



Internet de las Cosas  
Machine Learning



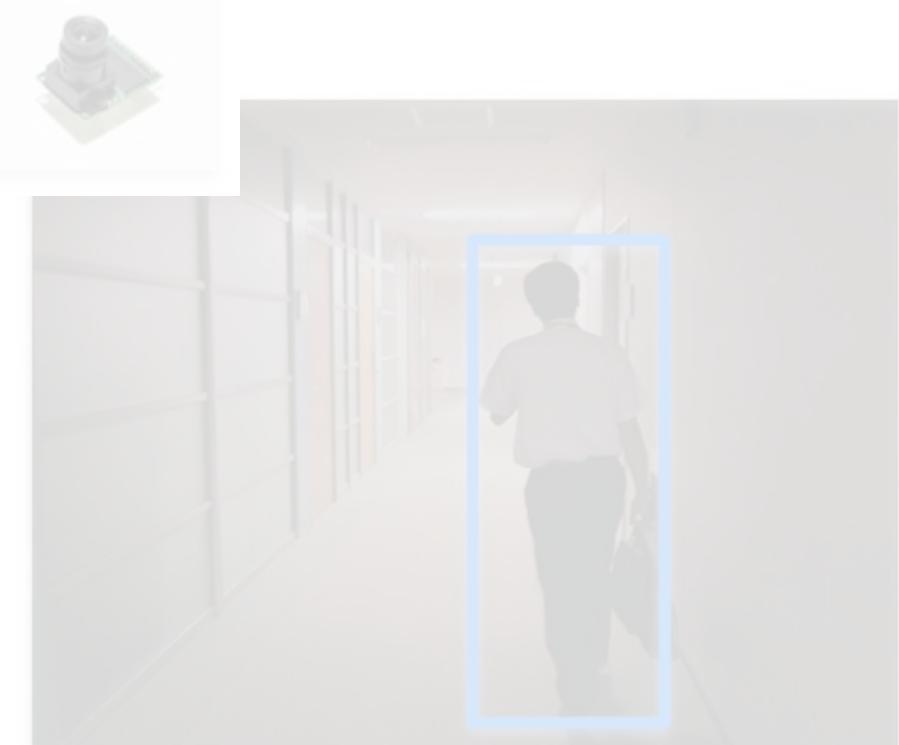
# Motion Classification, Anomaly Detection & Hands-On

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PUCE Ibarra, Ecuador



# Vision



# Sound



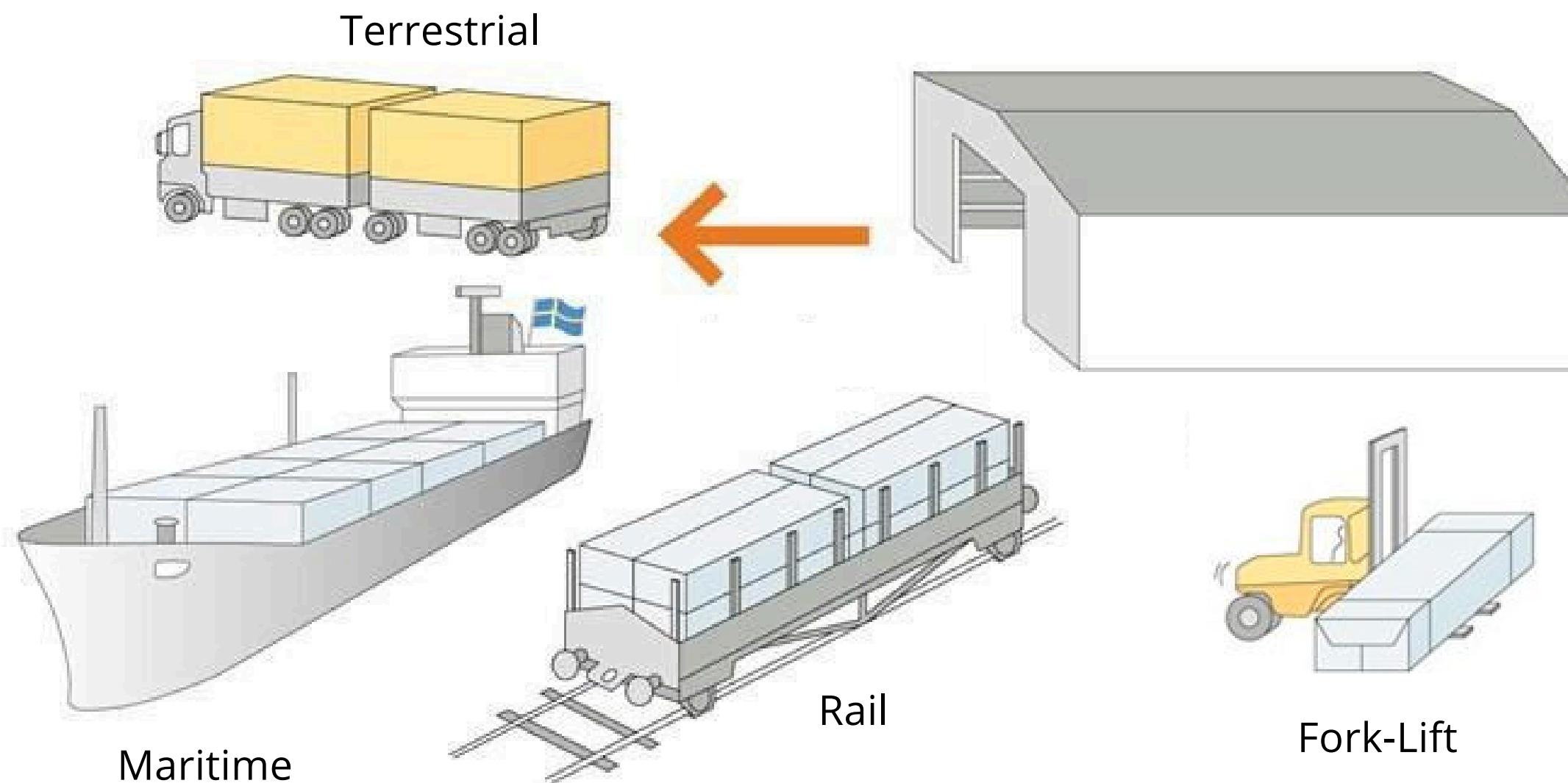
# Vibration



# Motion Classification



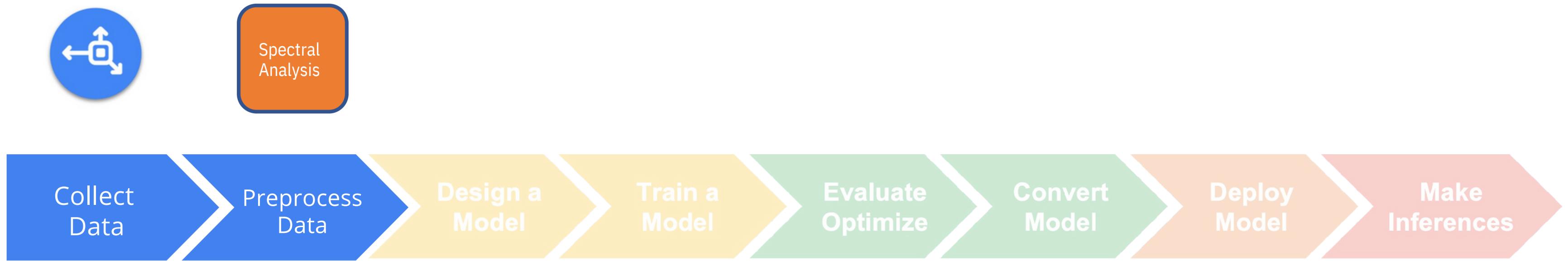
# Case Study: Mechanical Stresses in Transport



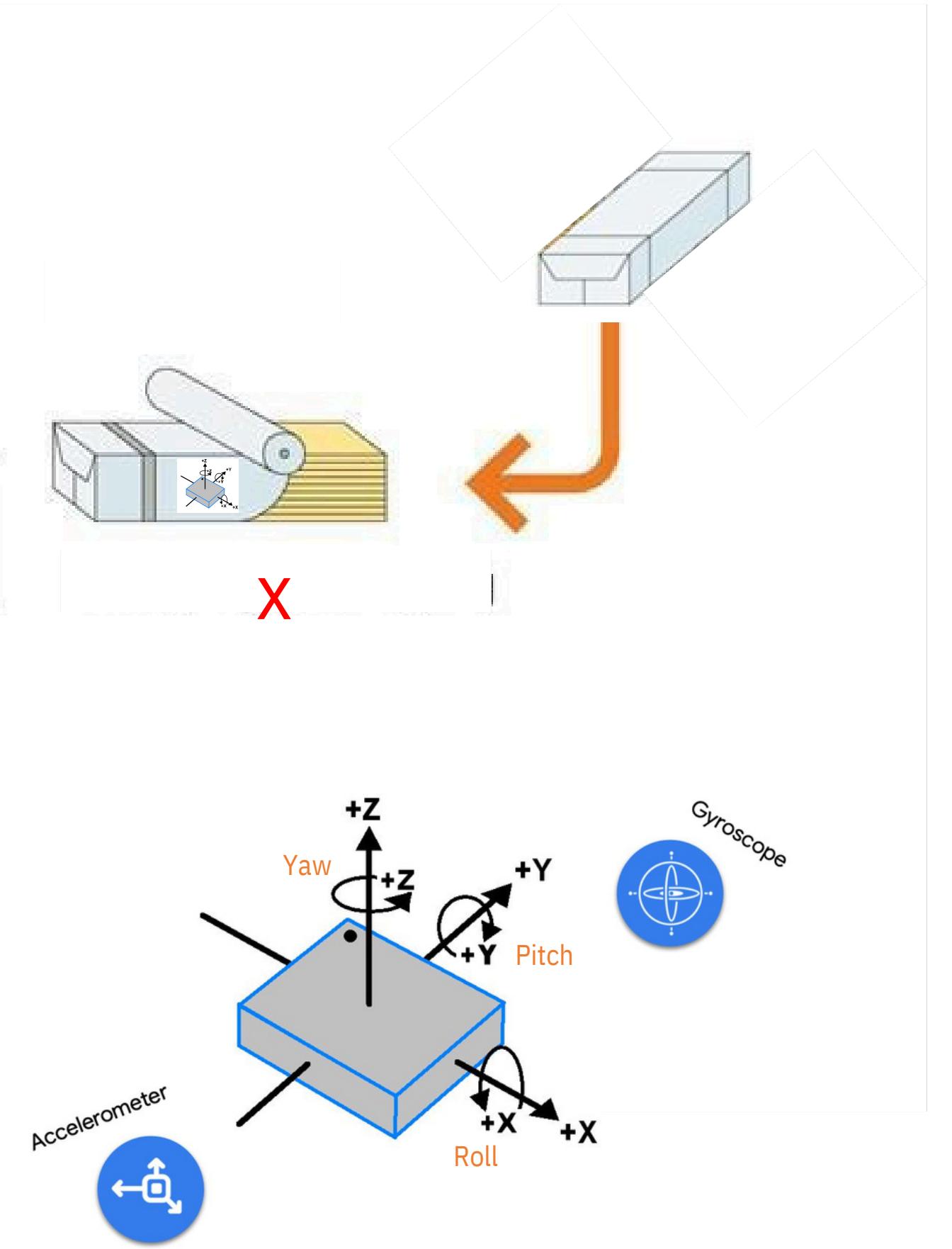
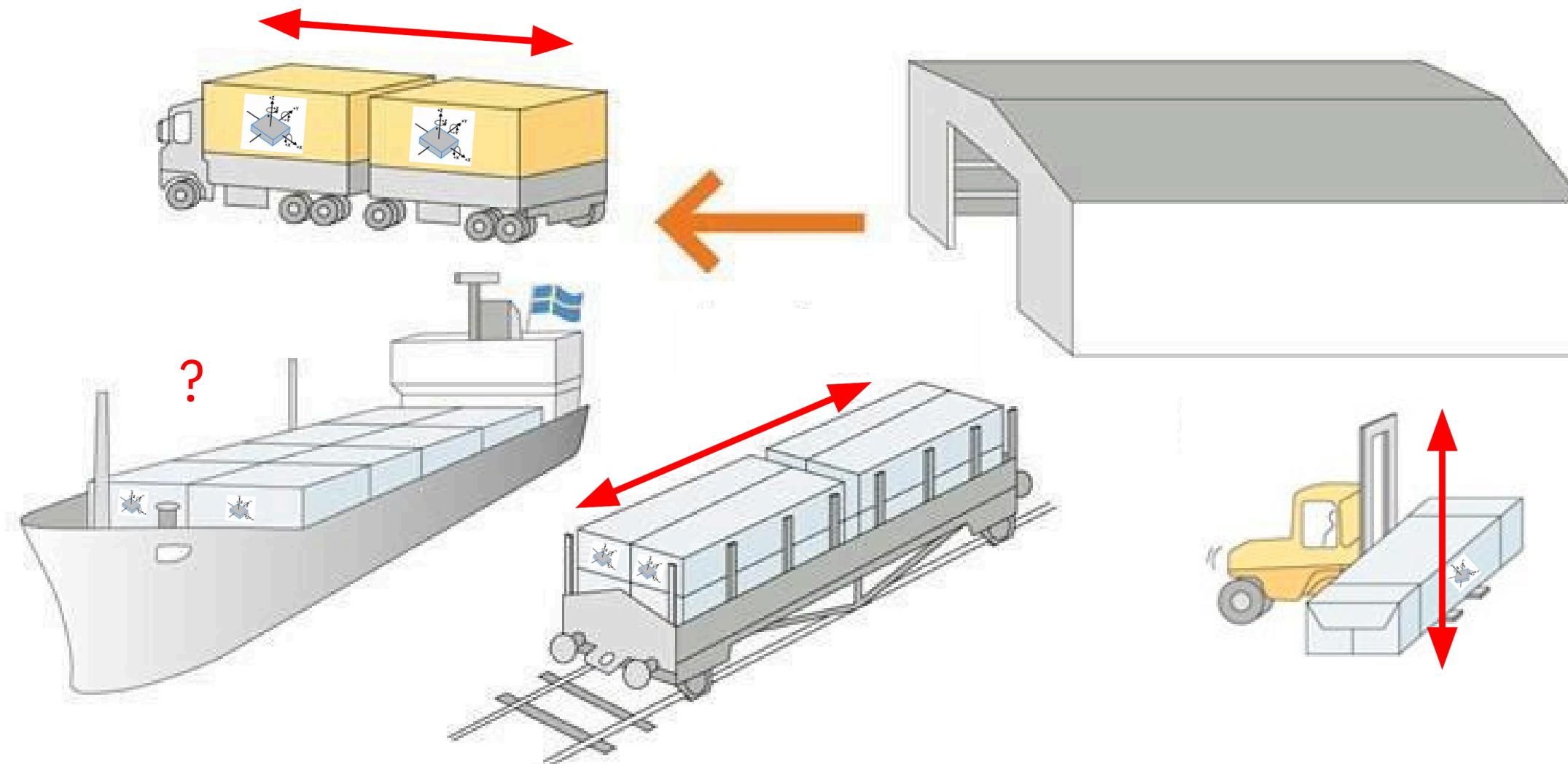
## Classes to study

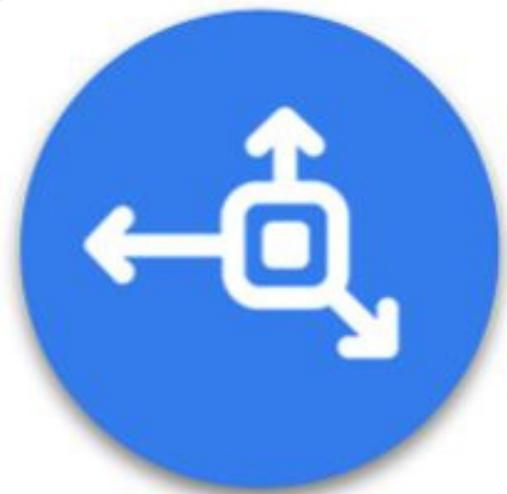
- Maritime
- Terrestrial (or Rail)
- Lift
- Idle

# Data Pre-Processing



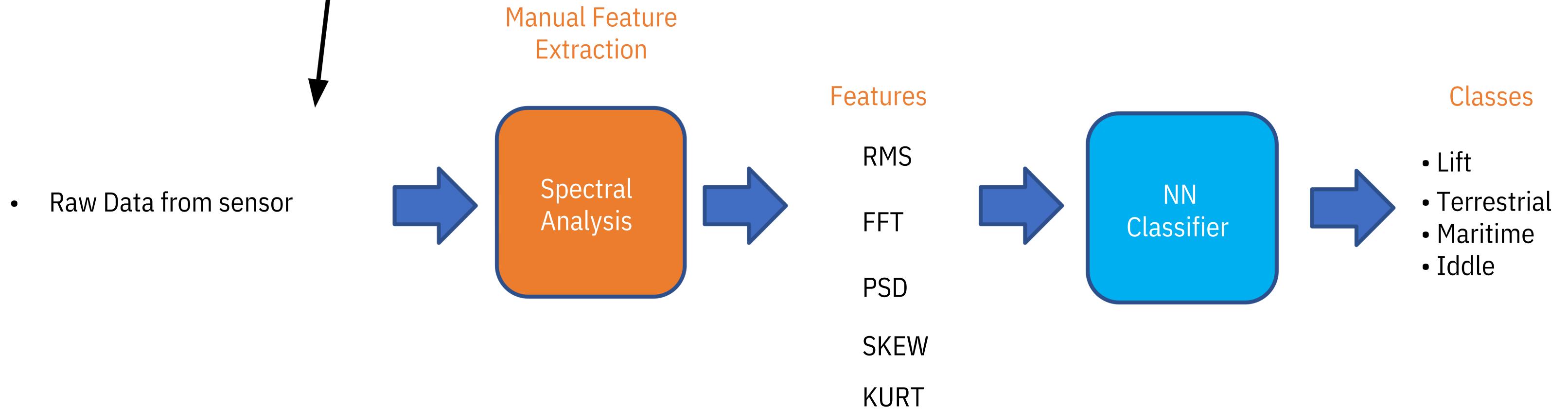
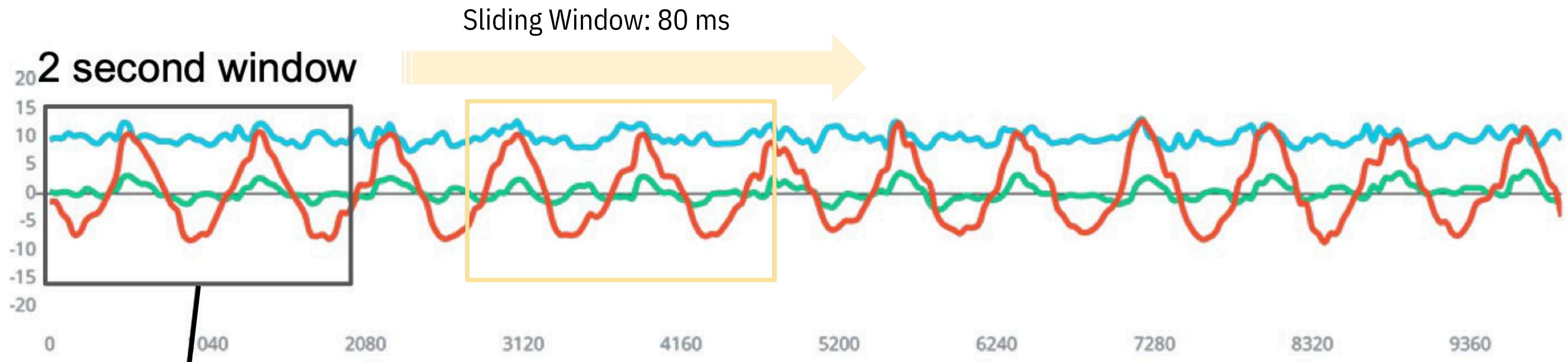
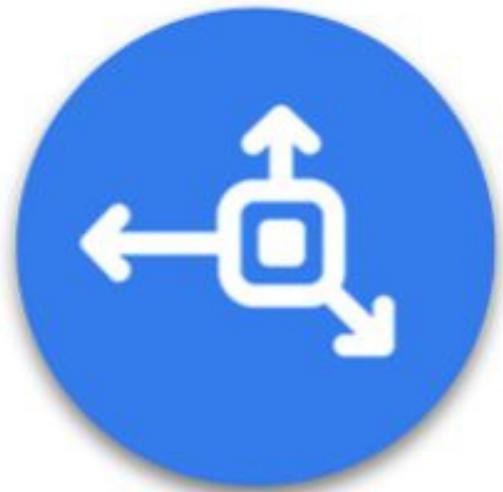
Collect  
Data



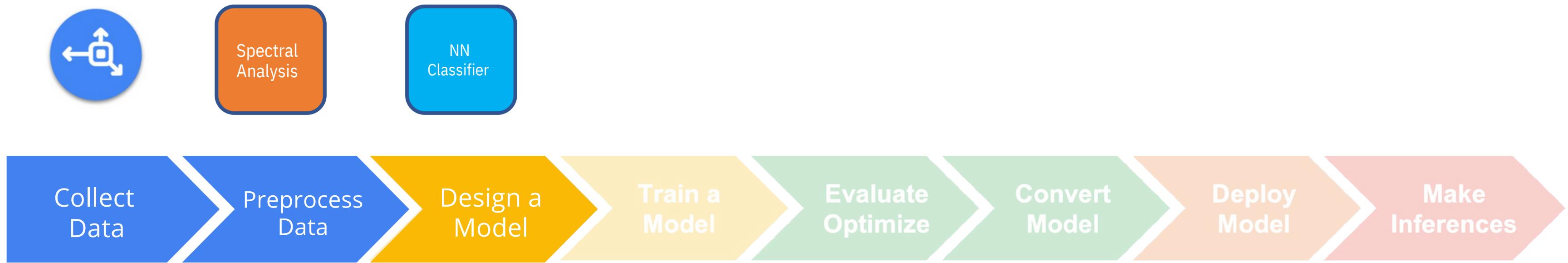


Window

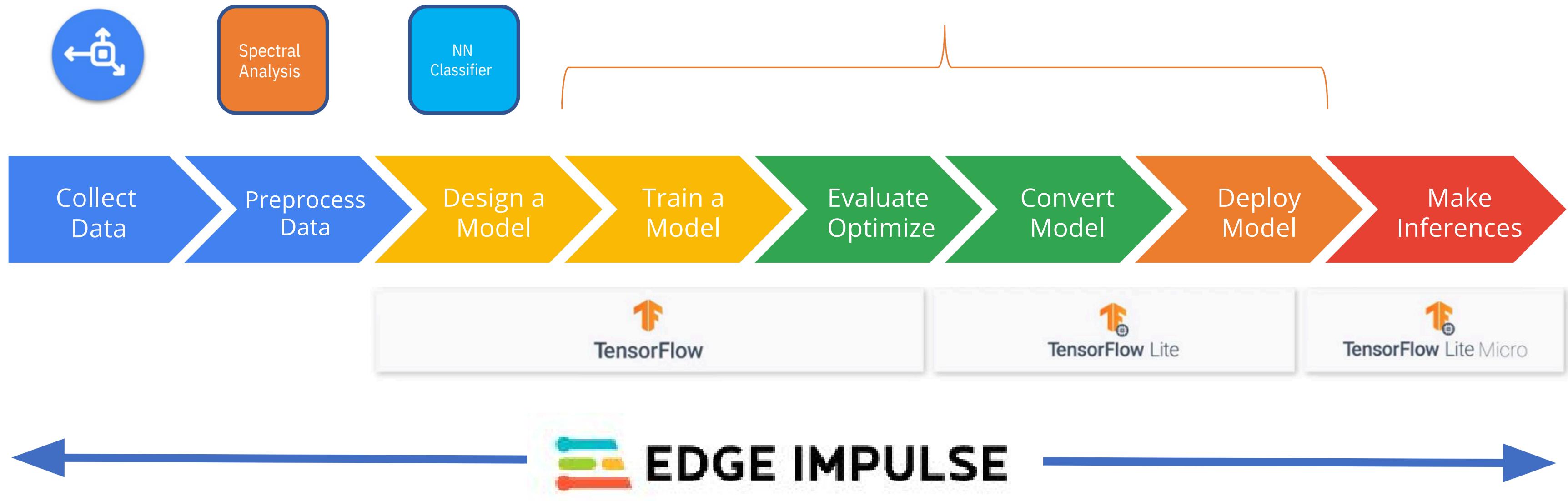




# Model Design (NN Classifier)



# Train, Evaluate, Convert, Deploy the Model



# Motion Classification

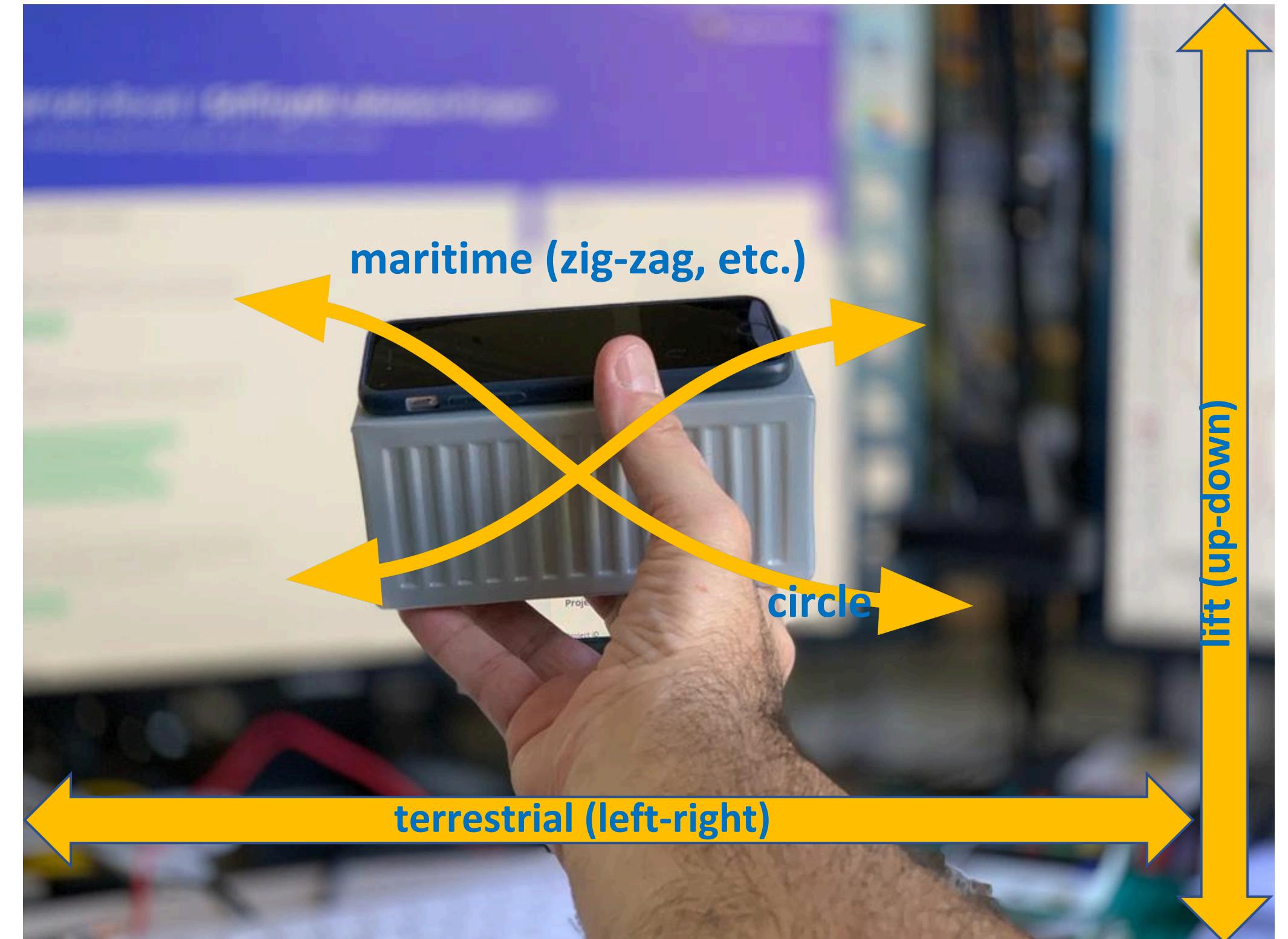
## Hands-On



# Motion Classification

## Transportation Classes

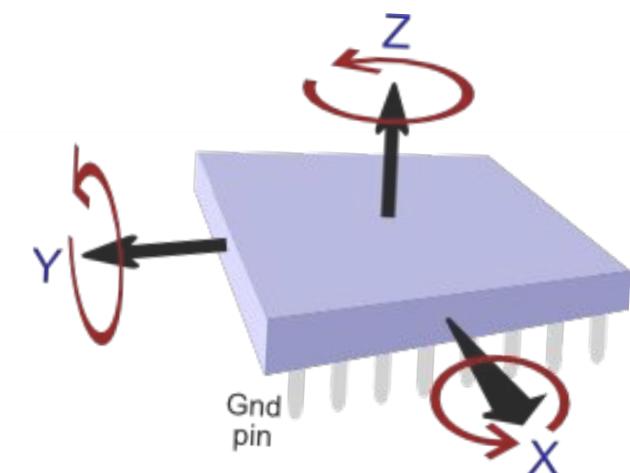
- **lift** (up-down)
- **terrestrial** (left-right)
- **maritime** (zig-zag, etc.)
- **idle**



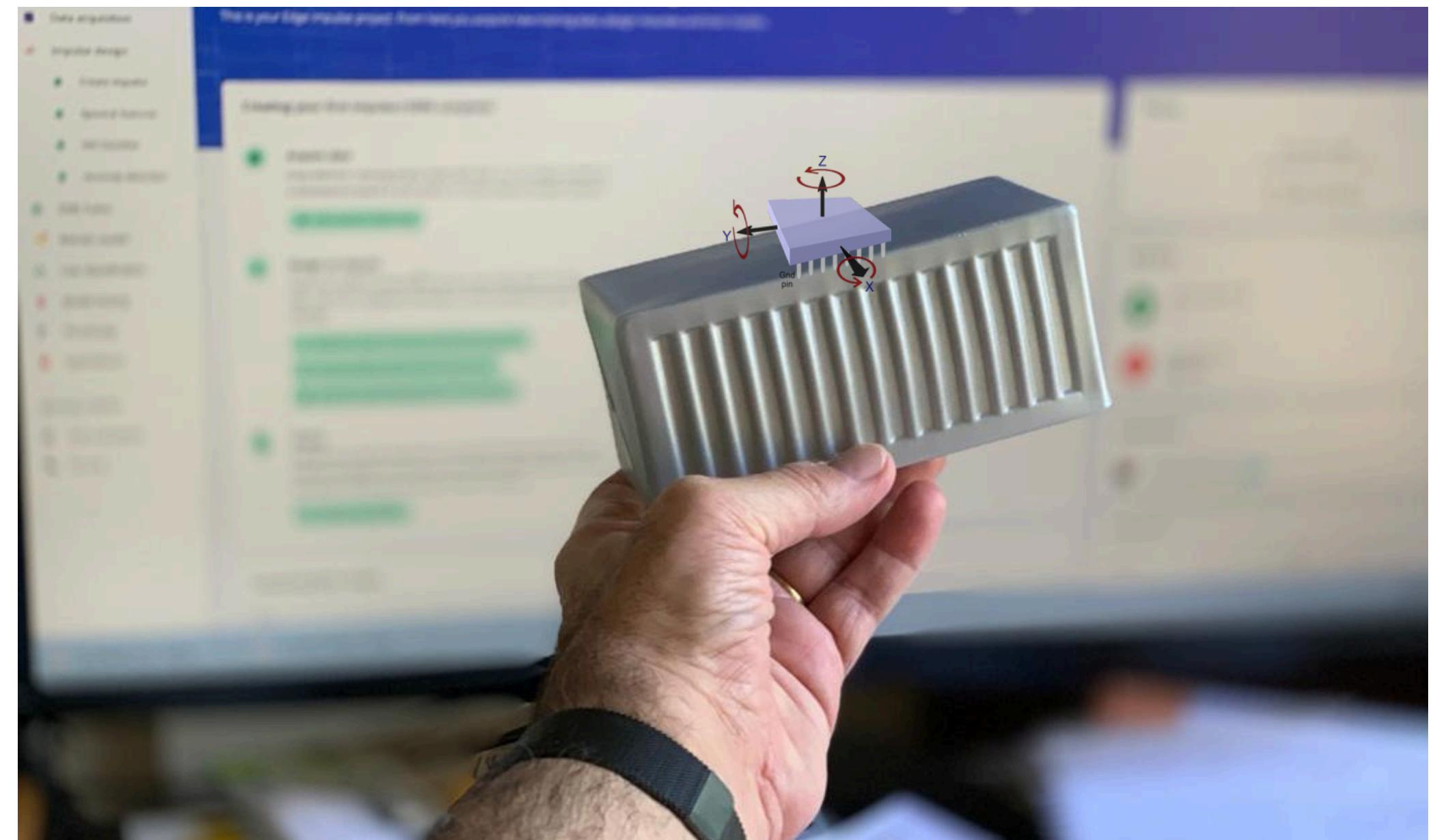
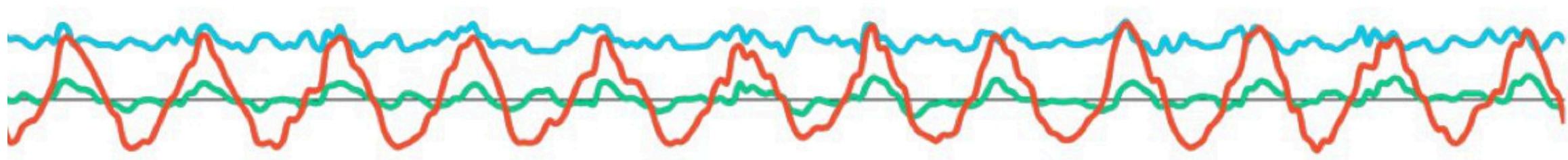
# Motion Classification

## Transportation Classes

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



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





1

- Dashboard
- Devices**
- Data acquisition

Experiments

EON Tuner

Impulse design

Create impulse

Image

Transfer learning

Retrain model

Live classification

Model testing

Deployment



### Upgrade Plan

Get access to higher job  
limits, collaborators and a full  
commercial license.

smarciniegas / Clasificación\_imagen-pucesi PERSONAL

Target: Cortex-M4F 80MHz



2

+ Connect a new device

### Your devices

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

No devices connected yet.

Learn how to connect a new device

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**EDGE IMPULSE**

- Dashboard
- Devices
- Data acquisition
- Experiments
- EON Tuner
- Impulse design
- Create impulse

Collect new data

Collect data directly from your phone, computer, device, or development board.

Scan QR code to connect to your phone

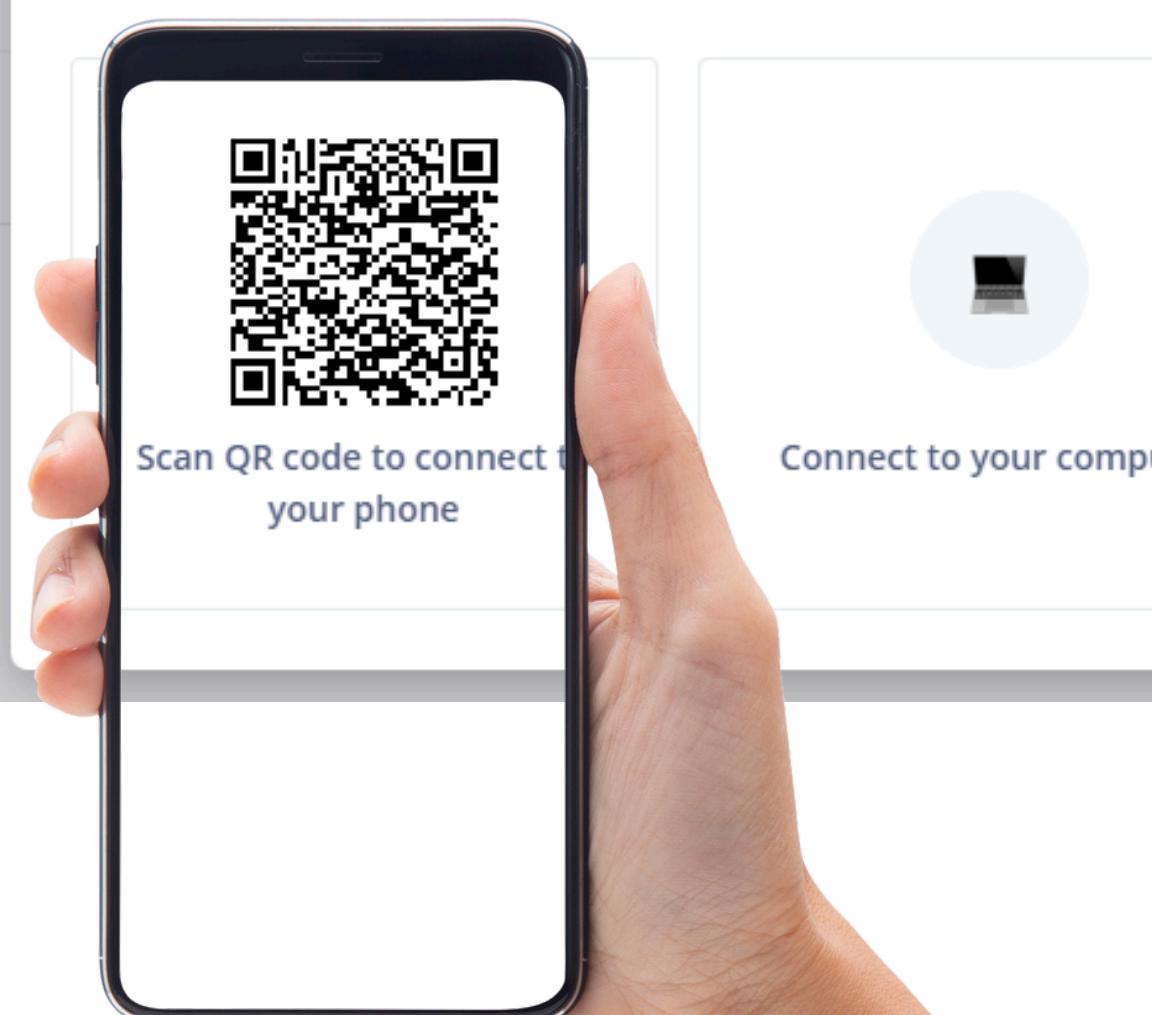
Connect to your computer

Connect your device or development board

Target: Cortex-M4F 80MHz

+ Connect a new device

SDK.



The Edge Impulse studio interface. On the left, a sidebar lists: Dashboard, Devices, Data acquisition, Experiments, EON Tuner, Impulse design (with sub-options Create impulse, Image, Transfer learning), and a dropdown menu. A central modal window titled "Collect new data" displays a large green checkmark icon, the text "Device 'phone\_m3djsdgk' is now connected", a sub-instruction "Go to 'Data acquisition' to collect data from this device.", a "Get started!" button with a gear icon, and a "Back" link. The top right corner shows "Target: Cortex-M4F 80MHz" and a user profile picture.

Collect new data

Device "phone\_m3djsdgk" is now connected

Get started!

Back

Dashboard

Devices

Data acquisition

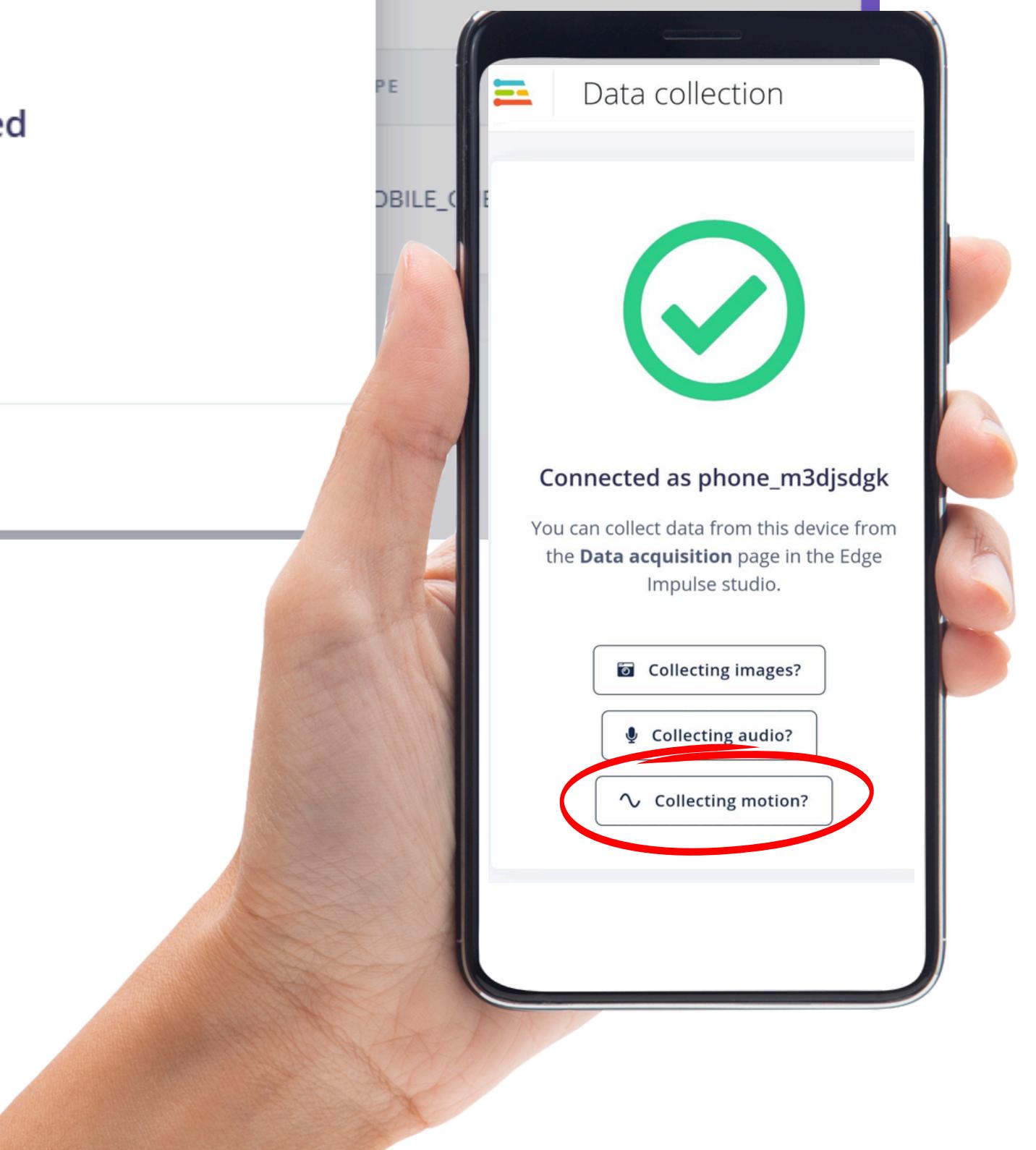
Experiments

EON Tuner

Impulse design

- Create impulse
- Image
- Transfer learning

Target: Cortex-M4F 80MHz





## Data collection



Connected as phone\_m3djsdgk

You can collect data from this device from  
the **Data acquisition** page in the Edge  
Impulse studio.

Collecting images?

Collecting audio?

Collecting motion?



## Data collection

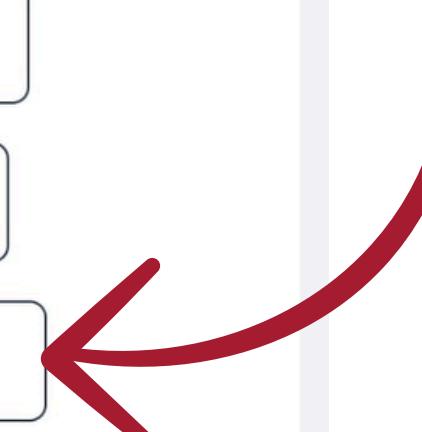
Label: Terrestre

Length: 10s.

Category: Split automatically (80/20) ▾

Start recording

Data captured with current settings: 0s





- Dashboard
- Devices
- Data acquisition
- Experiments
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Dataset   Data explorer   Data sources | CSV Wizard

DATA COLLECTED 7m 20s

TRAIN / TEST SPLIT 73% / 27%

Dataset

Training (33) Test (12)

SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
terrestrial.3he5...	terrestrial	nov 10 2022,...	10s	⋮
terrestrial.3he5...	terrestrial	nov 10 2022,...	9s	⋮
terrestrial.3he5...	terrestrial	nov 10 2022,...	10s	⋮
terrestrial.3he5...	terrestrial	nov 10 2022,...	10s	⋮
terrestrial.3he5...	terrestrial	nov 10 2022,...	10s	⋮

Collect data

Connect a device to start building your dataset.

RAW DATA

Click on a sample to load...



- Dashboard
- Devices Collect
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### Upgrade Plan

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Dataset Data explorer Data sources | CSV Wizard

DATA COLLECTED  
7m 20s



TRAIN / TEST SPLIT  
73% / 27%



### Dataset

Training (33) Test (12)

⚙️ ⚡ ✅ ☰

SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
terrestrial.3he5ctms	terrestrial	nov 10 2022, 14:3...	10s	⋮
terrestrial.3he5aftb	terrestrial	nov 10 2022, 14:3...	9s	⋮
terrestrial.3he5cet9	terrestrial	nov 10 2022, 14:3...	10s	⋮
terrestrial.3he5dq0d	terrestrial	nov 10 2022, 14:3...	10s	⋮
terrestrial.3he5ek0b	terrestrial	nov 10 2022, 14:3...	10s	⋮
terrestrial.3he5damu	terrestrial	nov 10 2022, 14:3...	10s	⋮
terrestrial.3he5e7gd	terrestrial	nov 10 2022, 14:3...	10s	⋮

### Collect data

⚡ [Connect a device to start building your dataset.](#)

### RAW DATA

#### terrestrial.3he5ctms



### Metadata

?

+



## Impulse #1



An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

Dashboard

Devices

Data acquisition

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Upgrade Plan

Get access to higher job  
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## Time series data



## Input axes (3)

accX, accY, accZ

## Window size

 2000 ms.

## Window increase (stride)

 200 ms.

## Frequency (Hz)

 62,5

## Zero-pad data

## Spectral Analysis



## Name

Spectral features

## Input axes (3)

- accX
- accY
- accZ

## Classification (Keras)



## Name

NN Classifier

## Input features

- Spectral features

## Output features

4 (idle, lift, maritime, terrestrial)

## Output features



4 (idle, lift, maritime, terrestrial)

Save Impulse

Dashboard

Devices

Data acquisition

Experiments

EON Tuner

Impulse design

Create impulse

Spectral features

NN Classifier

Retrain model

Live classification

Model testing

Deployment

Versioning

GETTING STARTED

Documentation



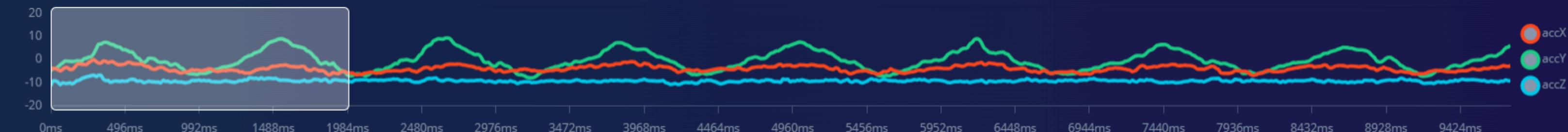
Upgrade Plan

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## Raw data

Show: All labels

terrestrial.3he5ctms (te)



## Raw features

Label

```
-3.4659, -4.6527, -11.0814, -3.7450, -3.6678, -9.0733, -3.7450, -3.6678, -9.0733, -4.1566, -2.9942, -9.58...
```

terrestrial

## Parameters

Autotune parameters

## Filter

Scale axes

1

Type

none

## Analysis

FFT length

256

Take log of spectrum?



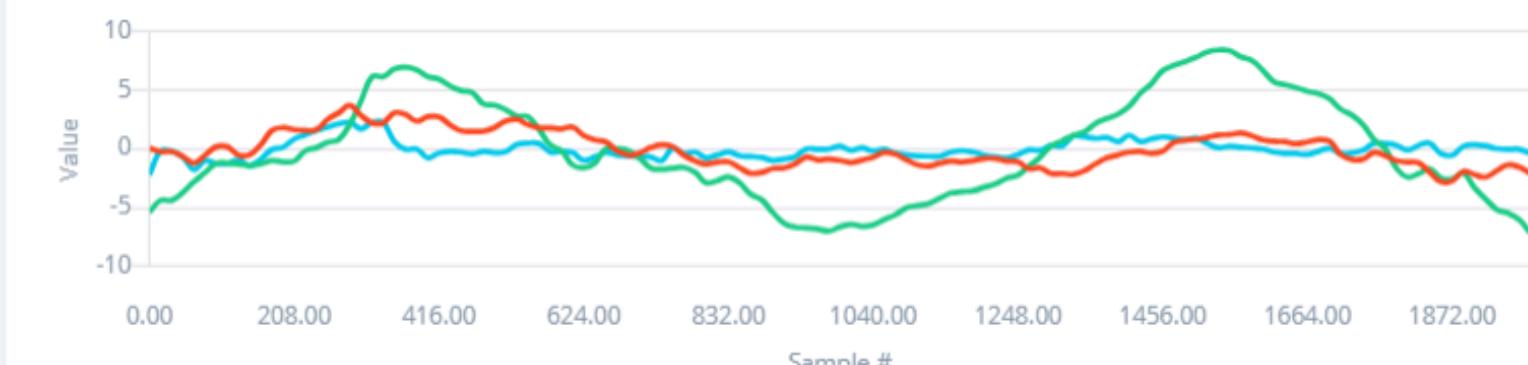
Overlap FFT frames?



Save parameters

## DSP result

## After filter



## Spectral power (log)



## Processed features

Característica	# Features	Fórmula	Significado	Uso/Aplicación
Dominio del Tiempo	9			
RMS (Root Mean Square)	3 (X,Y,Z)	$RMS = \sqrt{(\sum x^2/n)}$	Magnitud promedio de la señal	Mide la intensidad general del movimiento
SKEW (Skewness)	3 (X,Y,Z)	$SKEW = E[(x-\mu)^3]/\sigma^3$	Asimetría de la distribución	Detecta movimientos irregulares: - >0: cola derecha - <0: cola izquierda
KURT (Kurtosis)	3 (X,Y,Z)	$KURT = E[(x-\mu)^4]/\sigma^4$	Concentración alrededor de la media	Detecta eventos inusuales: - >3: más puntiaguda - <3: más plana
Dominio de la Frecuencia	384			
FFT (Fast Fourier Transform)	192 (64 bins × 3 ejes)	$X(k) = \sum[x(n)e^{(-j2\pi nk/N)}]$	Componentes de frecuencia	- Identifica patrones periódicos - Analiza composición frecuencial
PSD (Power Spectral Density)	192 (64 bins × 3 ejes)	$PSD =  FFT(x) ^2/N$	Distribución de energía por frecuencia	- Identifica frecuencias dominantes - Analiza concentración de energía

Parámetro	Valor	Efecto
FFT length	256	Define el número de puntos para el análisis frecuencial
Take log of spectrum	Activado	Mejora la visualización de componentes de baja amplitud
Overlap FFT frames	Activado	Mejora la resolución temporal y reduce efectos de borde

393 features

- [Dashboard](#)
- [Devices](#)
- [Data acquisition](#)
- [Experiments](#)
- [EON Tuner](#)
- [Impulse design](#) ▾
- [Create impulse](#)
- [Spectral features](#)
- [NN Classifier](#)
- [Retrain model](#)
- [Live classification](#)
- [Model testing](#)
- [Deployment](#)
- [Versioning](#)
- [\*\*GETTING STARTED\*\*](#)
- [Documentation](#)
- [Upgrade Plan](#)
- Get access to higher job limits, collaborators and a full commercial license.

## Neural Network settings

### Training settings

Number of training cycles [?](#)

Use learned optimizer [?](#)

Learning rate [?](#)

Training processor [?](#)

### Advanced training settings

#### Neural network architecture

- Input layer (393 features)**
- Dense layer (20 neurons)**
- Dense layer (10 neurons)**
- [Add an extra layer](#)
- Output layer (4 classes)**

**Save & train** ▾

## Model

Last training performance (validation set)

ACCURACY  
100.0%

LOSS  
0,00

Confusion matrix (validation set)

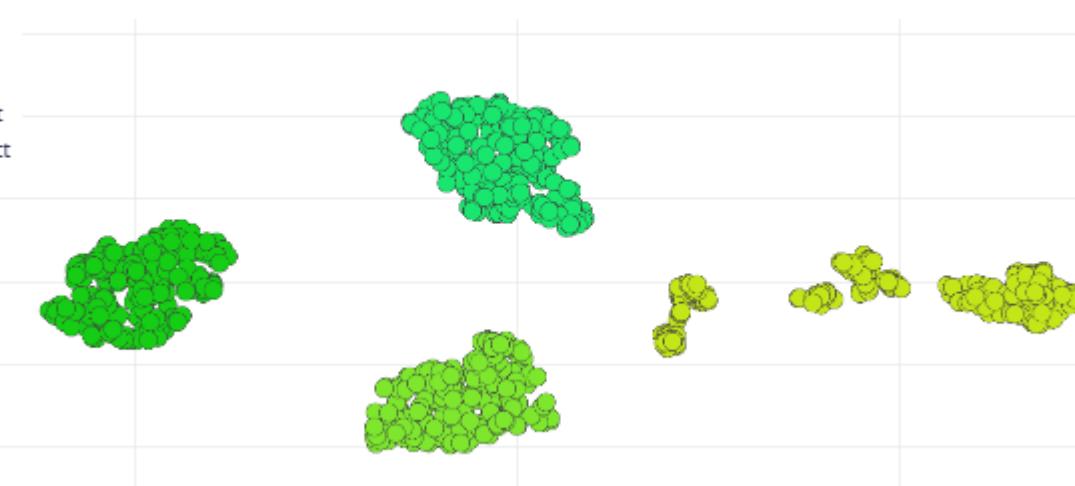
	IDLE	LIFT	MARITIME	TERRESTRIAL
IDLE	100%	0%	0%	0%
LIFT	0%	100%	0%	0%
MARITIME	0%	0%	100%	0%
TERRESTRIAL	0%	0%	0%	100%
F1 SCORE	1.00	1.00	1.00	1.00

Metrics (validation set)

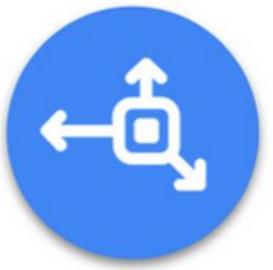
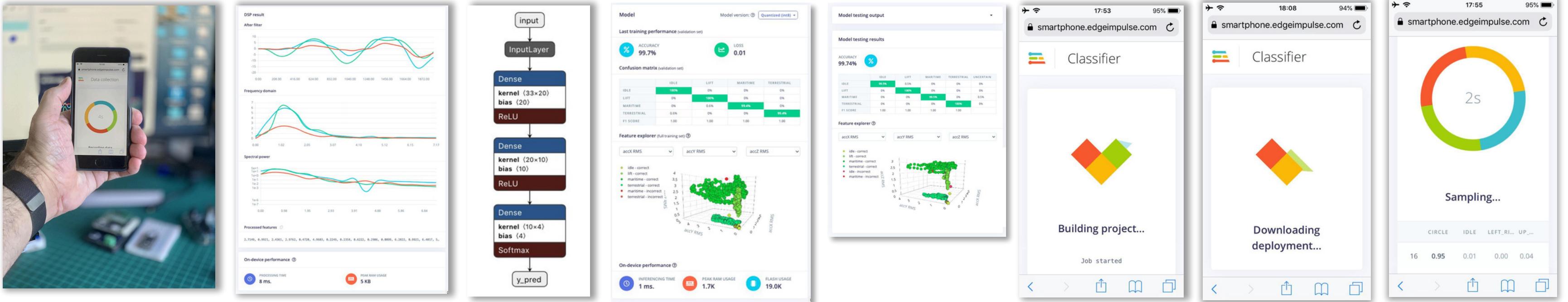
METRIC	VALUE
Area under ROC Curve <a href="#">?</a>	1.00
Weighted average Precision <a href="#">?</a>	1.00
Weighted average Recall <a href="#">?</a>	1.00
Weighted average F1 score <a href="#">?</a>	1.00

Data explorer (full training set) [?](#)

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

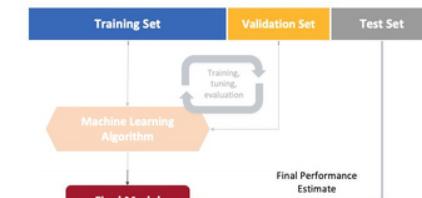
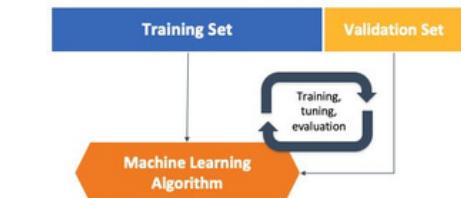


# Motion Classification - Summary



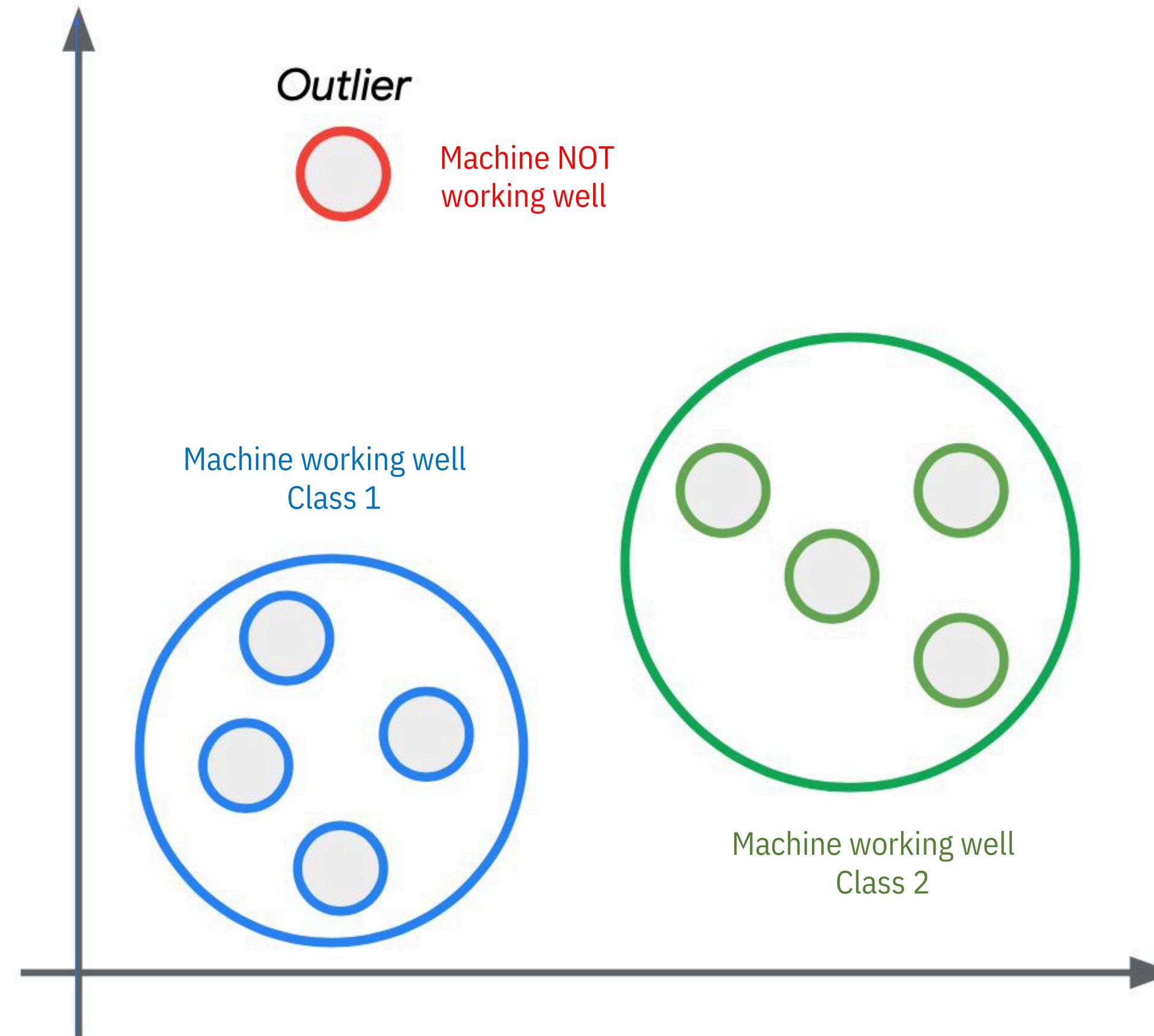
Spectral Analysis

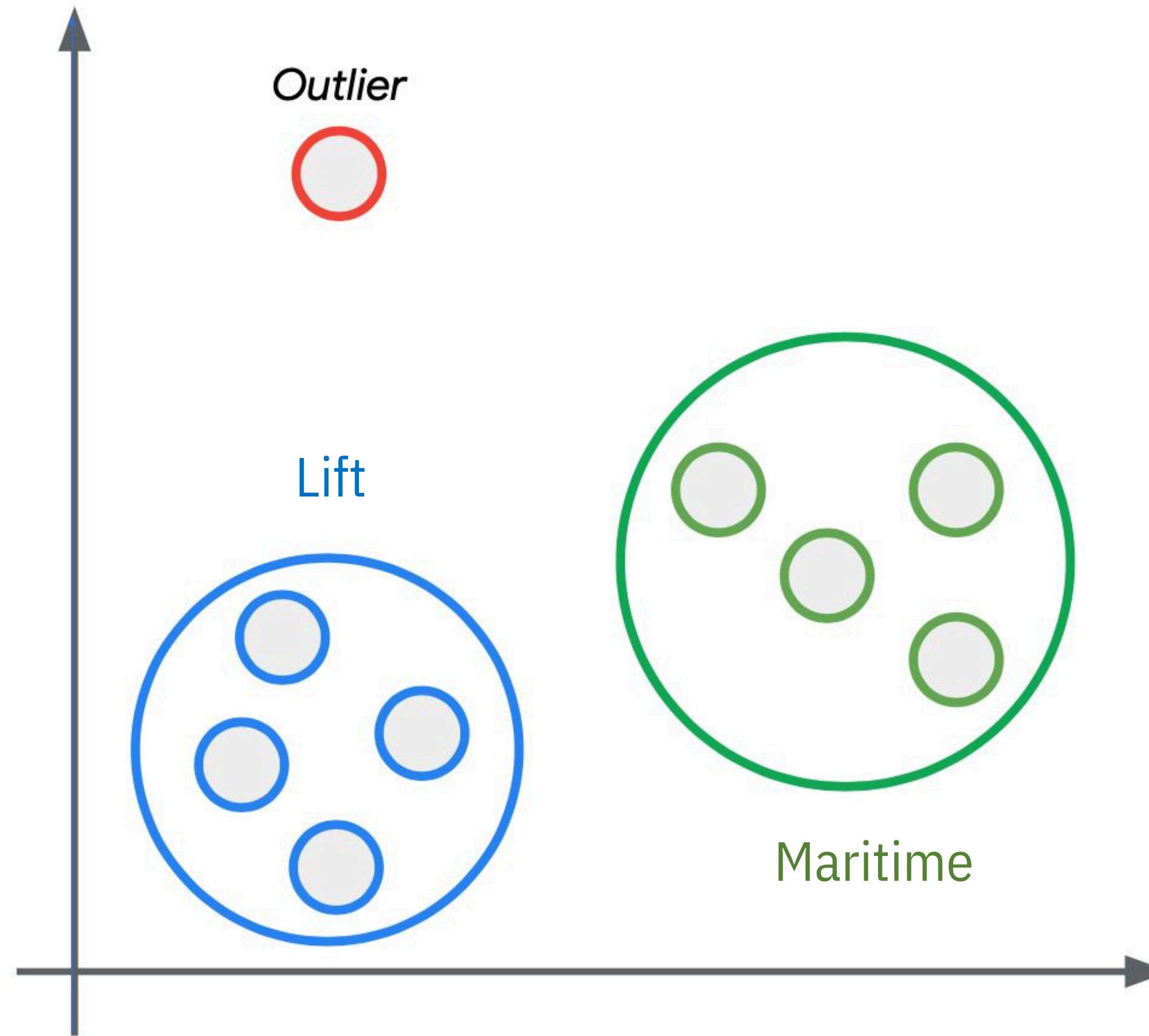
NN Classifier

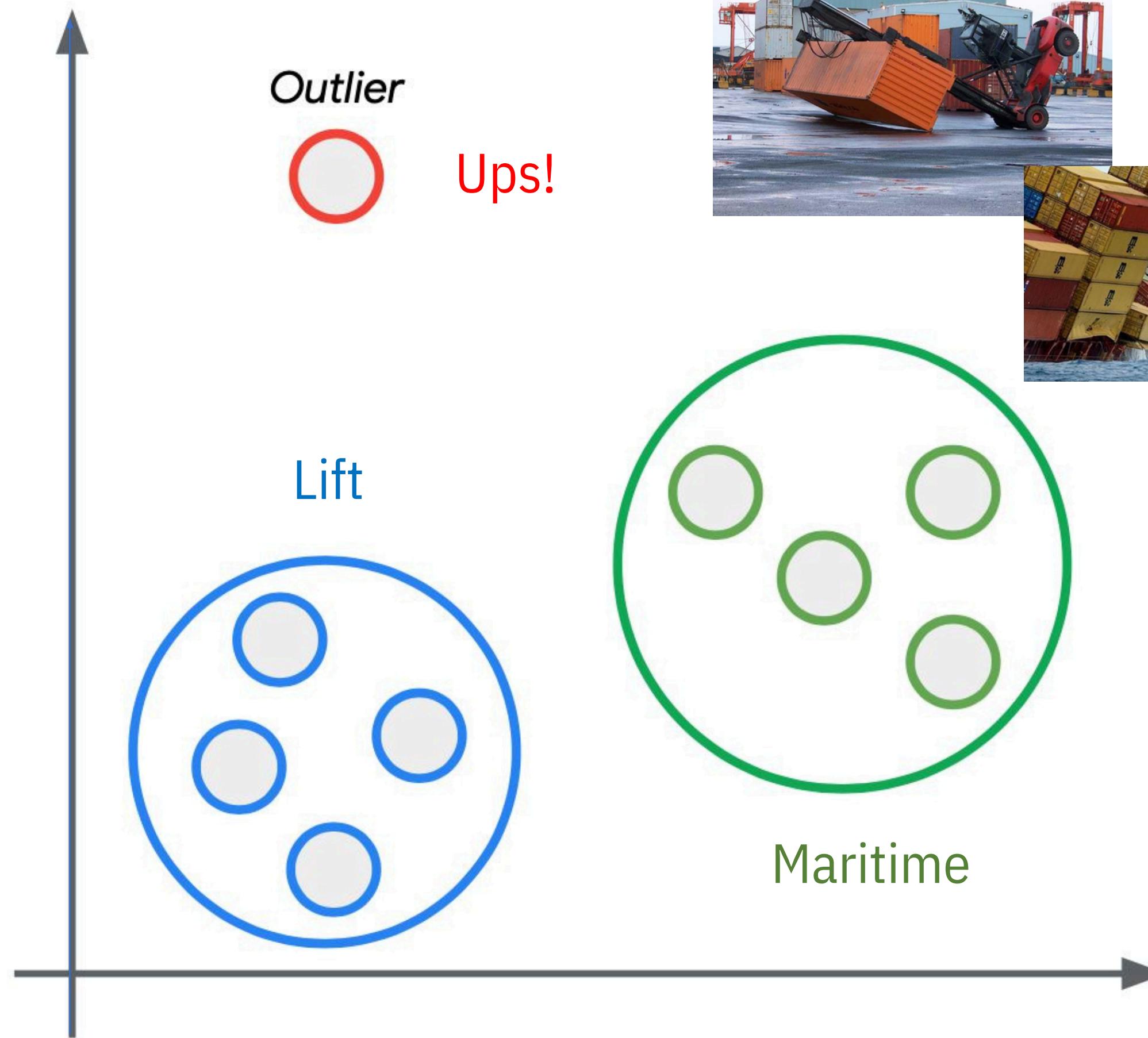


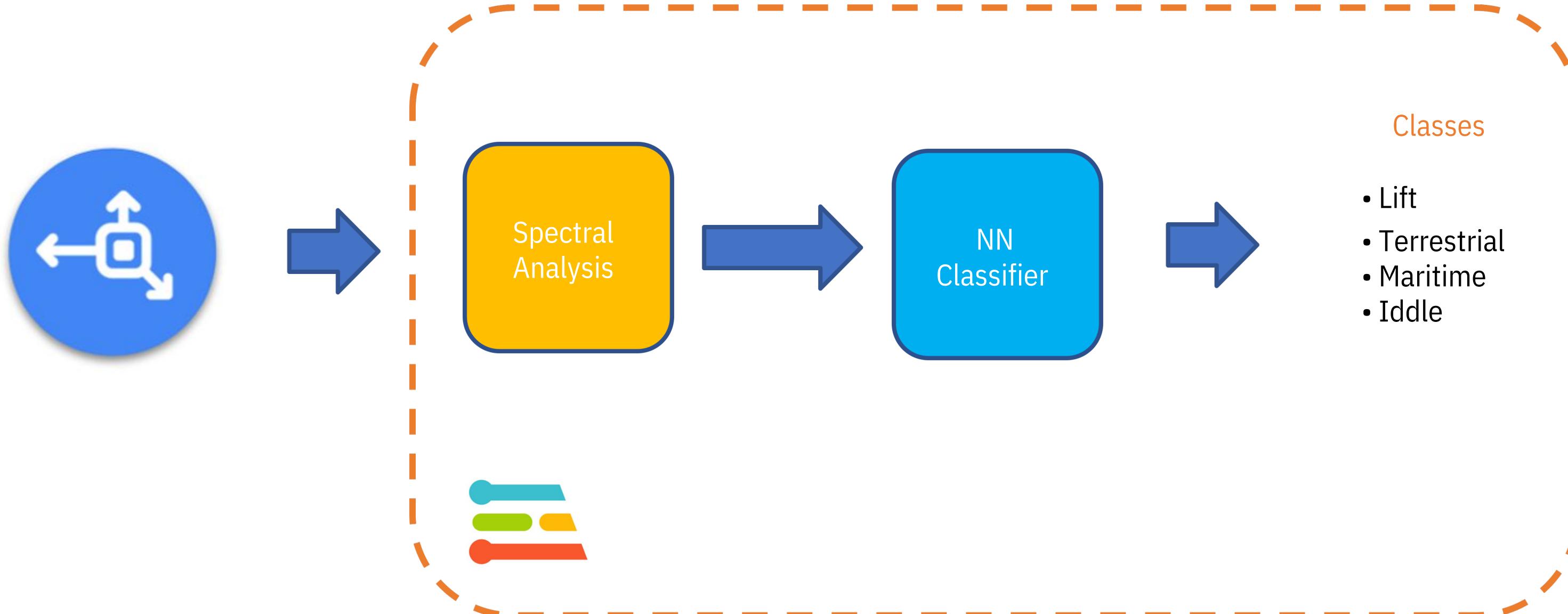
# Anomaly Detection Hands-On

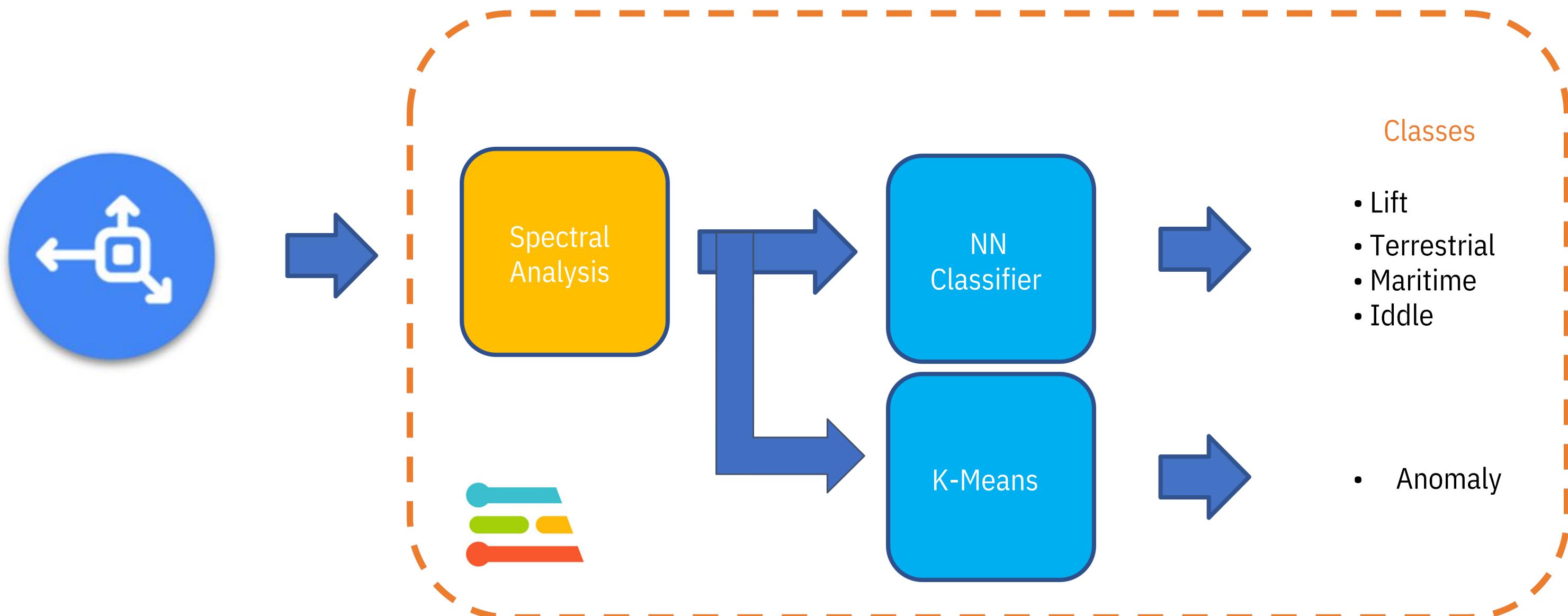












## EDGE IMPULSE

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

### GETTING STARTED

Documentation



### Upgrade Plan

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### Time series data

An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

**Input axes (3)**  
accX, accY, accZ

**Window size**  
2000 ms.

**Window increase (stride)**  
200 ms.

**Frequency (Hz)**  
62,5

**Zero-pad data**

### Spectral Analysis

**Name**  
Spectral features

**Input axes (3)**

accX  
 accY  
 accZ

### Classification (Keras)

**Name**  
NN Classifier

**Input features**

Spectral features  
 accX  
 accY  
 accZ

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

### Output features

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

Save Impulse

Add a processing block

### Anomaly Detection (K-means)

**Name**  
Anomaly detection

**Input features**

Spectral features

**Output features**  
1 (Anomaly score)



- Dashboard
- Devices
- Data acquisition
- Experiments
- EON Tuner
- Impulse design
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#### GETTING STARTED

Upgrade Plan

Get access to higher job limits, collaborators and a full commercial license.

[View plans](#)

### Anomaly detection settings

#### Cluster count

32

#### Axes

Select feature axes to include in model training.

[★ Select suggested axes](#)

- accX RMS
- accX Skewness
- accX Kurtosis
- accX Spectral Power 0.12 - 0.37 Hz
- accX Spectral Power 0.37 - 0.61 Hz
- accX Spectral Power 0.61 - 0.85 Hz
- accX Spectral Power 0.85 - 1.1 Hz
- accX Spectral Power 1.1 - 1.34 Hz
- accX Spectral Power 1.34 - 1.59 Hz
- accX Spectral Power 1.59 - 1.83 Hz
- accX Spectral Power 1.83 - 2.08 Hz
- accX Spectral Power 2.08 - 2.32 Hz ★
- accX Spectral Power 2.32 - 2.56 Hz
- accX Spectral Power 2.56 - 2.81 Hz
- accX Spectral Power 2.81 - 3.05 Hz
- accX Spectral Power 3.05 - 3.3 Hz
- accX Spectral Power 3.3 - 3.54 Hz
- accX Spectral Power 3.54 - 3.78 Hz
- accY Spectral Power 15.75 - 15.99 Hz
- accY Spectral Power 15.99 - 16.24 Hz
- accY Spectral Power 16.24 - 16.48 Hz
- accY Spectral Power 16.48 - 16.72 Hz
- accY Spectral Power 16.72 - 16.97 Hz
- accY Spectral Power 16.97 - 17.21 Hz
- accY Spectral Power 17.21 - 17.46 Hz
- accY Spectral Power 17.46 - 17.7 Hz
- accY Spectral Power 17.7 - 17.94 Hz
- accY Spectral Power 17.94 - 18.19 Hz
- accY Spectral Power 18.19 - 18.43 Hz
- accY Spectral Power 18.43 - 18.68 Hz
- accY Spectral Power 18.68 - 18.92 Hz
- accY Spectral Power 18.92 - 19.17 Hz
- accY Spectral Power 19.17 - 19.41 Hz
- accY Spectral Power 19.41 - 19.65 Hz
- accY Spectral Power 19.65 - 19.9 Hz
- accY Spectral Power 19.9 - 20.14 Hz

### Training output

#### Job started

Copying features from processing blocks...

Copying features from DSP block...

Copying features from DSP block OK

Copying features from processing blocks OK

#### Training model...

Scheduling job in cluster...

Container image pulled!

Job started

Training model OK

Job completed (success)

### Anomaly explorer

#### X Axis

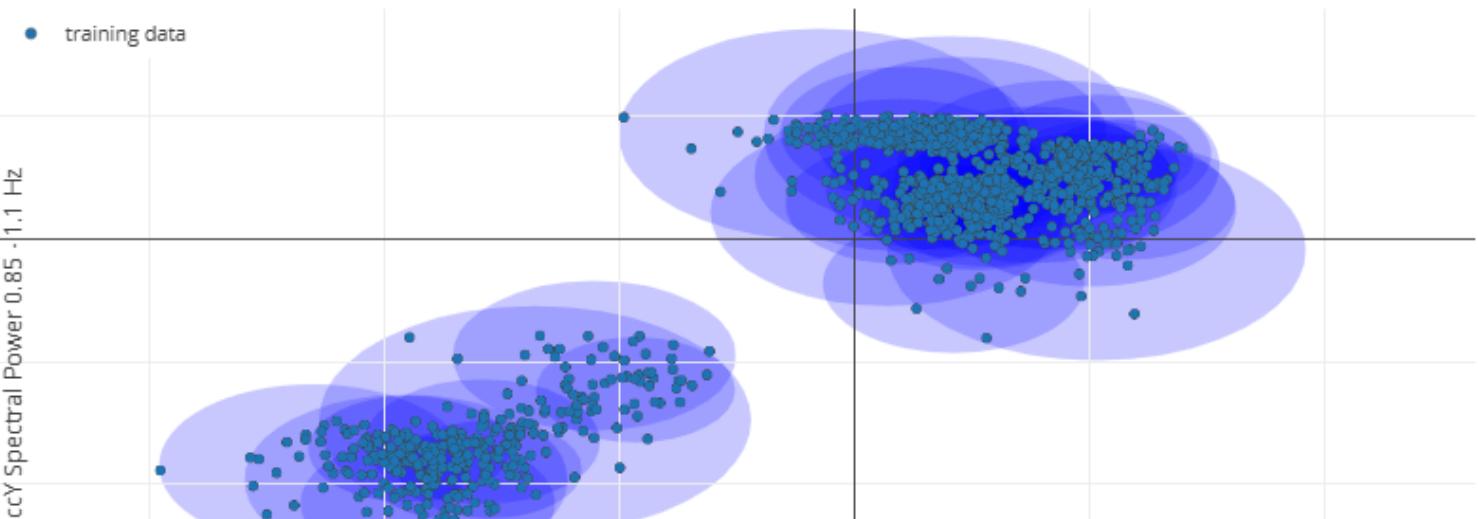
accX Spectral Power 2.08 - 2.32 Hz

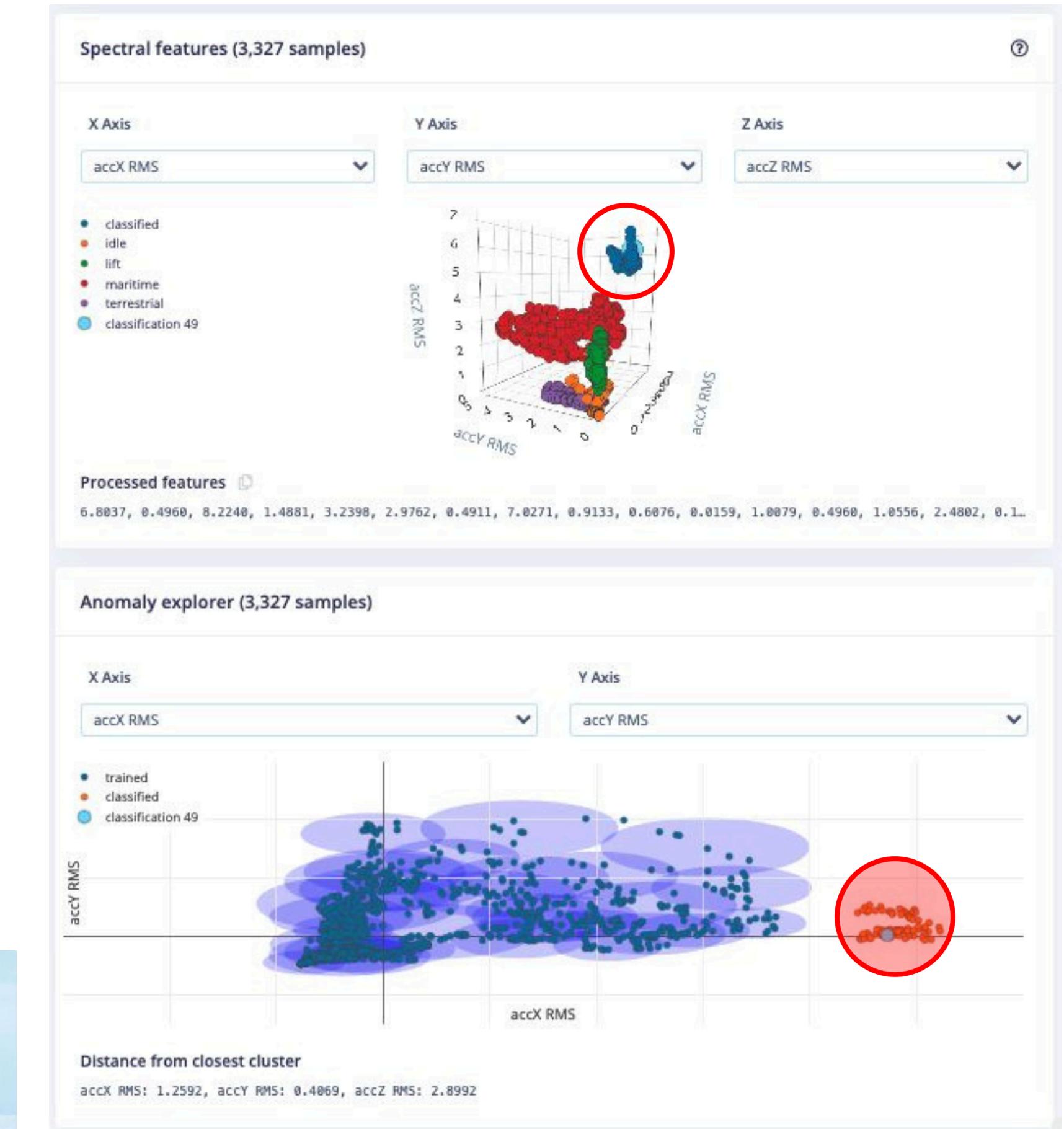
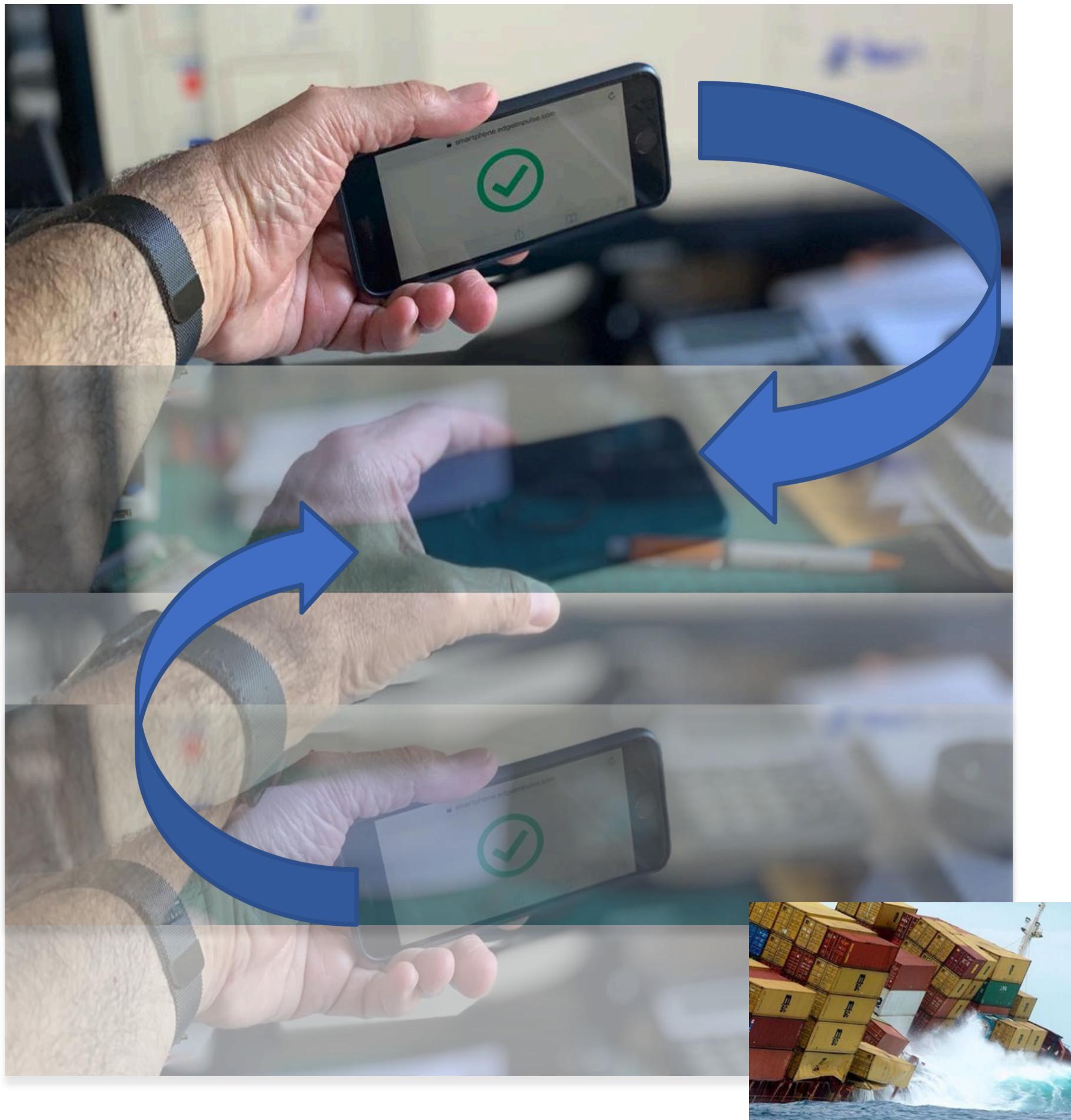
#### Y Axis

accY Spectral Power 0.85 - 1.1 Hz

#### Test data

-- No test data





# 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](#)



Internet de las Cosas  
Machine Learning



# Thanks