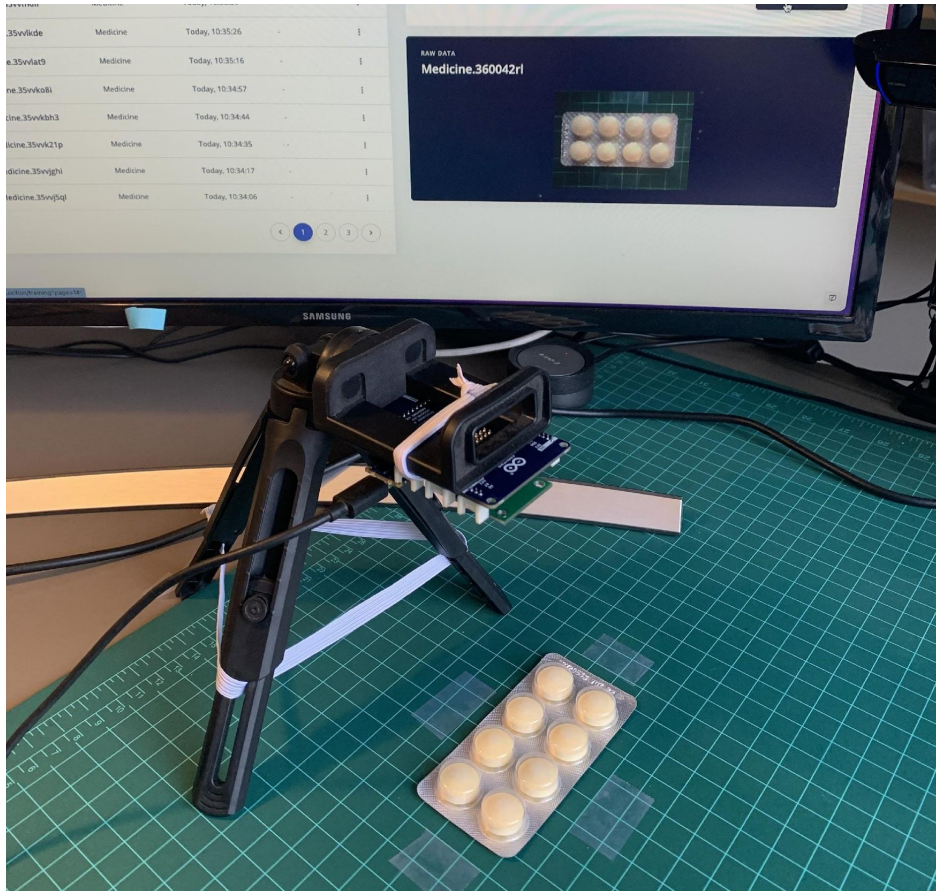
Frequency
16000Hz

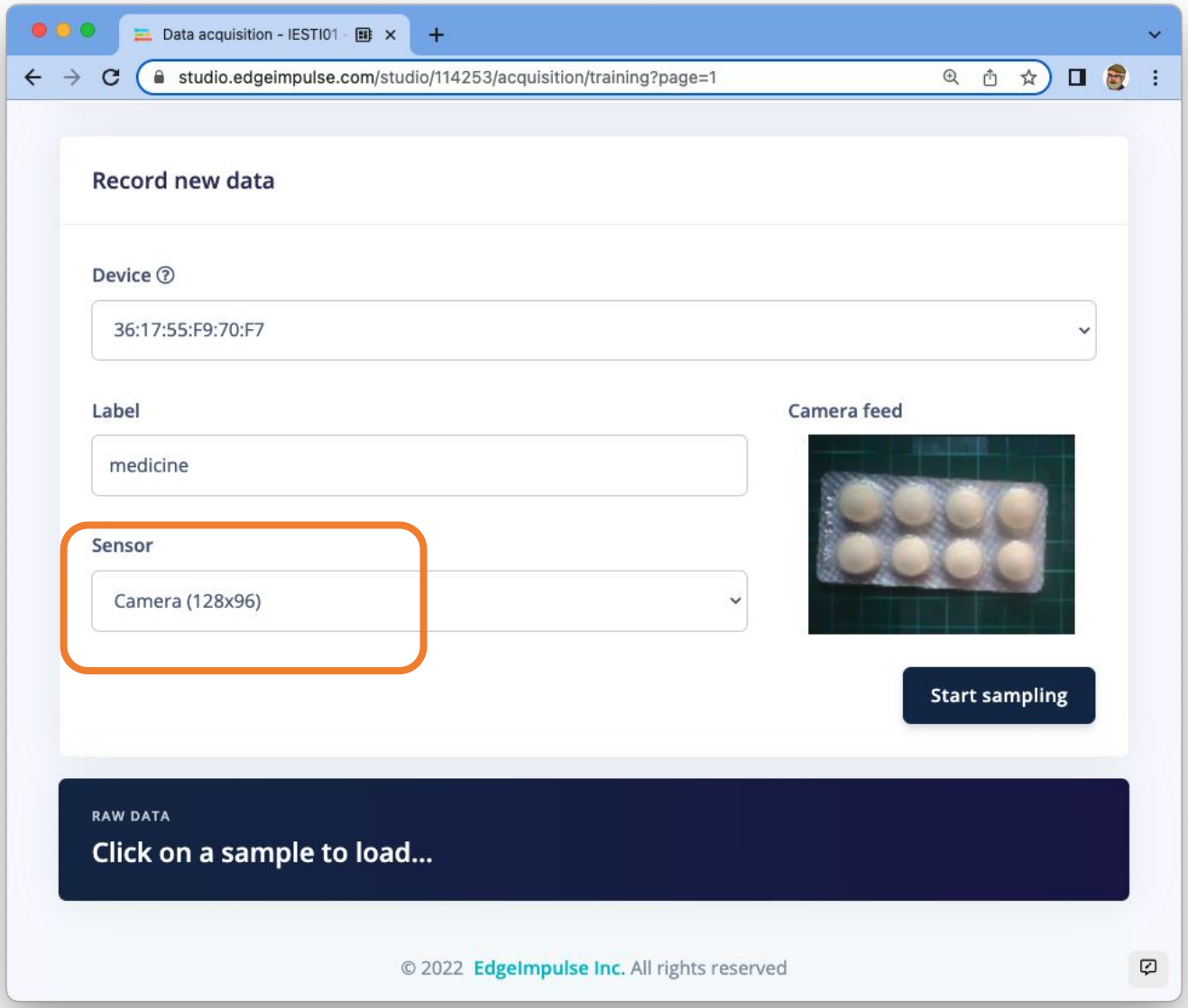
Start sampling

RAW DATA
unifei.29js37tq

0:10 / 0:10

Camera


RAW DATA
Medicine.360042rl
SAMSUNG


Data acquisition - IESTI01
studio.edgeimpulse.com/studio/114253/acquisition/training?page=1
Record new data
Device
36:17:55:F9:70:F7
Label
medicine
Sensor
Camera (128x96)
Camera feed
Start sampling
RAW DATA
Click on a sample to load...
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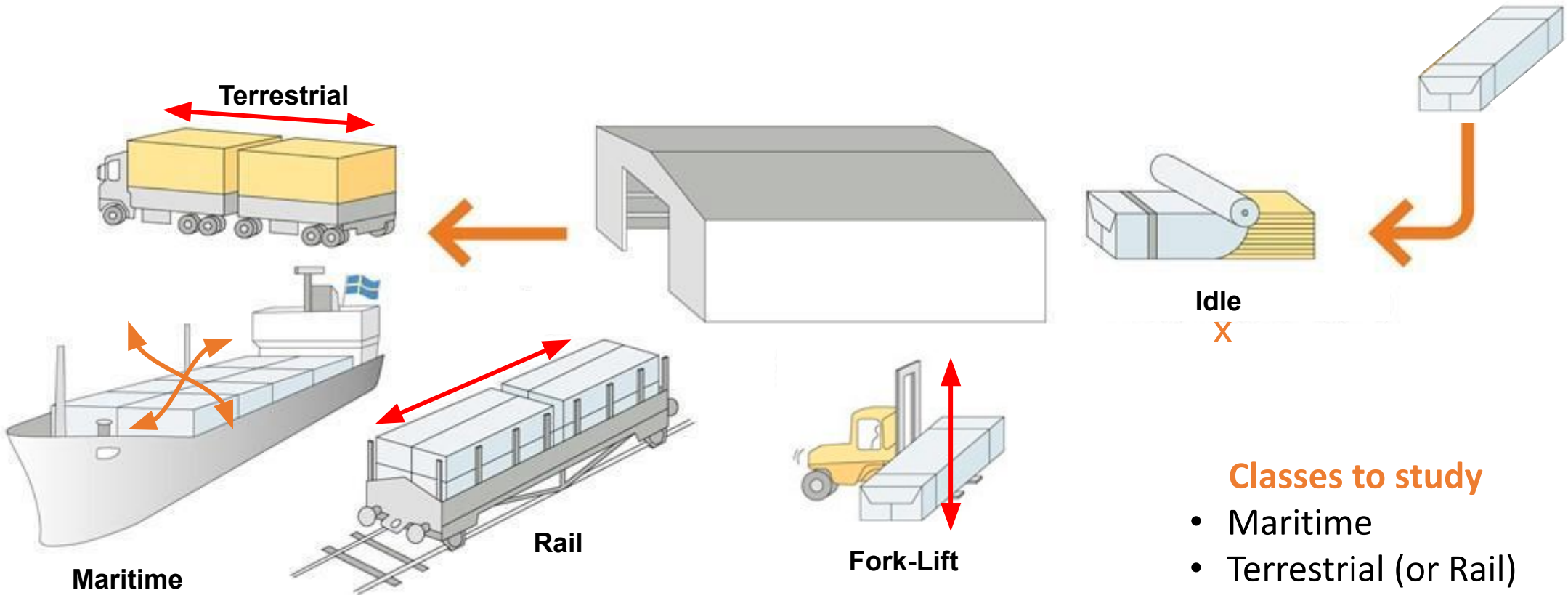
Motion Classification

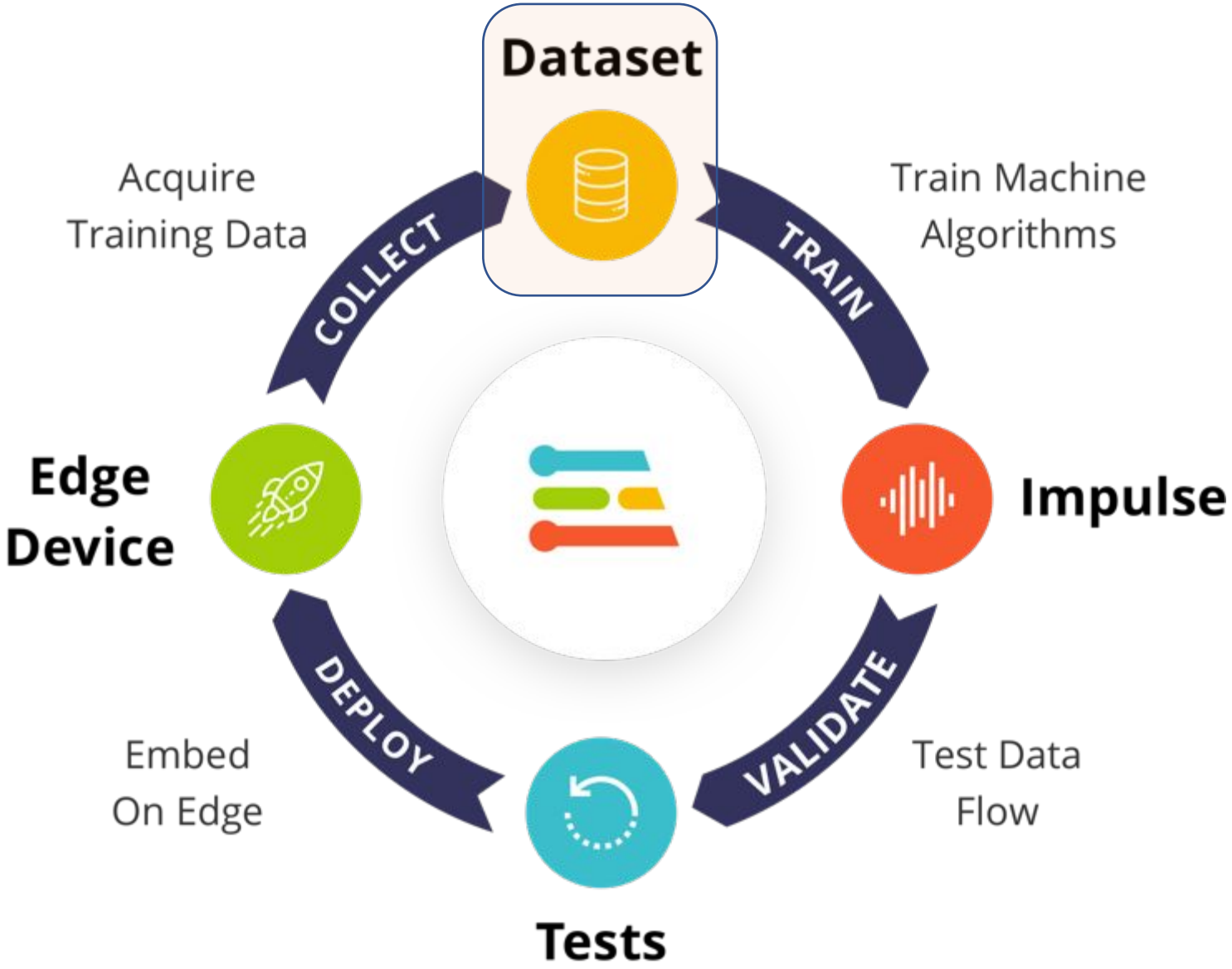
https://studio.edgeimpulse.com/public/230815/latest

Case Study: Mechanical Stresses in Transport

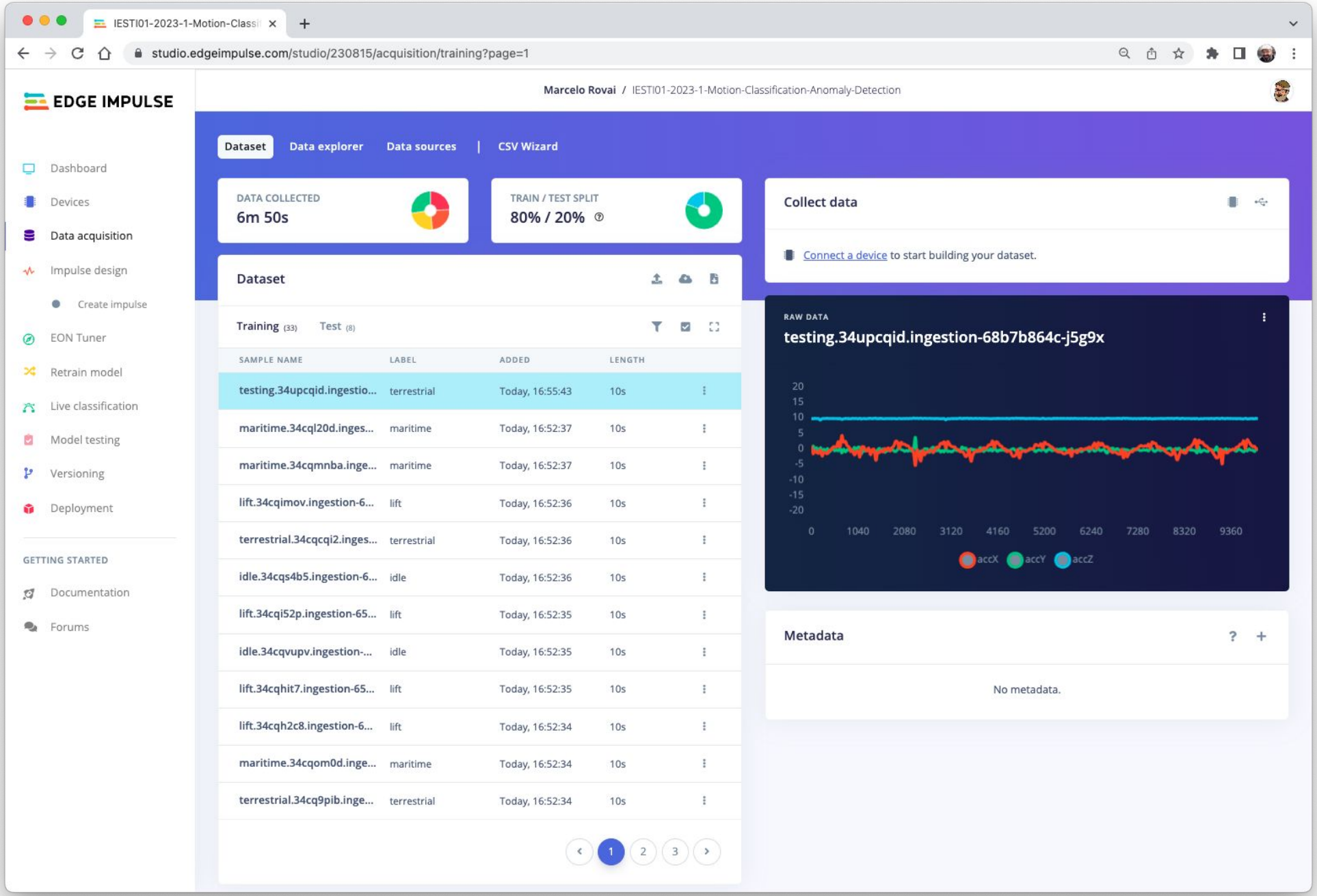


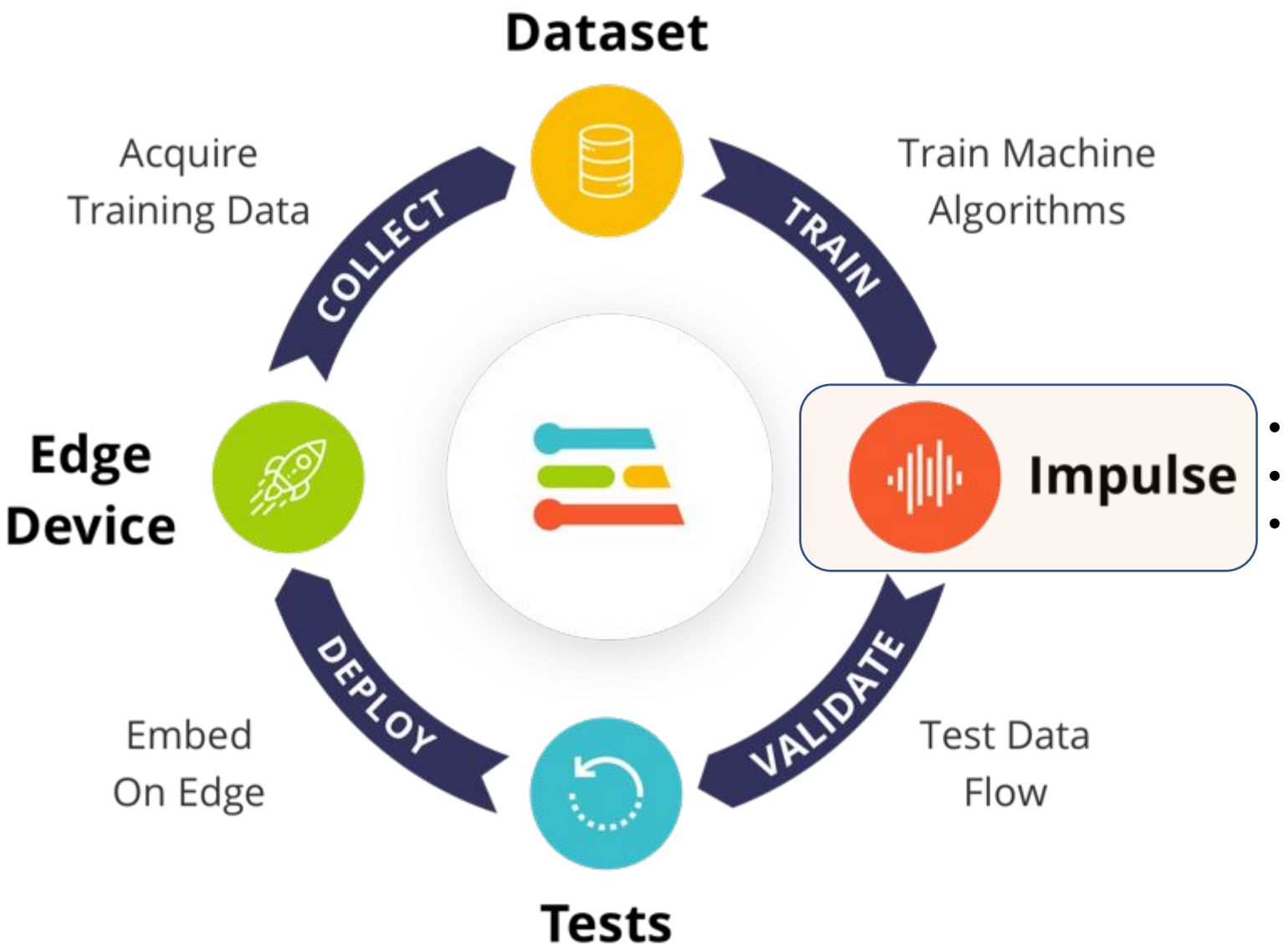
Classes to study

- Maritime
- Terrestrial (or Rail)
- Lift
- Idle

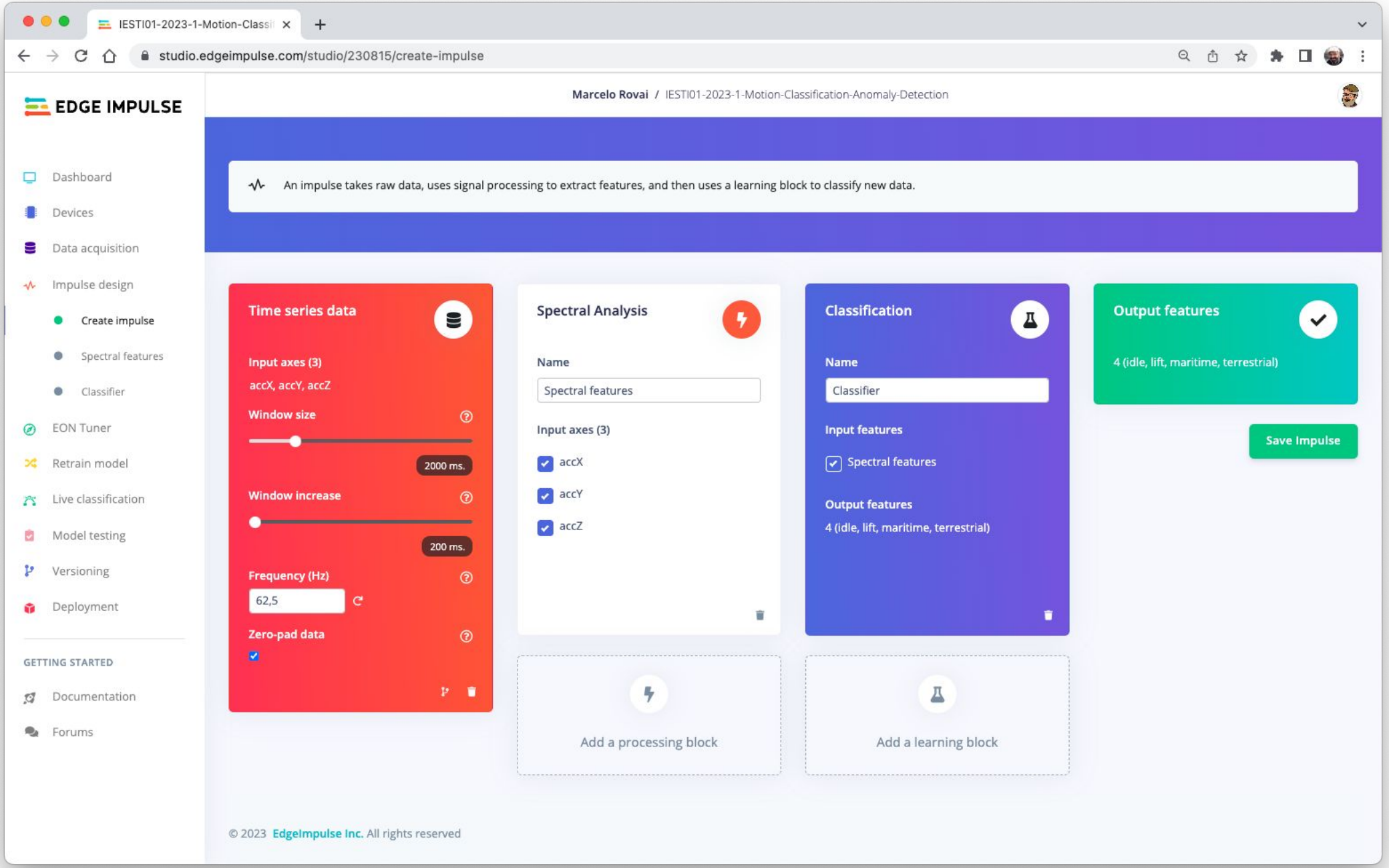


- Pre-Processing Data
- Design a Model
- Train a Model


IESTI01-2023-1-Motion-Classi
studio.edgeimpulse.com/studio/230815/acquisition/training?page=1
EDGE IMPULSE
Marcelo Rovai / IESTI01-2023-1-Motion-Classification-Anomaly-Detection
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
Dataset
Data explorer
Data sources
CSV Wizard
DATA COLLECTED
6m 50s
TRAIN / TEST SPLIT
80% / 20%
Collect data
Connect a device to start building your dataset.
Dataset
Training (33)
Test (8)
SAMPLE NAME
LABEL
ADDED
LENGTH
testing.34upcqid.ingestio... terrestrial Today, 16:55:43 10s
maritime.34cql20d.inges... maritime Today, 16:52:37 10s
maritime.34cqmnba.inge... maritime Today, 16:52:37 10s
lift.34cqimov.ingestion-6... lift Today, 16:52:36 10s
terrestrial.34cqcqi2.inges... terrestrial Today, 16:52:36 10s
idle.34cqs4b5.ingestion-6... idle Today, 16:52:36 10s
lift.34cqi52p.ingestion-65... lift Today, 16:52:35 10s
idle.34cqvupv.ingestion-... idle Today, 16:52:35 10s
lift.34cqhit7.ingestion-65... lift Today, 16:52:35 10s
lift.34cqh2c8.ingestion-6... lift Today, 16:52:34 10s
maritime.34cqom0d.inge... maritime Today, 16:52:34 10s
terrestrial.34cq9pib.inge... terrestrial Today, 16:52:34 10s
1
2
3
RAW DATA
testing.34upcqid.ingestion-68b7b864c-j5g9x
20
15
10
5
0
-5
-10
-15
-20
0
1040
2080
3120
4160
5200
6240
7280
8320
9360
accX
accY
accZ
Metadata
No metadata.



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


IESTI01-2023-1-Motion-Classi
studio.edgeimpulse.com/studio/230815/create-impulse
EDGE IMPULSE
Marcelo Rovai / IESTI01-2023-1-Motion-Classification-Anomaly-Detection
Dashboard
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Spectral features
Classifier
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.
Time series data
Input axes (3)
accX, accY, accZ
Window size
2000 ms.
Window increase
200 ms.
Frequency (Hz)
62,5
Zero-pad data
Spectral Analysis
Name
Spectral features
Input axes (3)
accX
accY
accZ
Classification
Name
Classifier
Input features
Spectral features
Output features
4 (idle, lift, maritime, terrestrial)
Output features
4 (idle, lift, maritime, terrestrial)
Save Impulse
Add a processing block
Add a learning block
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Spectral Analysis

- Spectral Analysis under the hood
- Edge Impulse - Spectral Analysis Block - Open in CoLab

Parameters

Autotune parameters

Filter

Scale axes: 0.0509920331756334

Input decimation ratio: 1

Type: low

Cut-off frequency: 15.625

Order: 6

Analysis

Type: FFT

FFT length: 32

Take log of spectrum? ☑

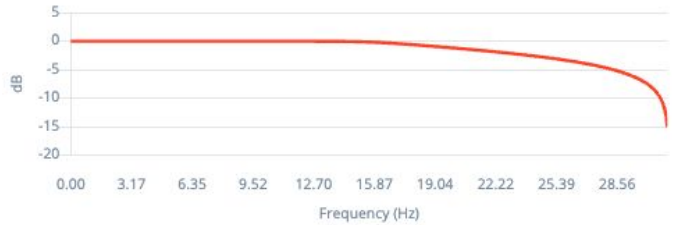
Overlap FFT frames? ☐

Improve low frequency resolution? ☐

Save parameters

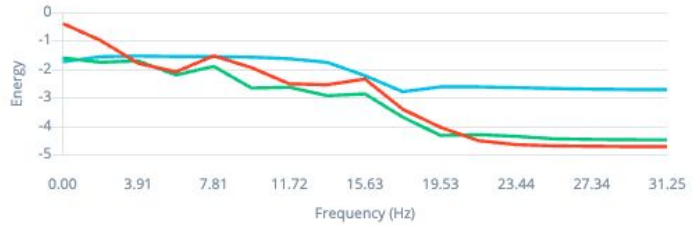
DSP result

Filter response



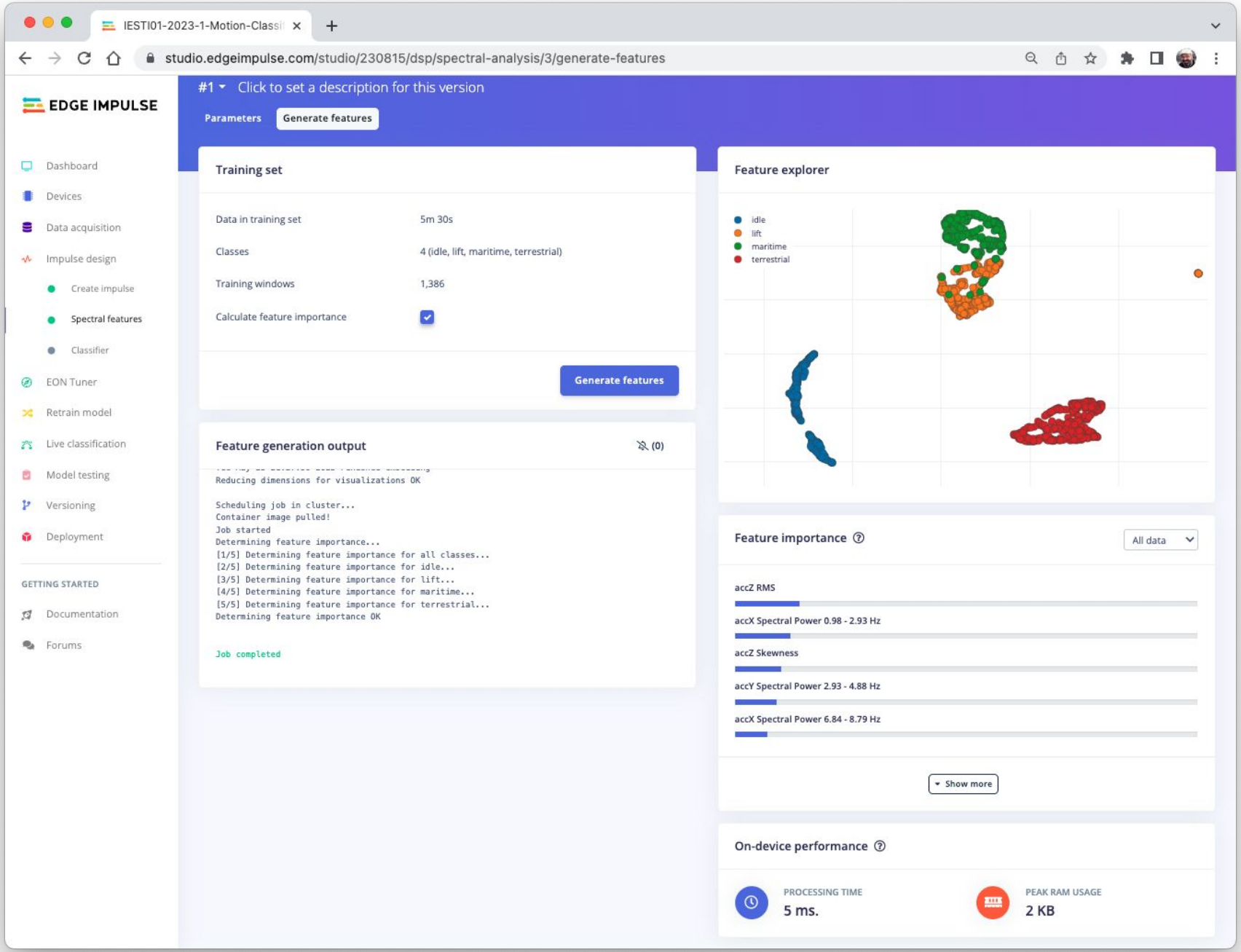
After filter

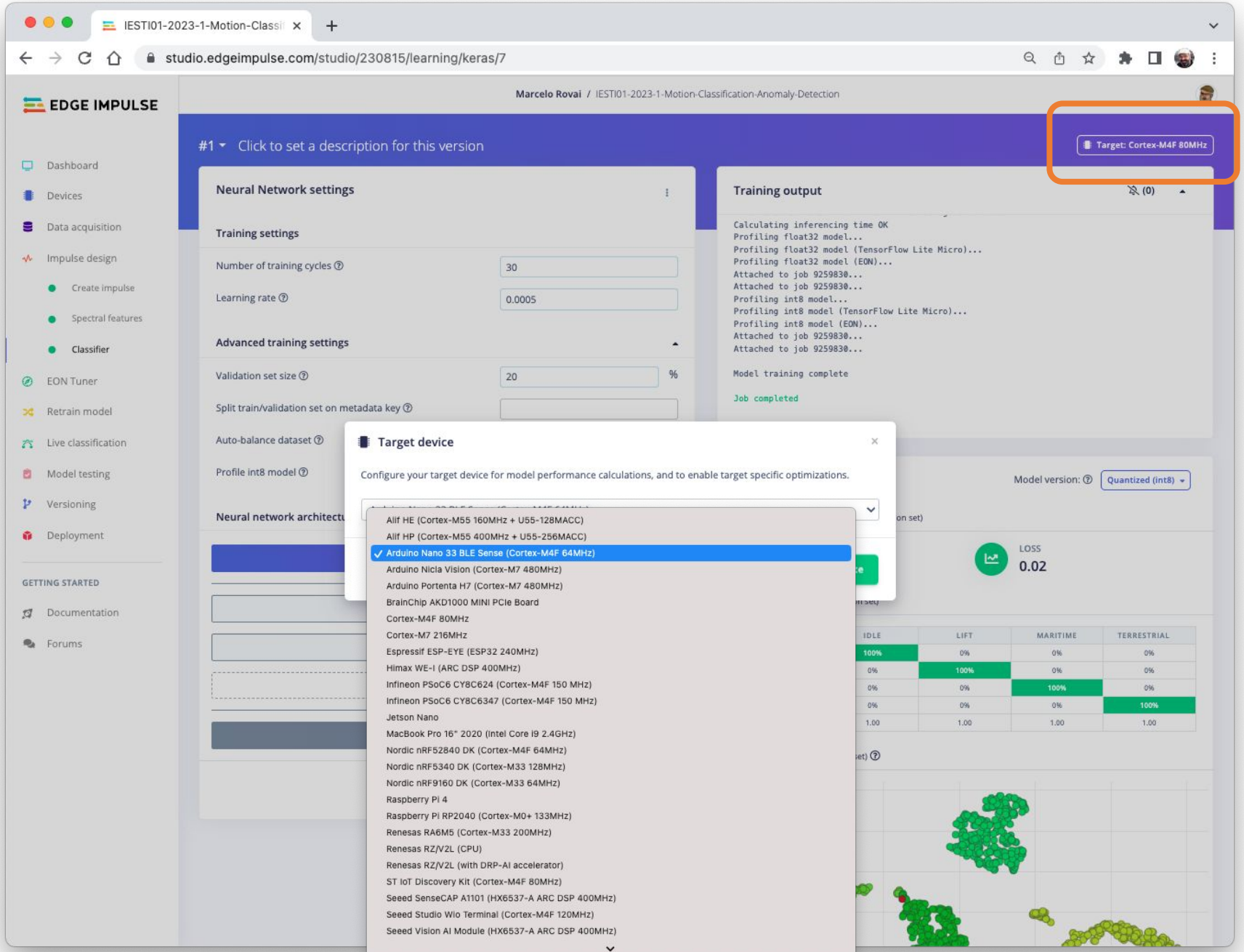
Spectral power (log)



Processed features

```
0.1410, -0.3215, -0.7833, 3.4014, 10.2211, -0.9719, -1.7806, -2.0805, -1.5185, -1.93…
```


IESTI01-2023-1-Motion-Classi
studio.edgeimpulse.com/studio/230815/dsp/spectral-analysis/3/generate-features
EDGE IMPULSE
#1 Click to set a description for this version
Parameters
Generate features
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
Spectral features
Classifier
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
Training set
Data in training set
5m 30s
Classes
4 (idle, lift, maritime, terrestrial)
Training windows
1,386
Calculate feature importance
Generate features
Feature generation output
(0)
Reducing dimensions for visualizations OK
Scheduling job in cluster...
Container image pulled!
Job started
Determining feature importance...
[1/5] Determining feature importance for all classes...
[2/5] Determining feature importance for idle...
[3/5] Determining feature importance for lift...
[4/5] Determining feature importance for maritime...
[5/5] Determining feature importance for terrestrial...
Determining feature importance OK
Job completed
Feature explorer
idle
lift
maritime
terrestrial
Feature importance
All data
accZ RMS
accX Spectral Power 0.98 - 2.93 Hz
accZ Skewness
accY Spectral Power 2.93 - 4.88 Hz
accX Spectral Power 6.84 - 8.79 Hz
Show more
On-device performance
PROCESSING TIME
5 ms.
PEAK RAM USAGE
2 KB


IESTI01-2023-1-Motion-Classi
studio.edgeimpulse.com/studio/230815/learning/keras/7
EDGE IMPULSE
Marcelo Rovai / IESTI01-2023-1-Motion-Classification-Anomaly-Detection
#1 Click to set a description for this version
Target: Cortex-M4F 80MHz
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
Spectral features
Classifier
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
Neural Network settings
Training settings
Number of training cycles
30
Learning rate
0.0005
Advanced training settings
Validation set size
20
%
Split train/validation set on metadata key
Auto-balance dataset
Profile int8 model
Training output
Calculating inferencing time OK
Profiling float32 model...
Profiling float32 model (TensorFlow Lite Micro)...
Profiling float32 model (EON)...
Attached to job 9259830...
Attached to job 9259830...
Profiling int8 model...
Profiling int8 model (TensorFlow Lite Micro)...
Profiling int8 model (EON)...
Attached to job 9259830...
Attached to job 9259830...
Model training complete
Job completed
Target device
Configure your target device for model performance calculations, and to enable target specific optimizations.
Alif HE (Cortex-M55 160MHz + U55-128MACC)
Alif HP (Cortex-M55 400MHz + U55-256MACC)
Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz)
Arduino Nicla Vision (Cortex-M7 480MHz)
Arduino Portenta H7 (Cortex-M7 480MHz)
BrainChip AKD1000 MINI PCIe Board
Cortex-M4F 80MHz
Cortex-M7 216MHz
Espressif ESP-EYE (ESP32 240MHz)
Himax WE-I (ARC DSP 400MHz)
Infineon PSoC6 CY8C624 (Cortex-M4F 150 MHz)
Infineon PSoC6 CY8C6347 (Cortex-M4F 150 MHz)
Jetson Nano
MacBook Pro 16" 2020 (Intel Core i9 2.4GHz)
Nordic nRF52840 DK (Cortex-M4F 64MHz)
Nordic nRF5340 DK (Cortex-M33 128MHz)
Nordic nRF9160 DK (Cortex-M33 64MHz)
Raspberry Pi 4
Raspberry Pi RP2040 (Cortex-M0+ 133MHz)
Renesas RA6M5 (Cortex-M33 200MHz)
Renesas RZ/V2L (CPU)
Renesas RZ/V2L (with DRP-AI accelerator)
ST IoT Discovery Kit (Cortex-M4F 80MHz)
Seeed SenseCAP A1101 (HX6537-A ARC DSP 400MHz)
Seeed Studio Wio Terminal (Cortex-M4F 120MHz)
Seeed Vision AI Module (HX6537-A ARC DSP 400MHz)
Model version:
Quantized (int8)
LOSS
0.02
IDLE
LIFT
MARITIME
TERRESTRIAL

Neural Network settings

Training settings

Number of training cycles: 30

Learning rate: 0.0005

Advanced training settings

Validation set size: 20 %

Split train/validation set on metadata key:

Auto-balance dataset: ☐

Profile int8 model: ☑

Neural network architecture

Input layer (39 features)

Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (4 classes)

Start training

Model

Model version: Quantized (int8)

Last training performance (validation set)

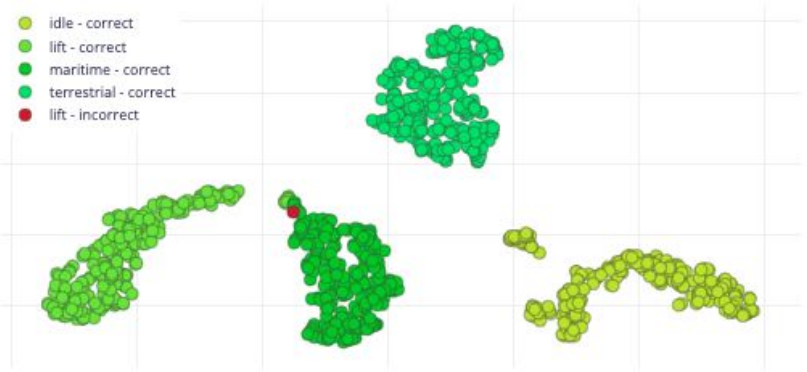
ACCURACY
100.0%

LOSS
0.02

Confusion matrix (validation set)

	IDLE	LIFT	MARITIME	TERRESTRIAL
IDLE	100%	0%	0%	0%
LIFT	0%	100%	0%	0%
MARITIME	0%	0%	100%	0%
TERRESTRIAL	0%	0%	0%	100%
F1 SCORE	1.00	1.00	1.00	1.00

Data explorer (full training set)

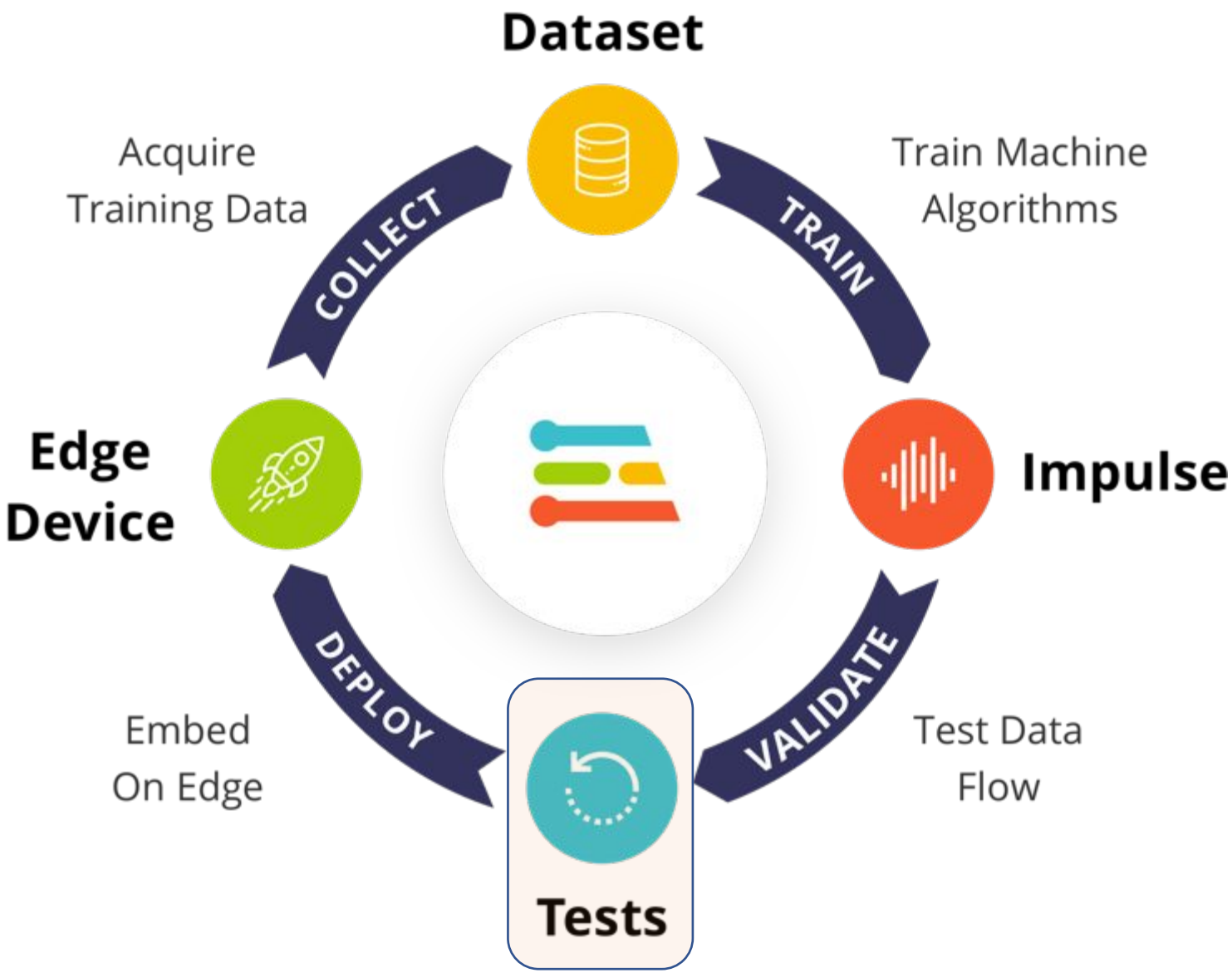


On-device performance

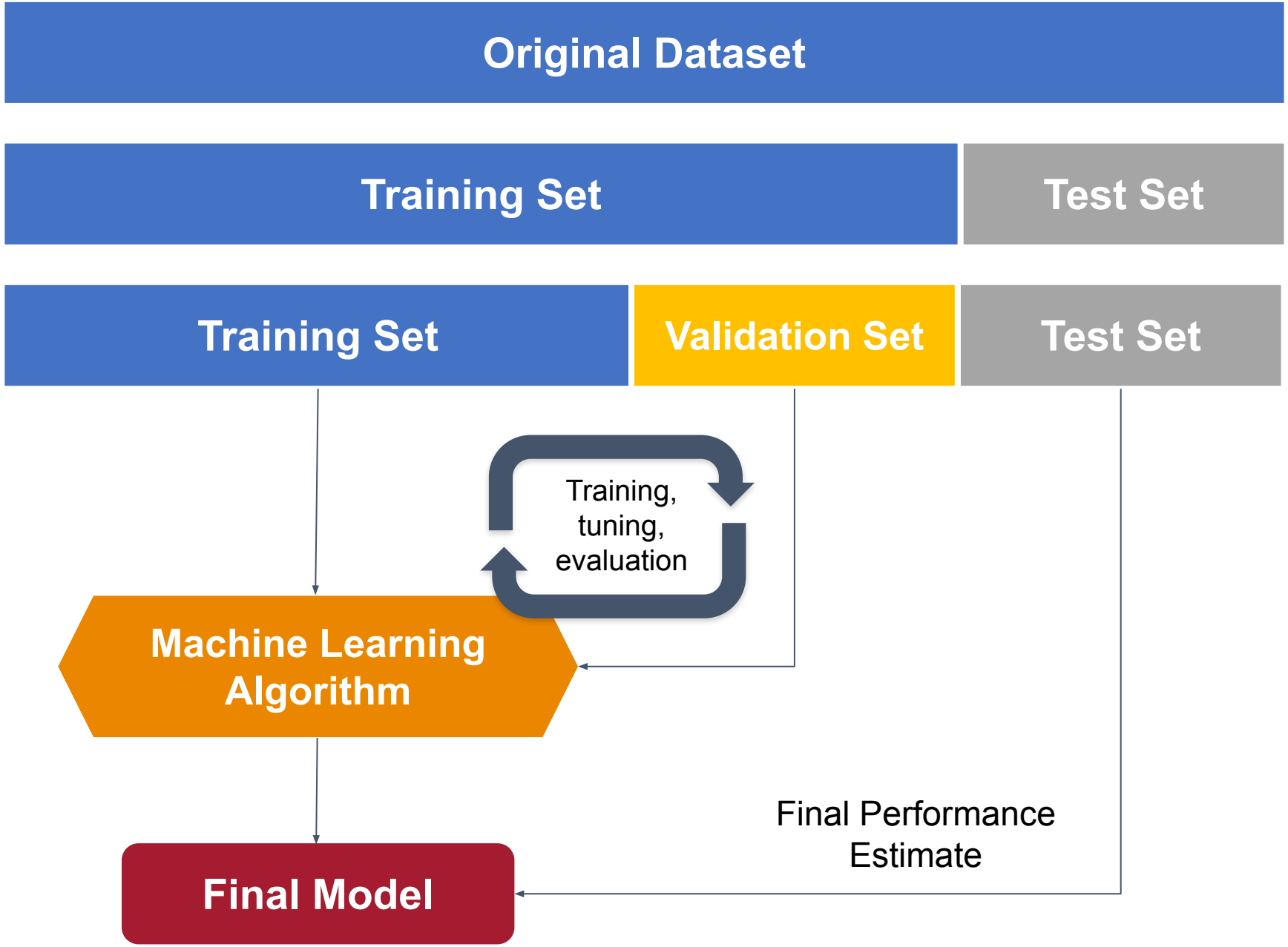
INFERENCING TIME
1 ms.

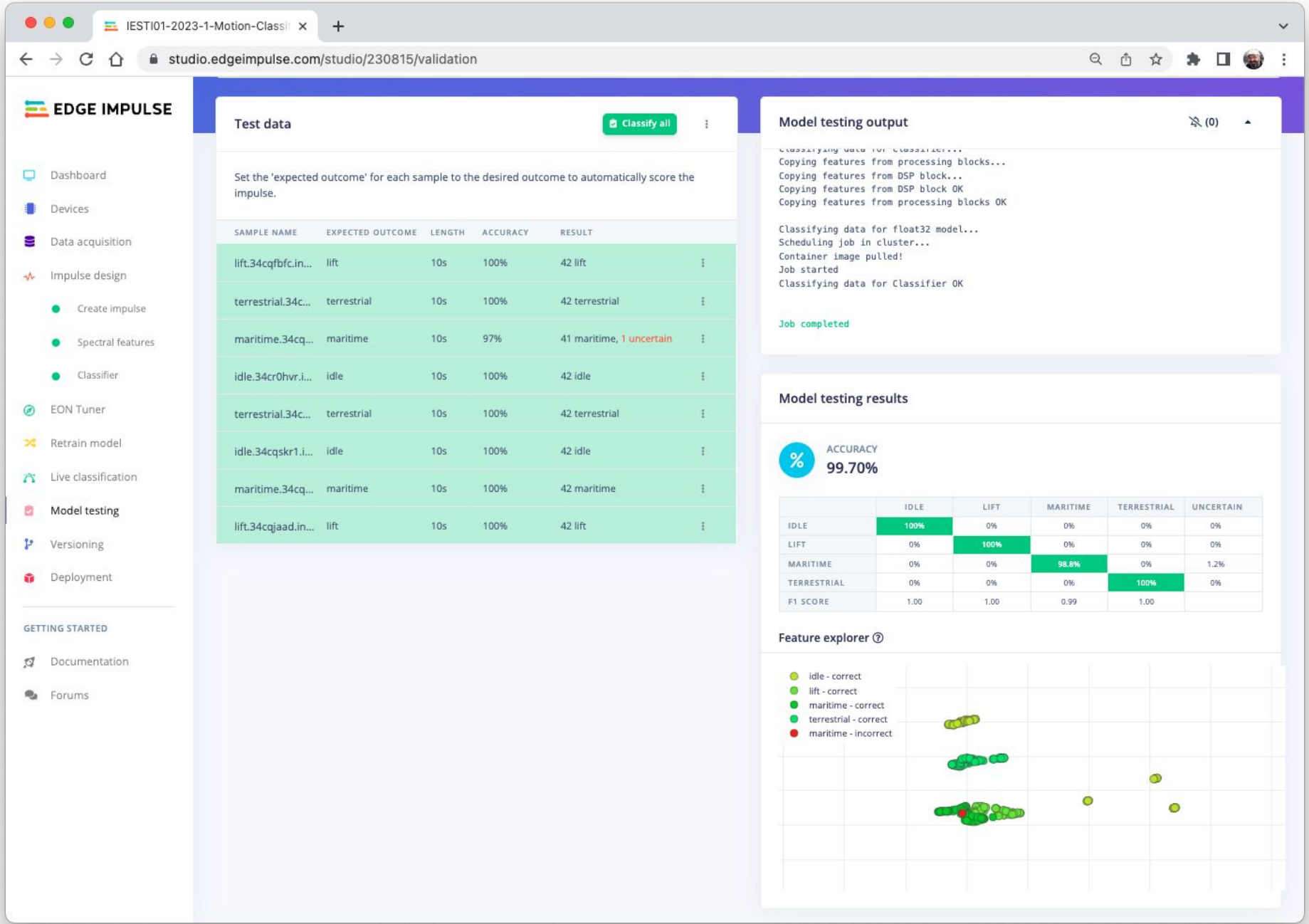
PEAK RAM USAGE
1.3K

FLASH USAGE
14.8K



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


Original Dataset
Training Set
Test Set
Training Set
Validation Set
Test Set
Training,
tuning,
evaluation
Machine Learning
Algorithm
Final Performance
Estimate
Final Model


IESTI01-2023-1-Motion-Classi
studio.edgeimpulse.com/studio/230815/validation
EDGE IMPULSE
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
Spectral features
Classifier
EON Tuner
Retrain model
Live classification
Model testing
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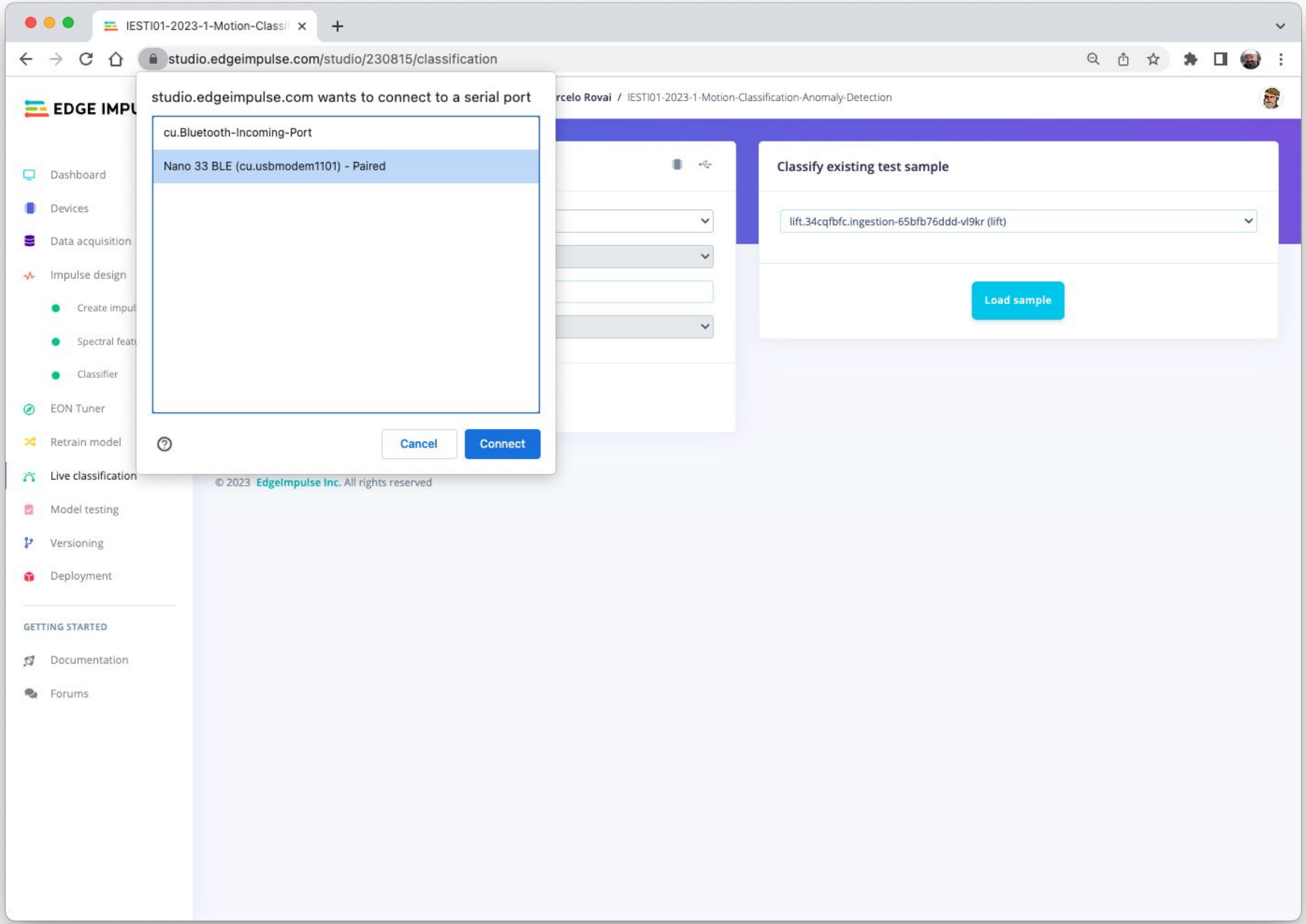
Deployment
GETTING STARTED
Documentation
Forums
Test data
Classify all
Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse.
SAMPLE NAME
EXPECTED OUTCOME
LENGTH
ACCURACY
RESULT
lift.34cqfbfc.in... lift 10s 100% 42 lift
terrestrial.34c... terrestrial 10s 100% 42 terrestrial
maritime.34cq... maritime 10s 97% 41 maritime, 1 uncertain
idle.34cr0hvr.i... idle 10s 100% 42 idle
terrestrial.34c... terrestrial 10s 100% 42 terrestrial
idle.34cqskr1.i... idle 10s 100% 42 idle
maritime.34cq... maritime 10s 100% 42 maritime
lift.34cqjaad.in... lift 10s 100% 42 lift
Model testing output
(0)
Copying features from processing blocks...
Copying features from DSP block...
Copying features from DSP block OK
Copying features from processing blocks OK
Classifying data for float32 model...
Scheduling job in cluster...
Container image pulled!
Job started
Classifying data for Classifier OK
Job completed
Model testing results
ACCURACY
99.70%
IDLE LIFT MARITIME TERRESTRIAL UNCERTAIN
IDLE 100% 0% 0% 0% 0%
LIFT 0% 100% 0% 0% 0%
MARITIME 0% 0% 98.8% 0% 1.2%
TERRESTRIAL 0% 0% 0% 100% 0%
F1 SCORE 1.00 1.00 0.99 1.00
Feature explorer
idle - correct
lift - correct
maritime - correct
terrestrial - correct
maritime - incorrect


IESTI01-2023-1-Motion-Classif
studio.edgeimpulse.com/studio/230815/classification
studio.edgeimpulse.com wants to connect to a serial port
cu.Bluetooth-Incoming-Port
Nano 33 BLE (cu.usbmodem1101) - Paired
Cancel
Connect
rcelo Rovai / IESTI01-2023-1-Motion-Classification-Anomaly-Detection
Classify existing test sample
lift.34cqfbfc.ingestion-65bfb76ddd-vl9kr (lift)
Load sample
Dashboard
Devices
Data acquisition
Impulse design
Create impul
Spectral feat
Classifier
EON Tuner
Retrain model
Live classification
Model testing
Versioning
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GETTING STARTED
Documentation
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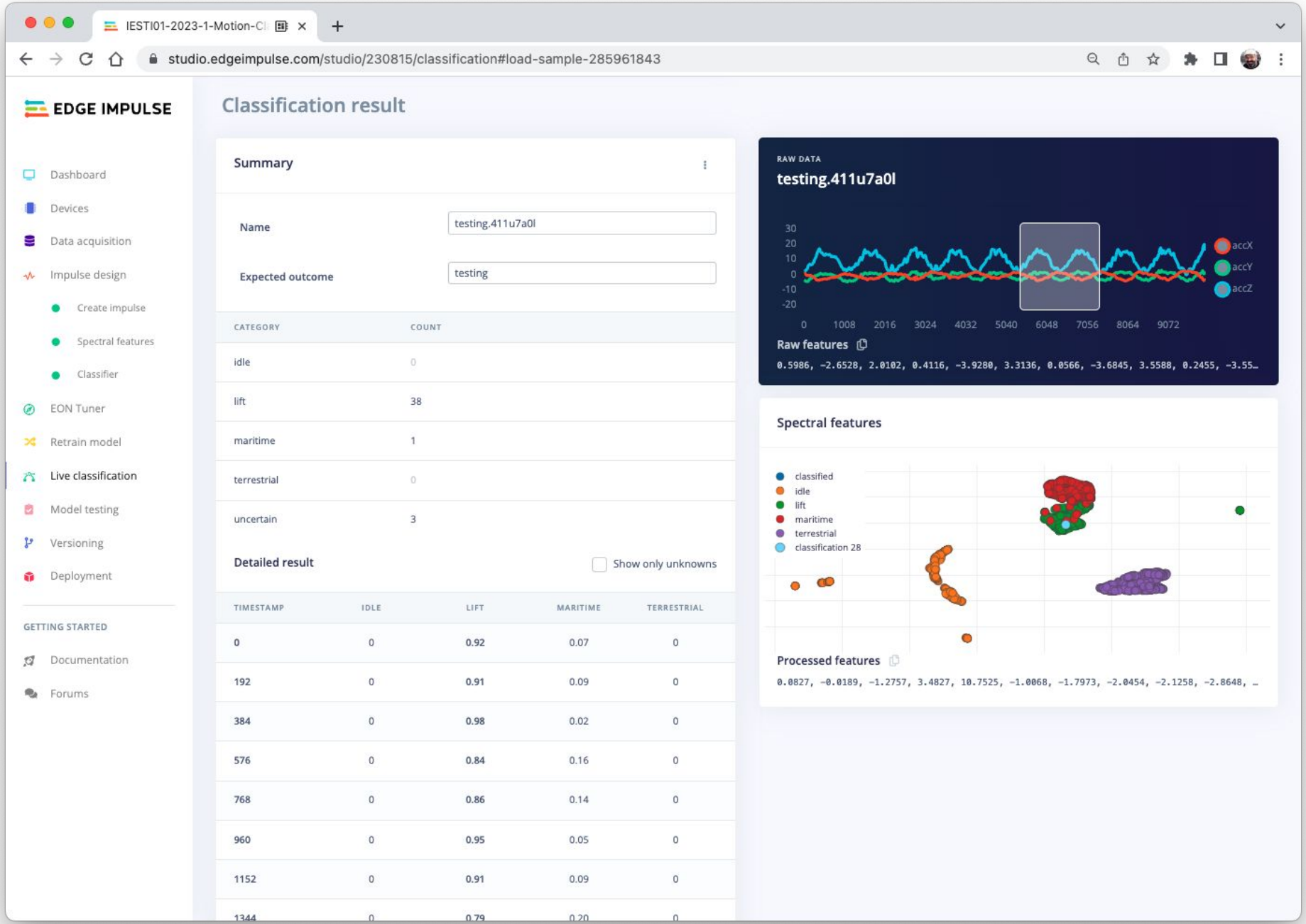
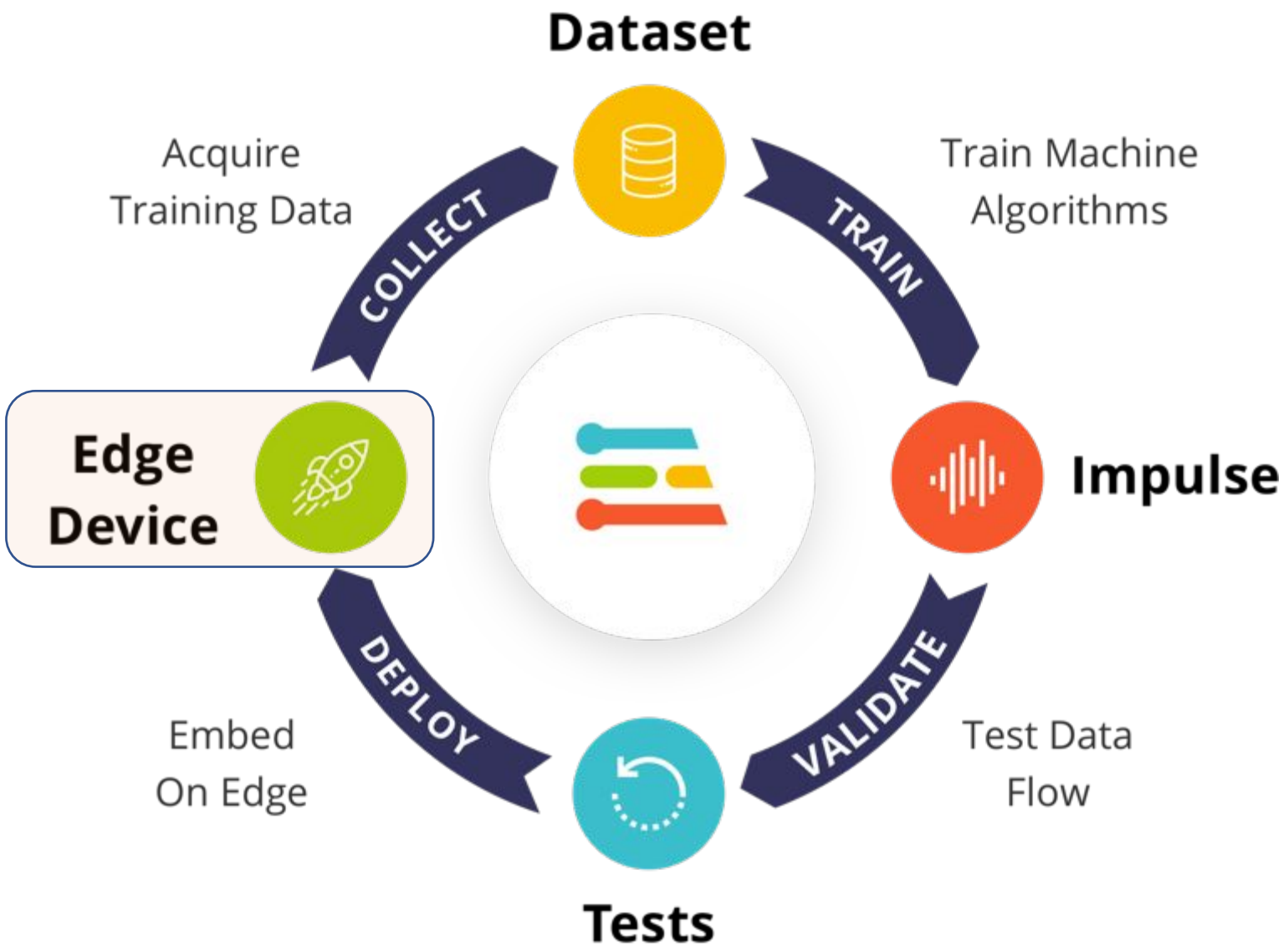
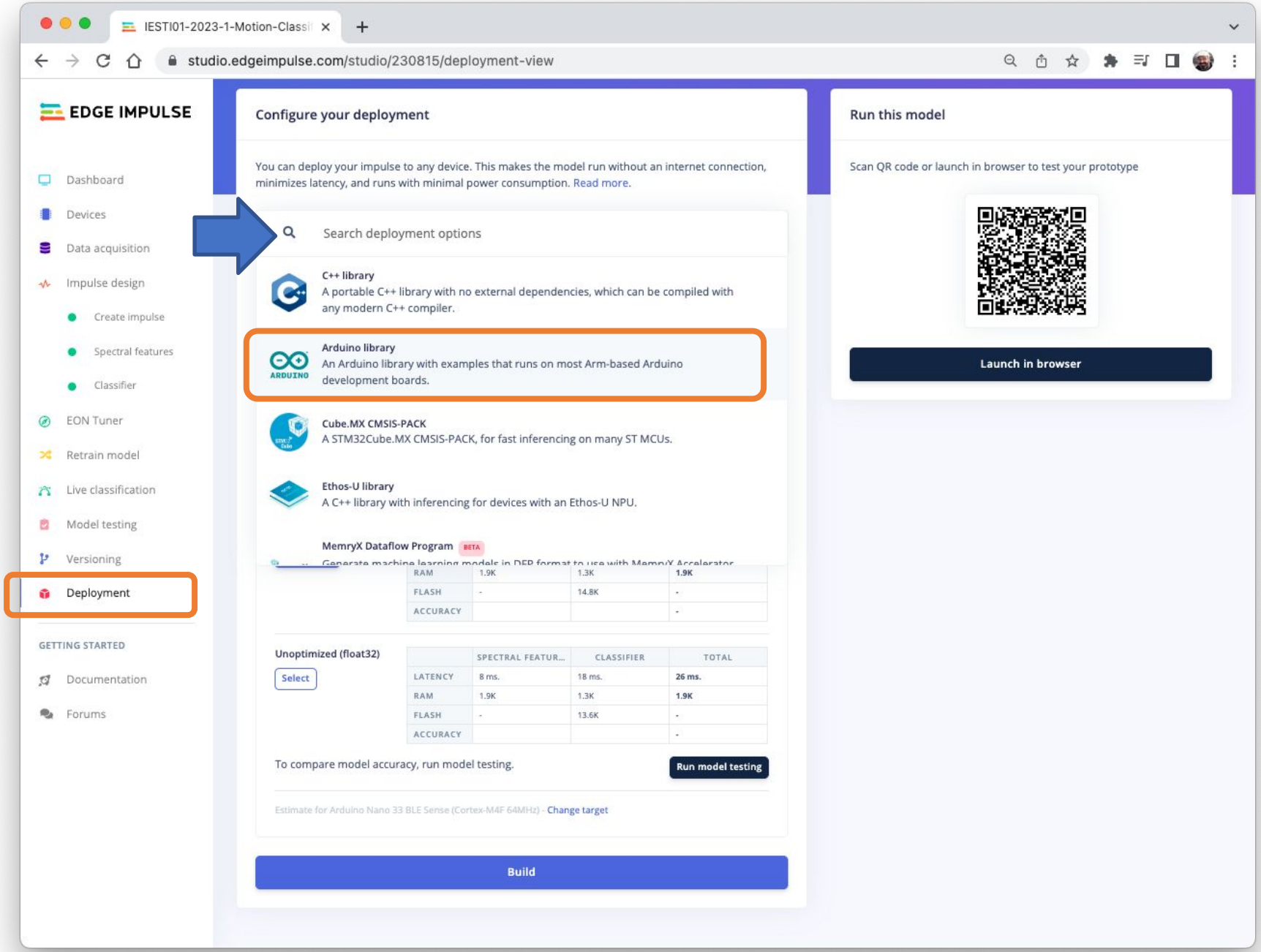

IESTI01-2023-1-Motion-Cl
studio.edgeimpulse.com/studio/230815/classification#load-sample-285961843
EDGE IMPULSE
Dashboard
Devices
Data acquisition
Impulse design
Create impulse
Spectral features
Classifier
EON Tuner
Retrain model
Live classification
Model testing
Versioning
Deployment
GETTING STARTED
Documentation
Forums
Classification result
Summary
Name
testing.411u7a0l
Expected outcome
testing
CATEGORY
COUNT
idle 0
lift 38
maritime 1
terrestrial 0
uncertain 3
Detailed result
Show only unknowns
TIMESTAMP IDLE LIFT MARITIME TERRESTRIAL
0 0 0.92 0.07 0
192 0 0.91 0.09 0
384 0 0.98 0.02 0
576 0 0.84 0.16 0
768 0 0.86 0.14 0
960 0 0.95 0.05 0
1152 0 0.91 0.09 0
1344 0 0.79 0.20 0
RAW DATA
testing.411u7a0l
30 20 10 0 -10 -20
0 1008 2016 3024 4032 5040 6048 7056 8064 9072
accX
accY
accZ
Raw features
0.5986, -2.6528, 2.0102, 0.4116, -3.9280, 3.3136, 0.0566, -3.6845, 3.5588, 0.2455, -3.55…
Spectral features
classified
idle
lift
maritime
terrestrial
classification 28
Processed features
0.0827, -0.0189, -1.2757, 3.4827, 10.7525, -1.0068, -1.7973, -2.0454, -2.1258, -2.8648, …



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


IESTI01-2023-1-Motion-Classif
studio.edgeimpulse.com/studio/230815/deployment-view
EDGE IMPULSE
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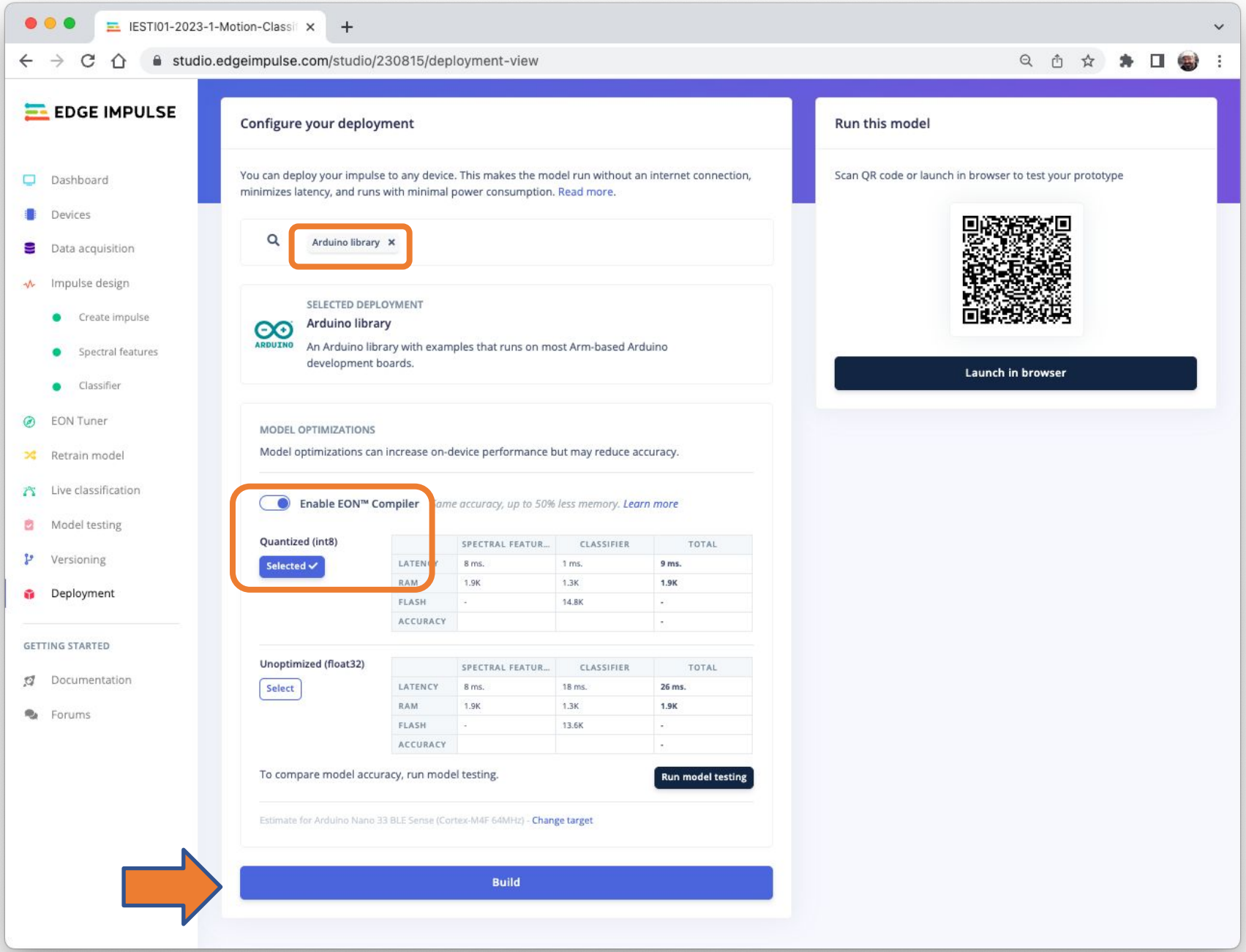
Configure your deployment
You can deploy your impulse to any device. This makes the model run without an internet connection, minimizes latency, and runs with minimal power consumption. Read more.
Search deployment options
C++ library
A portable C++ library with no external dependencies, which can be compiled with any modern C++ compiler.
Arduino library
An Arduino library with examples that runs on most Arm-based Arduino development boards.
Cube.MX CMSIS-PACK
A STM32Cube.MX CMSIS-PACK, for fast inferencing on many ST MCUs.
Ethos-U library
A C++ library with inferencing for devices with an Ethos-U NPU.
MemryX Dataflow Program
BETA
RAM 1.9K 1.3K 1.9K
FLASH - 14.8K -
ACCURACY -
Unoptimized (float32)
Select
SPECTRAL FEATUR... CLASSIFIER TOTAL
LATENCY 8 ms. 18 ms. 26 ms.
RAM 1.9K 1.3K 1.9K
FLASH - 13.6K -
ACCURACY -
To compare model accuracy, run model testing.
Run model testing
Estimate for Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz) - Change target
Build
Run this model
Scan QR code or launch in browser to test your prototype
Launch in browser


IESTI01-2023-1-Motion-Classif
studio.edgeimpulse.com/studio/230815/deployment-view
EDGE IMPULSE
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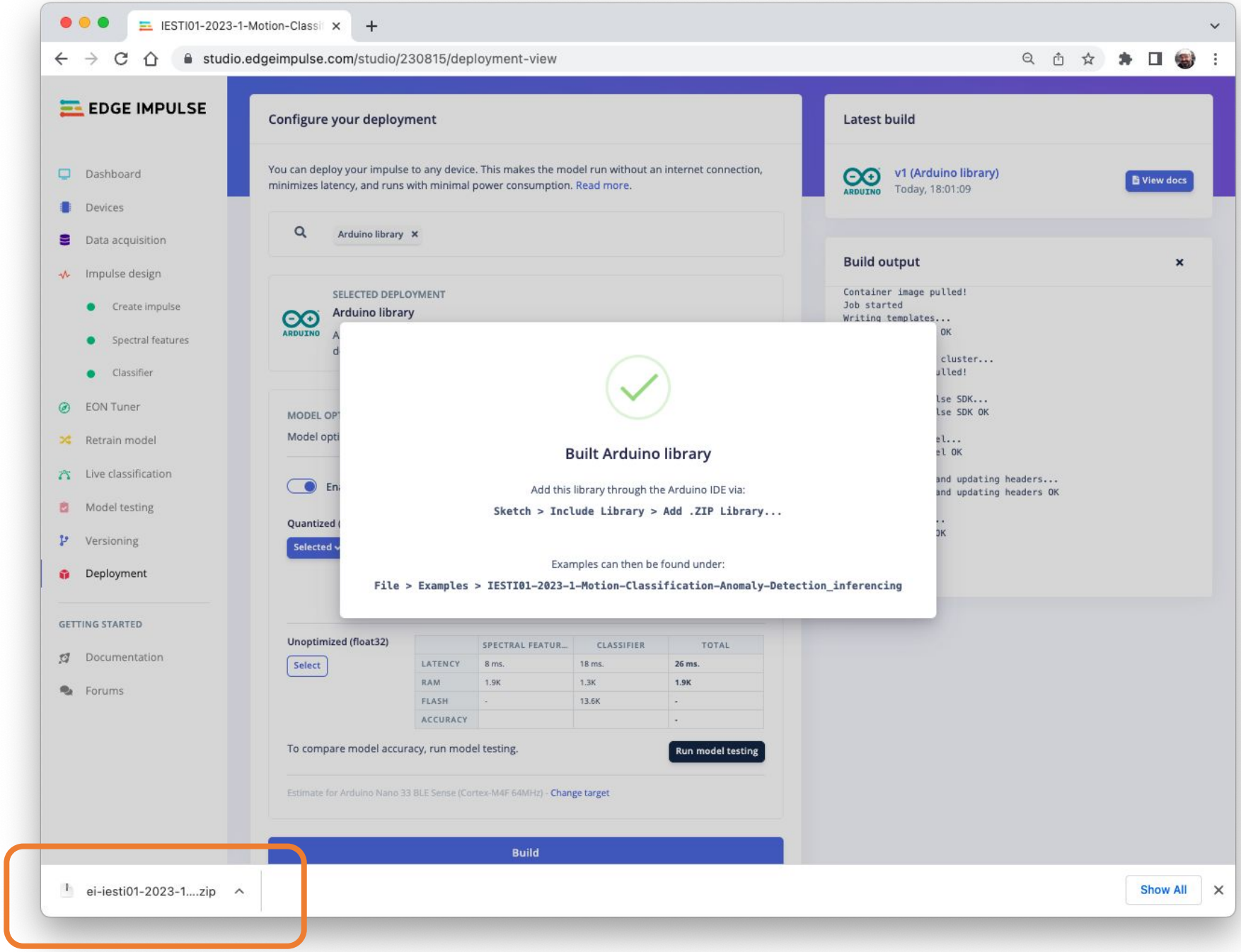
Forums
Configure your deployment
You can deploy your impulse to any device. This makes the model run without an internet connection, minimizes latency, and runs with minimal power consumption. Read more.
Arduino library
SELECTED DEPLOYMENT
Arduino library
An Arduino library with examples that runs on most Arm-based Arduino development boards.
MODEL OPTIMIZATIONS
Model optimizations can increase on-device performance but may reduce accuracy.
Enable EON™ Compiler
same accuracy, up to 50% less memory. Learn more
Quantized (int8)
Selected
SPECTRAL FEATUR... CLASSIFIER TOTAL
LATENCY 8 ms. 1 ms. 9 ms.
RAM 1.9K 1.3K 1.9K
FLASH - 14.8K -
ACCURACY -
Unoptimized (float32)
Select
SPECTRAL FEATUR... CLASSIFIER TOTAL
LATENCY 8 ms. 18 ms. 26 ms.
RAM 1.9K 1.3K 1.9K
FLASH - 13.6K -
ACCURACY -
To compare model accuracy, run model testing.
Run model testing
Estimate for Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz) - Change target
Build
Run this model
Scan QR code or launch in browser to test your prototype
Launch in browser


IESTI01-2023-1-Motion-Classif
studio.edgeimpulse.com/studio/230815/deployment-view
EDGE IMPULSE
Dashboard
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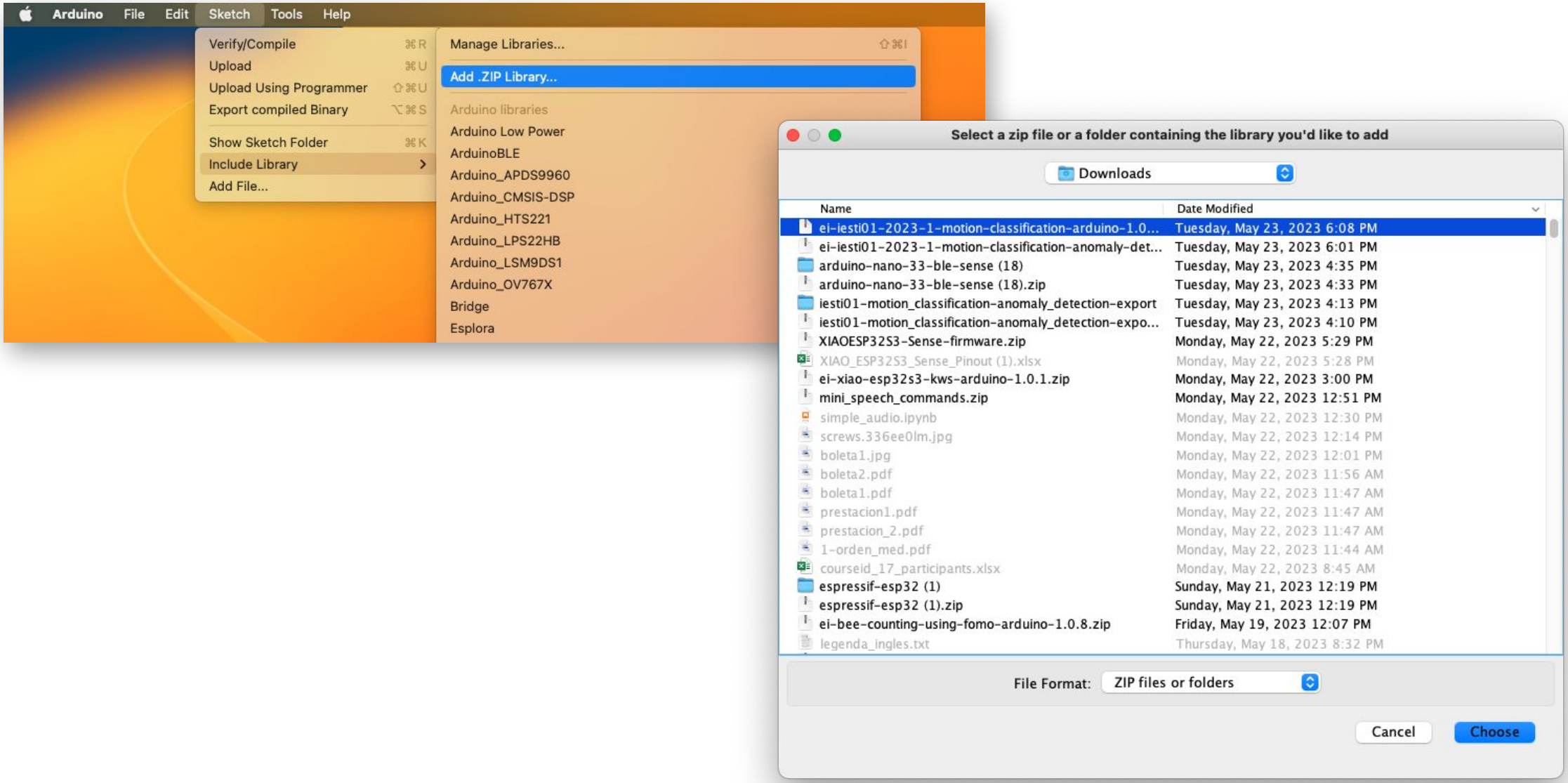
Configure your deployment
You can deploy your impulse to any device. This makes the model run without an internet connection, minimizes latency, and runs with minimal power consumption. Read more.
Arduino library
SELECTED DEPLOYMENT
Arduino library
Quantized
Selected
Unoptimized (float32)
Select
SPECTRAL FEATUR...
CLASSIFIER
TOTAL
LATENCY
8 ms.
18 ms.
26 ms.
RAM
1.9K
1.3K
1.9K
FLASH
13.6K
ACCURACY
To compare model accuracy, run model testing.
Run model testing
Estimate for Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz) - Change target
Build
Latest build
v1 (Arduino library)
Today, 18:01:09
View docs
Build output
Container image pulled!
Job started
Writing templates...
OK
Built Arduino library
Add this library through the Arduino IDE via:
Sketch > Include Library > Add .ZIP Library...
Examples can then be found under:
File > Examples > IESTI01-2023-1-Motion-Classification-Anomaly-Detection_inferencing
ei-iesti01-2023-1....zip
Show All


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_CMSIS-DSP
Arduino_HTS221
Arduino_LPS22HB
Arduino_LSM9DS1
Arduino_OV767X
Bridge
Esplora
Select a zip file or a folder containing the library you'd like to add
Downloads
Name
Date Modified
ei-iesti01-2023-1-motion-classification-arduino-1.0... Tuesday, May 23, 2023 6:08 PM
ei-iesti01-2023-1-motion-classification-anomaly-det... Tuesday, May 23, 2023 6:01 PM
arduino-nano-33-ble-sense (18) Tuesday, May 23, 2023 4:35 PM
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iesti01-motion_classification-anomaly_detection-export Tuesday, May 23, 2023 4:13 PM
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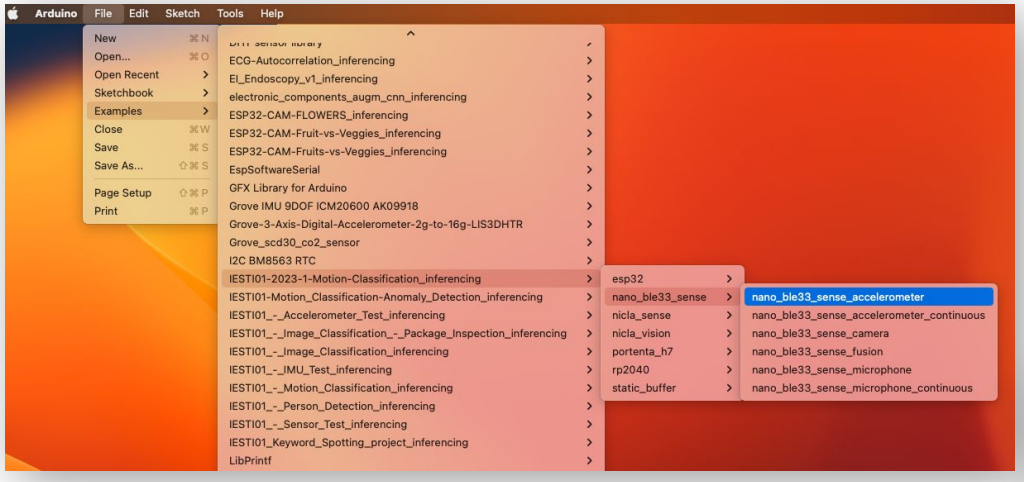
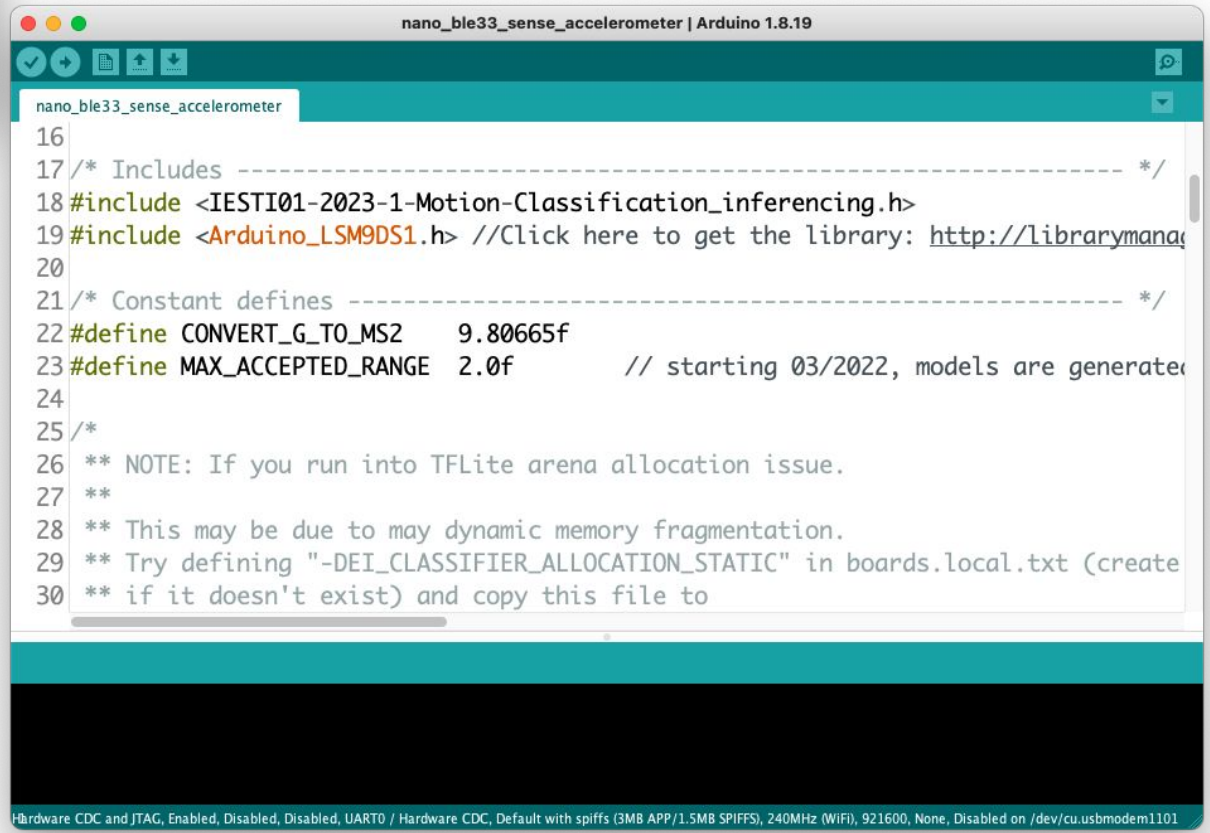
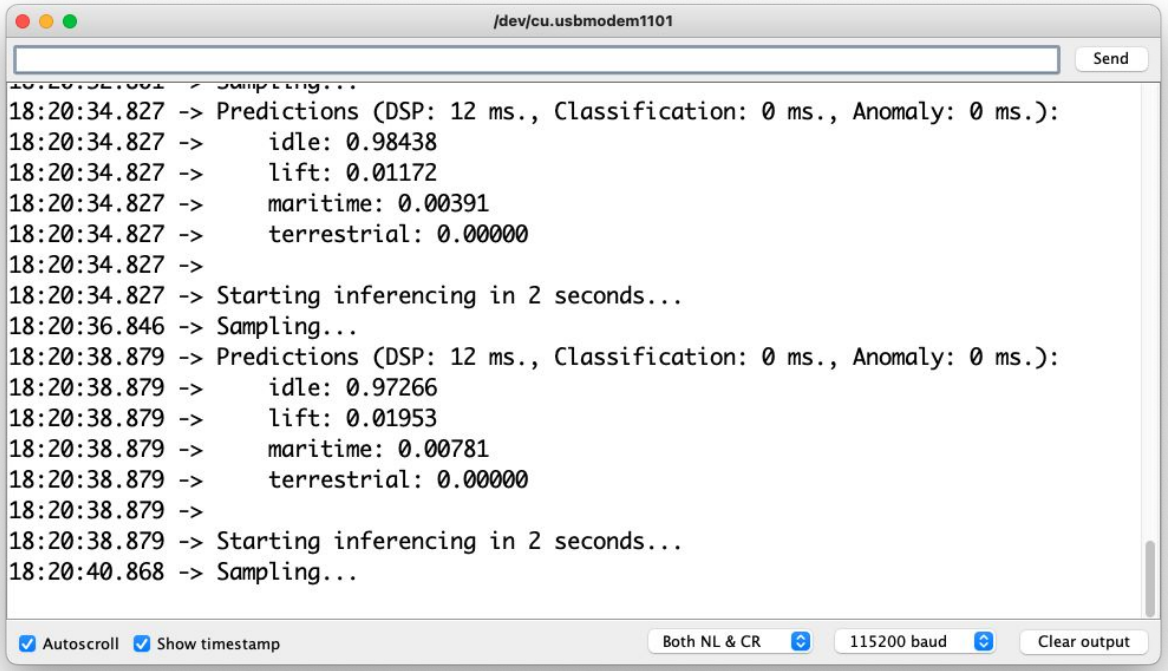
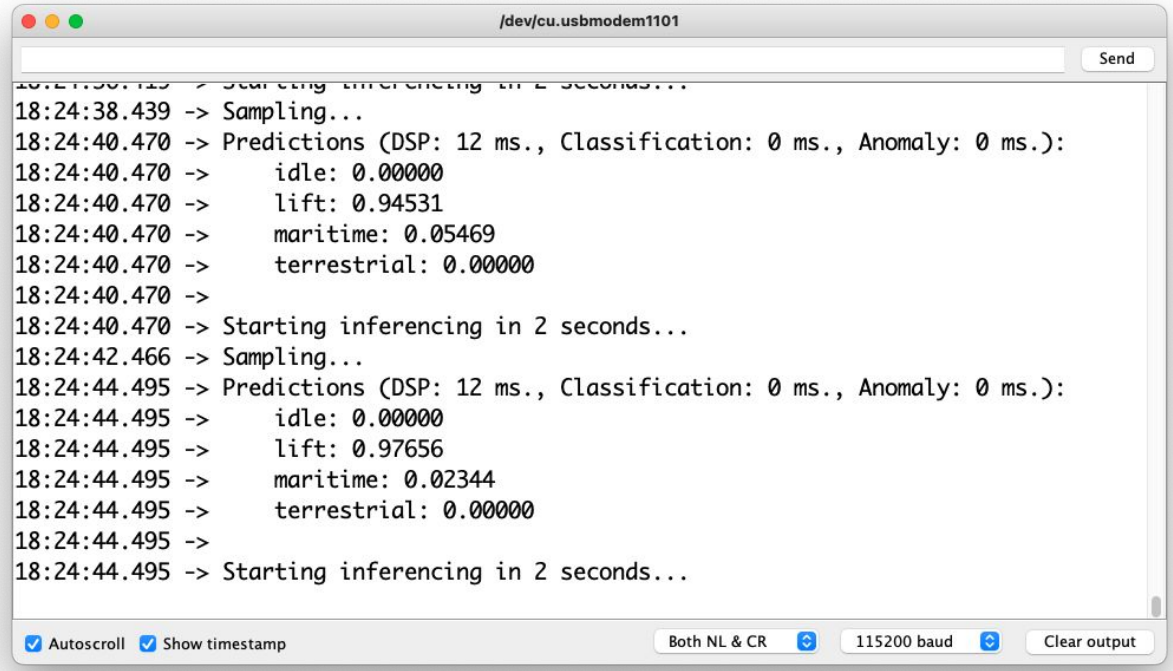
XIAOESP32S3-Sense-firmware.zip Monday, May 22, 2023 5:29 PM
XIAO_ESP32S3_Sense_Pinout (1).xlsx Monday, May 22, 2023 5:28 PM
ei-xiao-esp32s3-kws-arduino-1.0.1.zip Monday, May 22, 2023 3:00 PM
mini_speech_commands.zip Monday, May 22, 2023 12:51 PM
simple_audio.ipynb Monday, May 22, 2023 12:30 PM
screws.336ee0lm.jpg Monday, May 22, 2023 12:14 PM
boleta1.jpg Monday, May 22, 2023 12:01 PM
boleta2.pdf Monday, May 22, 2023 11:56 AM
boleta1.pdf Monday, May 22, 2023 11:47 AM
prestacion1.pdf Monday, May 22, 2023 11:47 AM
prestacion_2.pdf Monday, May 22, 2023 11:47 AM
1-orden_med.pdf Monday, May 22, 2023 11:44 AM
courseid_17_participants.xlsx Monday, May 22, 2023 8:45 AM
espressif-esp32 (1) Sunday, May 21, 2023 12:19 PM
espressif-esp32 (1).zip Sunday, May 21, 2023 12:19 PM
ei-bee-counting-using-fomo-arduino-1.0.8.zip Friday, May 19, 2023 12:07 PM
legenda_ingles.txt Thursday, May 18, 2023 8:32 PM
File Format:
ZIP files or folders
Cancel
Choose

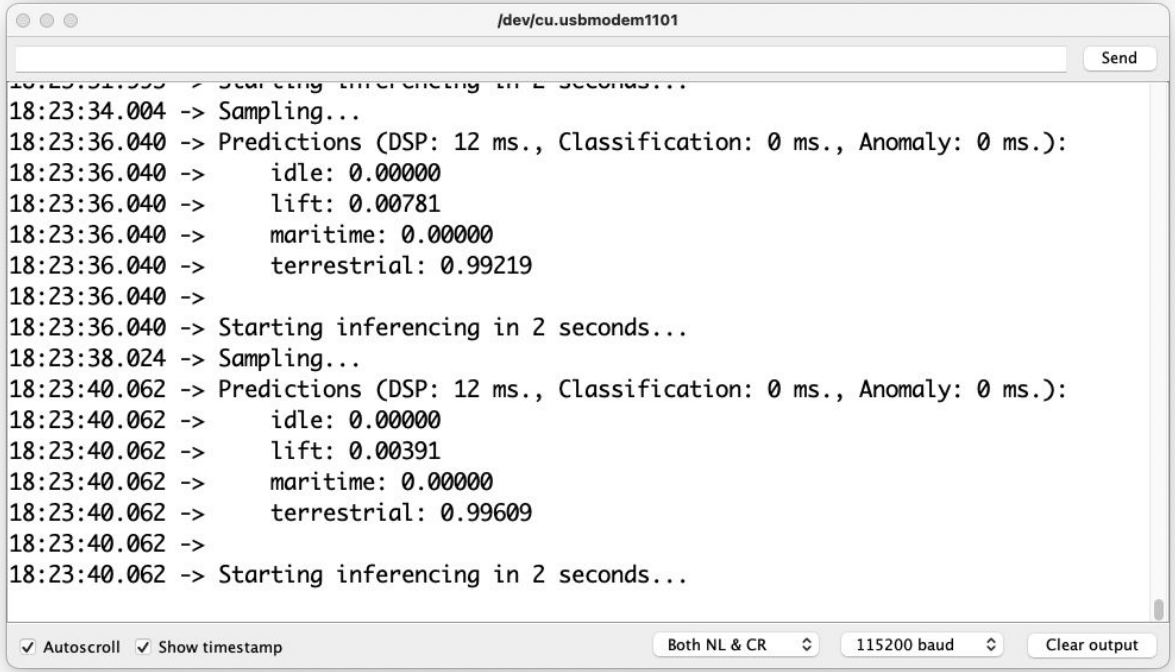

Arduino
File
Edit
Sketch
Tools
Help
New ⌘N
Open... ⌘O
Open Recent
Sketchbook
Examples
Close ⌘W
Save ⌘S
Save As... ⇧⌘S
Page Setup ⇧⌘P
Print ⌘P
ECG-Autocorrelation_inferencing
EI_Endoscopy_v1_inferencing
electronic_components_augm_cnn_inferencing
ESP32-CAM-FLOWERS_inferencing
ESP32-CAM-Fruit-vs-Veggies_inferencing
ESP32-CAM-Fruits-vs-Veggies_inferencing
EspSoftwareSerial
GFX Library for Arduino
Grove IMU 9DOF ICM20600 AK09918
Grove-3-Axis-Digital-Accelerometer-2g-to-16g-LIS3DHTR
Grove_scd30_co2_sensor
I2C BM8563 RTC
IESTI01-2023-1-Motion-Classification_inferencing
IESTI01-Motion_Classification-Anomaly_Detection_inferencing
IESTI01_-_Accelerometer_Test_inferencing
IESTI01_-_Image_Classification_-_Package_Inspection_inferencing
IESTI01_-_Image_Classification_inferencing
IESTI01_-_IMU_Test_inferencing
IESTI01_-_Motion_Classification_inferencing
IESTI01_-_Person_Detection_inferencing
IESTI01_-_Sensor_Test_inferencing
IESTI01_Keyword_Spotting_project_inferencing
LibPrintf
esp32
nano_ble33_sense
nicla_sense
nicla_vision
portenta_h7
rp2040
static_buffer
nano_ble33_sense_accelerometer
nano_ble33_sense_accelerometer_continuous
nano_ble33_sense_camera
nano_ble33_sense_fusion
nano_ble33_sense_microphone
nano_ble33_sense_microphone_continuous

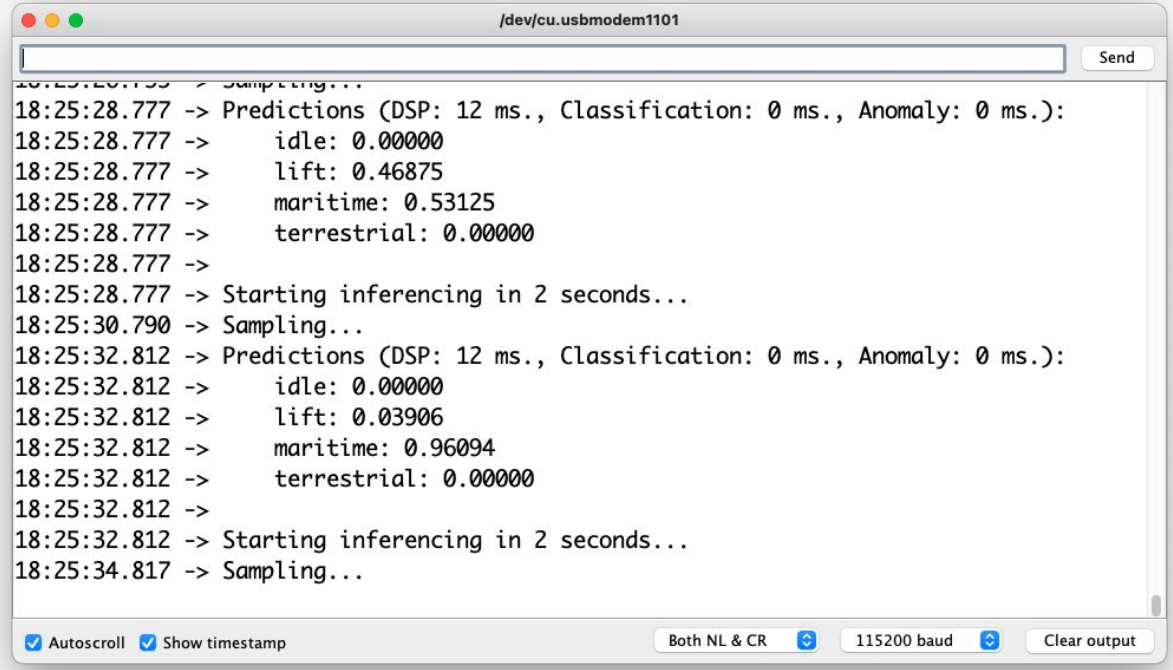

nano_ble33_sense_accelerometer | Arduino 1.8.19
nano_ble33_sense_accelerometer
16
17 /* Includes ---------- */
18 #include <IESTI01-2023-1-Motion-Classification_inferencing.h>
19 #include <Arduino_LSM9DS1.h> //Click here to get the library: http://librarymana
20
21 /* Constant defines ---------- */
22 #define CONVERT_G_TO_MS2 9.80665f
23 #define MAX_ACCEPTED_RANGE 2.0f // starting 03/2022, models are generate
24
25 /*
26 ** NOTE: If you run into TFLite arena allocation issue.
27 **
28 ** This may be due to may dynamic memory fragmentation.
29 ** Try defining "-DEI_CLASSIFIER_ALLOCATION_STATIC" in boards.local.txt (create
30 ** if it doesn't exist) and copy this file to
Hardware CDC and JTAG, Enabled, Disabled, Disabled, UART0 / Hardware CDC, Default with spiffs (3MB APP/1.5MB SPIFFS), 240MHz (WiFi), 921600, None, Disabled on /dev/cu.usbmodem1101

Model Inference


/dev/cu.usbmodem1101
Send
18:20:34.827 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:20:34.827 ->   idle: 0.98438
18:20:34.827 ->   lift: 0.01172
18:20:34.827 ->   maritime: 0.00391
18:20:34.827 ->   terrestrial: 0.00000
18:20:34.827 ->
18:20:34.827 -> Starting inferencing in 2 seconds...
18:20:36.846 -> Sampling...
18:20:38.879 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:20:38.879 ->   idle: 0.97266
18:20:38.879 ->   lift: 0.01953
18:20:38.879 ->   maritime: 0.00781
18:20:38.879 ->   terrestrial: 0.00000
18:20:38.879 ->
18:20:38.879 -> Starting inferencing in 2 seconds...
18:20:40.868 -> Sampling...
Autoscroll
Show timestamp
Both NL & CR
115200 baud
Clear output


/dev/cu.usbmodem1101
Send
18:24:38.439 -> Sampling...
18:24:40.470 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:24:40.470 ->   idle: 0.00000
18:24:40.470 ->   lift: 0.94531
18:24:40.470 ->   maritime: 0.05469
18:24:40.470 ->   terrestrial: 0.00000
18:24:40.470 ->
18:24:40.470 -> Starting inferencing in 2 seconds...
18:24:42.466 -> Sampling...
18:24:44.495 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:24:44.495 ->   idle: 0.00000
18:24:44.495 ->   lift: 0.97656
18:24:44.495 ->   maritime: 0.02344
18:24:44.495 ->   terrestrial: 0.00000
18:24:44.495 ->
18:24:44.495 -> Starting inferencing in 2 seconds...
Autoscroll
Show timestamp
Both NL & CR
115200 baud
Clear output


/dev/cu.usbmodem1101
Send
18:23:34.004 -> Sampling...
18:23:36.040 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:23:36.040 ->   idle: 0.00000
18:23:36.040 ->   lift: 0.00781
18:23:36.040 ->   maritime: 0.00000
18:23:36.040 ->   terrestrial: 0.99219
18:23:36.040 ->
18:23:36.040 -> Starting inferencing in 2 seconds...
18:23:38.024 -> Sampling...
18:23:40.062 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:23:40.062 ->   idle: 0.00000
18:23:40.062 ->   lift: 0.00391
18:23:40.062 ->   maritime: 0.00000
18:23:40.062 ->   terrestrial: 0.99609
18:23:40.062 ->
18:23:40.062 -> Starting inferencing in 2 seconds...
Autoscroll
Show timestamp
Both NL & CR
115200 baud
Clear output


/dev/cu.usbmodem1101
Send
18:25:28.777 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:25:28.777 ->   idle: 0.00000
18:25:28.777 ->   lift: 0.46875
18:25:28.777 ->   maritime: 0.53125
18:25:28.777 ->   terrestrial: 0.00000
18:25:28.777 ->
18:25:28.777 -> Starting inferencing in 2 seconds...
18:25:30.790 -> Sampling...
18:25:32.812 -> Predictions (DSP: 12 ms., Classification: 0 ms., Anomaly: 0 ms.):
18:25:32.812 ->   idle: 0.00000
18:25:32.812 ->   lift: 0.03906
18:25:32.812 ->   maritime: 0.96094
18:25:32.812 ->   terrestrial: 0.00000
18:25:32.812 ->
18:25:32.812 -> Starting inferencing in 2 seconds...
18:25:34.817 -> Sampling...
Autoscroll
Show timestamp
Both NL & CR
115200 baud
Clear output

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

I want to thank Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google, Professor Vijay Janapa Reddi and Brian Plancher from Harvard, and the rest of the TinyMLedu team 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

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