# Developing a "personal trainer" through TinyML

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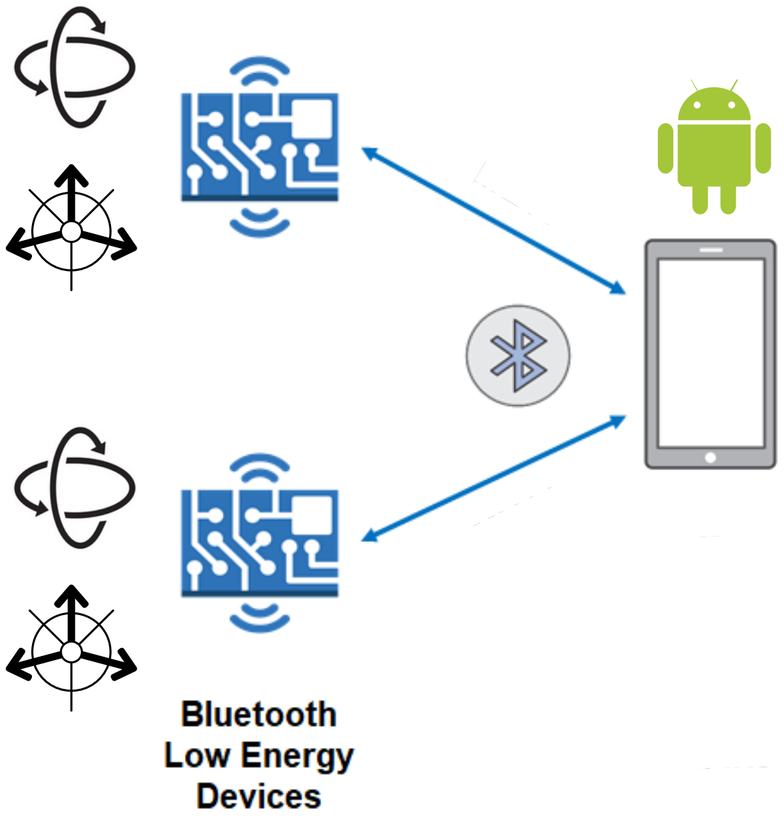



CNPq

TinyML4D

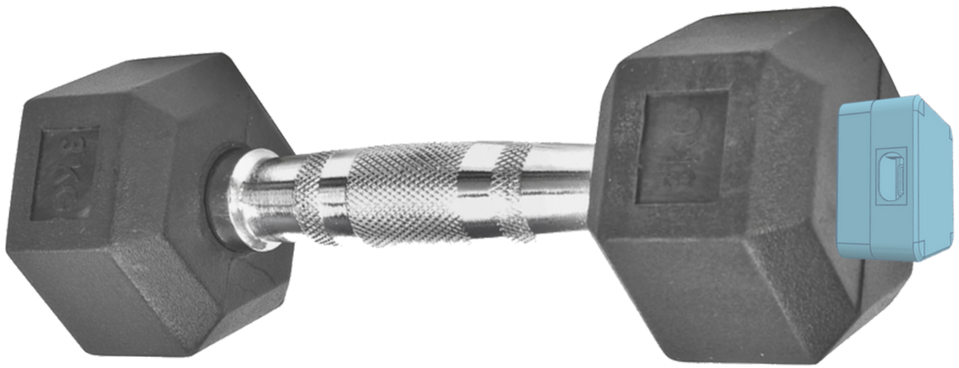
ICTP

seeed

# Our objective is to find a way to bring TinyML to a gym

Small in size and non-invasive

Communicates through bluetooth low energy



Source: Sports Distributors

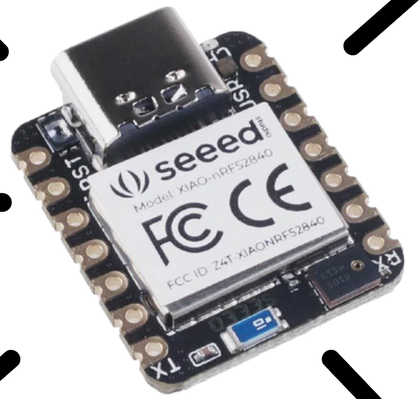
Battery-powered

# The Seeed XIAO nRF52840 Sense fits our needs, it has:

Ultra low power

Small in size, only 21 x 17.5mm

Built-in battery charge module



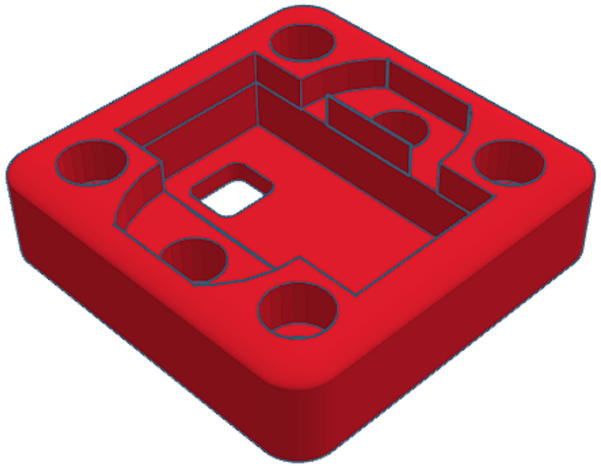

Source: Seeed Studio

Built-in accelerometer and gyroscope

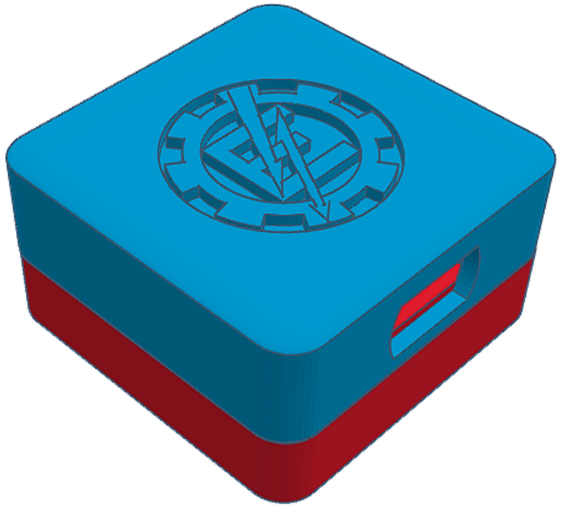
Built-in Bluetooth 5.0

Suitable for TinyML AI+IOT project.

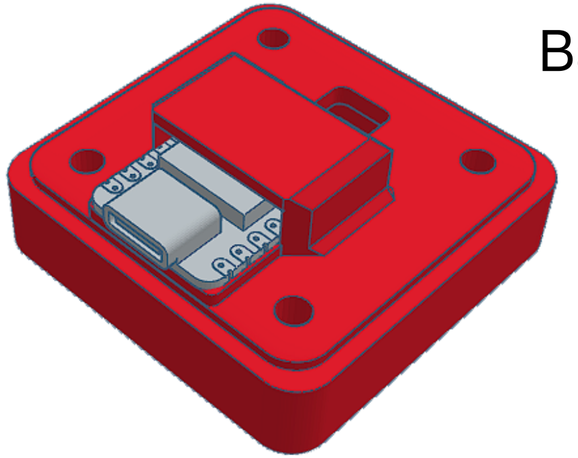
# A 3D printed casing allows protection and placing of the µC in a correct position



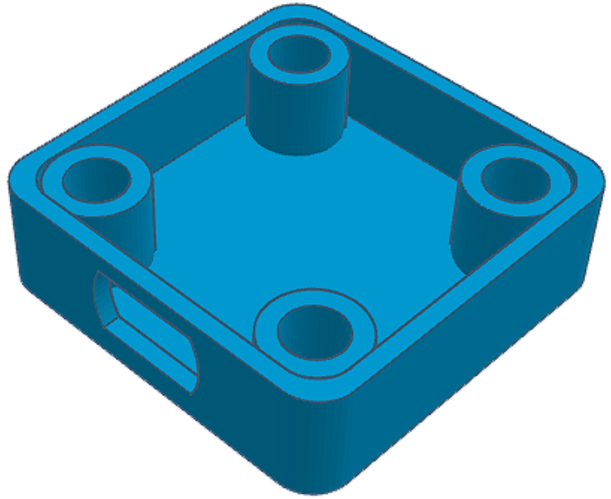
Battery compartment



Free of cables

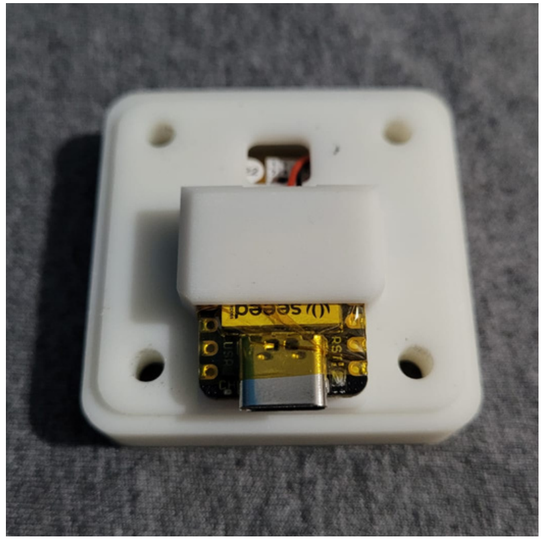


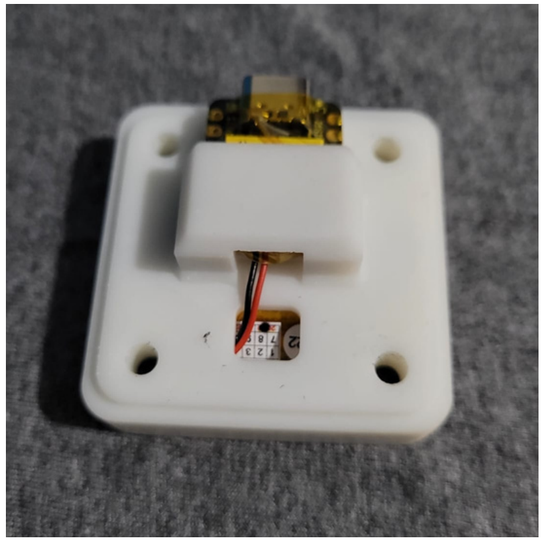
Keeps the µC from shaking



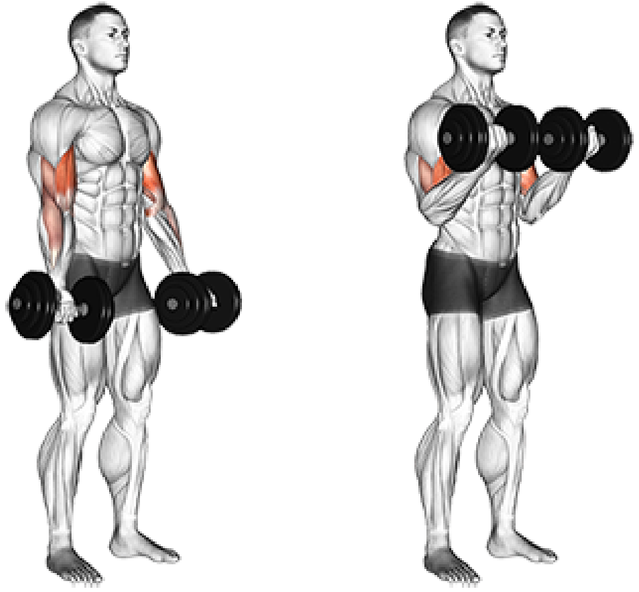
Held in place by screws

# Made to be easy to assemble and place on a dumbell

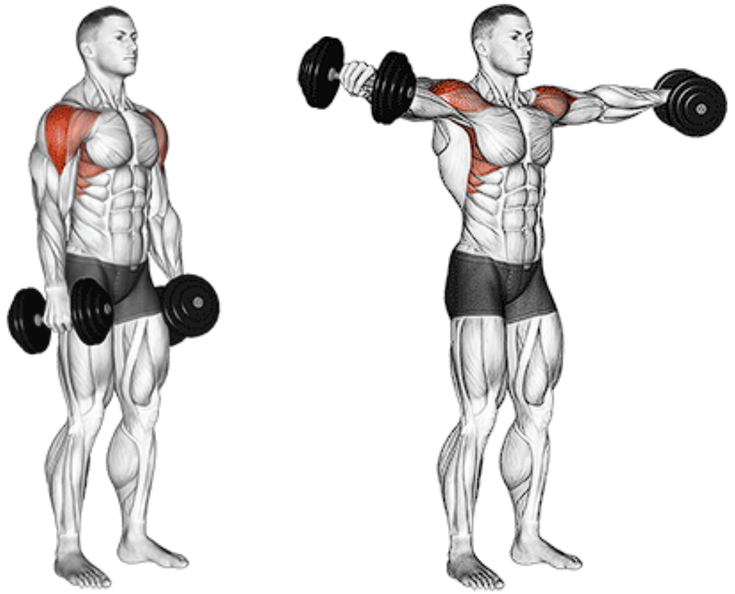




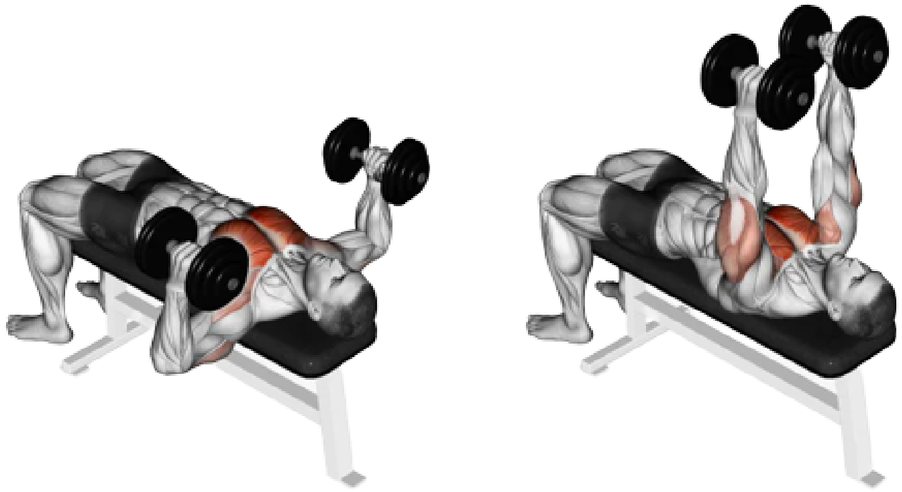

# For starters, we are classifying three different exercises



Biceps Curl

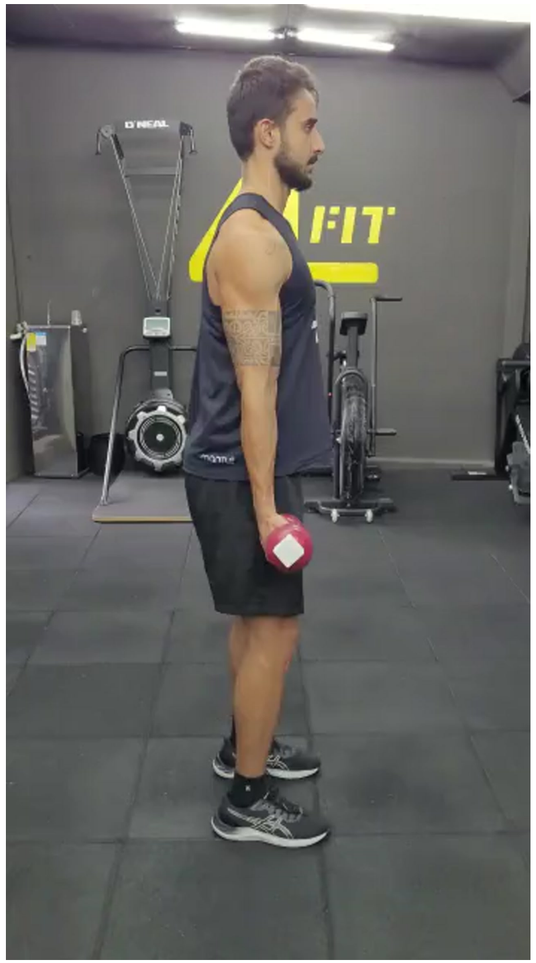


Lateral Raise



Bench Press

# These are examples of how to correctly execute these exercises

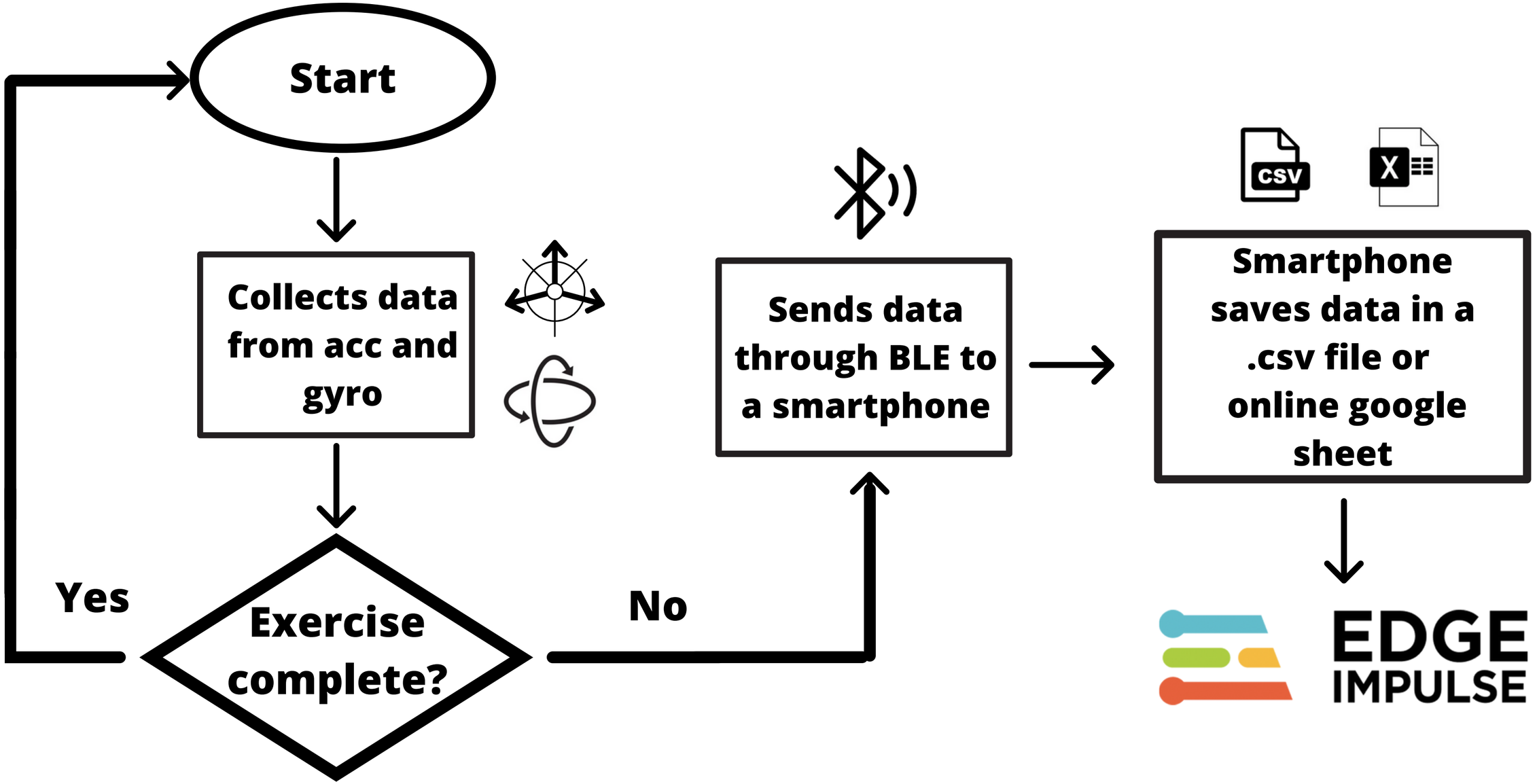



Biceps Curl

Bench Press


Lateral Raise

# With this setup, we can collect data in a real enviroment to form a dataset

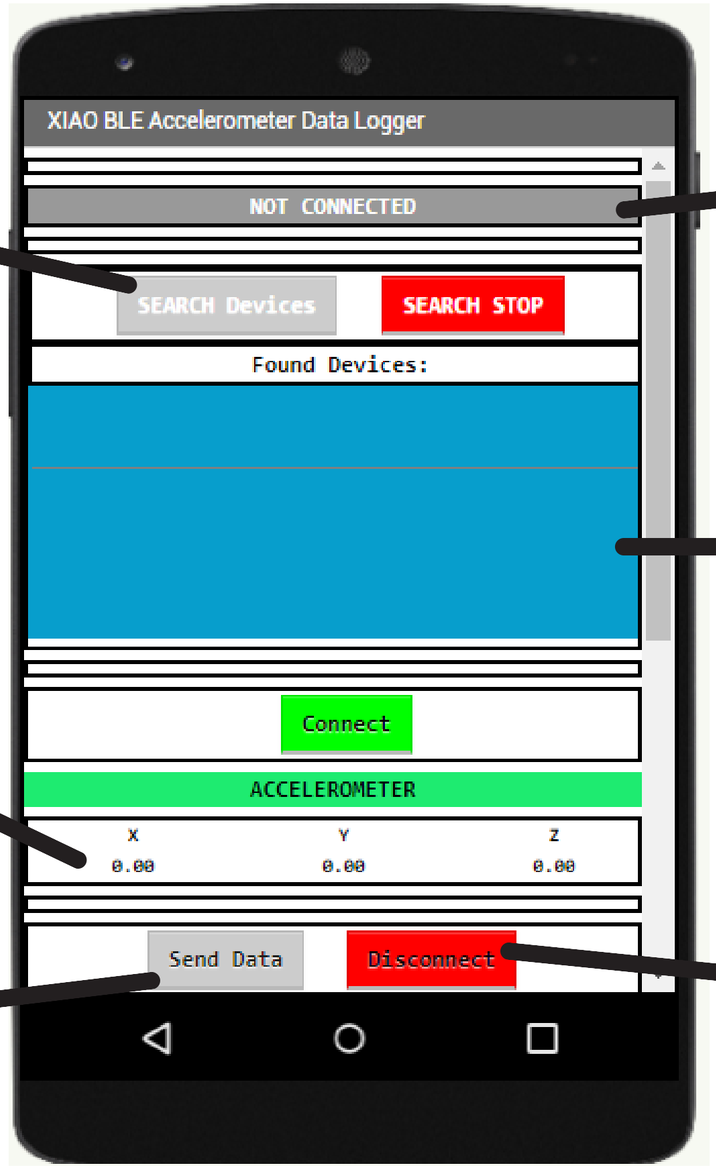


# An android app can be used as a data logger when collecting data and can be used to display inference results

Searches for any visible bluetooth connection

Displays current values being received

Sends data to an online google sheet



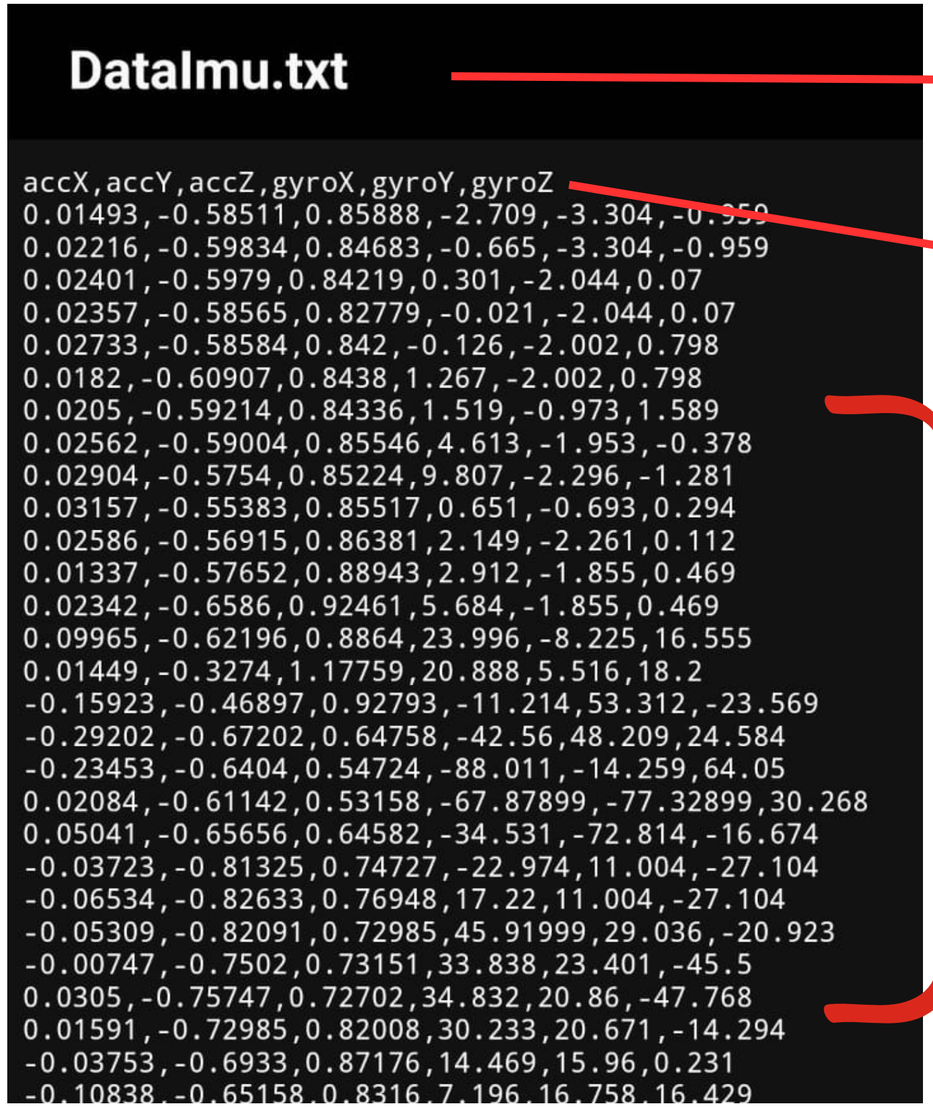

Bluetooth status

Shows all available connections

Finish current connection

# This is an example of the app collecting data through bluetooth

# The .csv file can be later uploaded into Edge Impulse

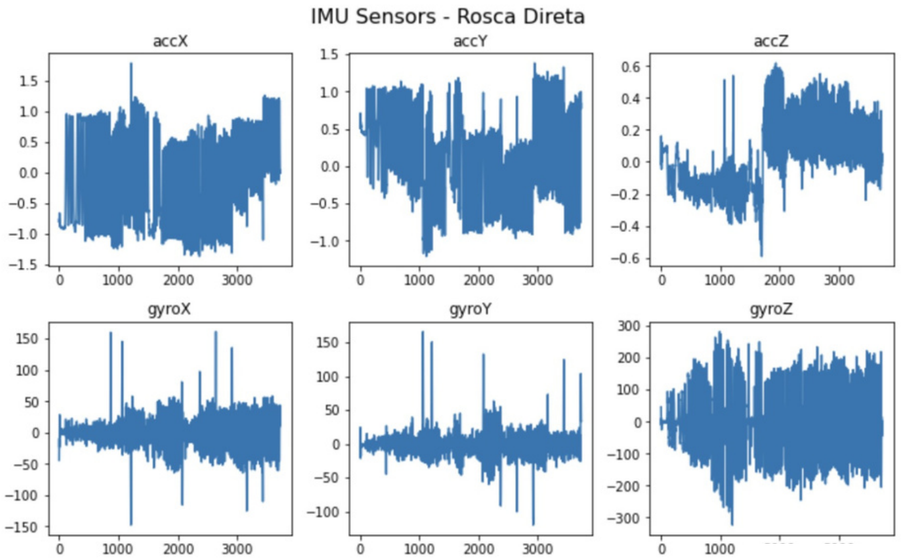



File name chosen to identify the data

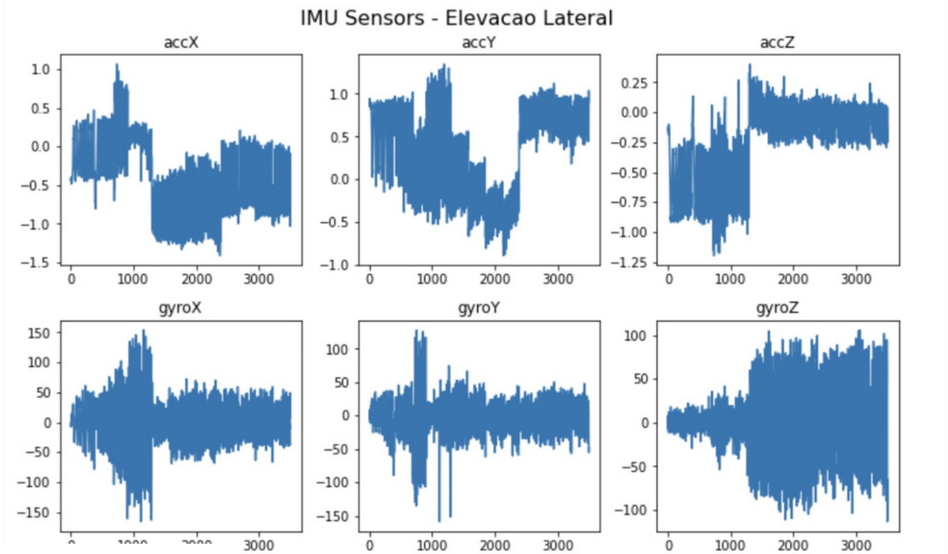
Header with the name of each sensor axis

Sensor data collected through bluetooth

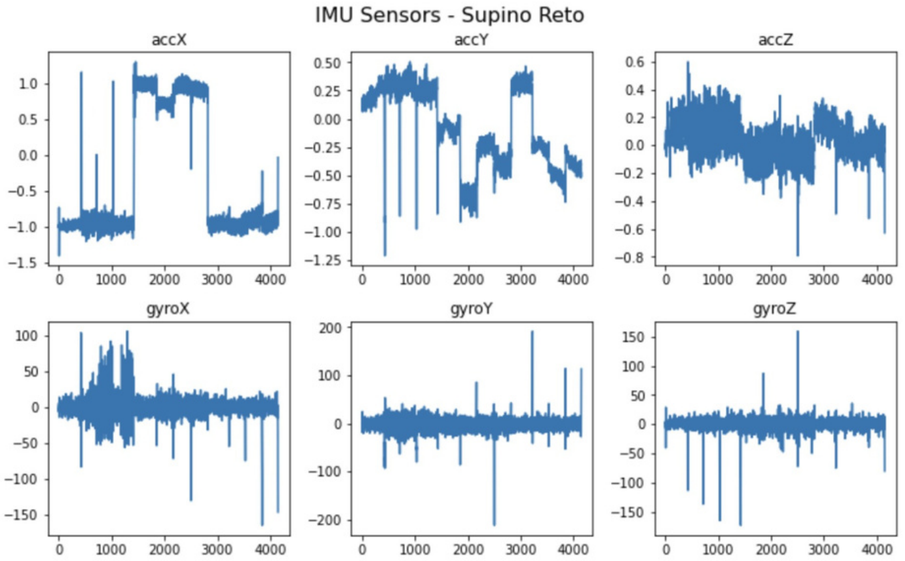
# The data variation in each axis can be visualized using graphs




Biceps Curl

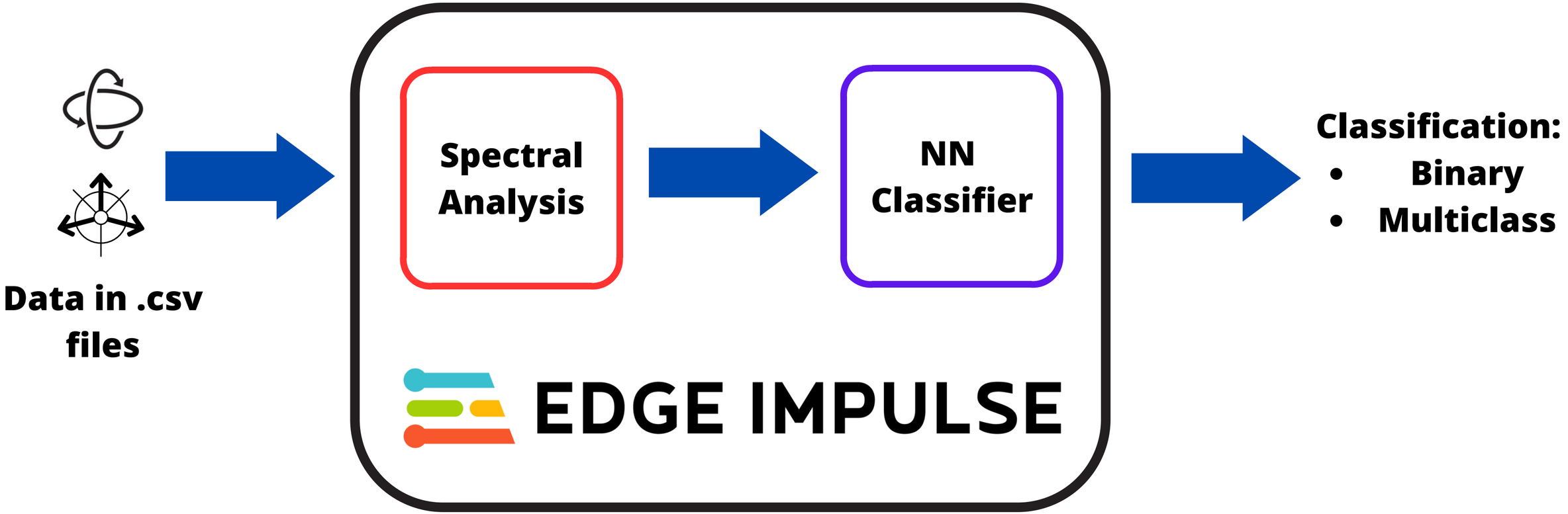



Lateral Raise

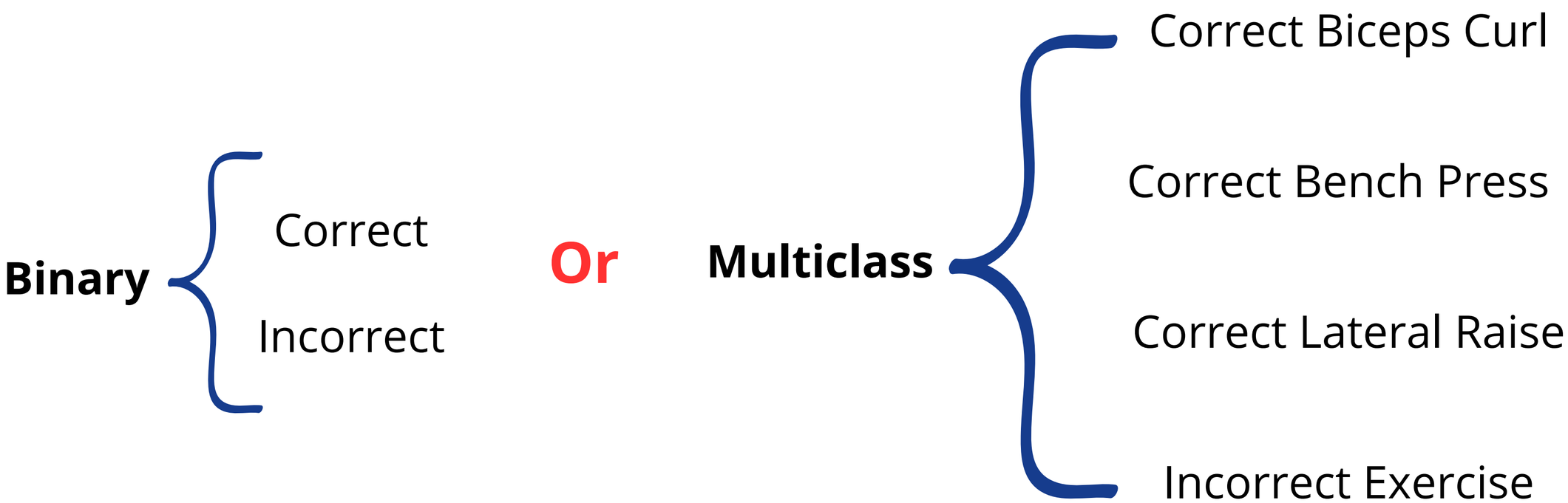



Bench Press

# With enough data collected, a model can be developed using Edge Impulse

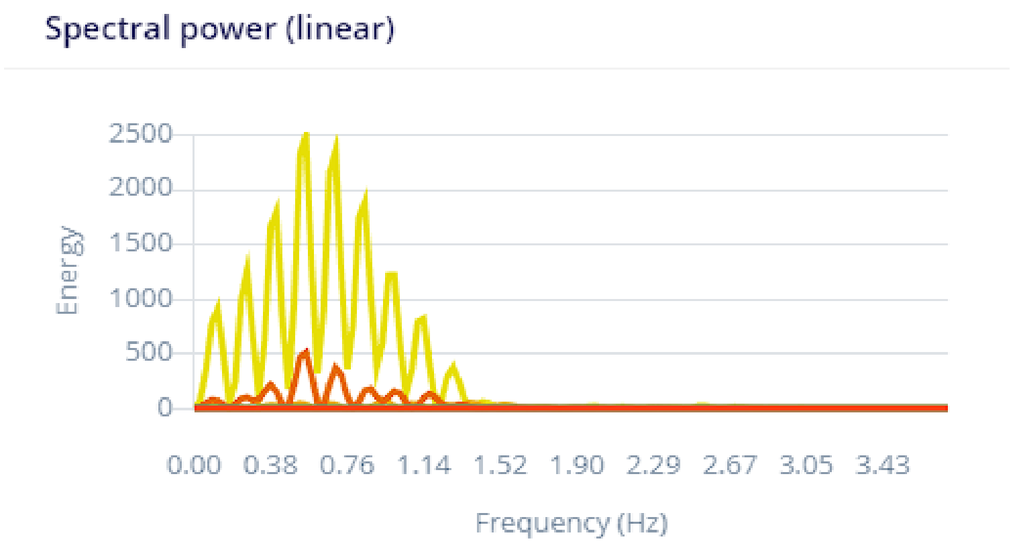


# The classification can be made in two ways



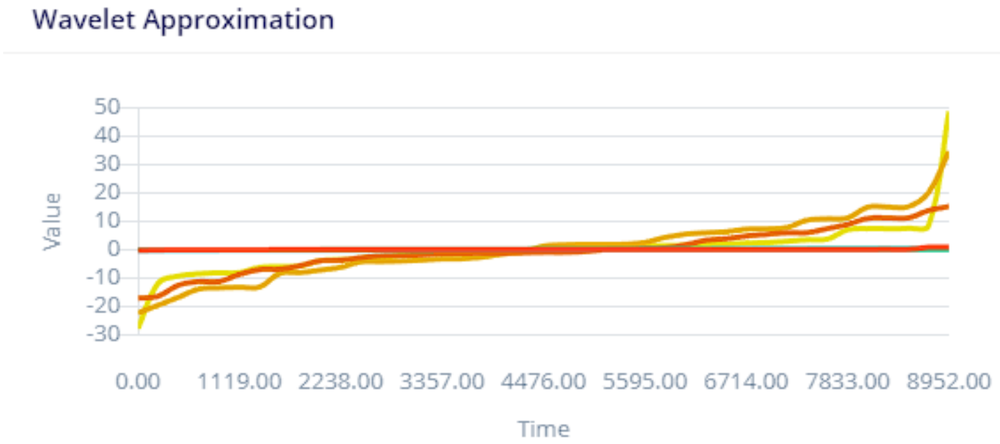
# The spectral analysis can be made using FFT or Wavelets

**FFT**




Great for breaking the signal power into frames

**Wavelet**




Great for signals with transient features or abrupt changes

# For standardized data, in our case, it does not matter which one is used

**Model** — Model version: Quantized (int8)

**Last training performance** (validation set)

| ACCURACY | LOSS |
|---|---|
| 99.9% | 0,00 |

**Confusion matrix** (validation set)

| | ELEVACAO_LATERAL | EXERCICIOS_ERRADOS | ROSCA_DIRETA | SUPINO_RETO |
|---|---|---|---|---|
| ELEVACAO_LATERAL | 100% | 0% | 0% | 0% |
| EXERCICIOS_ERRADOS | 0% | 100% | 0% | 0% |
| ROSCA_DIRETA | 0% | 0.6% | 99.4% | 0% |
| SUPINO_RETO | 0% | 0% | 0% | 100% |
| F1 SCORE | 1.00 | 1.00 | 1.00 | 1.00 |

Using FFT for spectral analysis

Using Wavelets for spectral analysis

**Model** — Model version: Quantized (int8)

**Last training performance** (validation set)

| ACCURACY | LOSS |
|---|---|
| 99.8% | 0,04 |

**Confusion matrix** (validation set)

| | ELEVACAO_LATERAL | EXERCICIOS_ERRADOS | ROSCA_DIRETA | SUPINO_RETO |
|---|---|---|---|---|
| ELEVACAO_LATERAL | 100% | 0% | 0% | 0% |
| EXERCICIOS_ERRADOS | 0% | 100% | 0% | 0% |
| ROSCA_DIRETA | 0% | 1.3% | 98.7% | 0% |
| SUPINO_RETO | 0% | 0% | 0% | 100% |
| F1 SCORE | 1.00 | 1.00 | 0.99 | 1.00 |

# Although 80% accuracy is not ideal, it is good enough for now

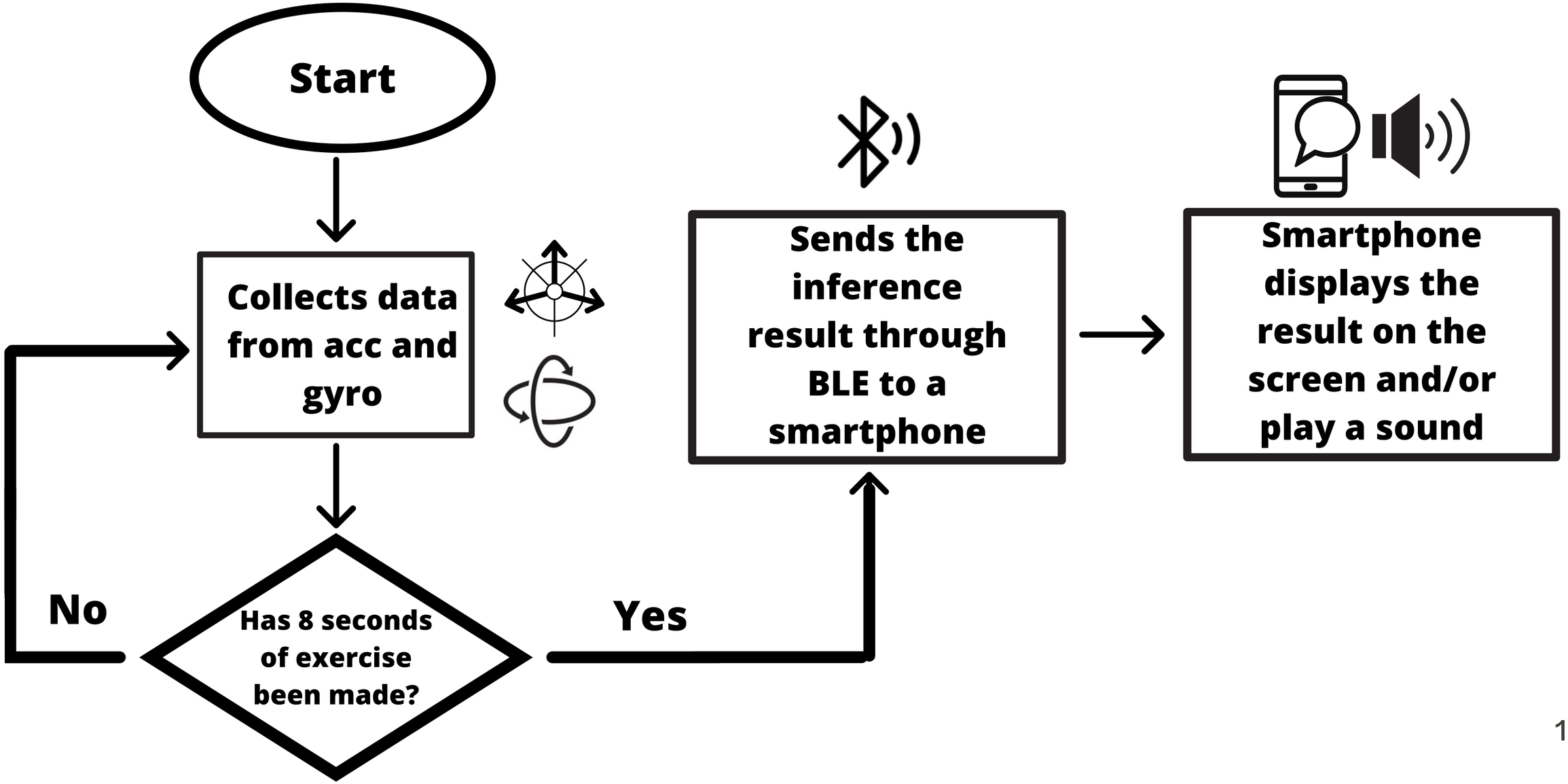
Model testing results

ACCURACY
80.40%

| | ELEVACAO_LATERA | EXERCICIOS_ERRAD | ROSCA_DIRETA | SUPINO_RETO | UNCERTAIN |
|---|---|---|---|---|---|
| ELEVACAO_LATERAL | **90.8%** | 8.6% | 0% | 0% | 0.6% |
| EXERCICIOS_ERRADOS | 1.2% | **74.9%** | 21.9% | 0.3% | 1.6% |
| ROSCA_DIRETA | 0.4% | 9.2% | **86.5%** | 0% | 3.8% |
| SUPINO_RETO | 0% | 10.4% | 0% | **89.0%** | 0.6% |
| F1 SCORE | 0.92 | 0.83 | 0.67 | 0.93 | |

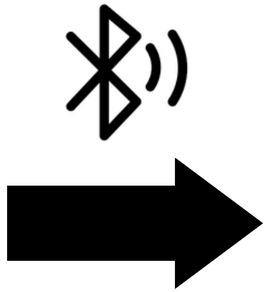
Testing of an FFT based model.

# Sending the inference results can be done using Bluetooth

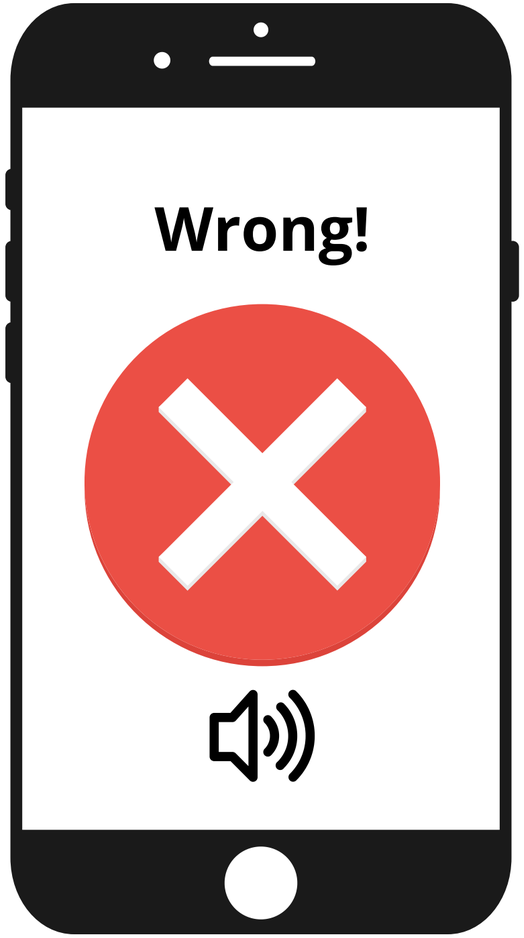


# A simple android app can be developed to display the inference result

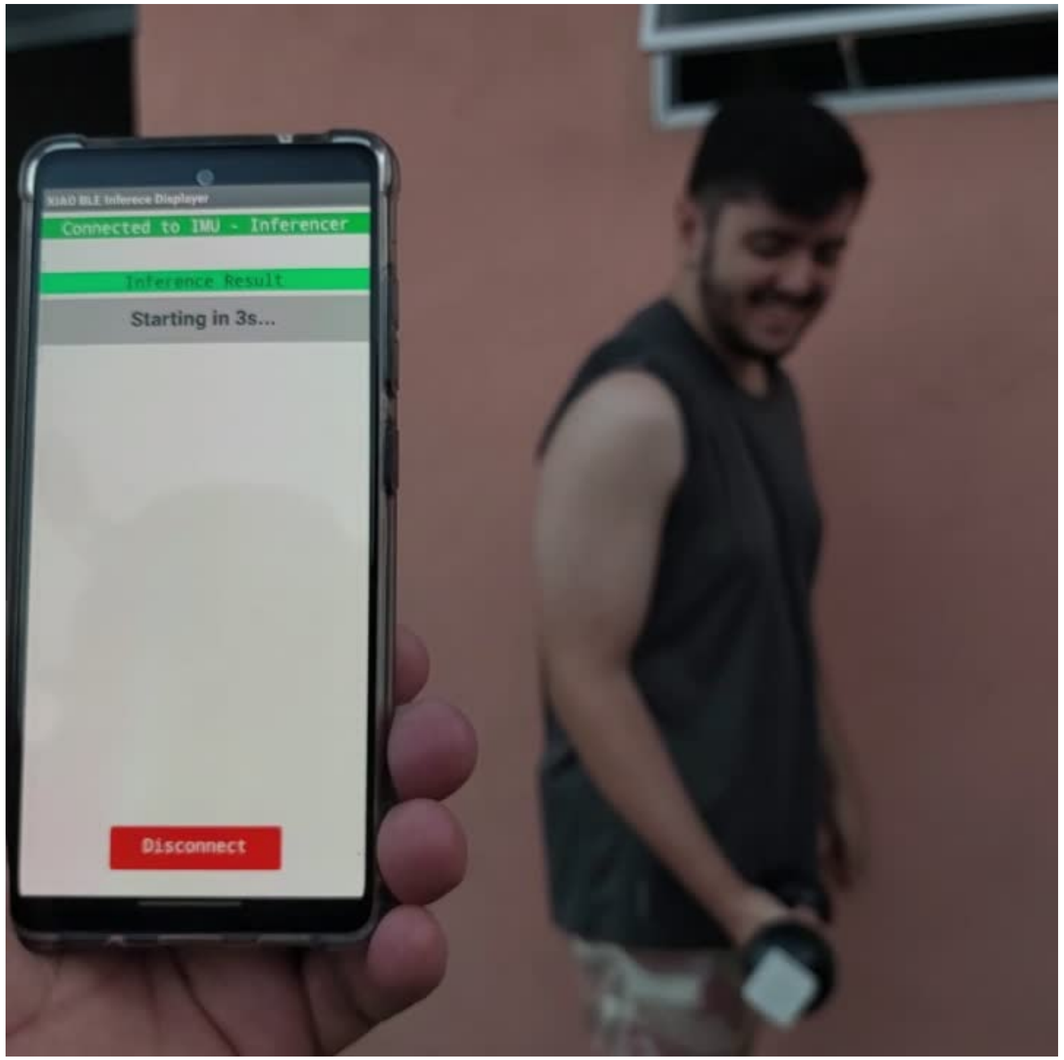

Source: Seeed Studio



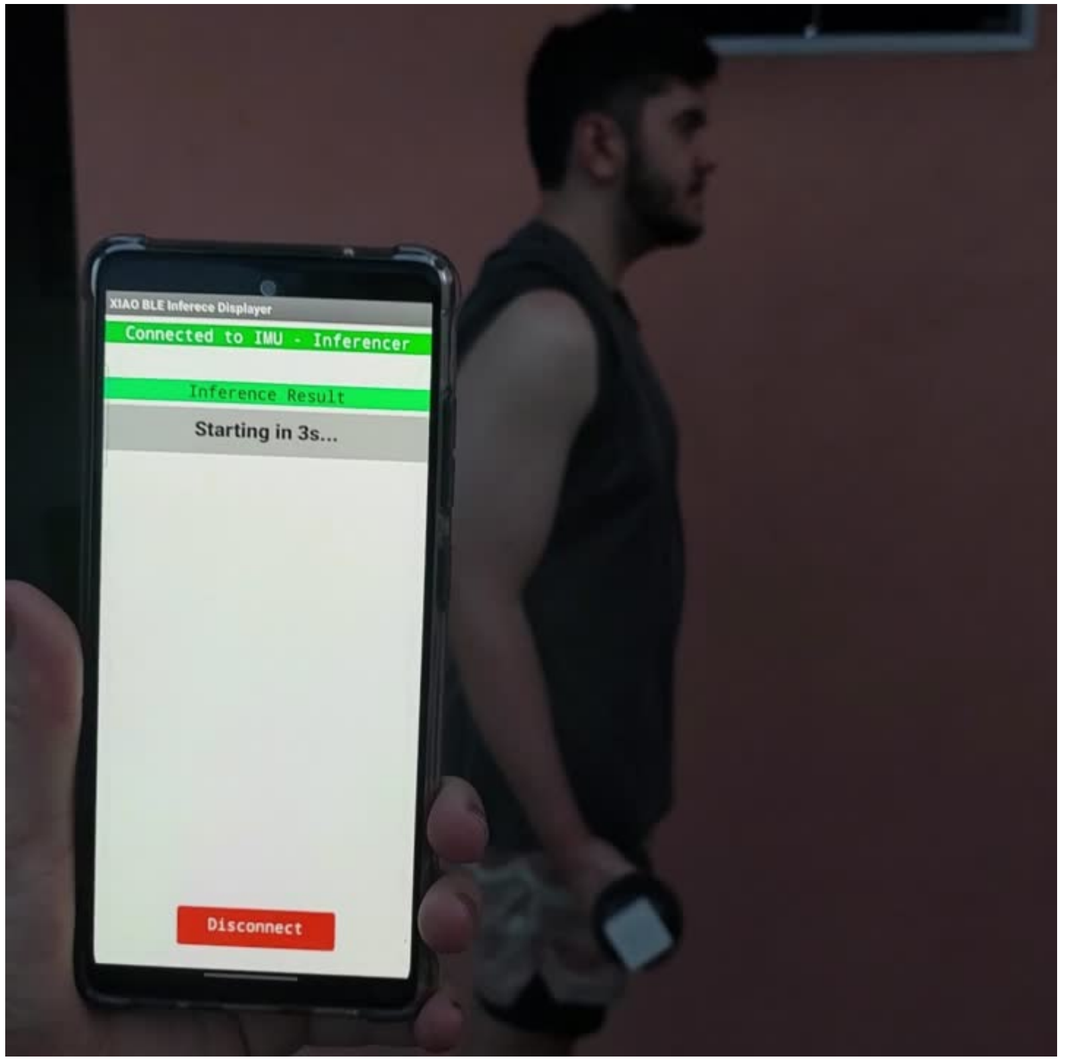

Or



# These examples show the app working as the inference displayer of a biceps curl




Correct Execution




Wrong Execution

# Any questions?

This project wouldn't be possible without the help and ideas from: *Supervisor* Marcelo Rovai, *Supervisor* José Alberto, João Vitor, Gabriel Vargas, Pedro Linhares, Rodrigo Pereira and Cleiton Nogueira.
Thank you!