Workshop on TinyML for Sustainable Development

# Advancements of TinyML in Santander, Colombia driven by the TinyML community and EdgeImpulse

Silvia Alejandra Sotelo López

July 25th , 2024

Universidad Pontificia Bolivariana

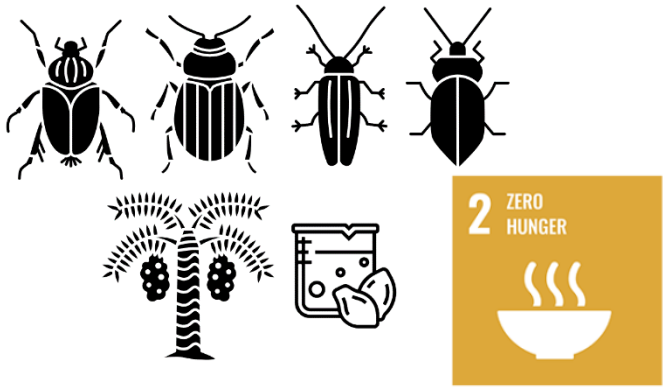
Acreditación Institucional
ALTA CALIDAD • MULTICAMPUS
Res. MEN No. 17228 del 24 de octubre de 2018 • 6 años • Vigilada Mineducación


Universidad Pontificia Bolivariana

TinyML in Santander, CO

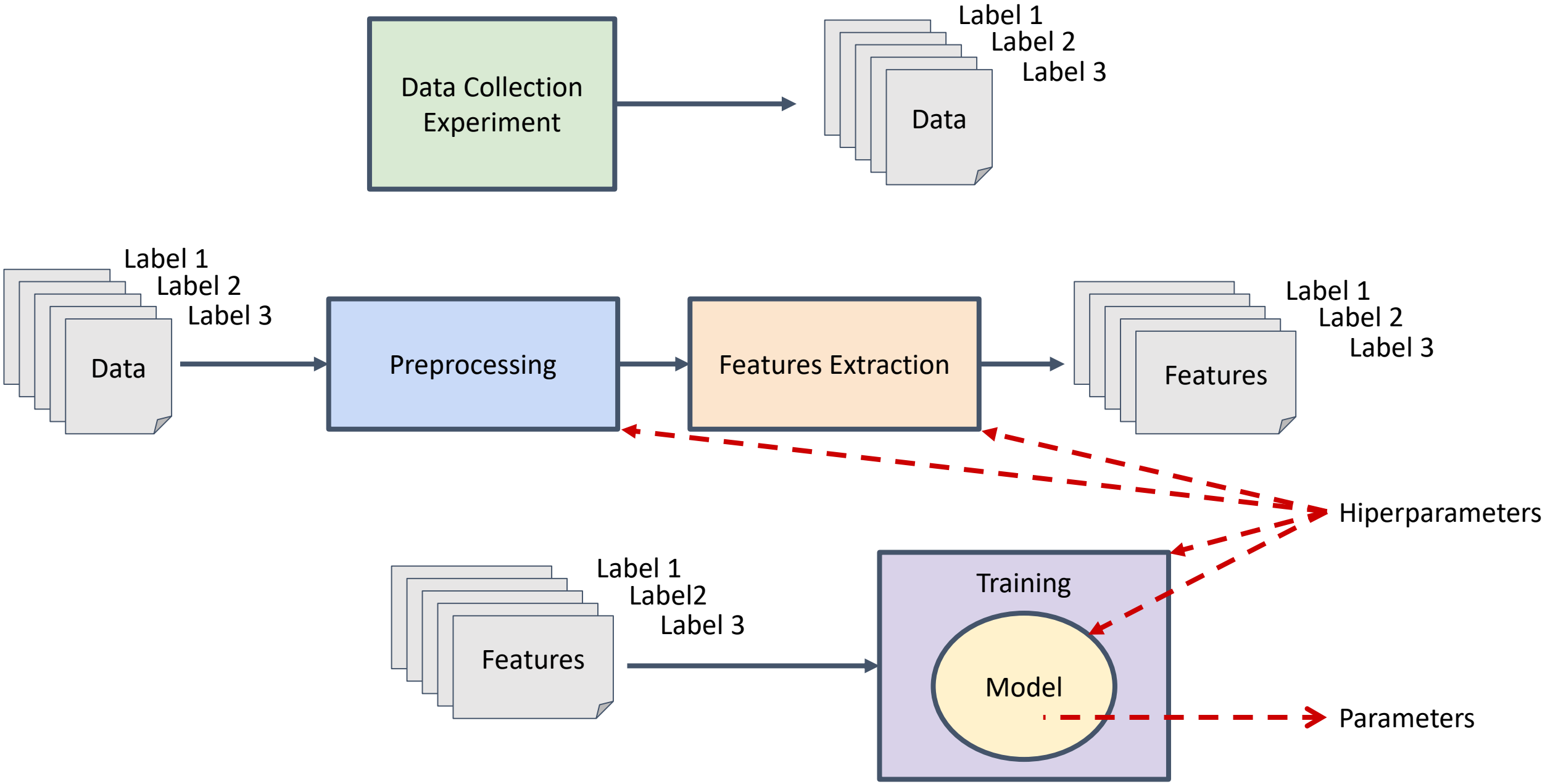
Graduation and postgraduate courses

TinyML for Agroindustry

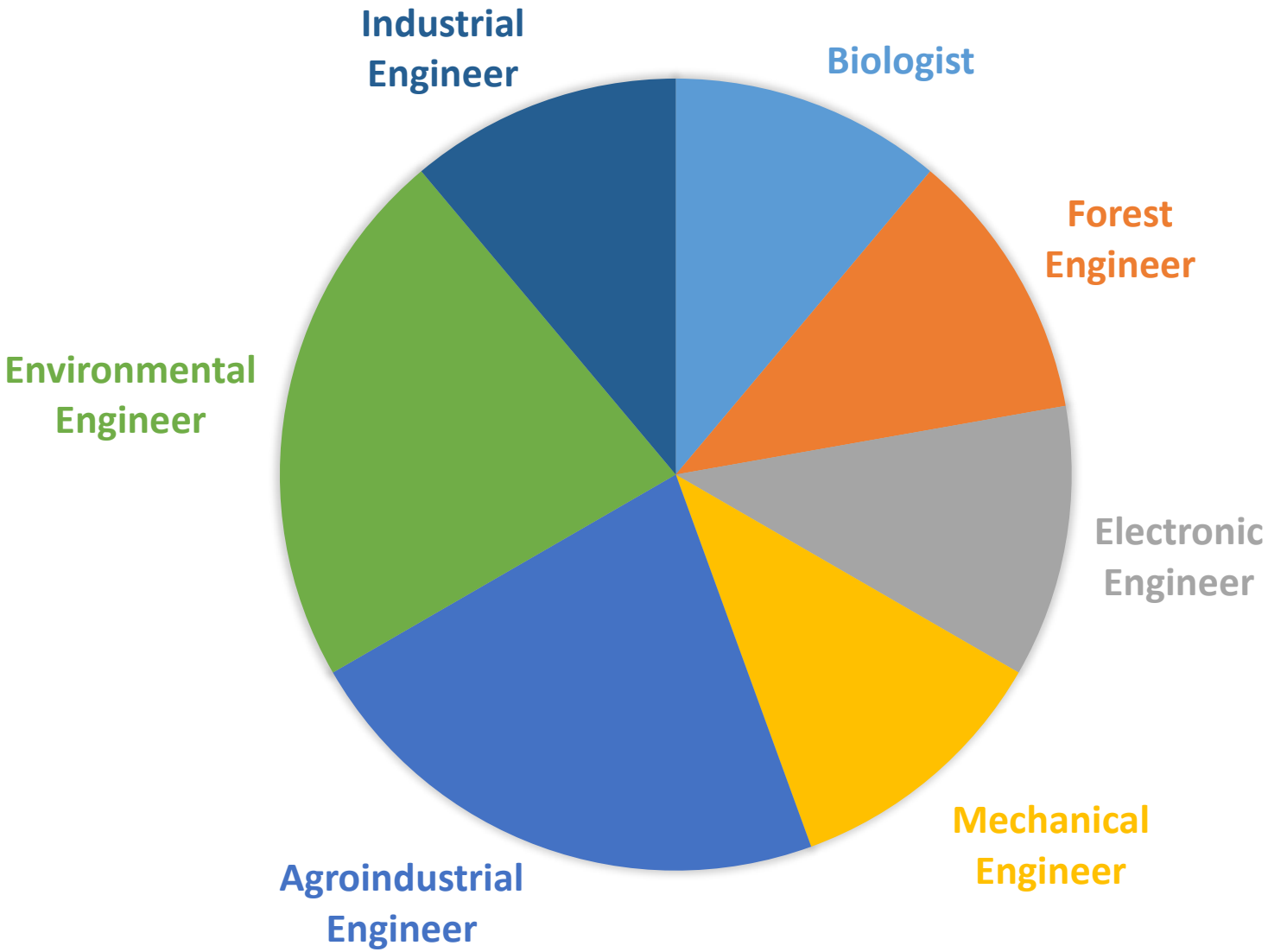


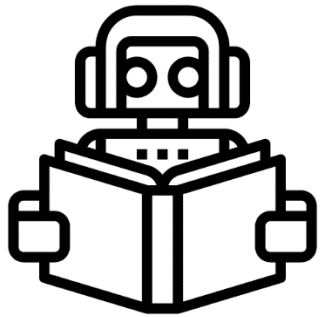

Student Research Hub

TinyML for Telemonitoring


Data Collection
Experiment
Label 1
Label 2
Label 3
Data
Label 1
Label 2
Label 3
Data
Preprocessing
Features Extraction
Label 1
Label 2
Label 3
Features
Hiperparameters
Label 1
Label2
Label 3
Features
Training
Model
Parameters

# Master's Course: MACHINE LEARNING APPLIED TO THE AGROINDUSTRY



# AUTOMATED SYSTEM FOR THE CLASSIFICATION OF 4 CLASSES OF COLEOPTERS

Students: Johan Hernández,  Hailyne Bohórquez, Fabián Osorio, Sandra López

Oil palm production contributes to Colombian economy, providing raw materials for various products such as palm oil, which is used in cooking, cosmetics, and industrial applications.

Red disease of Oil Palm

Significant economic losses

Due to the need to remove an  infected trees.

Preventative strategies involve regular monitoring of plantations

**Preventive actions: Monitoring in search of the black palm weevil (Rhynchophorus palmarum), its main vector**

Black Weevil

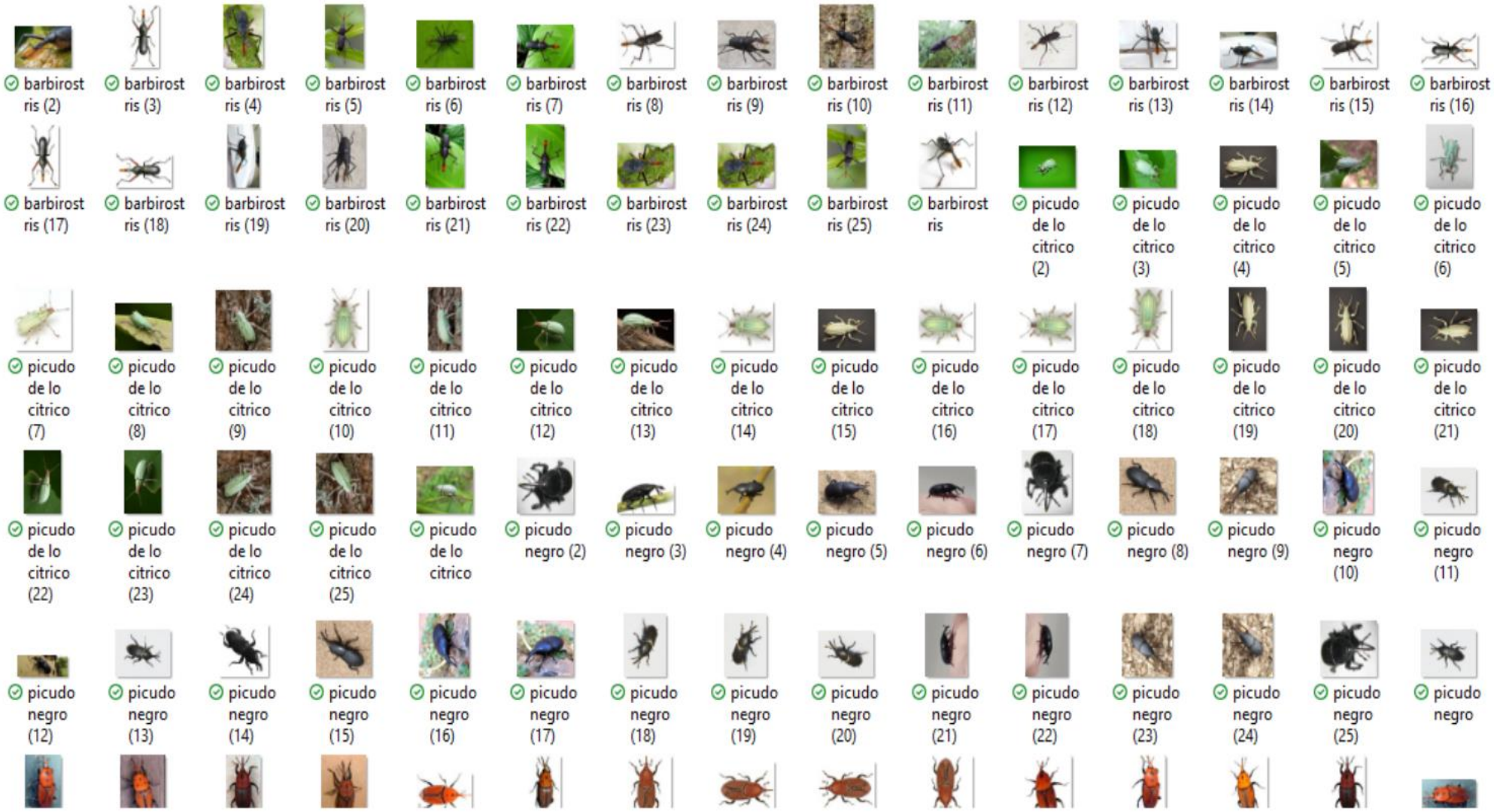
Red Weevil

Bearded Weevil

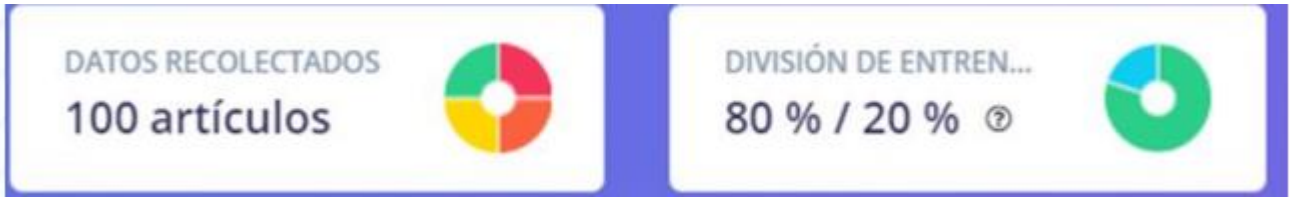
Citrus Root Weevil

# Dataset (25 images per class)

Red disease of Oil Palm

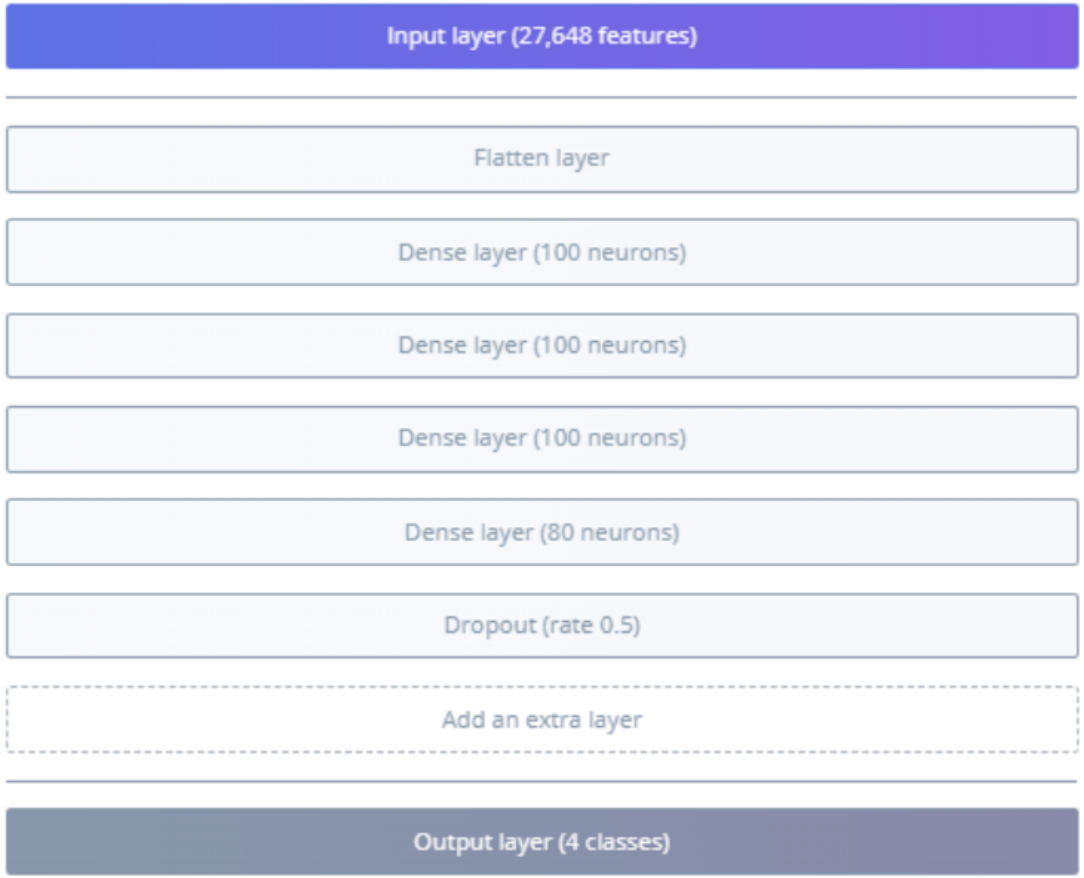


# Model I: Dense Neural Network










## Model

Model version: Quantized (int8)

### Last training performance (validation set)

ACCURACY
100.0%

LOSS
0,12

### Confusion matrix (validation set)

| | GORGOJO BARBUDO | PICUDO DE LO CITR | PICUDO NEGRO | PICUDO ROJO |
|---|---|---|---|---|
| GORGOJO BARBUDO | 100% | 0% | 0% | 0% |
| PICUDO DE LO CITR | 0% | 100% | 0% | 0% |
| PICUDO NEGRO | 0% | 0% | 100% | 0% |
| PICUDO ROJO | 0% | 0% | 0% | 100% |
| F1 SCORE | 1.00 | 1.00 | 1.00 | 1.00 |

### Resultados de las pruebas del modelo

EXACTITUD
100.00%

| | GORGOJO BARBUDO | PICUDO DE LO CÍTRICO | PICUDO NEGRO | PICUDO ROJO | INCIERTO |
|---|---|---|---|---|---|
| GORGOJO BARBUDO | 100% | 0% | 0% | 0% | 0% |
| PICUDO DE LO CÍTRICO | 0% | 100% | 0% | 0% | 0% |
| PICUDO NEGRO | 0% | 0% | 100% | 0% | 0% |
| PICUDO ROJO | 0% | 0% | 0% | 100% | 0% |
| PUNTUACIÓN F1 | 1.00 | 1.00 | 1.00 | 1.00 | |

Inferencing...

## Gorgojo Barbudo

Time per inference: 8 ms.

| | GORGOJO B... | PICUDO NE... | PICUDO RO... | PICUD... |
|---|---|---|---|---|
| 5... | 1.00 | 0.00 | 0.00 | 0.00 |
| 5... | 1.00 | 0.00 | 0.00 | 0.00 |
| 5... | 1.00 | 0.00 | 0.00 | 0.00 |
| 5... | 1.00 | 0.00 | 0.00 | 0.00 |
| 5... | 1.00 | 0.00 | 0.00 | 0.00 |

AA tphone.edgeimpulse.com

Inferencing...

## Picudo de lo Críticos

Time per inference: 5 ms.

| | GORGOJO B... | PICUDO NE... | PICUDO RO... | PICUD... |
|---|---|---|---|---|
| 4... | 0.00 | 0.00 | 0.00 | 1.00 |
| 4... | 0.00 | 0.00 | 0.00 | 1.00 |
| 4... | 0.00 | 0.00 | 0.00 | 1.00 |
| 4... | 0.00 | 0.00 | 0.00 | 1.00 |
| 4... | 0.00 | 0.00 | 0.00 | 1.00 |

AA tphone.edgeimpulse.com

Inferencing...

## Picudo Rojo

Time per inference: 5 ms.

| | GORGOJO B... | PICUDO NE... | PICUDO RO... | PICUD... |
|---|---|---|---|---|
| 3... | 0.00 | 0.00 | 1.00 | 0.00 |
| 3... | 0.00 | 0.00 | 1.00 | 0.00 |
| 3... | 0.00 | 0.00 | 1.00 | 0.00 |
| 3... | 0.00 | 0.00 | 1.00 | 0.00 |
| 3... | 0.00 | 0.00 | 1.00 | 0.00 |

AA tphone.edgeimpulse.com

Cámara

Inferencing...

## Picudo Negro

Time per inference: 4 ms.

| | GORGOJO B... | PICUDO NE... | PICUDO RO... | PICUD... |
|---|---|---|---|---|
| 1... | 0.00 | 1.00 | 0.00 | 0.00 |
| 1... | 0.00 | 1.00 | 0.00 | 0.00 |
| 1... | 0.00 | 1.00 | 0.00 | 0.00 |
| 1... | 0.00 | 1.00 | 0.00 | 0.00 |
| 1... | 0.00 | 1.00 | 0.00 | 0.00 |

AA tphone.edgeimpulse.com

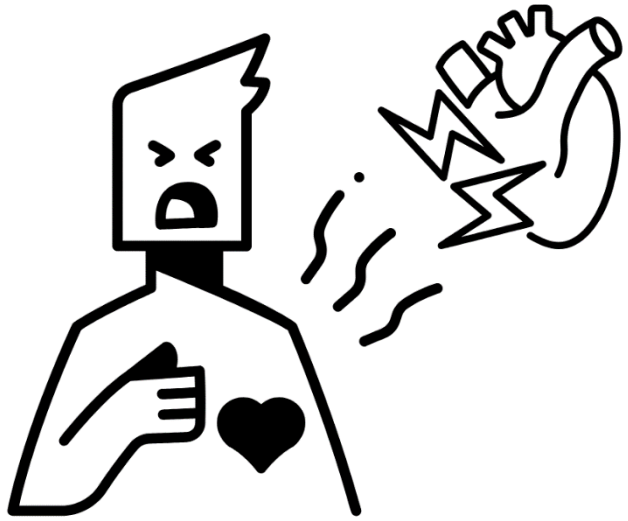
# STUDENT RESEARCH HUB UPB-BUCARAMANGA


Emmanuel Angarita
Brayan Arenas
Alejandra Muñoz
Santiago Pérez
Julian Zabaleta

# AUTOMATIC WEIGHT ESTIMATION USING KINEMATIC SIGNALS OF THE GAIT CYCLE THROUGH NEURAL NETWORKS FOR TELEMONITORING OF SUBJECTS WITH HEART FAILURE

**Heart failure** is a chronic condition where the heart muscle is unable to pump enough blood to meet the body's needs.

Weight gain of ~ 3 kg or more in 2 days is a WARNING SIGN that something may be wrong!!!



High probability to Re-hospitalization

Impact on patient outcomes and healthcare costs.

**ICare**

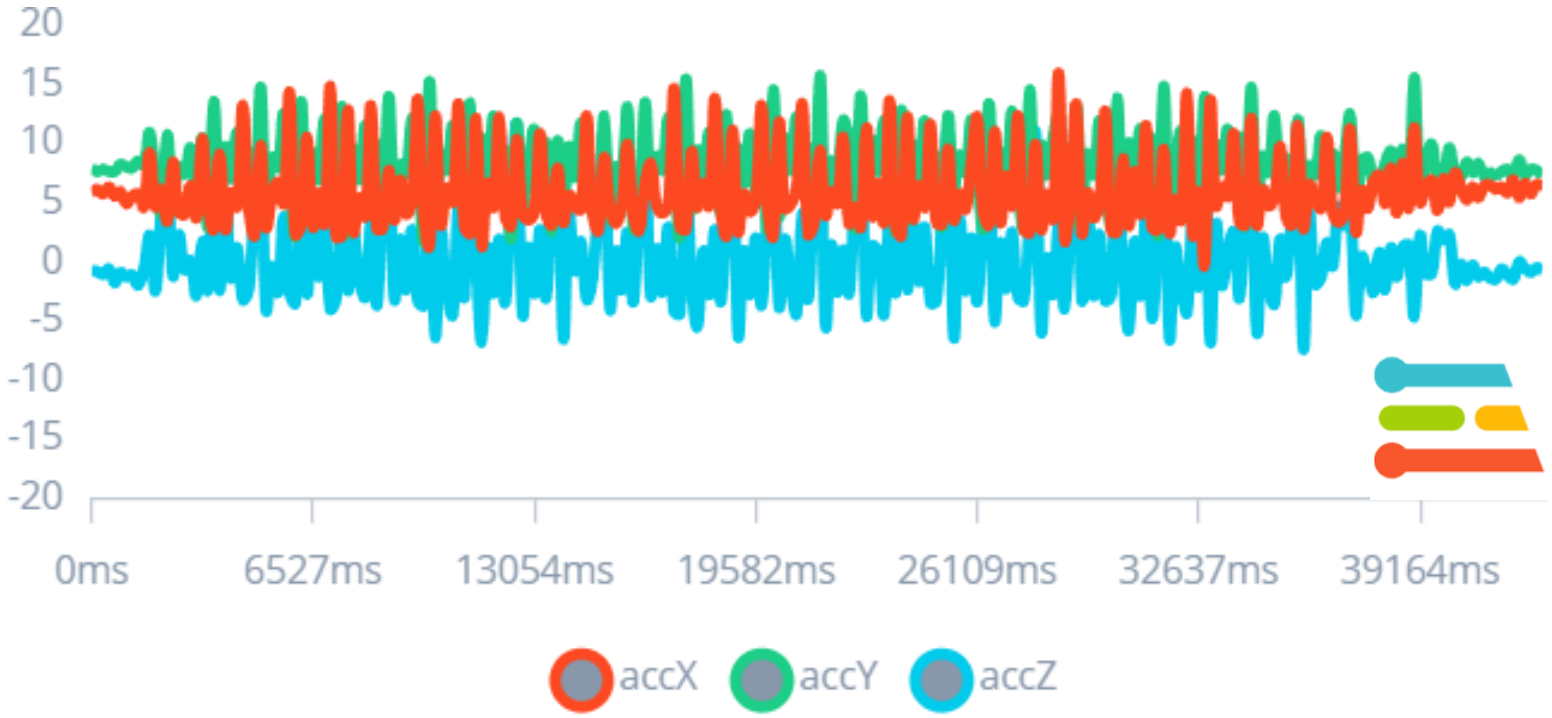


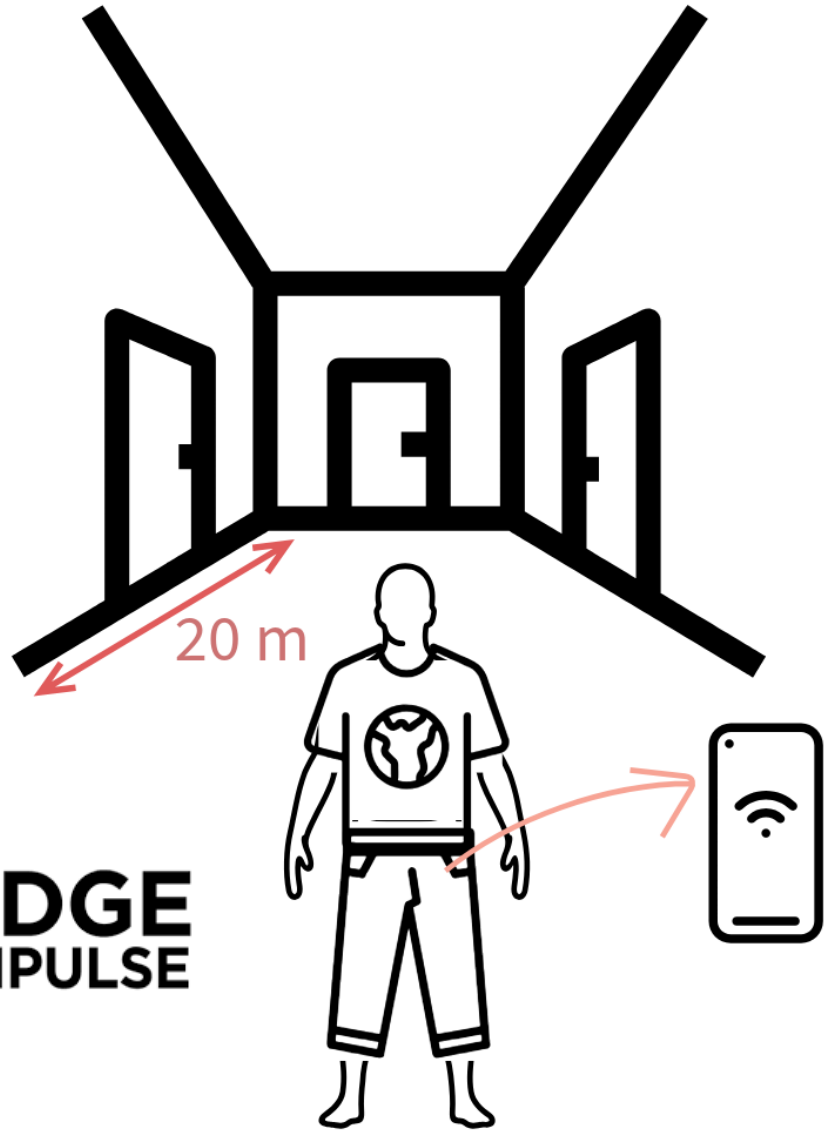
Students: David Martínez, Jesús Valero

## Experiment Overview

With the mobile device in the front pocket of pant, the subject walked in a straight line for 3 minutes along a 20 m hallway.

20 UPB Students
Mean: 68.5 kg
Standard Deviation: 19.6 kg
Minimum: 46.9 kg
Maximum: 130 kg
Sample frequency: 62.5 Hz



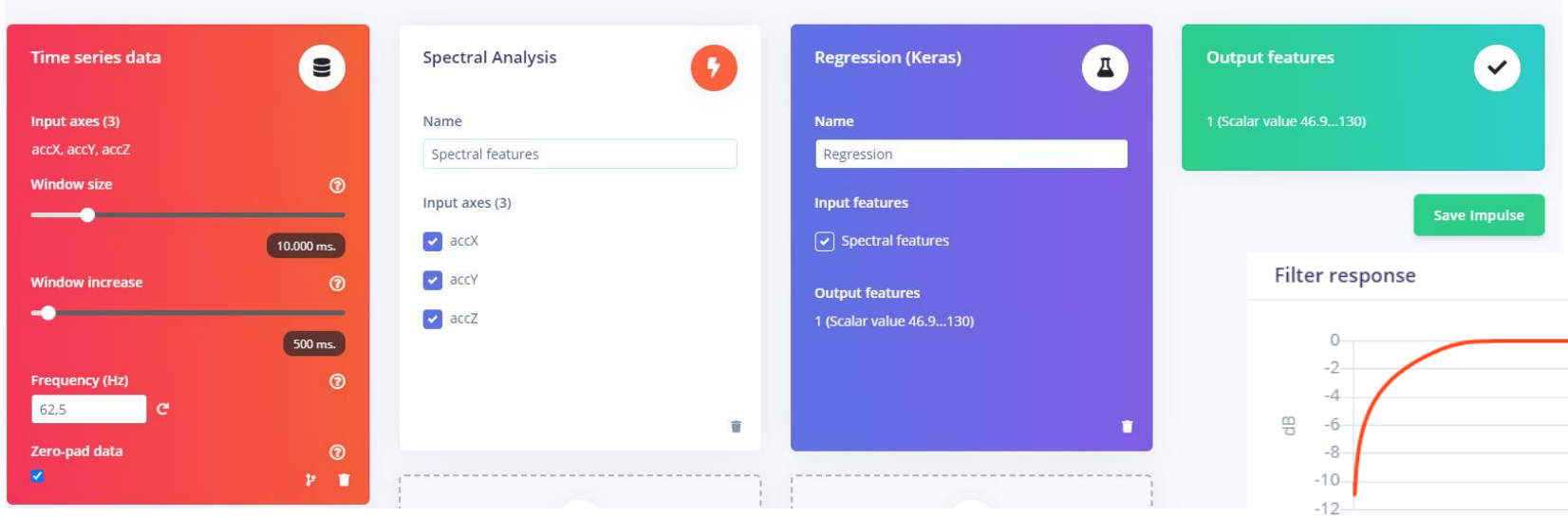




EDGE IMPULSE

Accelerometer: TDK-Invensense icm4x6xx
Moto G 30 y Moto G 22.

Sample frequency: 62.5 Hz

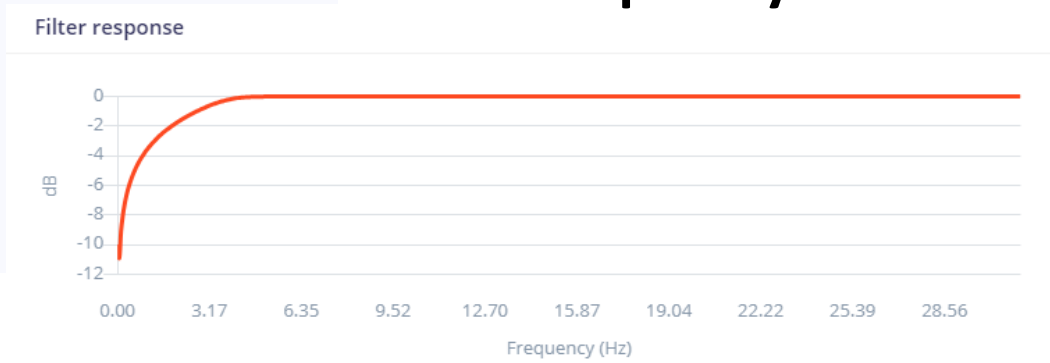
Students: Alejandra Muñoz, Daniel Russo, Santiago Pérez, Julián Zabaleta

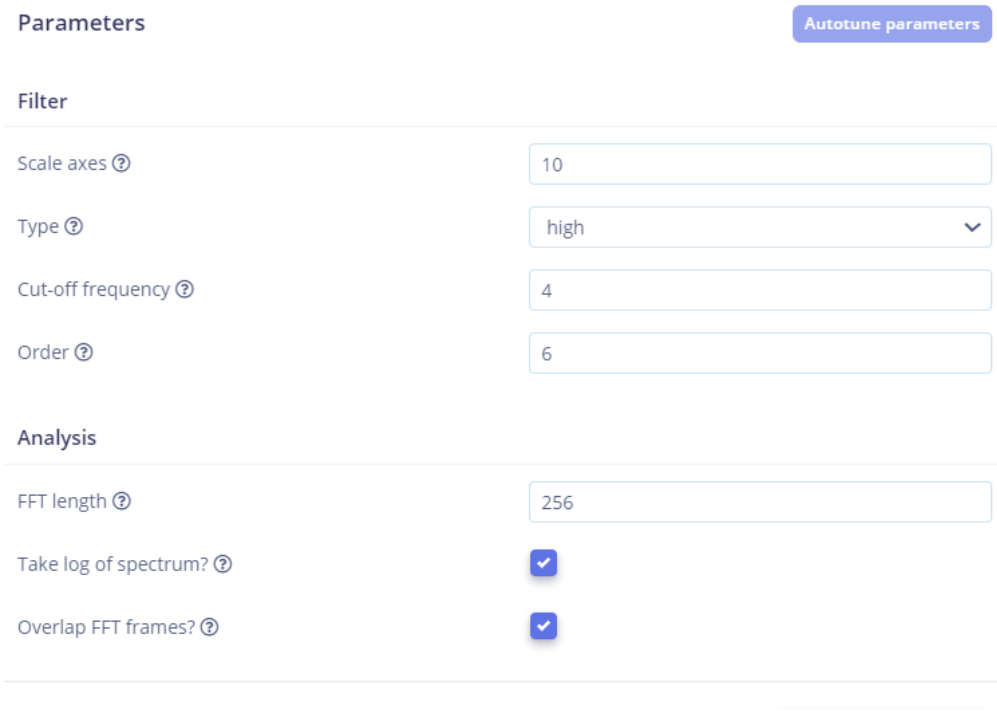


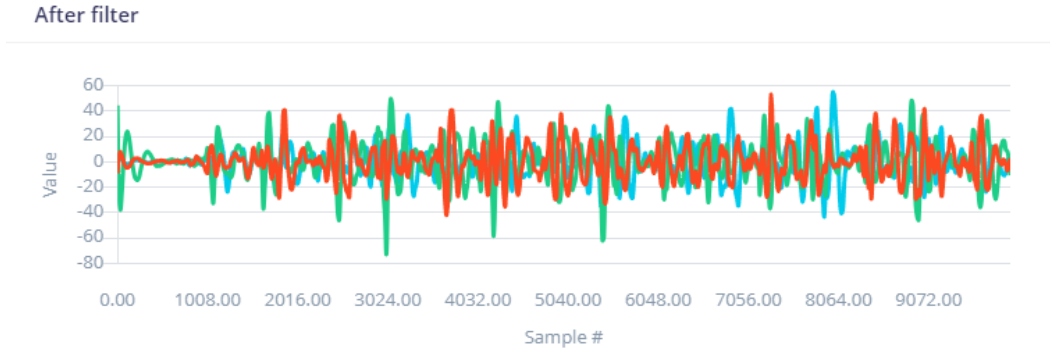

# FEATURES

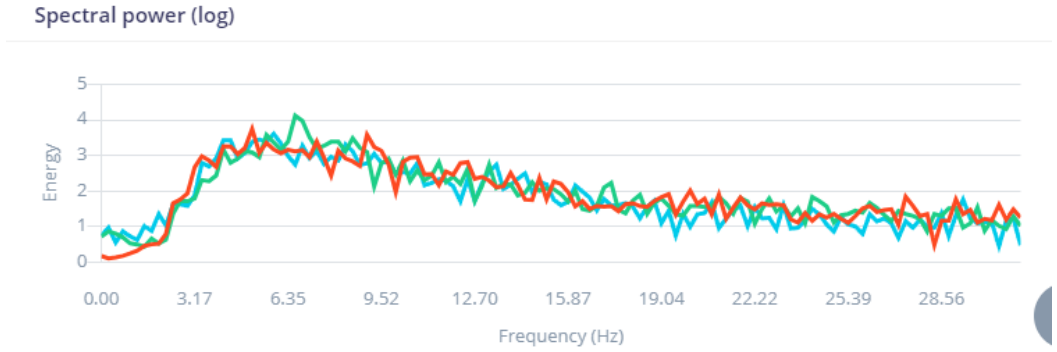
## Time domain

## Frequency domain



## Advanced training settings

Validation set size ⓘ 20 %

Split train/validation set on metadata key ⓘ

Profile int8 model ⓘ ☑

## Neural network architecture

Save

```python
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, InputLayer, Dropout, Conv1D, Conv2D, Flatten, Reshape,
    MaxPooling1D, MaxPooling2D, AveragePooling2D, BatchNormalization, TimeDistributed, Permute, ReLU,
    Softmax
from tensorflow.keras.optimizers import Adam
EPOCHS = args.epochs or 500
LEARNING_RATE = args.learning_rate or 0.001
# this controls the batch size, or you can manipulate the tf.data.Dataset objects yourself
BATCH_SIZE = 32
train_dataset = train_dataset.batch(BATCH_SIZE, drop_remainder=False)
validation_dataset = validation_dataset.batch(BATCH_SIZE, drop_remainder=False)

# model architecture
model = Sequential()
model.add(Dense(100, activation='relu'))
model.add(Dense(80, activation='relu'))
model.add(Dense(50, activation='relu'))
model.add(Dense(classes, name='y_pred'))

# this controls the learning rate
opt = Adam(learning_rate=LEARNING_RATE, beta_1=0.9, beta_2=0.999)
callbacks.append(BatchLoggerCallback(BATCH_SIZE, train_sample_count, epochs=EPOCHS))

# train the neural network
model.compile(loss='mean_squared_error', optimizer=opt, metrics=None)
model.fit(train_dataset, epochs=EPOCHS, validation_data=validation_dataset, verbose=2, callbacks
    =callbacks)

# Use this flag to disable per-channel quantization for a model.
# This can reduce RAM usage for convolutional models, but may have
# an impact on accuracy.
disable_per_channel_quantization = False
```

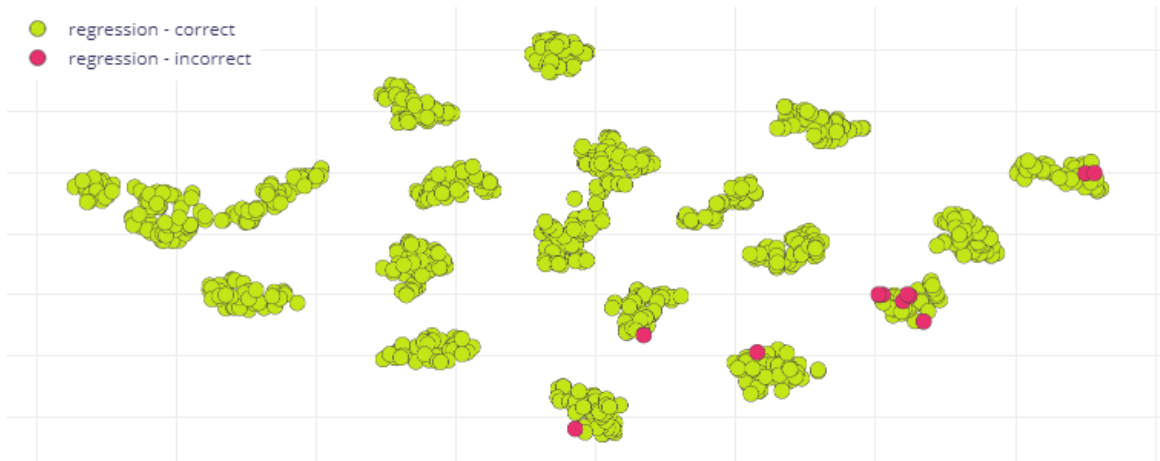
LOSS
1,27

### Metrics (validation set)

| METRIC | VALUE |
|---|---|
| Mean squared error ⓘ | 1.27 |
| Mean absolute error ⓘ | 0.85 |
| Explained variance score ⓘ | 1.00 |

### Data explorer (full training set) ⓘ

Maximum absolute regression error is 3, set thresholds.




### On-device performance ⓘ

Engine: ⓘ EON™ Compiler

INFERENCING TIME
16 ms.

PEAK RAM USAGE
1,8K

FLASH USAGE
57,3K

## Test data

Classify all

Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse. Maximum absolute regression error is 3, set thresholds.

| SAMPLE NAME | EXPECTED ... | LENGTH | ACCURACY | RESULT | ERROR |
|---|---|---|---|---|---|
| caminata_g22_21.3g... | 47.8 | 43s | 30% | 55.05 max, 51.28 ... | |
| caminata_g30_20.3g... | 60 | 45s | 68% | 66.49 max, 61.87 ... | |
| 80.caminata_g22_4.... | 80 | 45s | 64% | 83.13 max, 77.86 ... | |
| 78.caminata_g30_7.... | 78 | 53s | 98% | 80.89 max, 78.18 ... | |
| 63.caminata_g30_3.... | 63 | 55s | 100% | 64.96 max, 62.87 ... | |
| 79.5.caminata_g30_... | 79.5 | 43s | 97% | 82.33 max, 80.24 ... | |
| 91.4.caminata_g22_... | 91.4 | 46s | 97% | 94.04 max, 91.29 ... | |
| 130.caminata_g22_2... | 130 | 46s | 53% | 137.8 max, 125.7... | |
| 63.4.caminata_g30_... | 63.4 | 47s | 89% | 68.93 max, 64.86 ... | |

## Model testing output

(0)

### Results

Model version: Unoptimized (float32)

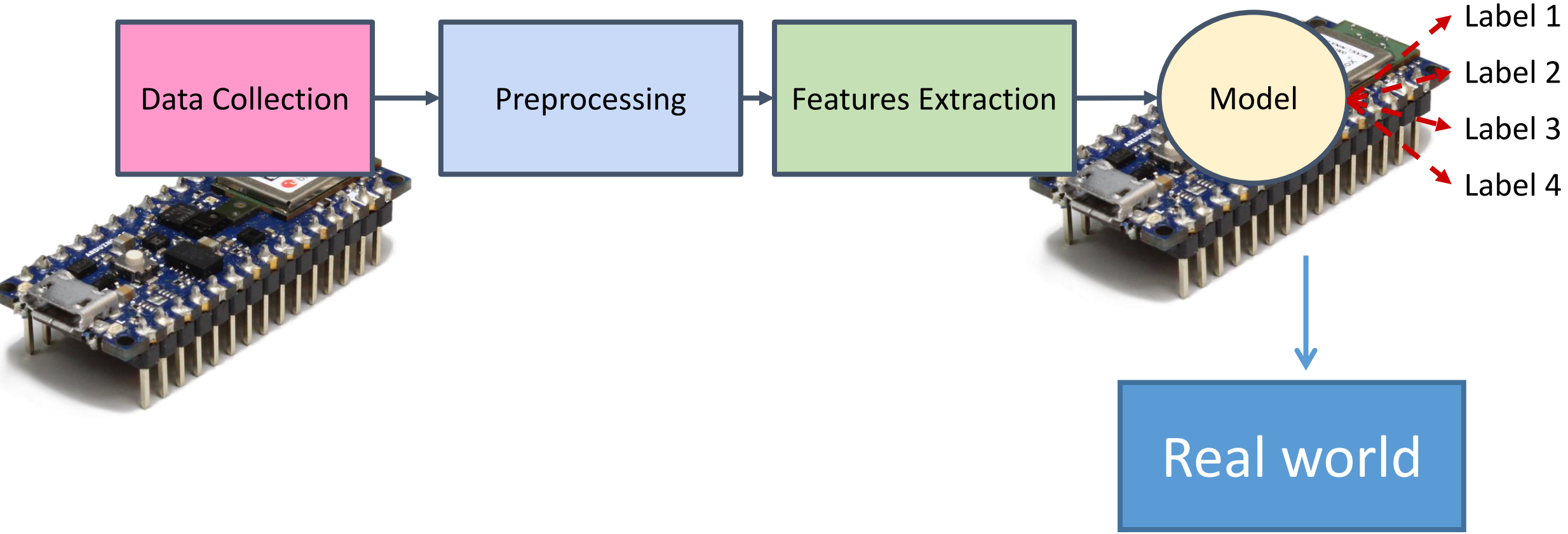
ACCURACY
73.63%

MEAN SQUARED ERROR
14.03

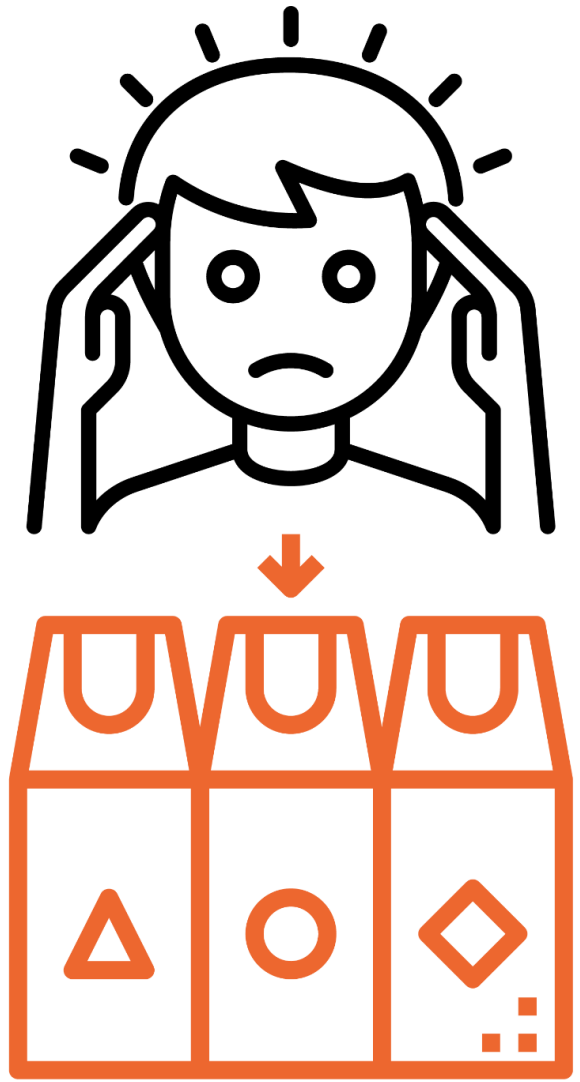
### Metrics for Regression

| METRIC | VALUE |
|---|---|
| Mean squared error | 14.03 |
| Mean absolute error | 2.37 |
| Explained variance score | 0.96 |

### Feature explorer


Data Collection
Preprocessing
Features Extraction
Model
Label 1
Label 2
Label 3
Label 4
Real world

# SOLID WASTE CLASSIFIER IN THE ECOCAMPUS UPB-BUCARAMANGA USING TINYML


# Muito Obrigada to the TinyML Community

For further information or collaboration opportunities,
please contact me at silvia.sotelo@upb.edu.co