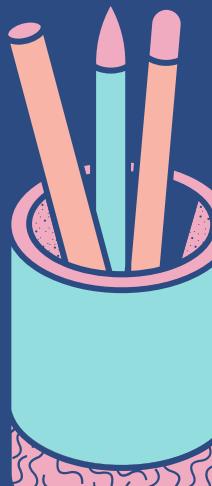


NHẬP MÔN LẬP TRÌNH ĐIỀU KHIỂN THIẾT BỊ THÔNG MINH

3D Unity Game using MPU6050 & TinyML

Họ tên sinh viên: Lê Mai Nguyên Thảo
MSSV: 19120661

TP. HCM, 15 THÁNG 1 NĂM 2023



Các nguồn tham khảo

1

Ý tưởng

3D Unity game using MPU6050 and TinyML Tutorial - Hackster.io

2

Xây dựng game Unity

Tanks - Unity Learn

3

Thu thập data và train model

Gesture Classification with Esp32 and TinyML - Hackster.io

4

Cài đặt, kết nối ESP32-CAM với Arduino IDE

(90) Cài Đặt Package ESP32 Trên Arduino IDE || How To Install ESP32 Package in Arduino IDE - YouTube

5

Kết nối Unity với Arduino

(90) How to Connect Arduino to Unity? #1 Serial Communication between Arduino and Unity. - YouTube

(90) Ardity - free plugin for connecting Arduino & Unity - YouTube

Chuẩn bị phần cứng

ESP32-CAM AI-Thinker



Cảm biến GY-521
6DOF IMU MPU6050



Điện trở 1/4W 1% 200R



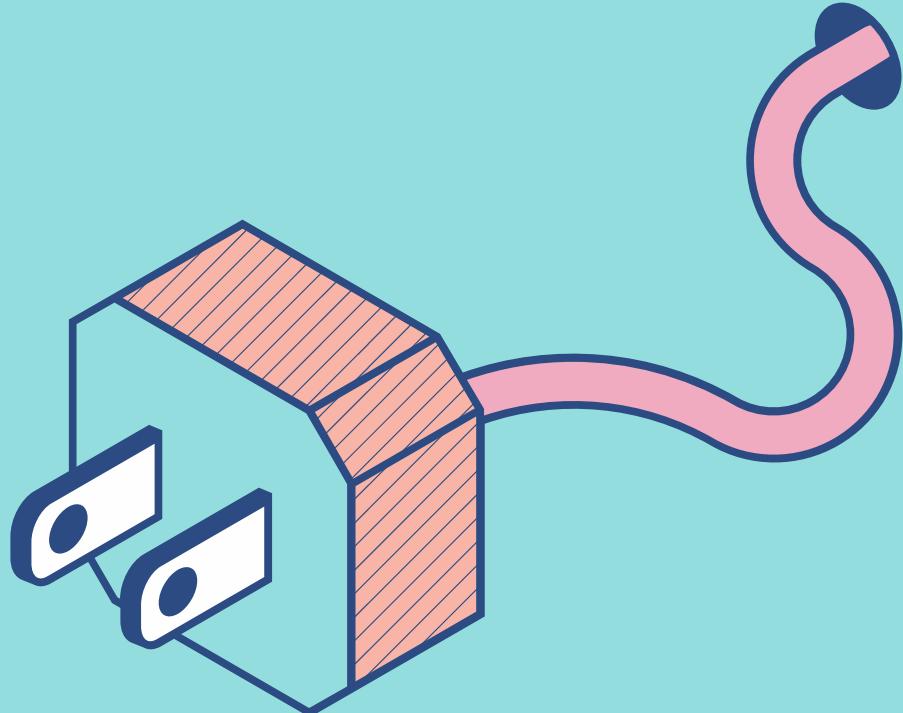
Solderless Breadboard



Jumper Wires



USB UART CH340G

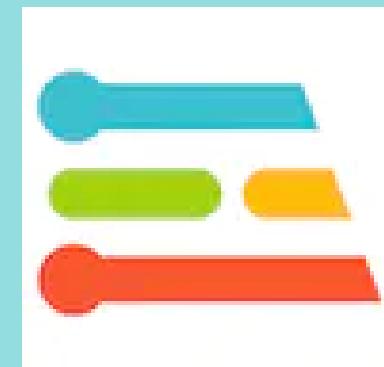


Chuẩn bị phần mềm và web

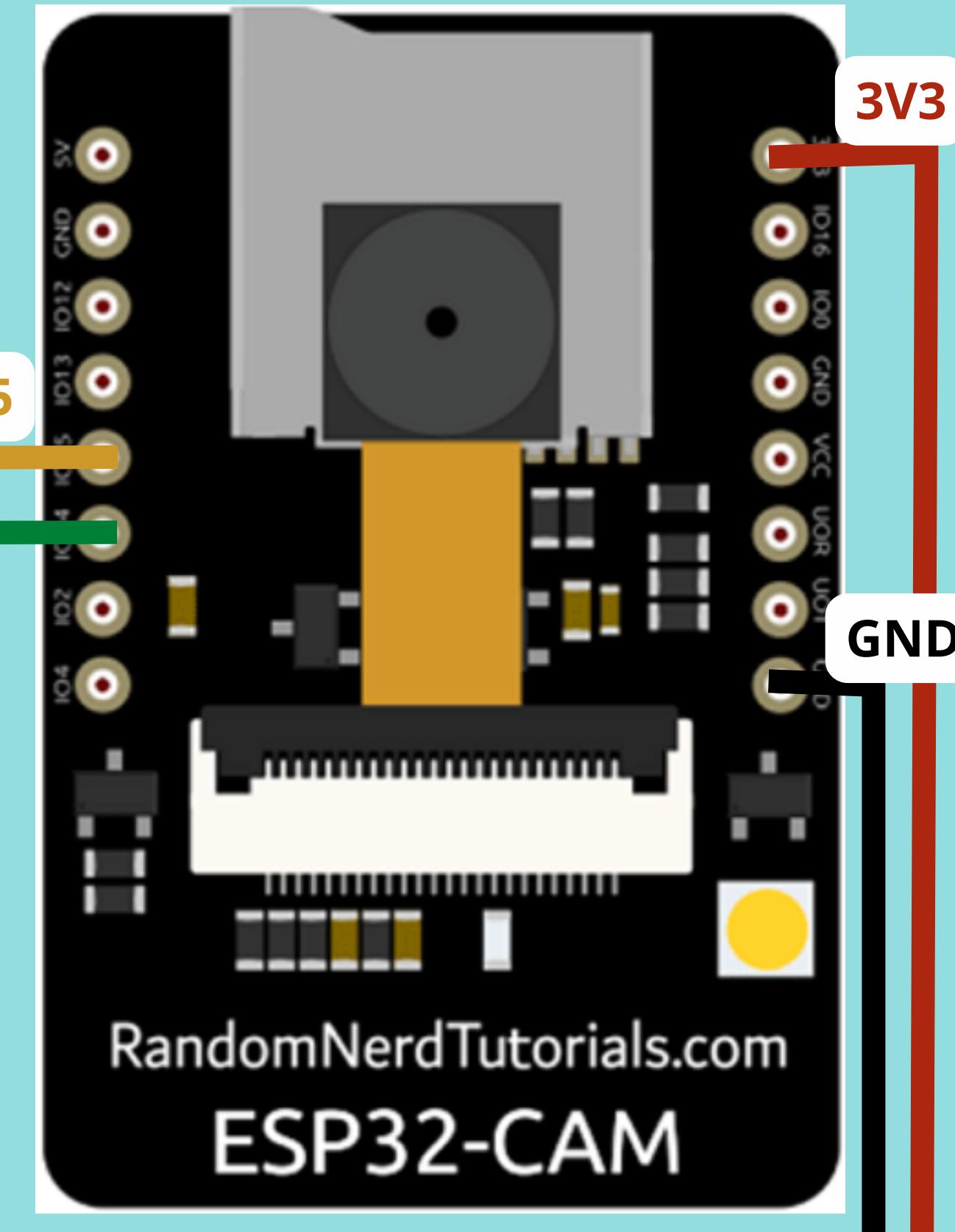
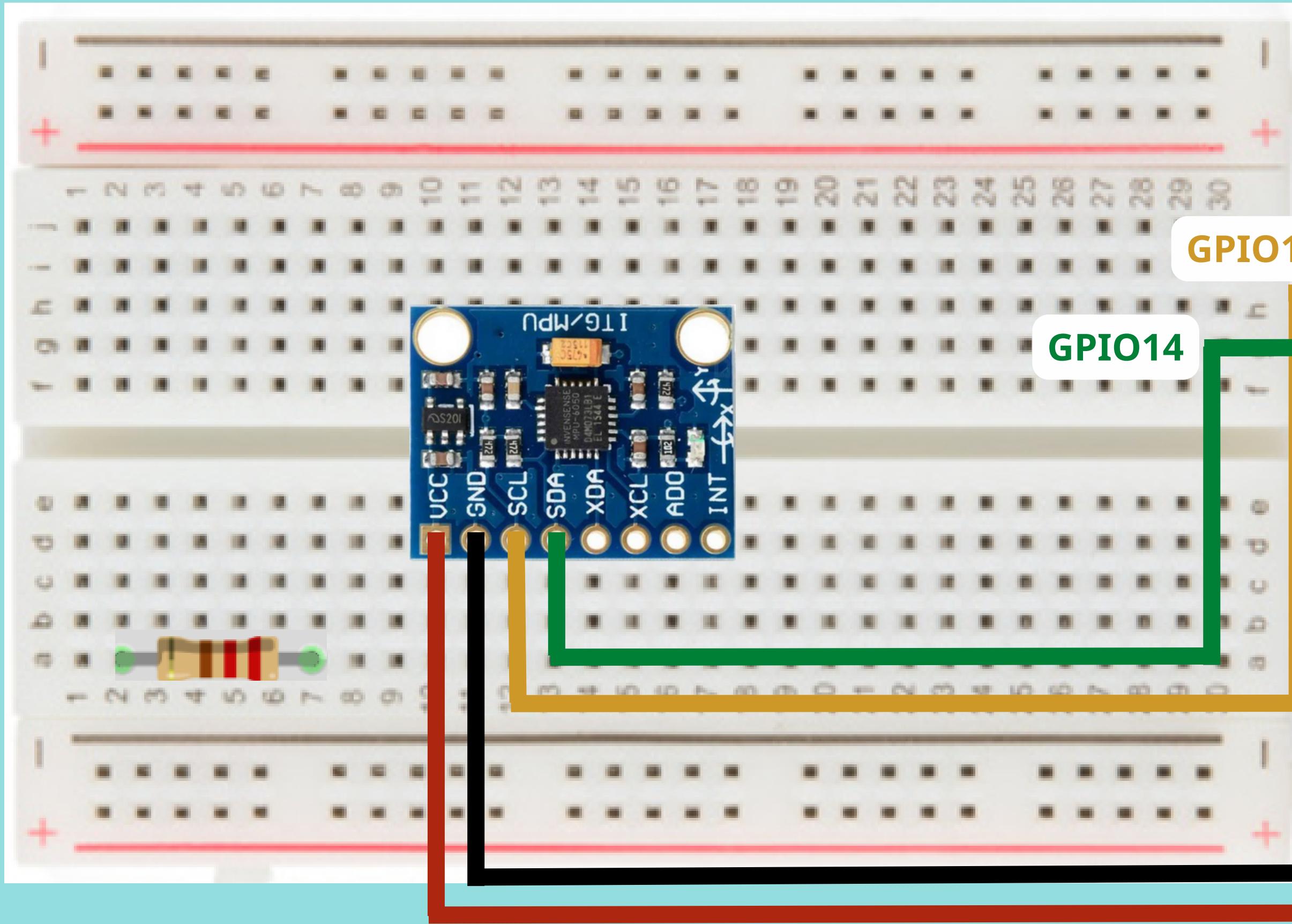
Arduino IDE

Edge Impulse

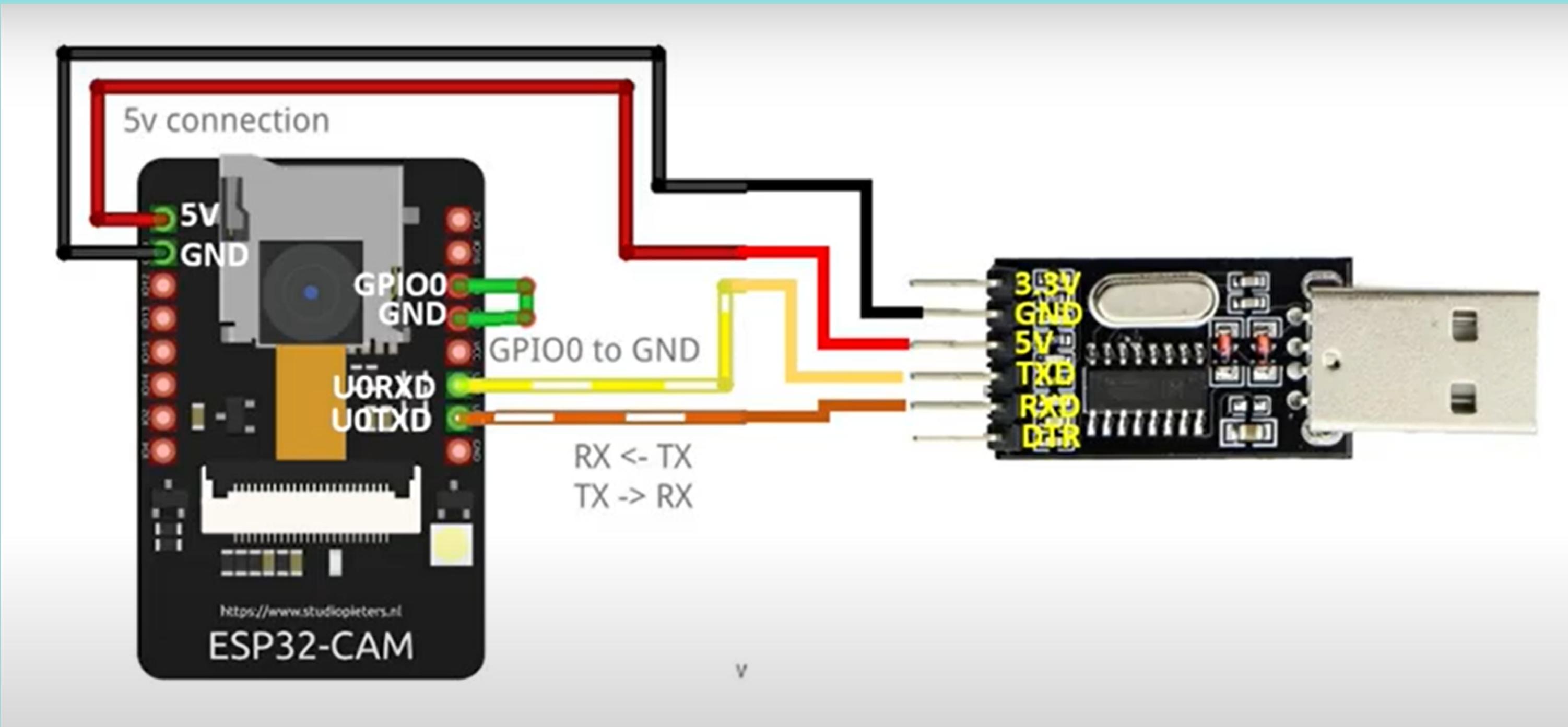
Unity



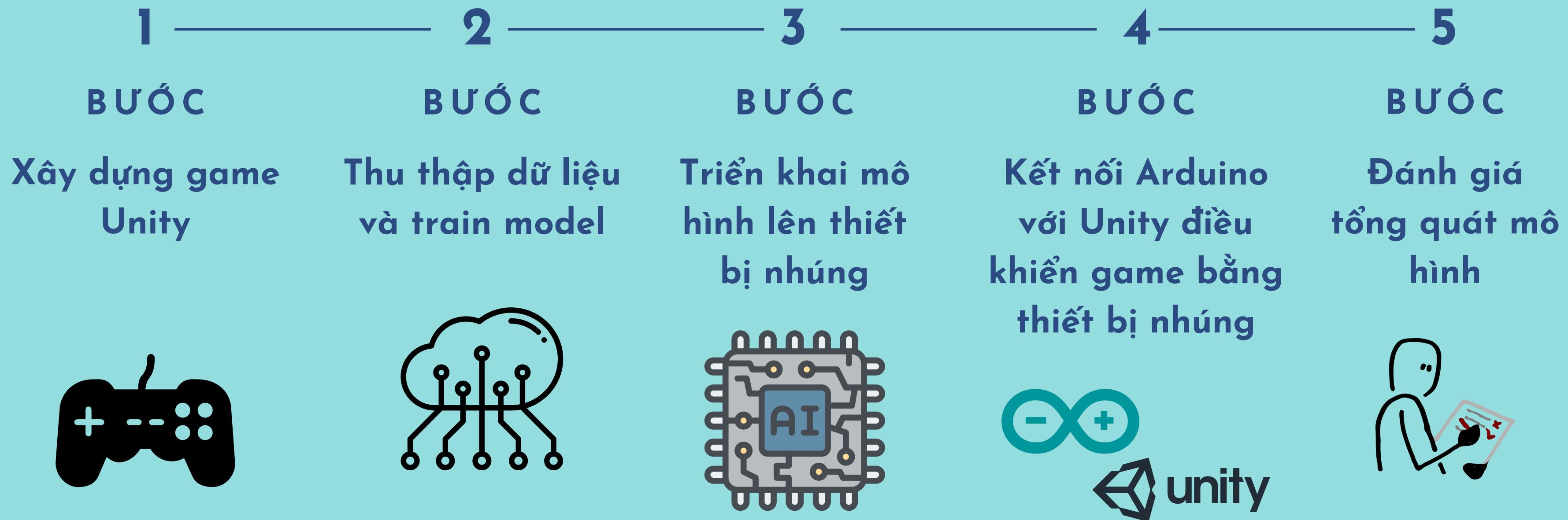
Schematics



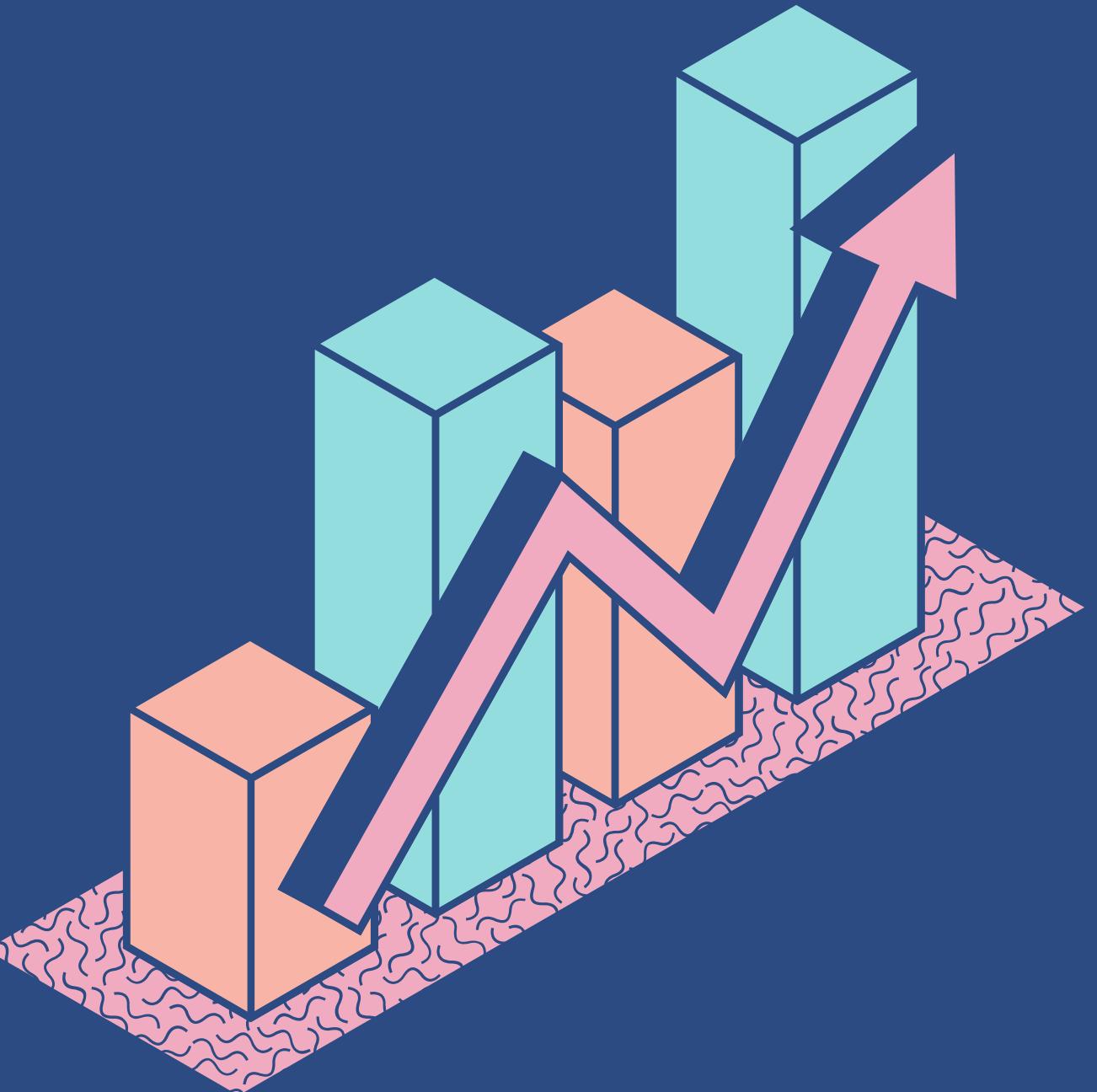
Kết nối ESP32-CAM với mạch nạp USB UART CH340G



Triển khai dự án

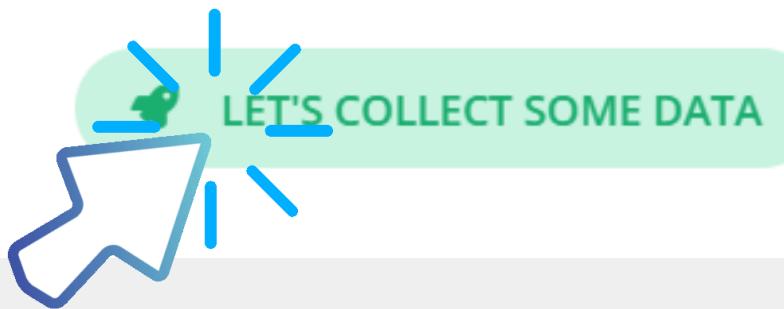


Thu thập dữ liệu bằng Edge Impulse

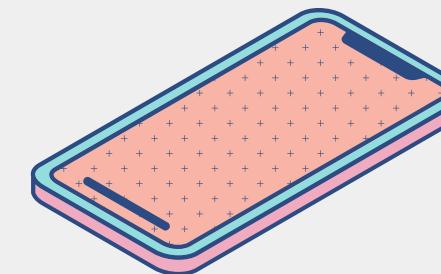


Acquire data

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



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 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

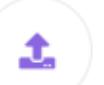
Capture data from any device or development board over a serial connection, in 10 lines of code.



[Show docs](#)

Upload data

Already have data? You can upload your existing datasets directly in WAV, JPG, PNG, CBOR, CSV, JSON, MP4 or AVI format.



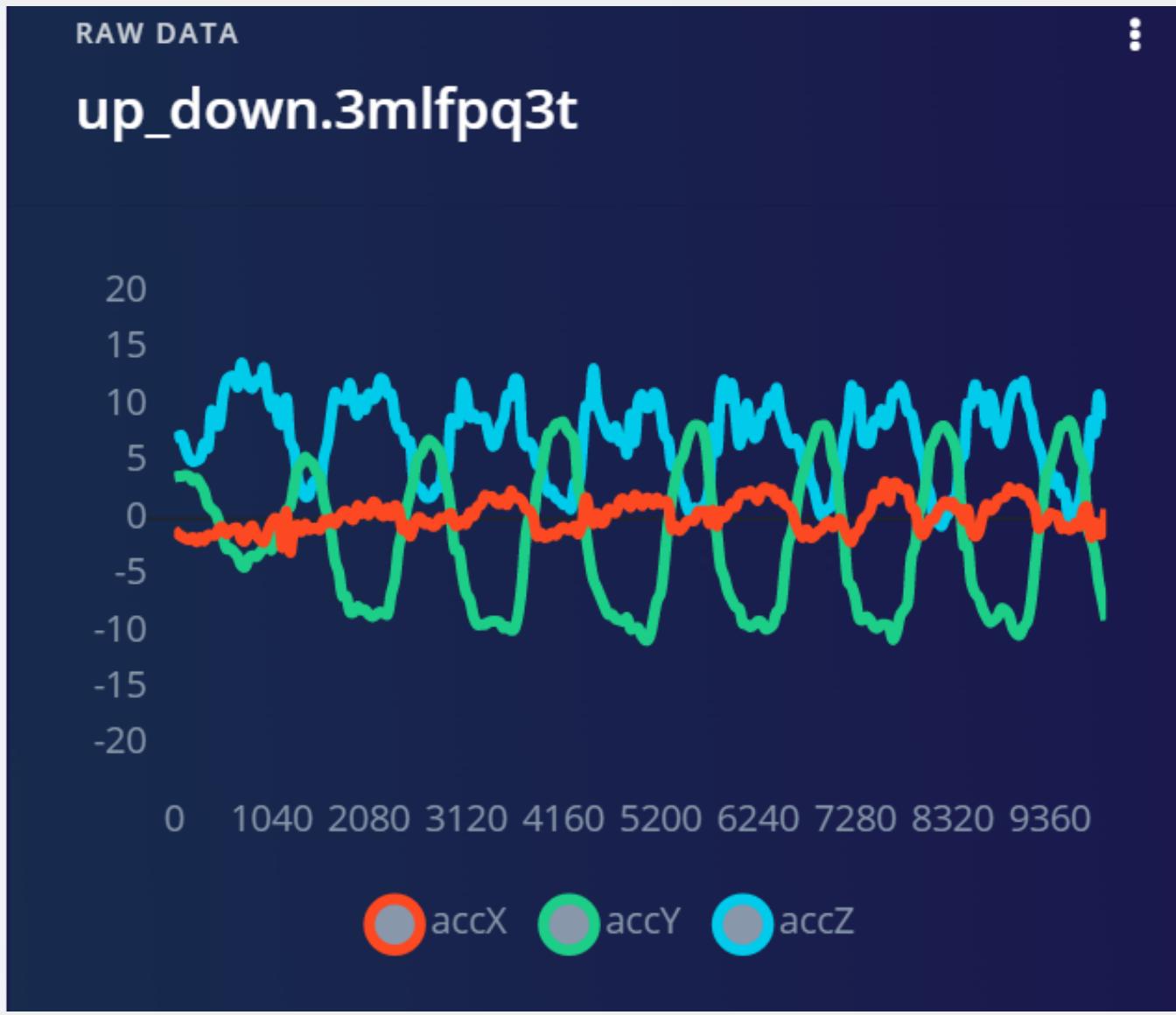
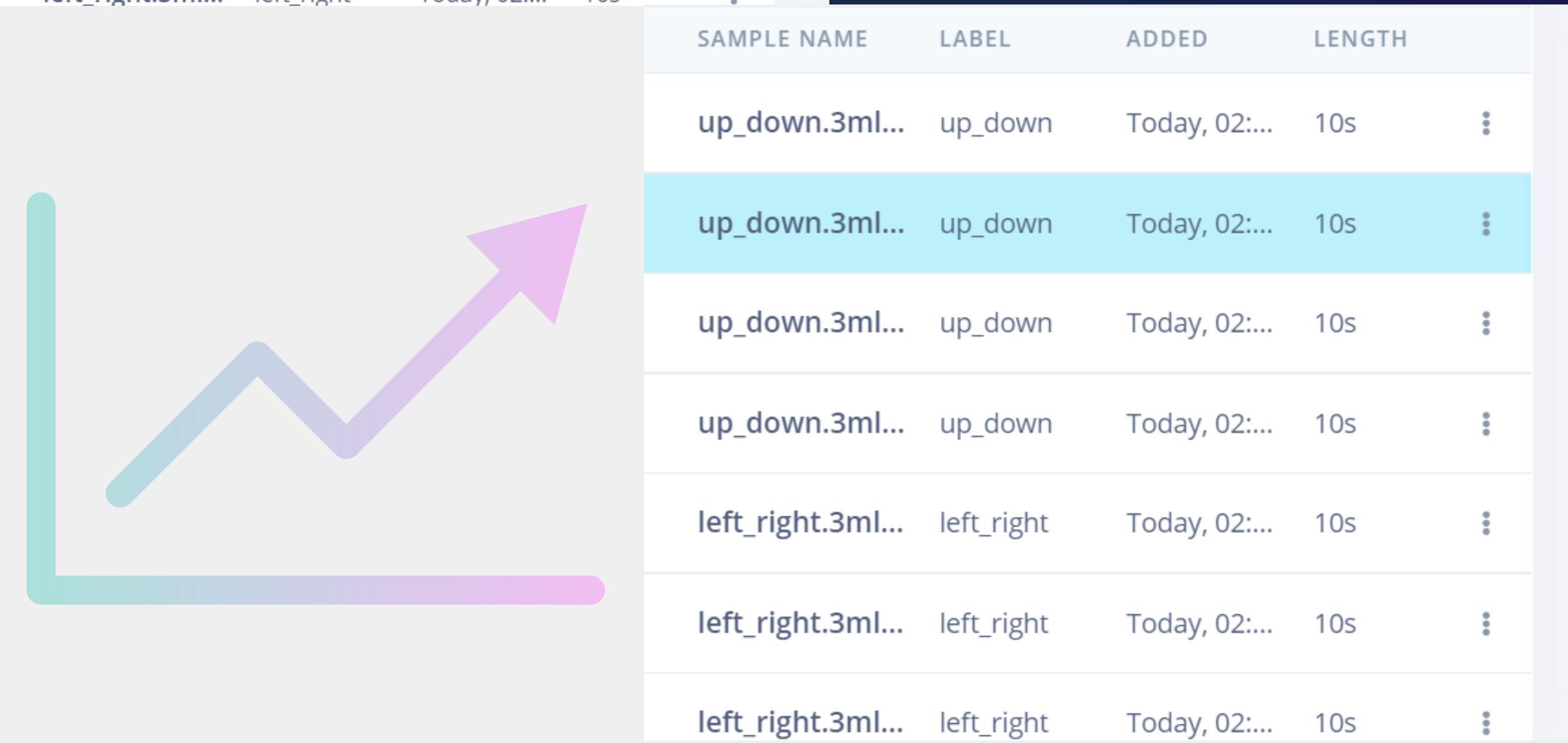
[Go to the uploader](#)

Integrate with your cloud

The enterprise version of Edge Impulse integrates directly with the data stored in your cloud platform.



[Learn more...](#)



 Dashboard Devices Data sources Data acquisition

Data acquisition

Dataset train / test split ratio

Training data is used to train your model, and **testing data** is used to test your model's accuracy after training. We recommend an approximate 80/20 train/test split ratio for your data for every class (or label) in your dataset, although especially large datasets may require less testing data.

SUGGESTED TRAIN / TEST SPLIT

80% / 20%

Labels in your dataset ②

LEFT_RIGHT

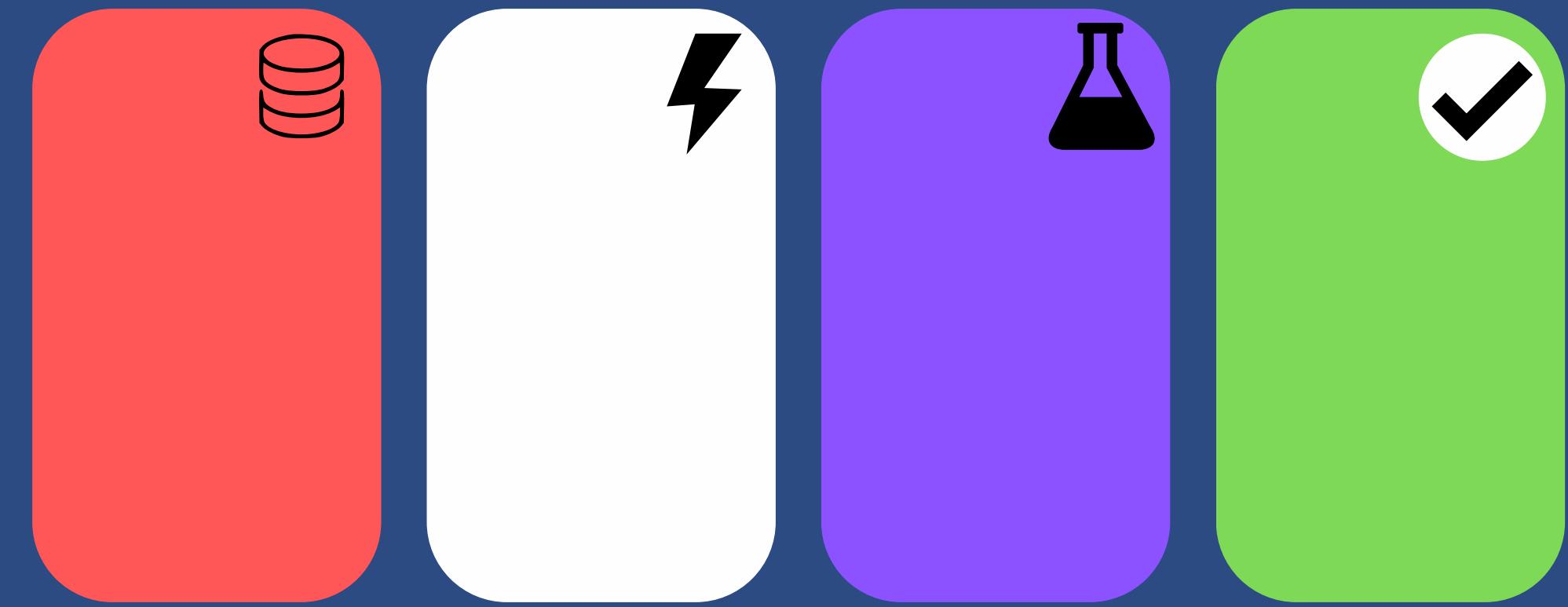
79% / 21% (1m 50s / 30s)

UP_DOWN

82% / 18% (1m 30s / 20s)

Dismiss

Tạo Impulse





Impulse design

Create impulse

Spectral features

Classifier



Time series data

Input axes (3)
accX, accY, accZ

Window size
 2000 ms.

Window increase
 200 ms.

Frequency (Hz)
62.5

Zero-pad data

Spectral Analysis

Name
Spectral features

Classification

Name
Classifier

Input features
 accX
 accY
 accZ

Output features
2 (left_right, up_down)

Output features

2 (left_right, up_down)

Save Impulse

Spectral Analysis



Name

Spectral features

Input axes (3)

accX

accY

accZ



⚡ Add a processing block

x

Did you know? You can bring your own DSP code.

DESCRIPTION	AUTHOR	RECOMMENDED
Spectral Analysis Great for analyzing repetitive motion, such as data from accelerometers. Extracts the frequency and power characteristics of a signal over time.	Edge Impulse	<button>Add</button>
IMU (Syntiant) Syntiant only. Great for analyzing repetitive motion, such as data from accelerometers. Extracts the frequency and power characteristics of a signal over time.	Syntiant	<button>Add</button>
Flatten Flatten an axis into a single value, useful for slow-moving averages like temperature data, in combination with other blocks.	Edge Impulse	<button>Add</button>
Spectrogram Extracts a spectrogram from audio or sensor data, great for non-voice audio or data with continuous frequencies.	Edge Impulse	<button>Add</button>

Classification



Name

Classifier

Input features

Spectral features

Output features

2 (left_right, up_down)



💡 Add a learning block

Did you know? You can bring your own model in PyTorch, Keras or scikit-learn.

DESCRIPTION

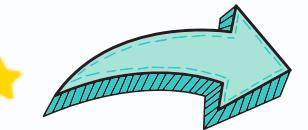
AUTHOR

RECOMMENDED

Classification

Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio.

Edge Impulse



Add

Anomaly Detection (K-means)

Find outliers in new data. Good for recognizing unknown states, and to complement classifiers. Works best with low dimensionality features like the output of the spectral features block.

Edge Impulse



Add

Regression

Learns patterns from data, and can apply these to new data. Great for predicting numeric continuous values.

Edge Impulse

Add

Classification (Keras) - BrainChip Akida™

Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio.

BrainChip

Add

Some learning blocks have been hidden based on the data in your project. [Show all blocks anyway](#)



Impulse design



Create impulse



Spectral features



Classifier

Parameters

Filter

Scale axes

1

Type

none

Spectral power

FFT length

16

Take log of
spectrum?



Overlap FFT frames?



Save parameters

Training set

Data in training set 3m 20s

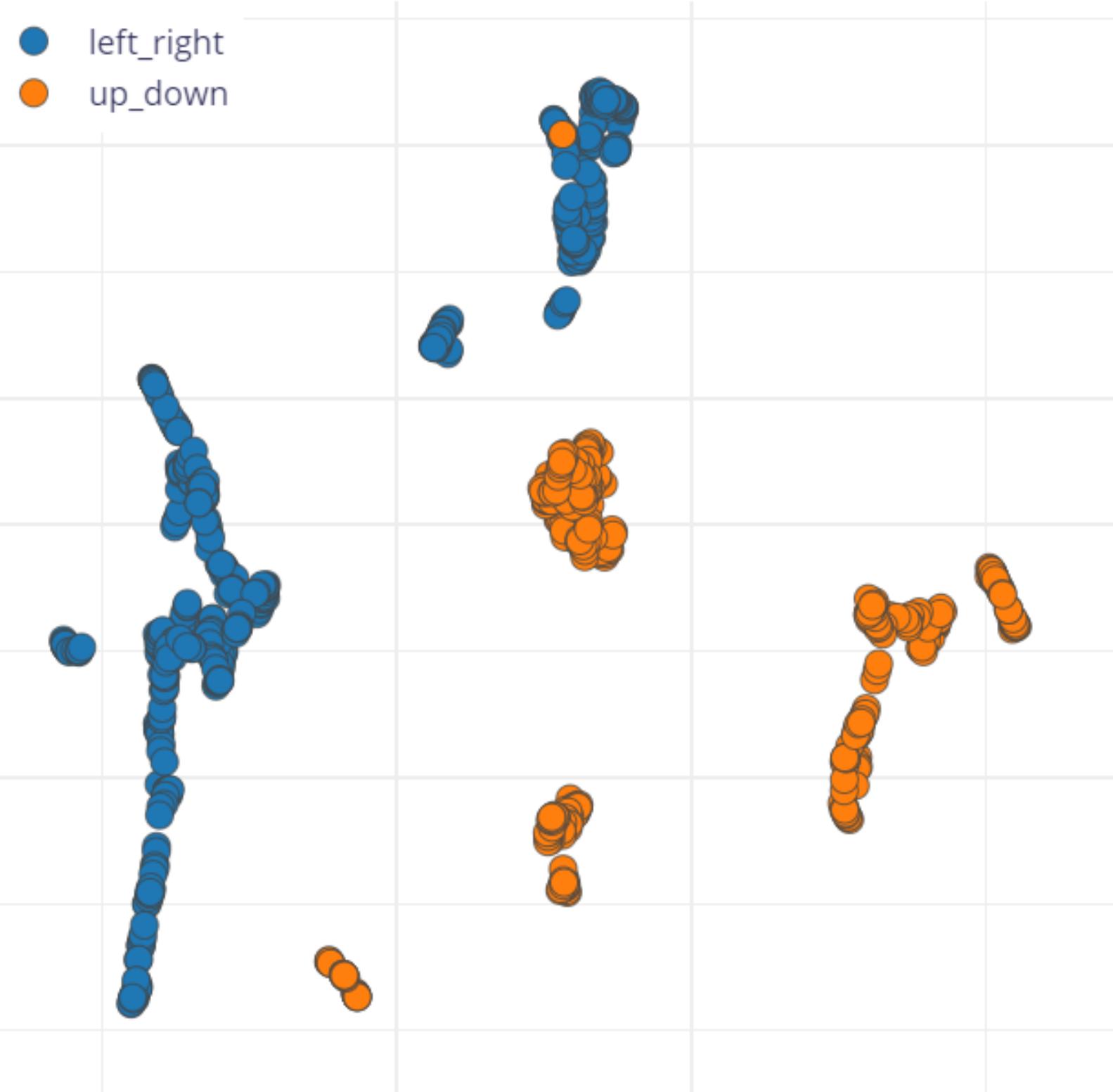
Classes 2 (left_right, up_down)

Training windows 840

Calculate feature
importance

Generate features

Feature explorer



After generate features

On-device performance ⓘ



PROCESSING
TIME
13 ms.



PEAK RAM
USAGE
2 KB

Train data





Impulse design



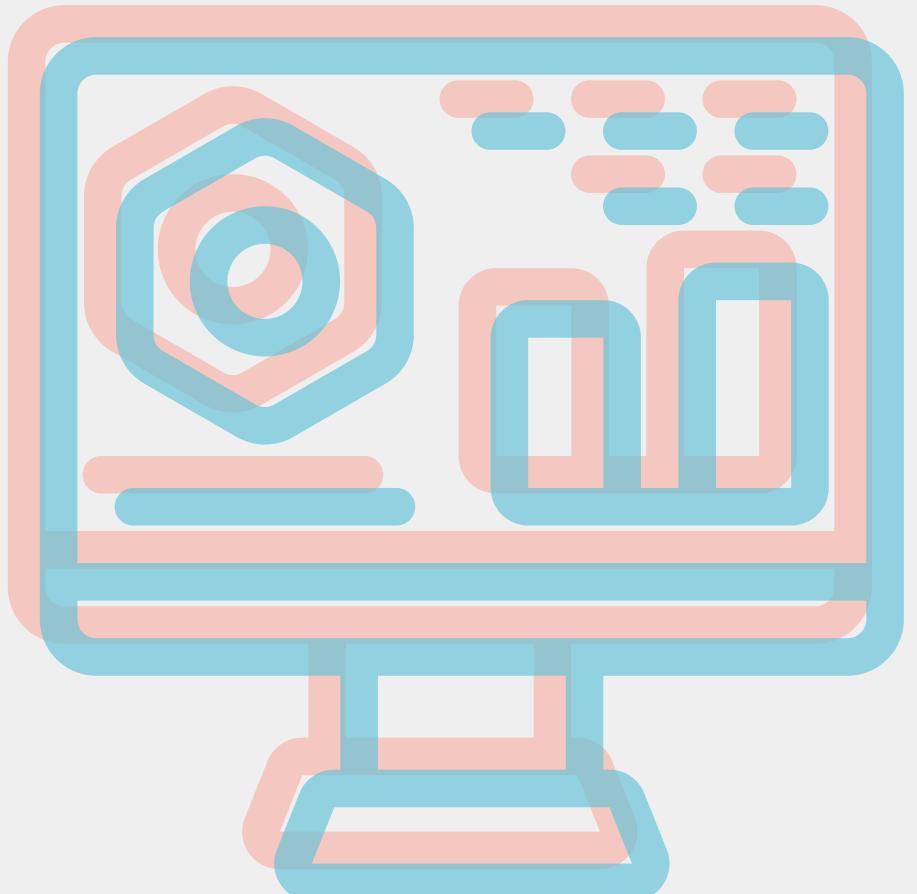
Create impulse



Spectral features



Classifier



Neural Network settings

Training settings

Number of training cycles ②

30

Learning rate ②

0.0005

Validation set size ②

20

%

Auto-balance dataset ②



Neural network architecture

Input layer (33 features)

Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (2 classes)

Start training

Last training performance (validation set)



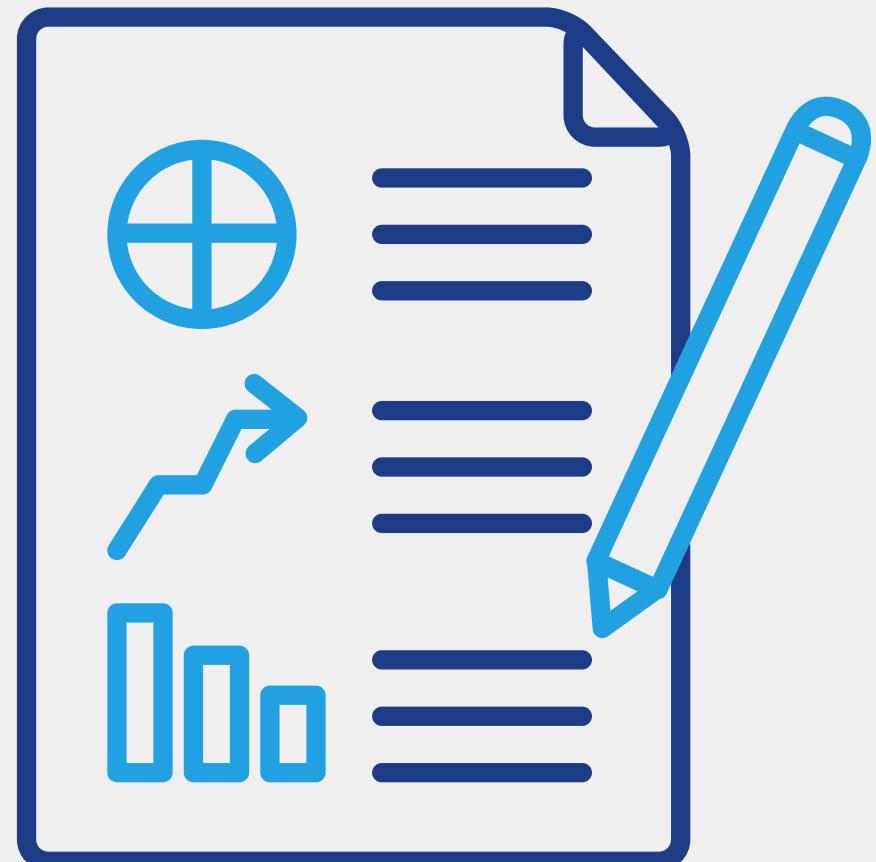
ACCURACY
99.4%



LOSS
0.03

Confusion matrix (validation set)

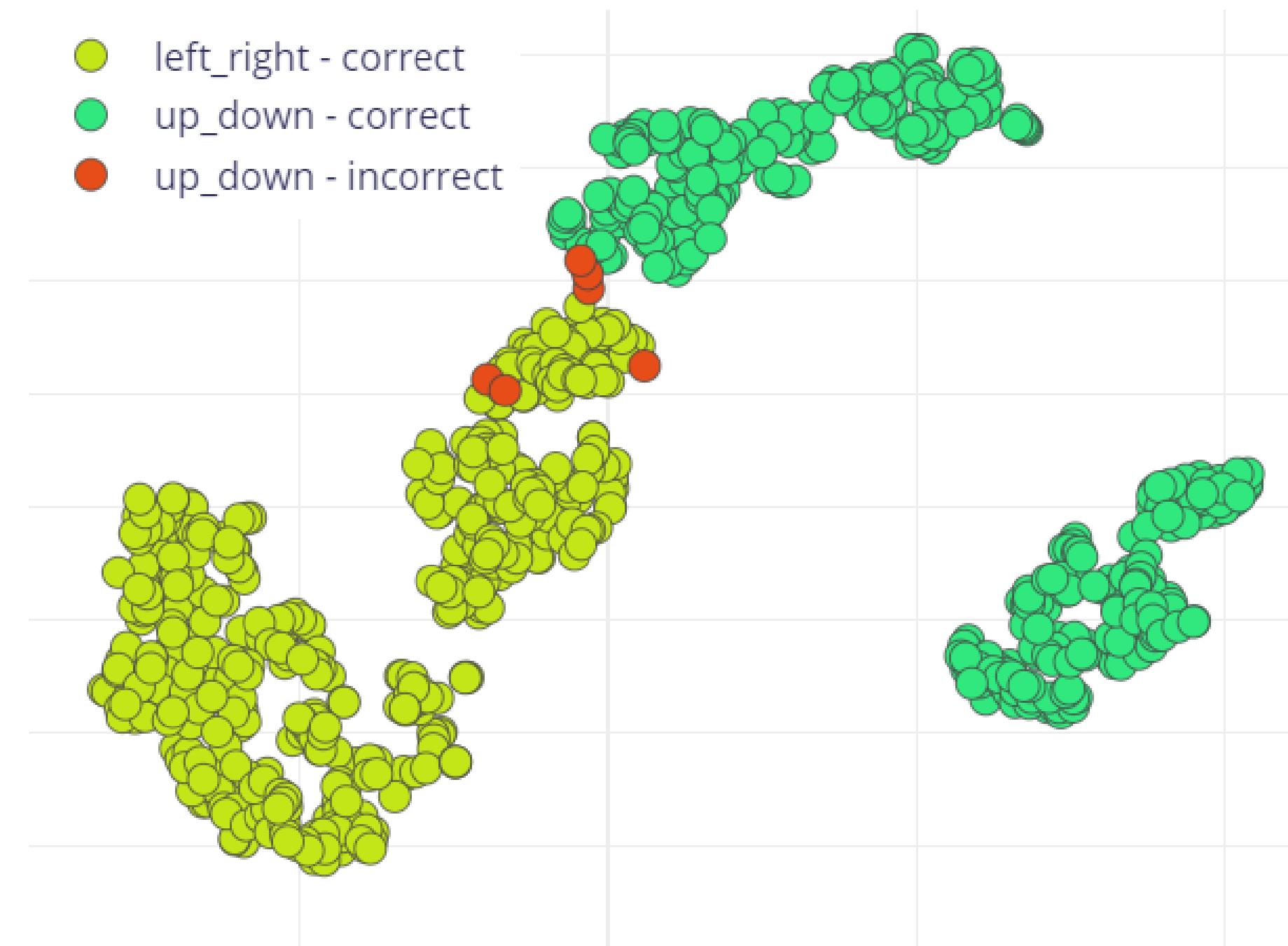
	LEFT_RIGHT	UP_DOWN
LEFT_RIGHT	100%	0%
UP_DOWN	1.3%	98.7%
F1 SCORE	0.99	0.99



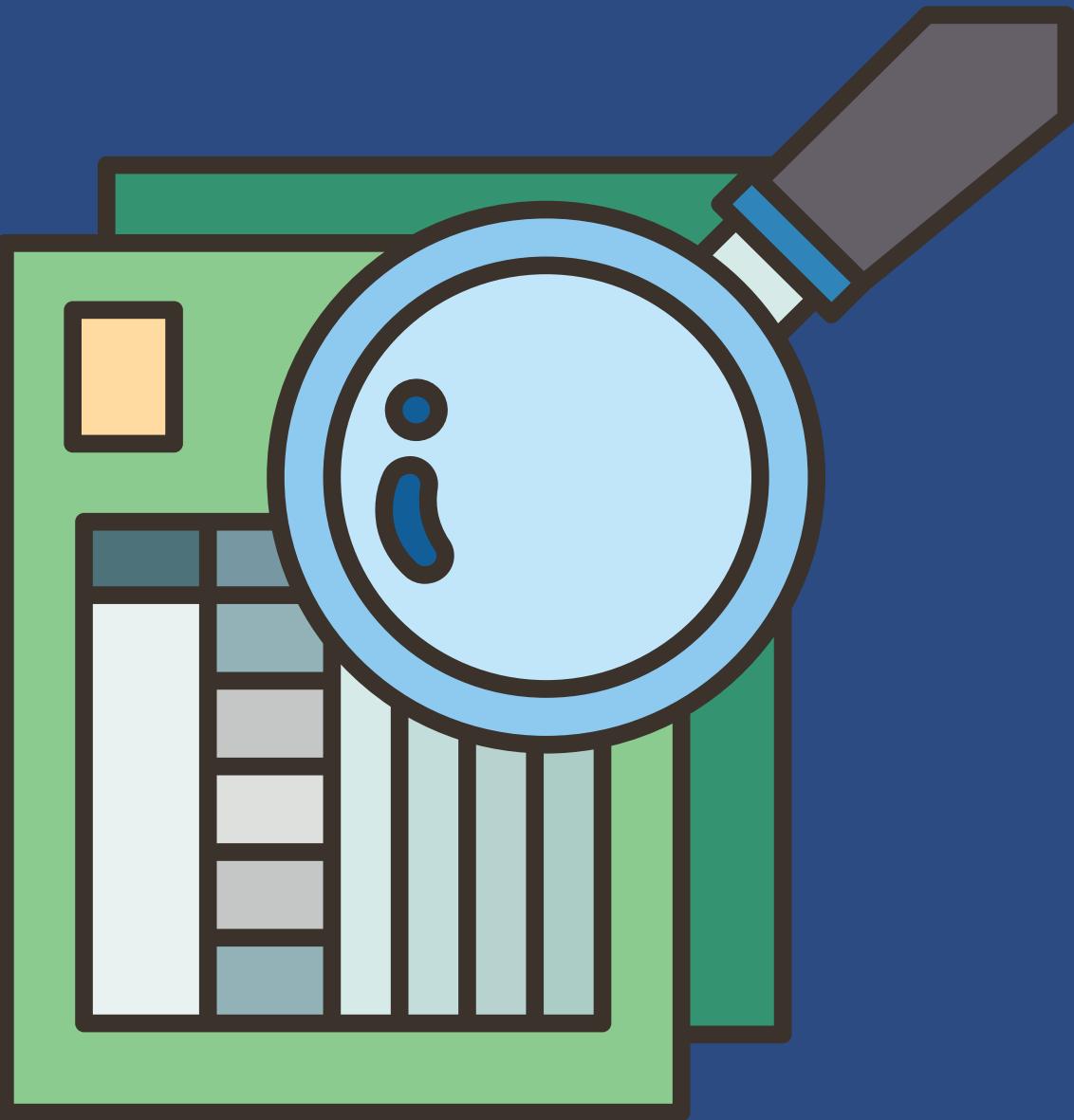
After training

Data explorer (full training set)

- left_right - correct
- up_down - correct
- up_down - incorrect



Test model





EON Tuner



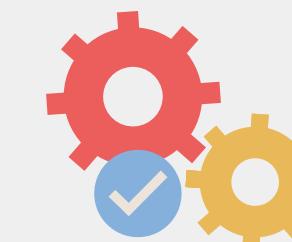
Retrain model



Live classification



Model testing



Test data

Classify all

⋮

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

SAMPL...	EXPECTED...	LE...	ACCU...	RESULT	⋮
left_ri...	left_right	10s	100%	42 left_right	⋮
left_ri...	left_right	10s	100%	42 left_right	⋮
up_d...	up_down	10s	100%	42 up_down	⋮
up_d...	up_down	10s	92%	39 up_down,...	⋮

Model testing results



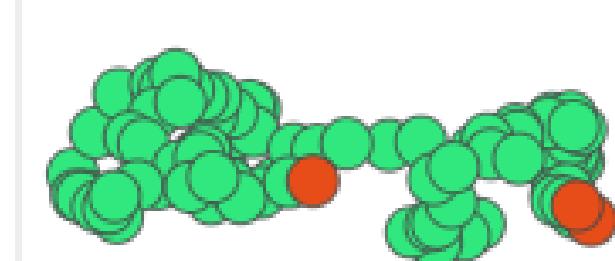
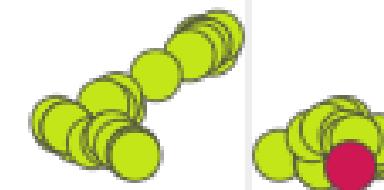
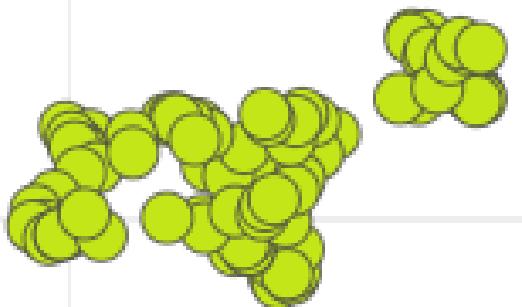
ACCURACY
98.10%

	LEFT_RIGHT	UP_DOWN	UNCERTAIN
LEFT_RIGHT	99.2%	0%	0.8%
UP_DOWN	3.6%	96.4%	0%
F1 SCORE	0.98	0.98	

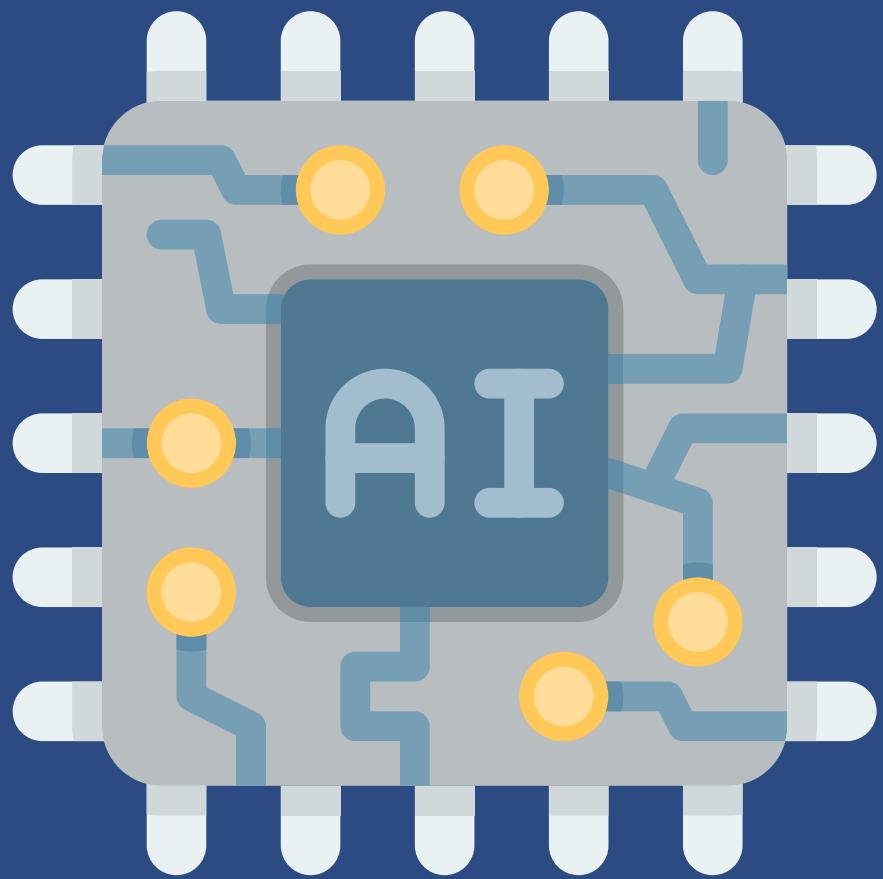
After testing

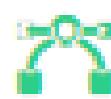
Feature explorer ⓘ

- left_right - correct
- up_down - correct
- left_right - incorrect
- up_down - incorrect



Triển khai mô hình lên thiết bị nhúng





Live classification



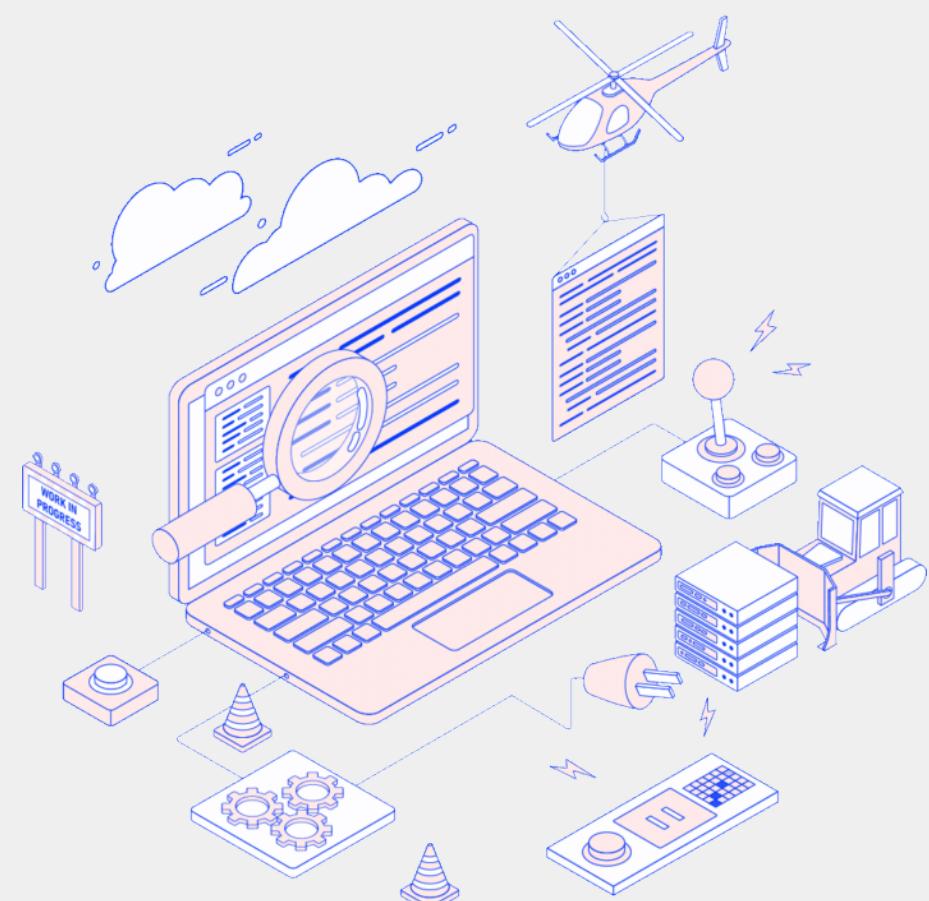
Model testing



Versioning



Deployment

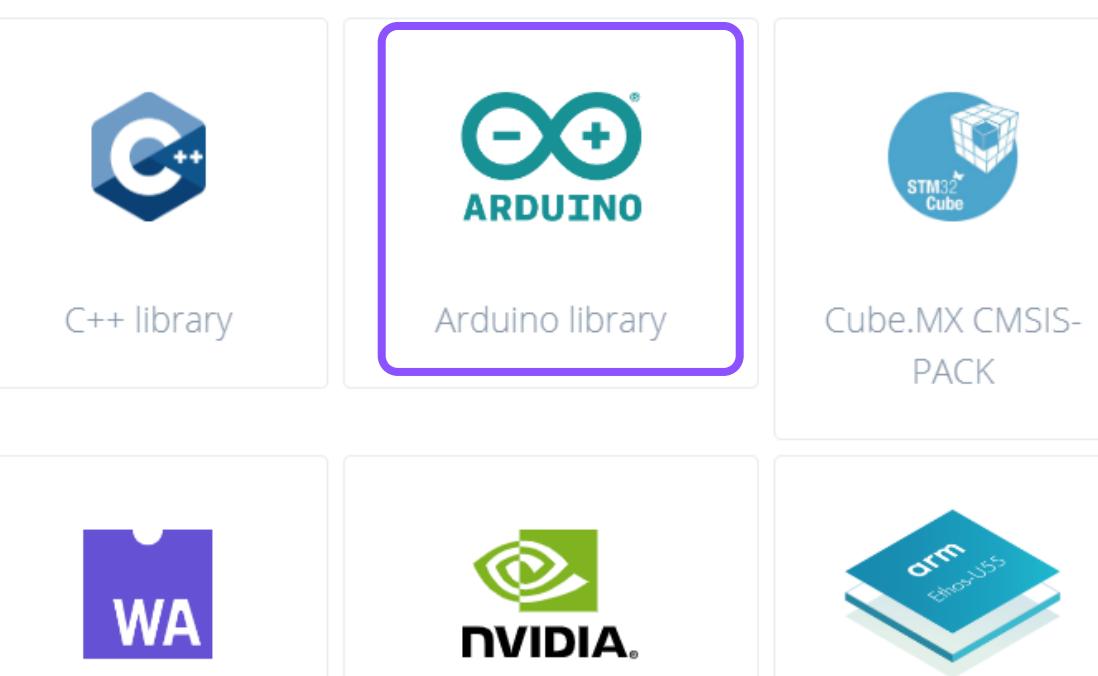


Deploy your impulse

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.



Enable EON™ Compiler

Same accuracy, up to 50% less memory. Open source.



Available optimizations for Classifier

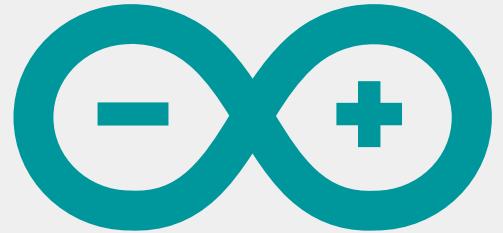
Quantized (int8)	RAM USA	LATENCY
Currently selected	1.8K	1 ms
Unoptimized (float32)	RAM USA	LATENCY
Click to select	1.8K	8 ms

Analyze optimizations

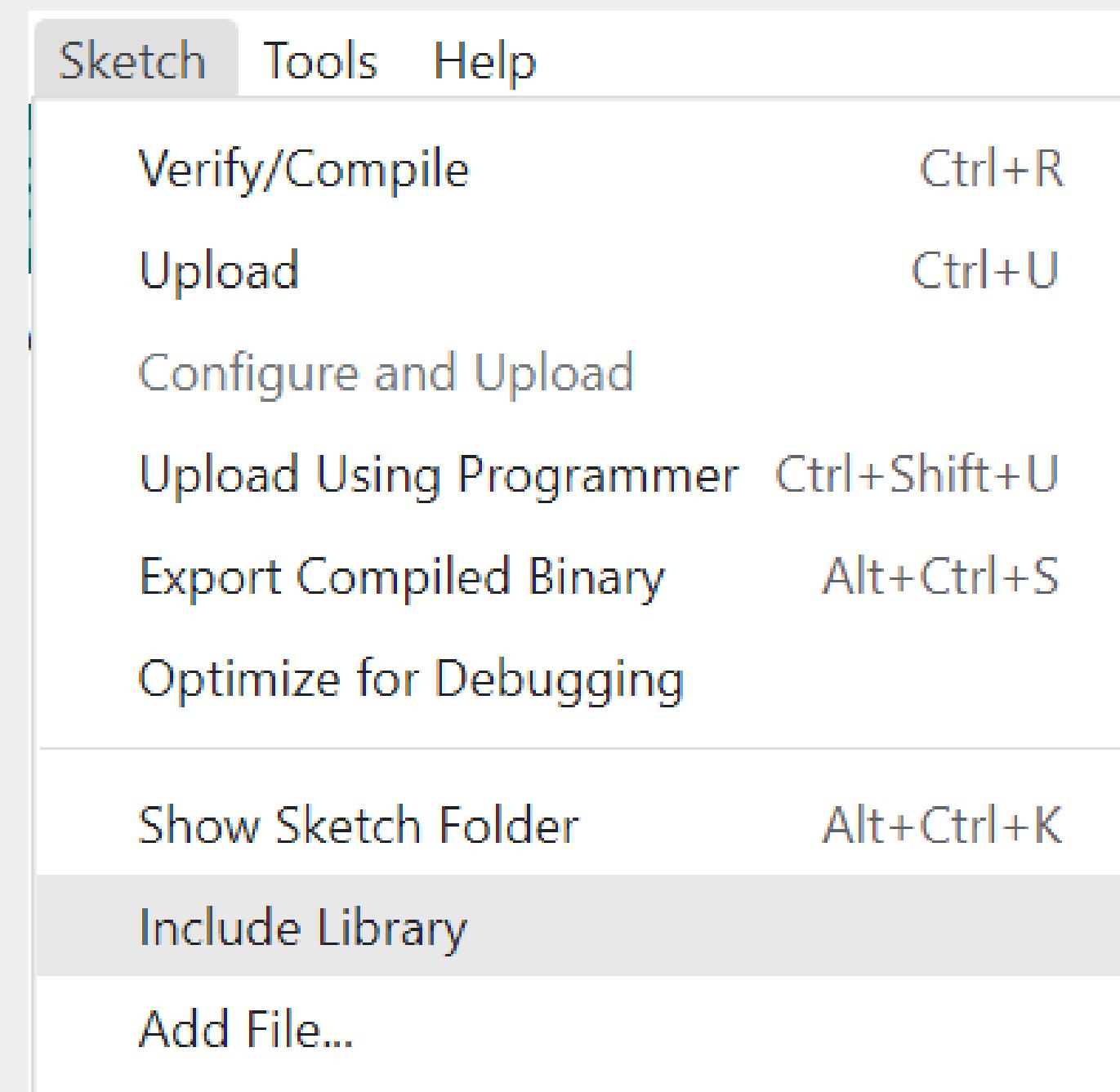
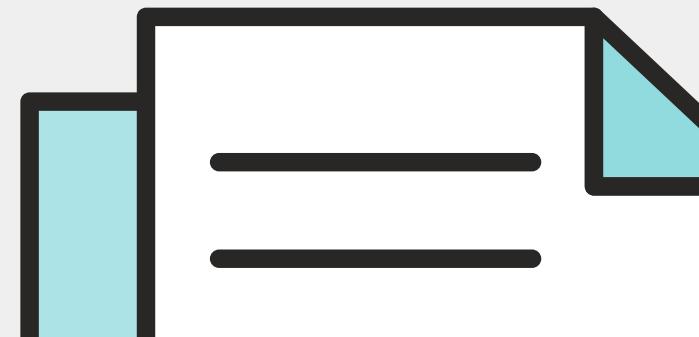
Estimate for Cortex-M4F 80MHz.



Build



Add library into project in Arduino IDE



Add .ZIP Library...

Arduino libraries

Arduino_BuiltIn

ArduinoOTA

BluetoothSerial

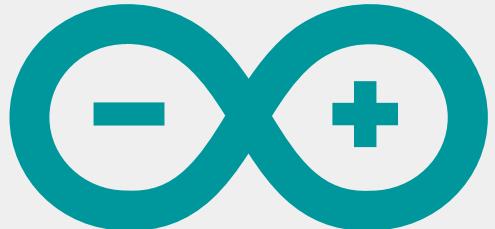
DNSServer

EEPROM

ESP Insights

ESP RainMaker





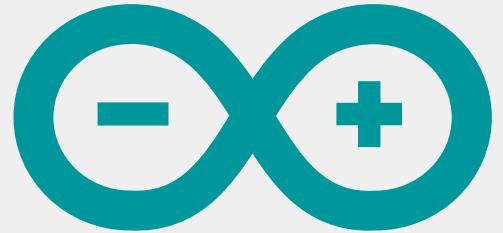
Can use example of .zip library to build file

The screenshot shows the Arduino IDE interface. The top menu bar includes File, Edit, Sketch, Tools, and Help. The File menu is currently open, displaying options like New Sketch, Open..., Examples, Close, Save, Preferences..., Advanced, and Quit, each with its corresponding keyboard shortcut. The 'Examples' option is highlighted with a gray background. Below the menu is a toolbar with Output and Serial Monitor buttons. To the right of the menu is a large list of available libraries, organized into sections. The 'Standard Libraries' section includes NetBIOS, Preferences, SD, SD_MMC, Servo, SimpleBLE, SPI, SPIFFS, Stepper, TFT, Ticker, Update, USB, WebServer, WiFi, WiFiClientSecure, WiFiProv, and Wire. The 'Examples from Custom Libraries' section lists Adafruit BusIO, Adafruit GFX Library, Adafruit MPU6050, Adafruit SSD1306, Adafruit Unified Sensor, motion-detect_inferencing, TensorFlowLite_ESP32, static_buffer, esp32, nano_ble33_sense, nicla_sense, nicla_vision, portenta_h7, and static_buffer. The 'motion-detect_inferencing' library is also highlighted with a gray background.

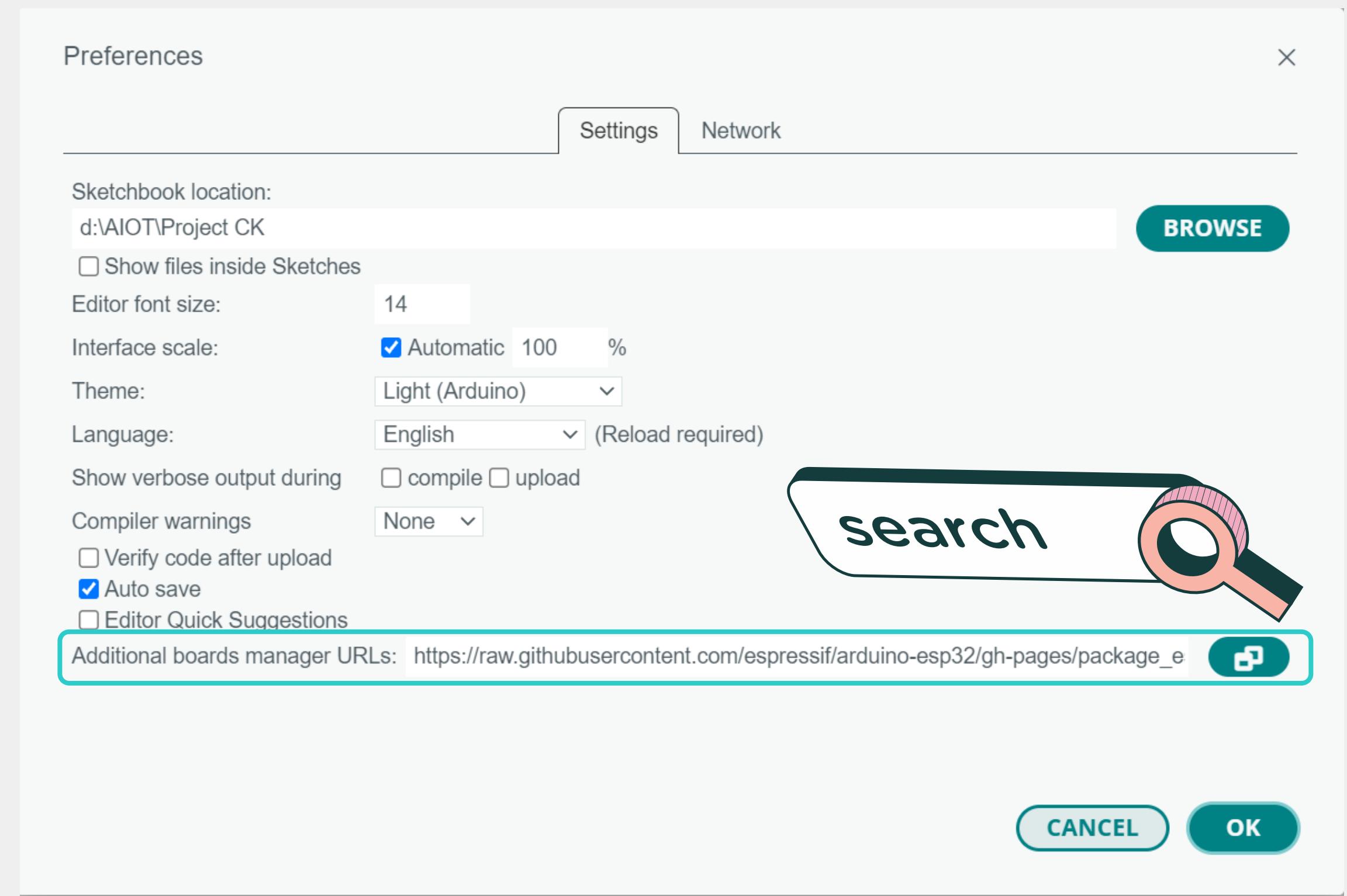
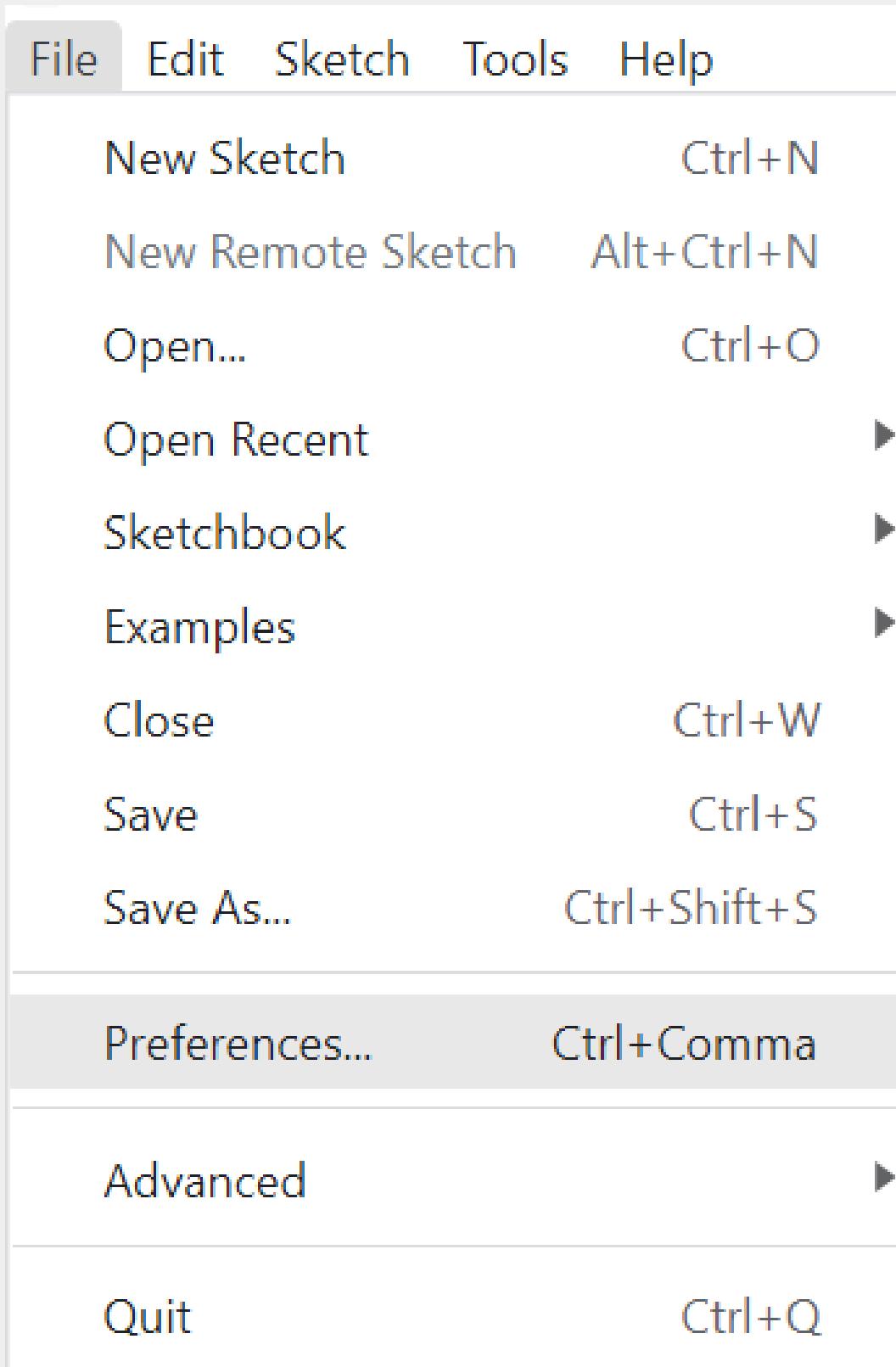
- File Edit Sketch Tools Help
- New Sketch Ctrl+N
- New Remote Sketch Alt+Ctrl+N
- Open... Ctrl+O
- Open Recent ▶
- Sketchbook ▶
- Examples ▶
- Close Ctrl+W
- Save Ctrl+S
- Save As... Ctrl+Shift+S
- Preferences... Ctrl+Comma
- Advanced ▶
- Quit Ctrl+Q

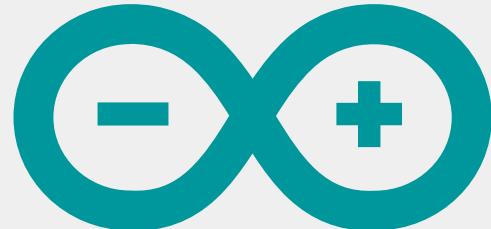
Output Serial Monitor

- NetBIOS
- Preferences
- SD
- SD_MMC
- Servo
- SimpleBLE
- SPI
- SPIFFS
- Stepper
- TFT
- Ticker
- Update
- USB
- WebServer
- WiFi
- WiFiClientSecure
- WiFiProv
- Wire
- Examples from Custom Libraries
- Adafruit BusIO
- Adafruit GFX Library
- Adafruit MPU6050
- Adafruit SSD1306
- Adafruit Unified Sensor
- motion-detect_inferencing
- TensorFlowLite_ESP32
- static_buffer
- esp32
- nano_ble33_sense
- nicla_sense
- nicla_vision
- portenta_h7
- static_buffer

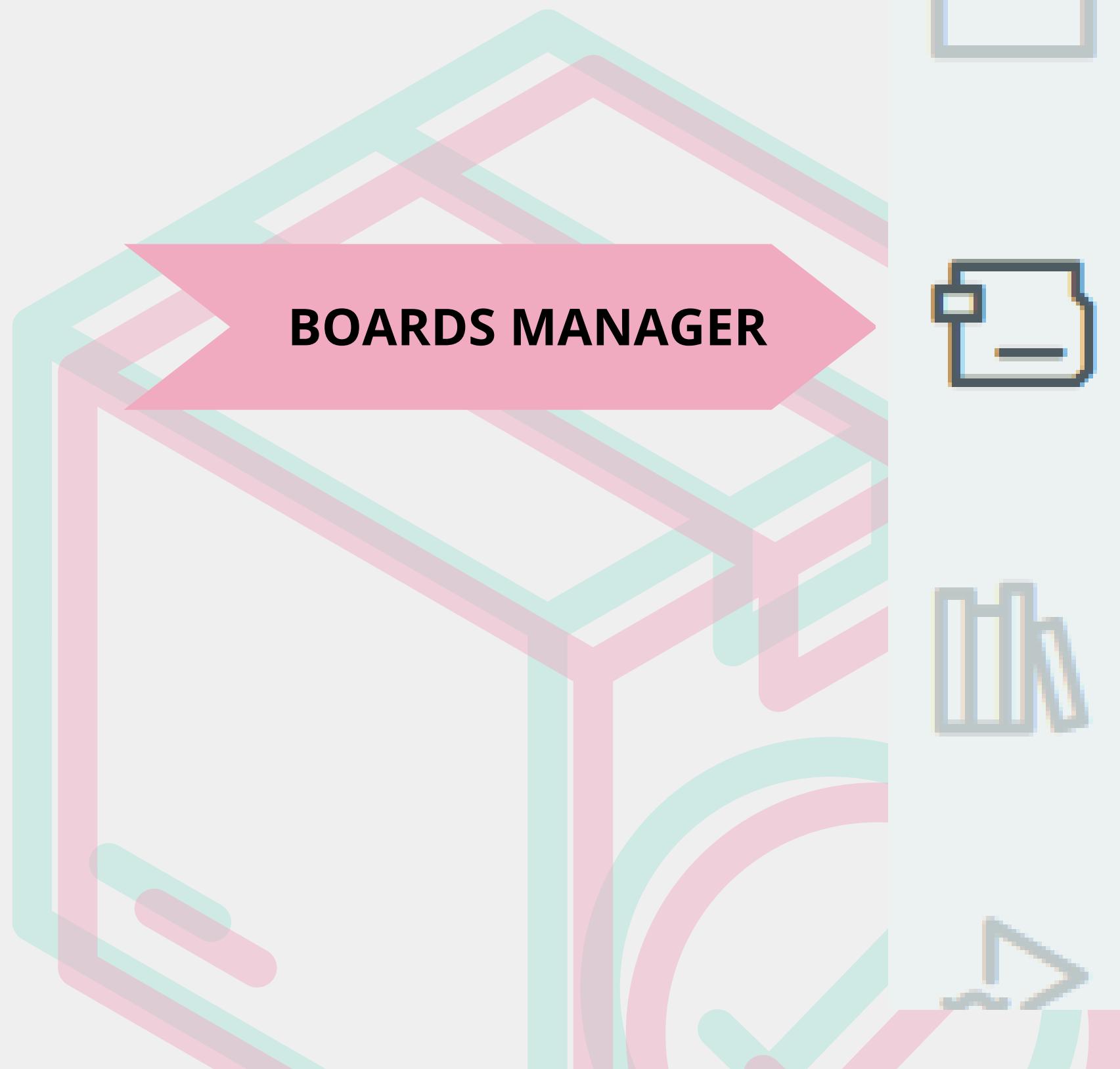


Install ESP32 package





Install ESP32 package



BOARDS MANAGER

esp32

Type

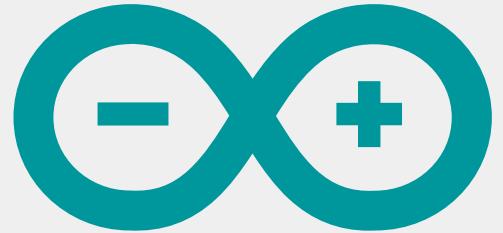
10

esp32 by Espressif Systems

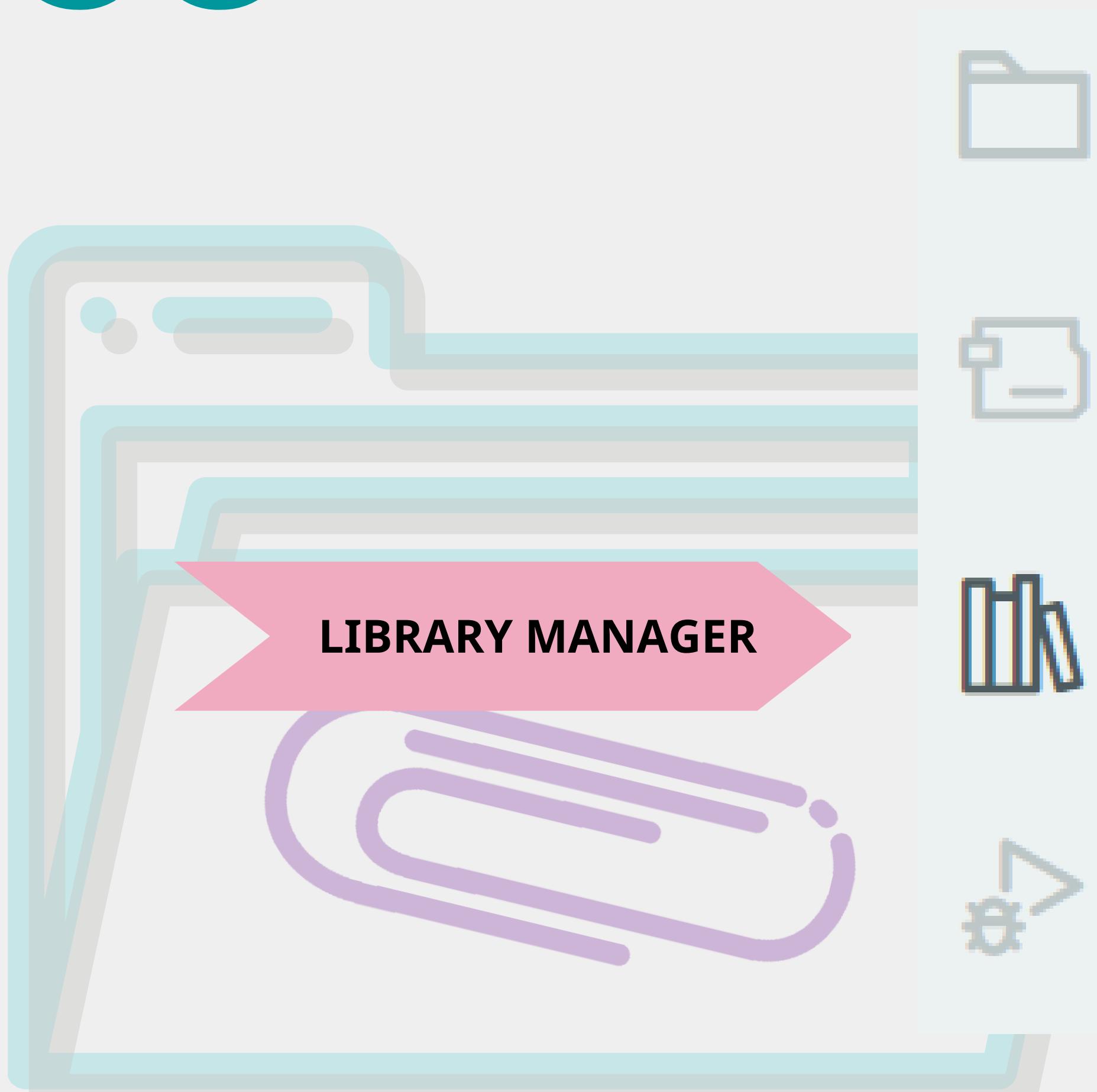
Version 2.0.6

INSTALLED

Boards included in this package:



Install Adafruit_MPU6050 library



LIBRARY MANAGER

Adafruit MPU6050

Type:

Installed

Topic:

All

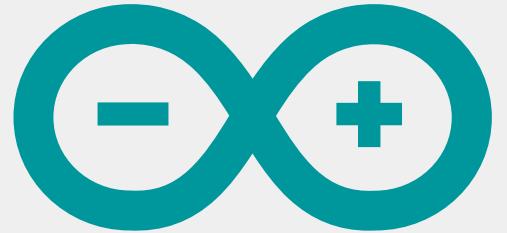
Adafruit MPU6050 by
Adafruit

Version 2.2.4

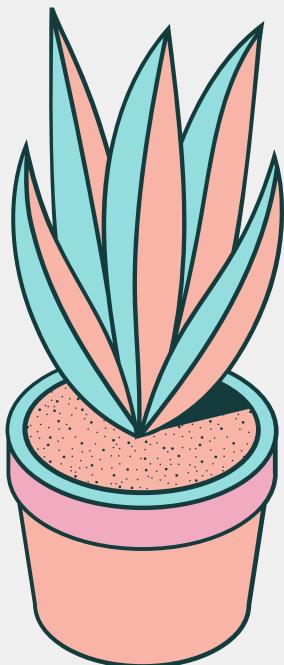
INSTALLED

Arduino library for the
MPU6050 sensors in the

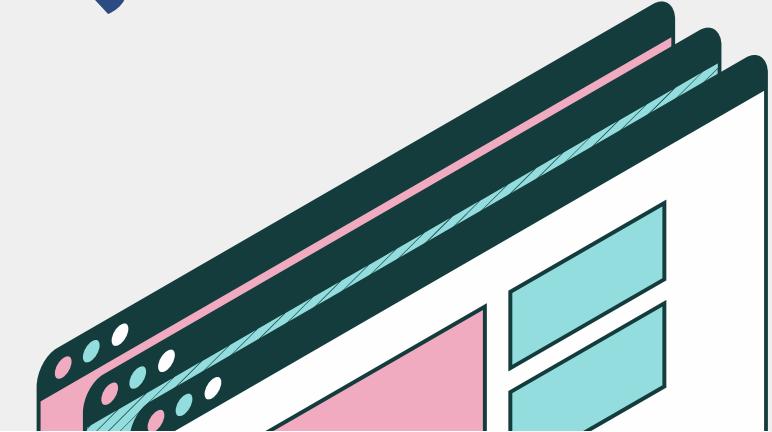
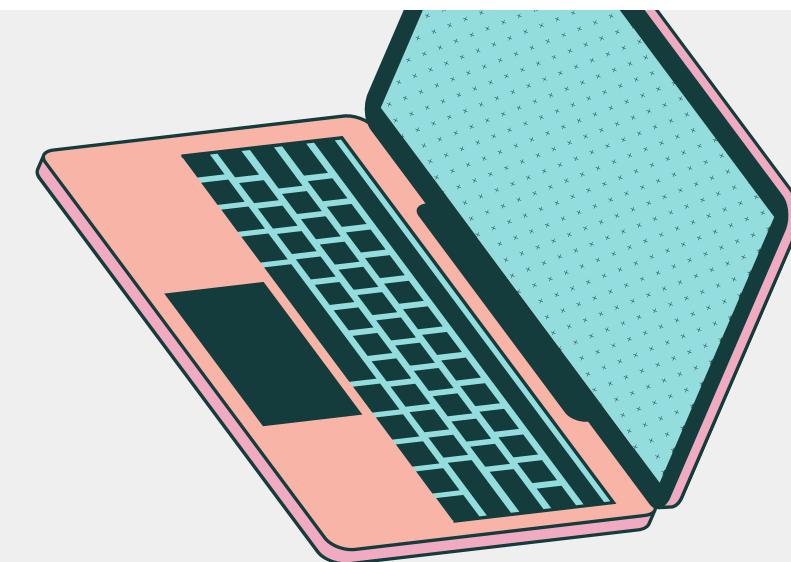
Adafruit IMU

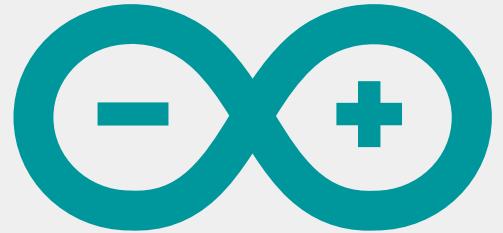


Include libraries into project



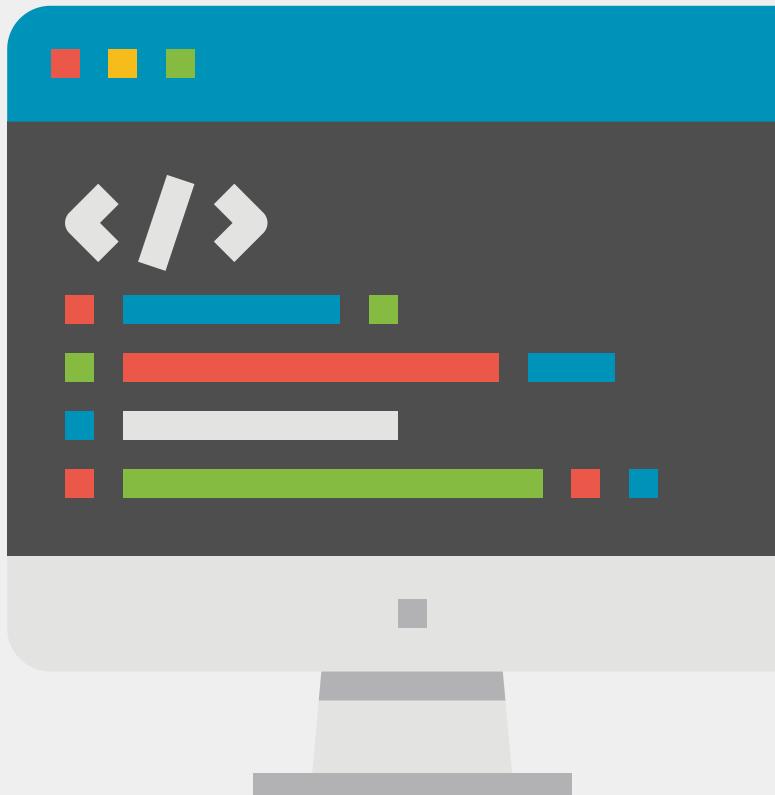
```
#include <Adafruit_MPU6050.h>
#include <Adafruit_Sensor.h>
#include <Wire.h>
#include <motion-detect_inferencing.h>
```





Define initial values and declare variables

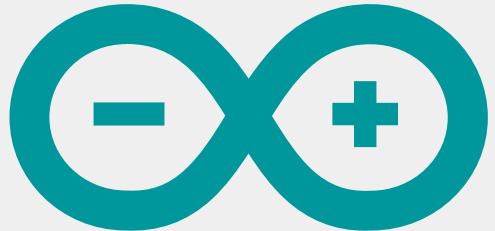
```
#define FREQUENCY_HZ 60
#define INTERVAL_MS (1000 / (FREQUENCY_HZ + 1))
#define epsilon 0.1
#define SDA 14
#define SCL 15
//#define PUSH_BUTTON 4
```



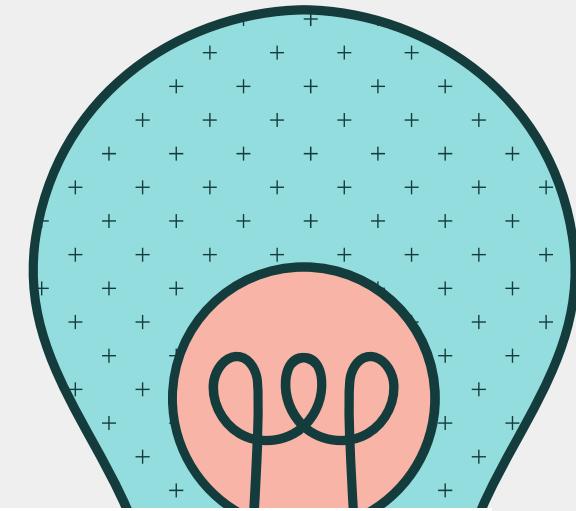
```
// objeto da classe Adafruit_MPU6050
Adafruit_MPU6050 mpu;

float features[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE];
size_t feature_ix = 0;

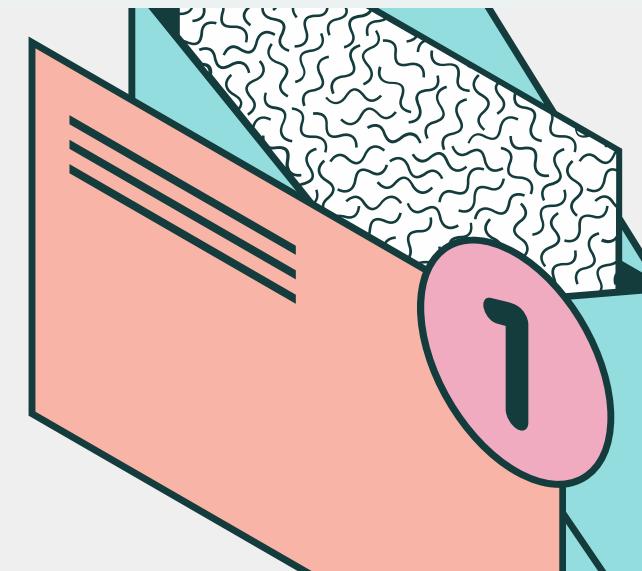
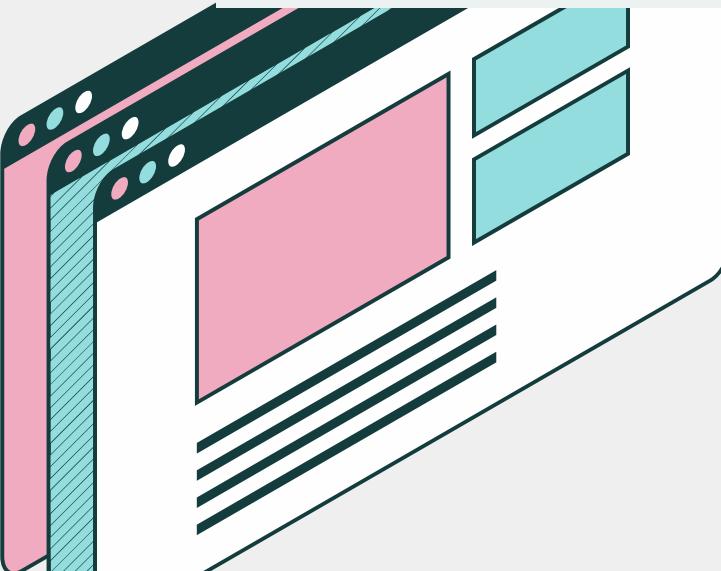
static unsigned long last_interval_ms = 0;
```

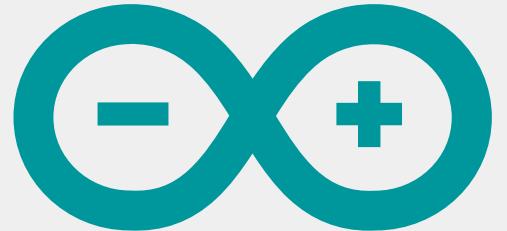


Additional function

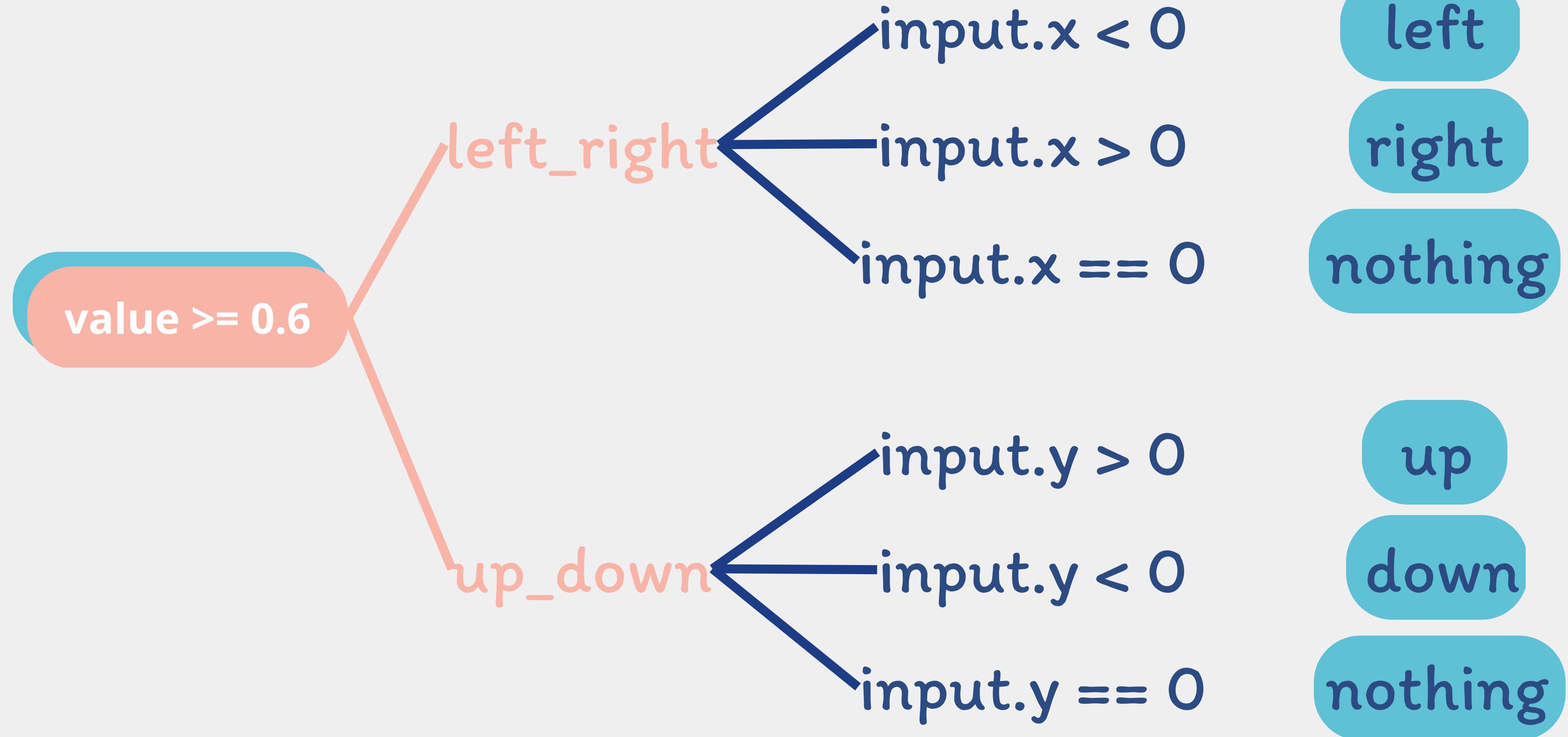


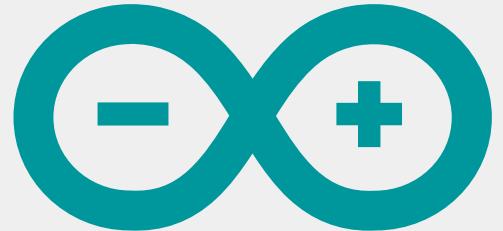
```
size_t find_Max(ei_impulse_result_t arr) {
    size_t maxid = 0;
    for (size_t ix = 1; ix < EI_CLASSIFIER_LABEL_COUNT; ix++) {
        if (arr.classification[ix].value > arr.classification[maxid].value) {
            maxid = ix;
        }
    }
    return maxid;
}
```



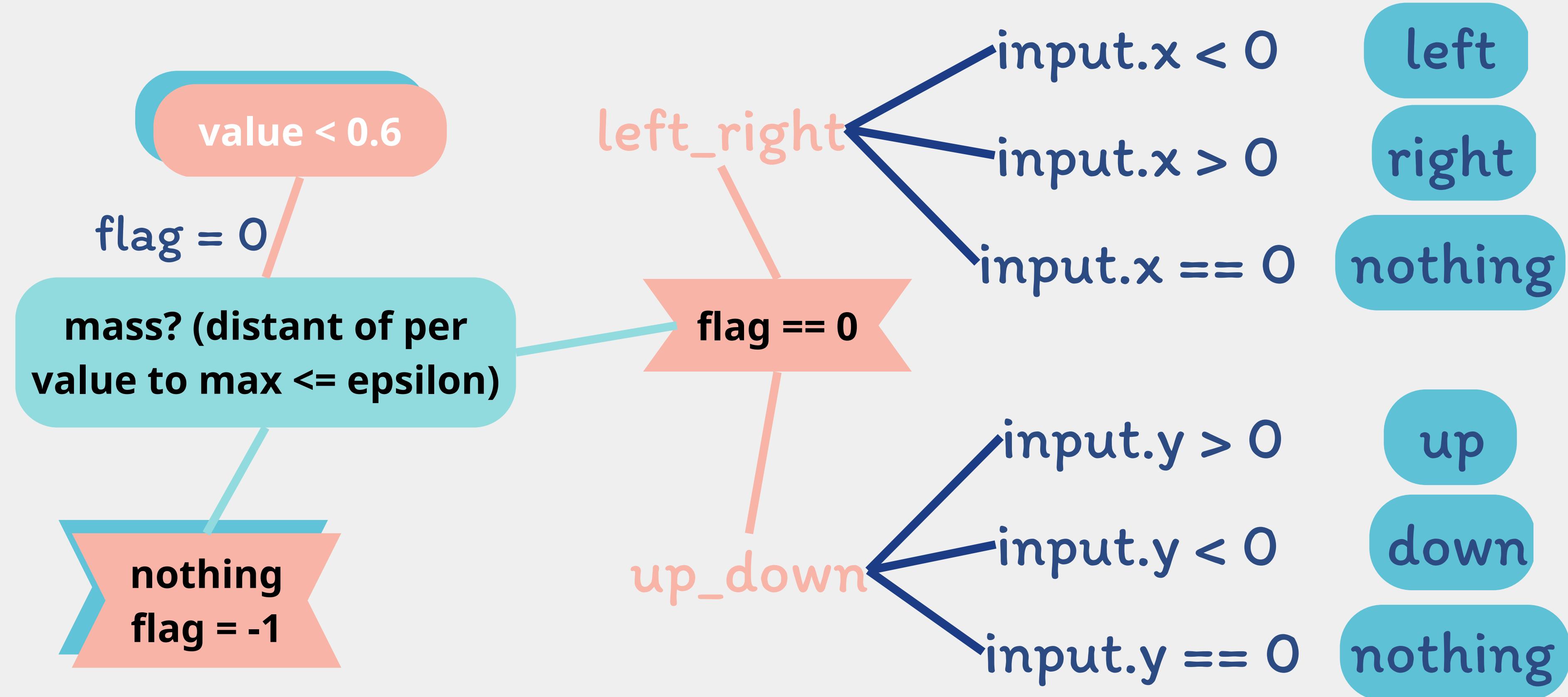


Classification input process

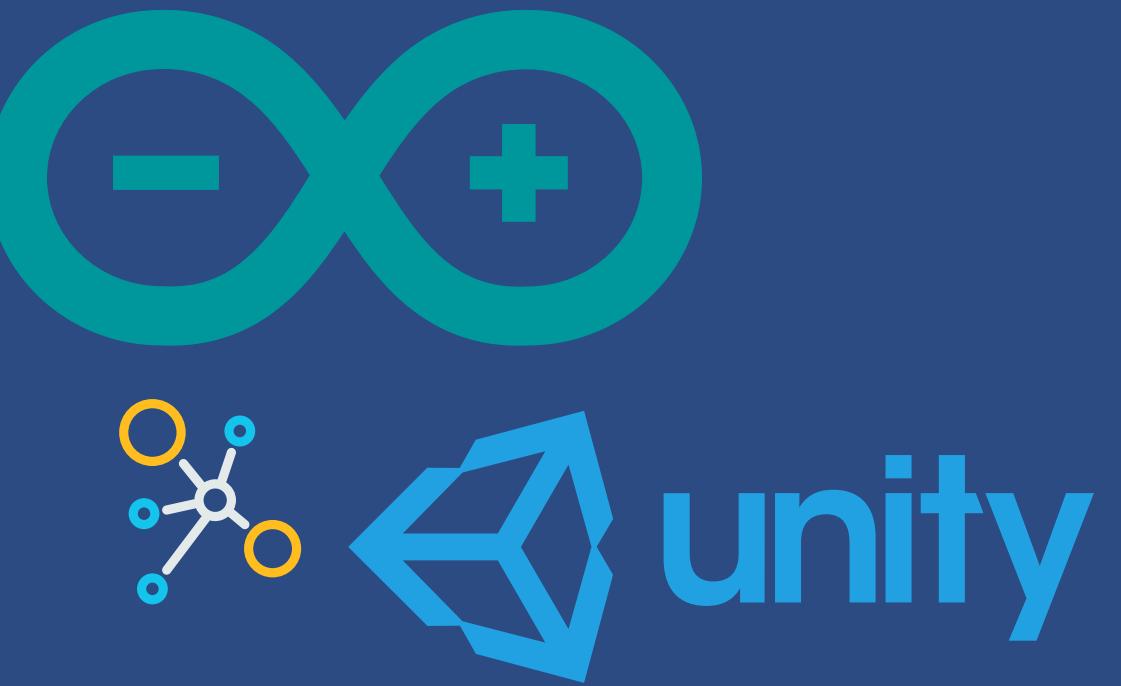




Classification input process



Kết nối Arduino với Unity





Install and import Ardity from Unity Asset Store

The screenshot shows the Unity Asset Store interface. On the left, there's a preview window for the Ardity package, which features a blue and yellow logo and a brief description of its purpose: connecting Arduino to Unity over a COM port. The main area displays the Package Manager with the Ardity package listed at version 1.1.0. To the right of the package listing is detailed information about the Ardity asset.

Ardity: Arduino + Unity communication made easy

Daniel Wilches · Version 1.1.0 - August 21, 2018 · asset store

Want to connect your Arduino to Unity over a COM port? Ardity allows bidirectional communication over COM ports from Unity. (Ardity was previously called SerialCommUnity, in case you are More...)

Images & Videos

Want to connect your Arduino to Unity over a COM port? Ardity allows bidirectional communication over COM ports from Unity. (Ardity was previously called SerialCommUnity, in case you are More...)

Package Size
Size: 718.52 KB (Number of files: 19)

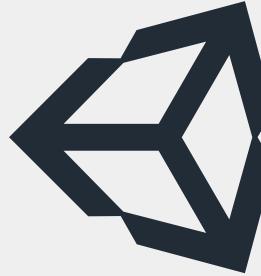
Supported Unity Versions
2018.2.0 or higher

Purchased Date
January 14, 2023

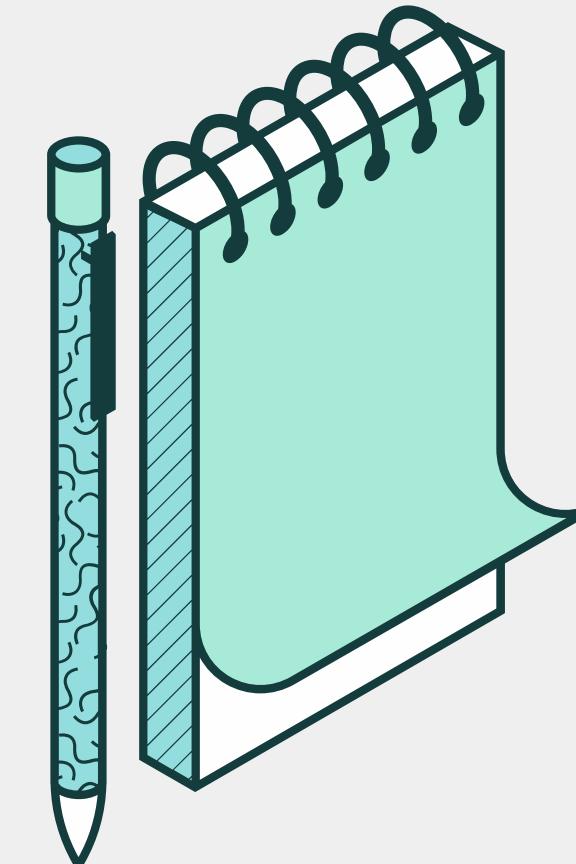
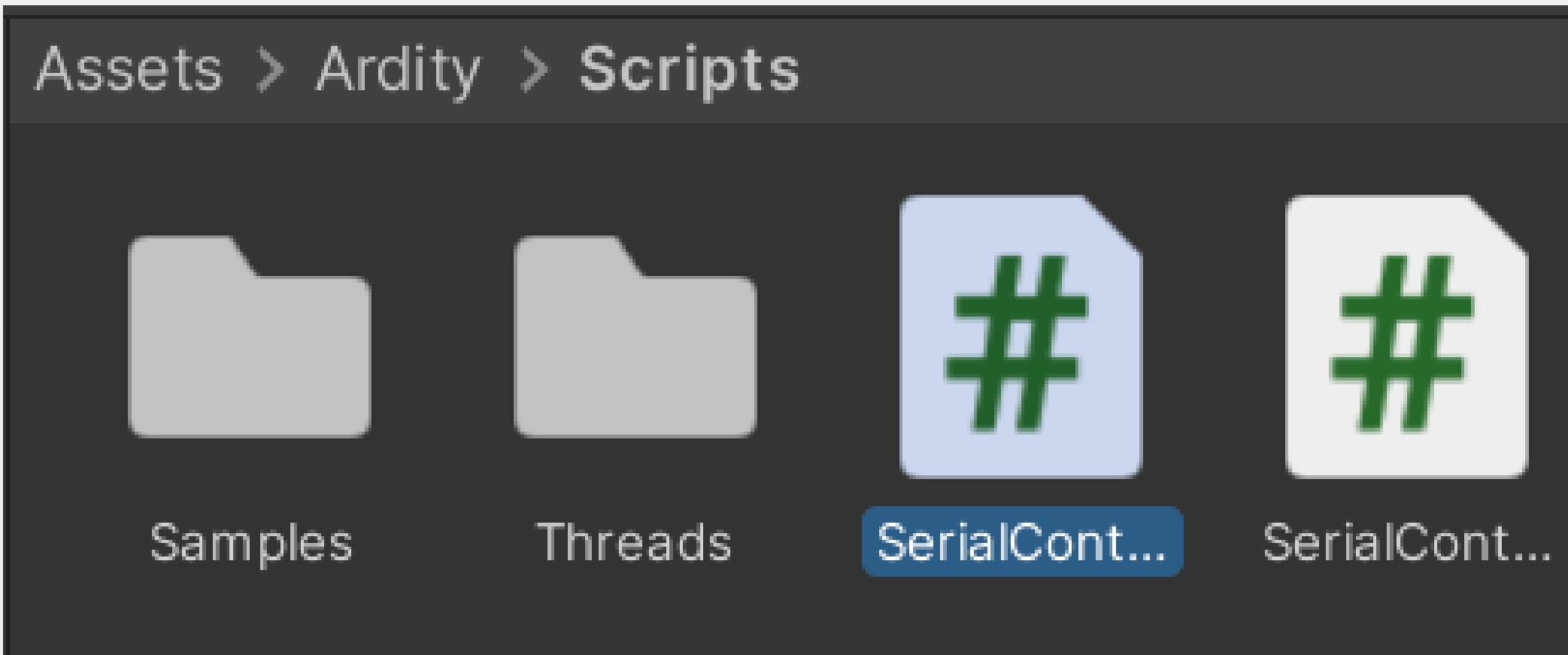
Release Details
1.1.0 (Current) - released on August 21, 2018 · More...
Original - released on August 21, 2018

Last update Jan 15, 05:52

Import Re-Download



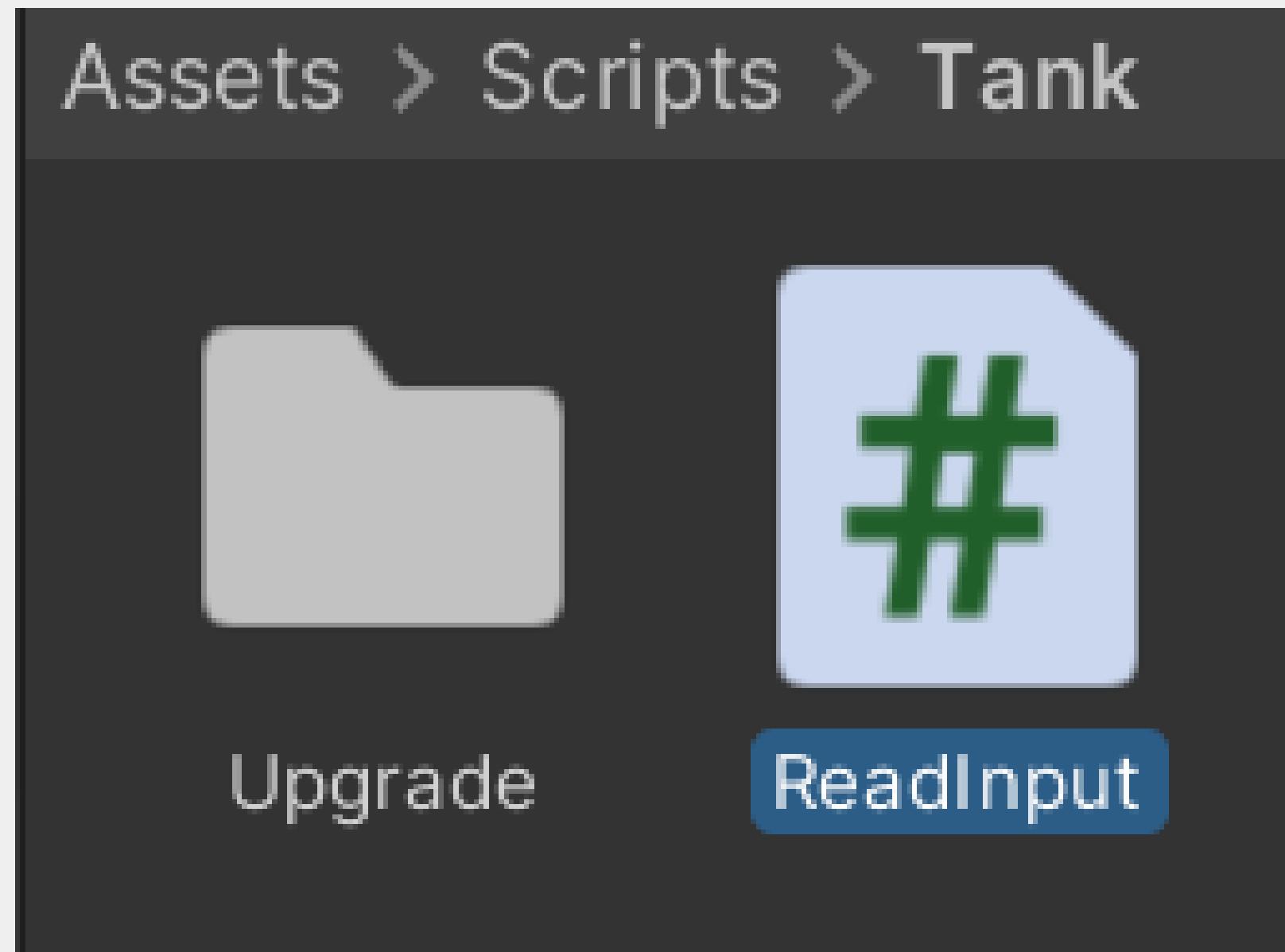
unity Update port COM and baud rate

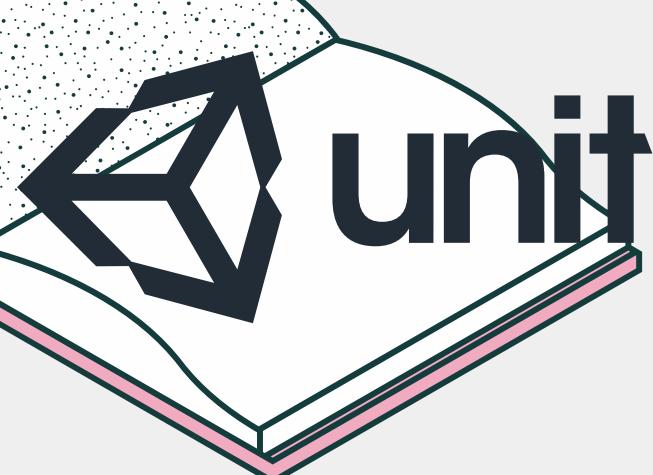


```
[Tooltip("Port name with which the SerialPort object will be created")]
public string portName = "COM4";

[Tooltip("Baud rate that the serial device is using to transmit data.")]
public int baudRate = 115200;
```

unity Create Read Input file and add it as component to object





unity

Read Input file

```
SerialPort data_stream = new SerialPort("COM4", 115200);
```

```
----->-----> ~~~~~~<-----<-----<
```

```
data_stream.Open();
```

```
if (data_stream.IsOpen)
{
    try
    {
        Movement(data_stream.ReadLine());
    }
    catch
    {
        throw;
    }
}
```

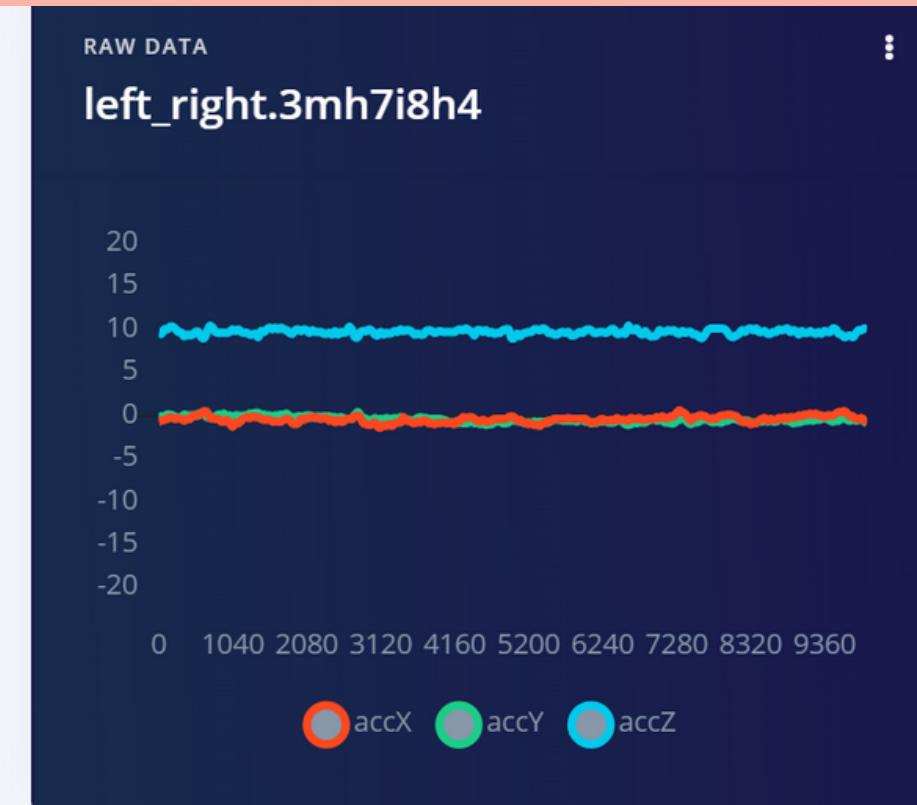
```
void Movement(string direction)
{
    if (direction == "left")
    {
        X = -1;
        Y = 0;
    }
    else if (direction == "right")
    {
        X = 1;
        Y = 0;
    }
    else if (direction == "up")
    {
        X = 0;
        Y = 1;
    }
    else if (direction == "down")
    {
        X = 0;
        Y = -1;
    }
    else
    {
        X = 0;
        Y = 0;
    }
}
```

Đánh giá tổng quát



Dữ liệu thu được

SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
left_right.3m...	left_right	Jan 13 202...	10s	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
left_right.3m...	left_right	Jan 13 202...	10s	⋮
left_right.3m...	left_right	Jan 13 202...	10s	⋮



Một số dữ liệu đầu vào cho
dải quang phổ giống nhau dù
khác label khiến cho việc
train model và detect hành
động dễ gây nhiễu

SAMPLE NAME	LABEL	ADDED	LENGTH	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
left_right.3m...	left_right	Jan 13 202...	10s	⋮
up_down.3m...	up_down	Jan 13 202...	10s	⋮
left_right.3m...	left_right	Jan 13 202...	10s	⋮
left_right.3m...	left_right	Jan 13 202...	10s	⋮



Kết quả sau khi train model



FEEDBACK

Kết quả sau khi train với độ chính xác cao, sai số nhỏ, chứng tỏ mô hình học tốt

Kết quả sau khi test model



Sau khi test model, kết quả cho độ chính xác là 98.1%, chứng tỏ mô hình này là đúng đắn

Model testing results



ACCURACY
98.10%

	LEFT_RIGHT	UP_DOWN	UNCERTAIN
LEFT_RIGHT	99.2%	0%	0.8%
UP_DOWN	3.6%	96.4%	0%
F1 SCORE	0.98	0.98	

Feature explorer ⓘ

- left_right - correct
- up_down - correct
- left_right - incorrect
- up_down - incorrect





Đưa mô hình vào thiết bị nhúng và điều khiển

Dữ liệu đầu vào có 1 phần gây nhiễu
dẫn đến việc nhận hành động từ thiết
bị có phần sai sót

Khi sử dụng thiết bị điều khiển game
Unity, chương trình vẫn còn chậm và lag

Phản trình bày của em đến đây là
hết. Cảm ơn Thầy đã lắng nghe!

