

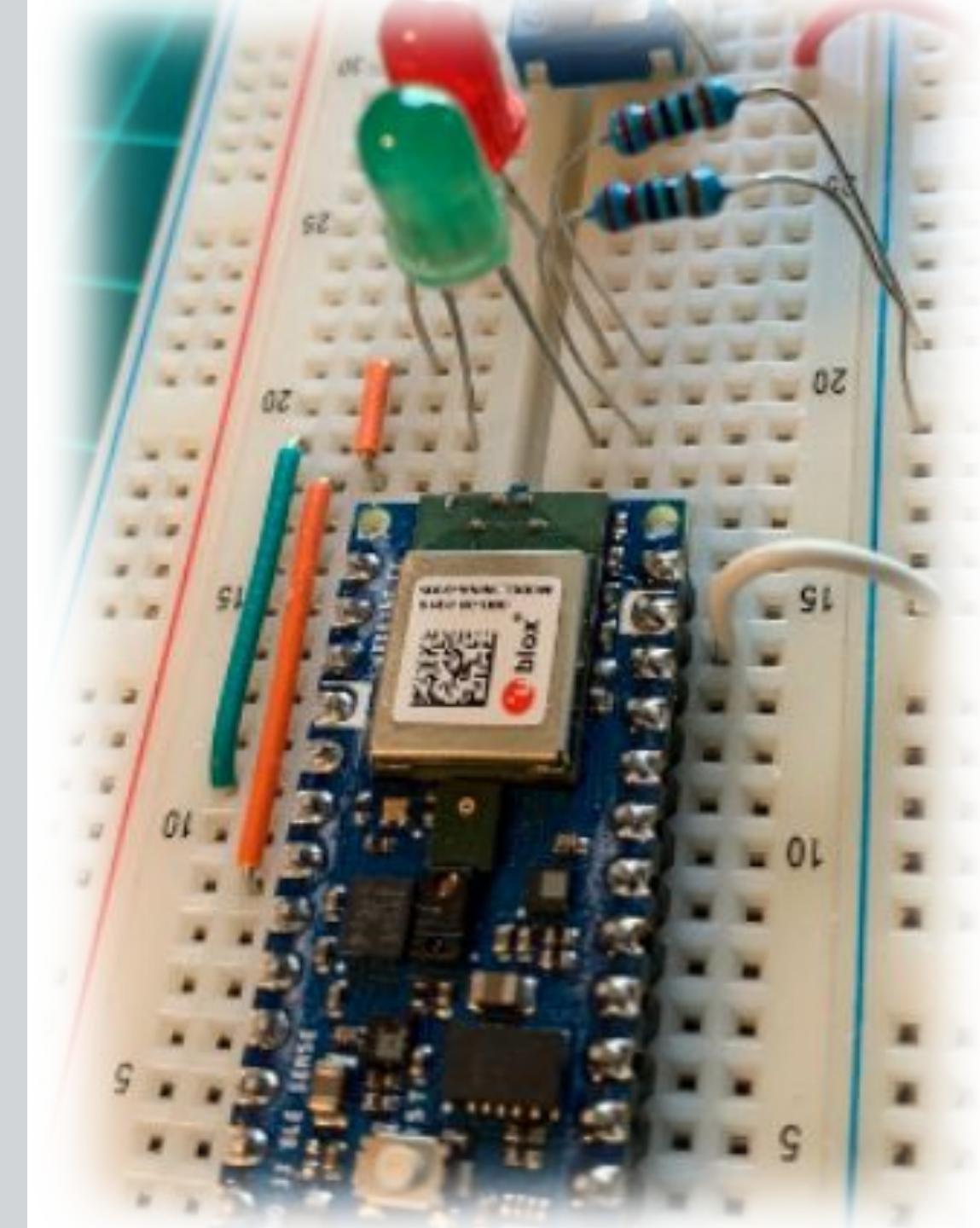
# IESTI01 – TinyML

## Embedded Machine Learning

### 19. Motion Classification



Prof. Marcelo Rovai  
UNIFEI



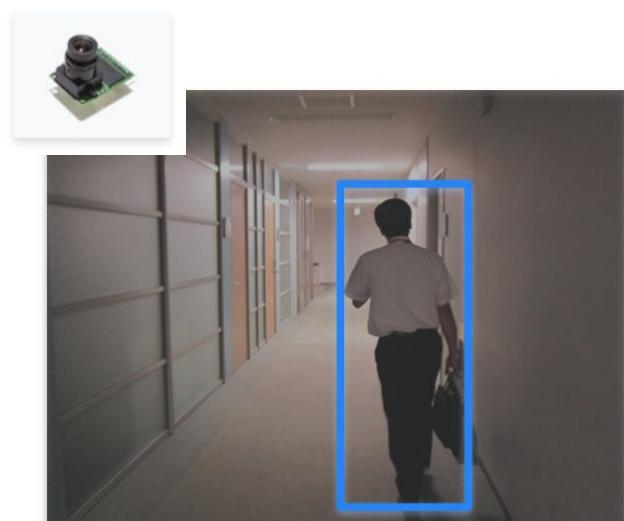
# Vibration



# Sound



# Vision



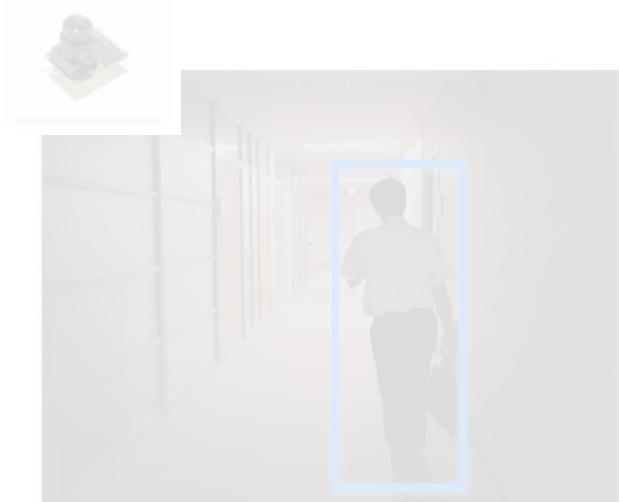
# Vibration



# Sound



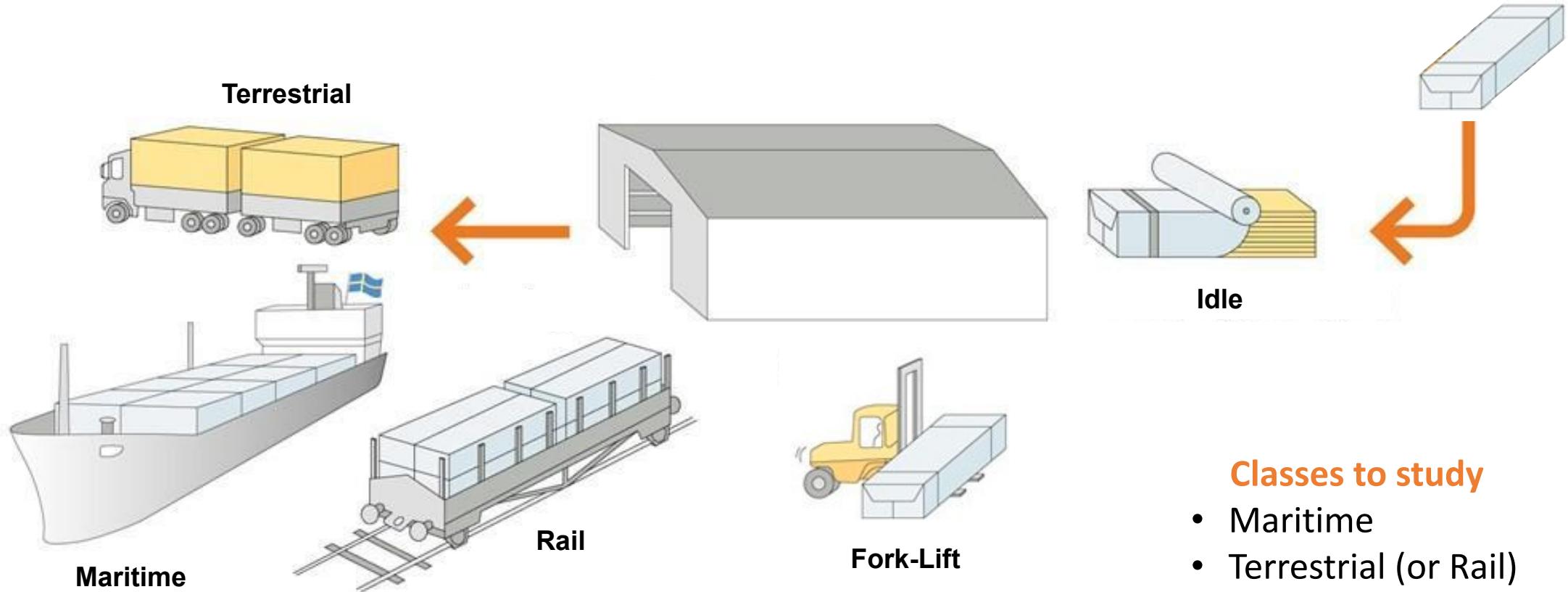
# Vision



# Motion Classification



# Case Study: Mechanical Stresses in Transport



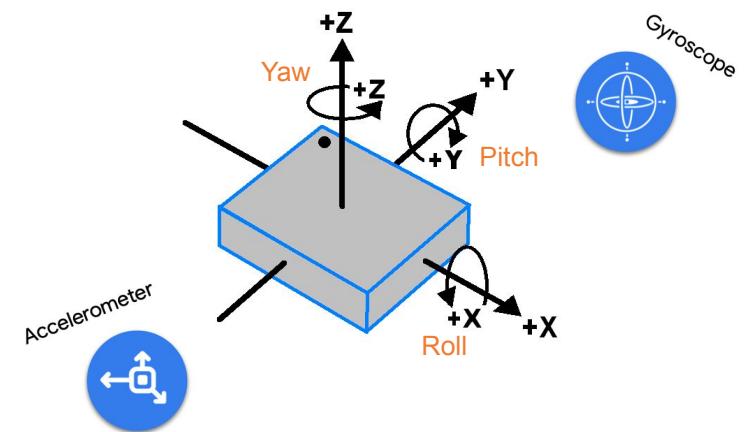
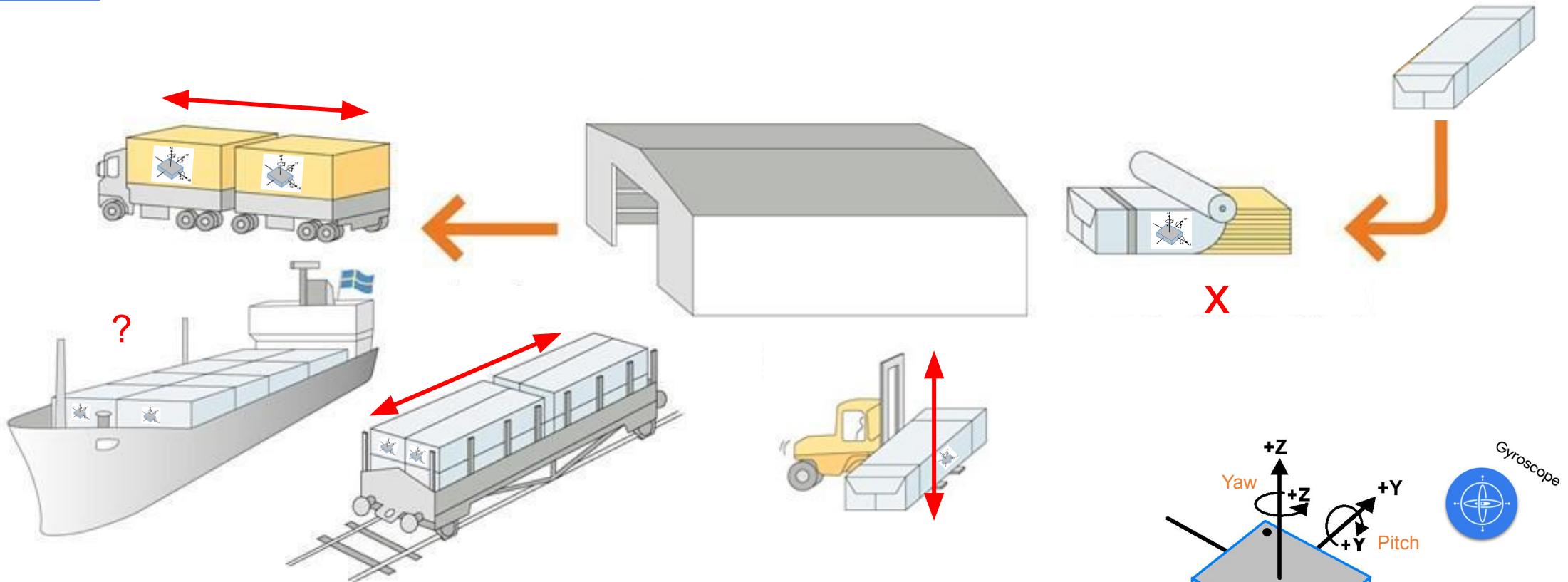
## Classes to study

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

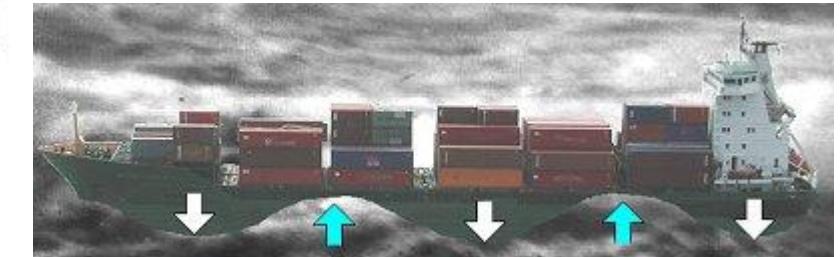
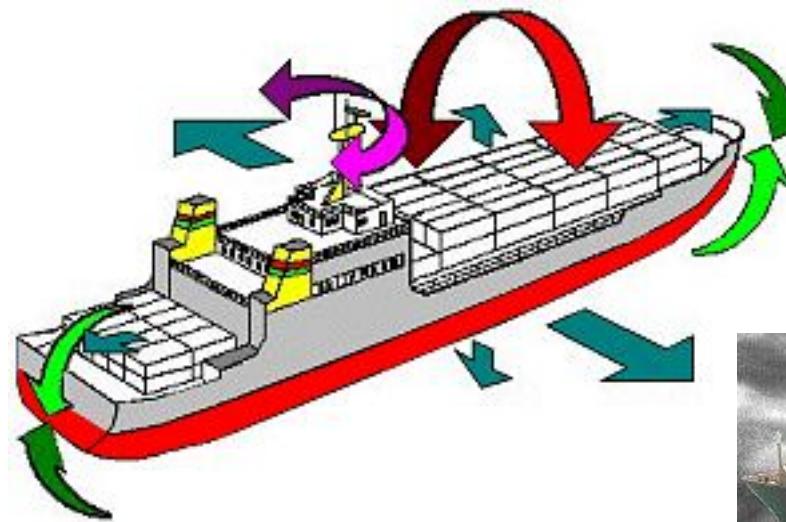
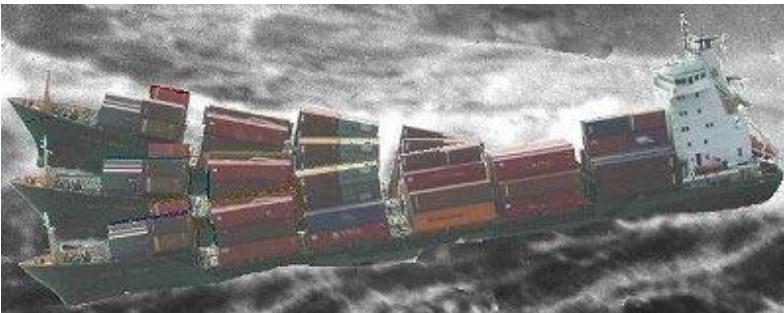
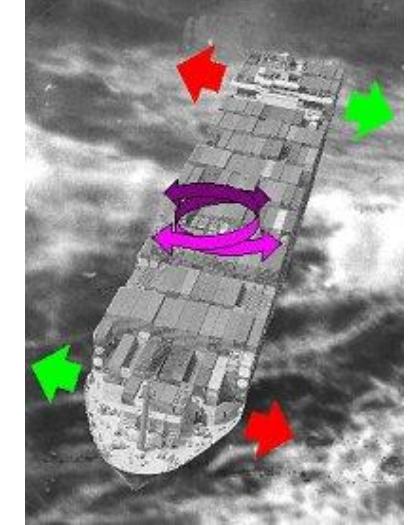
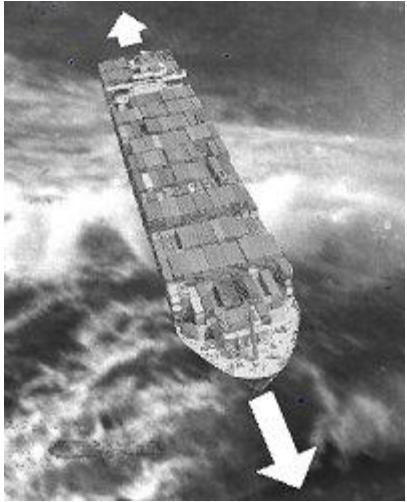
# Machine Learning Workflow



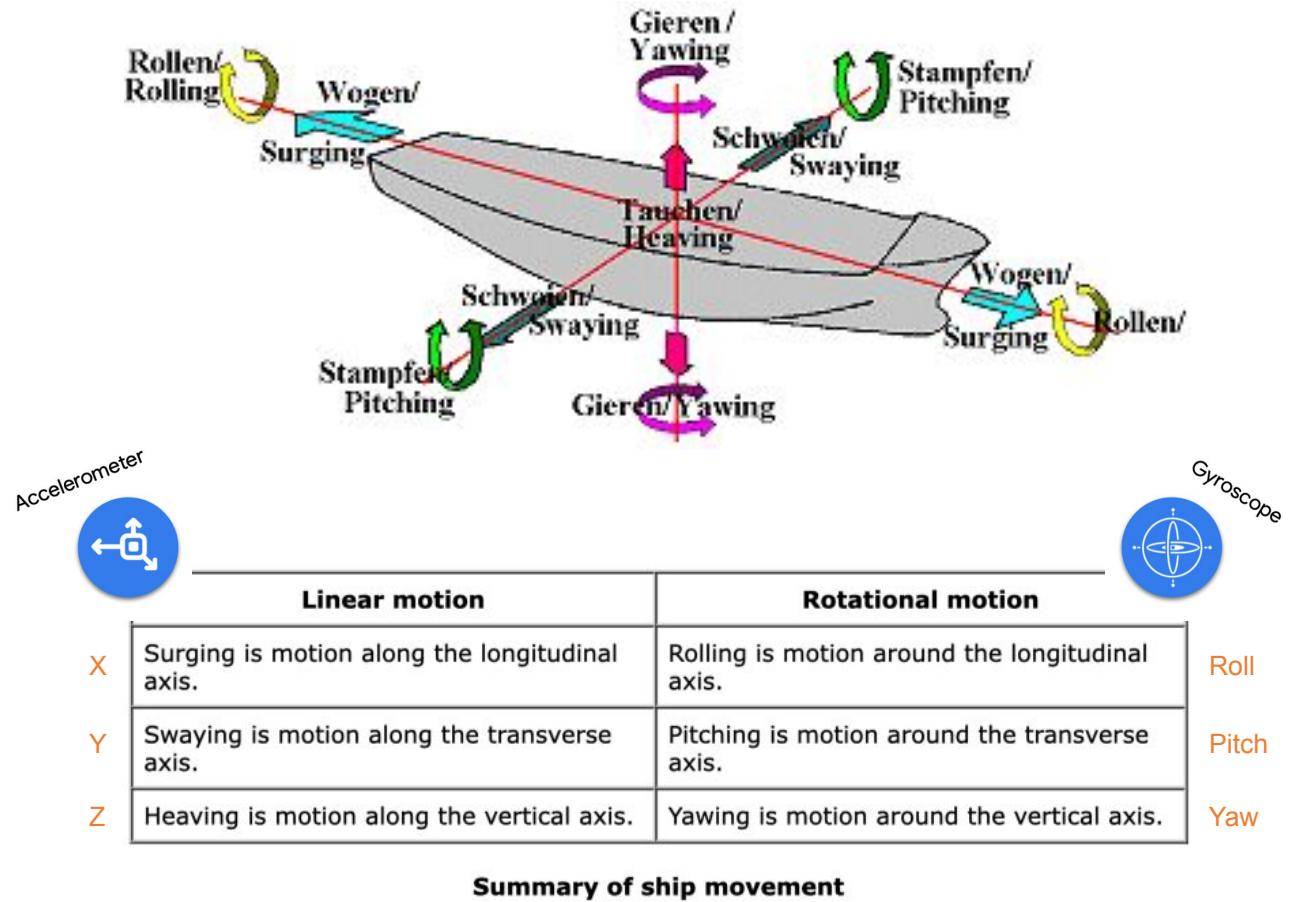
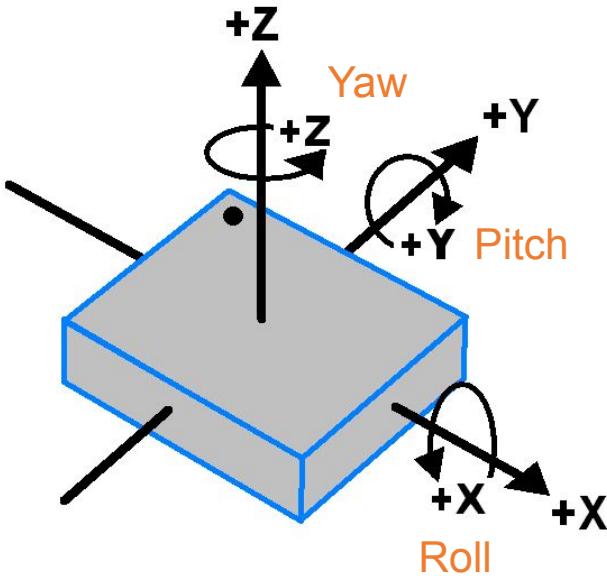
Collect  
Data



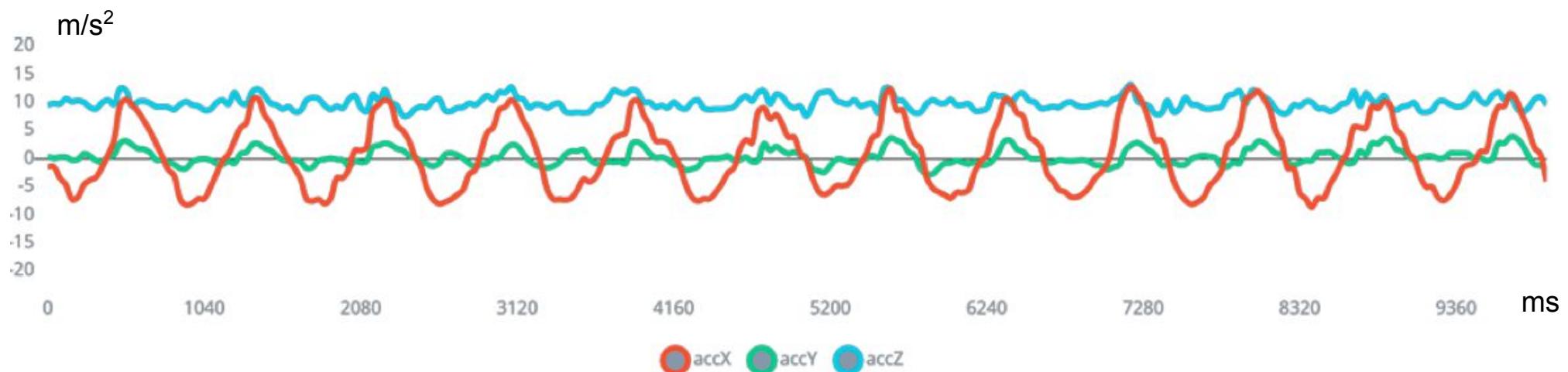
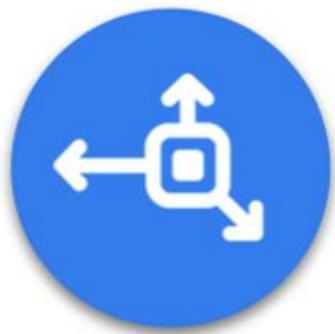
# Mechanical Stresses in Maritime Transport

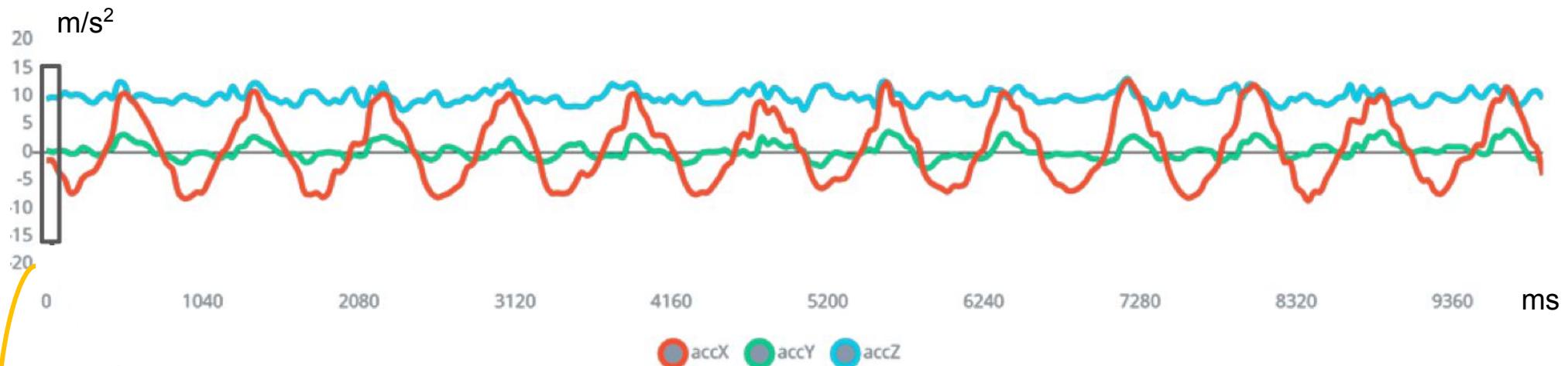
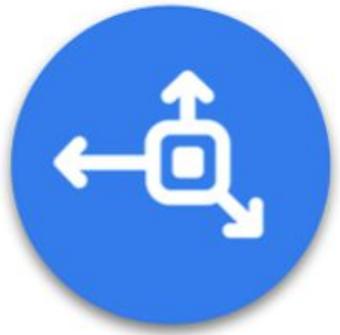


# Mechanical Stresses in Maritime Transport



Example: 10 seconds of accelerometer data, captured with a sample rate: 62.5 Hz





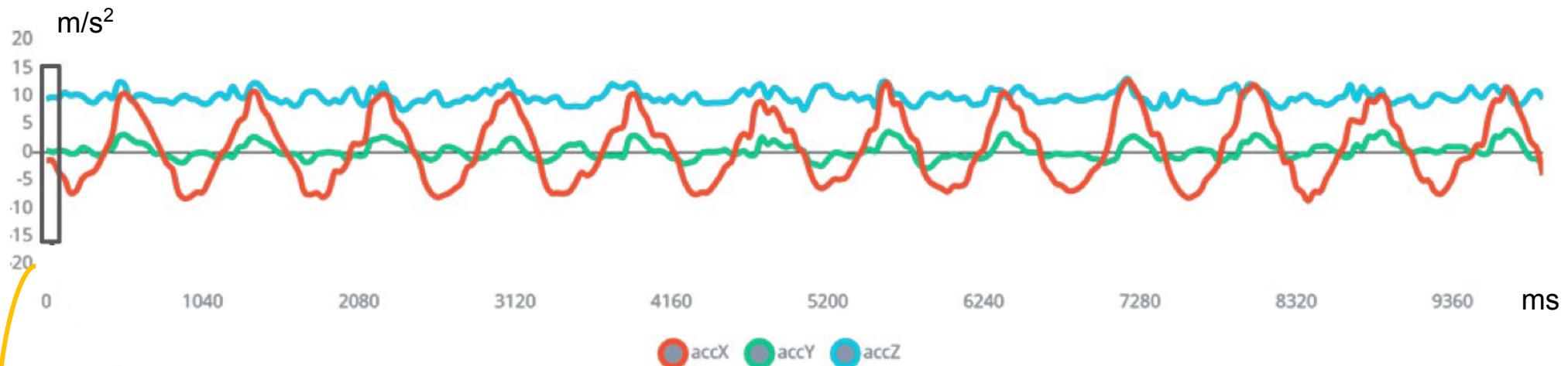
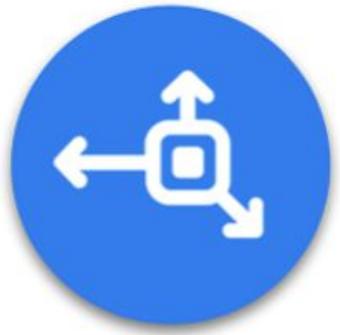
### Raw Features

- accX
- accY
- accZ



### Classes

- Lift
- Terrestrial
- Maritime
- Idle



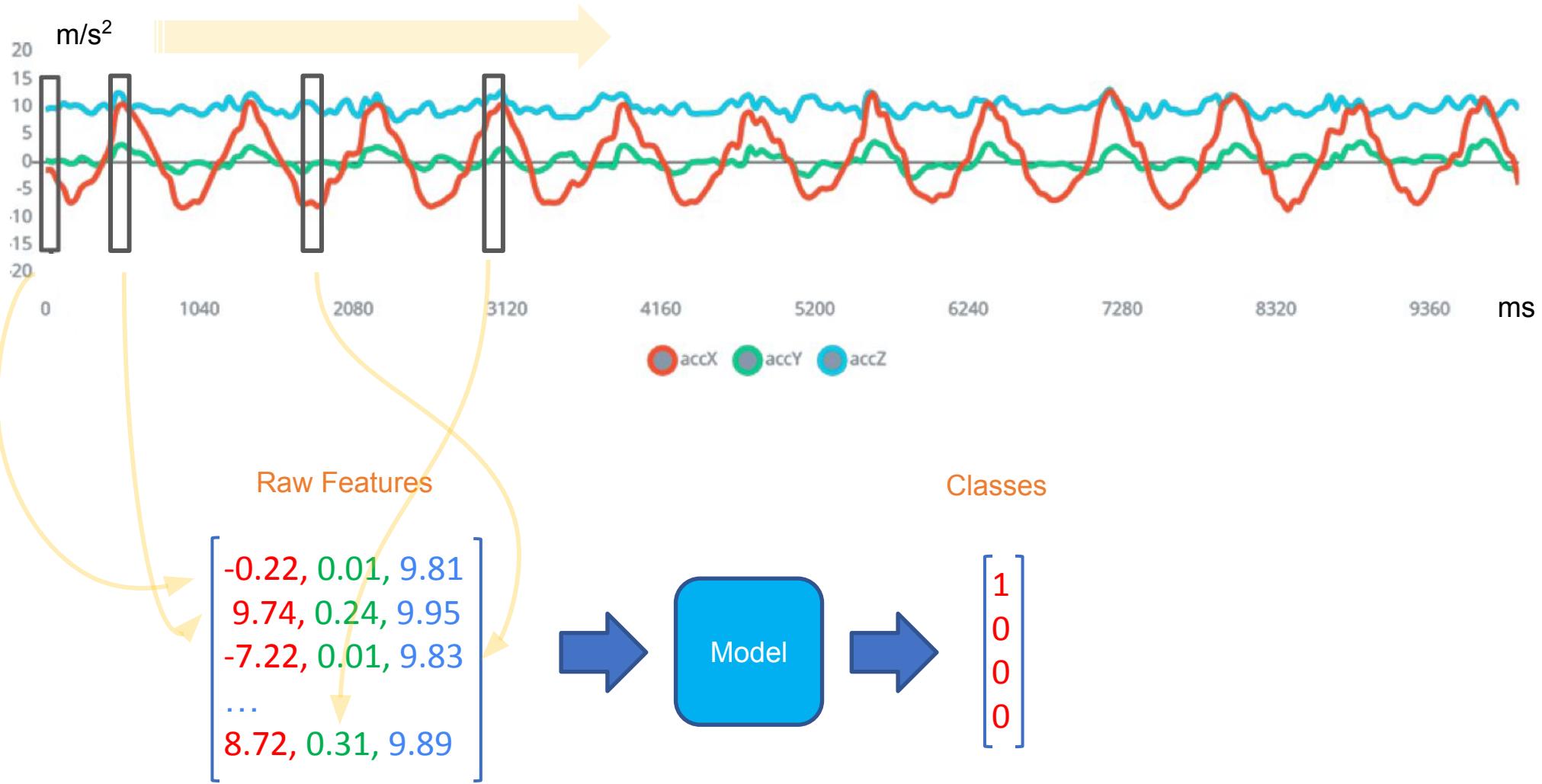
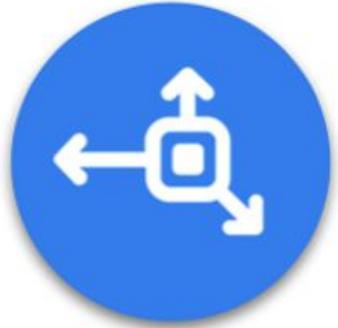
Raw Features

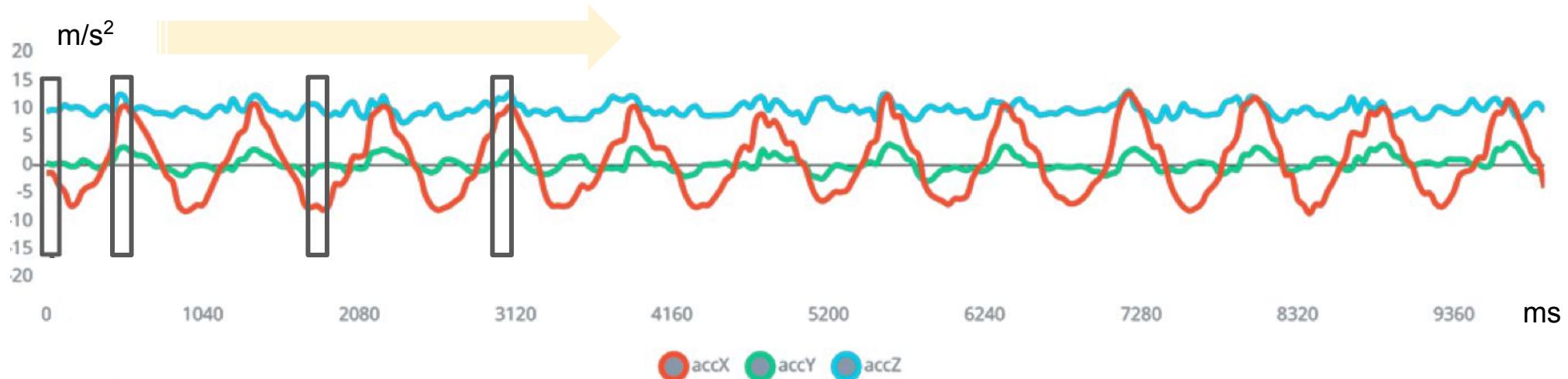
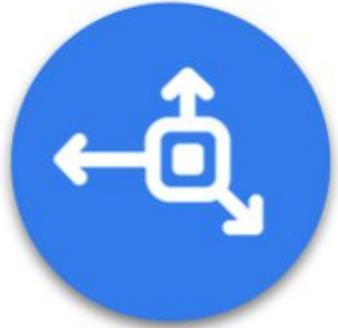
$$[-0.22, 0.01, 9.81]$$

Model

Classes

$$\begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

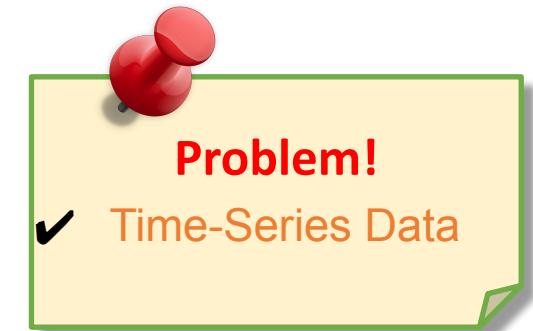


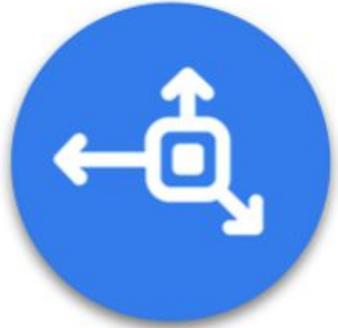


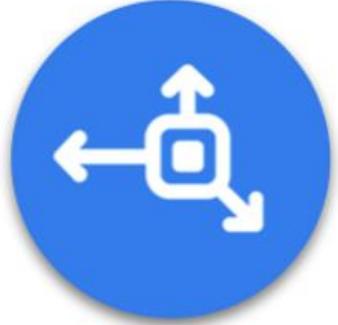
Raw Features

$$\begin{bmatrix} -0.22, 0.01, 9.81 \\ 9.74, 0.24, 9.95 \\ -7.22, 0.01, 9.83 \\ \dots \\ 8.72, 0.31, 9.89 \end{bmatrix}$$


Classes





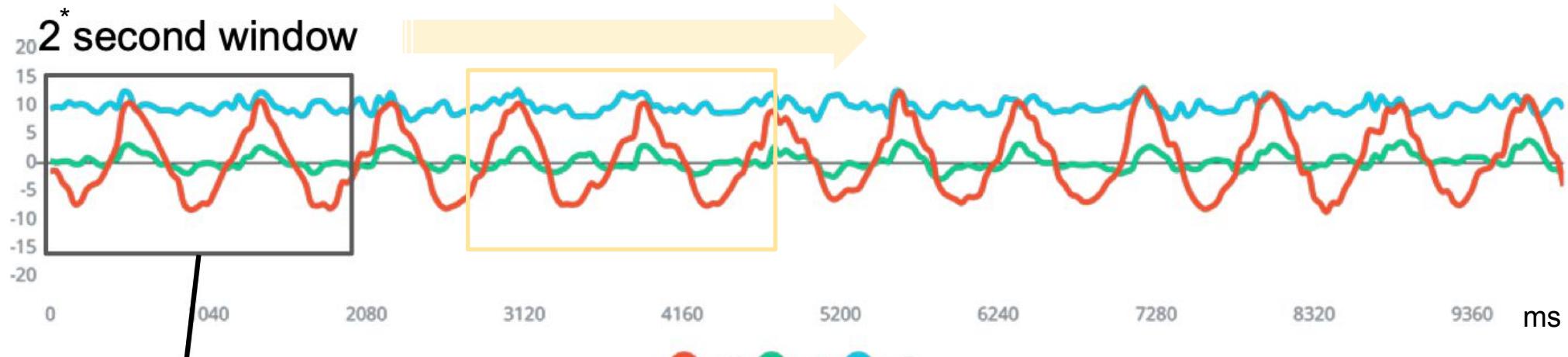
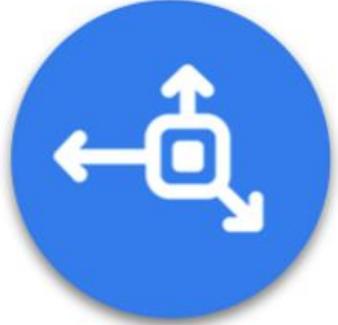


### Raw Features as a window

- 125\*\* samples for each axis (62.5Hz x 2s)
- 375 total features (125 x 3 axis)

\* 2 seconds is needed to capture 1 or 2 cycles of movement

\*\* 2 seconds at sample rate of 62.5 Hz -> 125 samples



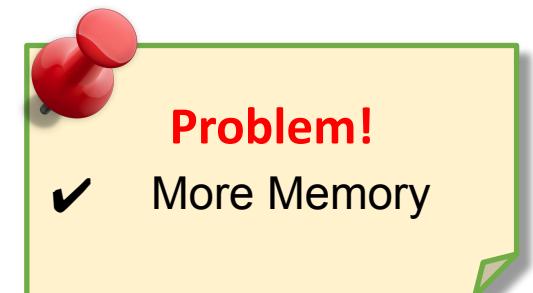
Raw Features as a window

- 125\*\* samples for each axis
- 375 total features



Automatic Feature Extraction using DL

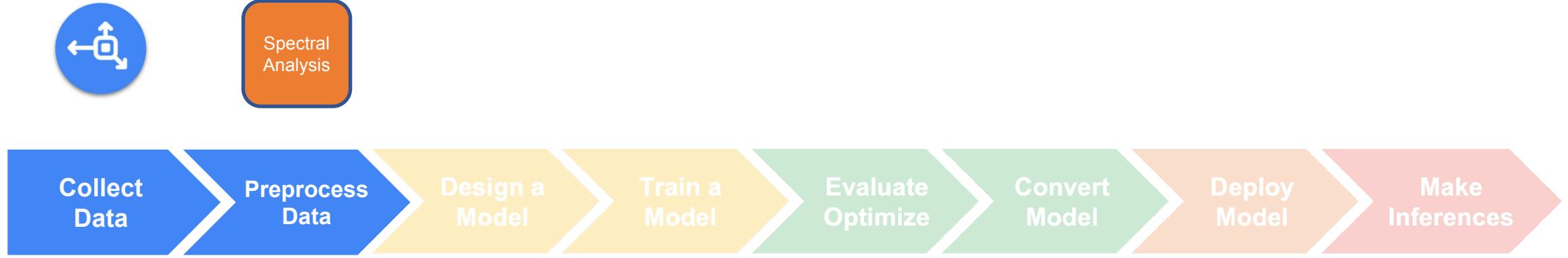
- Computational complexity
- Lots of training data

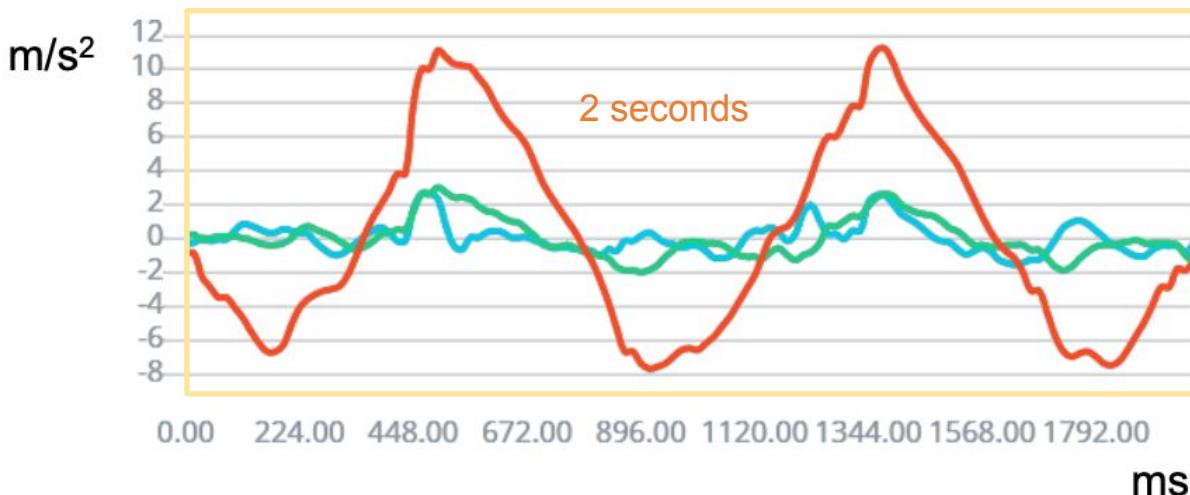


\* 2 seconds is needed to capture 1 or 2 cycles of movement

\*\* 2 seconds at sample rate of 62.5 Hz -> 125 samples

# Data Pre-Processing



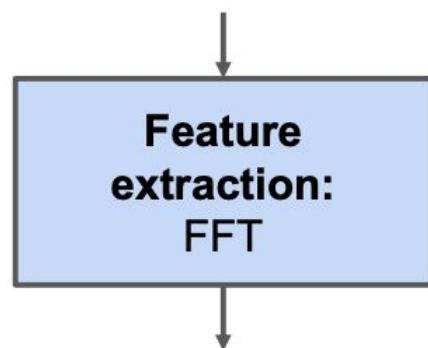
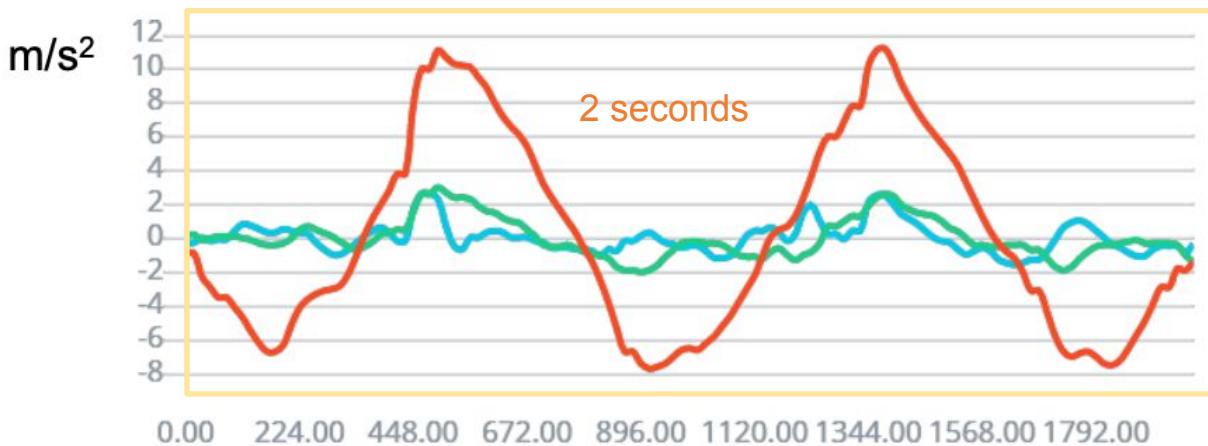


## Manual Feature Extraction

- 3 RMS (Root Mean Square) values  
- one for each axis (x, y, z)

$$x_{\text{RMS}} = \sqrt{\frac{1}{n} (x_1^2 + x_2^2 + \dots + x_n^2)}.$$

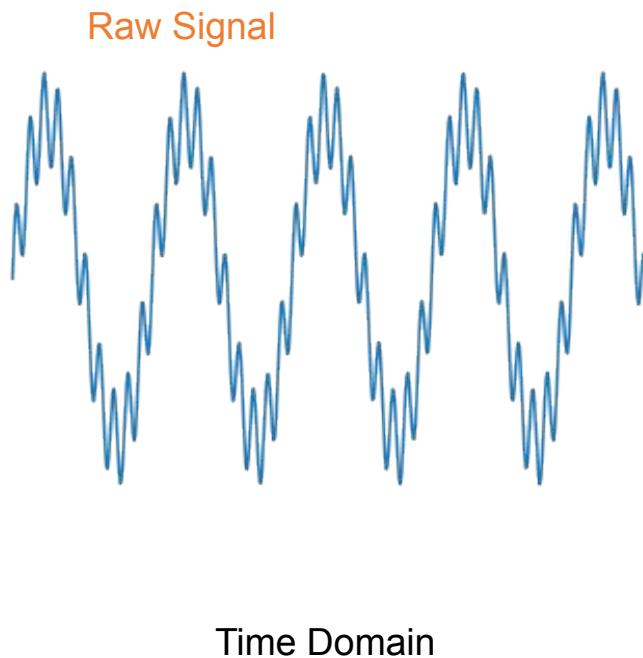
→ 125



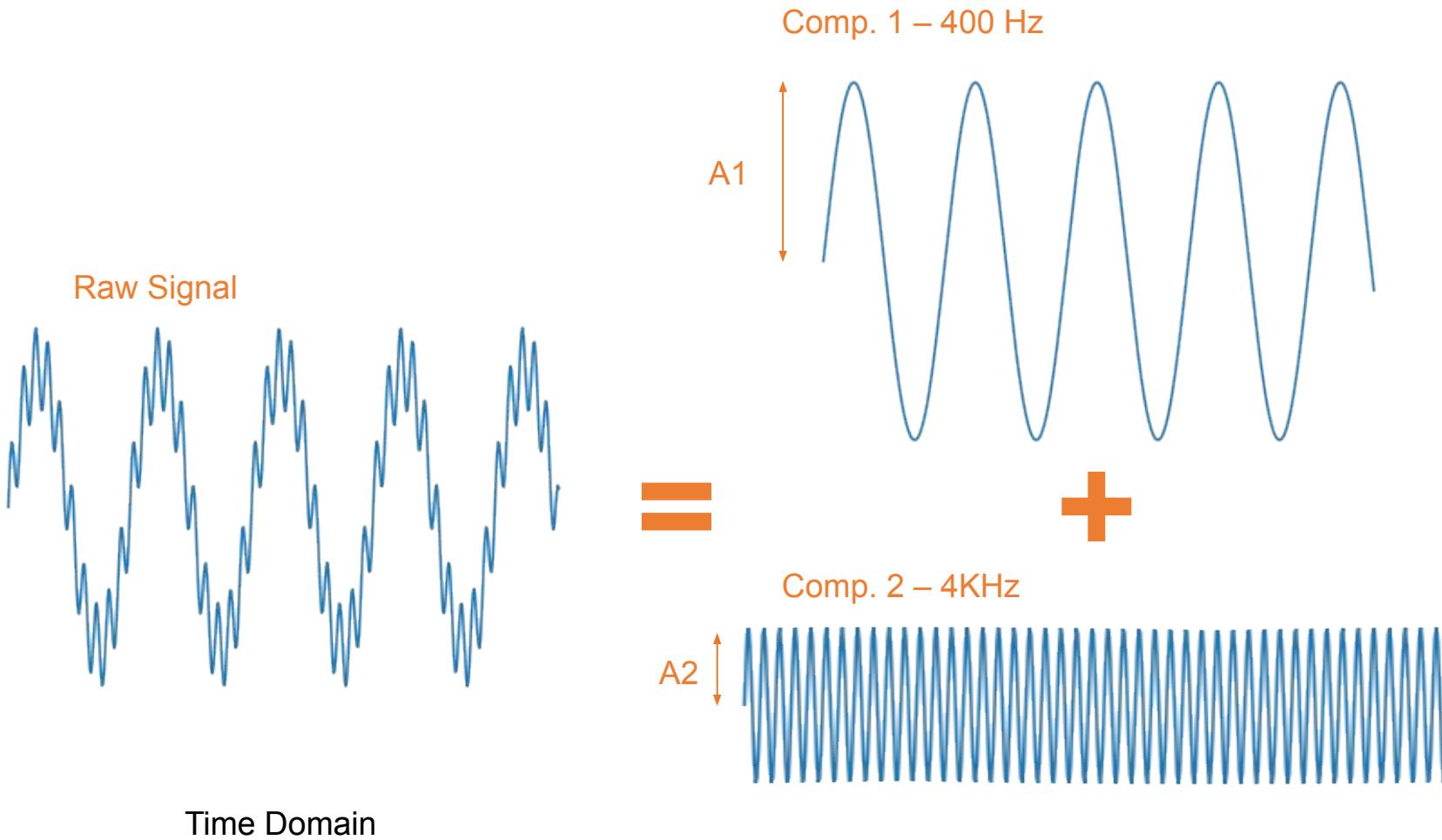
# Manual Feature Extraction

**3 RMS**

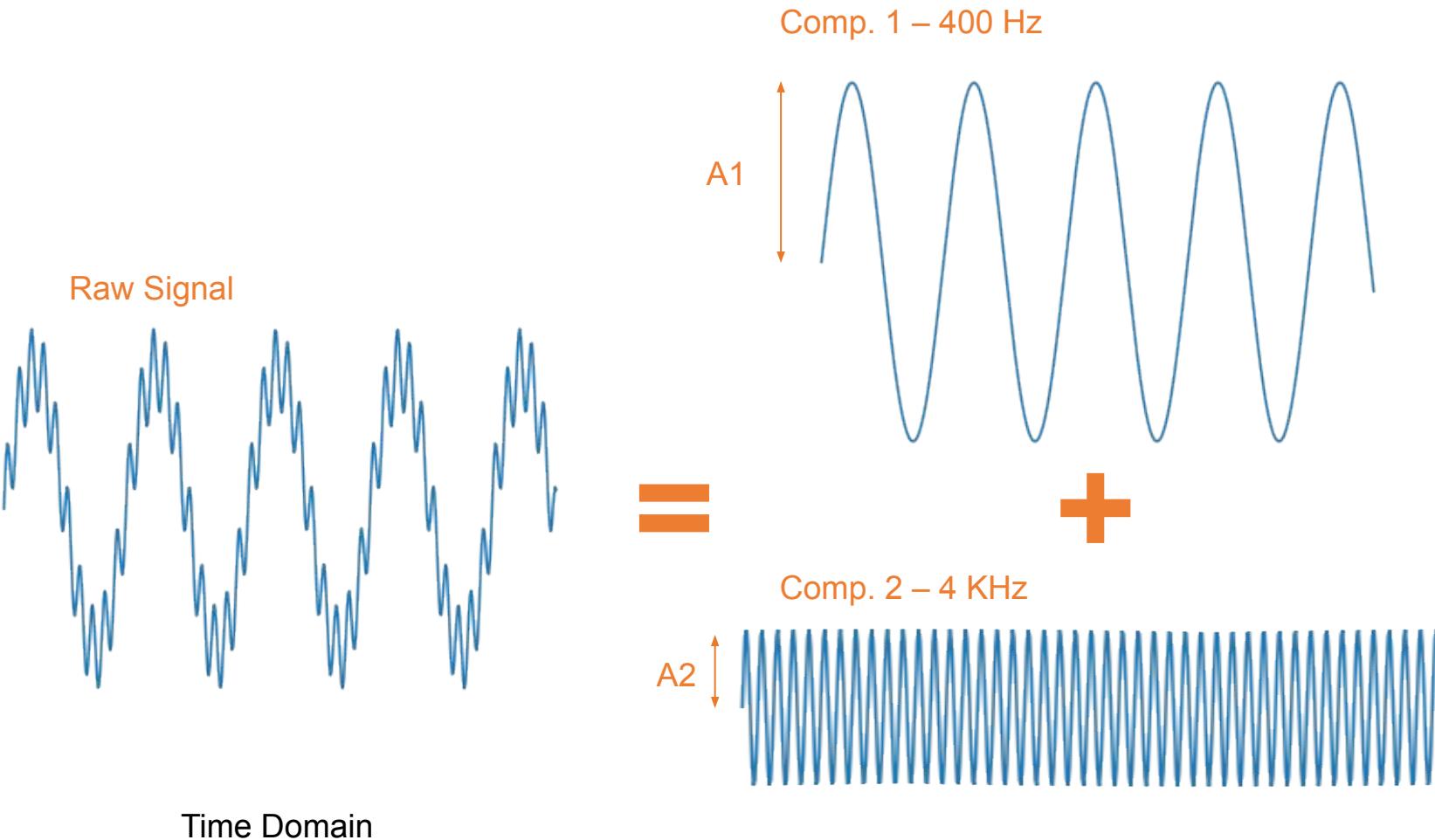
# Fast Fourier Transformer (FFT)



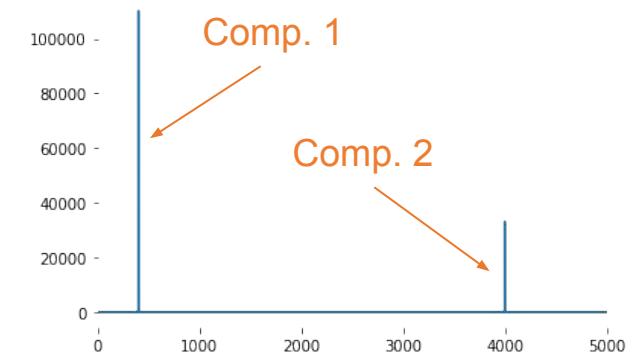
# Fast Fourier Transformer (FFT)



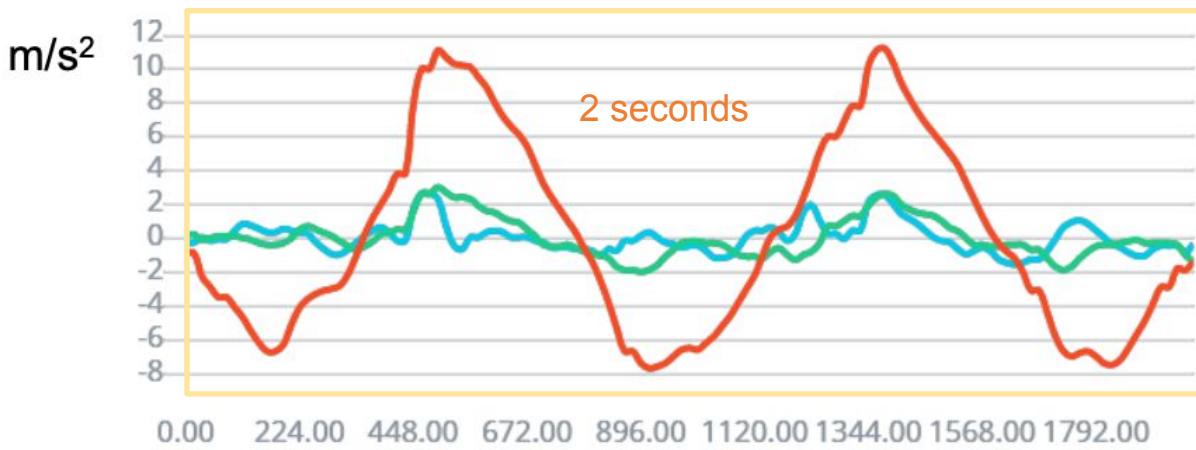
# Fast Fourier Transformer (FFT)



```
from scipy.fft import fft  
yf = fft(raw signal)  
plt.plot(xf, np.abs(yf));
```

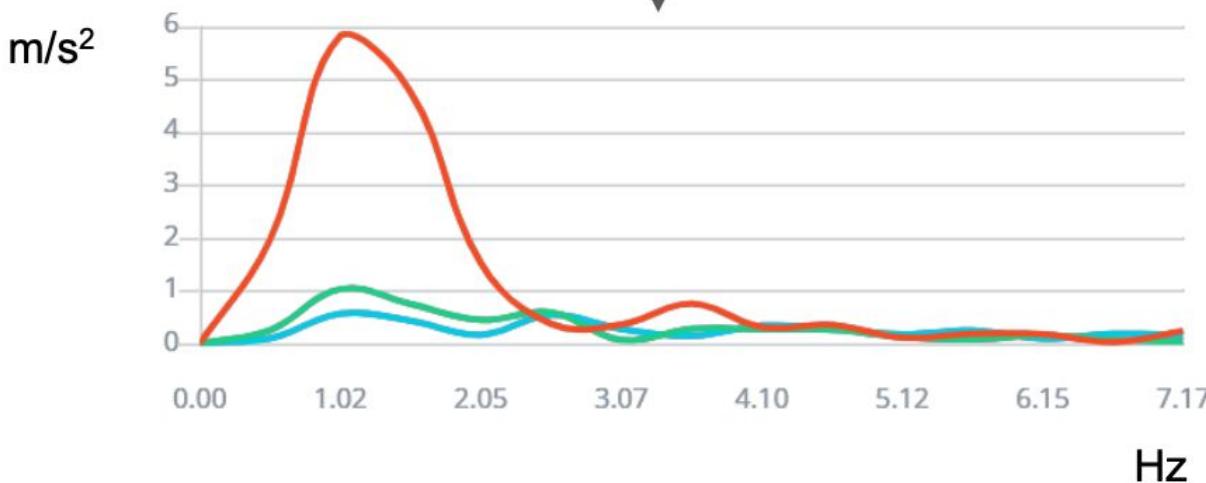
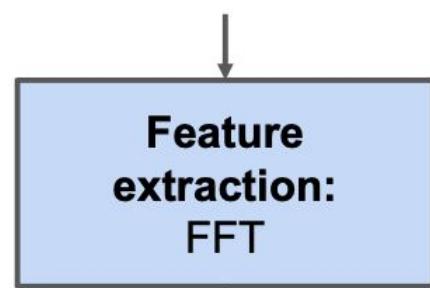


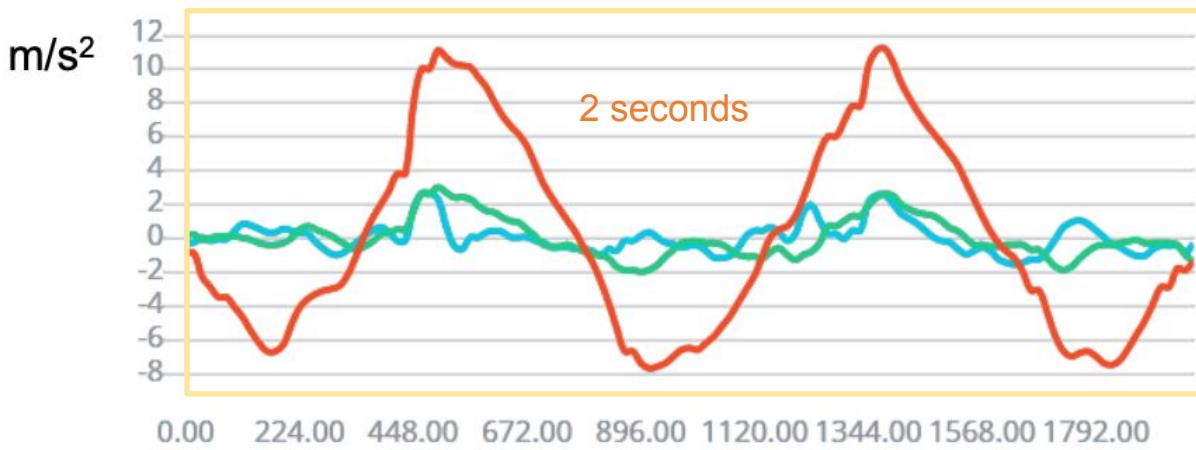
Frequency Domain



## Manual Feature Extraction

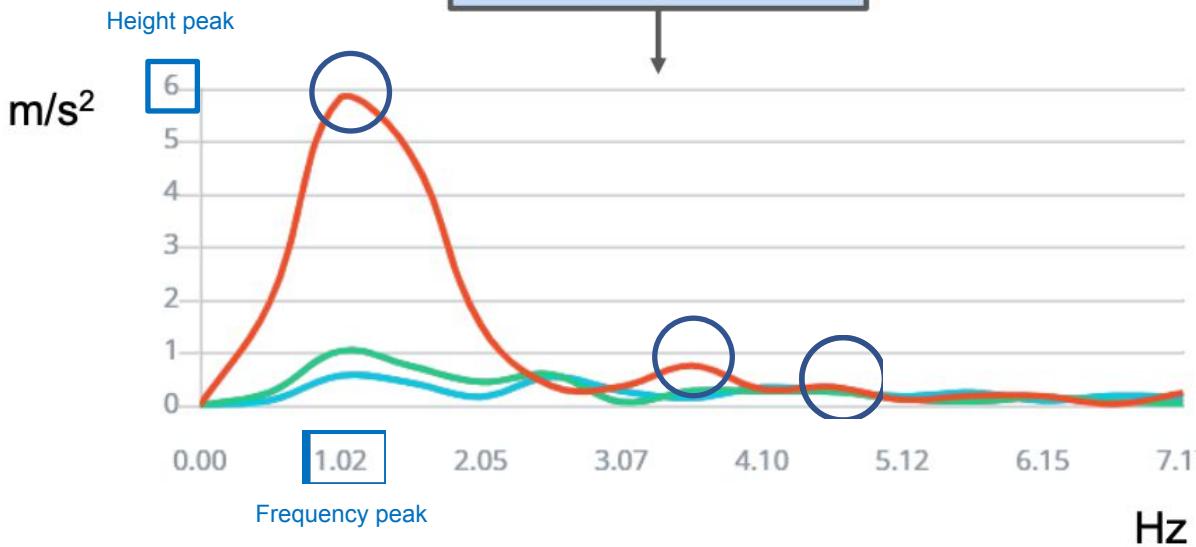
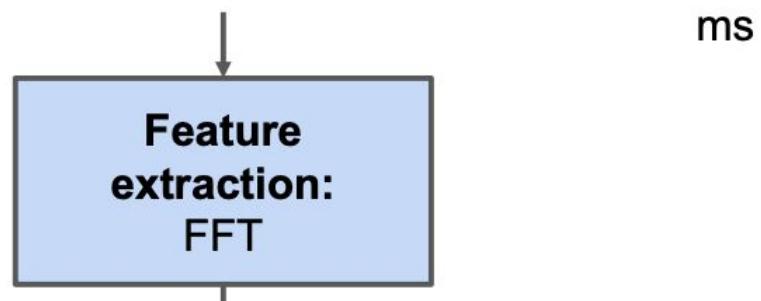
3 RMS



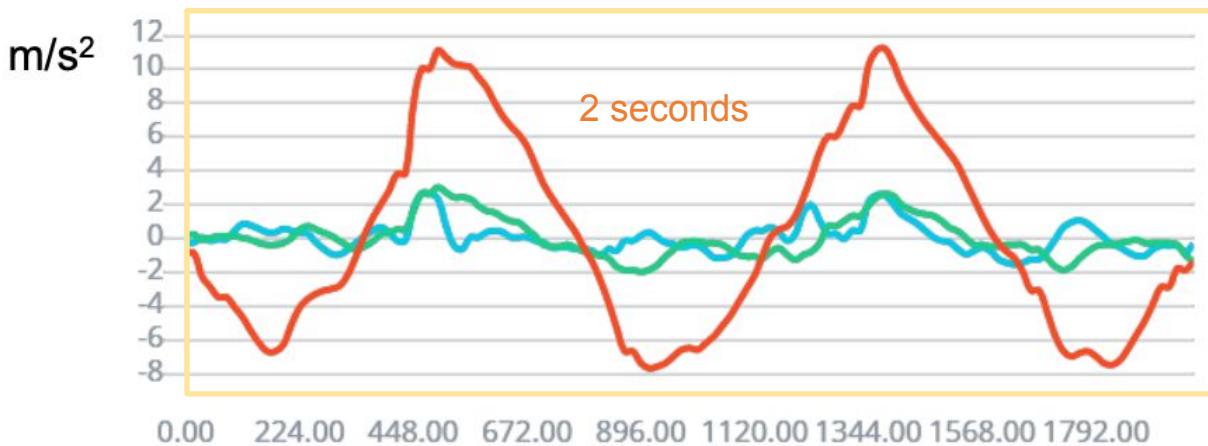


## Manual Feature Extraction

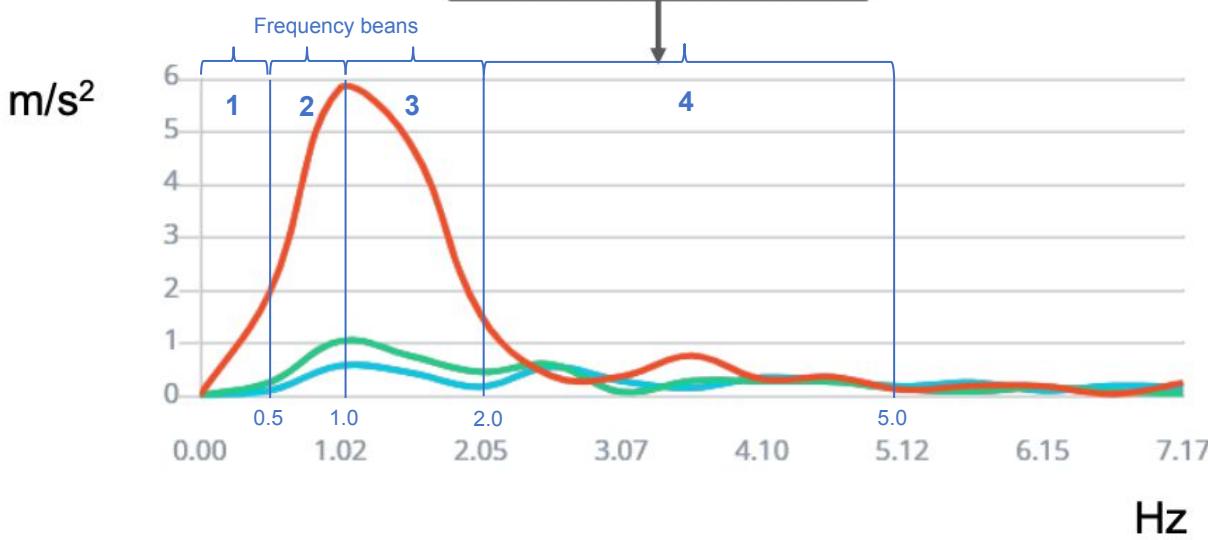
3 RMS



9 Height + 9 Freq. peak values



**Feature  
extraction:  
FFT**



# Manual Feature Extraction



**3 RMS + 9 HP + 9 FP + 12 PSD values**

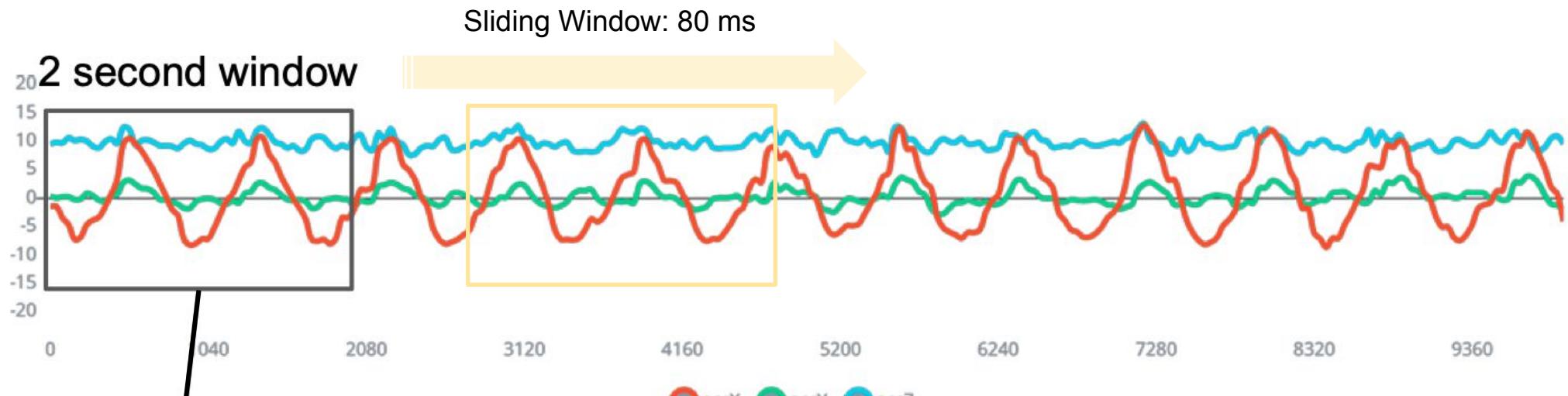
Power Spectral Density (PSD)



4 Frequency bins per axix

**Feature  
extraction:  
PSD**

<https://blog.endaq.com/why-the-power-spectral-density-psd-is-the-gold-standard-of-vibration-analysis>



375 Raw Features

- Raw Data from sensor

Manual Feature Extraction

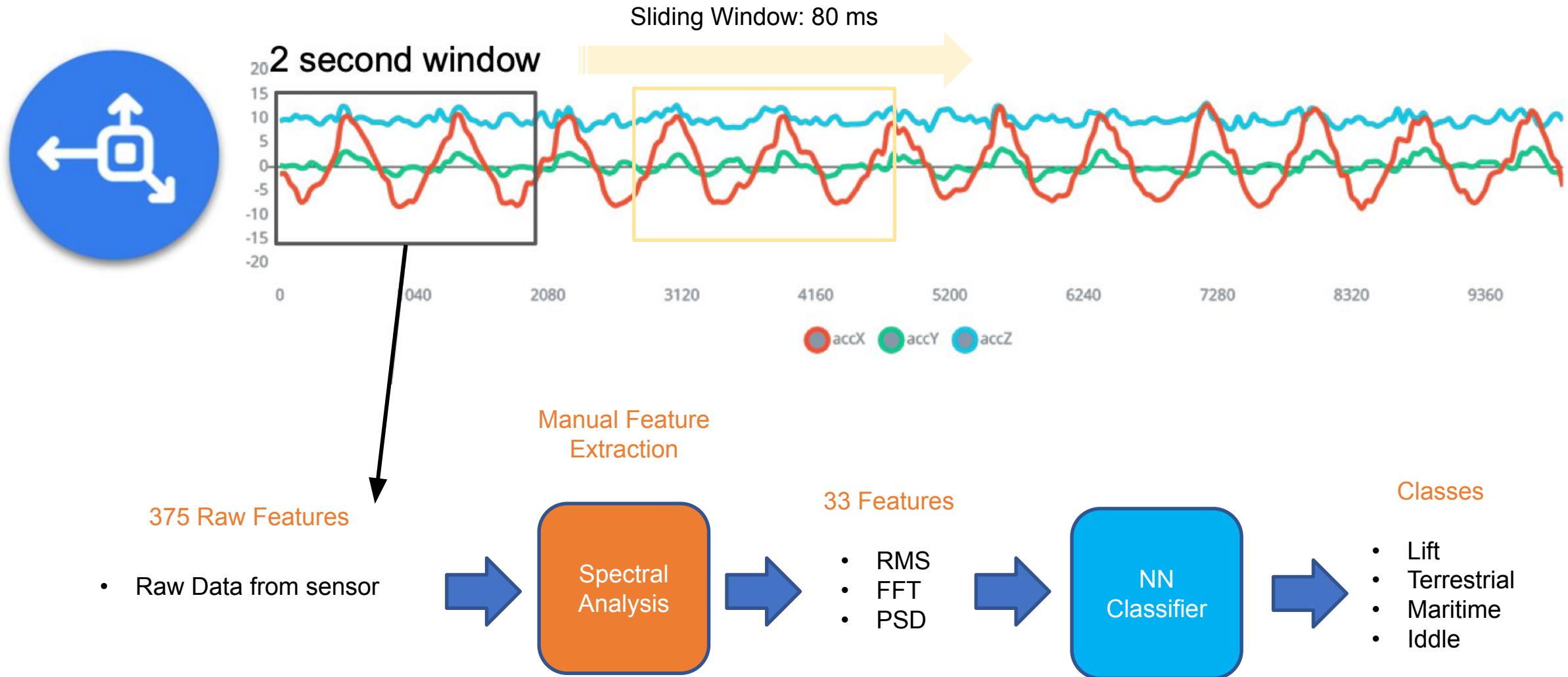
Spectral Analysis

11 Features

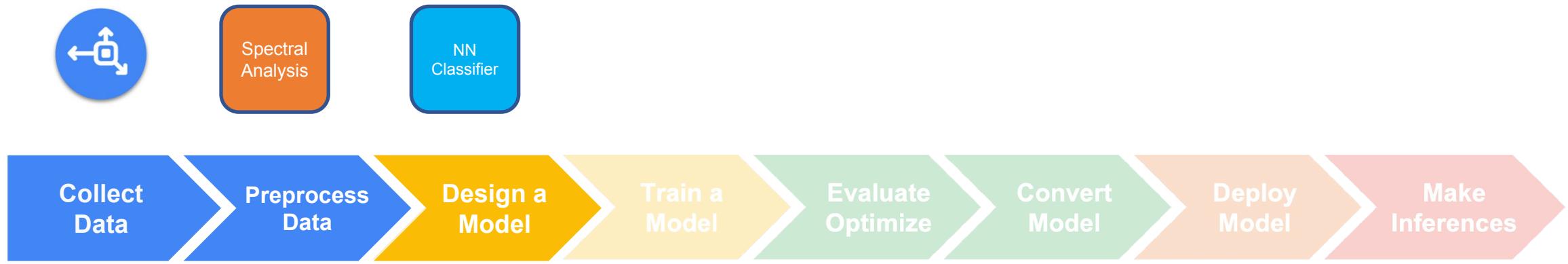
11 Features

11 Features

accX RMS	accY RMS
accX Peak	accY Peak
accX Spec	accY Spec
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 Peak 3 Height
accZ Spectral Power 0.1 - 0.5	accZ Spectral Power 0.5 - 1.0
accZ Spectral Power 0.5 - 1.0	accZ Spectral Power 1.0 - 2.0
accZ Spectral Power 1.0 - 2.0	accZ Spectral Power 2.0 - 5.0
accZ Spectral Power 2.0 - 5.0	



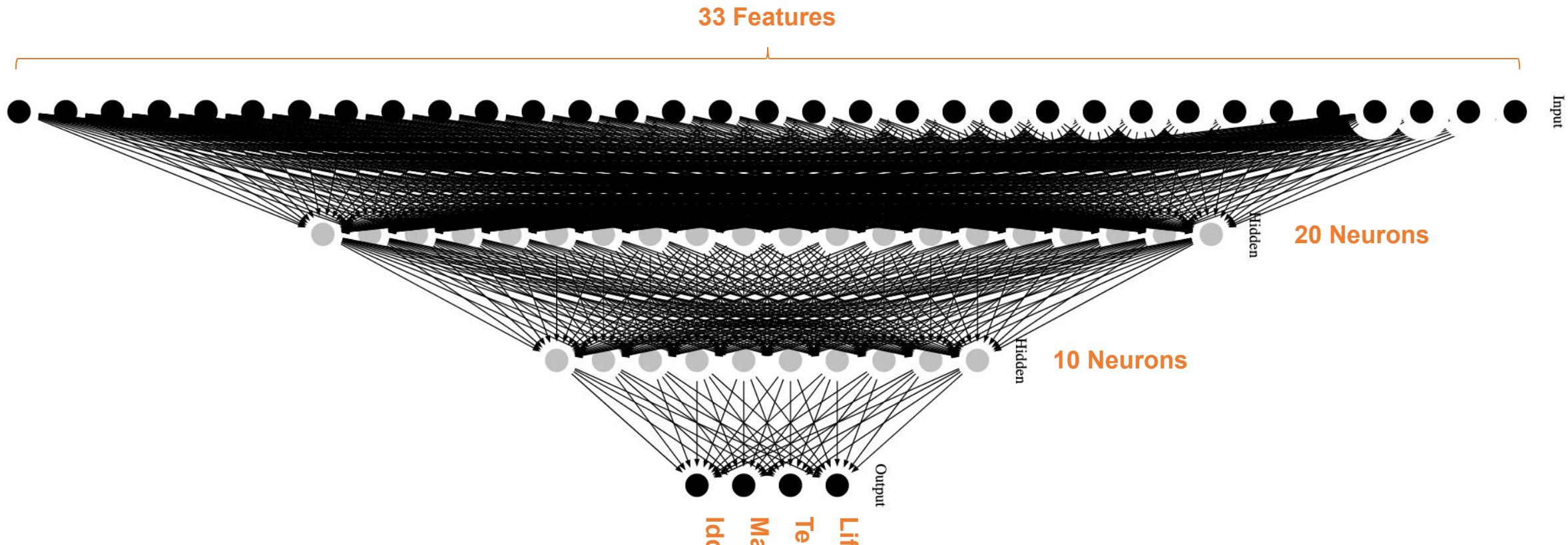
# Model Design (NN Classifier)



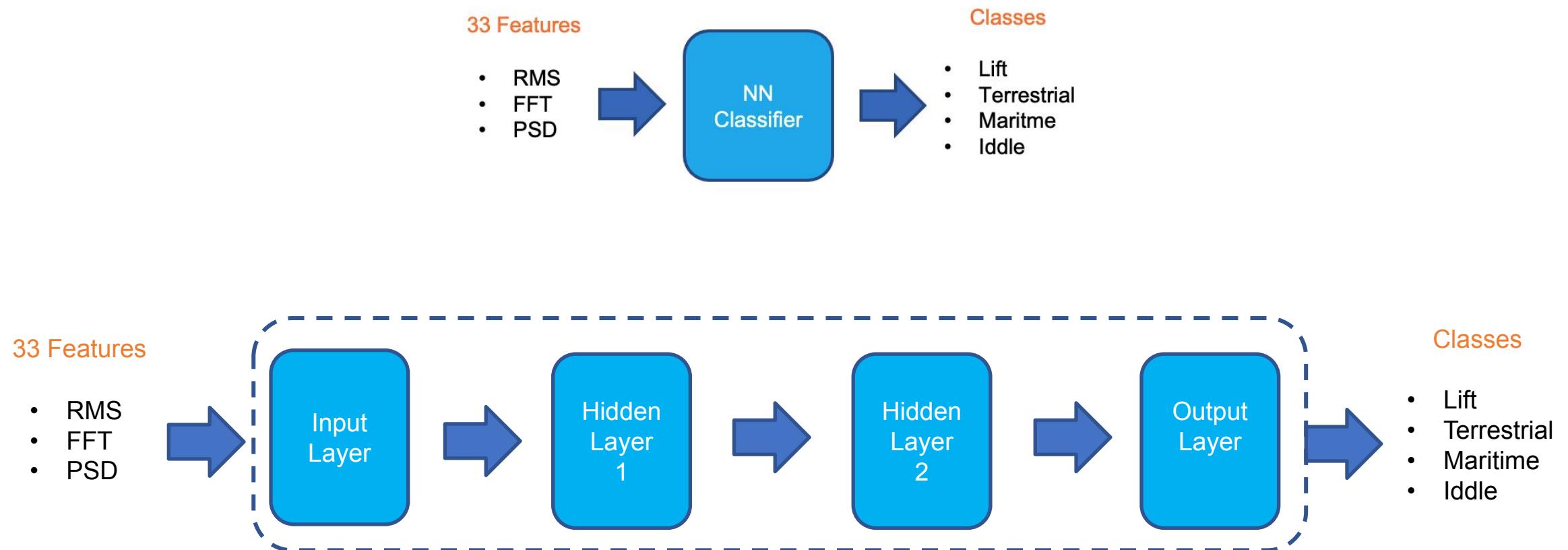
# Model Design (NN Classifier)



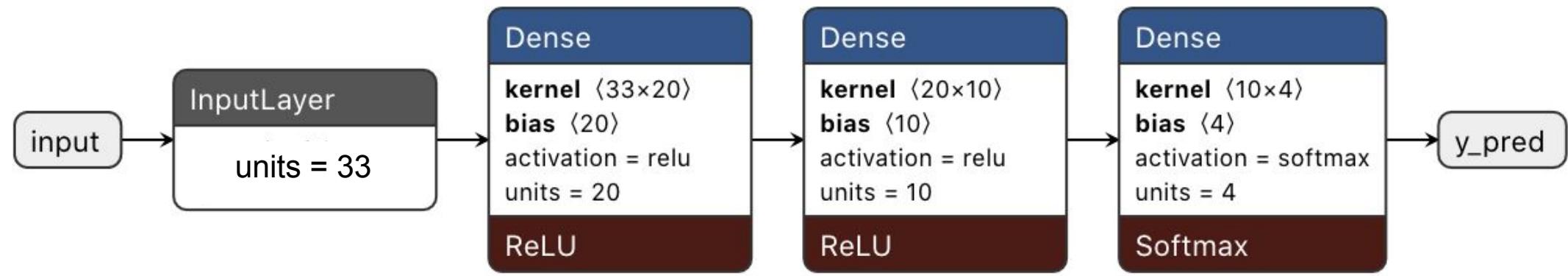
# Model Design (DNN Classifier)



# Model Design (DNN Classifier)

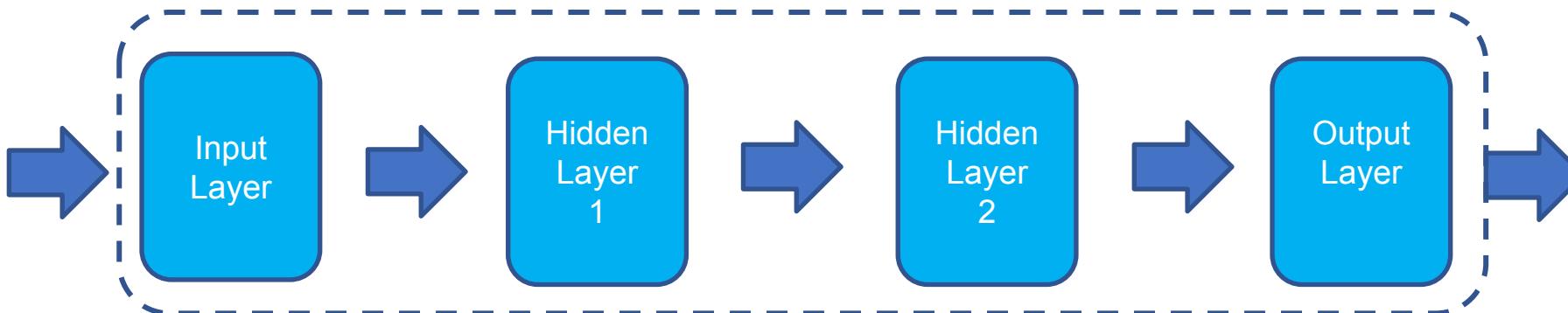


# Model Design (DNN Classifier)



33 Features

- RMS
- FFT
- PSD



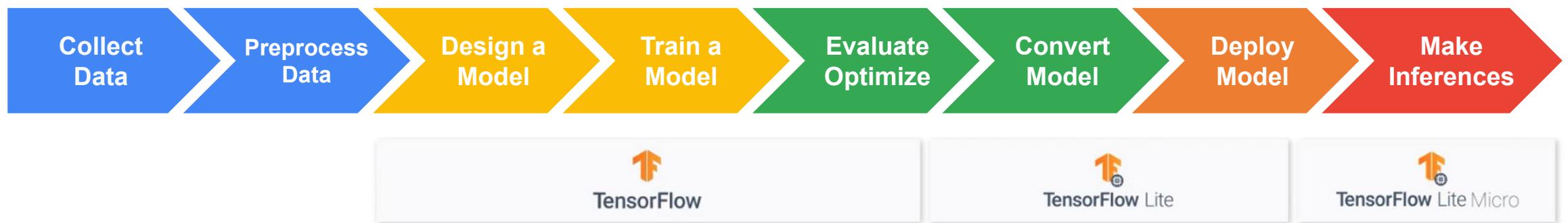
Classes

- Lift
- Terrestrial
- Maritime
- Idle

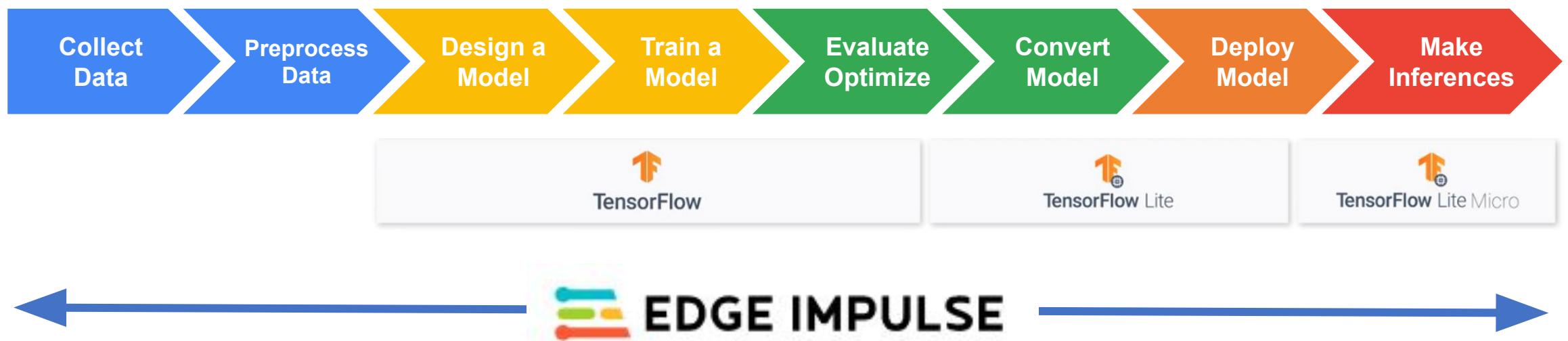
# Train, Evaluate, Convert, Deploy the Model



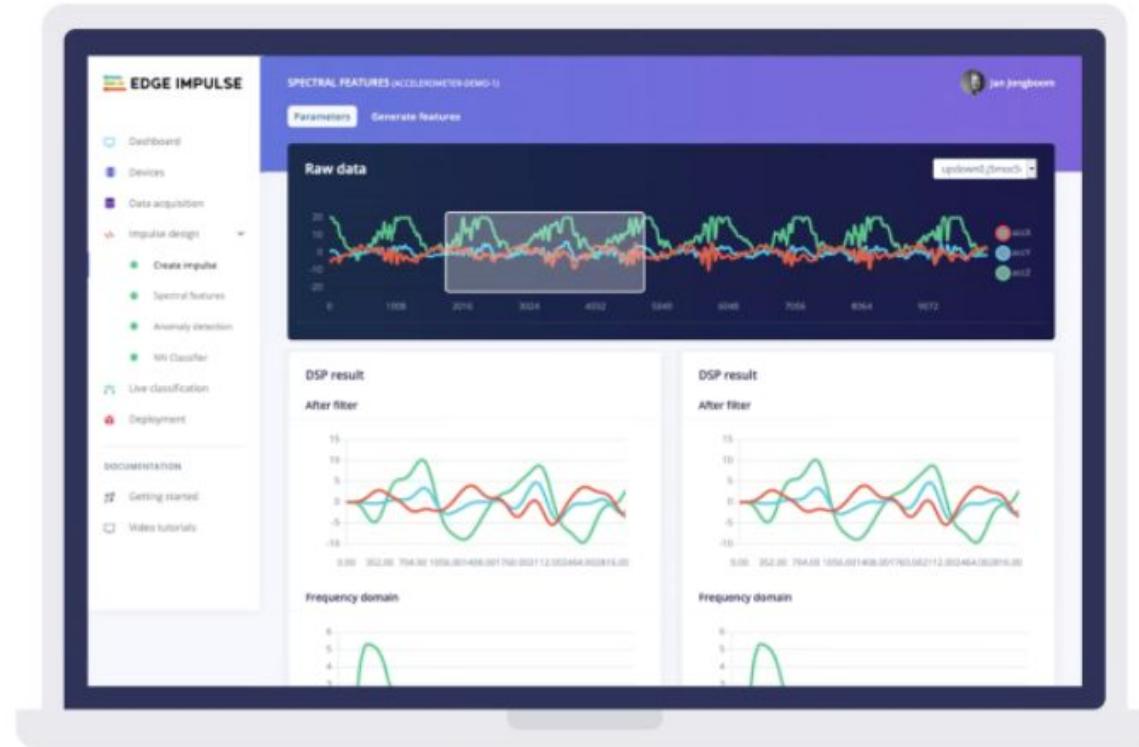
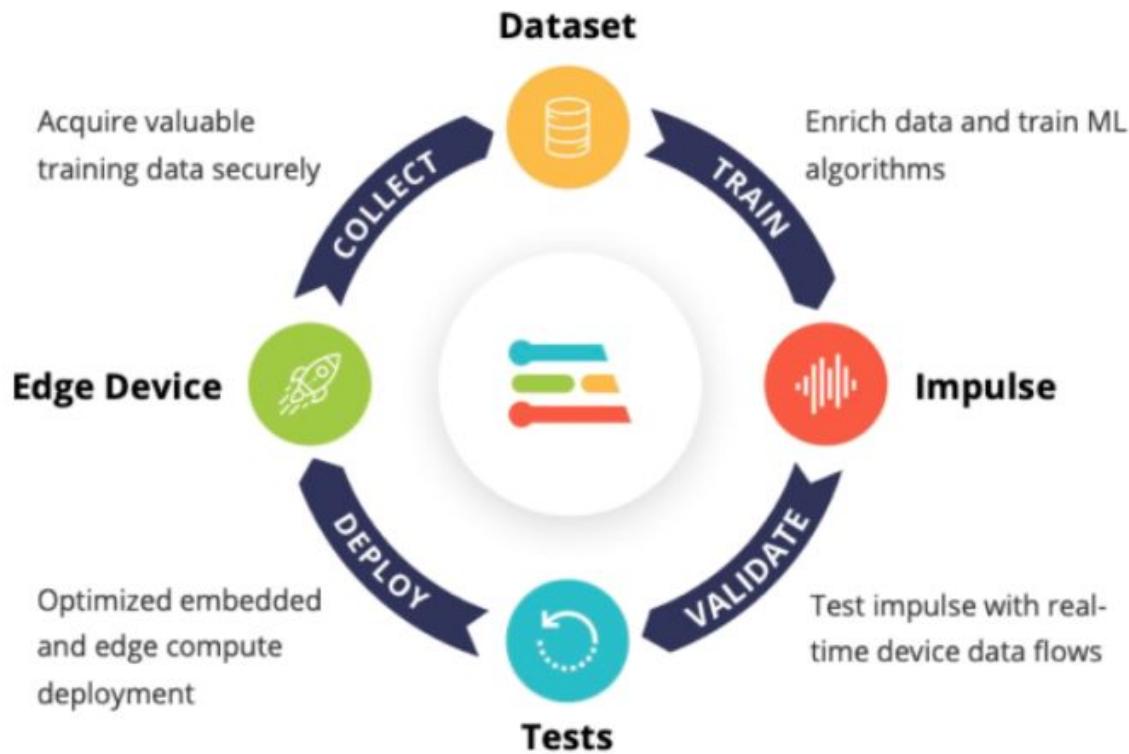
# Train, Evaluate, Convert, Deploy the Model



# Machine Learning Workflow



# EI Studio - Embedded ML platform



Learn more at <http://edgeimpulse.com>



Dashboard - SciTinyML-Motion-Project

studio.edgeimpulse.com/studio/51797

EDGE IMPULSE

Project info Keys Export

MJRoBot (Marcelo Rovai)

Dashboard Devices Data acquisition Impulse design Create impulse Spectral Analysis Neural Network (Ke...) EON Tuner Retrain model Live classification Model testing Versioning Deployment

GETTING STARTED Documentation Forums

MJRoBot (Marcelo Rovai) / SciTinyML-Motion-Project

This is your Edge Impulse project. From here you acquire new training data, design impulses and train models.

Creating your first impulse (100% complete)

Acquire data

Every Machine Learning project starts with data. You can capture data from a development board or your phone, or import data you already collected.

LET'S COLLECT SOME DATA

Design an impulse

Teach the model to interpret previously unseen data, based on historical data. Use this to categorize new data, or to find anomalies in sensor readings.

GETTING STARTED: CONTINUOUS MOTION RECOGNITION

GETTING STARTED: RESPONDING TO YOUR VOICE

GETTING STARTED: ADDING SIGHT TO YOUR SENSORS

Deploy

Package the complete impulse up, from signal processing code to trained model, and deploy it on your device. This ensures that the impulse runs with low latency and without requiring a network connection.

DEPLOY YOUR MODEL

Download block output

Sharing

Your project is private.

Make this project public

Summary

DEVICES CONNECTED 1

DATA COLLECTED 6m 41s

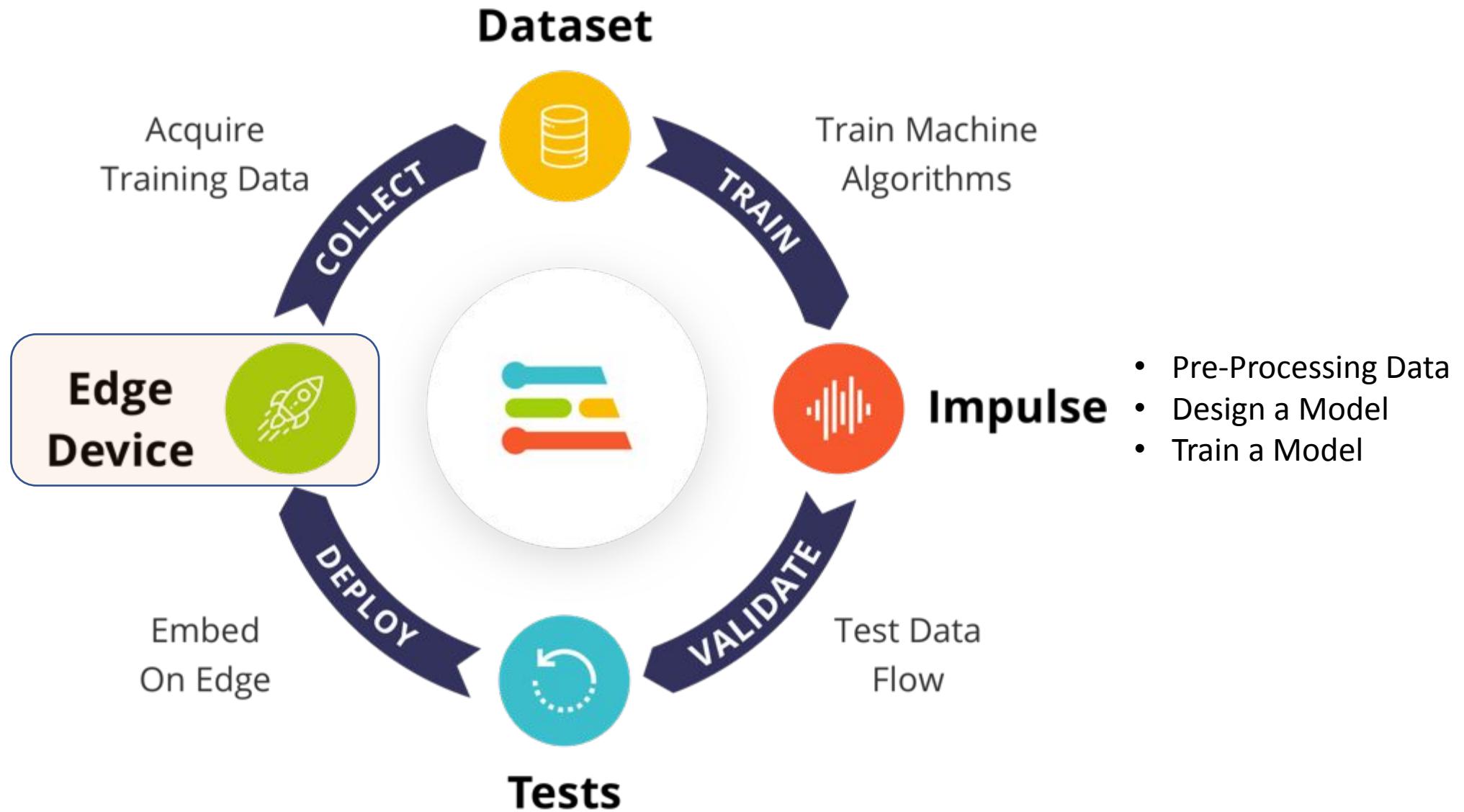
Collaborators

MJRoBot (Marcelo Rovai) OWNER

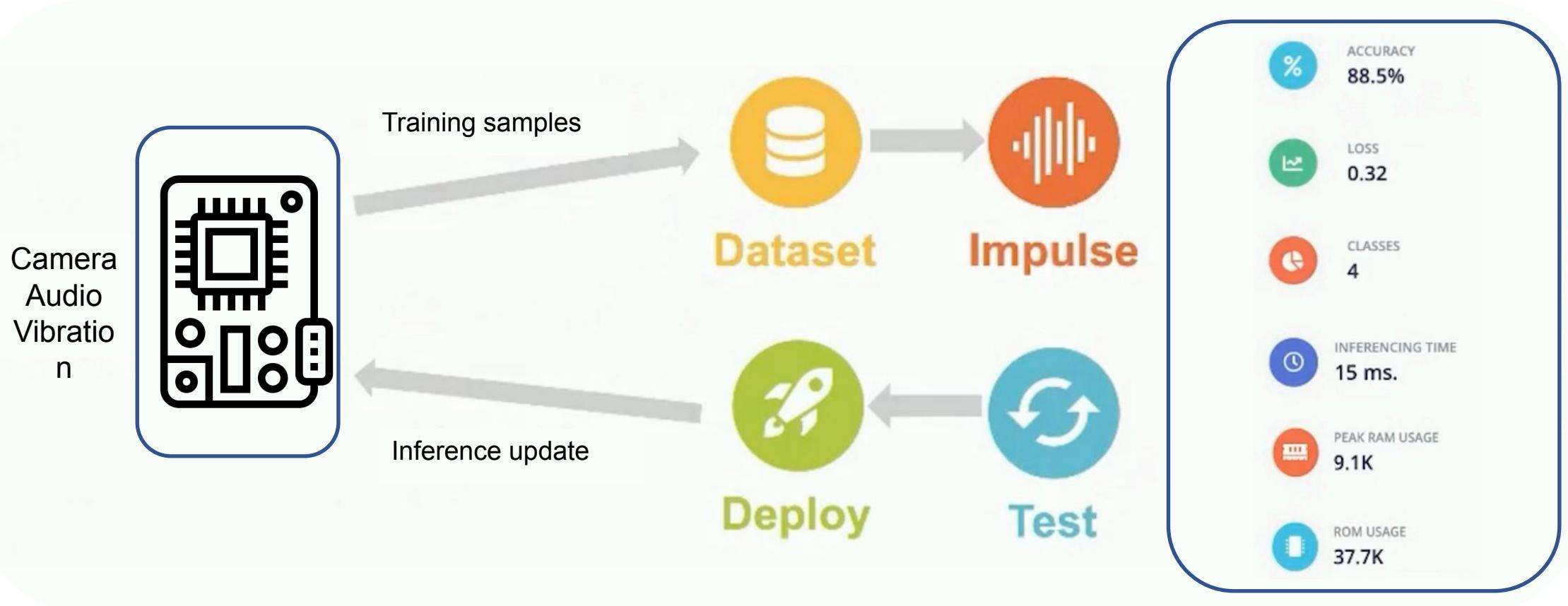
Project info

Project ID 51797

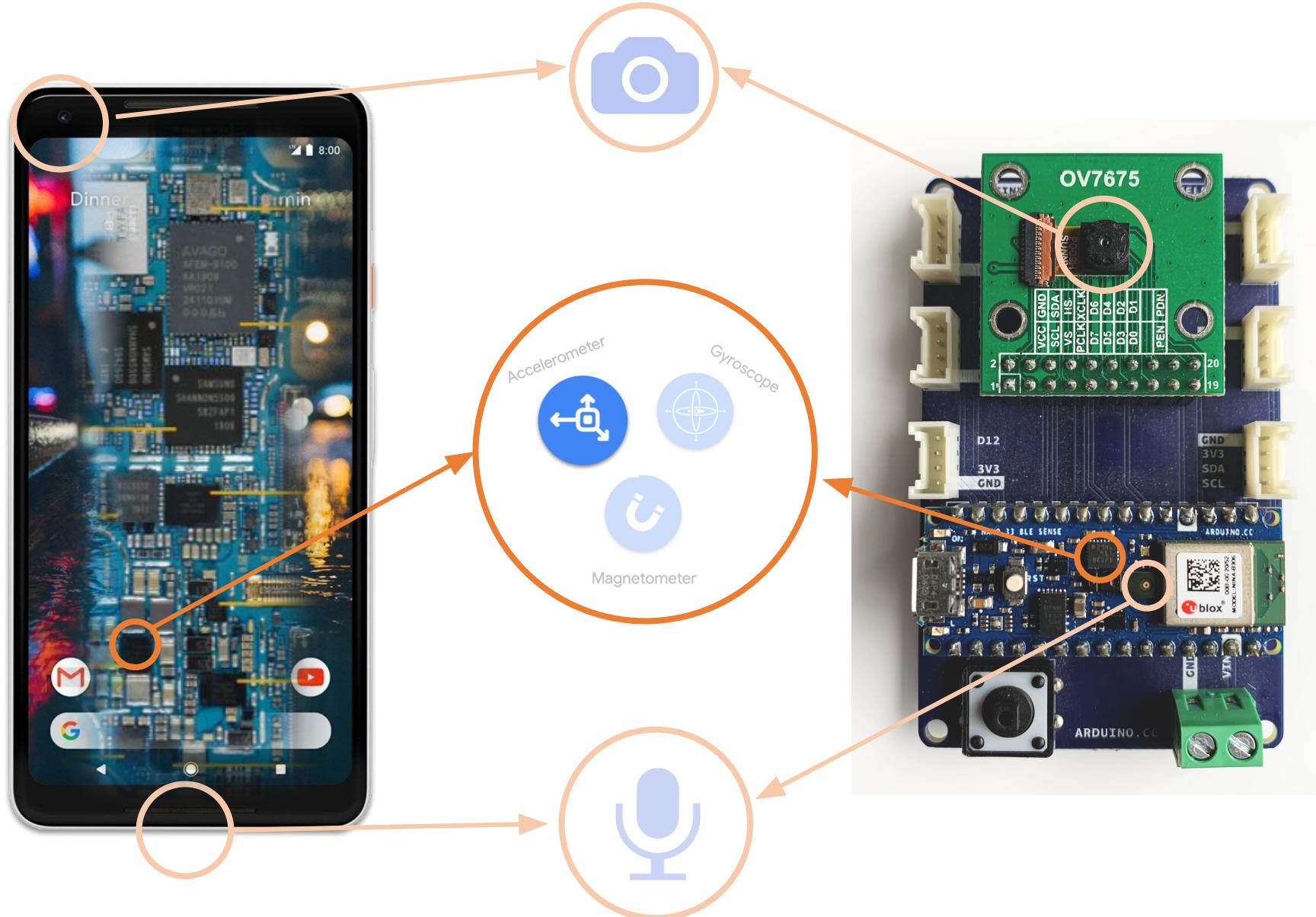
<https://studio.edgeimpulse.com/public/51963/latest>



# Data-driven engineering



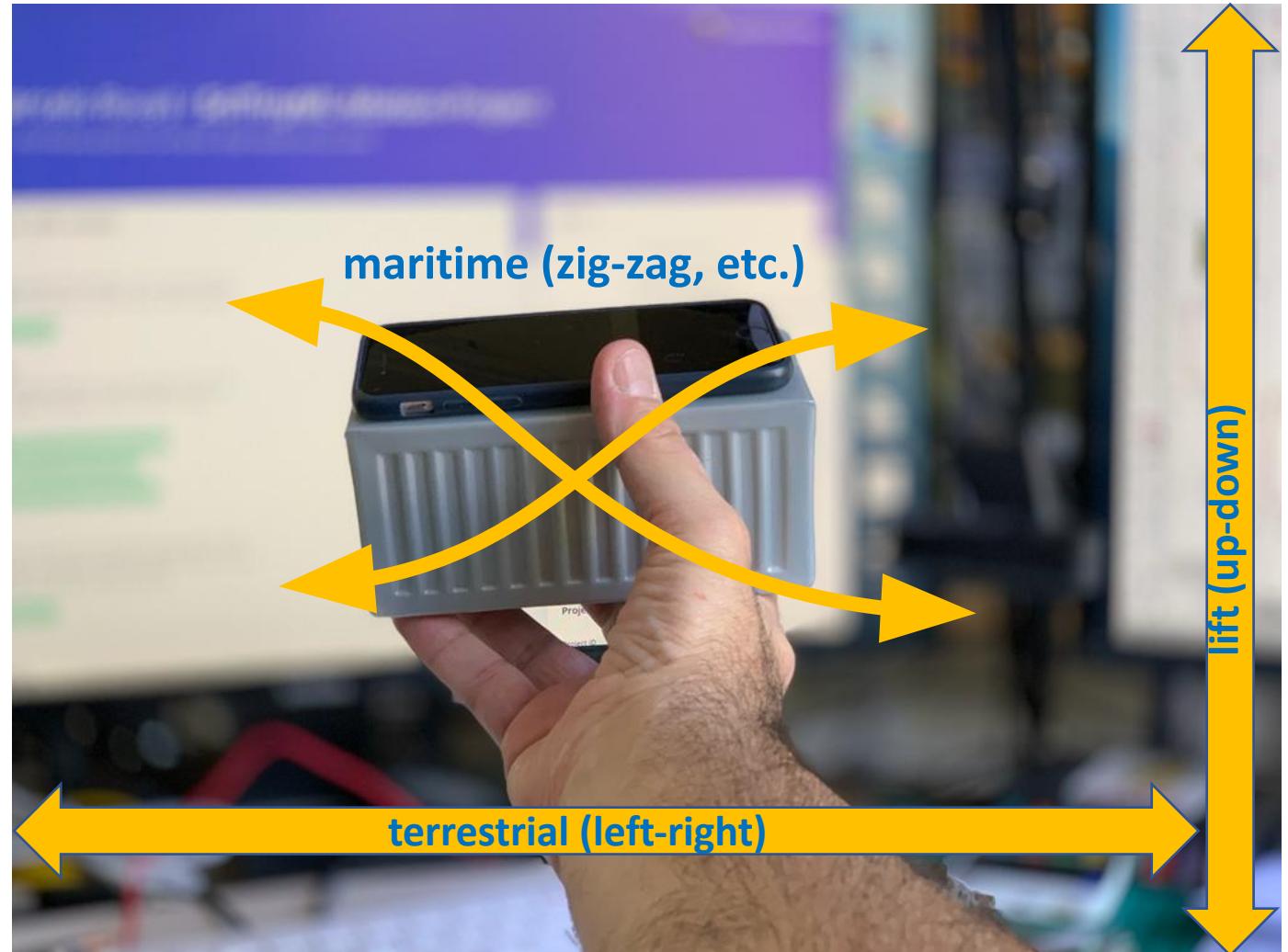
# Sensor - IMU (Inertial Measurement Unit)



# Motion Classification

## Transportation Classes

- **lift** (up-down)
- **terrestrial** (left-right)
- **maritime** (zig-zag, etc.)
- **idle**



# Motion Classification

## Transportation Classes

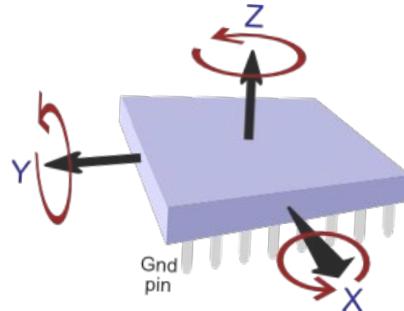
- **lift** (up-down)
- **terrestrial** (left-right)
- **maritime** (zig-zag, etc.)
- **idle**



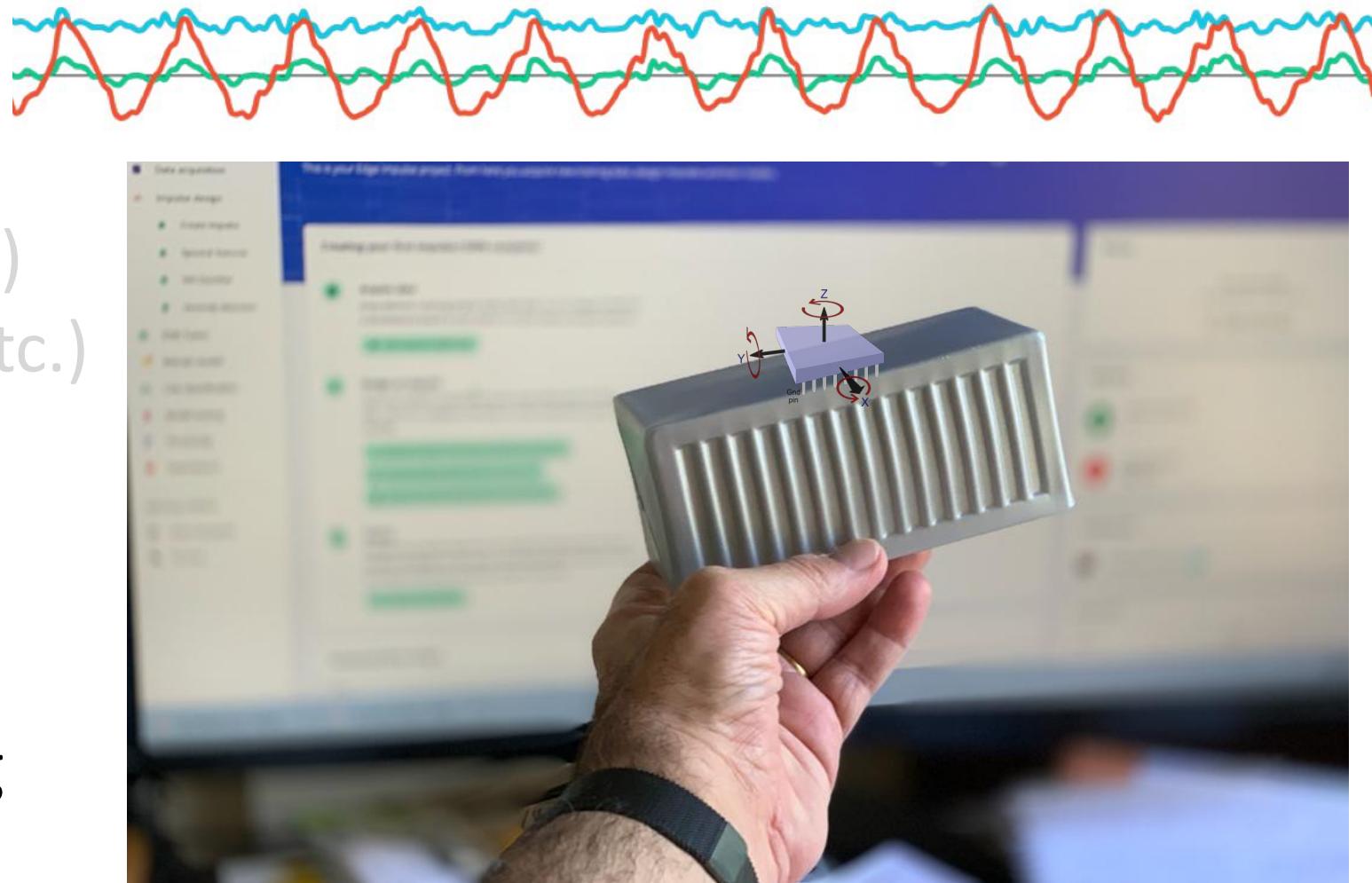
# Motion Classification

## Transportation Classes

- **lift** (up-down)
- **terrestrial** (left-right)
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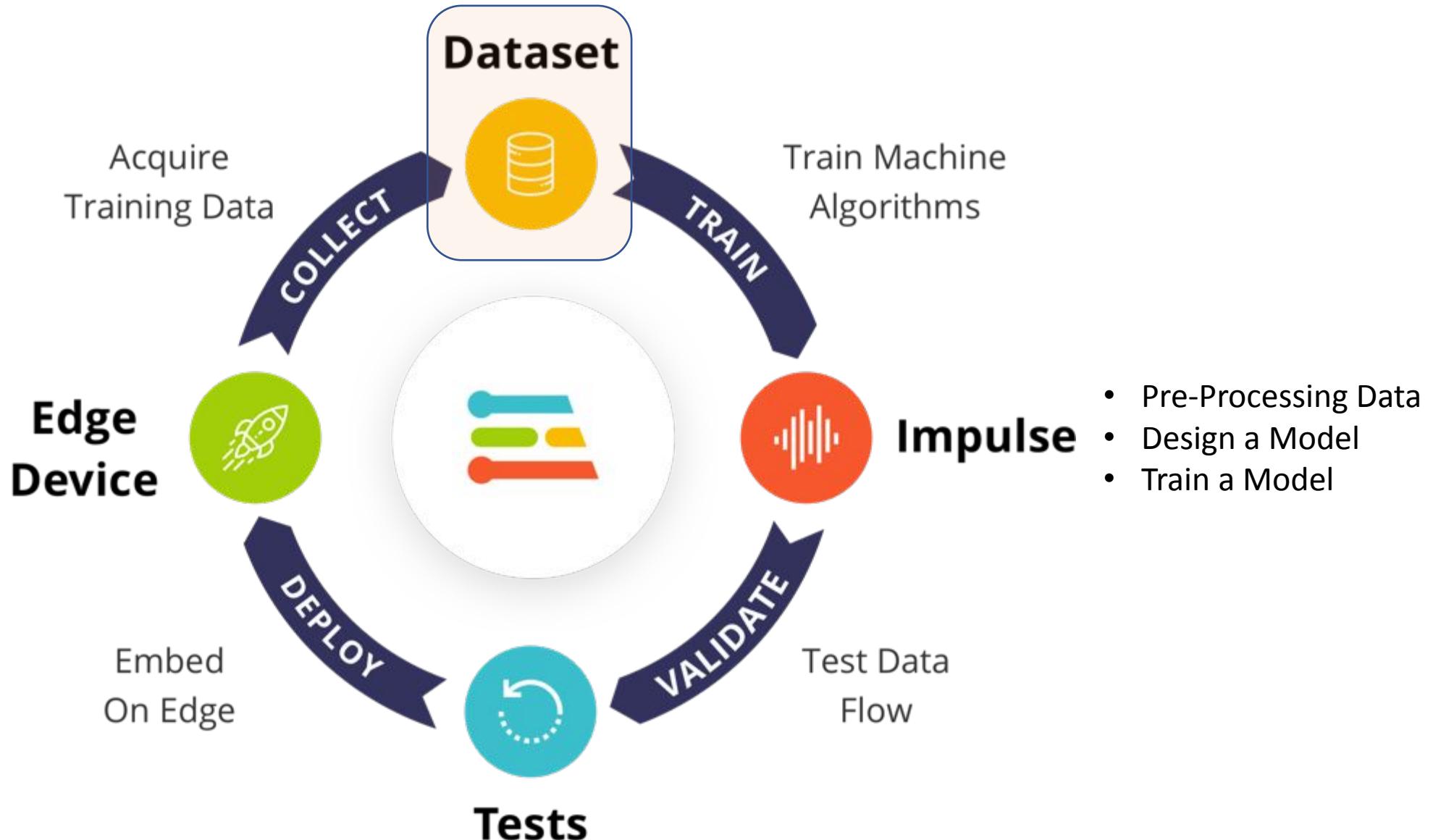


**Data:** collect & test using  
**accelerometer** as sensor



# Dataset Collection

## Using Smart-Phone



Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

Dashboard

Devices

Data acquisition

Impulse design

Create impulse

Retrain model

Live classification

Model testing

Versioning

Deployment

GETTING STARTED

Documentation

Forums

DEVICES (TINYML4D - PROJECT SETUP)

Your projects

Collect data

These are the ways you can 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.

**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**

+ Connect a new device

Marcelo Rovai

© 2021 Edge Impulse Inc.

A yellow arrow points to the 'Show QR code' button in the 'Use your mobile phone' section of the 'Collect data' modal.

Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

DEVICES (TINYML4D - PROJECT SETUP)

Your devices

+ Connect a new device

These are devices that are connected to the Edge Impulse remote management API, or have posted data to the ingestion SDK.

Collect data

You can collect data from any smartphone. From your smartphone go to [this URL](#), or scan the QR code below.



© 2021 Ed

Dashboard

Devices

Data acquisition

Impulse design

Create impulse

Retrain model

Live classification

Model testing

Versioning

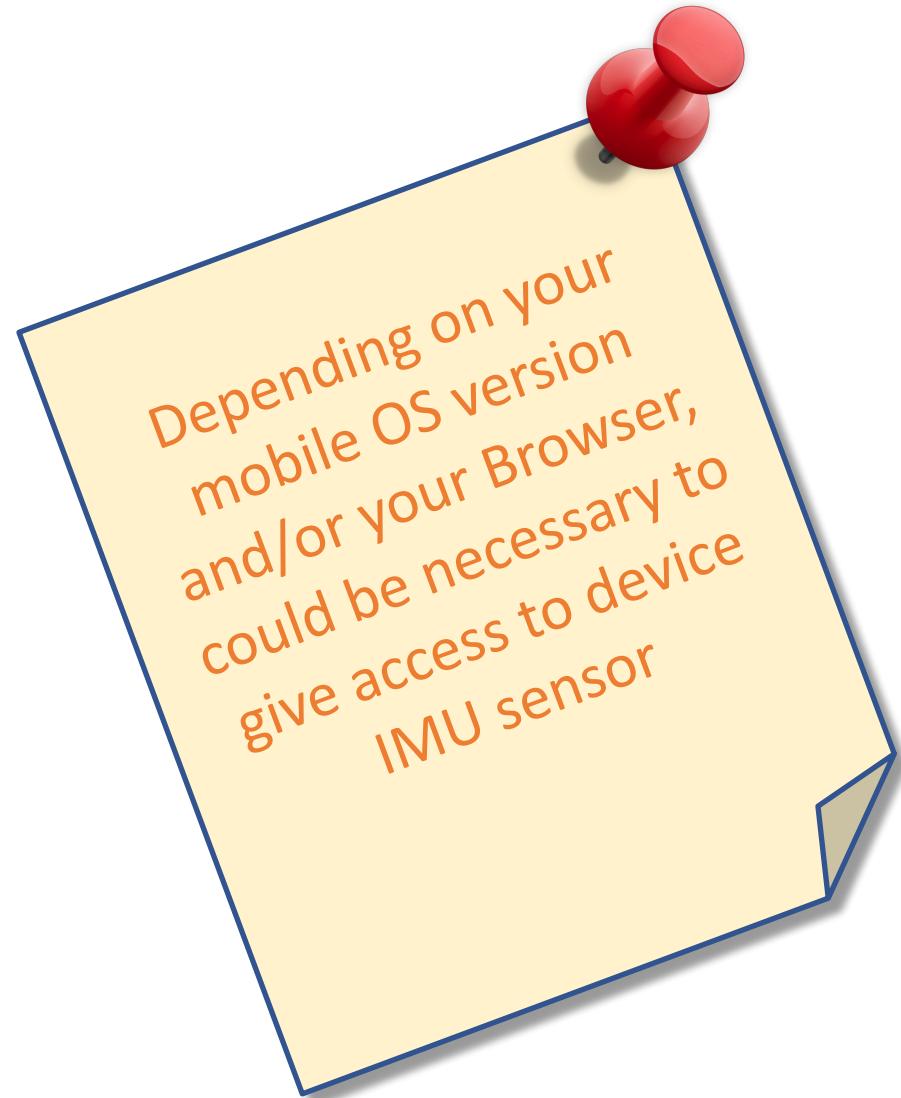
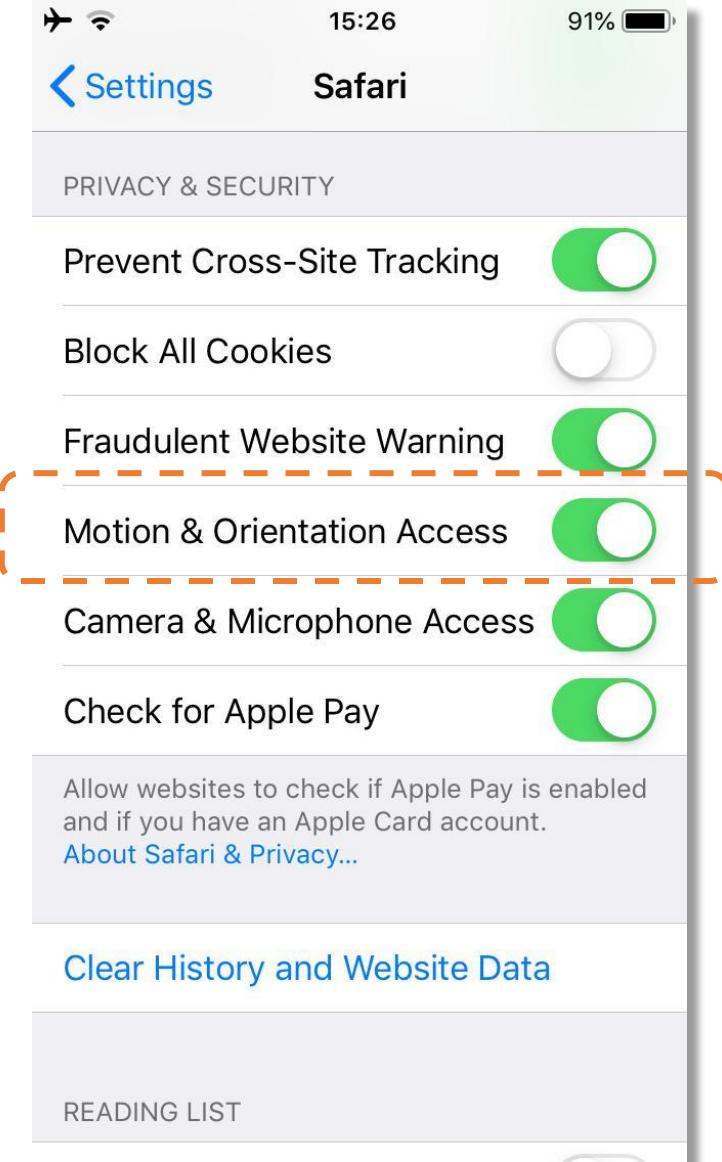
Deployment

GETTING STARTED

Documentation

Forums





Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

Devices

Your devices

These are devices that are connected to the Edge Impulse remote management API, or have posted data to the ingestion SDK.

NAME	ID	TYPE	SENSORS	REMO...	LAST SEEN
phone_kq6ray4k	phone_kq6ray4k	MOBILE CLIENT	Accelerometer, Microphone	...	Today, 12:06:04

+ Connect a new device

Collect data

Device phone\_kq6ray4k is now connected

Get started!

© 2021 Edge Impulse Inc.

Camera 12:07 22% smartphone.edgeimpulse.com

Data collection

Connected as phone\_kq6ray4k

You can collect data from this

A large yellow arrow points upwards towards the 'Get started!' button in the 'Collect data' modal.

Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

DEVICES (TINYML4D - PROJECT SETUP)

Marcelo Rovai

Your devices

+ Connect a new device

These are devices that are connected to the Edge Impulse remote management API, or have posted data to the ingestion SDK.

NAME	ID	TYPE	SENSORS	REMO...	LAST SEEN
phone_kq6ray4k	phone_kq6ray4k	MOBILE_CLIENT	Accelerometer, Microph...	●	Today, 12:06:04

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Dashboard

Devices (highlighted with orange dashed box)

Data acquisition

Impulse design

- Create impulse

Retrain model

Live classification

Model testing

Versioning

Deployment

GETTING STARTED

Documentation

Forums

Camera 12:07 22%

smartphone.edgeimpulse.com

Data collection

Connected as phone\_kq6ray4k

You can collect data from this



DATA ACQUISITION (TINYML4D - PROJECT SETUP)

Training data Test data

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

DATA COLLECTED -

LABELS 0

Record new data

Device ⓘ No devices connected

Label up\_down

Sensor

RAW DATA Click on a sample to load...

Connect using WebUSB

12:20 44% smartphone.edgeimpulse.com

Data collection

Not connected

Refresh this page to reconnect to Edge Impulse

The screenshot shows the Edge Impulse Data Acquisition interface for the TinyML4D project setup. On the left sidebar, under the 'Data acquisition' section, there is an orange dashed box highlighting the 'Devices' and 'Data acquisition' items. The main panel displays a message: 'Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options'. Below this, it shows 'DATA COLLECTED -' and 'LABELS 0'. A large central area is titled 'Record new data' with a sub-section 'Device ⓘ' which displays 'No devices connected'. To the right, there's a 'Connect using WebUSB' button. The top right corner shows a user profile for 'Marcelo Rovai' and a system status bar with '12:20' and '44%' battery level. A yellow arrow points to the 'No devices connected' message. In the bottom right corner, there's a large red circle with a white 'X' and the text 'Not connected' followed by the instruction 'Refresh this page to reconnect to Edge Impulse'.

**Collect Data**

The screenshot shows the Edge Impulse Data Acquisition interface. On the left, a sidebar menu includes options like Dashboard, Devices, Data acquisition (highlighted with an orange dashed box), and Create impulse, Spectral Analysis, Neural Network (Keras). The main area displays 'DATA ACQUISITION (SCITINYML-MOTION-PROJECT)' with tabs for Training data and Test data. A message says 'Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options'. Below is a summary: 'DATA COLLECTED 5m 13s' and 'TRAIN / TEST SPLIT 80% / 20%'. A 'Collected data' table lists 15 entries, mostly labeled 'idle'. To the right, the 'Record new data' section shows a 'Device' dropdown set to 'phone\_kq6ray4k', a 'Label' input set to 'maritime' (highlighted with an orange dashed box), a 'Sample length (ms.)' input set to '10000', a 'Sensor' dropdown set to 'Accelerometer' (highlighted with an orange dashed box), a 'Frequency' dropdown set to '62.5Hz', and a large blue 'Start sampling' button. A yellow arrow points from the 'Start sampling' button towards the 'Data collection' panel on the right. The 'Data collection' panel shows a circular progress bar with '4s' and a 'Recording data' status. The top right corner shows the user profile 'MJRoBot (Marcelo Rovai)'.

DATA ACQUISITION (SCITINYML-MOTION-PROJECT)

Training data Test data

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

DATA COLLECTED  
5m 13s

TRAIN / TEST SPLIT  
80% / 20%

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
idle.2hstvpk2	idle	Oct 14 2021, 17:54:22	10s	⋮
idle.2hstuaut	idle	Oct 14 2021, 17:53:34	10s	⋮
idle.2hstt0q3	idle	Oct 14 2021, 17:53:16	10s	⋮
idle.2hstt9dk	idle	Oct 14 2021, 17:53:00	10s	⋮
idle.2hstp4a	idle	Oct 14 2021, 17:52:43	10s	⋮
idle.2hstrkad	idle	Oct 14 2021, 17:52:06	10s	⋮
idle.2hstr3kf	idle	Oct 14 2021, 17:51:49	10s	⋮
idle.2hstqaj	idle	Oct 14 2021, 17:51:32	10s	⋮
maritime.2hstpku3	maritime	Oct 14 2021, 17:51:01	10s	⋮
maritime.2hsto9ki	maritime	Oct 14 2021, 17:50:16	10s	⋮
maritime.2hstnnqu	maritime	Oct 14 2021, 17:49:58	10s	⋮
maritime.2hstn60c	maritime	Oct 14 2021, 17:49:40	10s	⋮

Record new data

Device: phone\_kq6ray4k

Label: maritime

Sample length (ms.): 10000

Sensor: Accelerometer

Frequency: 62.5Hz

Start sampling

Sensor dropdown: Accelerometer (highlighted with an orange dashed box)

Data collection

4s

Recording data

## Collect Data

EDGE IMPULSE

DATA ACQUISITION (SCITINYML-MOTION-PROJECT)

Training data Test data

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

DATA COLLECTED  
5m 13s

TRAIN / TEST SPLIT  
80% / 20%

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
idle.2hstvpk2	idle	Oct 14 2021, 17:54:22	10s
idle.2hstuaut	idle	Oct 14 2021, 17:53:34	10s
idle.2hstt0q3	idle	Oct 14 2021, 17:53:16	10s
idle.2hstt9dk	idle	Oct 14 2021, 17:53:00	10s
idle.2hstp4a	idle	Oct 14 2021, 17:52:43	10s
idle.2hstrkad	idle	Oct 14 2021, 17:52:06	10s
idle.2hstr3kf	idle	Oct 14 2021, 17:51:49	10s
idle.2hstqaj	idle	Oct 14 2021, 17:51:32	10s
maritime.2hstpku3	maritime	Oct 14 2021, 17:51:01	10s
maritime.2hsto9ki	maritime	Oct 14 2021, 17:50:16	10s
maritime.2hstnnqu	maritime	Oct 14 2021, 17:49:58	10s
maritime.2hstn60c	maritime	Oct 14 2021, 17:49:40	10s

Record new data

Device: phone\_kq6ray4k

Label: maritime

Sample length (ms.): 10000

Sensor: Accelerometer

Frequency: 62.5Hz

Start sampling

RAW DATA  
maritime.2hstpku3

accX accY accZ

The screenshot shows the Edge Impulse Data Acquisition interface. A large blue arrow on the left points towards the 'Data acquisition' section. The main area displays a summary of collected data (5m 13s total, 80% train, 20% test split) and a table of individual samples with columns for name, label, added date, and length. To the right, there's a 'Record new data' section with fields for device (set to 'phone\_kq6ray4k'), label ('maritime'), sample length (10000 ms), sensor ('Accelerometer'), and frequency (62.5Hz). Below this is a 'RAW DATA' plot titled 'maritime.2hstpku3' showing three overlapping time-series lines (accX, accY, accZ) over a 10-second interval. The plot includes numerical scales from -20 to 20 on the y-axis and sample indices from 1008 to 9075 on the x-axis.

Collect  
Data

## Original Dataset

## Original Dataset

Collect  
Data

Training Set

Test Set

## Original Dataset

Training Set

Test Set

Training Set

Validation Set

Test Set

Collect  
Data

## Original Dataset

Training Set

Test Set

Collect  
Data

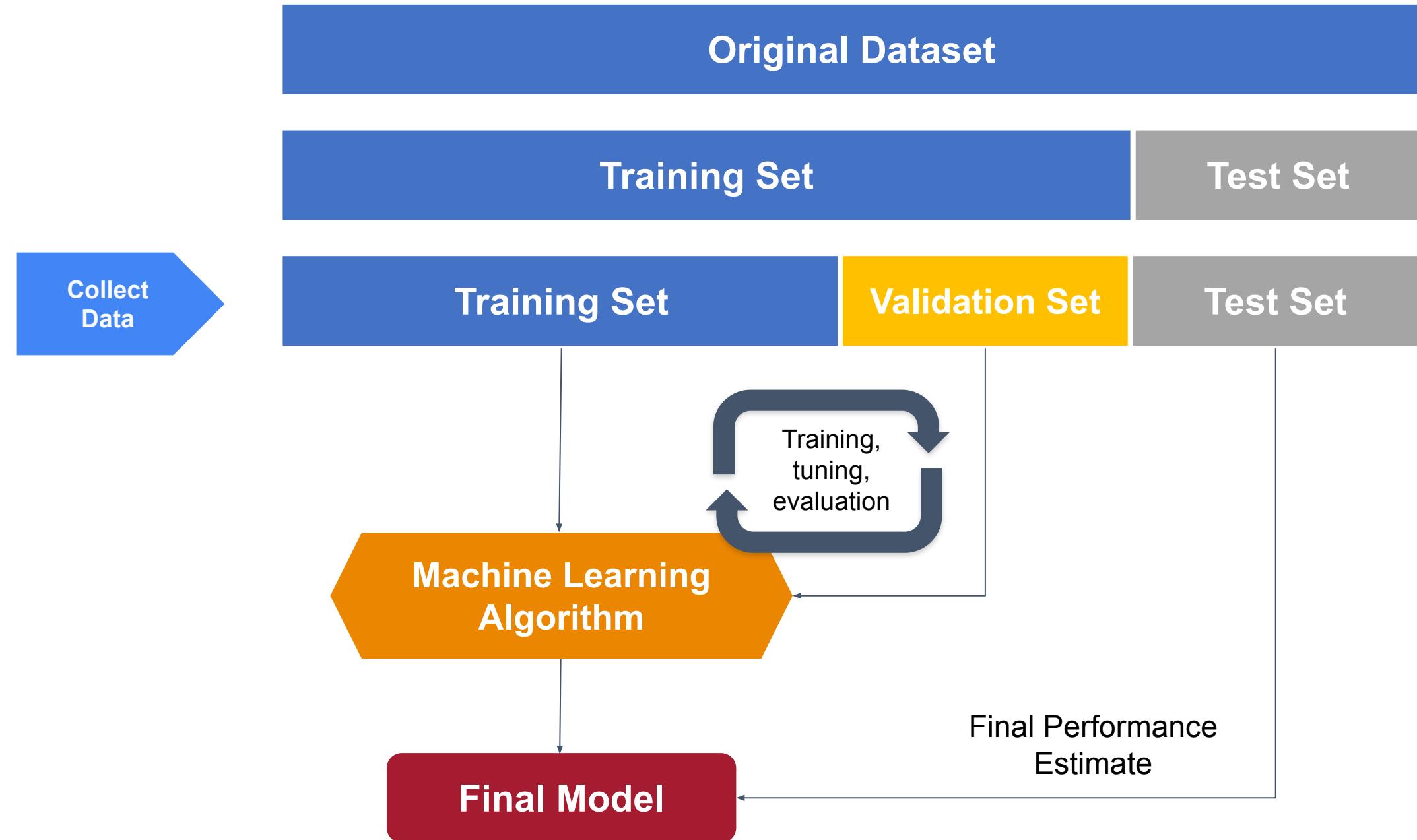
Training Set

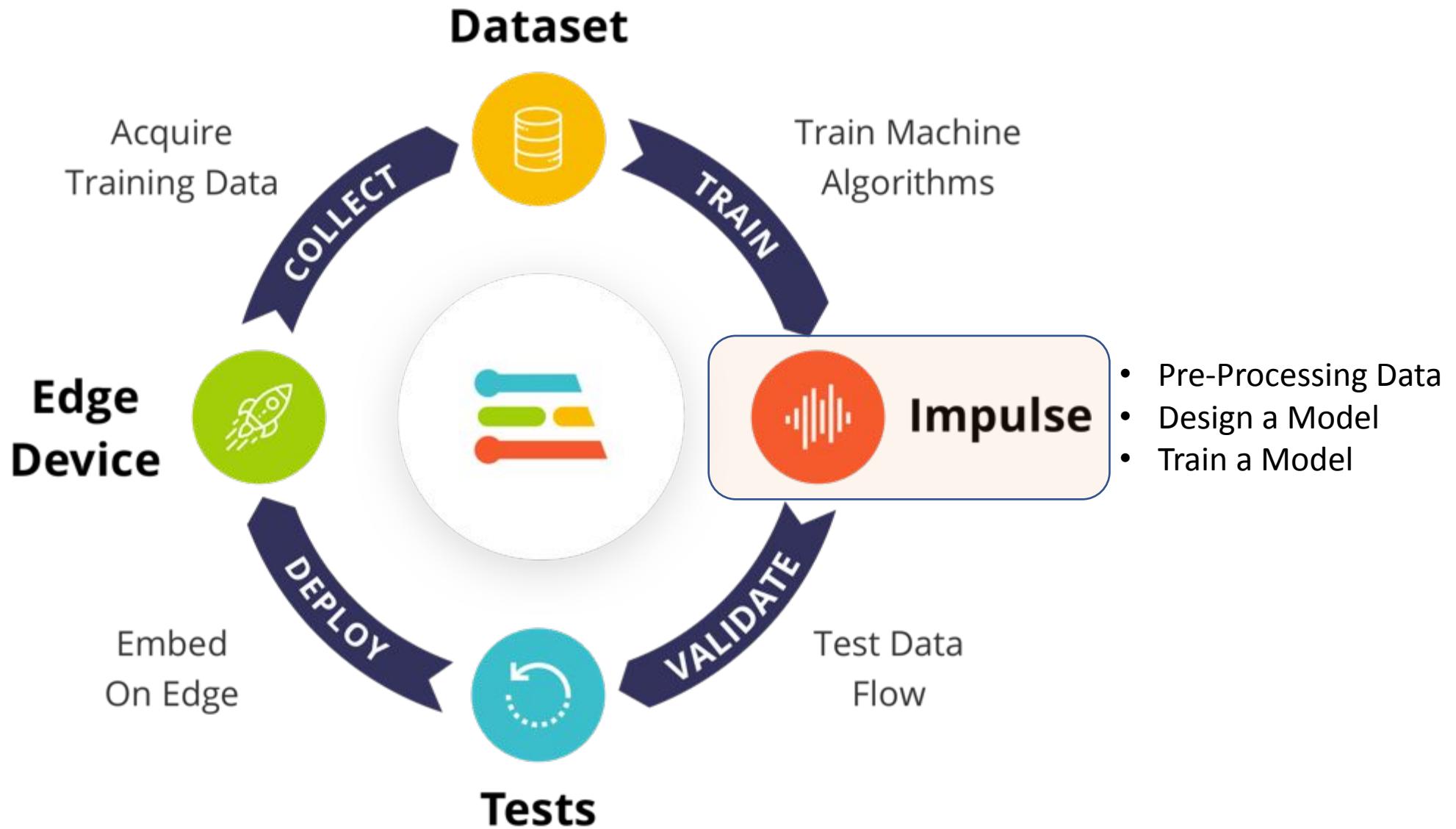
Validation Set

Test Set

Training,  
tuning,  
evaluation

Machine Learning  
Algorithm





Time series data

Axes  
accX, accY, accZ

Window size  
2000 ms.

Window increase  
80 ms.

Frequency (Hz)  
62.5

Zero-pad data

Spectral Analysis

Name  
Spectral Analysis

Input axes  
 accX  
 accY  
 accZ

Neural Network (Keras)

Name  
Neural Network (Keras)

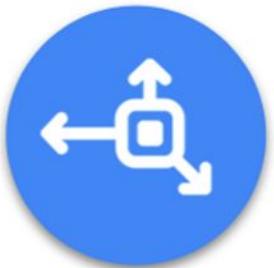
Input features  
 Spectral Analysis

Output features  
4 (idle, lift, maritime, terrestrial)

Output features

4 (idle, lift, maritime, terrestrial)

**Save Impulse**



Spectral Analysis



NN Classifier



Classes

- Lift
- Terrestrial
- Maritime
- Idle

# Preprocess Data

Spectral Analysis - SciTinyML - [+](#)

studio.edgeimpulse.com/studio/51797/dsp/spectral-analysis/11

EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
  - Create impulse
  - Spectral Analysis
  - Neural Network (Keras)
- EON Tuner
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

GETTING STARTED

- Documentation
- Forums

Raw data

Raw features

375 Raw Features

Parameters

Scaling

Scale axes

Filter

Type: low

Cut-off frequency: 3

Order: 6

Spectral power

FFT length: 128

No. of peaks: 3

Peaks threshold: 0.1

Power edges: 0.1, 0.5, 1.0, 2.0, 5.0

RMS

FFT

PSD

Save parameters

33 Processed Features

DSP result

After filter

Frequency domain

Spectral power

Processed features

On-device performance

PROCESSING TIME: 8 ms.

PEAK RAM USAGE: 5 KB

maritime.2hstrnnq (maritime)

accX  
accY  
accZ

The screenshot shows the Edge Impulse Studio interface for a spectral analysis project. On the left, a sidebar lists various tools and documentation. The main area displays raw data from three acceleration sensors (accX, accY, accZ) over time, followed by a list of 375 raw features. Below this, a set of parameters for spectral power analysis is shown, including FFT length (128), number of peaks (3), and a power edges list (0.1, 0.5, 1.0, 2.0, 5.0). A large orange bracket groups RMS, FFT, and PSD under the heading '33 Processed Features'. To the right, processed data is visualized in several plots: a frequency domain plot showing amplitude vs. frequency, a spectral power plot on a log scale, and a plot of 33 processed features. Performance metrics at the bottom indicate a processing time of 8 ms and peak RAM usage of 5 KB.

**Preprocess Data**

The screenshot shows the Edge Impulse Studio interface for a project titled "SPECTRAL ANALYSIS (SCITINYML-MOTION-PROJECT) #1 - EON Tuner Primary".

**Left Sidebar:**

- Dashboard
- Devices
- Data acquisition
- Impulse design
  - Create impulse
  - Spectral Analysis
  - Neural Network (Ke...)
- EON Tuner
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

**GETTING STARTED**

- Documentation
- Forums

**Main Content Area:**

**Spectral Analysis (SciTinyML-Motion-Project) #1 - EON Tuner Primary**

**Parameters** tab selected.

**Training set** details:

- Data in training set: 5m 22s
- Classes: 4 (idle, lift, maritime, terrestrial)
- Window length: 2000 ms.
- Window increase: 80 ms.
- Training windows: 3,230

**Generate features** button.

**Feature explorer (3,132 samples)** section:

- X Axis: accX RMS
- Y Axis: accY RMS
- Z Axis: accZ RMS

Legend: idle (blue), lift (orange), maritime (green), terrestrial (red).

3D scatter plot showing the distribution of samples across the three axes.

**On-device performance** section:

- PROCESSING TIME: 8 ms.
- PEAK RAM USAGE: 5 KB

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**Design a Model**

Neural Network (Keras) - SciTI

studio.edgeimpulse.com/studio/51797/learning/keras/12

**EDGE IMPULSE**

Dashboard

Devices

Data acquisition

Impulse design

- Create impulse
- Spectral Analysis
- Neural Network (Ker...

EON Tuner

Retrain model

Live classification

Model testing

Versioning

Deployment

GETTING STARTED

Documentation

Forums

**Neural Network settings**

Training settings

Number of training cycles ② EPOCHS 30

Learning rate ② Lr 0.0005

Neural network architecture

Input layer (33 features)

Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (4 features)

Start training

Training output

```
graph TD; input --> InputLayer[InputLayer]; InputLayer --> Dense1[Dense<br/>kernel 33x20<br/>bias 20]; Dense1 --> ReLU1[ReLU]; ReLU1 --> Dense2[Dense<br/>kernel 20x10<br/>bias 10]; Dense2 --> ReLU2[ReLU]; ReLU2 --> Dense3[Dense<br/>kernel 10x4<br/>bias 4]; Dense3 --> Softmax[Softmax]; Softmax --> y_pred[y_pred]
```

Train a Model

Neural Network (Keras) - SciTI

studio.edgeimpulse.com/studio/51797/learning/keras/12

### EDGE IMPULSE

Dashboard

Devices

Data acquisition

Impulse design

- Create impulse
- Spectral Analysis
- Neural Network (Keras)

EON Tuner

Retrain model

Live classification

Model testing

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### Neural Network settings

#### Training settings

Number of training cycles ② EPOCHS 30

Learning rate ② Lr 0.0005

#### Neural network architecture

Input layer (33 features)

Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (4 features)

Start training

### Training output

#### Model

Model version: ② Quantized (int8)

#### Last training performance (validation set)

ACCURACY 99.7% LOSS 0.01

#### Confusion matrix (validation set)

	IDLE	LIFT	MARITIME	TERRESTRIAL
IDLE	100%	0%	0%	0%
LIFT	0%	100%	0%	0%
MARITIME	0%	0.6%	99.4%	0%
TERRESTRIAL	0.6%	0%	0%	99.4%
F1 SCORE	1.00	1.00	1.00	1.00

#### Feature explorer (full training set) ②

accX RMS accY RMS accZ RMS

- idle - correct
- lift - correct
- maritime - correct
- terrestrial - correct
- maritime - incorrect
- terrestrial - incorrect

#### On-device performance ②

INFERRING TIME 1 ms. PEAK RAM USAGE 1.7K FLASH USAGE 19.0K

**Evaluate  
Optimize**

Neural Network (Keras) - SciTI

studio.edgeimpulse.com/studio/51797/learning/keras/12

**EDGE IMPULSE**

Dashboard

Devices

Data acquisition

Impulse design

- Create impulse
- Spectral Analysis
- Neural Network (Ke...)

EON Tuner

Retrain model

Live classification

Model testing

Versioning

Deployment

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**Neural Network settings**

Training settings

Number of training cycles ② 30

Learning rate ② 0.0005

Neural network architecture

Input layer (33 features)

Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (4 features)

**Start training**

**Training Set** | **Validation Set**

Machine Learning Algorithm

Training, tuning, evaluation

**Training output**

**Model**

Model version: ② Quantized (int8)

Last training performance (validation set)

ACCURACY 99.7%

LOSS 0.01

Confusion matrix (validation set)

	IDLE	LIFT	MARITIME	TERRESTRIAL
IDLE	100%	0%	0%	0%
LIFT	0%	100%	0%	0%
MARITIME	0%	0.6%	99.4%	0%
TERRESTRIAL	0.6%	0%	0%	99.4%
F1 SCORE	1.00	1.00	1.00	1.00

Feature explorer (full training set) ②

accX RMS accY RMS accZ RMS

- idle - correct
- lift - correct
- maritime - correct
- terrestrial - correct
- maritime - incorrect
- terrestrial - incorrect

3D scatter plot showing feature distribution:

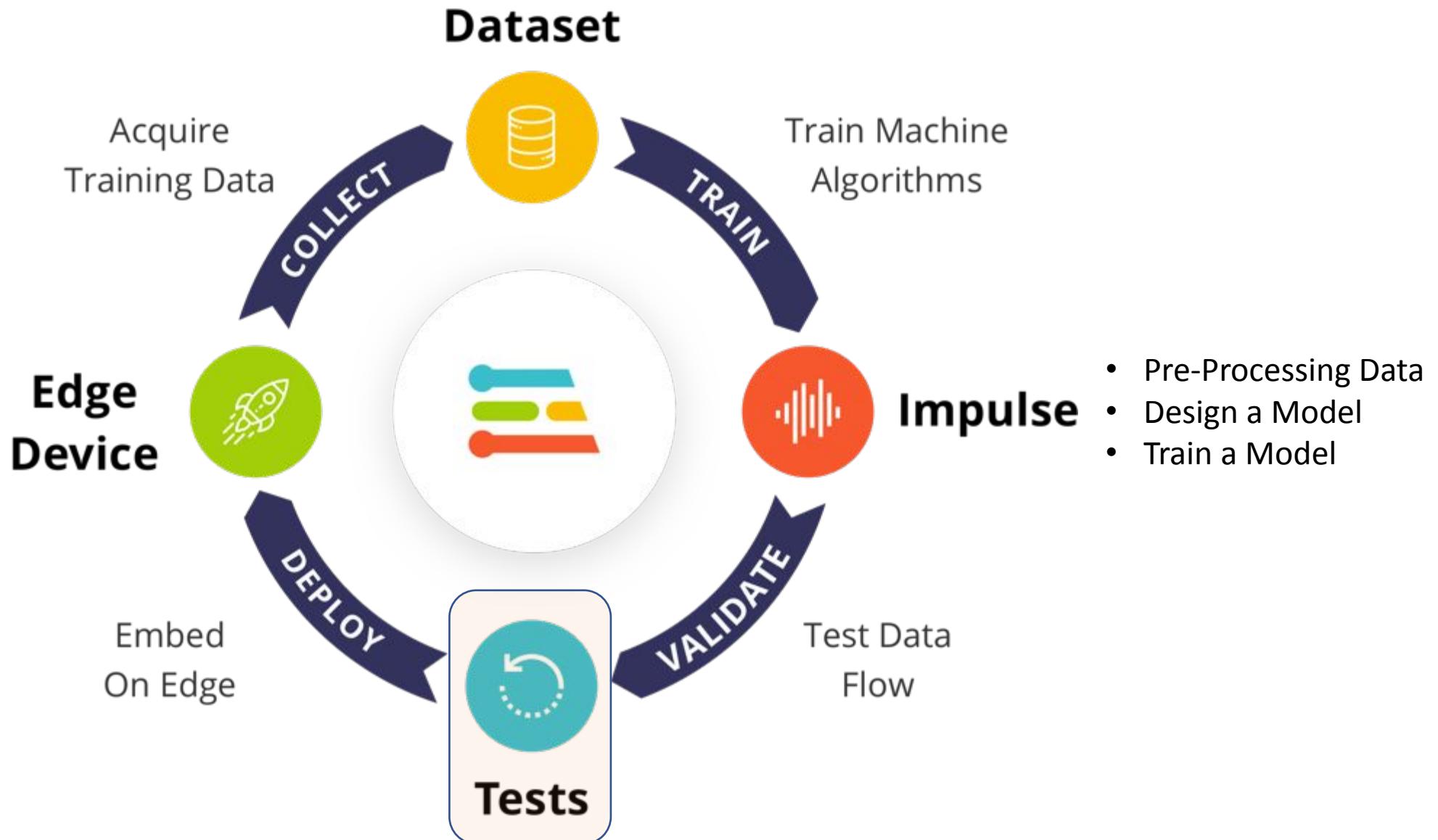
Estimate for Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz), compiled with Edge Impulse EON™ compiler

On-device performance ②

INFERENCING TIME 1 ms.

PEAK RAM USAGE 1.7K

FLASH USAGE 19.0K



**Evaluate  
Optimize**

Model testing - SciTinyML-Motion-Project

studio.edgeimpulse.com/studio/51797/validation

EDGE IMPULSE

MODEL TESTING (SCITINYML-MOTION-PROJECT)

MJRoBot (Marcelo Rovai)

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
testing.2hvft...	testing	10s		98 testing
terrestrial.2...	terrestrial	10s	100%	98 terrestrial
terrestrial.2...	terrestrial	10s	100%	98 terrestrial
lift.2hssi1t6	lift	10s	100%	98 lift
lift.2hst8tvj	lift	10s	100%	98 lift

Model testing output

Model testing results

ACCURACY 99.74% %

	IDLE	LIFT	MARITIME	TERRESTRIAL	UNCERTAIN
IDLE	99.5%	0.5%	0%	0%	0%
LIFT	0%	100%	0%	0%	0%
MARITIME	0%	0%	99.5%	0%	0.5%
TERRESTRIAL	0%	0%	0%	100%	0%
F1 SCORE	1.00	1.00	1.00	1.00	1.00

Feature explorer

accX RMS accY RMS accZ RMS

Machine Learning Algorithm

Training Set Validation Set Test Set

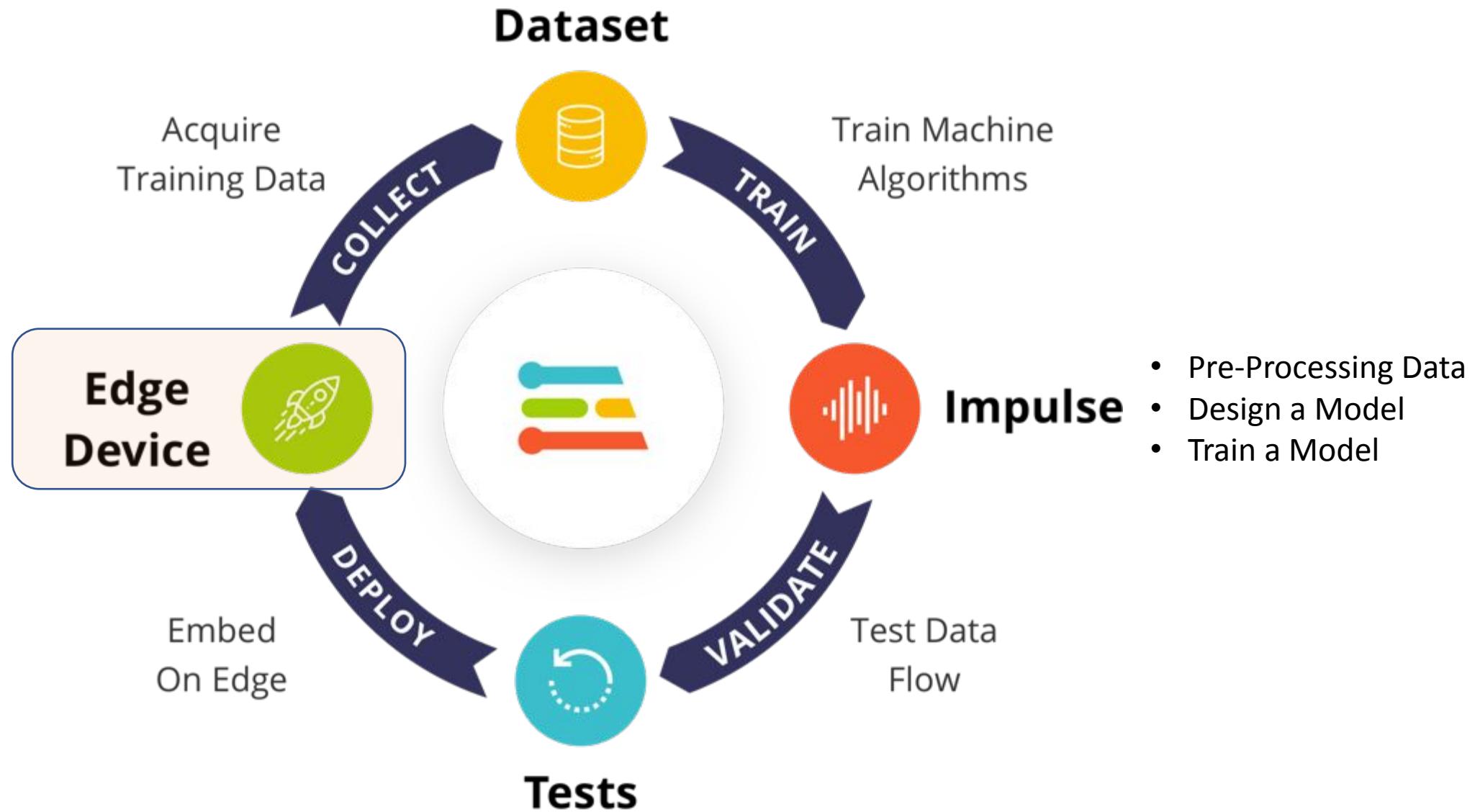
Training, tuning, evaluation

Final Performance Estimate

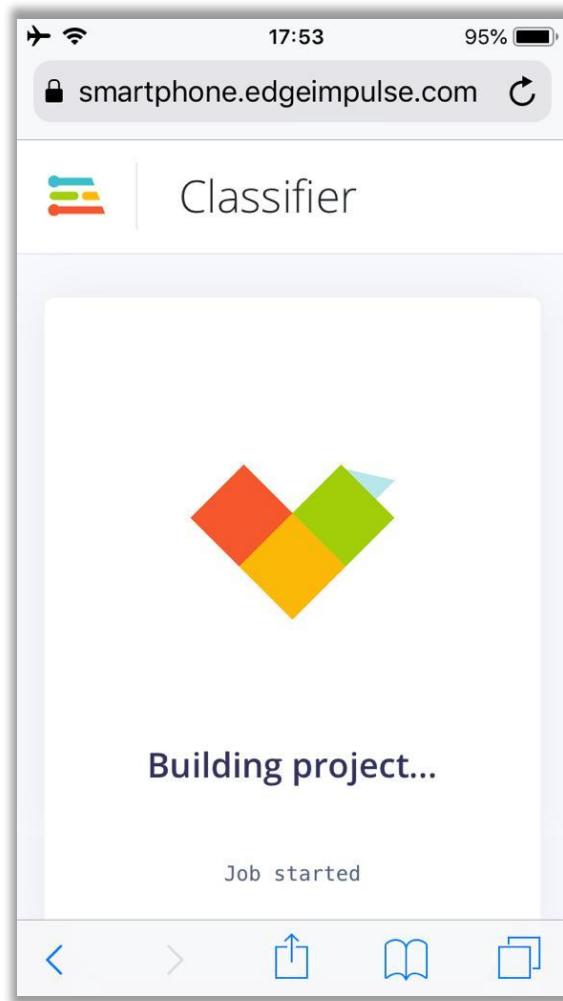
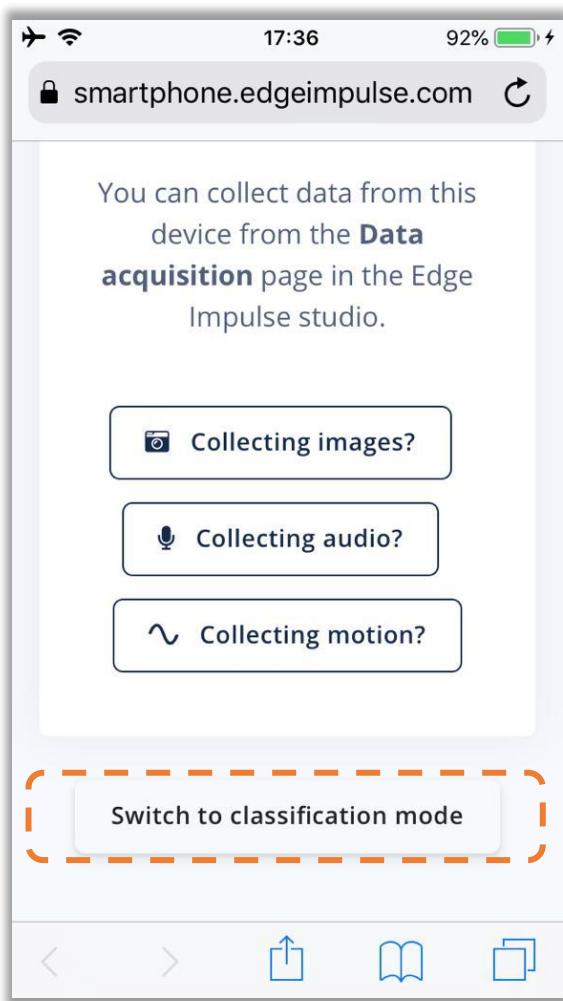
Final Model

idle - correct  
lift - correct  
maritime - correct  
terrestrial - correct  
idle - incorrect  
maritime - incorrect

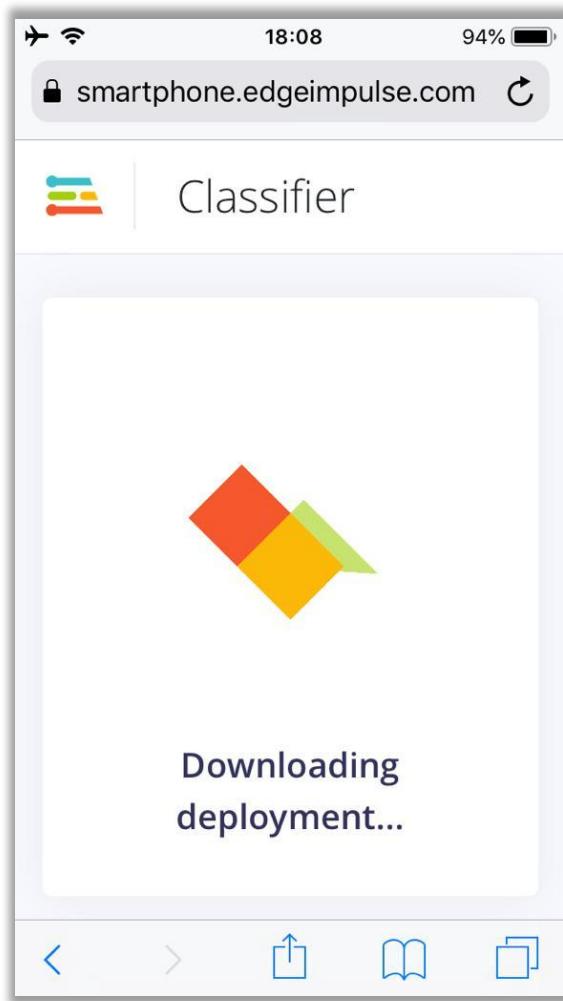
3D Scatter Plot: accX RMS, accY RMS, accZ RMS



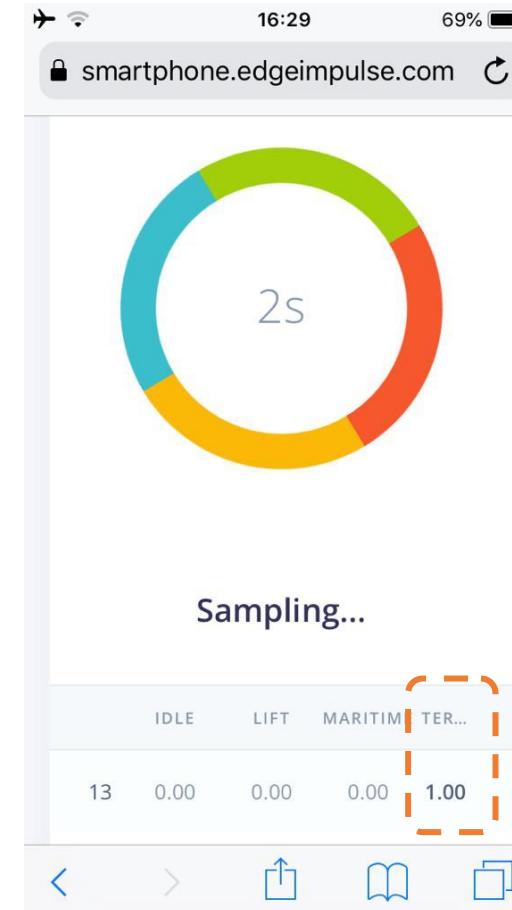
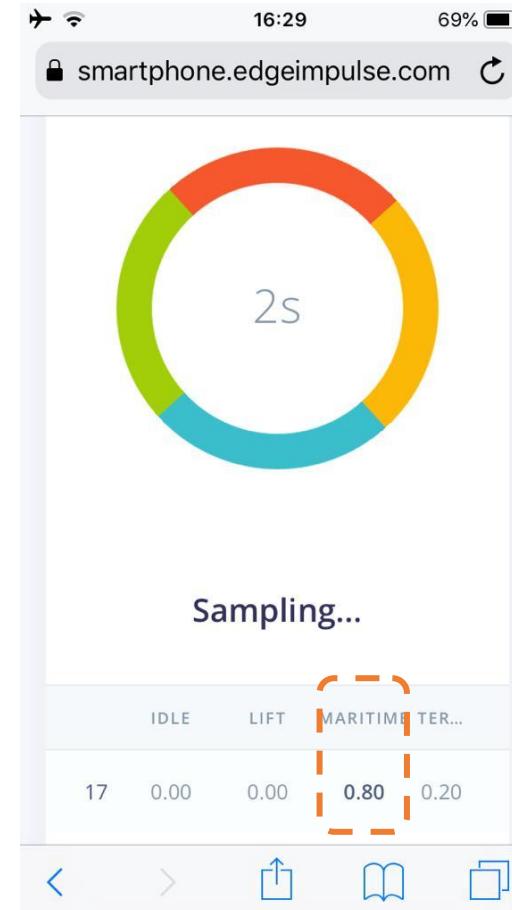
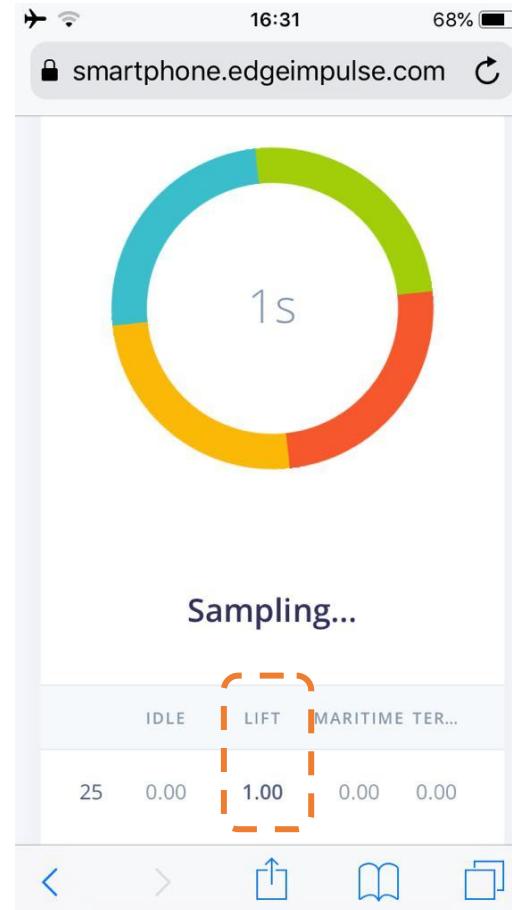
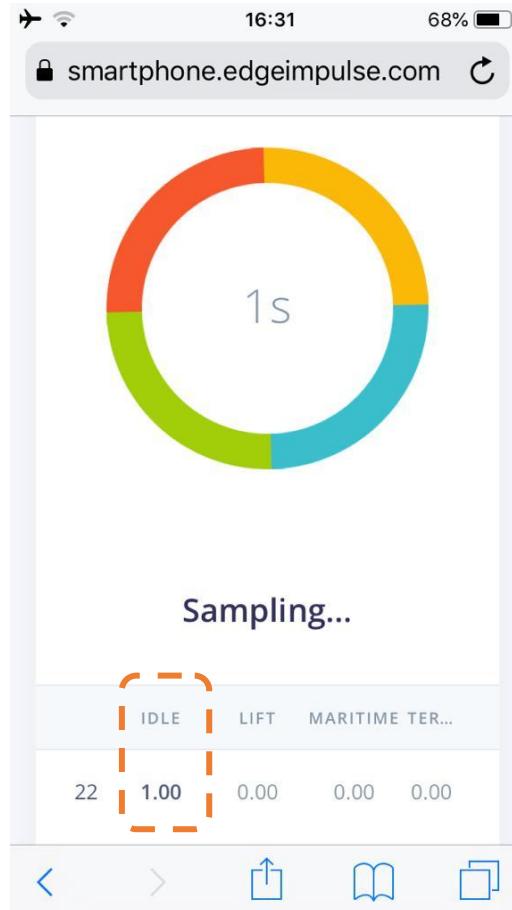
## Convert Model



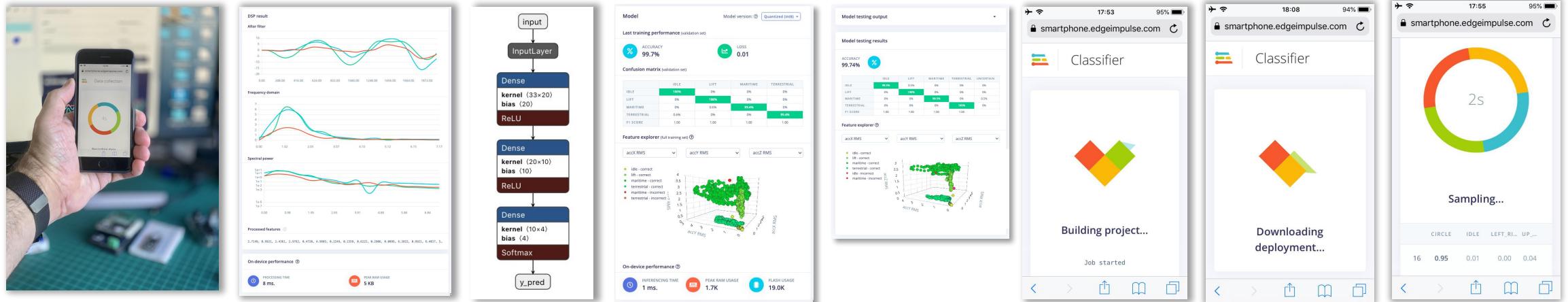
## Deploy Model



## Make Inferences

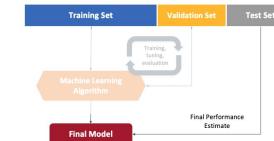


# Motion Classification - Summary



Spectral Analysis

NN Classifier



# Dataset Collection

## Using MCUs

# Arduino Nano-33 BLE Edge Impulse – Installation

Select project - Edge Impulse

studio.edgeimpulse.com/studio/select-project

EDGE IMPULSE

MJRoBot (Marcelo Rovai)

# Select project

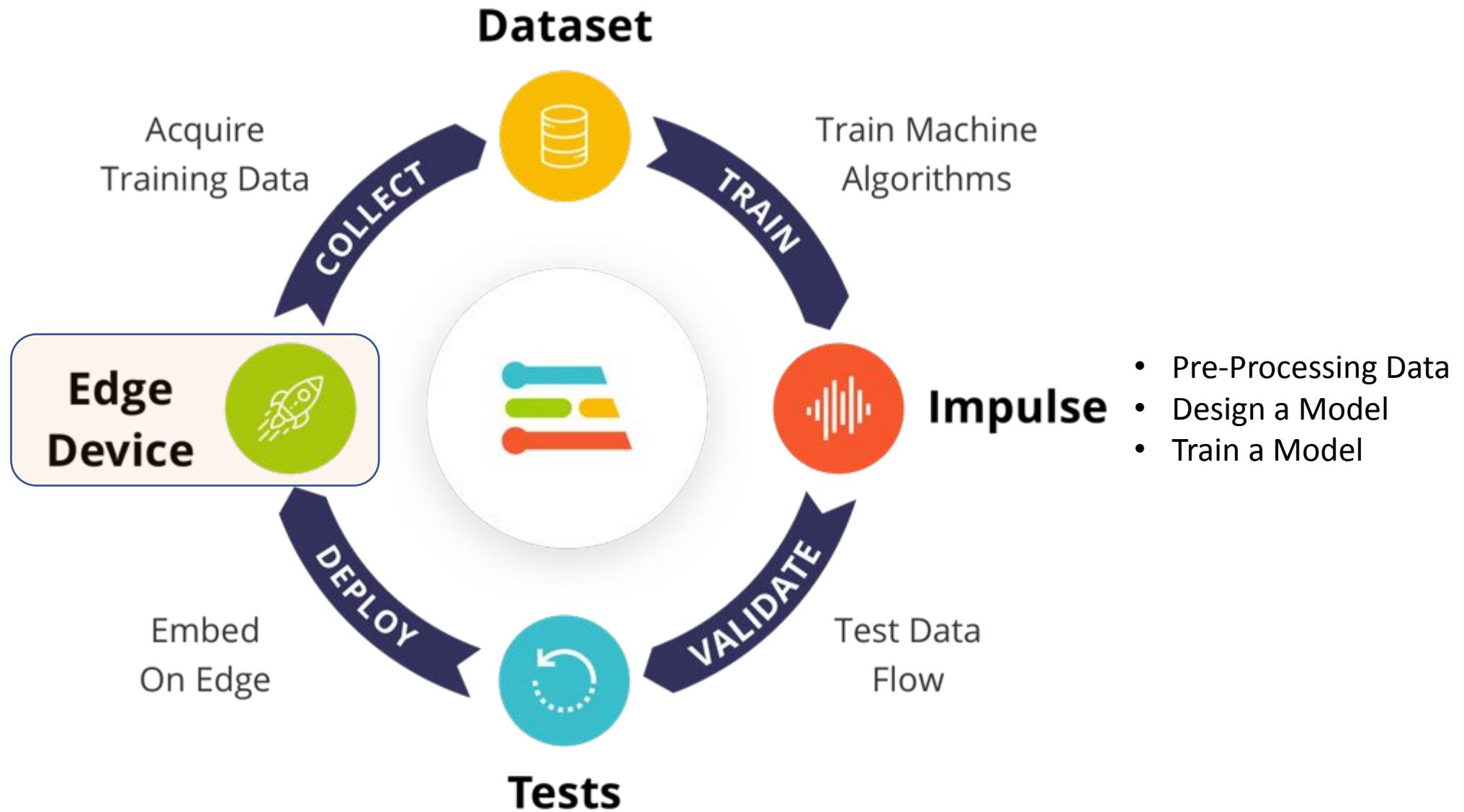
Select your Edge Impulse project, or create a new one.

NAME	COLLABORATORS
MJRoBot (Marcelo Rovai) / IESTI01 - Nano Motion Classification	?
MJRoBot (Marcelo Rovai) / oi_rovis_kws	
MJRoBot (Marcelo Rovai) / Eggs AI	
MJRoBot (Marcelo Rovai) / Accelerometer-Nano-Ble-IoT	
MJRoBot (Marcelo Rovai) / video_tinyml_raw	
MJRoBot (Marcelo Rovai) / Pico_Motion_Detection	
MJRoBot (Marcelo Rovai) / oi_rovis_kws_meetup	

Create project

Enter a name for your new project

Cancel Create new project



The screenshot shows the Edge Impulse studio interface on a web browser. The left sidebar contains navigation links such as Dashboard, Devices (highlighted with a red box and number 1), Data acquisition, Impulse design, Create impulse, EON Tuner, Retrain model, Live classification, Model testing, Versioning, Deployment, Documentation, and Forums. The main content area is titled "DEVICES (IESTI01 - NANO MOTION CLASSIFICATION)" and displays a "Your devices" section with a message about connected devices. A central modal window is open, titled "Collect data", with the sub-section "Connect a fully supported development board". This section includes a "Browse dev boards" button (highlighted with a red box and number 2) and a "Show QR code" button. The modal also lists other collection methods: "Use your mobile phone", "Use your computer", "Data from any device with the data forwarder", "Upload data", and "Integrate with your cloud". The bottom of the modal has a "Contact us" button. The URL bar at the bottom of the browser shows the page is https://docs.edgeimpulse.com/docs/fully-supported-development-boards.

Devices - IESTI01 - Nano Motion Classification

studio.edgeimpulse.com/studio/61345/devices

EDGE IMPULSE

1

2

3

Devices

Data acquisition

Impulse design

Create impulse

EON Tuner

Retrain model

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GETTING STARTED

Documentation

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DEVICES (IESTI01 - NANO MOTION CLASSIFICATION)

Your devices

These are devices that are connected to the Edge Impulse remote management API, or have posted data to the ingestion SDK.

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 computer

Collect data

Data from any device with the data forwarder

Show docs

Upload data

Go to the uploader

Integrate with your cloud

Contact us

https://docs.edgeimpulse.com/docs/fully-supported-development-boards

**DOCUMENTATION**

- Getting Started
- API and SDK references
- What is embedded ML, anyway?
- Frequently asked questions

**DEVELOPMENT BOARDS****Overview**

- ST B-L475E-IOT01A
- Arduino Nano 33 BLE Sense
- Eta Compute ECM3532 AI Sensor
- Eta Compute ECM3532 AI Vision
- OpenMV Cam H7 Plus
- Himax WE-I Plus
- Nordic Semi nRF52840 DK
- Nordic Semi nRF5340 DK
- SiLabs Thunderboard Sense 2
- Sony's Spresense
- Arduino Portenta H7 + Vision shield (preview)
- Raspberry Pi 4
- NVIDIA Jetson Nano
- Mobile phone
- Porting guide

**COMMUNITY BOARDS**

- Seeed Wio Terminal
- Agora Product Development Kit

# Overview

There is a list of development boards that are fully supported by Edge Impulse. These boards come with a special firmware which enables data collection from all their sensors, allows you to build new ready-to-go binaries that include your trained impulse, and come with examples on integrating your impulse with your custom firmware. These boards are the perfect way to start building Machine Learning solutions on real embedded hardware.

- [ST B-L475E-IOT01A \(or Discovery Kit\)](#)
- [Arduino Nano 33 BLE Sense](#)
- [Eta Compute ECM3532 AI Sensor](#)
- [Eta Compute ECM3532 AI Vision](#)
- [OpenMV Cam H7 Plus](#)
- [Himax WE-I Plus](#)
- [Nordic Semiconductor nRF52840 DK](#)
- [Nordic Semiconductor nRF5340 DK](#)
- [Silicon Labs Thunderboard Sense 2](#)
- [Sony's Spresense](#)
- [Arduino Portenta H7 + Vision shield](#) (preview support)
- [Raspberry Pi 4](#)
- [NVIDIA Jetson Nano](#)



Different development board? No problem, you can always collect data using the [Data forwarder](#) or the [Edge Impulse for Linux](#) SDK, and deploy your model back to the device with the [Running your impulse locally](#) tutorials.

Just want to experience Edge Impulse? You can also use your [Mobile phone](#)!

Updated 7 days ago

# EI CLI

EDGE IMPULSE Home API Reference Log In

Guides > Arduino Nano 33 BLE Sense Search 36K

**DOCUMENTATION**

- Getting Started
- API and SDK references
- What is embedded ML, anyway?
- Frequently asked questions

**DEVELOPMENT BOARDS**

- Overview
- ST B-L475E-IOT01A
- Arduino Nano 33 BLE Sense**
- Eta Compute ECM3532 AI Sensor
- Eta Compute ECM3532 AI Vision
- OpenMV Cam H7 Plus
- Himax WE-I Plus
- Nordic Semi nRF52840 DK
- Nordic Semi nRF5340 DK
- SiLabs Thunderboard Sense 2
- Sony's Spresense
- Arduino Portenta H7 + Vision shield (preview)
- Raspberry Pi 4
- NVIDIA Jetson Nano
- Mobile phone
- Porting guide

**COMMUNITY BOARDS**

- Seeed Wio Terminal
- Agora Product Development Kit

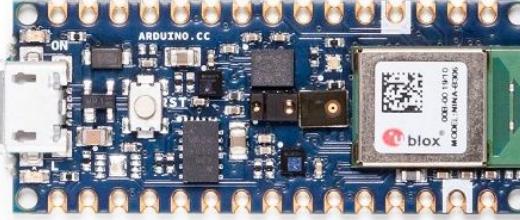
**EDGE IMPULSE FOR LINUX**

- Edge Impulse for Linux
- Linux Node.js SDK
- Linux Go SDK
- Linux C++ SDK
- Linux Python SDK

## Arduino Nano 33 BLE Sense

The Arduino Nano 33 BLE Sense is a tiny development board with a Cortex-M4 microcontroller, motion sensors, a microphone and BLE - and it's fully supported by Edge Impulse. You'll be able to sample raw data, build models, and deploy trained machine learning models directly from the studio. It's available for around 30 USD from [Arduino](#) and a wide range of distributors.

The Edge Impulse firmware for this development board is open source and hosted on GitHub: [edgeimpulse/firmware-arduino-nano-33-ble-sense](#).



**Installing dependencies**

To set this device up in Edge Impulse, you will need to install the following software:

1. [Edge Impulse CLI](#).
2. [Arduino CLI](#).
  - Here's an [instruction video for Windows](#).
  - The [Arduino website](#) has instructions for macOS and Linux.
3. On Linux:
  - GNU Screen: install for example via `sudo apt install screen`.

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

**DOCUMENTATION**

- [Getting Started](#)
- [API and SDK references](#)
- [What is embedded ML, anyway?](#)
- [Frequently asked questions](#)

**DEVELOPMENT BOARDS**

- [Overview](#)
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**COMMUNITY BOARDS**

- [Seeed Wio Terminal](#)
- [Agora Product Development Kit](#)

**EDGE IMPULSE FOR LINUX**

## Installation

# Edge Impulse CLI optional Installation

This Edge Impulse CLI is used to control local devices, act as a proxy to synchronise data for devices that don't have an internet connection, and to upload and convert local files. The CLI consists of seven tools:

- [edge-impulse-daemon](#) - configures devices over serial, and acts as a proxy for devices that do not have an IP connection.
- [edge-impulse-uploader](#) - allows uploading and signing local files.
- [edge-impulse-data-forwarder](#) - a very easy way to collect data from any device over a serial connection, and forward the data to Edge Impulse.
- [edge-impulse-run-impulse](#) - show the impulse running on your device.
- [edge-impulse-blocks](#) - create organizational transformation blocks.
- [eta-flash-tool](#) - to flash the Eta Compute ECM3532 AI Sensor.
- [himax-flash-tool](#) - to flash the Himax WE-I Plus.

Connect to devices without the CLI? Recent versions of Google Chrome and Microsoft Edge can connect directly to fully-supported development boards, without the CLI. See [this blog post](#) for more information.

### Installation - macOS and Windows

- 
1. Install [Python 3](#) on your host computer.
  2. Install [Node.js](#) v14 or higher on your host computer.
    - For Windows users, install the Additional Node.js tools when prompted. You may skip this setup if you have Visual Studio 2015 or more.
  3. Install the CLI tools via:

```
npm install -g edge-impulse-cli --force
```

You should now have the tools available in your PATH.

### Installation - Linux/Ubuntu and Raspbian OS

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- [OpenMV Cam H7 Plus](#)
- [Himax WE-I Plus](#)
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- [Nordic Semi nRF5340 DK](#)
- [SiLabs Thunderboard Sense 2](#)
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**COMMUNITY BOARDS**

- [Seeed Wio Terminal](#)
- [Agora Product Development Kit](#)

**EDGE IMPULSE FOR LINUX**

## Installation

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  - For Windows users, install the **Additional Node.js tools** when prompted. You may skip this setup if you have Visual Studio 2015 or more.

3. Install the CLI tools via:

```
npm install -g edge-impulse-cli --force
```

You should now have the tools available in your PATH.

### Installation - Linux/Ubuntu and Raspbian OS



# Arduino CLI

EDGE IMPULSE Home API Reference Log In

Guides > Arduino Nano 33 BLE Sense Search 36K

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**EDGE IMPULSE FOR LINUX**

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## Arduino Nano 33 BLE Sense

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The Edge Impulse firmware for this development board is open source and hosted on GitHub: [edgeimpulse/firmware-arduino-nano-33-ble-sense](#).



**Arduino Nano 33 BLE Sense**

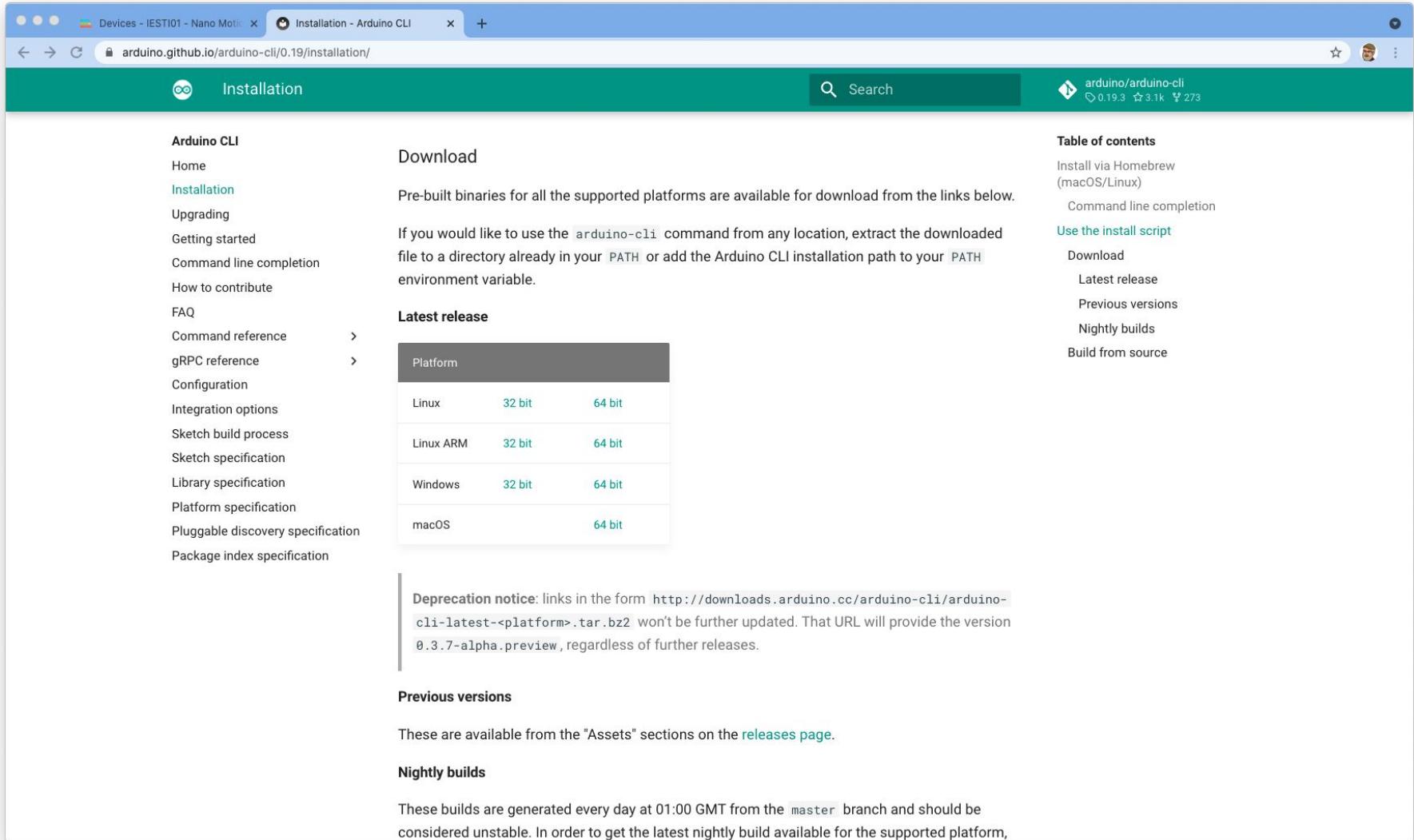
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To set this device up in Edge Impulse, you will need to install the following software:

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  - Here's an [instruction video for Windows](#).
  - The [Arduino website](#) has instructions for macOS and Linux.
3. On Linux:
  - GNU Screen: install for example via `sudo apt install screen`.

A large blue arrow points from the bottom right towards the "Arduino CLI" section of the list.

# Arduino CLI



The screenshot shows the "Installation" page for the Arduino CLI on GitHub. The URL in the address bar is [arduino.github.io/arduino-cli/0.19/installation/](https://arduino.github.io/arduino-cli/0.19/installation/). The page has a green header with the title "Installation". On the left, there's a sidebar with links like Home, Installation (which is active), Upgrading, Getting started, Command line completion, How to contribute, FAQ, Command reference, gRPC reference, Configuration, Integration options, Sketch build process, Sketch specification, Library specification, Platform specification, Pluggable discovery specification, and Package index specification. The main content area has a section titled "Download" with instructions for pre-built binaries. It includes a table for the "Latest release" showing download links for Linux, Linux ARM, Windows, and macOS in 32-bit and 64-bit versions. Below this is a "Deprecation notice" about old URLs. There are also sections for "Previous versions" and "Nightly builds". A "Table of contents" sidebar on the right lists various installation and usage options.

Platform	32 bit	64 bit
Linux	<a href="#">32 bit</a>	<a href="#">64 bit</a>
Linux ARM	<a href="#">32 bit</a>	<a href="#">64 bit</a>
Windows	<a href="#">32 bit</a>	<a href="#">64 bit</a>
macOS		<a href="#">64 bit</a>

**Deprecation notice:** links in the form <http://downloads.arduino.cc/arduino-cli/arduino-cli-latest-<platform>.tar.bz2> won't be further updated. That URL will provide the version 0.3.7-alpha.preview, regardless of further releases.

**Previous versions**  
These are available from the "Assets" sections on the [releases page](#).

**Nightly builds**  
These builds are generated every day at 01:00 GMT from the `master` branch and should be considered unstable. In order to get the latest nightly build available for the supported platform,



See this video for Windows installation: <https://www.youtube.com/watch?v=1jMWsFER-Bc>

**DOCUMENTATION**

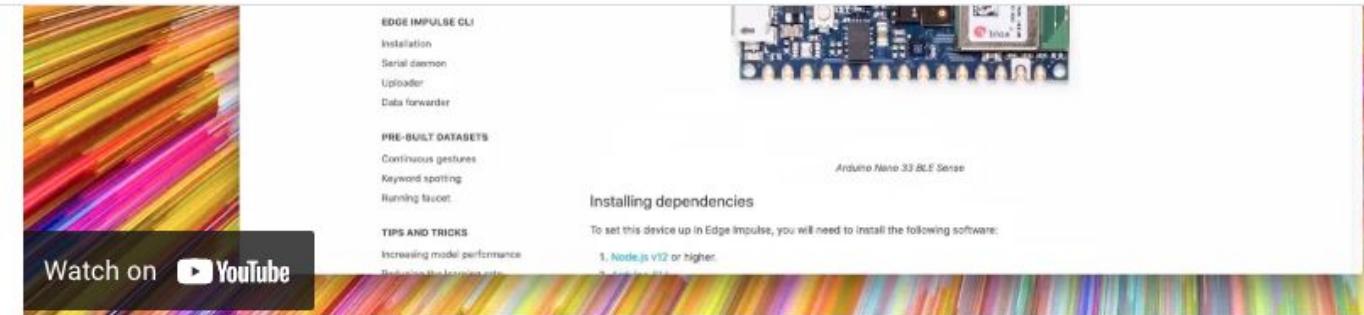
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**COMMUNITY BOARDS**

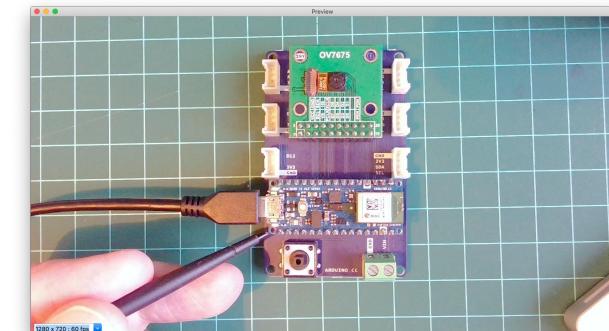
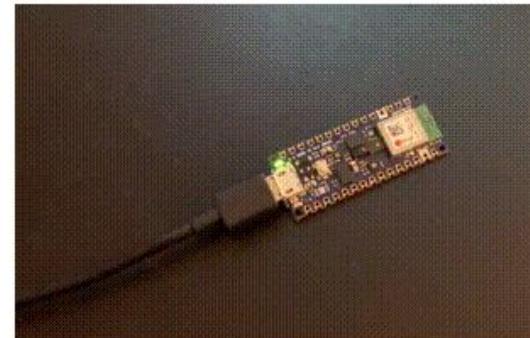
- Seeed Wio Terminal
- Agora Product Development Kit



The screenshot shows the Edge Impulse website with the Arduino Nano 33 BLE Sense development board highlighted. A 'Watch on YouTube' button is visible. The page includes sections for 'EDGE IMPULSE CLI', 'PRE-BUILT DATABASES', and 'TIPS AND TRICKS'.

**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. 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**

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- What is embedded ML, anyway?
- Frequently asked questions

**DEVELOPMENT BOARDS**

- Overview

ST B-L475E-IOT01A

**Arduino Nano 33 BLE Sense**

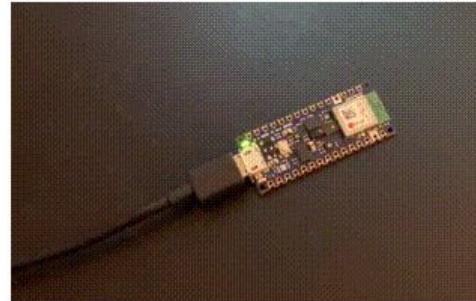
- Eta Compute ECM3532 AI Sensor
- Eta Compute ECM3532 AI Vision
- OpenMV Cam H7 Plus
- Himax WE-I Plus
- Nordic Semi nRF52840 DK
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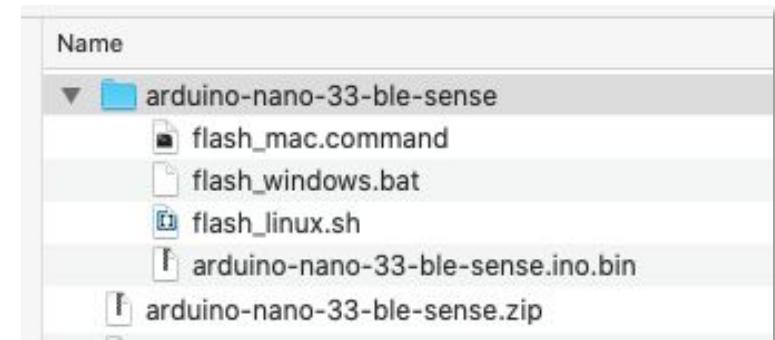
1

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3. Wait until flashing is complete, and press the RESET button once to launch the new firmware.

**3. Setting keys**

2

# MacOS

```
mjrovai — flash_mac.command — 126x44
Last login: Tue Nov  9 12:15:56 on ttys002
You have new mail.
/Users/mjrovai/Downloads/arduino-nano-33-ble-sense\ \(2\)/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-33-ble-sense\ \(2\)/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

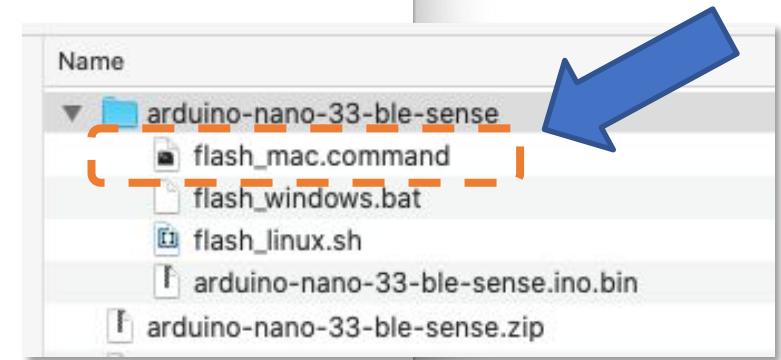
Done in 0.001 seconds
Write 280848 bytes to flash (69 pages)
[=====] 100% (69/69 pages)
Done in 10.984 seconds

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.

[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.

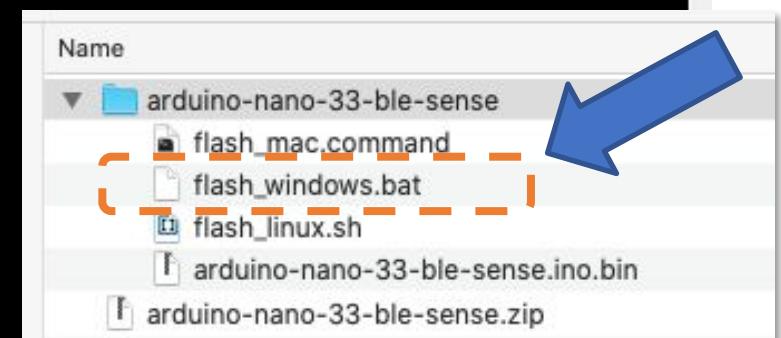
C:\Users\GUILH>arduino-cli
Arduino Command Line Interface (arduino-cli).

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.
```

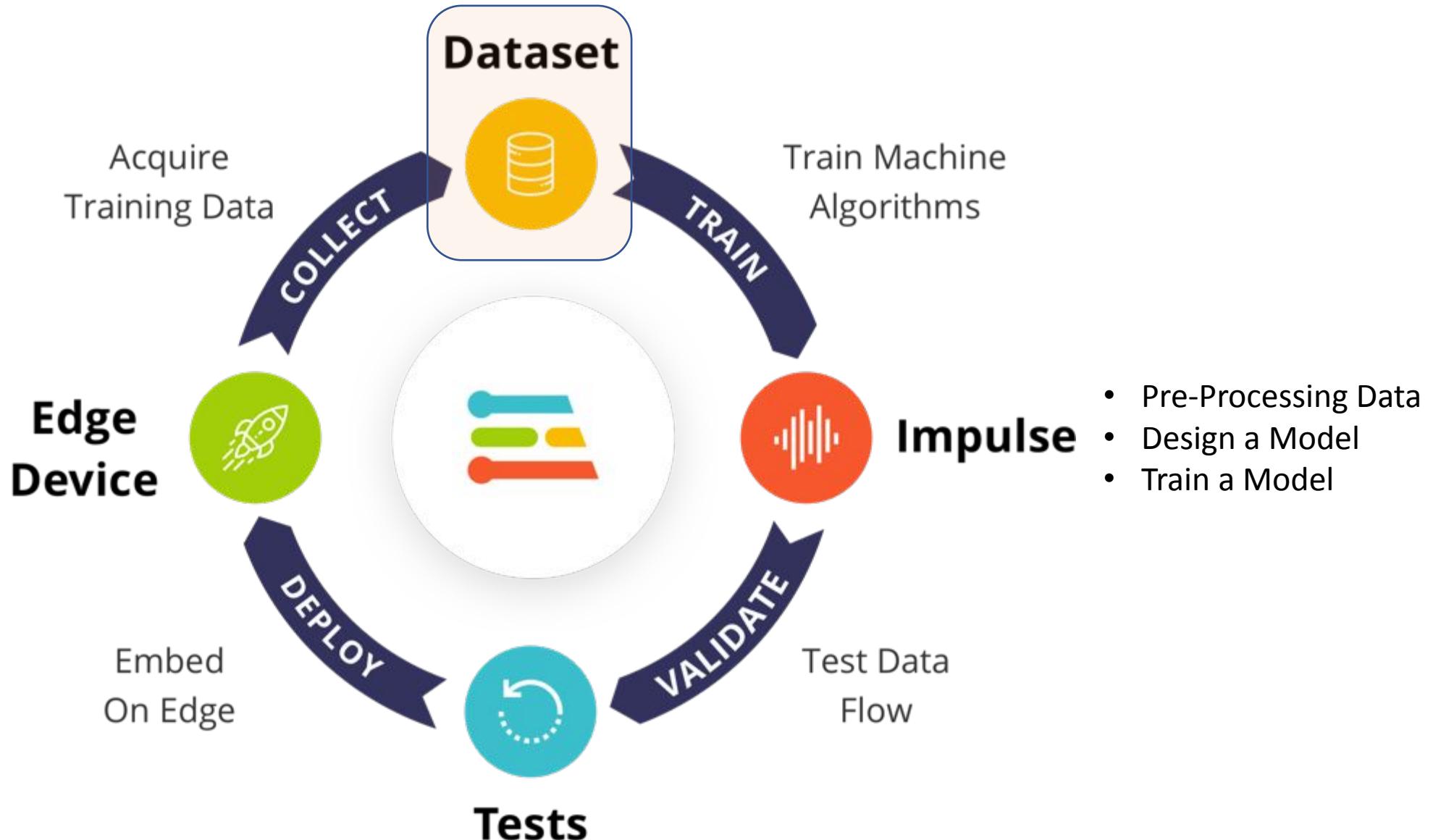
1. Press Nano-33 Reset button Twice
2. With Nano-33 LED Flashing:



# Windows 10

```
cmd C:\WINDOWS\system32\cmd.exe
Finding Arduino Mbed core...
arduino:mbed_nano 2.0.0      2.0.0  Arduino Mbed OS Nano Boards
Finding Arduino Mbed core OK
Finding Arduino Nano 33 BLE...
Finding Arduino Nano 33 BLE OK at COM11
arduino:mbed_nano 2.0.0      2.0.0  Arduino Mbed OS Nano Boards
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 0.002 seconds
Write 525440 bytes to flash (129 pages)
[=====] 100% (129/129 pages)          □ Nano-33 LED Stop Flashing
Done in 22.296 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'
Pressione qualquer tecla para continuar. . .
```



The screenshot shows the Edge Impulse Studio interface on a Mac OS X system. The left sidebar contains navigation links like Dashboard, Devices, Data acquisition, and Model testing. The main workspace displays a connection dialog for a serial port and a central area for managing datasets.

**Connection Dialog:**

- Device Selection:** A dropdown menu lists available serial ports:
  - cu.Bluetooth-Incoming-Port
  - cu.MALS
  - cu.RovaisAirPods-Wirelessi
  - cu.SOC** (highlighted with a blue box)
  - Nano 33 BLE (cu.usbmodem145101)** (highlighted with a blue box)
- Buttons:** A large blue arrow labeled **2** points to the "Connect" button at the bottom right of the dialog.
- Text:** "No data has been collected yet" is displayed below the buttons.

**Main Workspace:**

- Record new data:** A section with a "Connect using WebUSB" button, highlighted with a blue box and labeled **1**.
- RAW DATA:** A dark blue panel with the text "Click on a sample to load...".
- Blue Arrows:** Two blue arrows point from the highlighted areas in the connection dialog towards the corresponding areas in the main workspace.

**Bottom Right Text:** "WebUSB works fine in Windows"

DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)

Training data Test data

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

DATA COLLECTED

No data collected yet

Let's collect some data

Record new data

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

Label: terrestrial

Sample length (ms.): 10000

Sensor: Built-in accelerometer

Frequency: 100Hz

Start sampling

RAW DATA  
Click on a sample to load...

A screenshot of the Edge Impulse Data Acquisition interface. On the left, a sidebar lists various project management and development tools. The main area is titled 'DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)' and shows a 'Record new data' form. This form includes fields for 'Device' (set to 36:17:55:F9:70:F7), 'Label' (set to 'terrestrial'), 'Sample length (ms.)' (set to 10000), 'Sensor' (set to 'Built-in accelerometer'), and 'Frequency' (set to 100Hz). A large blue arrow points to the 'Start sampling' button at the bottom right of the form. Below the form, a dark blue bar displays the text 'RAW DATA' and 'Click on a sample to load...'. The top of the page shows a browser header with the URL 'studio.edgeimpulse.com/studio/61345/acquisition/training?page=1'.

Devices - IESTI01 - Nano Motion Classification

studio.edgeimpulse.com/studio/61345/devices

EDGE IMPULSE

DEVICES (IESTI01 - NANO MOTION CLASSIFICATION)

MJRoBot (Marcelo Rovai)

Your devices

+ Connect a new device

These are devices that are connected to the Edge Impulse remote management API, or have posted data to the ingestion SDK.

NAME	ID	TYPE	SENSORS	REMOTE M...	LAST SEEN
 36:17:55:F9:70:F7	36:17:55:F9:70:F7	ARDUINO_NANO33BLE	Built-in accelerometer, Built-in microphone...	●	Today, 12:26:49

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Dashboard

Devices

Data acquisition

Impulse design

Create impulse

EON Tuner

Retrain model

Live classification

Model testing

Versioning

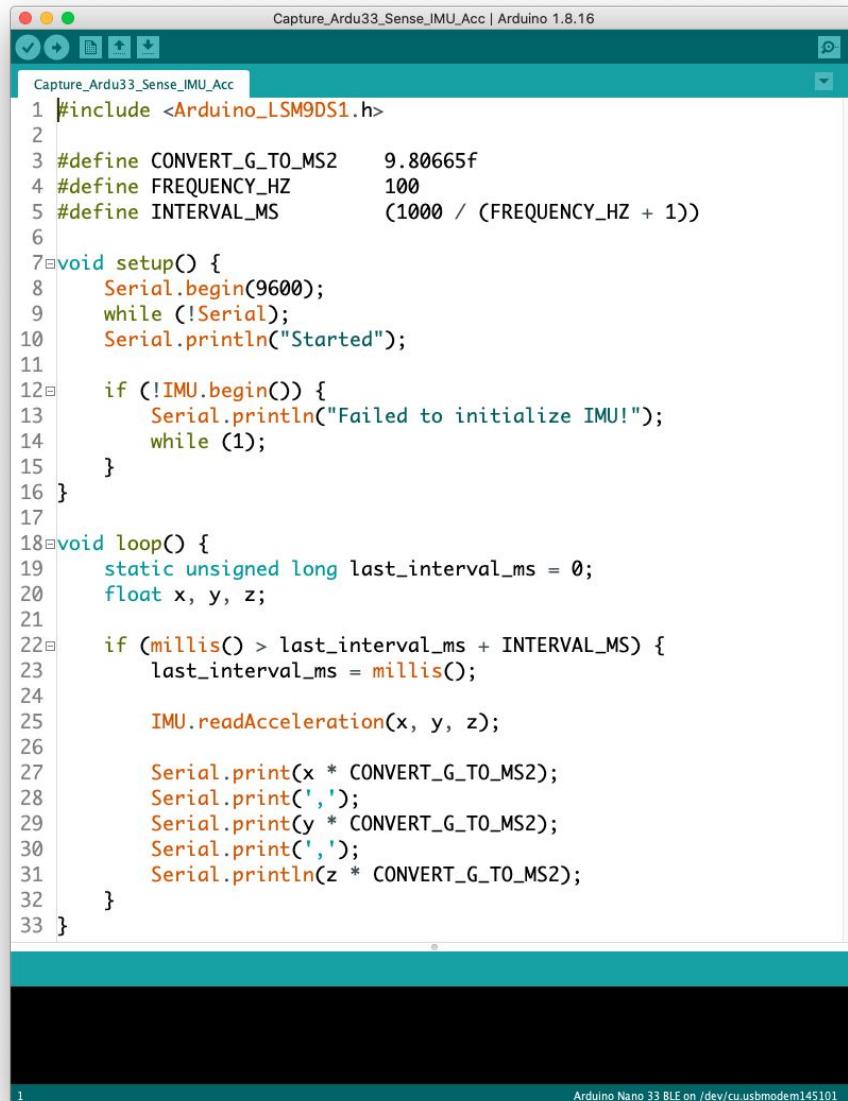
Deployment

GETTING STARTED

Documentation

Forums

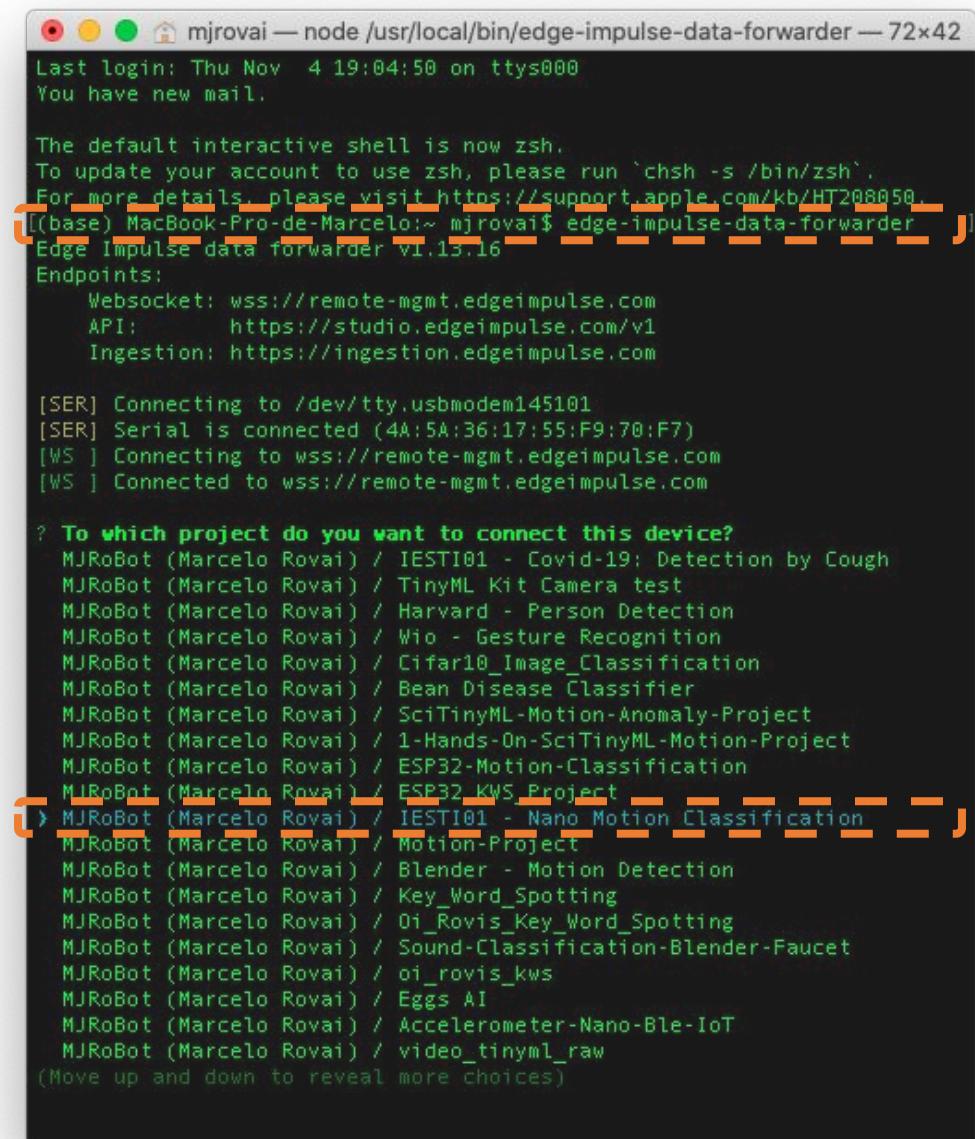
# Alternative Data Capture using EI CLI: \$ edge-impulse-data-forwarder



The screenshot shows the Arduino IDE interface with the following details:

- Title bar: Capture\_Ardu33\_Sense\_IMU\_Acc | Arduino 1.8.16
- Code area:

```
1 #include <Arduino_LSM9DS1.h>
2
3 #define CONVERT_G_TO_MS2 9.80665f
4 #define FREQUENCY_HZ 100
5 #define INTERVAL_MS (1000 / (FREQUENCY_HZ + 1))
6
7 void setup() {
8     Serial.begin(9600);
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 }
```
- Bottom status bar: Arduino Nano 33 BLE on /dev/cu.usbmodem145101



The terminal window displays the following output:

```
mjrovai — node /usr/local/bin/edge-impulse-data-forwarder — 72x42
Last login: Thu Nov  4 19:04:50 on ttys000
You have new mail.

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$ edge-impulse-data-forwarder
Edge Impulse data forwarder v1.13.16
Endpoints:
  Websocket: wss://remote-mgmt.edgeimpulse.com
  API: https://studio.edgeimpulse.com/v1
  Ingestion: https://ingestion.edgeimpulse.com

[SER] Connecting to /dev/tty.usbmodem145101
[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 - Covid-19: Detection by Cough
MJRobot (Marcelo Rovai) / TinyML Kit Camera test
MJRobot (Marcelo Rovai) / Harvard - Person Detection
MJRobot (Marcelo Rovai) / Wio - Gesture Recognition
MJRobot (Marcelo Rovai) / Cifar10_Image_Classification
MJRobot (Marcelo Rovai) / Bean Disease Classifier
MJRobot (Marcelo Rovai) / SciTinyML-Motion-Anomaly-Project
MJRobot (Marcelo Rovai) / 1-Hands-On-SciTinyML-Motion-Project
MJRobot (Marcelo Rovai) / ESP32-Motion-Classification
MJRobot (Marcelo Rovai) / ESP32_KWS_Project
MJRobot (Marcelo Rovai) / IESTI01 - Nano Motion Classification
MJRobot (Marcelo Rovai) / Motion-Project
MJRobot (Marcelo Rovai) / Blender - Motion Detection
MJRobot (Marcelo Rovai) / Key_Word_Spotting
MJRobot (Marcelo Rovai) / Oi_Rovis_Key_Word_Spotting
MJRobot (Marcelo Rovai) / Sound-Classification-Blender-Faucet
MJRobot (Marcelo Rovai) / oi_rovis_kws
MJRobot (Marcelo Rovai) / Eggs AI
MJRobot (Marcelo Rovai) / Accelerometer-Nano-Ble-IoT
MJRobot (Marcelo Rovai) / video_tinyml_raw
(Move up and down to reveal more choices)
```

```
mjrovai — node /usr/local/bin/edge-impulse-data-forwarder — 117x26
(base) MacBook-Pro-de-Marcelo:~ mjrovai$ 
(base) MacBook-Pro-de-Marcelo:~ mjrovai$ 
(base) MacBook-Pro-de-Marcelo:~ mjrovai$ edge-impulse-data-forwarder
[Edge Impulse data forwarder v1.13.16
[Endpoints:
[ Websocket: wss://remote-mgmt.edgeimpulse.com
  API:      https://studio.edgeimpulse.com/v1
  Ingestion: https://ingestion.edgeimpulse.com

[SER] Connecting to /dev/tty.usbmodem145101
[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 - Nano Motion Classification
[SER] Detecting data frequency...
[SER] Detected data frequency: 100Hz

? 3 sensor axes detected (example values: [-0.13, -0.34, 9.81]). What do y
ou 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 - Nano Motion Classification"
[WS ] Go to https://studio.edgeimpulse.com/studio/61345/acquisition/training to build your machine learning model!

```

Devices - IESTI01 - Nano Motion Classification

studio.edgeimpulse.com/studio/61345/devices

EDGE IMPULSE

DEVICES (IESTI01 - NANO MOTION CLASSIFICATION)

MJRoBot (Marcelo Rovai)

Your devices

+ Connect a new device

These are devices that are connected to the Edge impulse remote management API, or have posted data to the ingestion SDK.

NAME	ID	TYPE	SENSORS	REMOTE M...	LAST SEEN
 Nano	4A:5A:36:17:55:F9:70:F7	DATA_FORWARDER	 Sensor with 3 axes (accX, accY, accZ)		Today, 12:42:15
 36:17:55:F9:70:F7	36:17:55:F9:70:F7	ARDUINO_NANO33BLE	 Built-in accelerometer, Built-in microphone		Today, 12:26:49

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GETTING STARTED

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DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)

Training data Test data

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

DATA COLLECTED 10s TRAIN / TEST SPLIT 100% / 0% ⚠

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
terrestrial.json.2jbimlk	terrestrial	Today, 13:01:46	10s

Record new data

Device ②: Nano

Label: terrestrial

Sample length (ms.): 10000

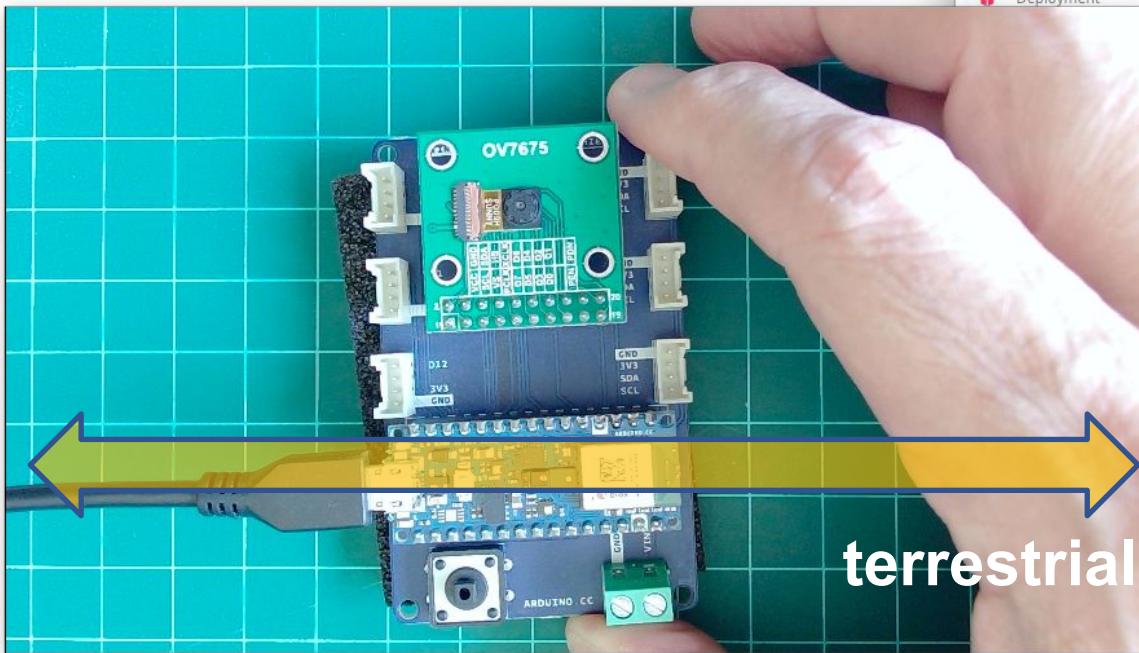
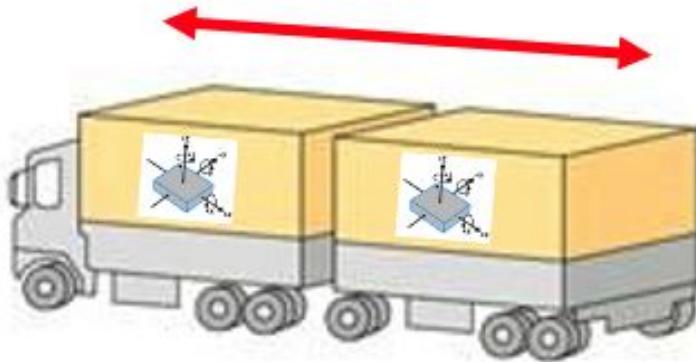
Sensor: Sensor with 3 axes (accX, accY, accZ)

Frequency: 100Hz

Start sampling

RAW DATA  
terrestrial.json.2jbimlk

# Label: terrestrial

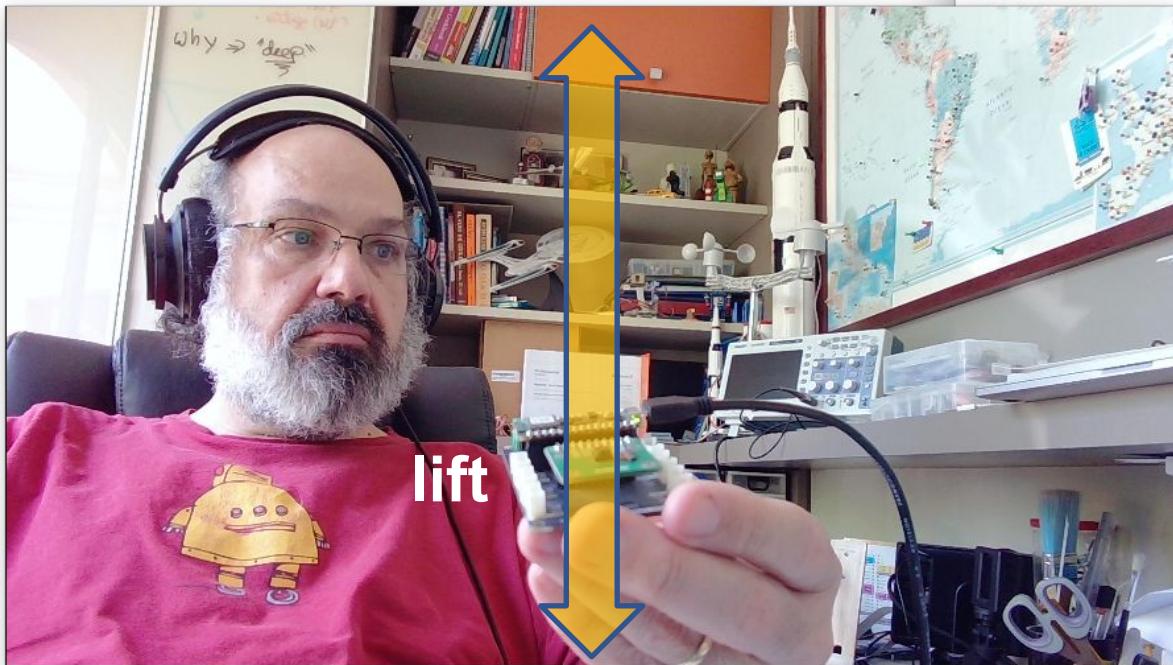
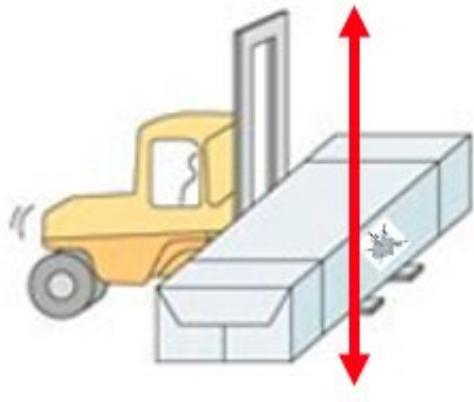


The screenshot shows the Edge Impulse Data Acquisition interface. On the left, a sidebar lists options: Dashboard, Devices, Data acquisition (selected), Impulse design, Create impulse, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main area displays "DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)" with tabs for "Training data" (selected) and "Test data". A message box says: "Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options". Below this, a summary shows "DATA COLLECTED 1m 40s" and "TRAIN / TEST SPLIT 100% / 0%". A table titled "Collected data" lists ten entries, all labeled "terrestrial":

SAMPLE NAME	LABEL	ADDED	LENGTH
terrestrial.json.2jv...	terrestrial	Today, 14:26:56	10s
terrestrial.json.2jv...	terrestrial	Today, 14:26:29	10s
terrestrial.json.2jv...	terrestrial	Today, 14:26:06	10s
terrestrial.json.2jv...	terrestrial	Today, 14:25:48	10s
terrestrial.json.2jv...	terrestrial	Today, 14:25:29	10s
terrestrial.json.2jv...	terrestrial	Today, 14:25:04	10s
terrestrial.json.2jv...	terrestrial	Today, 14:24:45	10s
terrestrial.json.2jv...	terrestrial	Today, 14:24:21	10s
terrestrial.json.2jvf...	terrestrial	Today, 14:17:45	10s

To the right, a "Record new data" section allows connecting via WebUSB, selecting a device (Nano), setting a label (terrestrial), sample length (10000 ms), sensor (Sensor with 3 axes (accX, accY, accZ)), and frequency (100Hz). A "Start sampling" button is present. At the bottom, a "RAW DATA" section shows a graph for "terrestrial.json.2jvgelce" with three axes: accX (red), accY (green), and accZ (blue).

# Label: LIFT



studio.edgeimpulse.com/studio/61345/acquisition/training?page=1

EDGE IMPULSE

DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)

MJRoBot (Marcelo Rovai)

Training data Test data

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

DATA COLLECTED 3m 20s TRAIN / TEST SPLIT 100% / 0%

SAMPLE NAME	LABEL	ADDED	LENGTH
lift.json.2jvhbt7	lift	Today, 14:42:04	10s
lift.json.2jvh9pe3	lift	Today, 14:41:45	10s
lift.json.2jvh96uh	lift	Today, 14:41:26	10s
lift.json.2jvh8j6q	lift	Today, 14:41:06	10s
lift.json.2jvh80rg	lift	Today, 14:40:47	10s
lift.json.2jvh7g2v	lift	Today, 14:40:30	10s
lift.json.2jvh6uqu	lift	Today, 14:40:12	10s
lift.json.2jvh6c6a	lift	Today, 14:39:53	10s
lift.json.2jvh5qbe	lift	Today, 14:39:35	10s
lift.json.2jvh55hs	lift	Today, 14:39:14	10s
terrestrial.json.2jv...	terrestrial	Today, 14:26:56	10s
terrestrial.json.2jv...	terrestrial	Today, 14:26:29	10s

Record new data

Device Nano

Label lift

Sample length (ms.) 10000

Sensor Sensor with 3 axes (accX, accY, accZ)

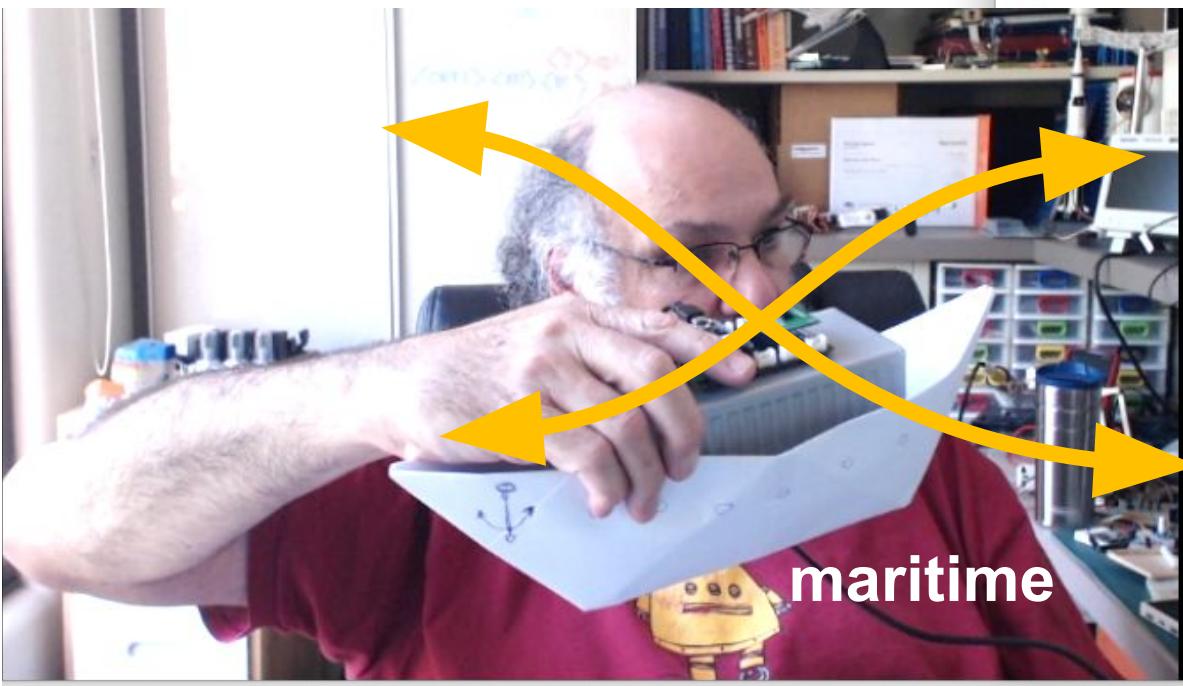
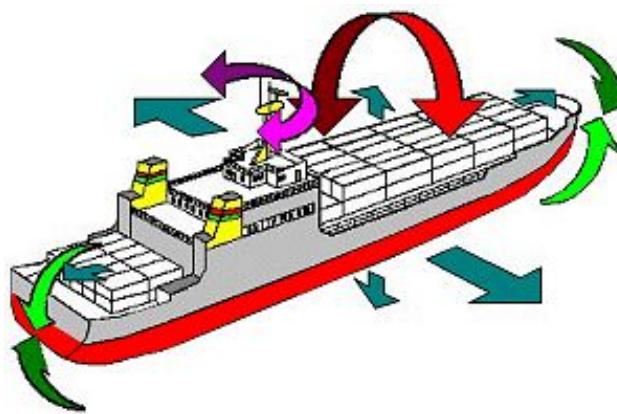
Frequency 100Hz

Start sampling

RAW DATA lift.json.2jvhbt7

A line graph titled 'RAW DATA lift.json.2jvhbt7' showing three data series: accX (red), accY (green), and accZ (blue). The x-axis represents time in milliseconds from 0 to 9360, and the y-axis represents the raw data values from -20 to 20. The graph shows periodic, high-frequency oscillations characteristic of a lifting motion.

# Label: maritime



Data acquisition - IESTI01 - Na

studio.edgeimpulse.com/studio/61345/acquisition/training?page=1

MJRoBot (Marcelo Rovai)

EDGE IMPULSE

DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)

Training data Test data

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

DATA COLLECTED  
5m 0s

TRAIN / TEST SPLIT  
100% / 0% ▲

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
maritime.json.2jvi6...	maritime	Today, 14:57:35	10s
maritime.json.2jvi6...	maritime	Today, 14:57:13	10s
maritime.json.2jvi5...	maritime	Today, 14:56:48	10s
maritime.json.2jvi4...	maritime	Today, 14:56:31	10s
maritime.json.2jvi4...	maritime	Today, 14:56:13	10s
maritime.json.2jvi3...	maritime	Today, 14:55:55	10s
maritime.json.2jvi3...	maritime	Today, 14:55:36	10s
maritime.json.2jvi2...	maritime	Today, 14:55:19	10s
maritime.json.2jvi2...	maritime	Today, 14:55:00	10s
maritime.json.2jvi1...	maritime	Today, 14:54:42	10s
lift.json.2jhbt7	lift	Today, 14:42:04	10s
lift.json.2vh9pe3	lift	Today, 14:41:45	10s

Record new data

Device: Nano

Label: maritime

Sample length (ms): 10000

Sensor: Sensor with 3 axes (accX, accY, accZ)

Frequency: 100Hz

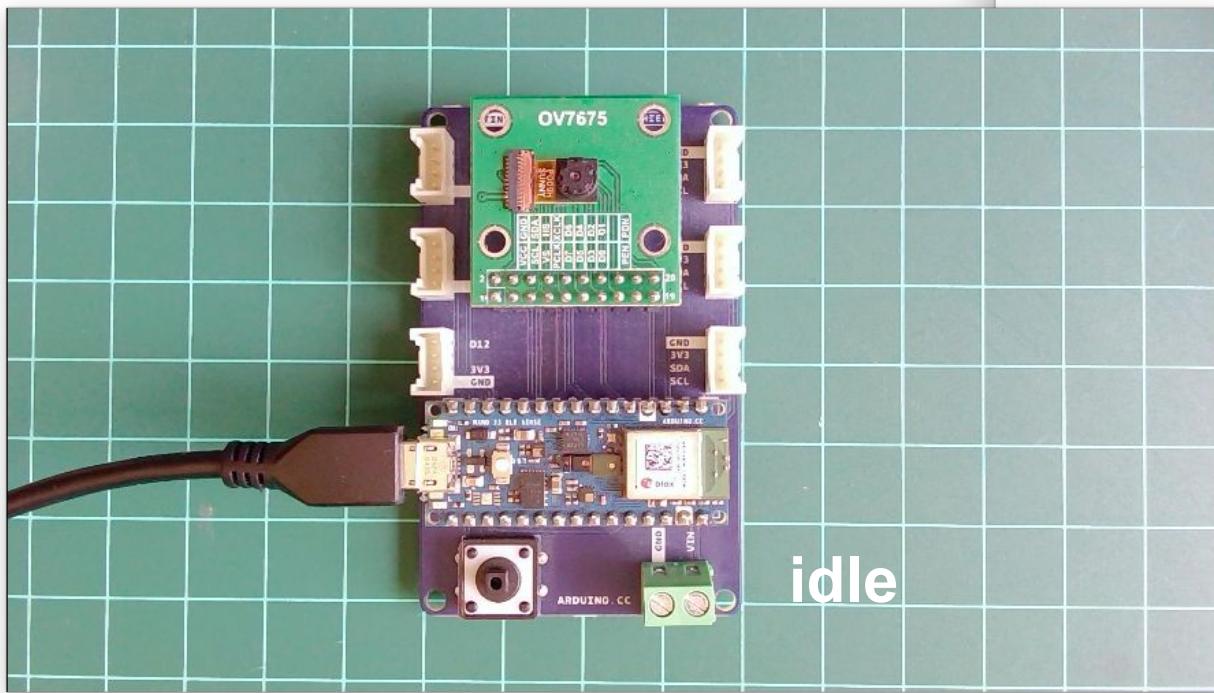
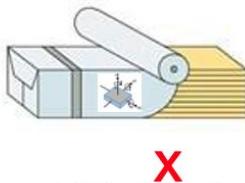
Start sampling

RAW DATA  
maritime.json.2jvi6p3r

accX accY accZ

1040 2080 3120 4160 5200 6240 7280 8320 9360

# Label: idle



Data acquisition - IESTI01 - Na +

studio.edgeimpulse.com/studio/61345/acquisition/training?page=1

MJRoBot (Marcelo Rovai)

EDGE IMPULSE

DATA ACQUISITION (IESTI01 - NANO MOTION CLASSIFICATION)

Training data Test data

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

DATA COLLECTED 6m 40s TRAIN / TEST SPLIT 100% / 0% ▲

Record new data Connect using WebUSB

Device Nano

Label idle Sample length (ms.) 100000

Sensor Sensor with 3 axes (accX, accY, accZ) Frequency 100Hz

Start sampling

RAW DATA idle.json.2jvif14

SAMPLE NAME	LABEL	ADDED	LENGTH
idle.json.2jvif14	idle	Today, 15:06:09	1m 40s
maritime.json.2jvi6...	maritime	Today, 14:57:35	10s
maritime.json.2jvi6...	maritime	Today, 14:57:13	10s
maritime.json.2jvi5...	maritime	Today, 14:56:48	10s
maritime.json.2jvi4...	maritime	Today, 14:56:31	10s
maritime.json.2jvi4...	maritime	Today, 14:56:13	10s
maritime.json.2jvi3...	maritime	Today, 14:55:55	10s
maritime.json.2jvi3...	maritime	Today, 14:55:36	10s
maritime.json.2jvi2...	maritime	Today, 14:55:19	10s
maritime.json.2jvi2...	maritime	Today, 14:55:00	10s
maritime.json.2jvi1...	maritime	Today, 14:54:42	10s
lift.json.2jhbt7	lift	Today, 14:42:04	10s

accX accY accZ

Dashboard - IESTI01 - Nano M

studio.edgeimpulse.com/studio/61345

**EDGE IMPULSE**

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

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- Documentation
- Forums

Download block output

No downloads available yet

Performance settings

Use GPU for training

Parallel DSP jobs

Job limit in minutes

DSP file size limit (MB)

Administrative zone

Show Linux deploy options

Save experiments

Danger zone

Perform train / test split

Delete this project

Delete all data in this project

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Dashboard - IESTI01 - Nano M

studio.edgeimpulse.com/studio/61345

**EDGE IMPULSE**

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

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- Documentation
- Forums

Download block output

No downloads available yet

Performance settings

Use GPU for training

Parallel DSP jobs

Job limit in minutes

DSP file size limit (MB)

Administrative zone

Show Linux deploy options

Save experiments

Danger zone

Performing split...

Delete this project

Delete all data in this project

Project info

Project ID 61345

Labeling method One label per data

Latency calculations Cortex-M4F 80M

?

Perform train / test split

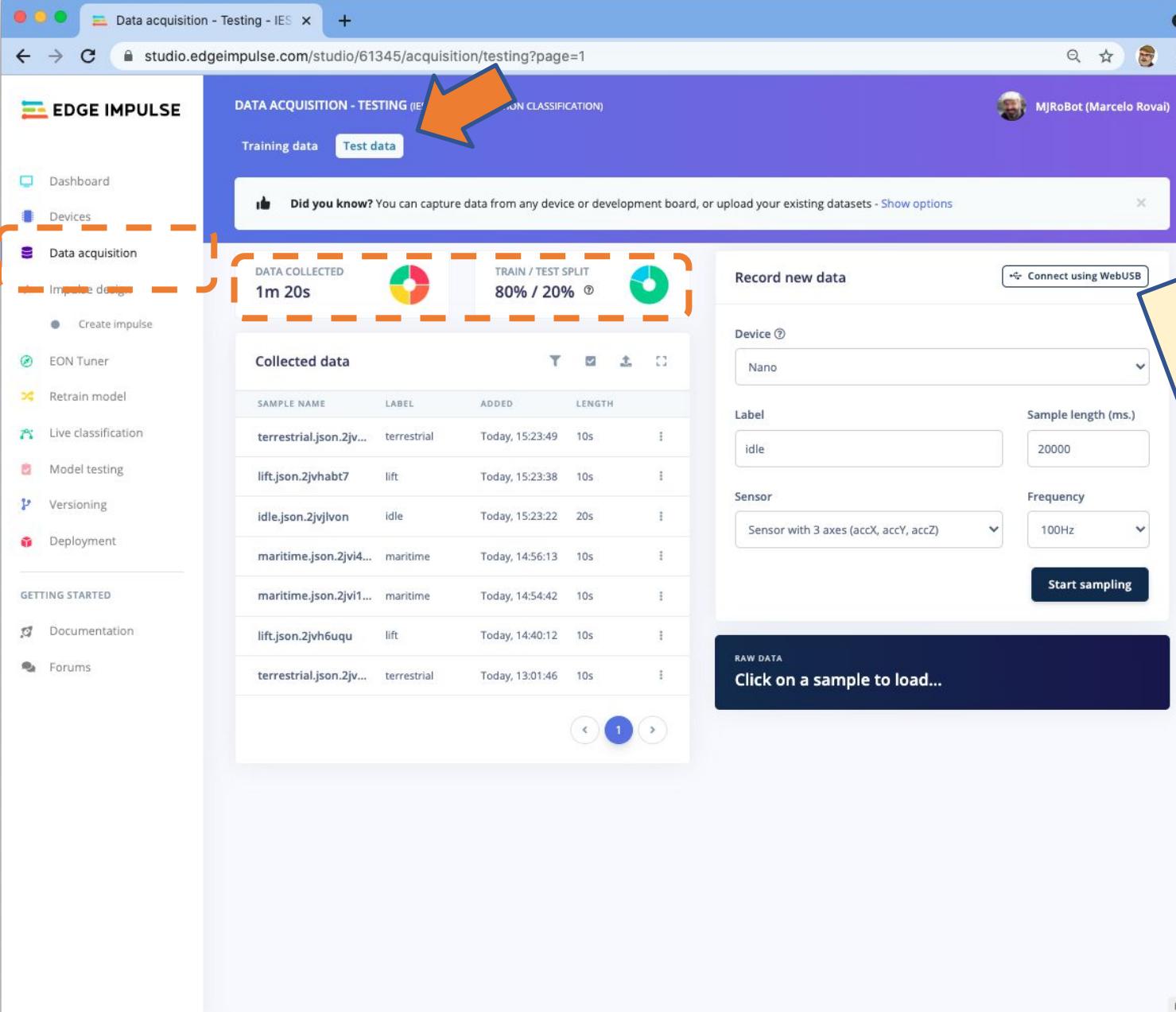
Are you sure you want to rebalance your dataset? This splits all your data automatically between the training and testing set, and resets the categories for all data. This is irrevocable!

Cancel Yes, perform the train / test split

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The screenshot shows the Edge Impulse studio interface for data acquisition testing. On the left, a sidebar menu is visible with options like Dashboard, Devices, Data acquisition (which is selected and highlighted with an orange dashed border), Impulse design, EON Tuner, Retrain model, Live classification, Model testing, Versioning, Deployment, Documentation, and Forums. The main area is titled "DATA ACQUISITION - TESTING (IE5000)" and shows a summary: "DATA COLLECTED 40s" with a pie chart icon, and "TRAIN / TEST SPLIT 90% / 10%" with a slider icon. Below this, a table titled "Collected data" lists four samples: "maritime.json.2jvi4..." (label: maritime), "maritime.json.2jvi1..." (label: maritime), "lift.json.2jh6uqu" (label: lift), and "terrestrial.json.2jv..." (label: terrestrial). Each sample entry includes columns for SAMPLE NAME, LABEL, ADDED, LENGTH, and three vertical ellipsis icons. A blue arrow points from the sidebar's "Data acquisition" section towards the "Test data" tab. A tooltip message at the top says: "Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options". On the right, a "Record new data" form is open, showing fields for Device (set to Nano), Label (idle), Sample length (ms.) (set to 100000), Sensor (Sensor with 3 axes (accX, accY, accZ)), and Frequency (set to 100Hz). At the bottom, a dark blue bar says "RAW DATA Click on a sample to load...".

Automatic split was not  
good. Proceed with  
manual split



**EDGE IMPULSE**

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Impulse design

Create impulse

EON Tuner

Retrain model

Live classification

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**DATA ACQUISITION - TESTING (IEP)** (IEP) DATA CLASSIFICATION

Training data Test data

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

DATA COLLECTED  
1m 20s

TRAIN / TEST SPLIT  
80% / 20%

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
terrestrial.json.2jv...	terrestrial	Today, 15:23:49	10s
lift.json.2jhhabt7	lift	Today, 15:23:38	10s
idle.json.2jyjlvon	idle	Today, 15:23:22	20s
maritime.json.2jvi4...	maritime	Today, 14:56:13	10s
maritime.json.2jvi1...	maritime	Today, 14:54:42	10s
lift.json.2vh6uqu	lift	Today, 14:40:12	10s
terrestrial.json.2jv...	terrestrial	Today, 13:01:46	10s

Record new data

Device ?

Nano

Label

idle

Sample length (ms.)

20000

Sensor

Sensor with 3 axes (accX, accY, accZ)

Frequency

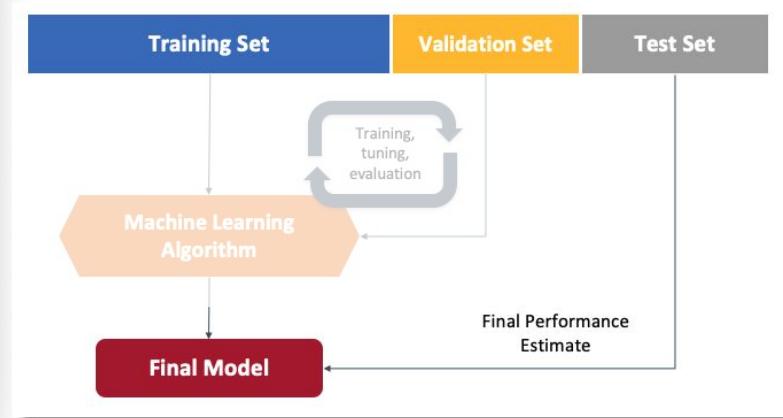
100Hz

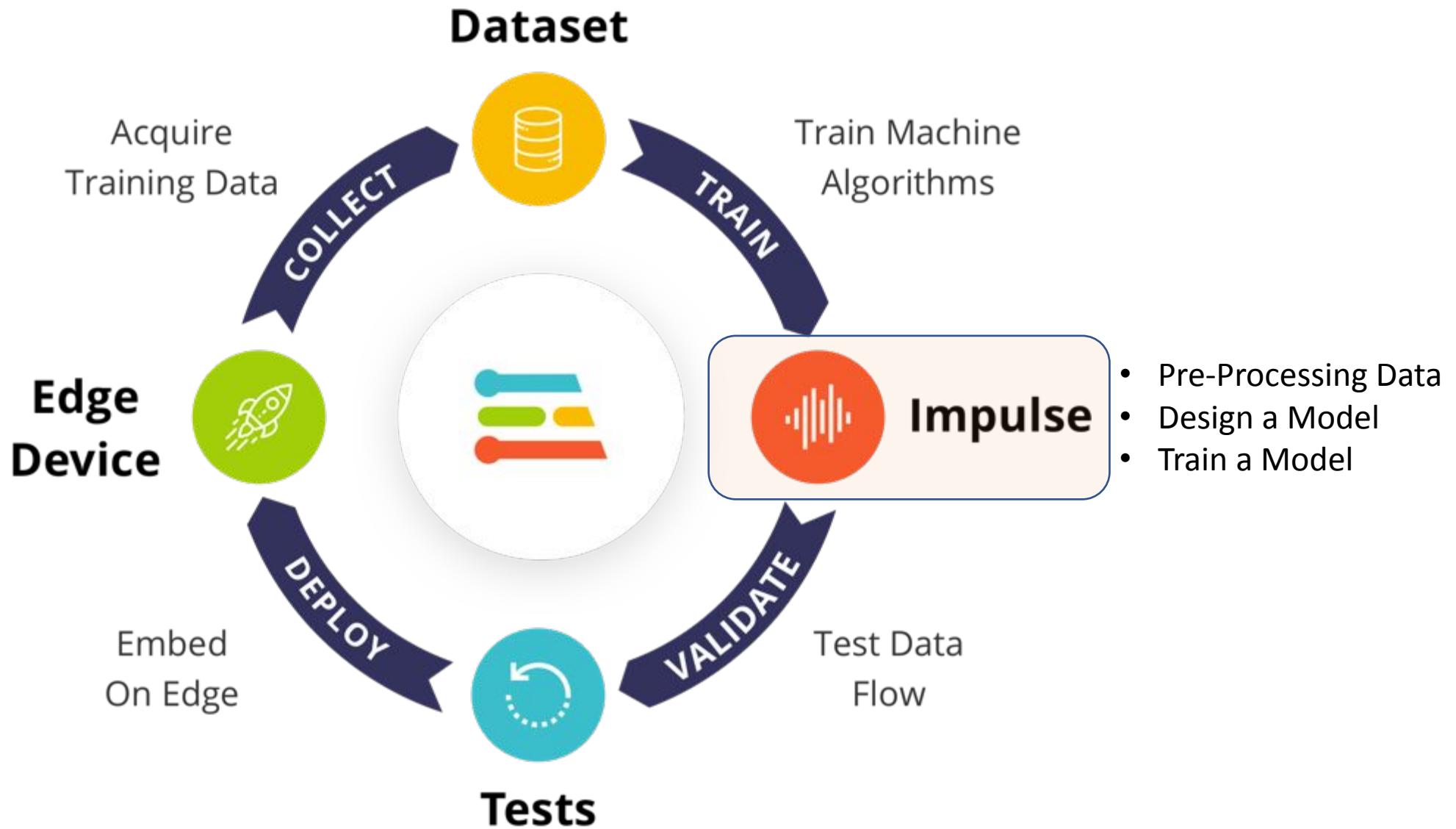
Start sampling

RAW DATA

Click on a sample to load...

Dataset is balanced  
(have representative samples from all classes)  
and split 80%/20%





Create impulse - IESTI01 - Nano Motion Classification

studio.edgeimpulse.com/studio/61345/create-impulse

MJRoBot (Marcelo Rovai)

EDGE IMPULSE

CREATE IMPULSE (IESTI01 - NANO MOTION CLASSIFICATION)

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

Classification (Keras)

Name: NN Classifier

Input features: Spectral features

Output features: 4 (idle, lift, maritime, terrestrial)

Save Impulse

Add a processing block

Add a learning block

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Spectral features - IESTI01 - N

studio.edgeimpulse.com/studio/61345/dsp/spectral-analysis/3

### Raw data

terrestrial.json.2jvgdqv9 (terrestrial)

accX accY accZ

### Raw features

1.6400, -0.9700, 9.8000, 1.7100, -0.6400, 9.8100, 1.8500, -0.4200, 9.7900, 1.7800, -0.5200, 9.7500, 1.7100,...

### Parameters

#### Scaling

Scale axes

#### Filter

Type  Cut-off frequency  Order

#### Spectral power

FFT length  No. of peaks  Peaks threshold  Power edges

Save parameters

### DSP result

#### After filter

#### Frequency domain

#### Spectral power

#### Processed features

1.9614, 0.7937, 2.6663, 0.0000, 0.0000, 0.0000, 0.0000, 0.4550, 0.0489, 0.0025, 0.2078, 2.3810, 0.1...

#### On-device performance

PROCESSING TIME **9 ms.** PEAK RAM USAGE **5 KB**

Spectral features - IESTI01 - N

studio.edgeimpulse.com/studio/61345/dsp/spectral-analysis/3/generate-features

**EDGE IMPULSE**

SPECTRAL FEATURES (IESTI01 - NANO MOTION CLASSIFICATION)

#1 ▾ Click to set a description for this version

Parameters **Generate features**

**Training set**

Data in training set 5m 20s

Classes 4 (idle, lift, maritime, terrestrial)

Window length 2000 ms.

Window increase 80 ms.

Training windows 3,400

**Feature explorer (3,400 samples)**

X Axis accX RMS Y Axis accY RMS Z Axis accZ RMS

idle (blue), lift (orange), maritime (green), terrestrial (red)

**Feature generation output**

Job started  
Creating windows from 25 files...  
[ 0/25] Creating windows from files...  
[ 1/25] Creating windows from files...  
[25/25] Creating windows from files...  
Created 3400 windows: idle: 976, lift: 808, maritime: 808, terrestrial: 808

Creating features  
[ 1/3400] Creating features...  
[ 898/3400] Creating features...  
[1798/3400] Creating features...  
[2704/3400] Creating features...  
[3400/3400] Creating features...  
Created features

Job completed

**On-device performance**

PROCESSING TIME 9 ms. PEAK RAM USAGE 5 KB

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MJRoBot (Marcelo Rovai)

### Neural Network settings

#### Training settings

Number of training cycles ?  
30

Learning rate ?  
0.0005

#### Neural network architecture

- Input layer (33 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 <b>99.9%</b>		LOSS <b>0.01</b>
--	--------------------------	--	---------------------

#### Confusion matrix (validation set)

	IDLE	LIFT	MARITIME	TERRESTRIAL
IDLE	<b>100%</b>	0%	0%	0%
LIFT	0%	<b>99.4%</b>	0.6%	0%
MARITIME	0%	0%	<b>100%</b>	0%
TERRESTRIAL	0%	0%	0%	<b>100%</b>
F1 SCORE	1.00	1.00	1.00	1.00

#### Feature explorer (full training set) ?

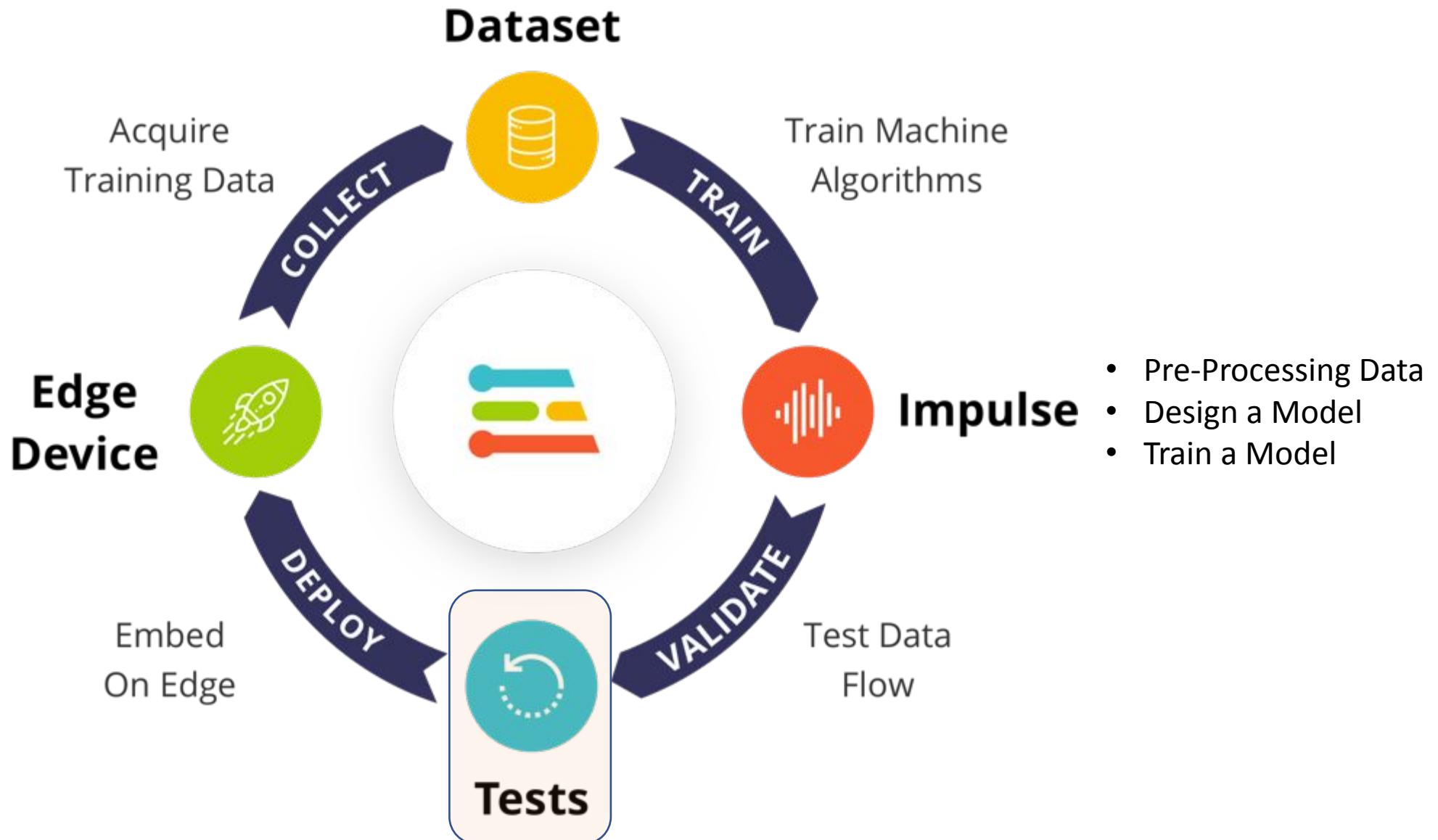
accX RMS ▼ accY RMS ▼ accZ RMS ▼

Legend:

- idle - correct
- lift - correct
- maritime - correct
- terrestrial - correct
- lift - incorrect

#### On-device performance ?

	INFERRING TIME <b>1 ms.</b>		PEAK RAM USAGE <b>1.7K</b>		FLASH USAGE <b>19.0K</b>
--	--------------------------------	--	-------------------------------	--	-----------------------------



Model testing - IESTI01 - Nano

studio.edgeimpulse.com/studio/61345/validation

## EDGE IMPULSE

**Test data**

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

SAMPLE NAME	EXPECTED OUTCOME	LENGTH	ACCURACY	RESULT	⋮
terrestrial.json.2...	terrestrial	10s	100%	101 terrestrial	⋮
lift.json.2jhbt7	lift	10s	100%	101 lift	⋮
idle.json.2jvjlvn	idle	20s	100%	226 idle	⋮
maritime.json.2j...	maritime	10s	100%	101 maritime	⋮
maritime.json.2j...	maritime	10s	100%	101 maritime	⋮
lift.json.2jh6uqu	lift	10s	100%	101 lift	⋮
terrestrial.json.2...	terrestrial	10s	100%	101 terrestrial	⋮

**Model testing output**

Classifying data for NN Classifier...  
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...  
Job started  
Classifying data for NN Classifier OK

**Job completed**

**Model testing results**

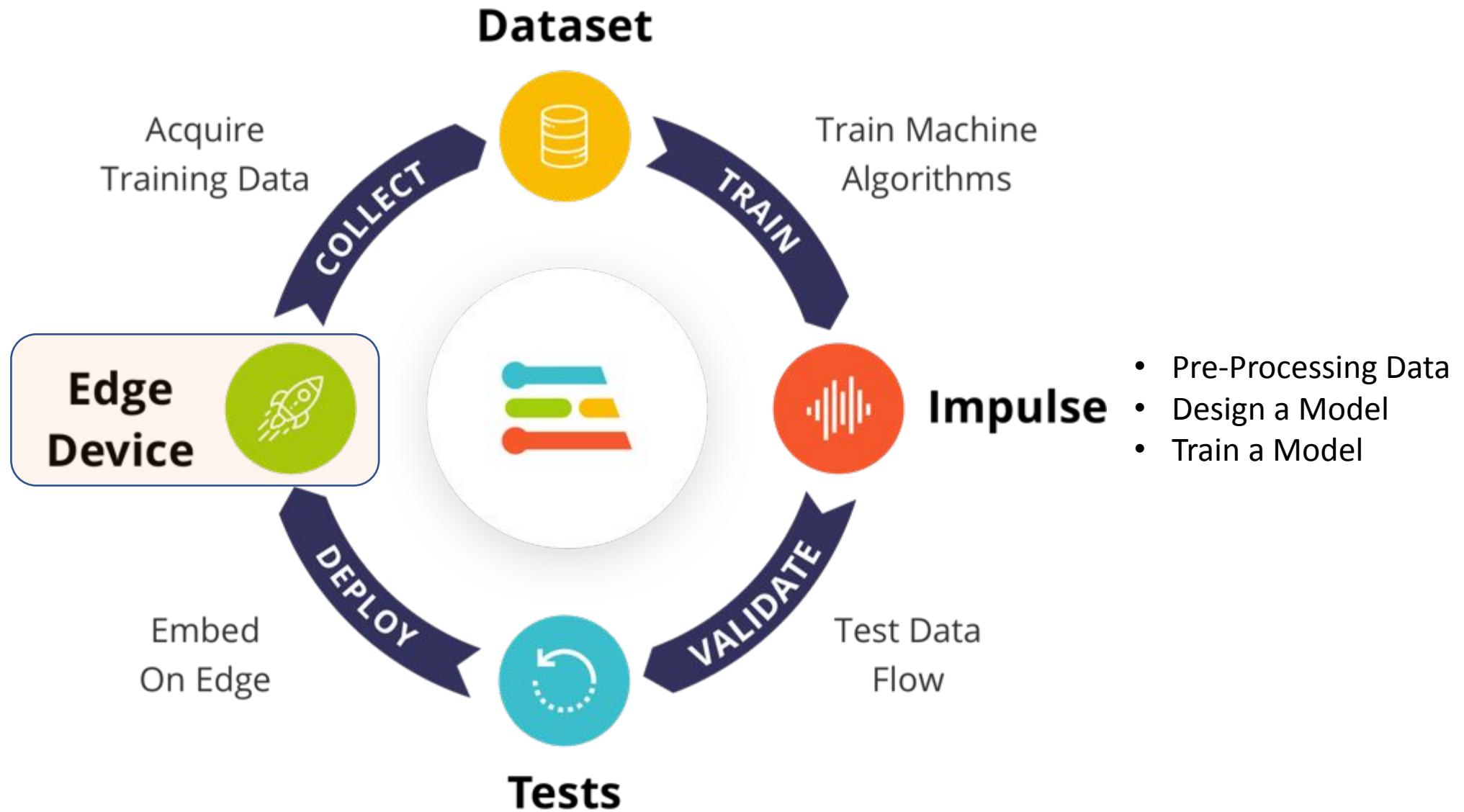
**ACCURACY**  
**100.00%**

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

**Feature explorer**

accX RMS accY RMS accZ RMS

- idle - correct
- lift - correct
- maritime - correct
- terrestrial - correct



Deployment - IESTI01 - Nano Motion Classification

studio.edgeimpulse.com/studio/61345/deployment

EDGE IMPULSE

DEPLOYMENT (IESTI01 - NANO MOTION CLASSIFICATION)

MJRoBot (Marcelo Rovai)

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

Build firmware

Or get a ready-to-go binary for your development board that includes your impulse.

ST IoT Discovery Kit Arduino Nano 33 BLE Sense Eta Compute ECM3532 AI Sensor

SiLabs Thunderboard Sense 2 Himax WE-I Plus Nordic nRF52840 DK + IKS02A1

Nordic nRF5340 DK + IKS02A1 Nordic nRF9160 DK + IKS02A1 Nordic Thingy:91

ei-iesti01---nano....zip

Show All

Build output

```
Creating job... OK (ID: 1646786)
Writing templates...
Writing templates OK
Copying Edge Impulse SDK...
Copying Edge Impulse SDK OK
Compiling EON model...
Compiling EON model OK
Removing clutter and updating headers...
Removing clutter and updating headers OK
Creating archive...
Job started
Creating archive OK
Job completed
```

Deployment - IESTI01 - Nano Motion Classification

studio.edgeimpulse.com/studio/61345/deployment

**EDGE IMPULSE**

- 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

SiLabs Thunderboard Sense 2

Himax WE-I Plus

Nordic nRF52840 DK + IKS02A1

Nordic nRF5340 DK + IKS02A1

Nordic nRF9160 DK + IKS02A1

Nordic Thingy:91

Sony's Spsesense

**Select optimizations (optional)**

Model optimizations can increase on-device performance. Choose from recommended choices for your target. Click [View all optimizations](#) to see more.

**Enable EON™ Compiler**

Same accuracy, up to 50% less RAM usage.

**Available optimizations for NN Classifier**

Optimization	RAM Usage	Latency	Confusion Matrix																				
<b>Quantized (int8) ★</b>	1.1K	1 ms	<table border="1"><tr><td>100</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>100</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>100</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td><td>100</td><td>0</td></tr></table>	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0
100	0	0	0	0																			
0	100	0	0	0																			
0	0	100	0	0																			
0	0	0	100	0																			
<b>Unoptimized (float32)</b>	19.0K	100%	<table border="1"><tr><td>100</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>100</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>100</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td><td>100</td><td>0</td></tr></table>	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0
100	0	0	0	0																			
0	100	0	0	0																			
0	0	100	0	0																			
0	0	0	100	0																			

Currently selected

This optimization is recommended for best performance.

Click to select

Estimate for Cortex-M4F 80MHz

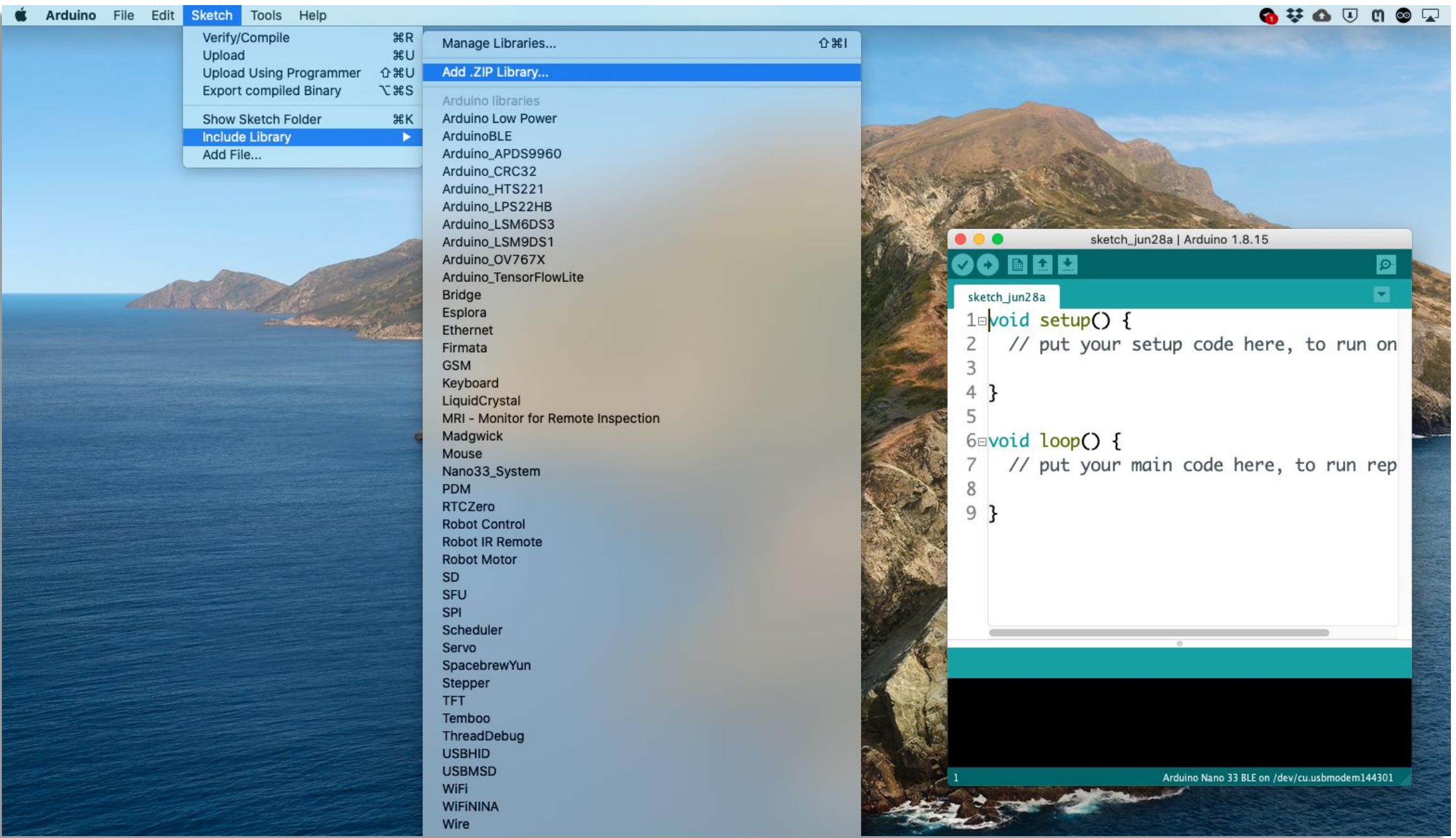
Build

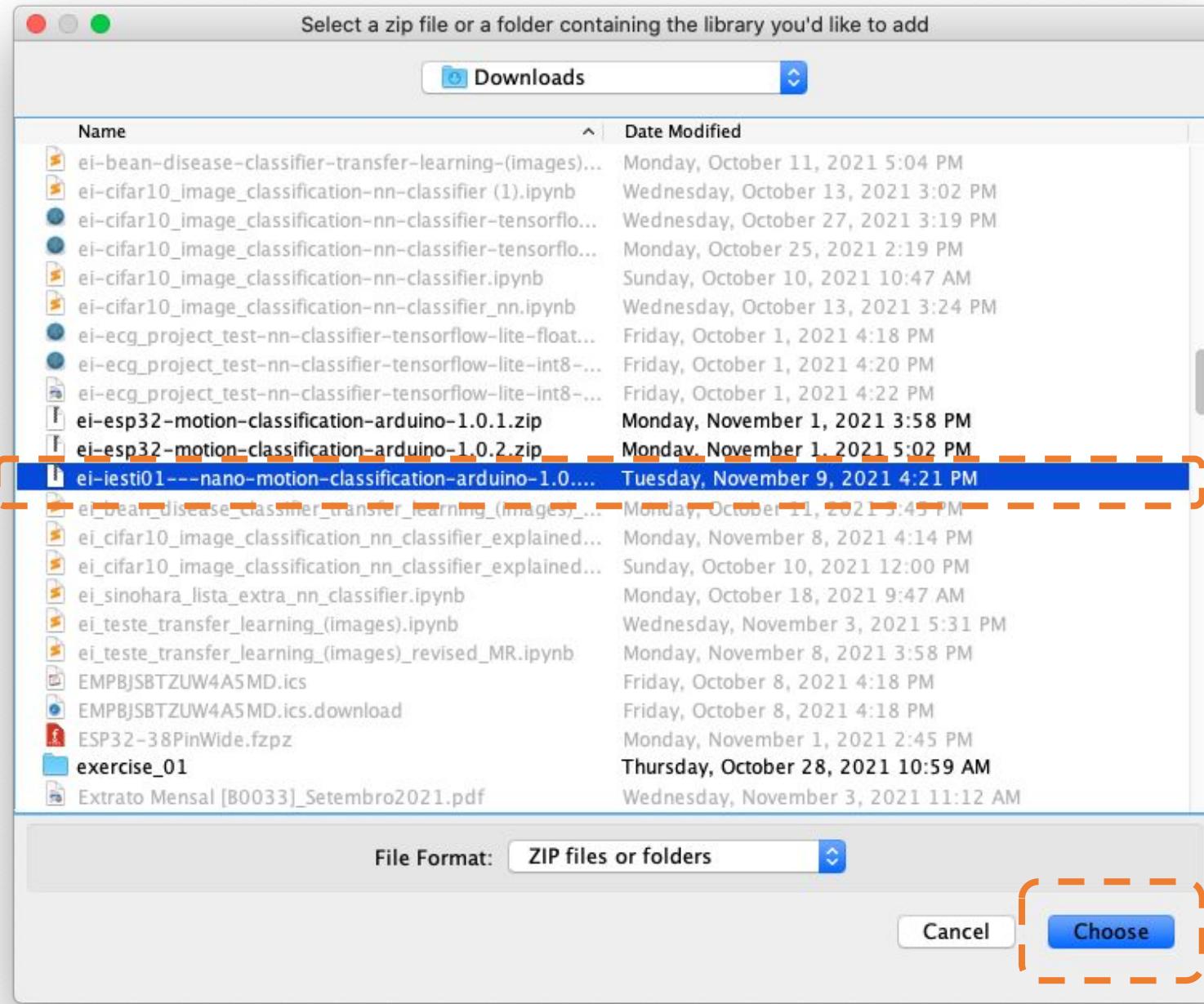
**Build output**

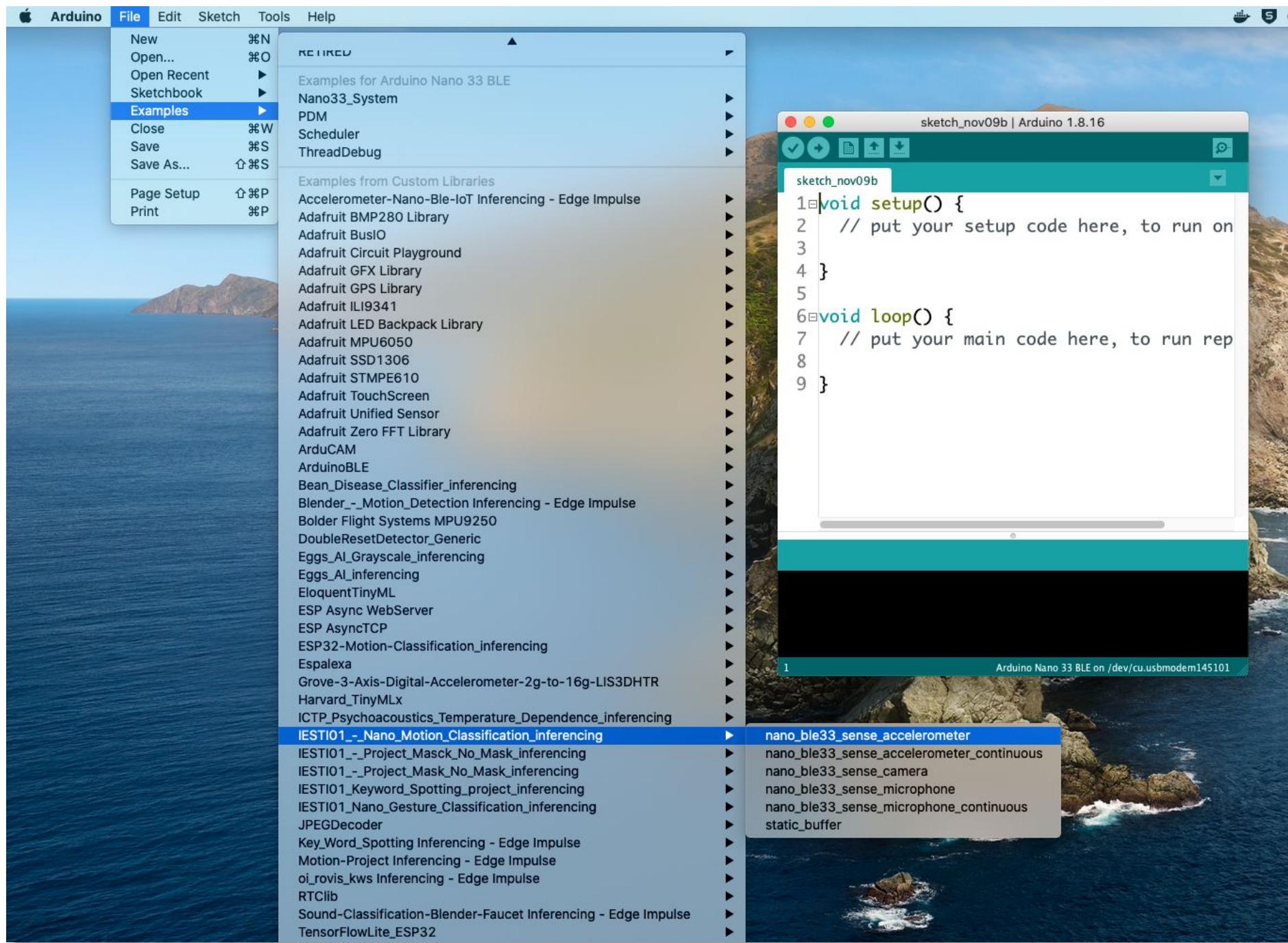
```
Creating job... OK (ID: 1646786)
Writing templates...
Writing templates OK
Copying Edge Impulse SDK...
Copying Edge Impulse SDK OK
Compiling EON model...
Compiling EON model OK
Removing clutter and updating headers...
Removing clutter and updating headers OK
Creating archive...
Archive OK
```

ei-iesti01---nano....zip

Show All







# Model Inference

Arduino File Edit Sketch Tools Help

/dev/cu.usbmodem145101

Sampling...

Predictions (DSP: 20 ms., Classification: 0 ms., Anomaly: 0 ms.):

- idle: 0.00000
- lift: 0.00000
- maritime: 0.00000
- terrestrial: 0.99609

Starting inferencing in 2 seconds...

Sampling...

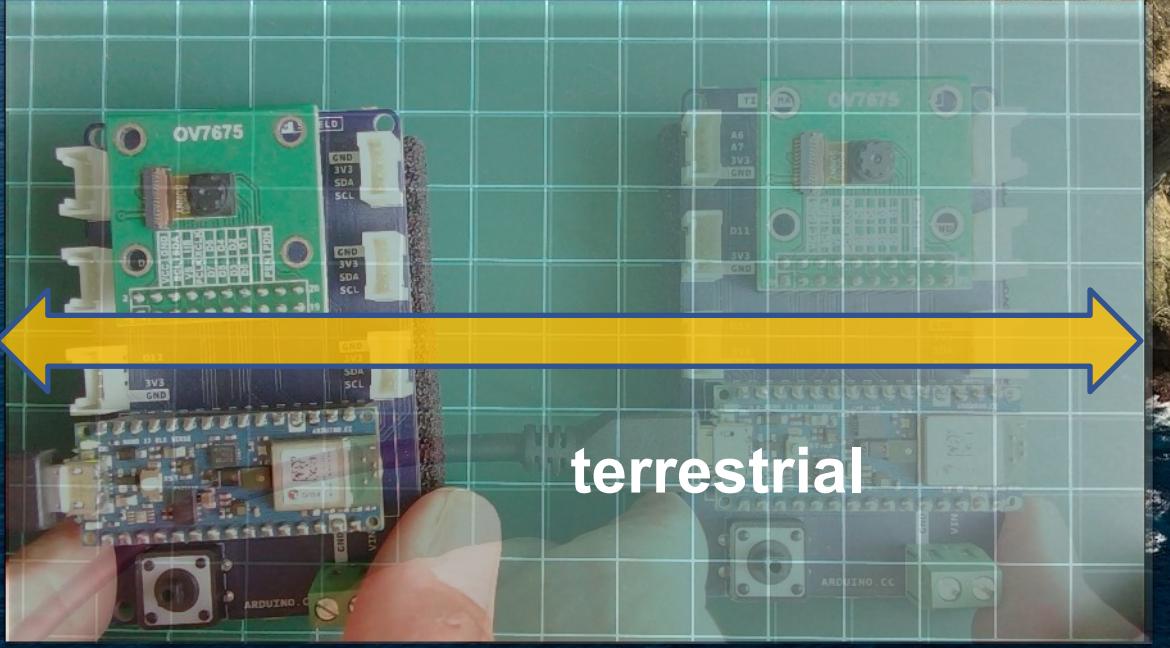
Predictions (DSP: 20 ms., Classification: 1 ms., Anomaly: 0 ms.):

- idle: 0.00000
- lift: 0.00000
- maritime: 0.00000
- terrestrial: 0.99609

Starting inferencing in 2 seconds...

Autoscroll  Show timestamp

Both NL & CR 115200 baud Clear output



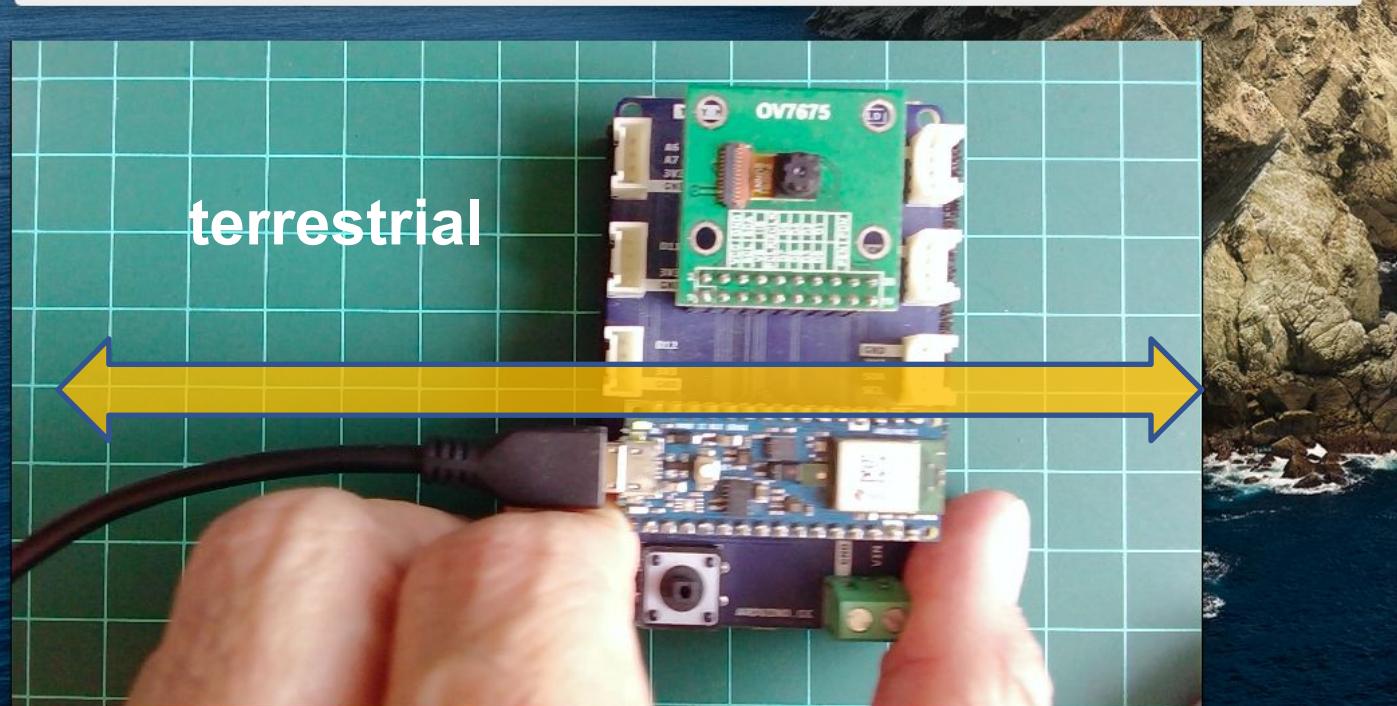
Done in 6.027 seconds  
reset()

Arduino Nano 33 BLE on /dev/cu.usbmodem145101

nano\_ble33\_sense\_accelerometer | Arduino 1.8.16

```
/* Edge Impulse Arduino examples
 * Copyright (c) 2021 EdgeImpulse Inc.
 *
 * Permission is hereby granted, free of charge, to any person obtaining a copy
 * of this software and associated documentation files (the "Software"), to
 * deal in the Software without restriction, including without limitation the rights
 * to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
 * copies of the Software, and to permit persons to whom the Software is
 * furnished to do so, subject to the following conditions:
 *
 * The above copyright notice and this permission notice shall be included in
 * all copies or substantial portions of the Software.
 *
 * THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
 * IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
 * FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE
 * AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
 * LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM
 * OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN
 * THE SOFTWARE.
 */
/*
 * Includes -----
#include <IESTI01_-_Nano_Motion_Classification_inferencing.h>
#include <Arduino_LSM9DS1.h>
*
/* Constant defines -----
#define CONVERT_G_TO_MS2 9.80665f
*
/* Private variables -----
static bool debug_nn = false; // Set this to true to see e.g. features generated by the neural network.
```

15



```
nano_ble33_sense_accelerometer_continuous | Arduino 1.8.16
rometer_continuous

STI01_-_Nano_Motion_Classification_inferencing.h>
duino_LSM9DS1.h>

defines -
ERT_G_TO_MS2      9.80665f

variables -
debug_nn = false; // Set this to true to see e.g. features
_t run_inference_every_ms = 200;
Thread inference_thread(osPriorityLow);
buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE] = { 0 };
inference_buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE];

eclaration */
erence_background();

Arduino setup function

our setup code here, to run once:
egin(115200);
rintln("Edge Impulse Inferencing Demo");

.begin() {
rintf("Failed to initialize IMU!\r\n");
rintf("IMU initialized\r\n");

onds
```

TinyML motion classification uses  
on **Real Life**

# Cow Monitoring

## Using the Internet of Things for Agricultural Monitoring

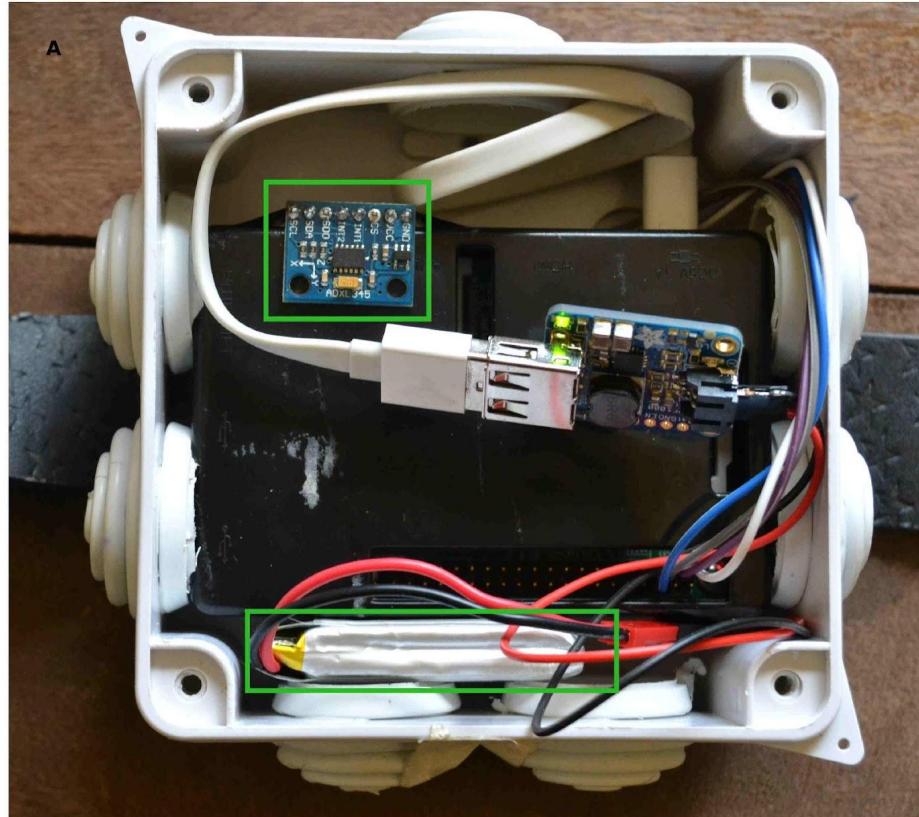
"We aim to deploy a variety of sensors for agricultural monitoring. One of the projects involves using **accelerometer sensors** to monitor activity levels in dairy cows with a view to determining when the cows are on heat or when they are sick."



Ciira wa Maina, Ph.D.

Senior Lecturer  
Department of Electrical and Electronic Engineering  
Dedan Kimathi University of Technology  
Nyeri Kenya  
Email: ciira.maina@dkut.ac.ke

Kenia



<https://sites.google.com/site/cwamainadekut/research>



# Predict and classify common Elephant behavior



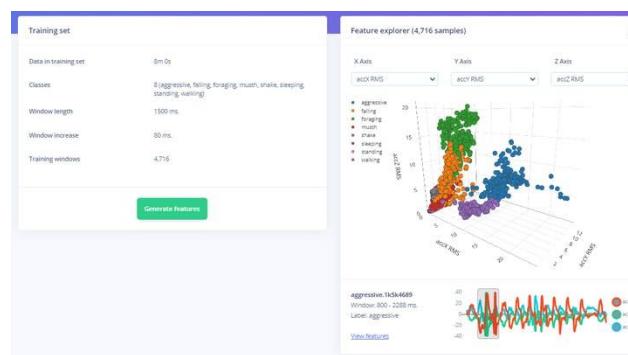
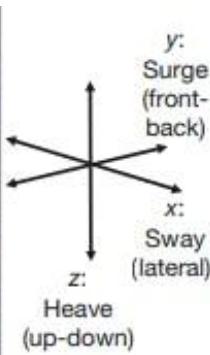
Aggressive



Standing



Sleeping



[https://www.hackster.io/dhruvsheth\\_electet-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a#toc-accelerometer-data-models-4](https://www.hackster.io/dhruvsheth_electet-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a#toc-accelerometer-data-models-4)

# Reading Material

# Main references

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

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

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

**Thanks**  
**And stay safe!**



**UNIFEI**