



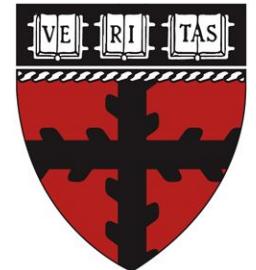
CNMAC
2022

XLI Congresso Nacional
de Matemática Aplicada
e Computacional

Topics in Applied Machine Learning: A Hands-on Approach – MS12 (Vibration)

Marcelo José Rovai and José Alberto Ferreira Filho
UNIFEI - Universidade Federal de Itajubá, Brazil

Flávio Calmon and Lucas Monteiro Paes
Harvard University, USA



Sound



Vibration



Vision



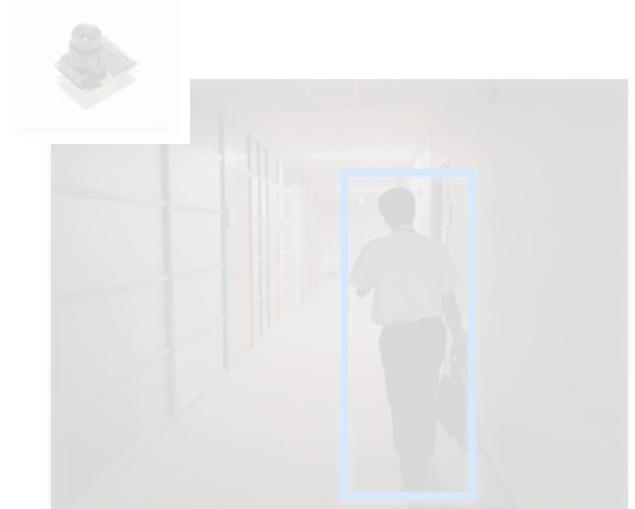
Sound



Vibration



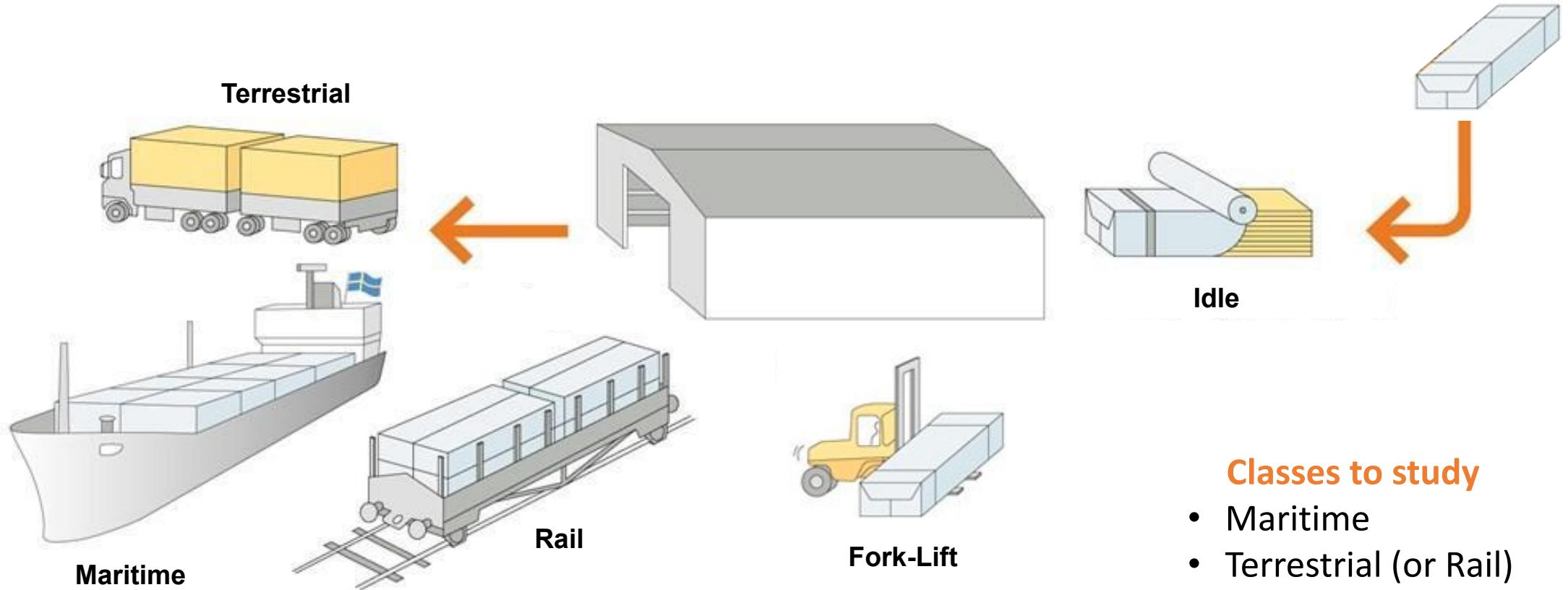
Vision



Motion Classification



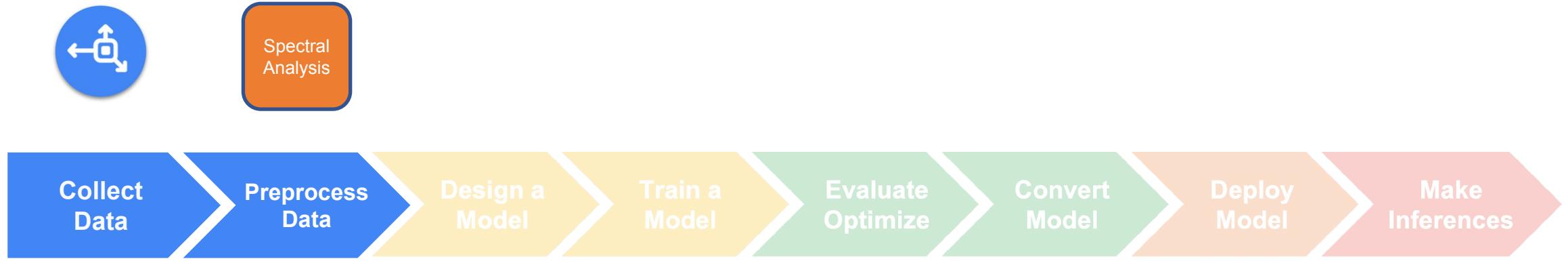
Case Study: Mechanical Stresses in Transport



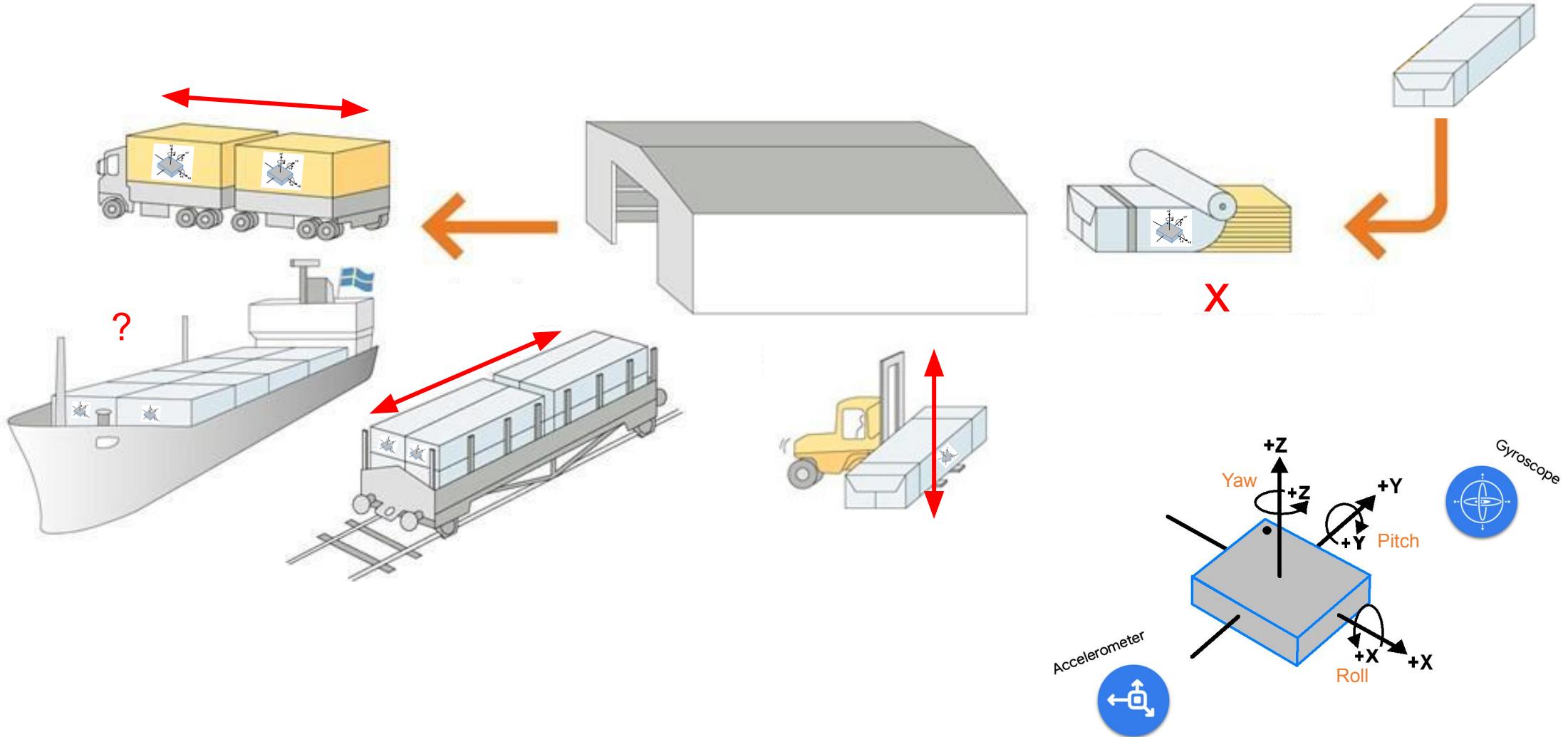
Classes to study

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

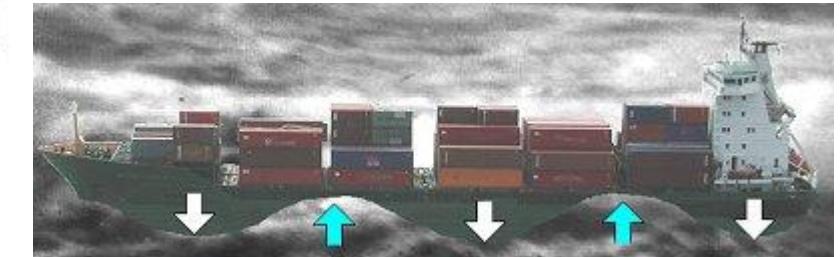
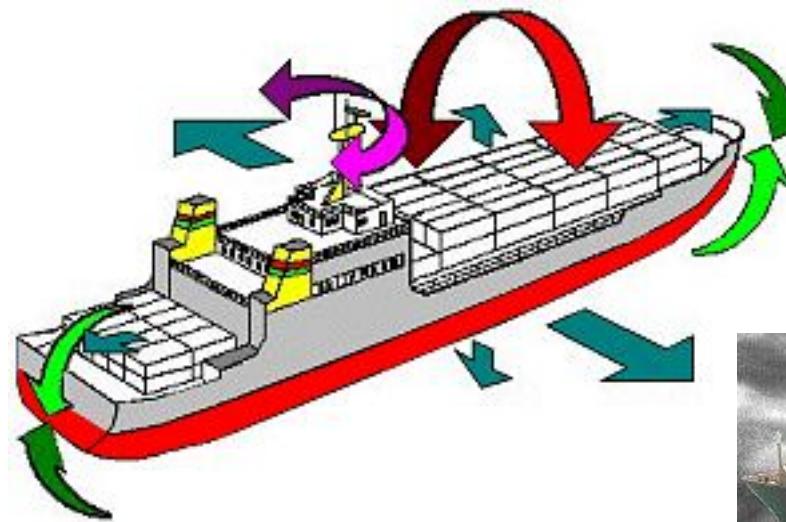
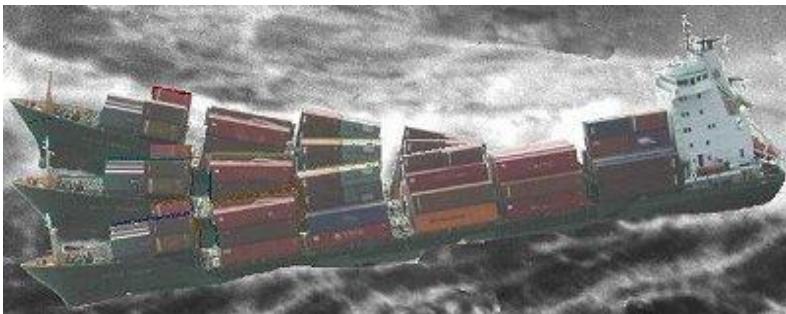
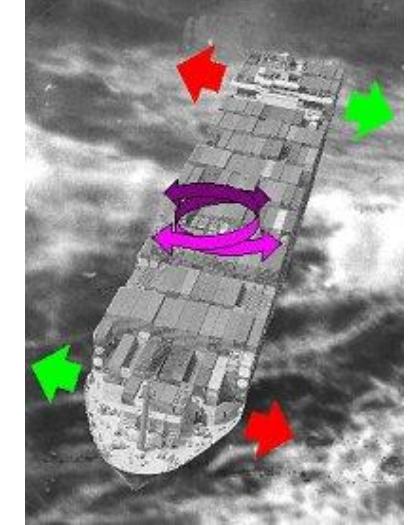
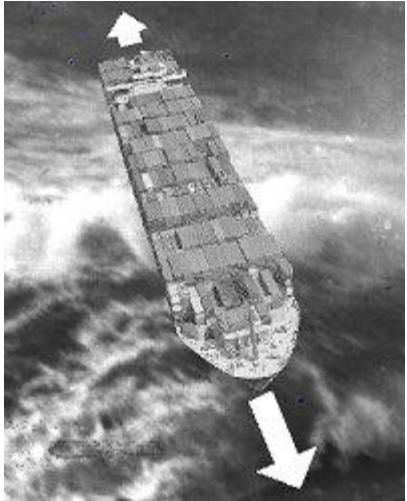
Data Pre-Processing



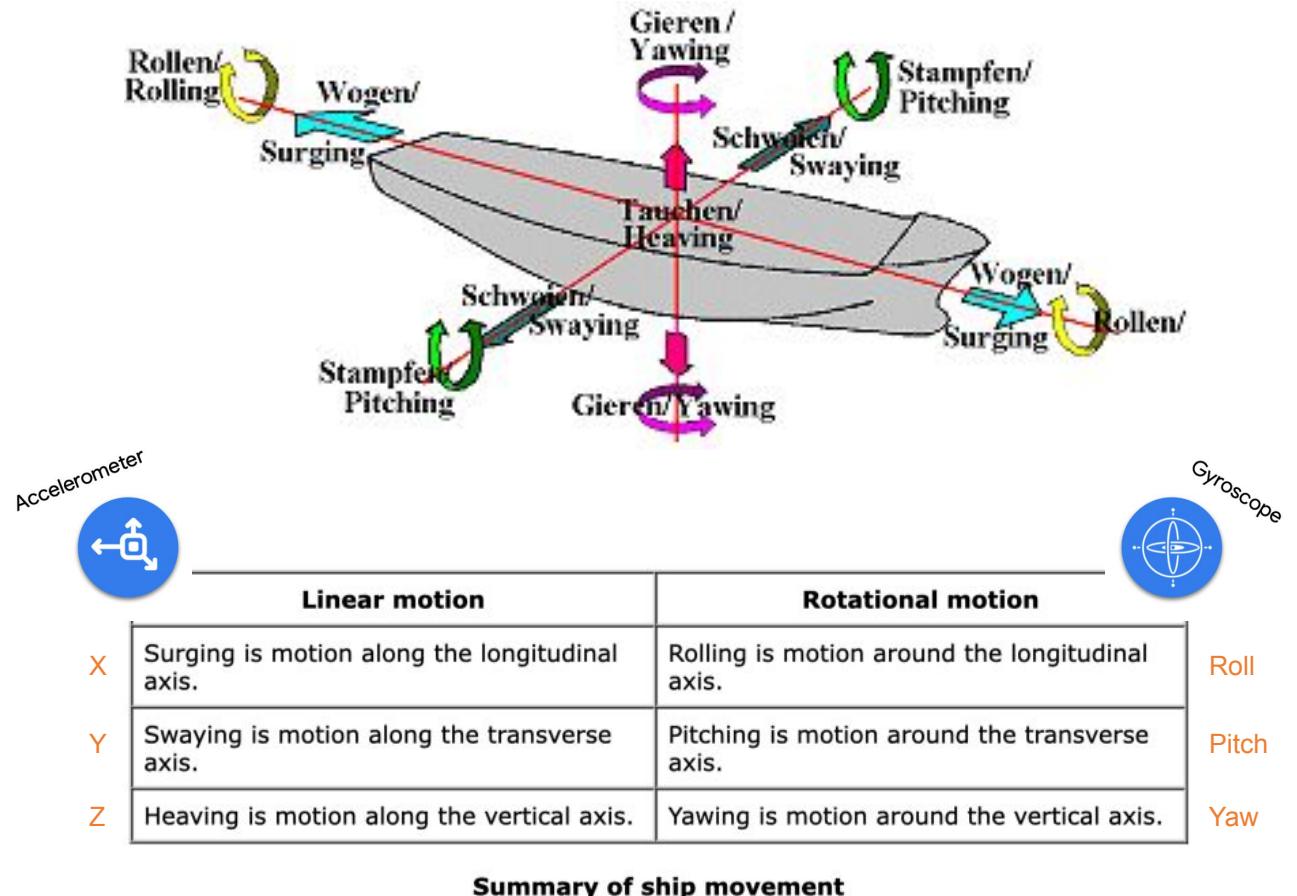
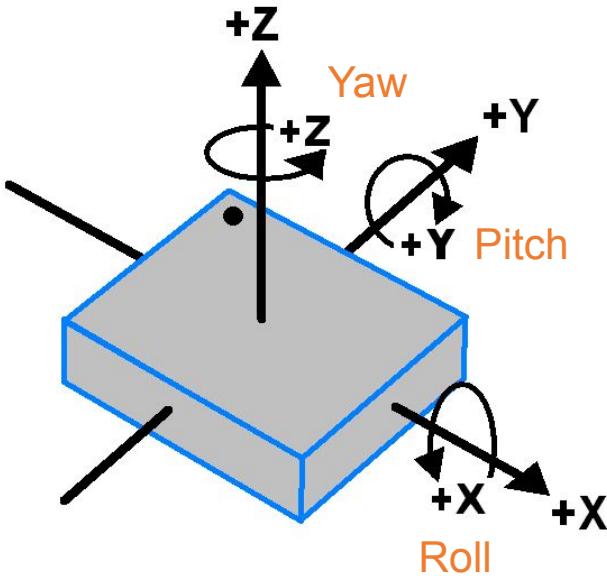
Collect Data



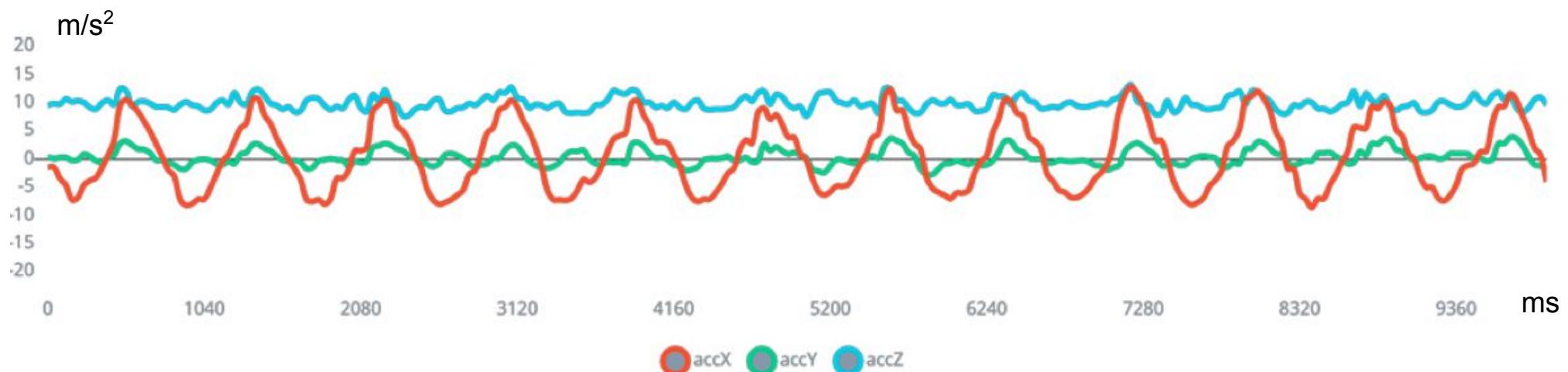
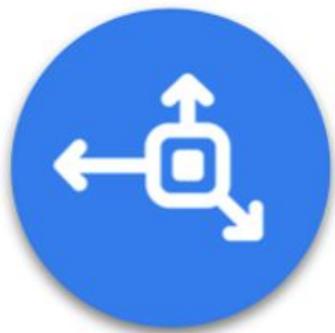
Mechanical Stresses in Maritime Transport

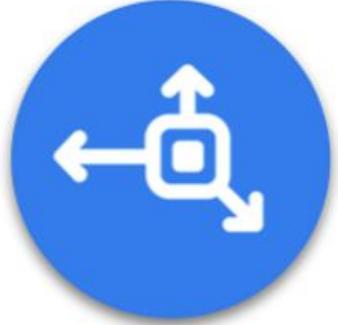


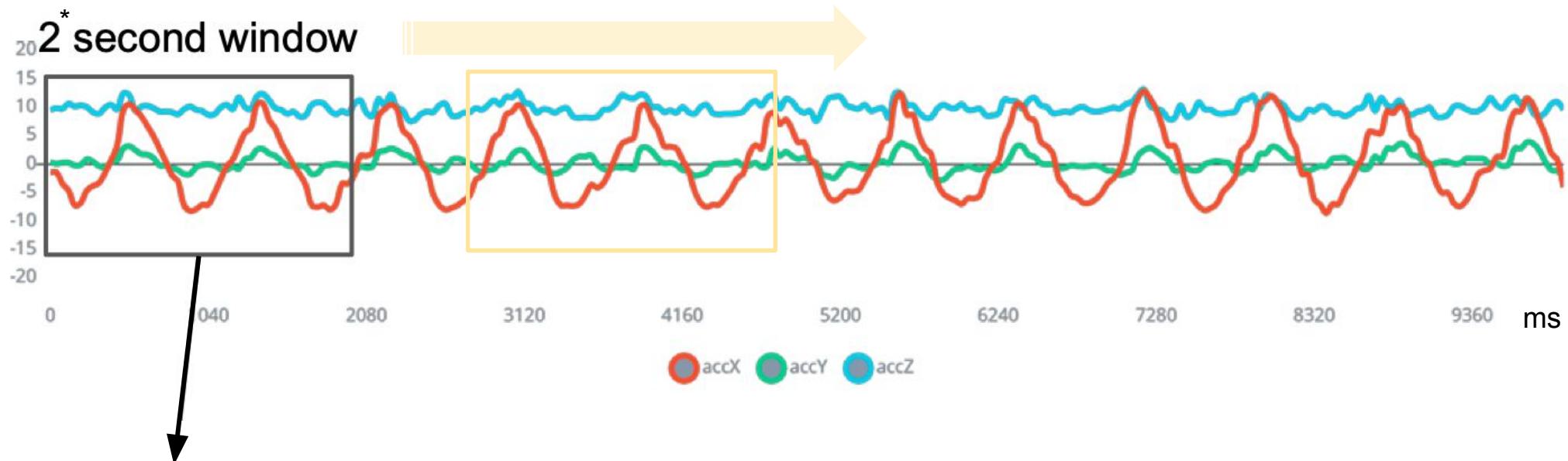
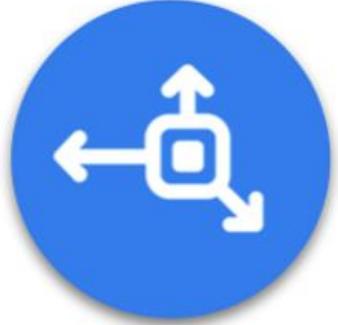
Mechanical Stresses in Maritime Transport



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





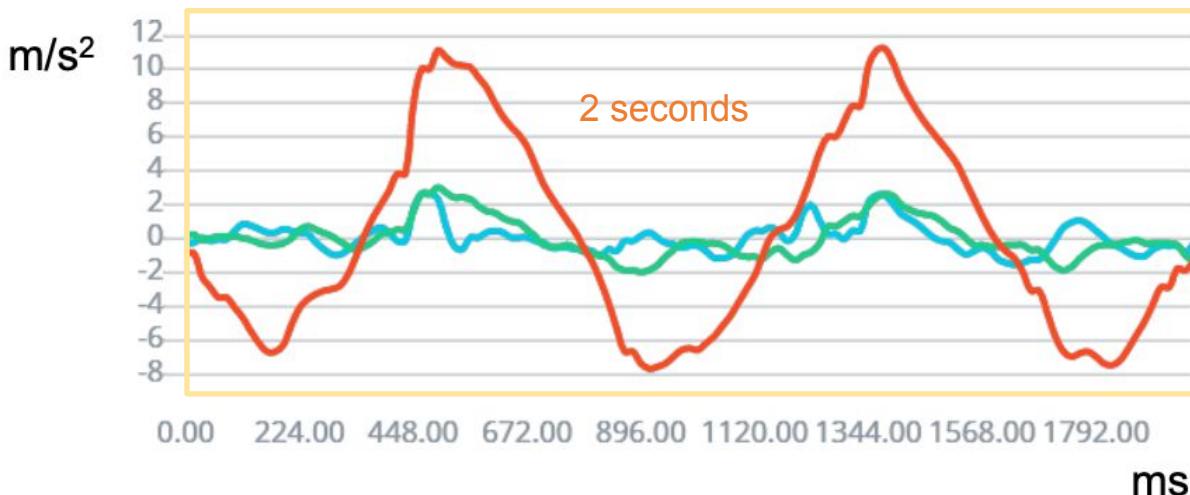


Raw Features as a window

- 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

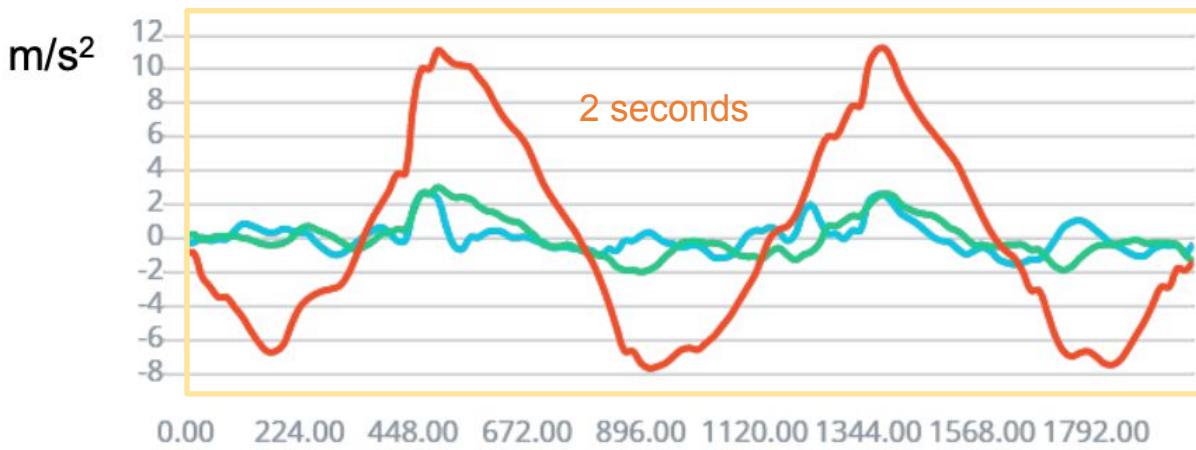


Manual Feature Extraction

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

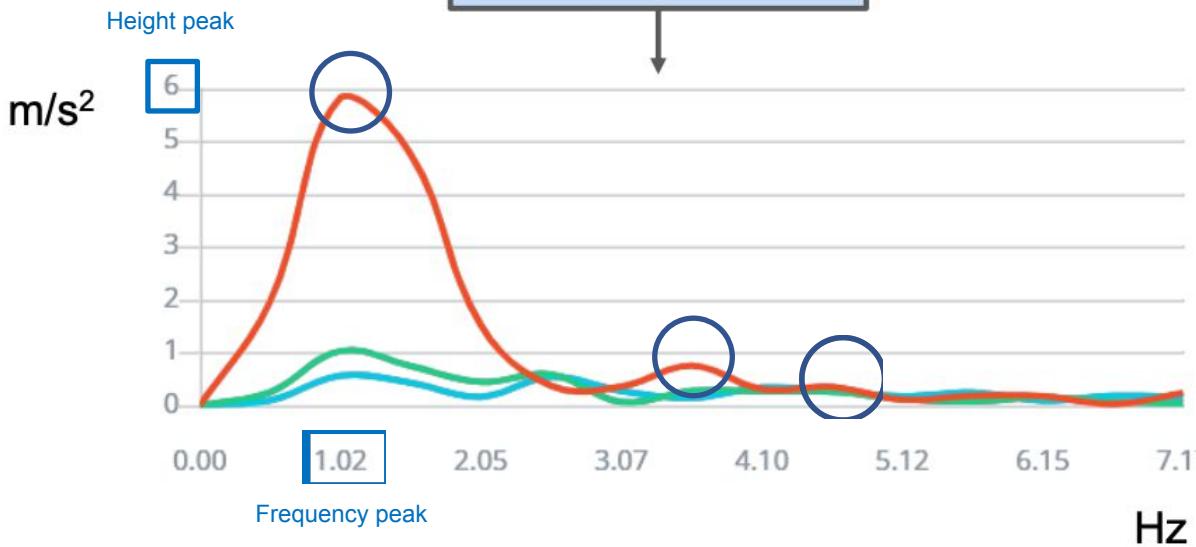
$$x_{\text{RMS}} = \sqrt{\frac{1}{n} (x_1^2 + x_2^2 + \dots + x_n^2)}.$$

→ 125

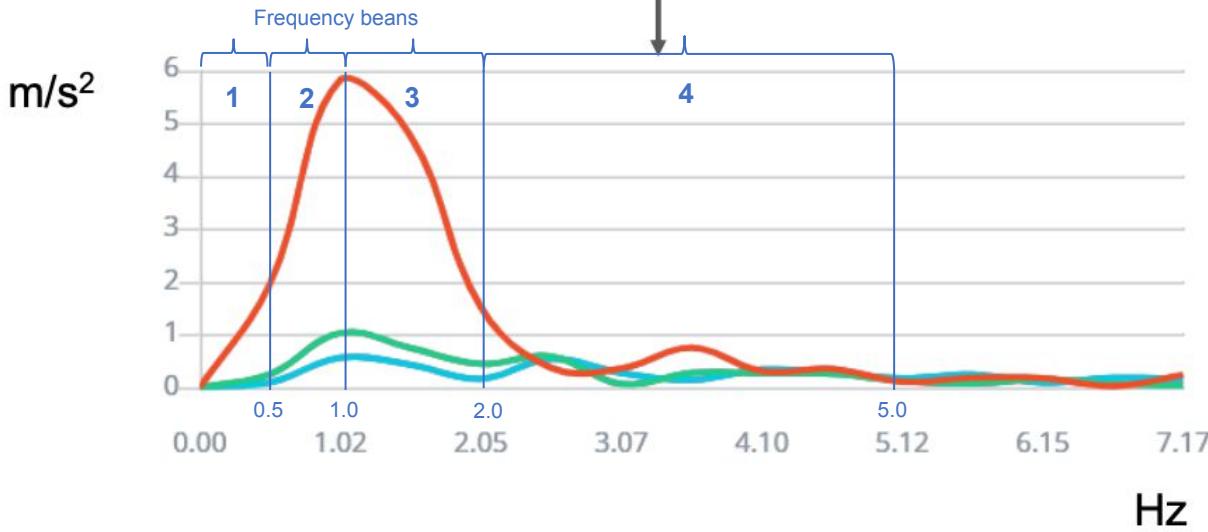
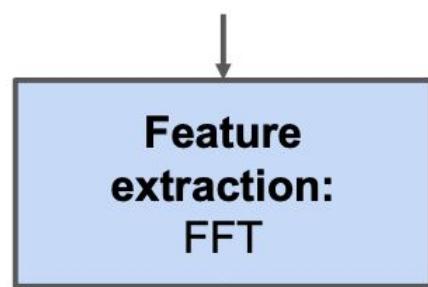
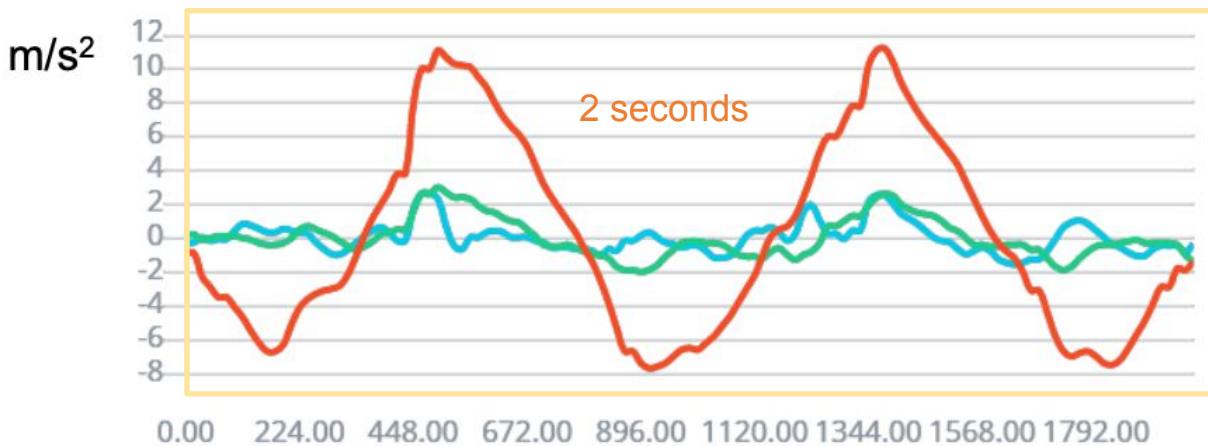


Manual Feature Extraction

3 RMS



9 Height + 9 Freq. peak values



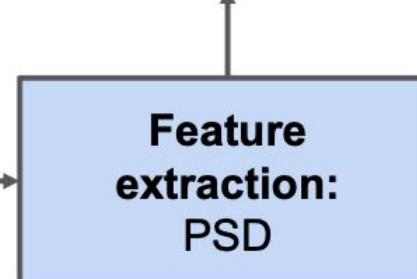
Manual Feature Extraction

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

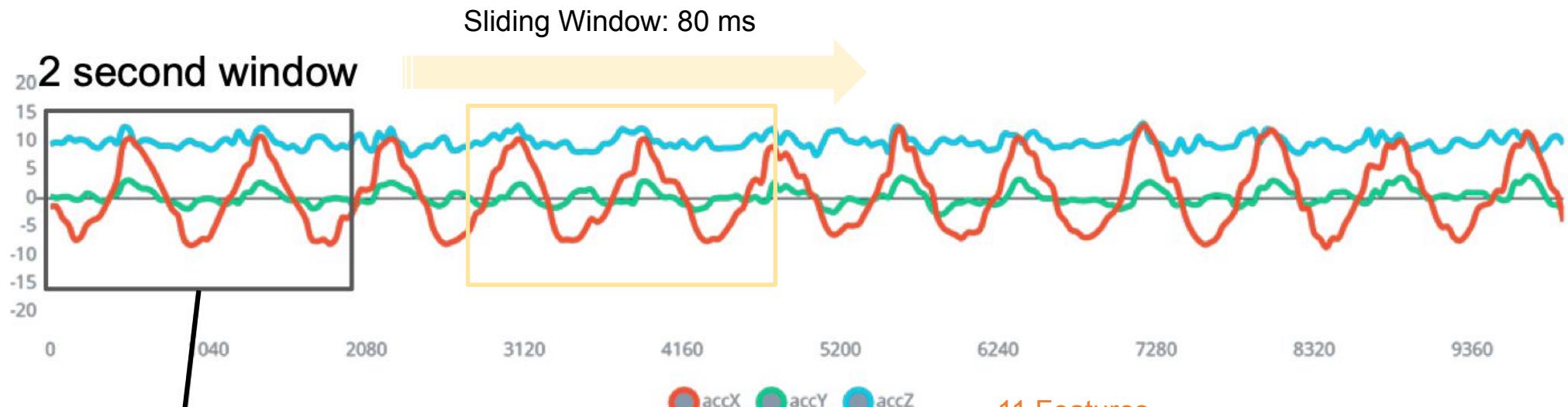
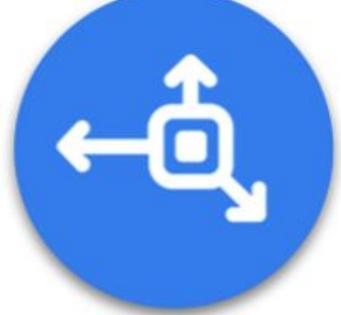
Power Spectral Density (PSD)



4 Frequency bins per axis



<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

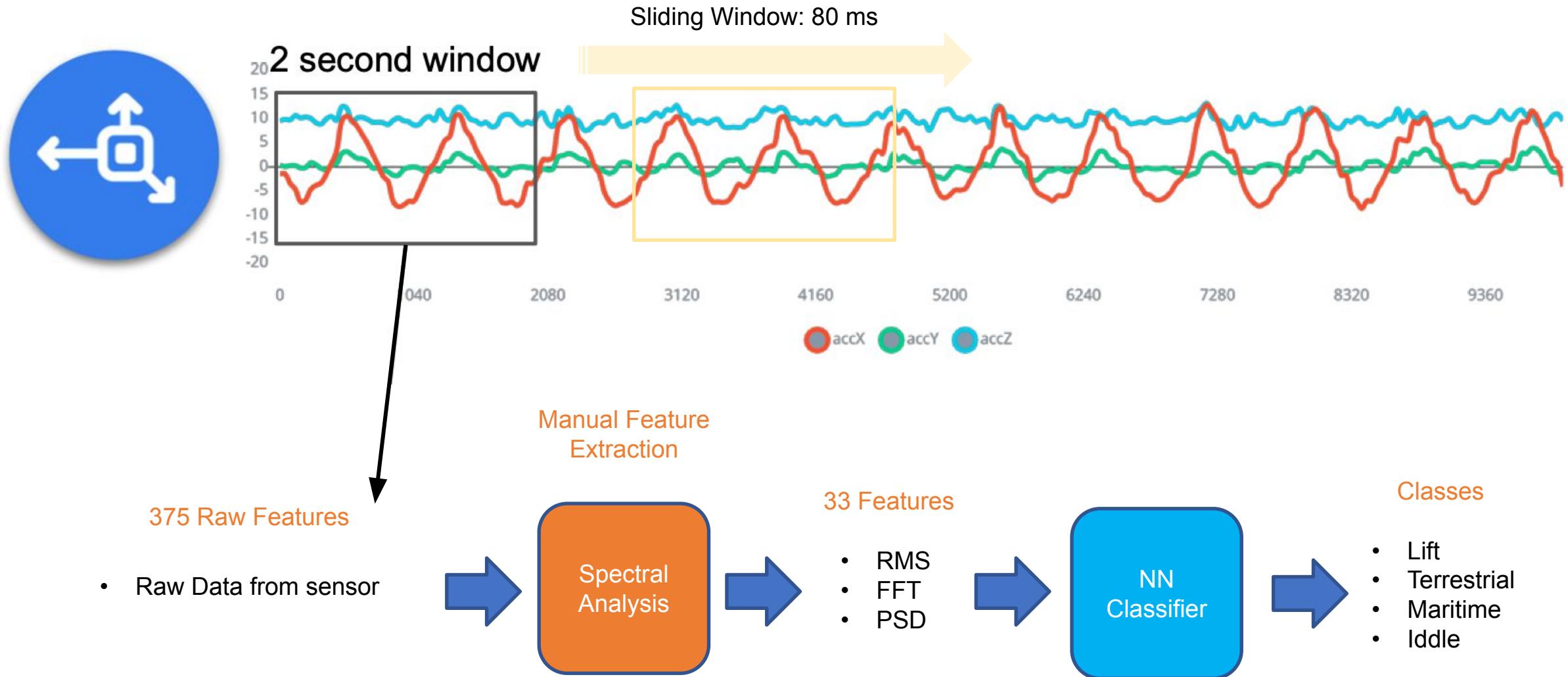
Spectral Analysis

11 Features

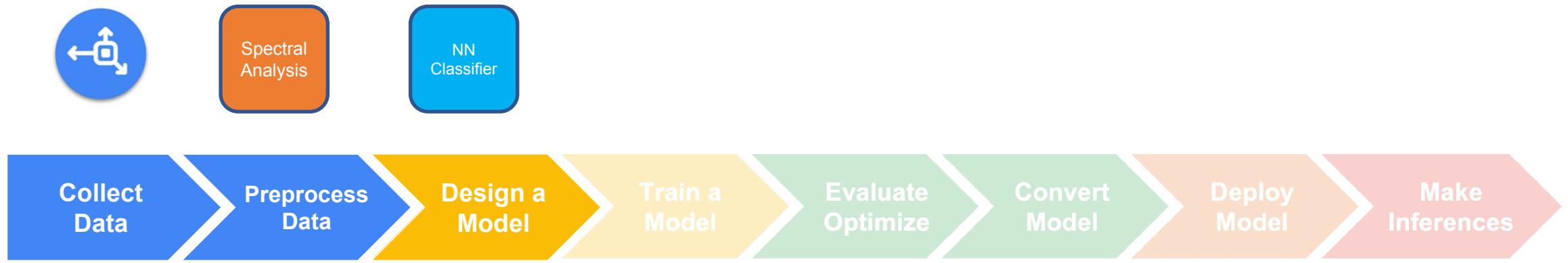
11 Features

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 Spectral Power 0.1 - 0.5
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	



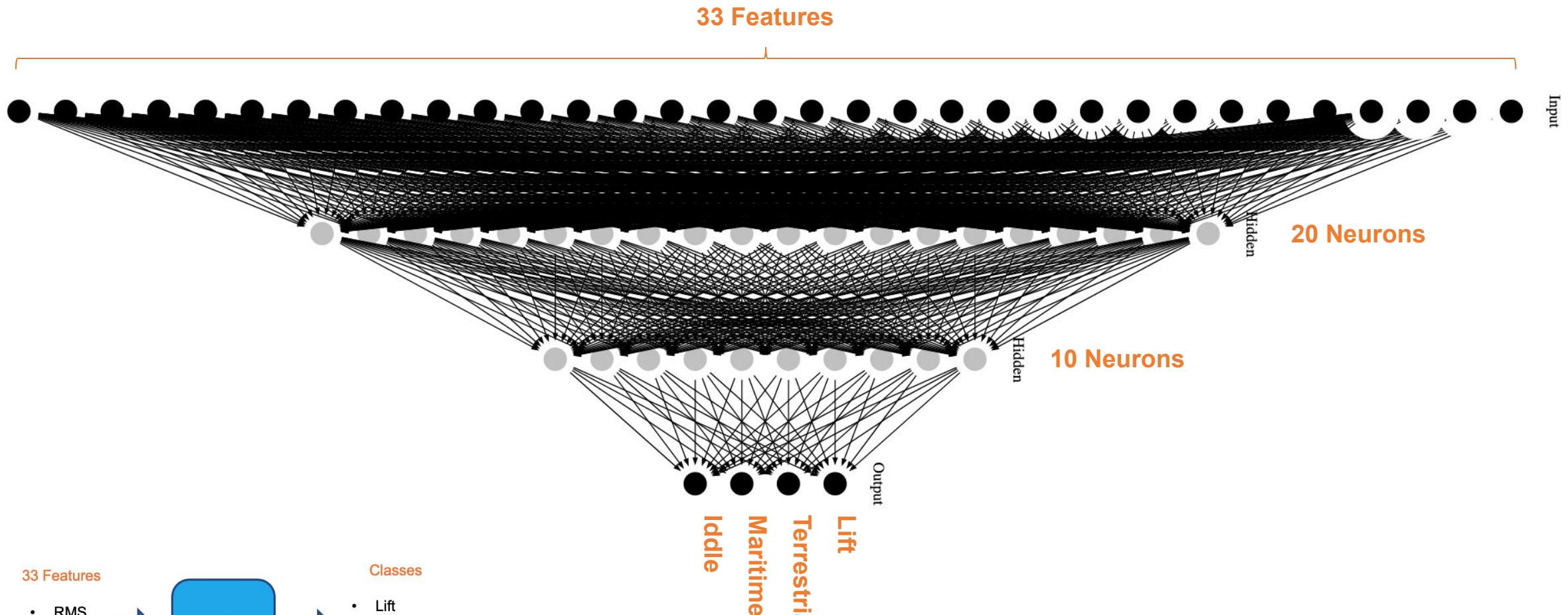
Model Design (NN Classifier)



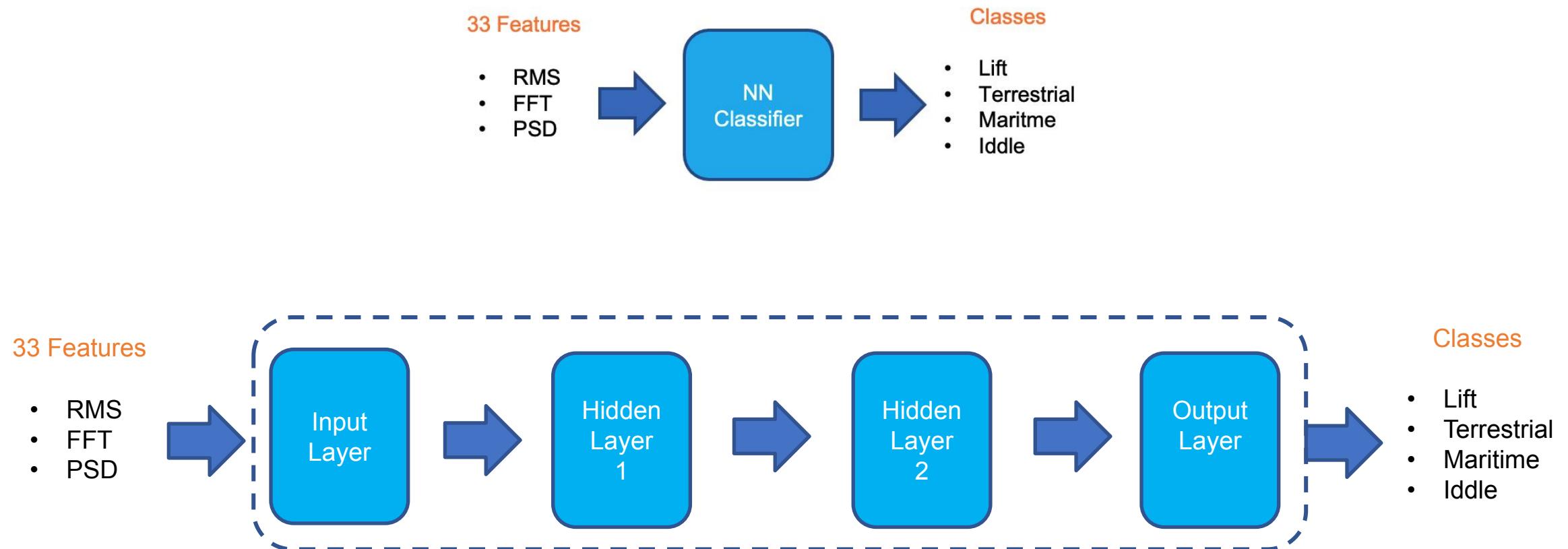
Model Design (NN Classifier)



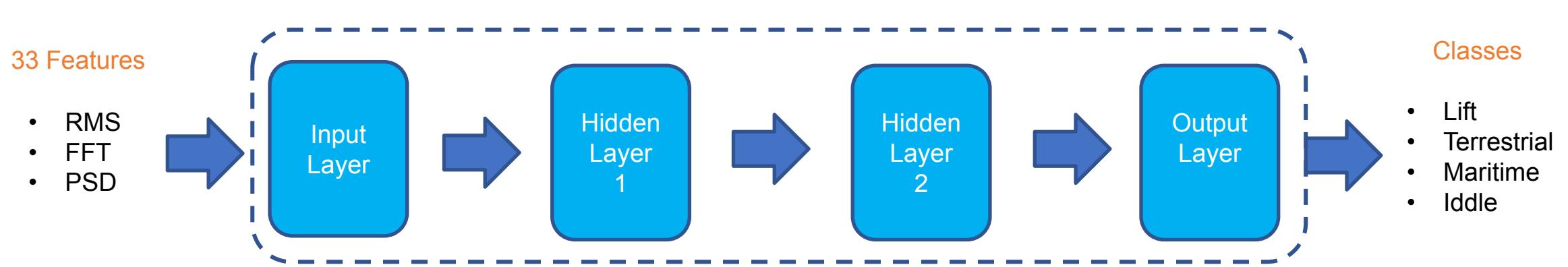
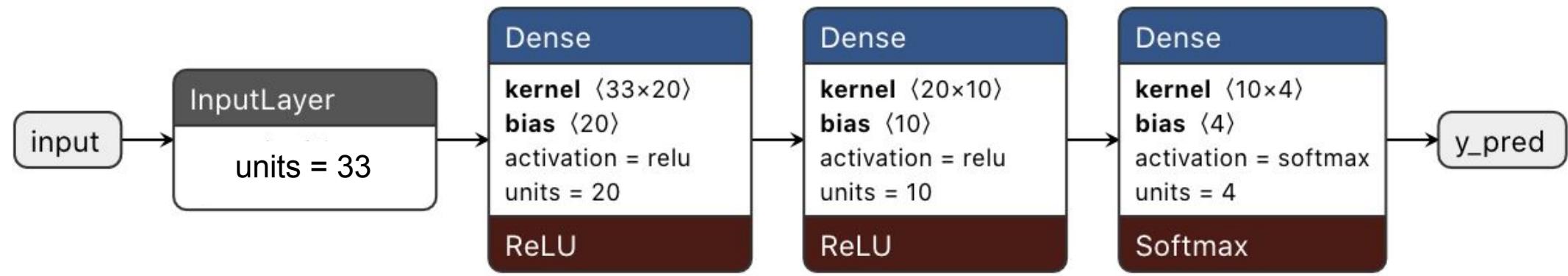
Model Design (DNN Classifier)



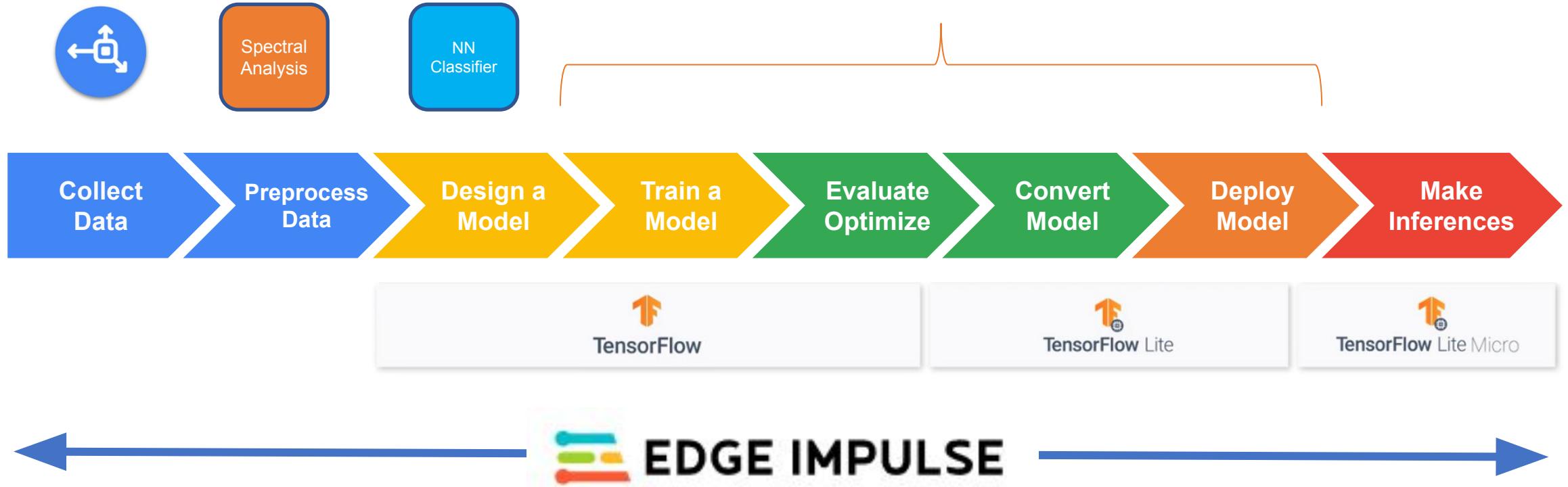
Model Design (DNN Classifier)



Model Design (DNN Classifier)



Train, Evaluate, Convert, Deploy the Model



Motion Classification

Hands-On

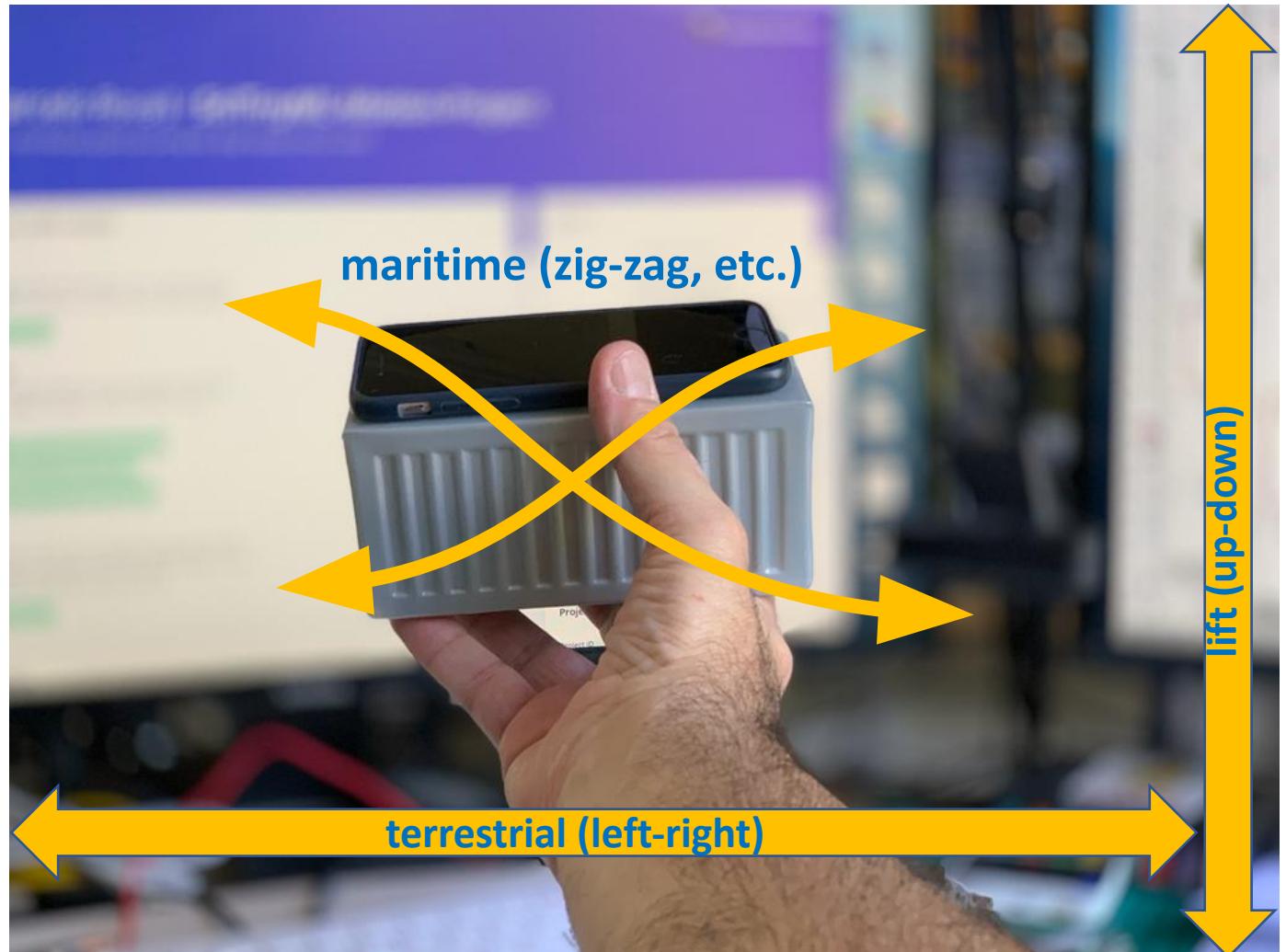
<https://studio.edgeimpulse.com/public/139905/latest>



Motion Classification

Transportation Classes

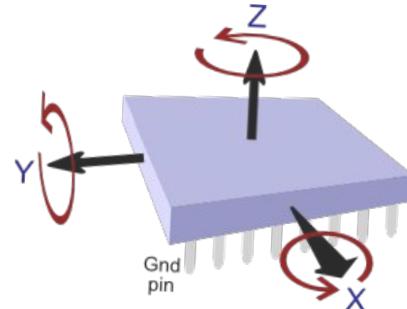
- **lift** (up-down)
- **terrestrial** (left-right)
- **maritime** (zig-zag, etc.)
- **idle**



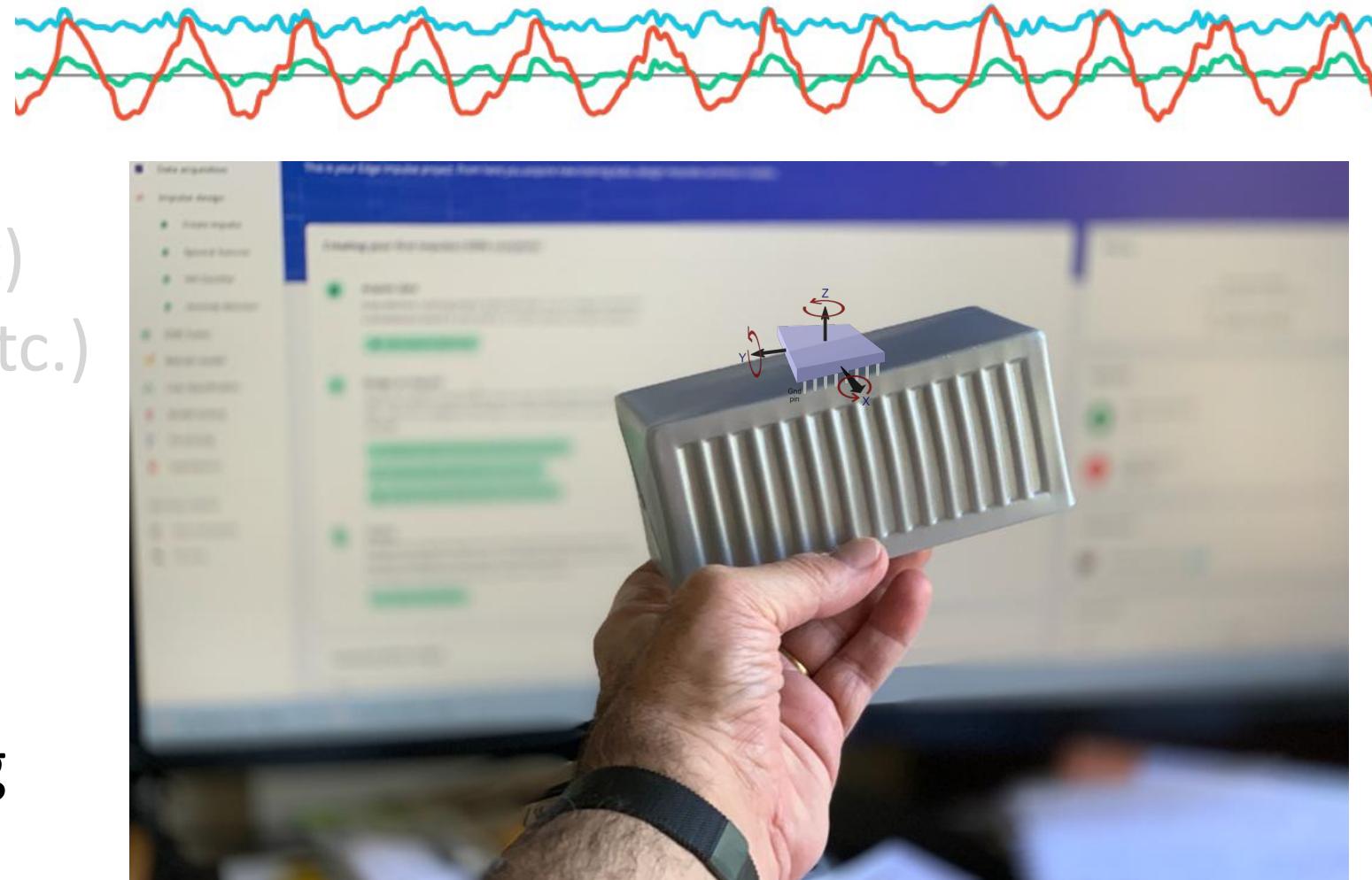
Motion Classification

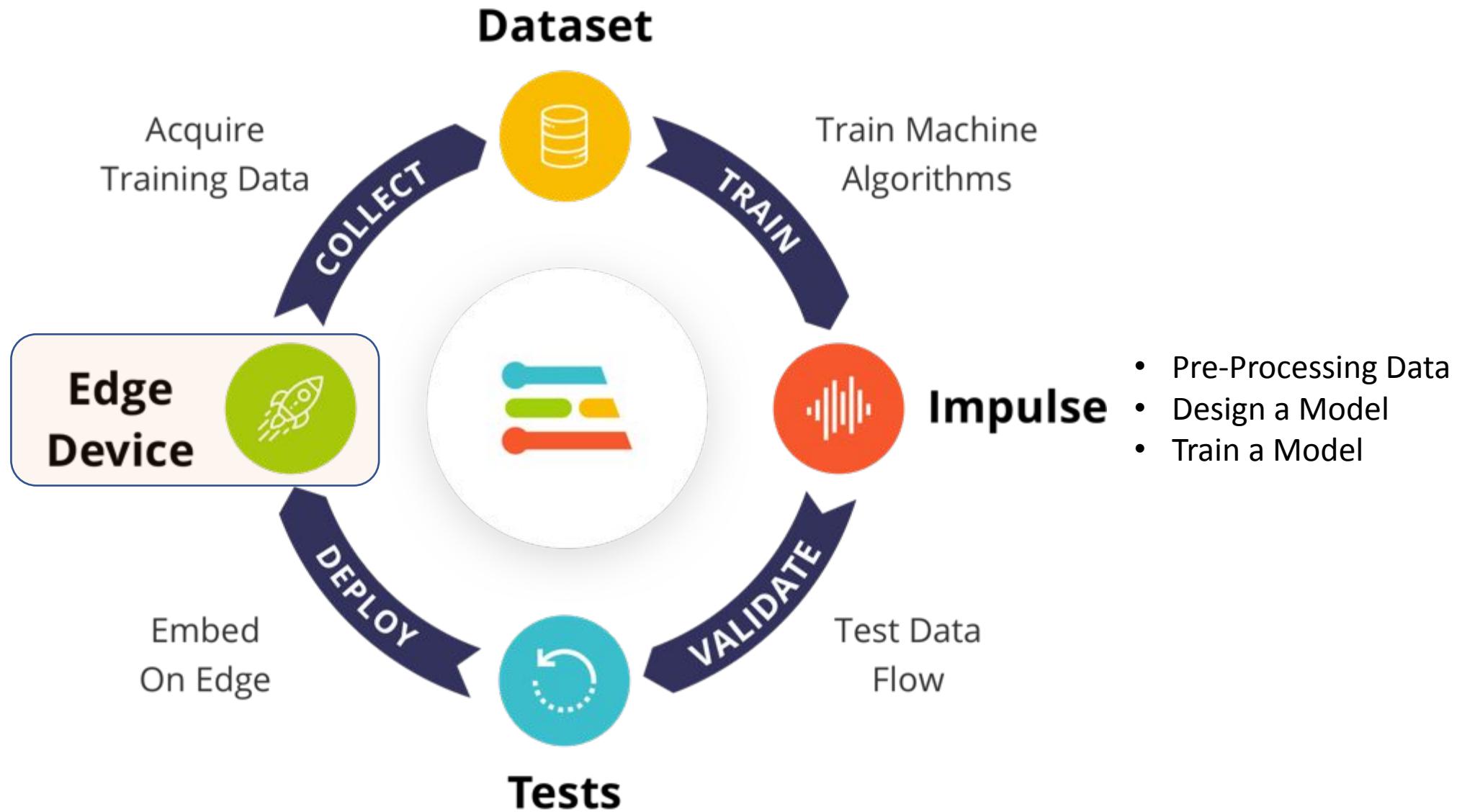
Transportation Classes

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



Data: collect & test using
accelerometer as sensor





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 devices

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

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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

Devices

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GETTING STARTED

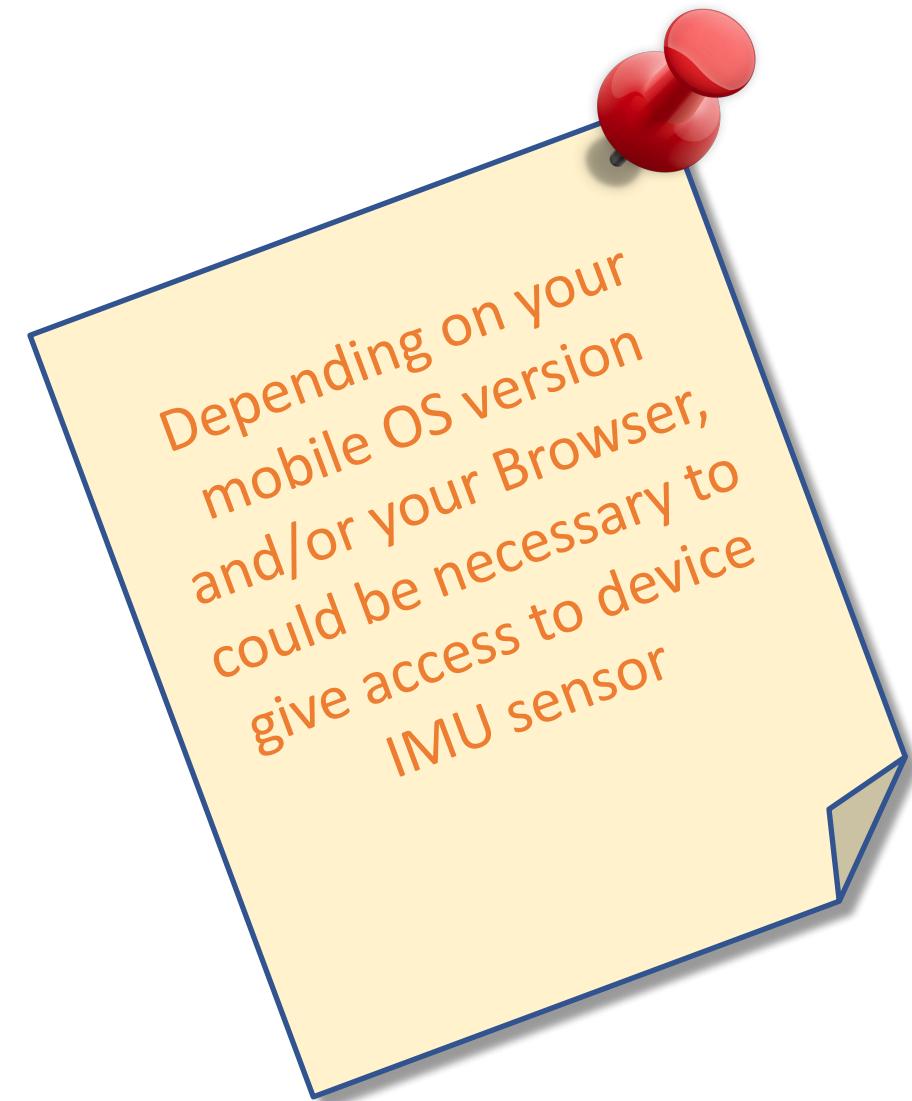
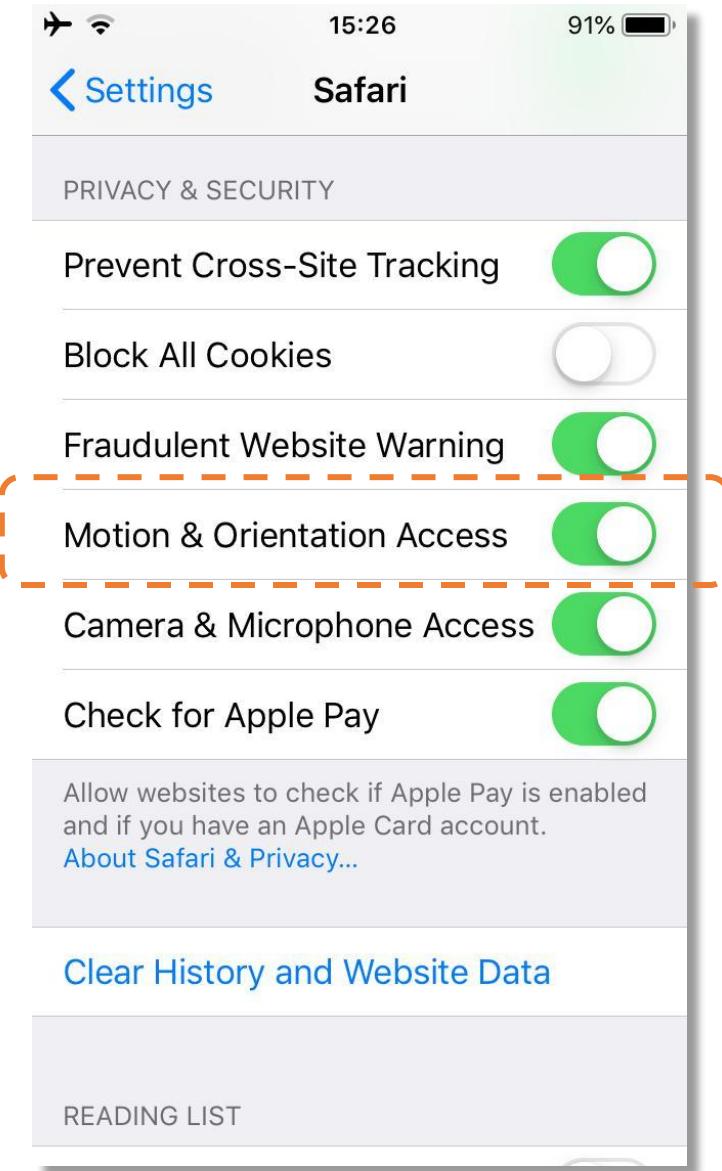
Documentation

Forums

Marcelo Rovai

WEBSITE QR CODE
Open "edgeimpulse.com" in Safari





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

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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

Collect data

Device phone_kq6ray4k is now connected

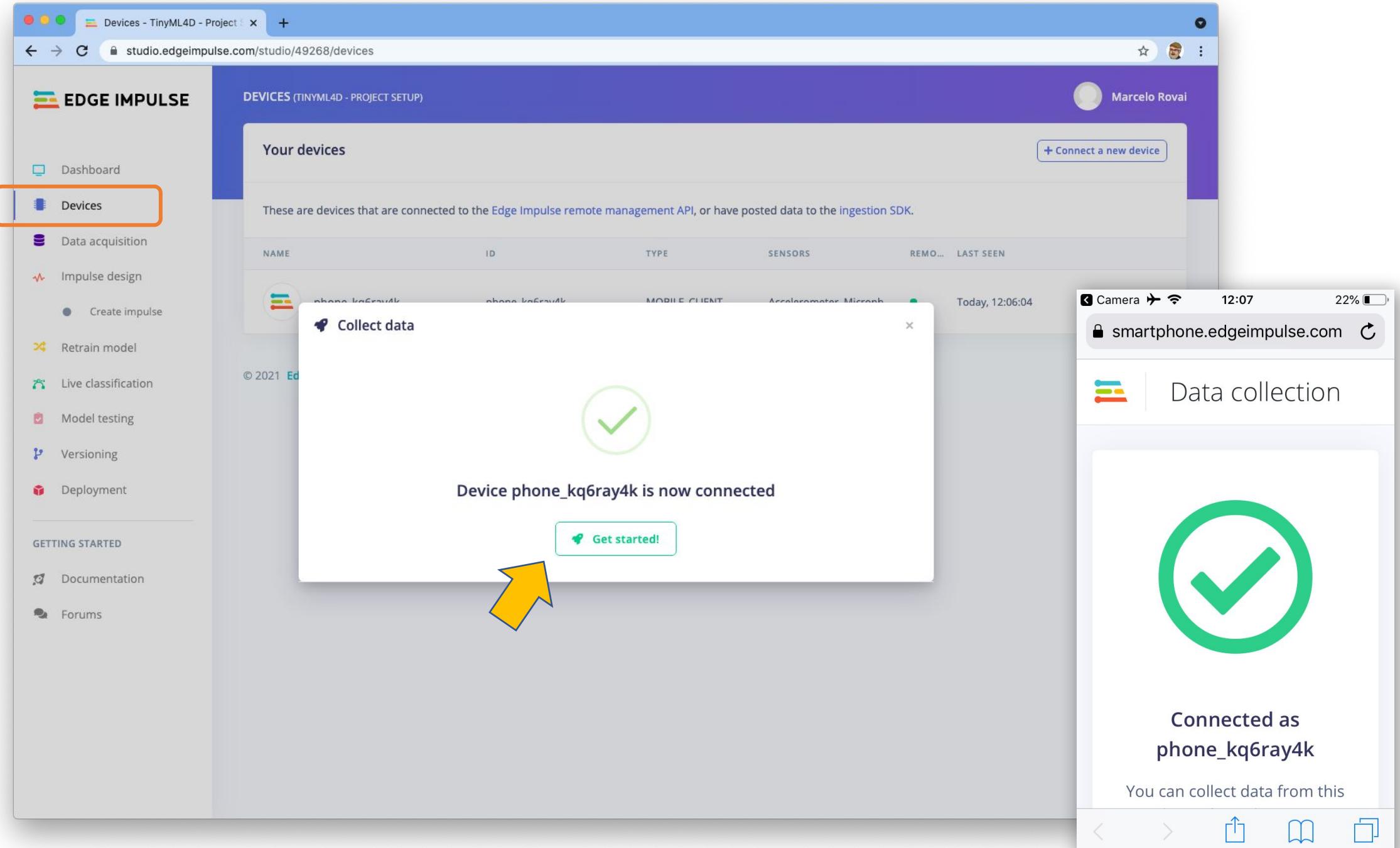
Get started!

smartphone.edgeimpulse.com 12:07 22% Camera WiFi

Data collection

Connected as phone_kq6ray4k

You can collect data from this



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

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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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smartphone.edgeimpulse.com 12:07 22% Camera WiFi

Data collection

Connected as phone_kq6ray4k

You can collect data from this

A yellow arrow points from the 'phone_kq6ray4k' device row in the Edge Impulse studio to the smartphone screen on the right, indicating a connection between the two.

EDGE IMPULSE

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

Not connected

Refresh this page to reconnect to Edge Impulse

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

Documentation Forums

GETTING STARTED

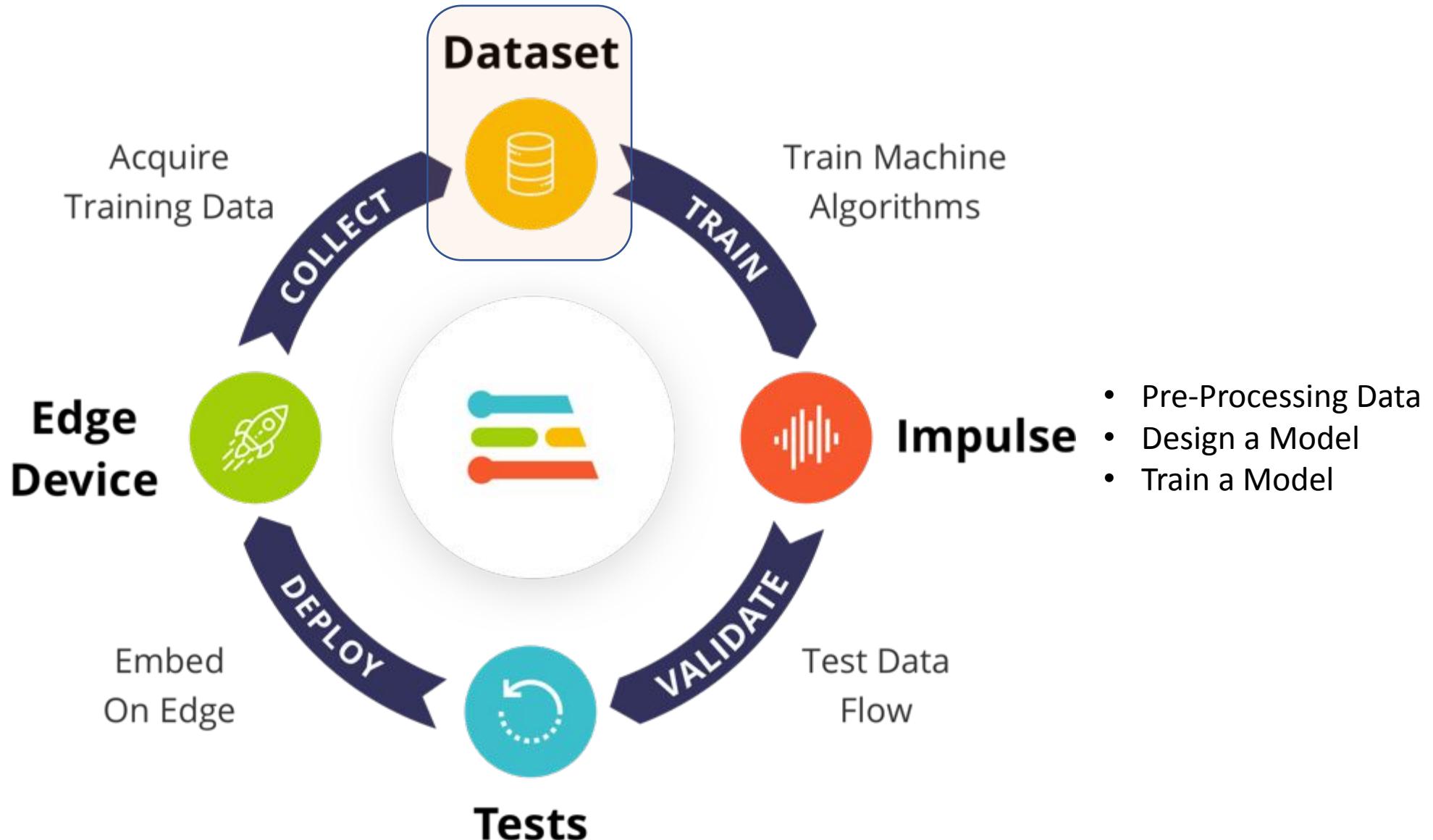
Marcelo Rovai

smartphone.edgeimpulse.com

12:20 44% smartphone.edgeimpulse.com

Not connected

Refresh this page to reconnect to Edge Impulse



Collect Data

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%**

Record new data

Device: phone_kq6ray4k

Label: maritime

Sample length (ms.): 10000

Sensor: Accelerometer

Frequency: 62.5Hz

Start sampling

Sensor: Accelerometer
Microphone
Camera

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	⋮

4s

Recording data

Collect Data

The screenshot shows the Edge Impulse Data Acquisition interface on a web browser. A large blue arrow on the left points towards the 'Data acquisition' section. A yellow arrow points from the 'Data acquisition' section to the 'Collected data' table. A red box highlights the 'DATA COLLECTED' summary at the top.

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 [Connect using WebUSB](#)

Device phone_kq6ray4k

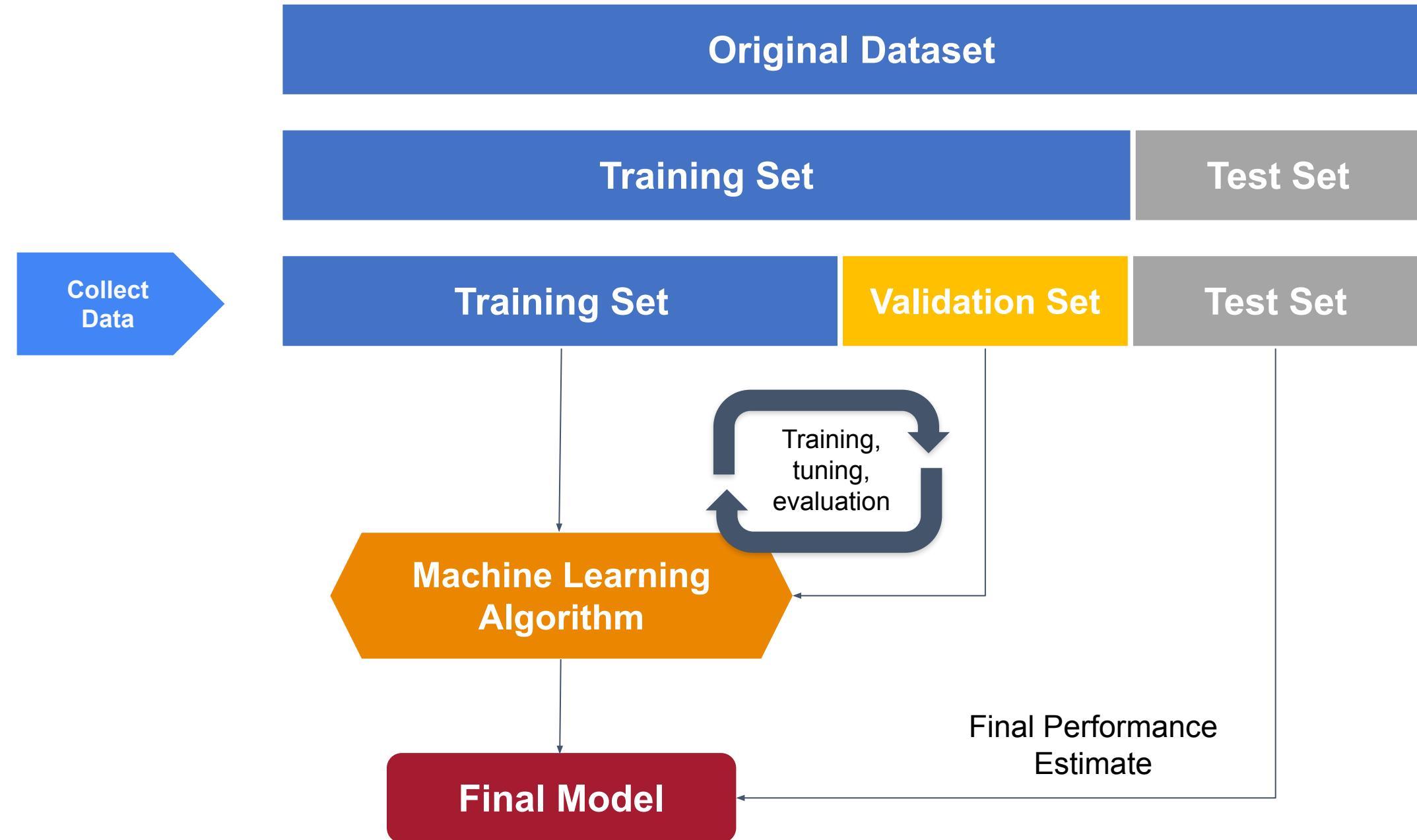
Label **Sample length (ms.)**

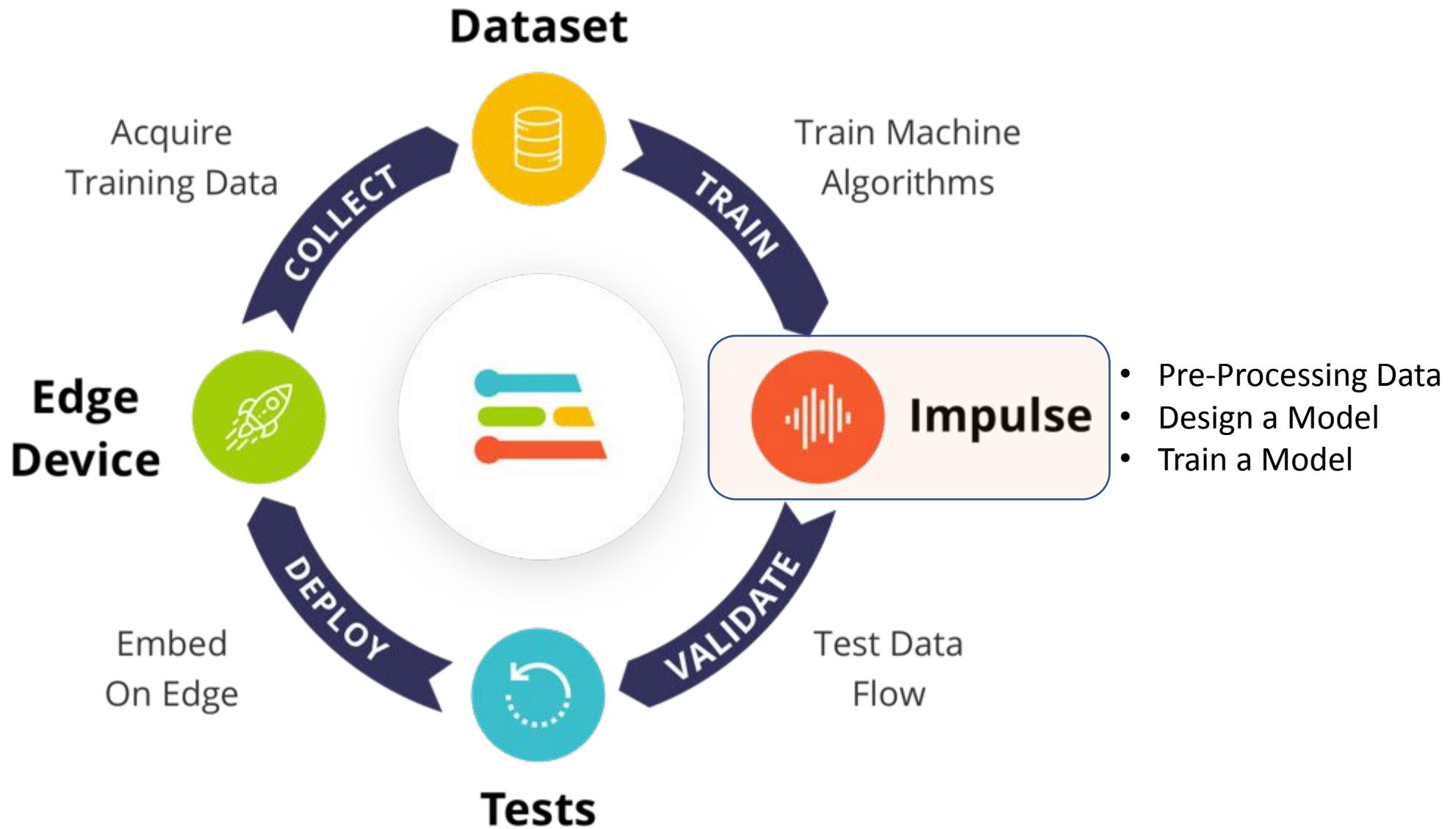
Sensor Accelerometer **Frequency** 62.5Hz

Start sampling

RAW DATA **maritime.2hstpku3**

The chart displays three data series: accX (red), accY (green), and accZ (blue). The x-axis represents time in milliseconds (ms) from 0 to 9075, with major ticks at 1008, 2016, 3025, 4033, 5041, 6050, 7058, 8067, and 9075. The y-axis ranges from -20 to 20. The data shows periodic, high-frequency oscillations characteristic of maritime motion.





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



Classes

- Lift
- Terrestrial
- Maritime
- Idle

Preprocess Data

Spectral Analysis - SciTinyML - [+](#)

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

Raw data

maritime.2hstrnnqu (maritime)

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 GETTING STARTED Documentation Forums

Raw features

375 Raw Features

Parameters Scaling Scale axes 1

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

DSP result

After filter

Frequency domain

Spectral power

Processed features

On-device performance

PROCESSING TIME 8 ms. PEAK RAM USAGE 5 KB

The screenshot shows the Edge Impulse Studio interface for a project titled "Spectral Analysis - SciTinyML". On the left, a sidebar lists various tools and documentation. The main area displays raw sensor data (accX, accY, accZ) over time, followed by a section for extracting "Raw features". The "Parameters" section includes fields for scaling (Scale axes: 1), filtering (Type: low, Cut-off frequency: 3, Order: 6), and spectral power extraction (FFT length: 128, No. of peaks: 3, Peaks threshold: 0.1, Power edges: 0.1, 0.5, 1.0, 2.0, 5.0). A large orange bracket groups "RMS", "FFT", and "PSD" under the heading "375 Raw Features". Below this, a "Save parameters" button is visible. To the right, the "DSP result" section shows a "After filter" plot with three colored lines (red, green, blue) and three frequency domain plots (Power spectrum density vs Frequency). An orange bracket groups the first three plots under the heading "Processed features". At the bottom, "On-device performance" metrics show 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 **Generate features**

Training set

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

Feature explorer (3,132 samples)

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 data points clustered by class (idle, lift, maritime, terrestrial) based on the selected X, Y, and Z axes.

On-device performance

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

Bottom Left: © 2021 EdgeImpulse Inc. All rights reserved

Design a Model

Neural Network (Keras) - SciTI

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

EDGE IMPULSE

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

The diagram illustrates a neural network architecture. It starts with an 'input' node at the top, which points down to an 'InputLayer' block. This is followed by a sequence of layers: a 'Dense' layer with 'kernel (33x20)' and 'bias (20)', followed by a 'ReLU' activation block. Another 'Dense' layer with 'kernel (20x10)' and 'bias (10)' is shown, also followed by a 'ReLU' block. The final 'Dense' layer has 'kernel (10x4)' and 'bias (4)', leading to a 'Softmax' block at the bottom. The output of the Softmax block is labeled 'y_pred'. Blue arrows point from the 'InputLayer' and each 'Dense' layer back to their corresponding configuration boxes in the 'Neural network architecture' section of the interface.

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

Versioning

Deployment

GETTING STARTED

Documentation

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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

Evaluate Optimize

The screenshot shows the Edge Impulse web studio interface. On the left, a green arrow points right, labeled "Evaluate Optimize". The main area is divided into two main sections: "Neural Network settings" on the left and "Training output" on the right.

Neural Network settings

Training settings

- Number of training cycles: 30
- Learning rate: 0.0005

Neural network architecture

```

graph TD
    Input[Input layer (33 features)] --> Dense1[Dense layer (20 neurons)]
    Dense1 --> Dense2[Dense layer (10 neurons)]
    Dense2 --> Output[Output layer (4 features)]
  
```

Start training

Training Set and **Validation Set** diagram:

```

graph TD
    TS[Training Set] --> ML[Machine Learning Algorithm]
    VS[Validation Set] --> ML
    ML --> TTE[Training, tuning, evaluation]
    TTE --> TS
  
```

Training output

Model (Model version: Quantized (int8))

Last training performance (validation set)

	ACCUACY	LOSS
%	99.7%	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)

Selected features: accX RMS, accY RMS, accZ RMS

Legend:

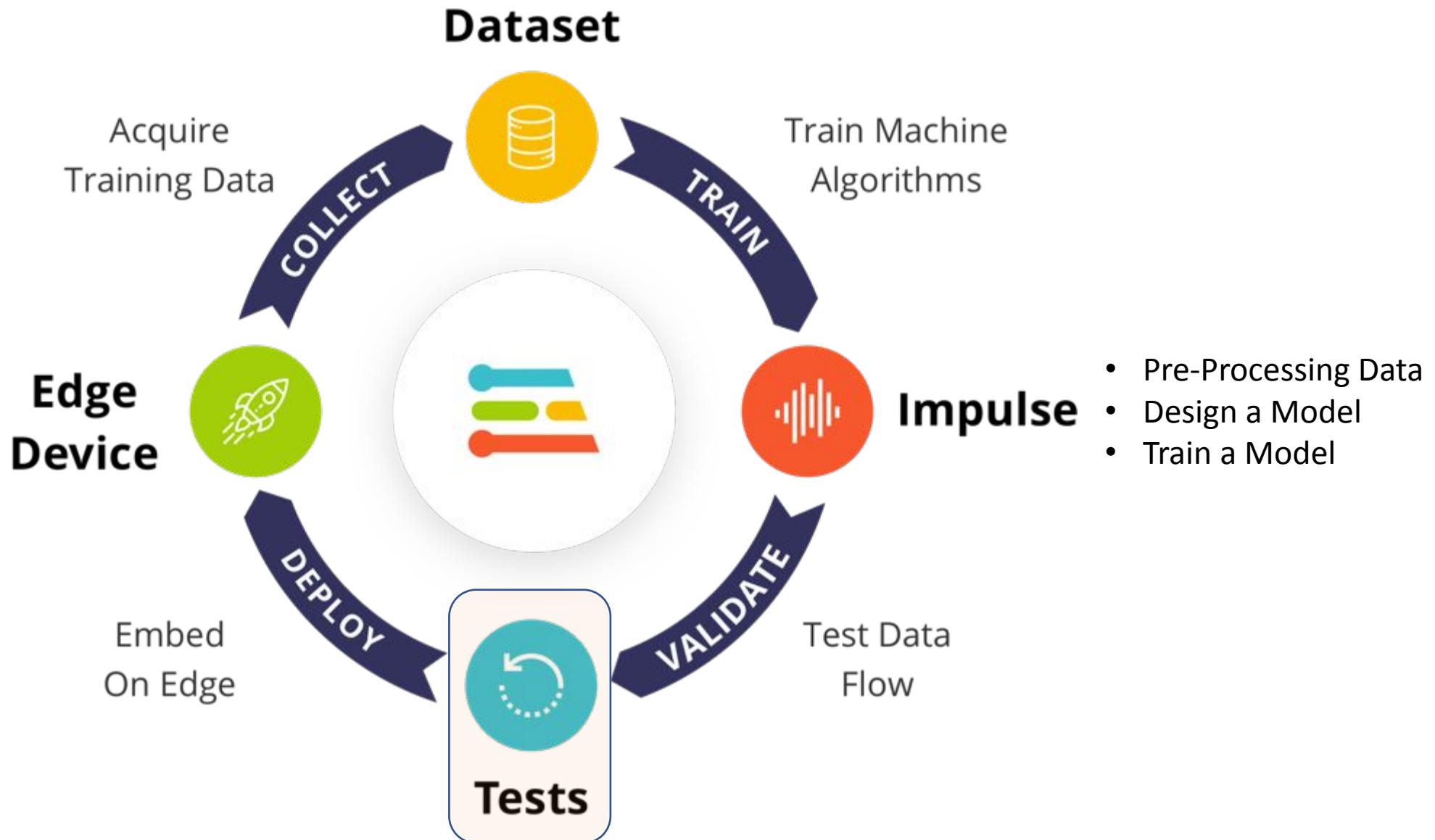
- idle - correct
- lift - correct
- maritime - correct
- terrestrial - correct
- maritime - incorrect
- terrestrial - incorrect

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

	INFERENCE TIME	PEAK RAM USAGE	FLASH USAGE
1 ms.	1.7K	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	

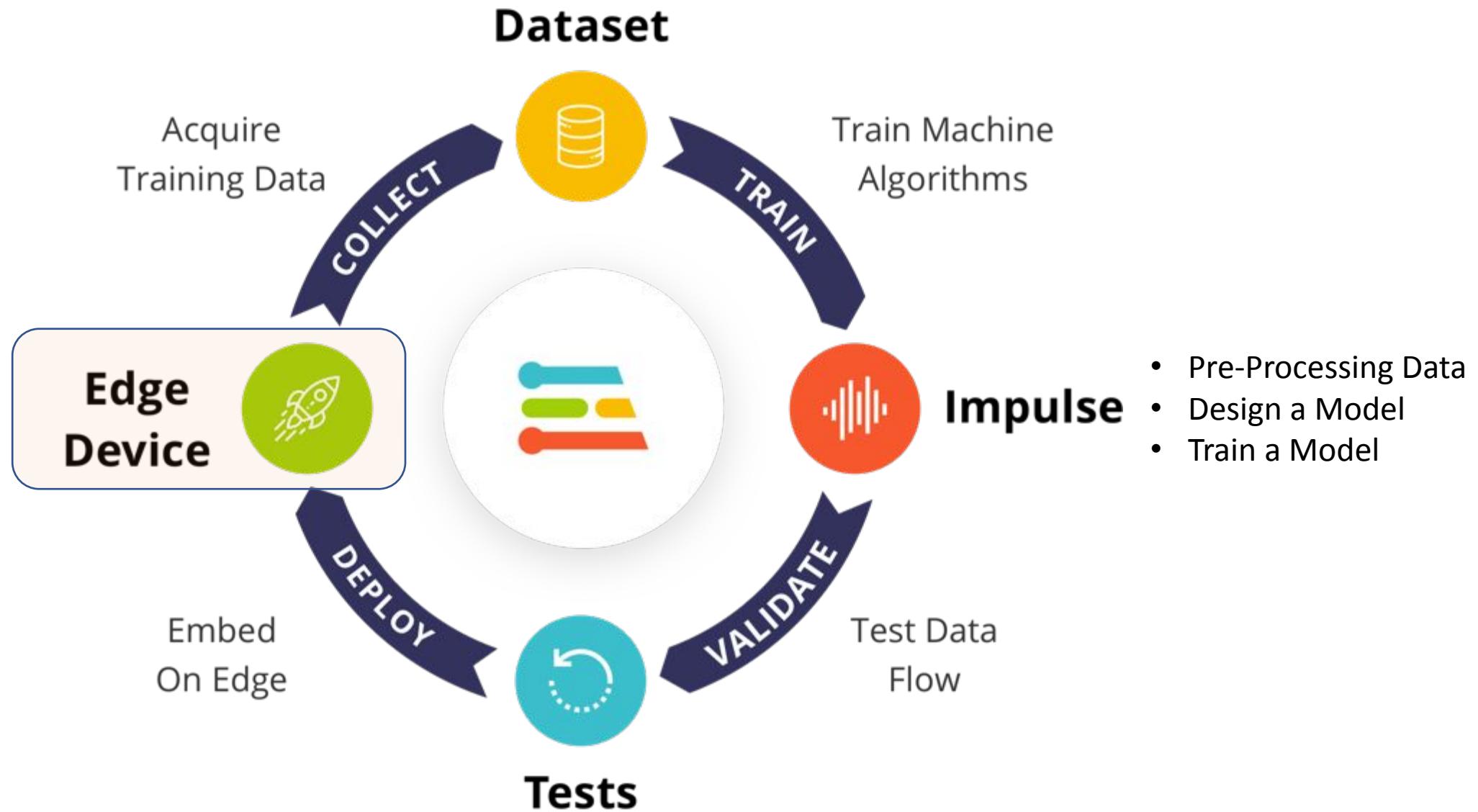
Feature explorer

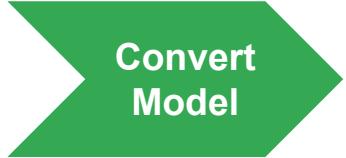
accX RMS accY RMS accZ RMS

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

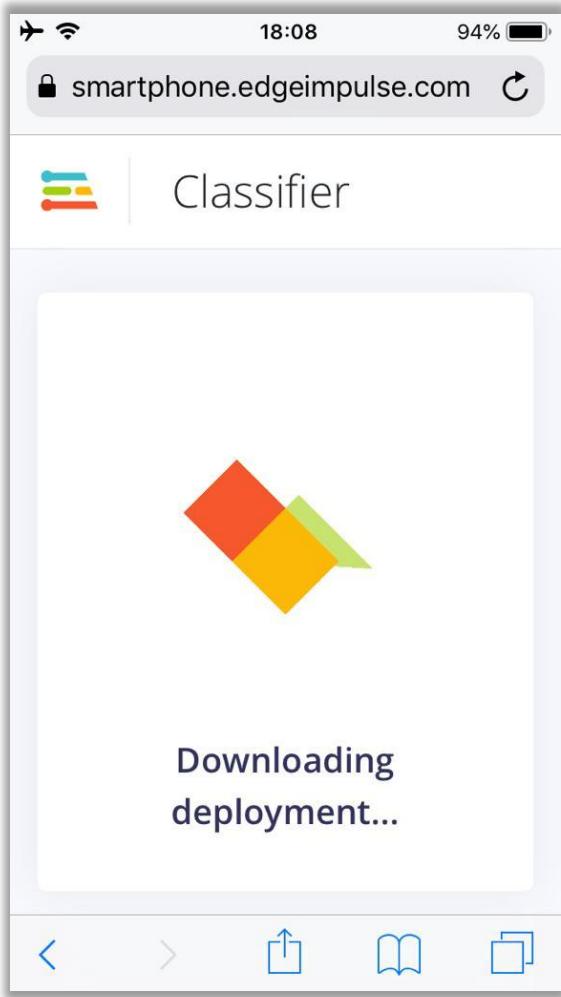
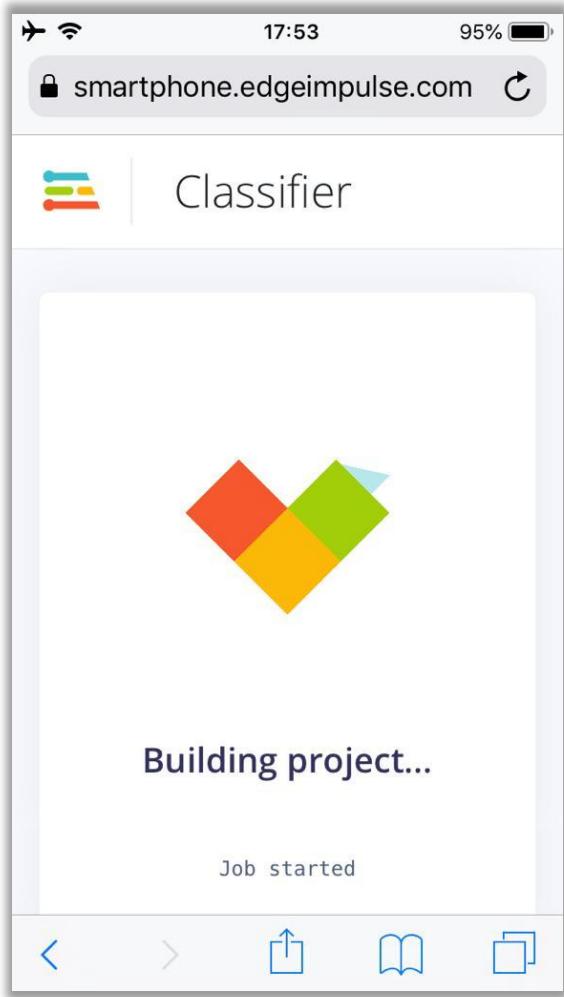
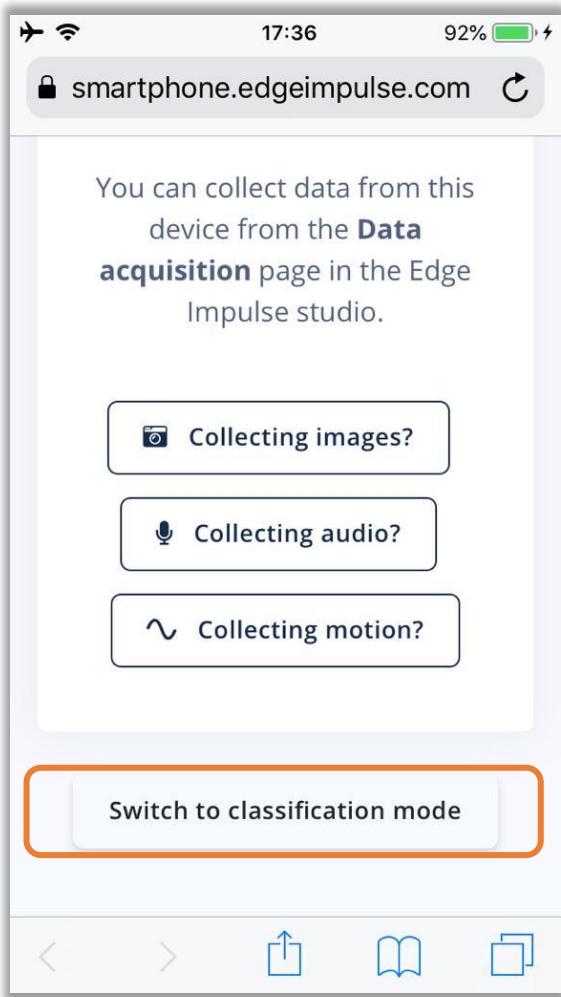
3D scatter plot showing data points for accX RMS, accY RMS, and accZ RMS. The plot shows clusters of green points (correct classifications) and a few red points (incorrect classifications).

```
graph TD; TS[Training Set] --> ML[Machine Learning Algorithm]; VS[Validation Set] --> ML; TS --> FPE[Final Performance Estimate]; ML --> FM[Final Model]; ML -- "Training, tuning, evaluation" --> TS;
```

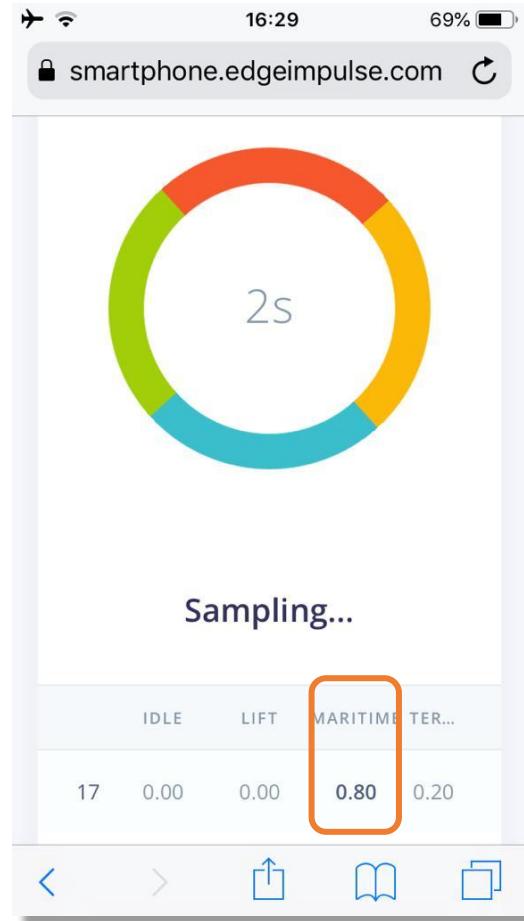
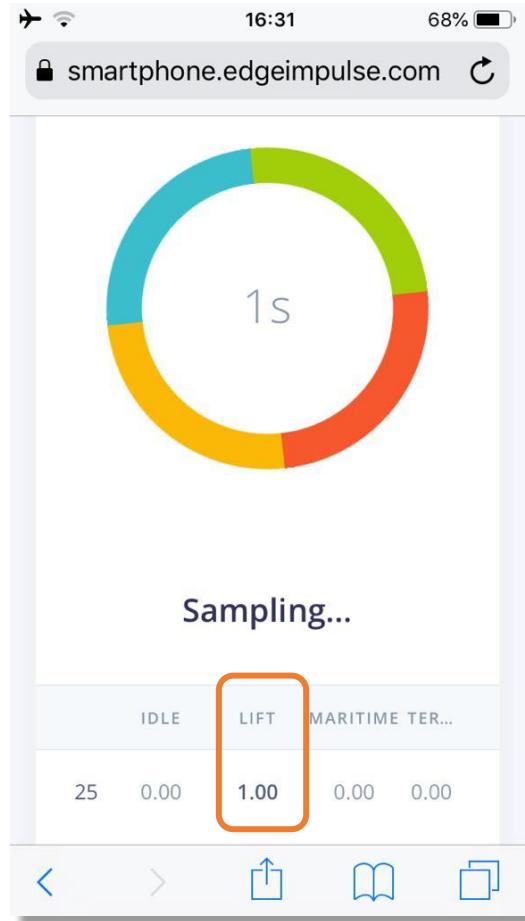
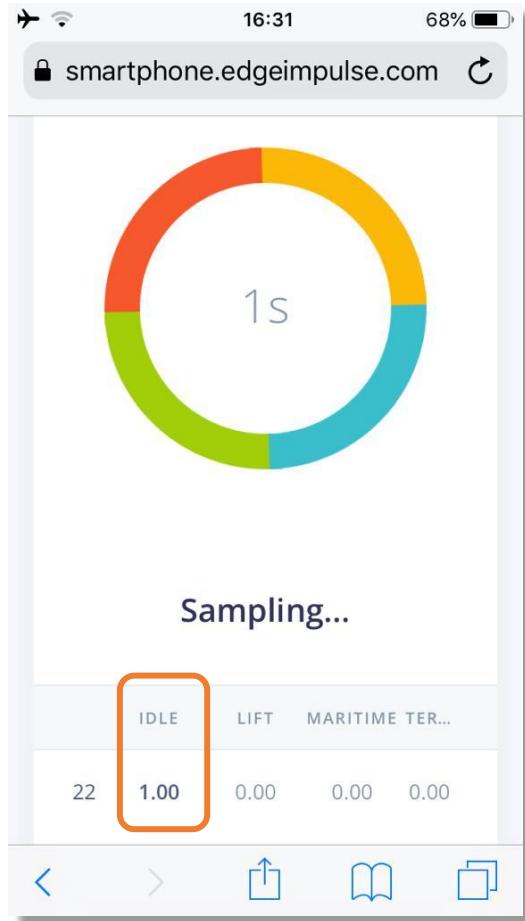




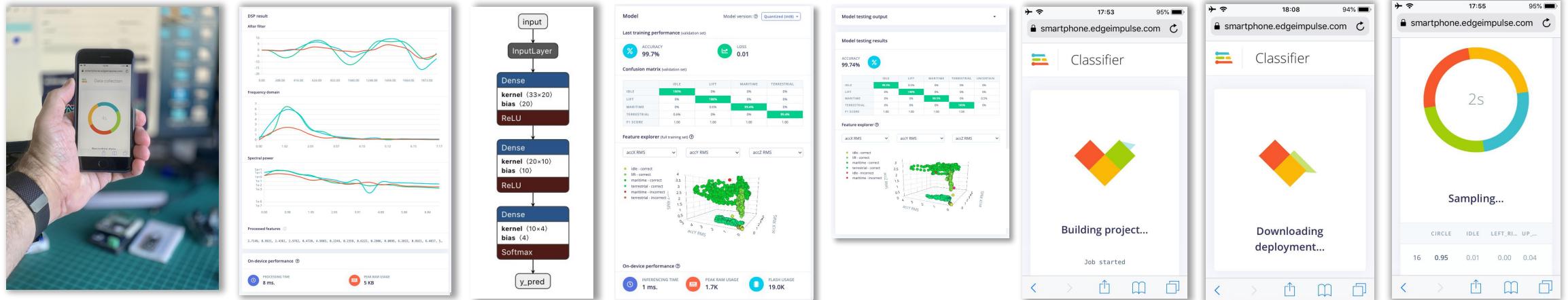
Convert Model



Make
Inferences

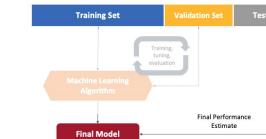


Motion Classification - Summary



Spectral Analysis

NN Classifier



Predict and classify common Elephant behavior



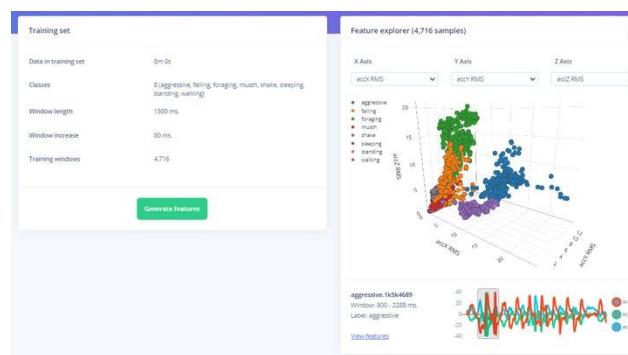
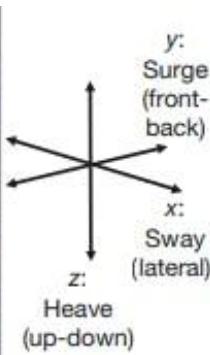
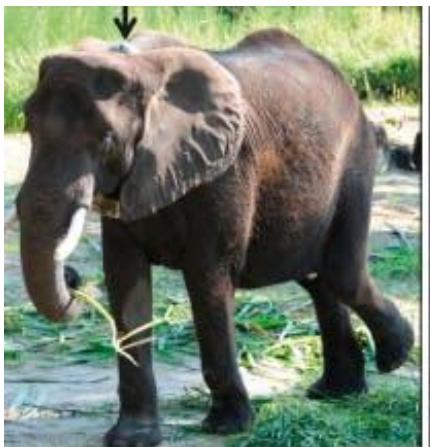
Aggressive



Standing



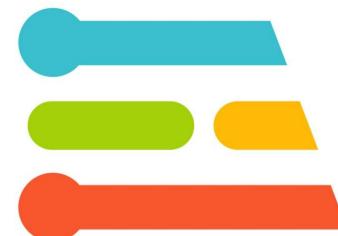
Sleeping

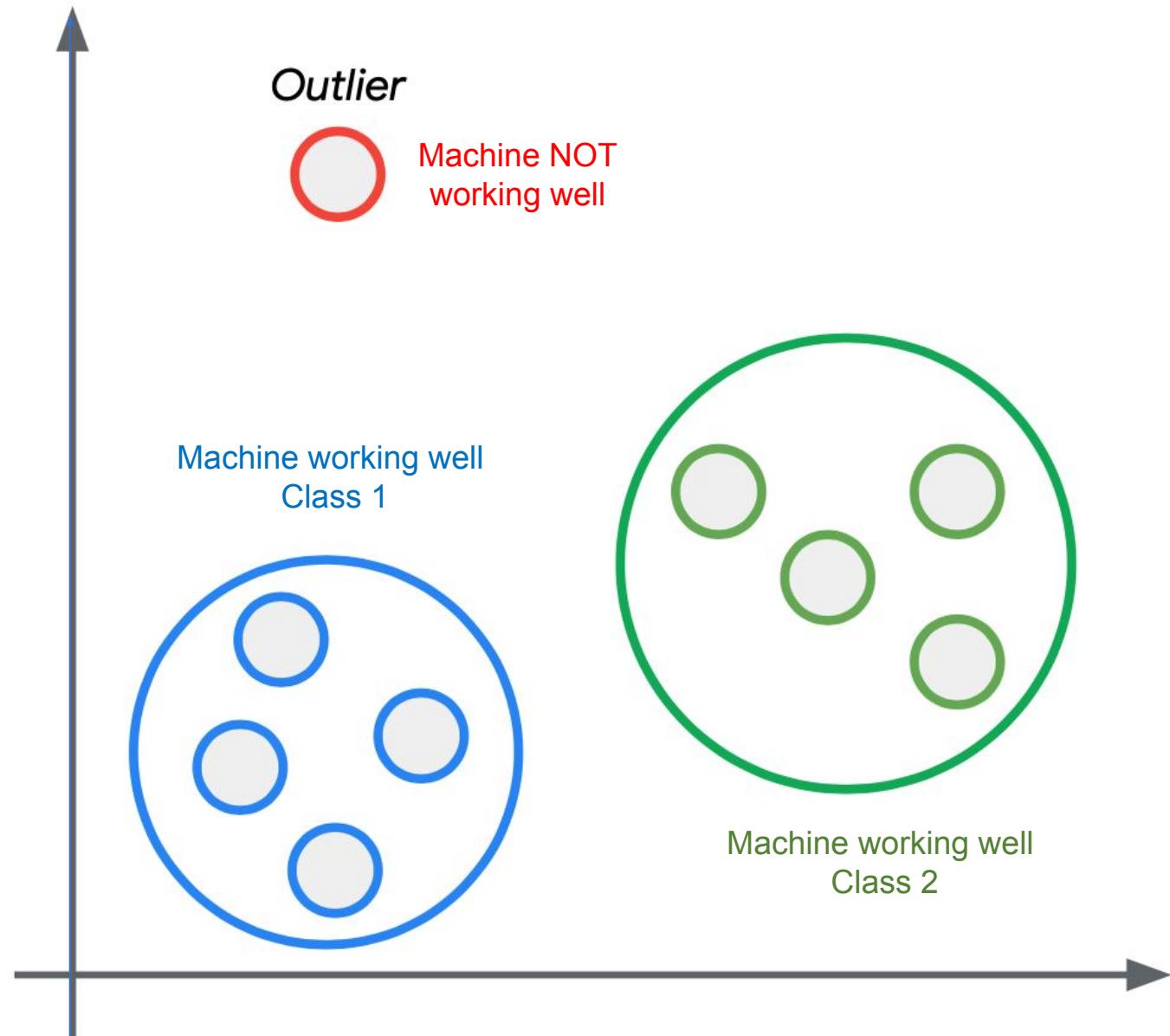


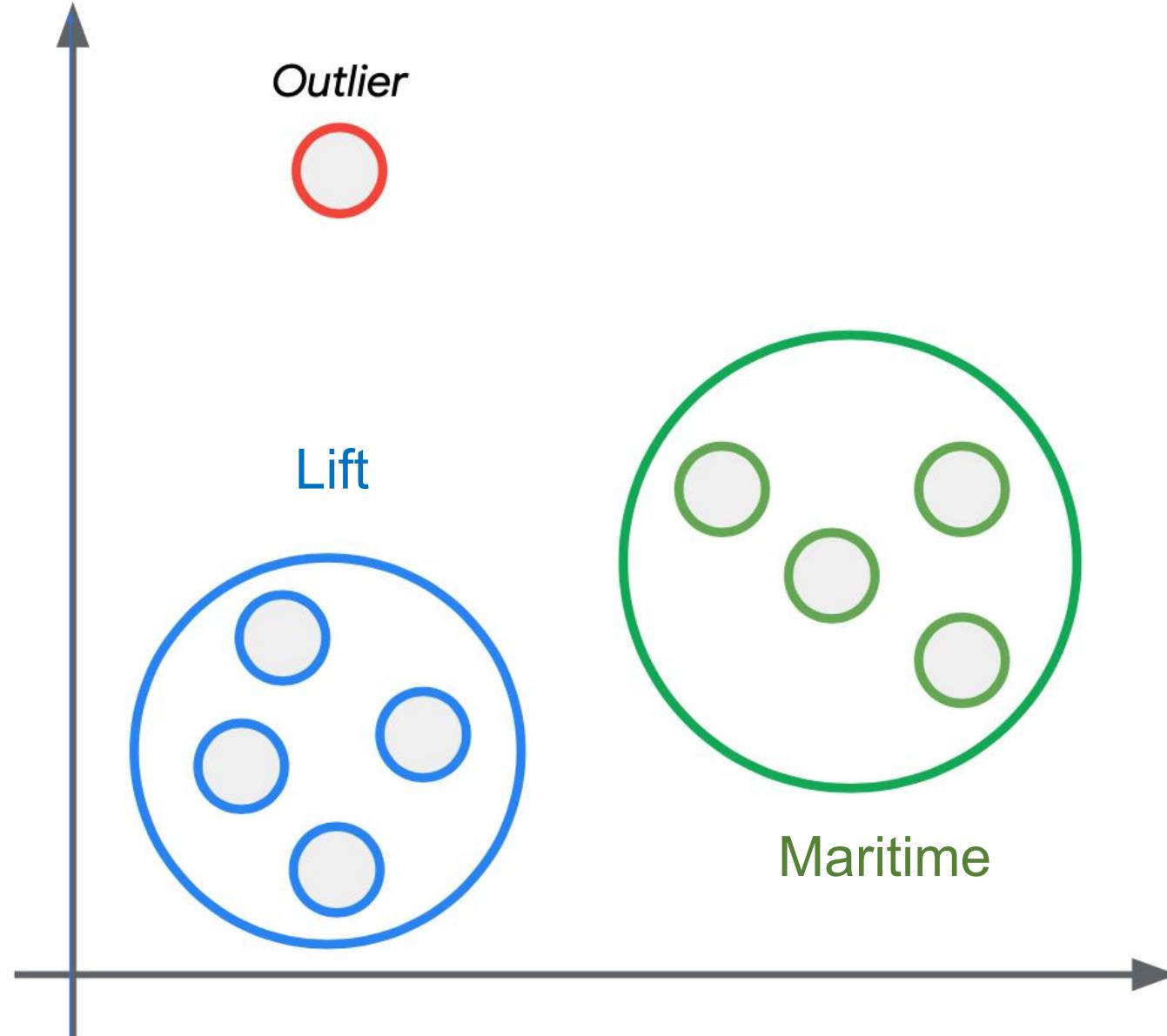
https://www.hackster.io/dhruvsheth_electet-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a

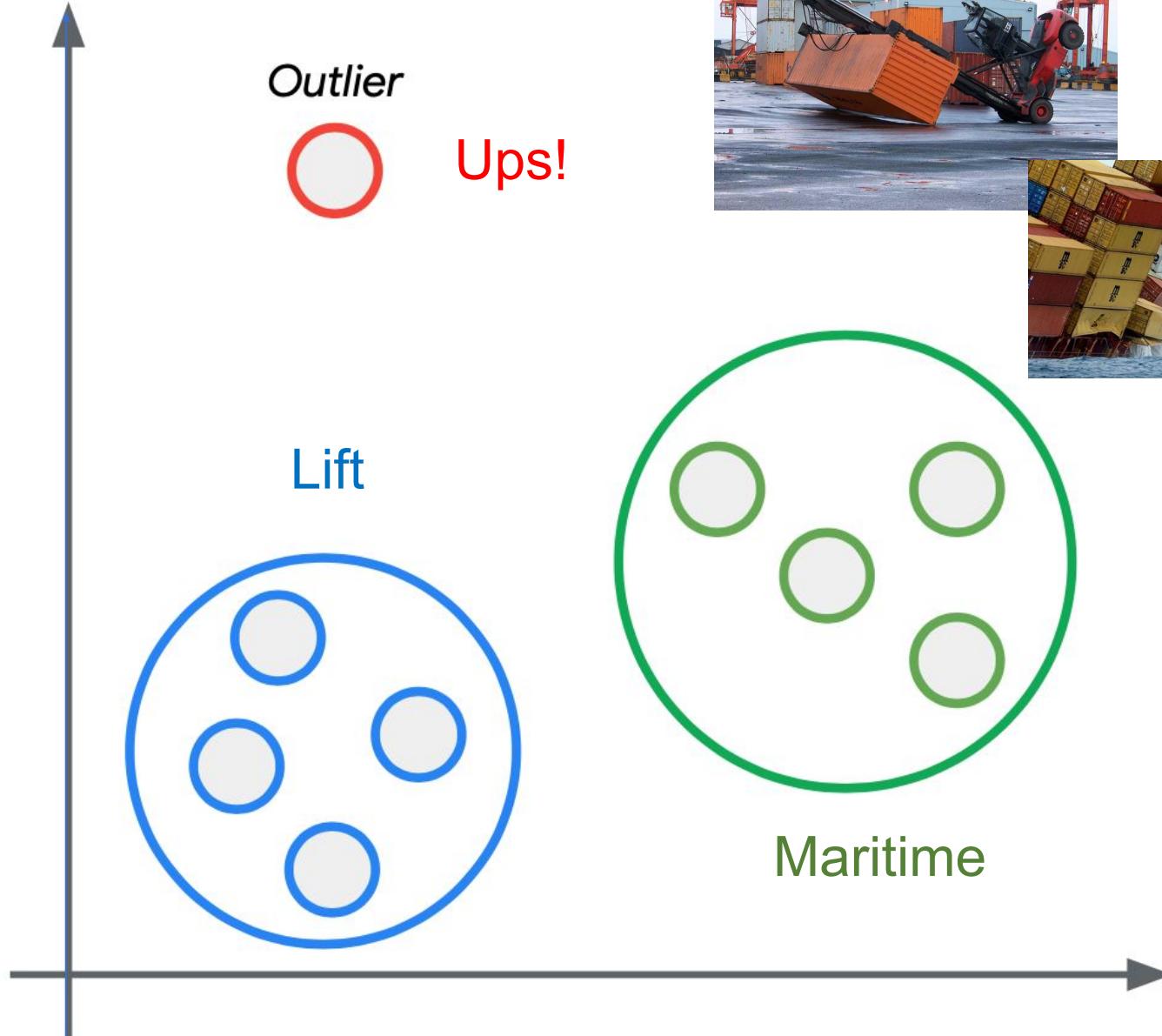


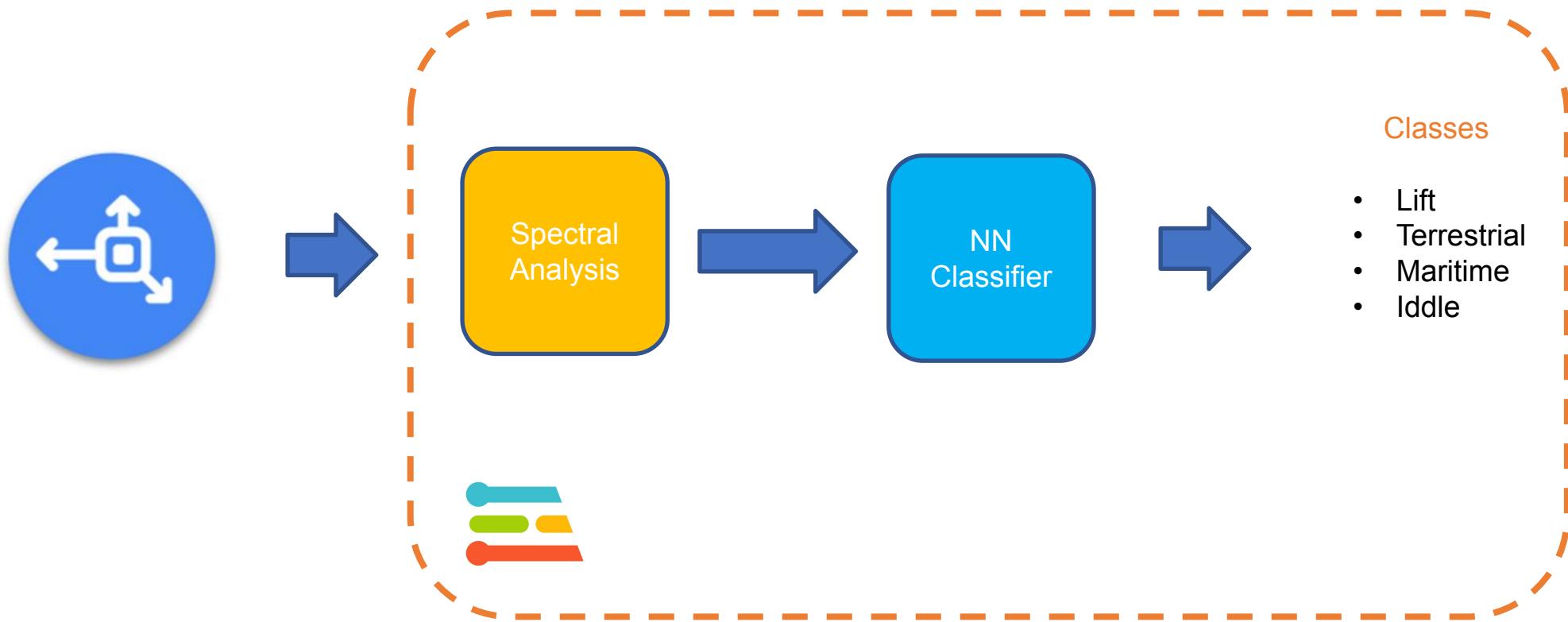
Anomaly Detection Hands-On

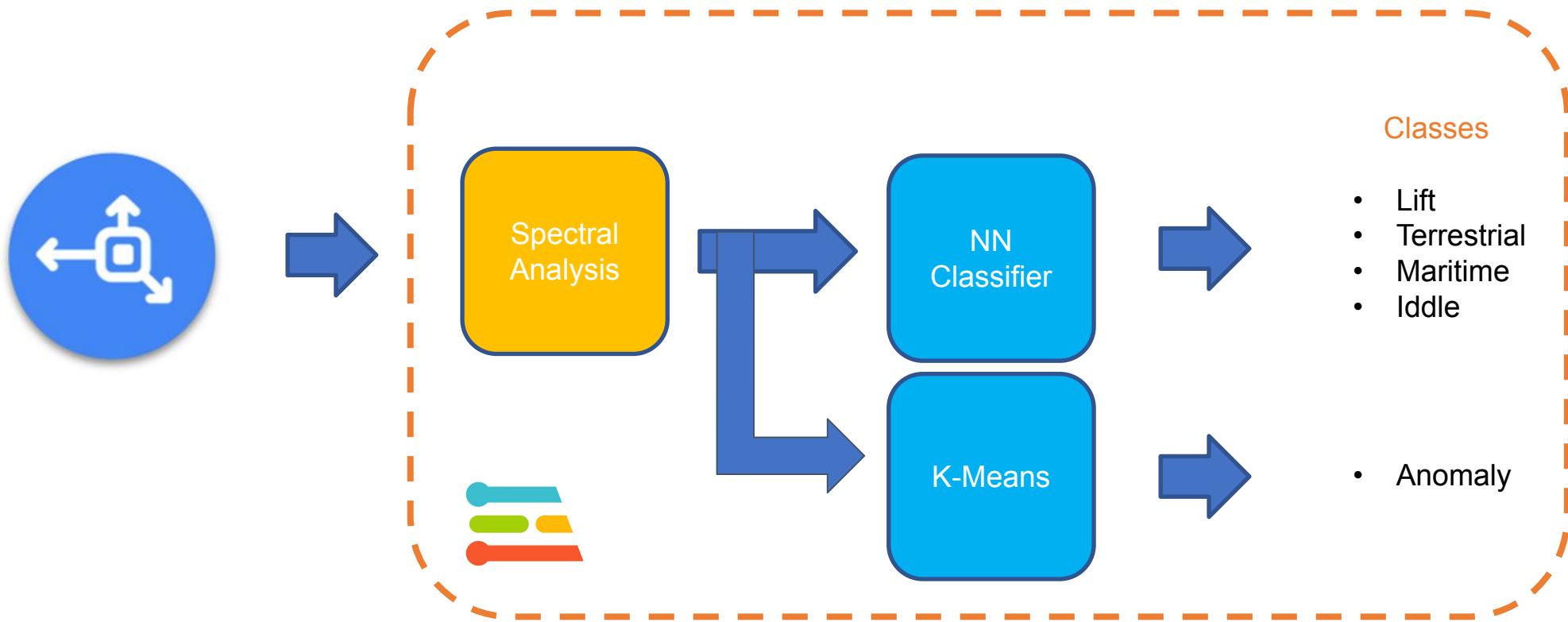












Create impulse - IESTI01 - Nano Motion Classification

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

Spectral Analysis

Classification (Keras)

Output features

Axes
accX, accY, accZ

Window size

Window increase

Frequency (Hz)
100

Zero-pad data

Add a learning block

Some learning blocks have been hidden based on the data in your project.

DESCRIPTION	AUTHOR	RECOMMENDED
Classification (Keras) Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio.	EdgImpulse Inc.	
Anomaly Detection (K-means) Find outliers in new data. Good for recognizing unknown states, and to complement classifiers.	EdgImpulse Inc.	
Regression (Keras) Learns patterns from data, and can apply these to new data. Great for predicting numeric continuous values.	EdgImpulse Inc.	

Save Impulse

Cancel

GETTING STARTED

Documentation

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Create impulse - IESTI01 - Nano Motion Classification

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

MJRoBot (Marcelo Rovai)

EDGE IMPULSE

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)

Output features

5 (idle, lift, maritime, terrestrial, Anomaly score)

Anomaly Detection (K-means)

Name: Anomaly detection

Input features: Spectral features

Output features: 1 (Anomaly score)

Add a processing block

Save Impulse

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Anomaly detection - SciTinyML

studio.edgeimpulse.com/studio/51963/learning/anomaly/52

EDGE IMPULSE

ANOMALY DETECTION (SCITINYML-MOTION-ANOMALY-PROJECT)

#1 ▾ Click to set a description for this version

Anomaly detection settings

Cluster count: 4

Axes: accX RMS ★ accX Peak 1 Freq accX Peak 1 Height accX Peak 2 Freq accX Peak 2 Height accX Peak 3 Freq accX Peak 3 Height accX Spectral Power 0.1 - 0.5 accX Spectral Power 0.5 - 1.0 accX Spectral Power 1.0 - 2.0 accX Spectral Power 2.0 - 5.0 accZ RMS ★ accZ Peak 1 Freq accZ Peak 1 Height accZ Peak 2 Freq accZ Peak 2 Height accZ Peak 3 Freq accZ Peak 3 Height accZ Spectral Power 0.1 - 0.5 accZ Spectral Power 0.5 - 1.0 accZ Spectral Power 1.0 - 2.0 accZ Spectral Power 2.0 - 5.0 accY RMS ★ accY Peak 1 Freq accY Peak 1 Height accY Peak 2 Freq accY Peak 2 Height accY Peak 3 Freq accY Peak 3 Height

Select all axes

Anomaly explorer (3,230 samples)

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

trained

accY RMS

accX RMS

Training output

Copying features from processing blocks...
Copying features from DSP block...
Copying features from DSP block OK
Copying features from processing blocks OK

Training model
Job started
scaler scale [1.23777729 1.02773968 1.10088427] mean [0.95382248 0.94990646 1.12868147] var [1.53209261 1.05624885 1.21194617]
trained_clusters ([{'center': [-0.5379795432090759, -0.30185389518737793, -0.8996922373771667], 'max_error': 1.80506750641951}, {'center': [-0.2765962481498718, -0.5444689393043518, 0.5496397018432617], 'max_error': 1.4696349225868046}, {'center': [0.4085573256015776, 2.168626173019409, 1.249598737182617], 'max_error': 2.749243312802676}, {'center': [2.1753463745117188, 0.555717945098877, 1.3917098804534912], 'max_error': 2.6628344654985634}])

Job completed

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Anomaly detection - SciTinyML

studio.edgeimpulse.com/studio/51963/learning/anomaly/52

EDGE IMPULSE

ANOMALY DETECTION (SCITINYML-MOTION-ANOMALY-PROJECT)

#1 ▾ Click to set a description for this version

Anomaly detection settings

Cluster count: 32

Axes: accX RMS ★ accX Peak 1 Freq accX Peak 1 Height accX Peak 2 Freq accX Peak 2 Height accX Peak 3 Freq accX Peak 3 Height accX Spectral Power 0.1 - 0.5 accX Spectral Power 0.5 - 1.0 accX Spectral Power 1.0 - 2.0 accX Spectral Power 2.0 - 5.0 accZ RMS ★ accZ Peak 1 Freq accZ Peak 1 Height accZ Peak 2 Freq accZ Peak 2 Height accZ Peak 3 Freq accZ Peak 3 Height accZ Spectral Power 0.1 - 0.5 accZ Spectral Power 0.5 - 1.0 accZ Spectral Power 1.0 - 2.0 accZ Spectral Power 2.0 - 5.0 accY RMS ★ accY Peak 1 Freq accY Peak 1 Height accY Peak 2 Freq accY Peak 2 Height accY Peak 3 Freq accY Peak 3 Height accY Spectral Power 0.1 - 0.5 accY Spectral Power 0.5 - 1.0 accY Spectral Power 1.0 - 2.0 accY Spectral Power 2.0 - 5.0

Select all axes

Anomaly explorer (3,230 samples)

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

● trained

Training output

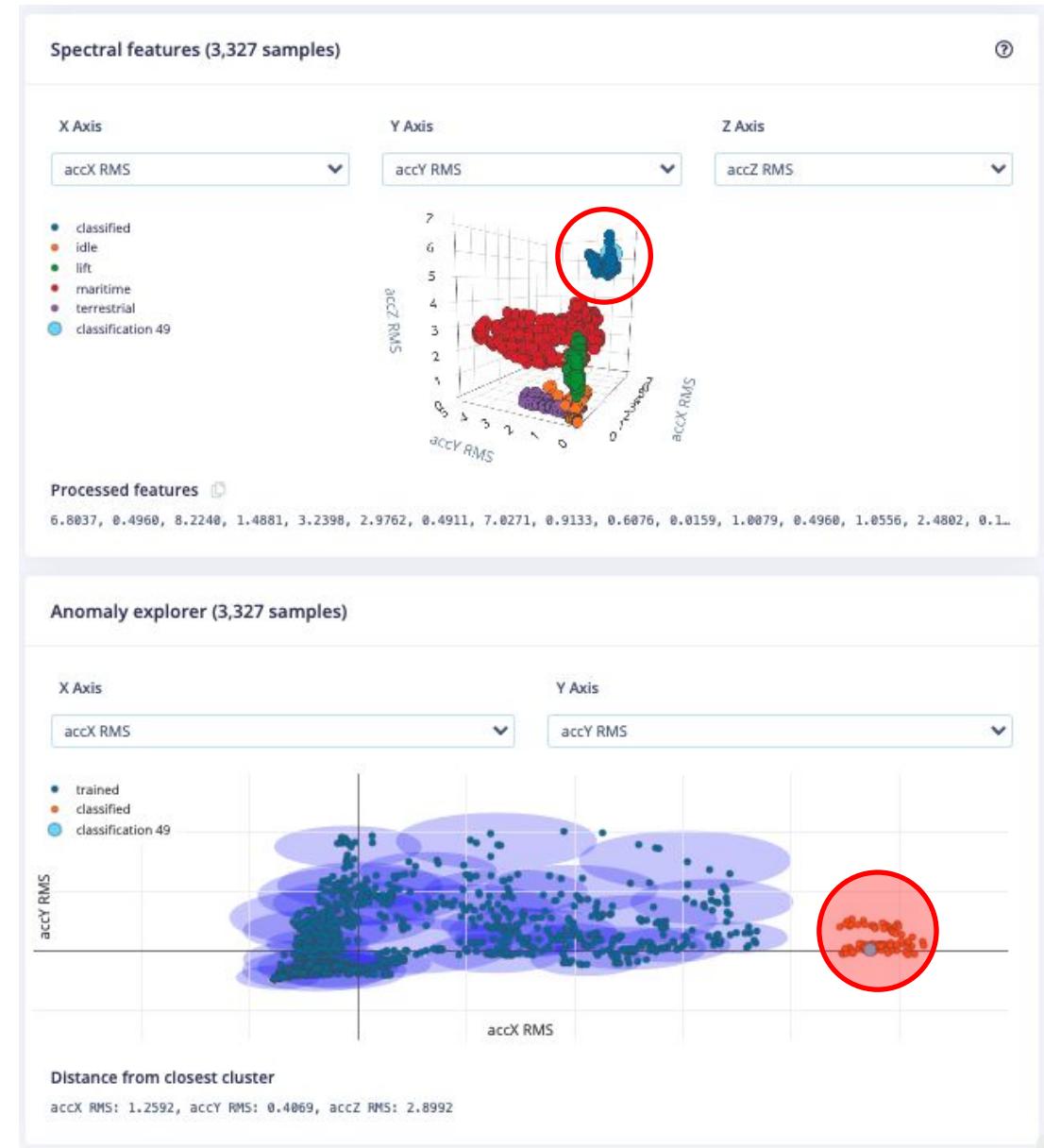
```

0.6358923488456604}, {"center": [0.2331821322441101, -0.44085508584976196, 1.193619966506958], "max_error": 0.43379442394199896}, {"center": [-0.84211855307221413, 1.622160792350769, 1.563327550888615], "max_error": 0.7400662371471811}, {"center": [2.5153045654296875, 0.10167547315359116, 1.1958473920822144], "max_error": 0.6889784598589724}, {"center": [0.6476534008979797, 2.6941537857055664, 1.7468148469924927], "max_error": 0.6253048107657685}, {"center": [-0.09443876147270203, 3.532026529312134, 1.4222177267074585], "max_error": 0.6722667084735653}, {"center": [2.1073172092437744, -2.998228887184143, 0.9732017517089844], "max_error": 0.5098888571637854}, {"center": [1.360011339187622, 2.0014262199401855, 0.6398685574531555], "max_error": 0.75014806960636}, {"center": [1.362937688275146, 0.8849844336509785, 1.6627943515777588], "max_error": 0.5872878607683915}, {"center": [1.6086387634277344, 0.635323166847229, 0.2745974659919739], "max_error": 0.7719379326342638}, {"center": [2.882452487945566, 0.21148265898227692, 1.768933892250061], "max_error": 0.5465858786758827}, {"center": [3.2645251750946045, 1.6626498699188232, 1.3556557893753852], "max_error": 0.7446547869773675}, {"center": [1.2767698420158757, 3.724461978643799, 1.3416912555694581], "max_error": 0.91880358736727107}, {"center": [3.0170180797576904, 3.0672569274902344, 0.8234216570854187], "max_error": 0.9686505165548877}]

```

Job completed

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CNMAC_Motion_Anomaly - De X +

studio.edgeimpulse.com/studio/139905/deployment

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 - Create impulse
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- Deployment

Scan this QR code

To run your impulse on your mobile phone, click [here](#) or scan the QR code.



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15:49 AA 39

phone.edgeimpulse.com

Classifier

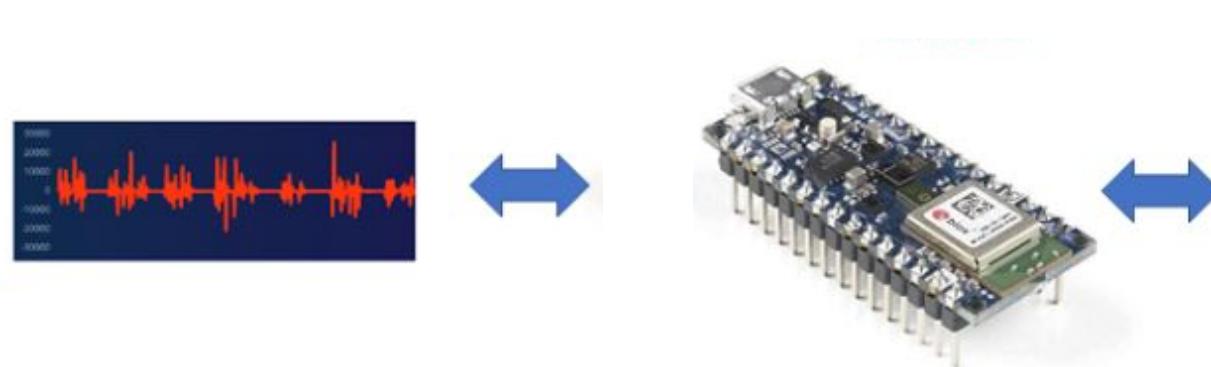
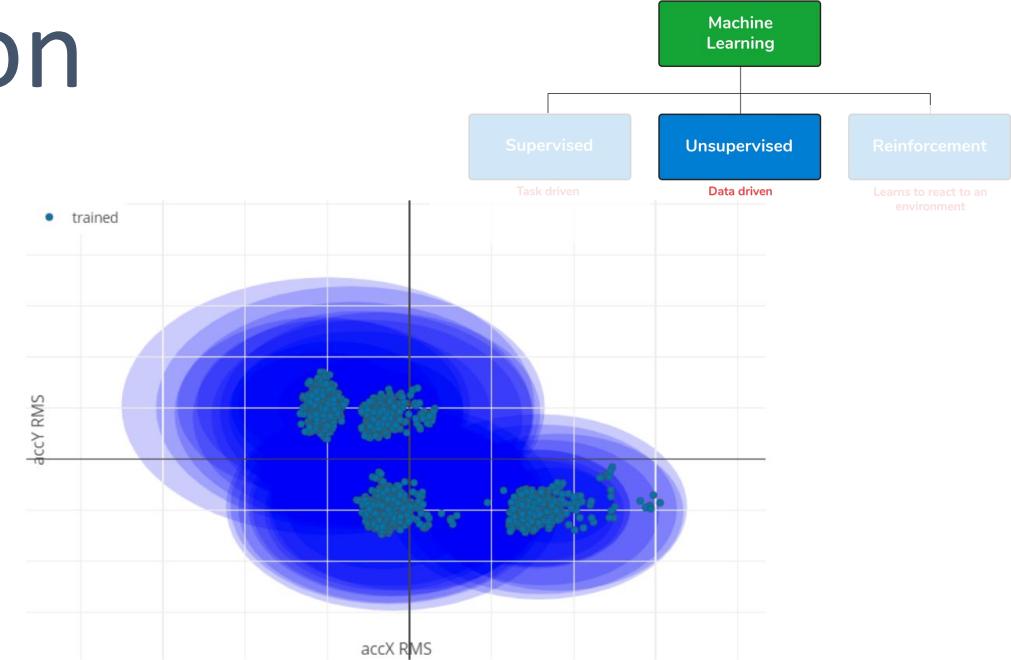
Sampling... 6s

	IDLE	LIFT	MARITIME	TERRESTRIAL	ANOMALY
4	0.00	0.00	1.00	0.00	2.00
3	0.01	0.00	0.16	0.83	-0.10

< >  

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Industrial – Anomaly Detection



IESTI01 2021.2 - Final Group Project: Bearing Failure Detection

To learn more about Edge AI

- UNIFEI - IESTI01 TinyML - Machine Learning for Embedding Devices
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- "Deep Learning with Python" book by François Chollet
- "TinyML" book by Pete Warden, Daniel Situnayake
- "TinyML Cookbook" by Gian Marco Iodice
- "AI at the Edge" book by Daniel Situnayake, Jenny Plunkett

Thanks

