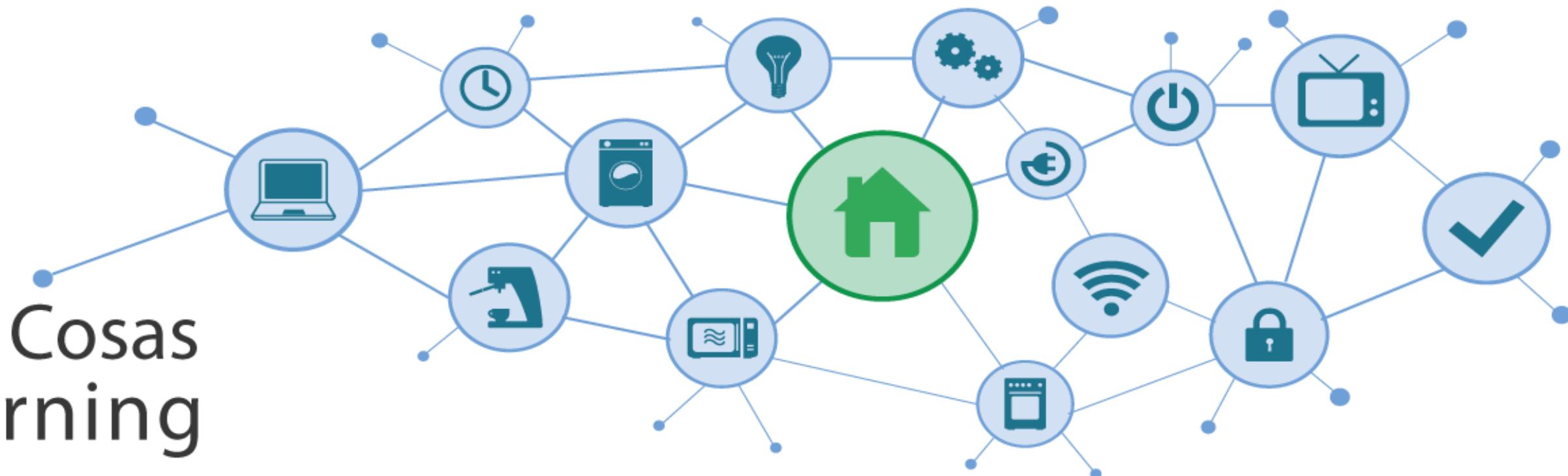


Track4  
IoT

Internet de las Cosas  
Machine Learning



## Image Classification Application

Prof. Stalin Arciniegas  
PUCE Ibarra  
[smarciniegas@pucesi.edu.ec](mailto:smarciniegas@pucesi.edu.ec)

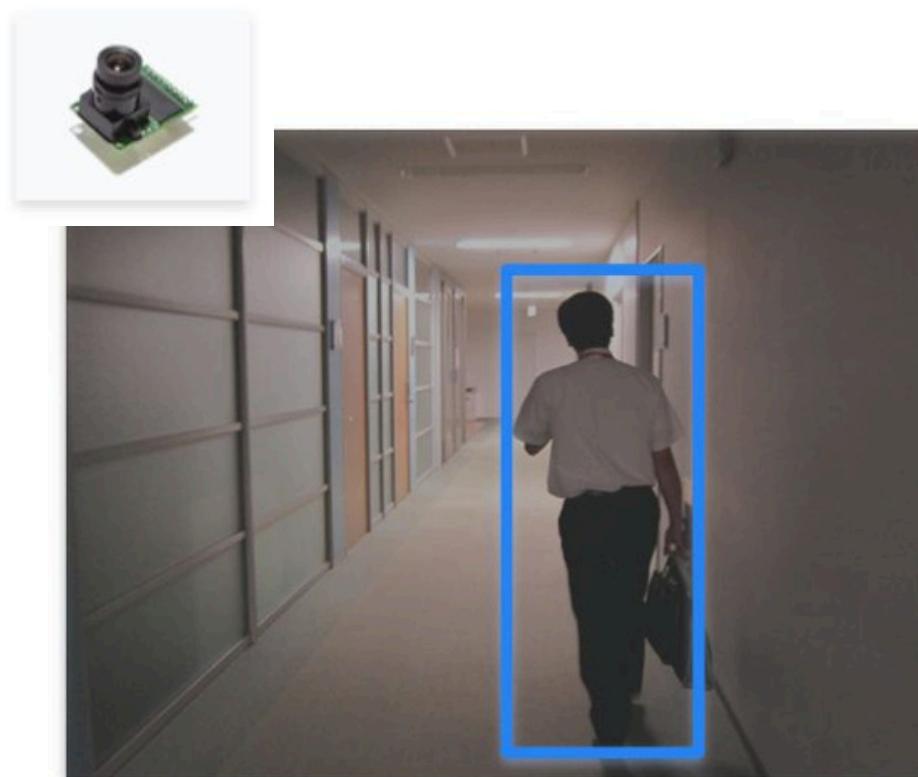




El Mgs. Stalin Arciniegas es docente a tiempo completo de la Escuela de Ingeniería de la PUCE Ibarra desde el 2012, actualmente es el director de Escuela de Ingeniería. Obtuvo los siguientes títulos: Máster Universitario en visual Analytics and Big Data, Magister para la Gestión y Práctica Docente, e Ingeniero en Mecatrónica.

Actualmente, forma parte del grupo de investigación en sistemas Inteligentes (GISI) y el grupo TinyML4D Academic Network, donde ha participado en 7 proyectos, de los cuales en 2 ha sido director, y ha publicado alrededor de 32 artículos científicos en revistas indexadas. El campo de la investigación que actualmente se encuentra activo es TinyML. (Machine Learning en dispositivos electrónicos de bajo consumo).

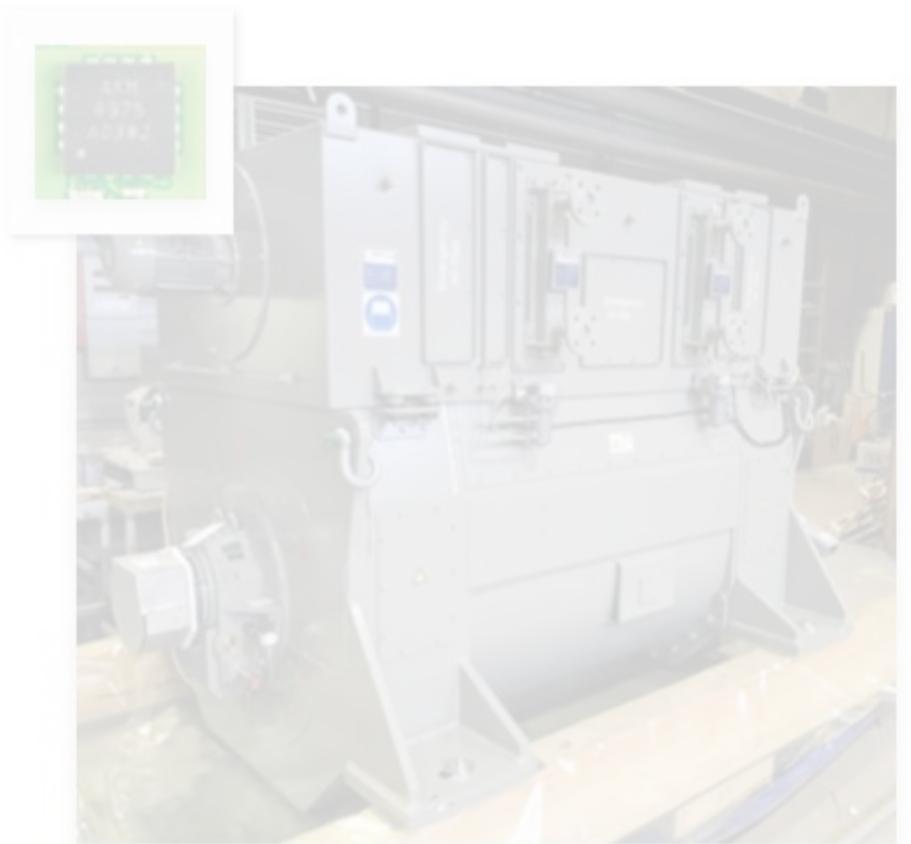
# Vision



# Sound



# Vibration

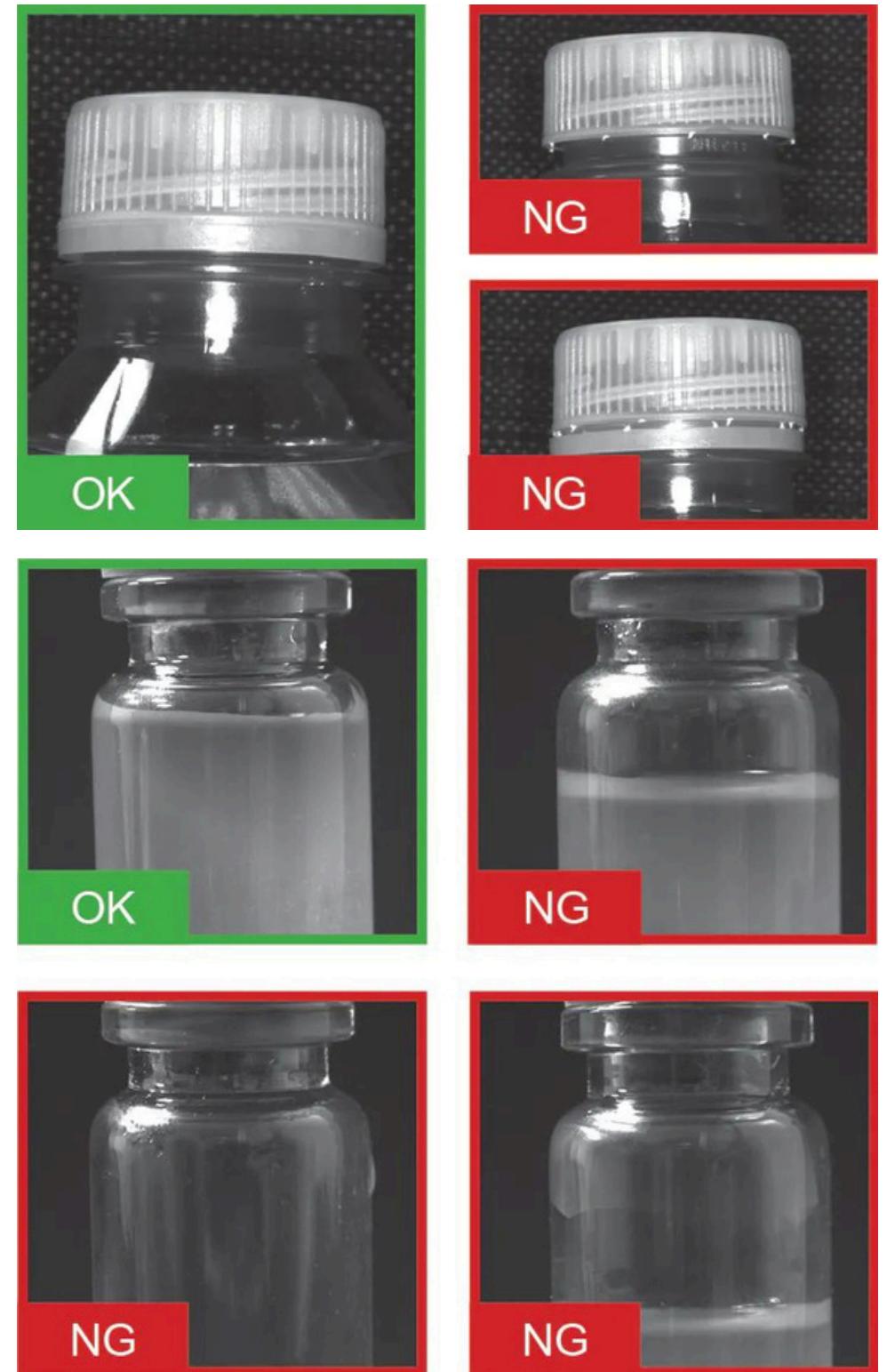


# Image Classification

## Application: Design, Train, Test and Deploy



# Package Inspection

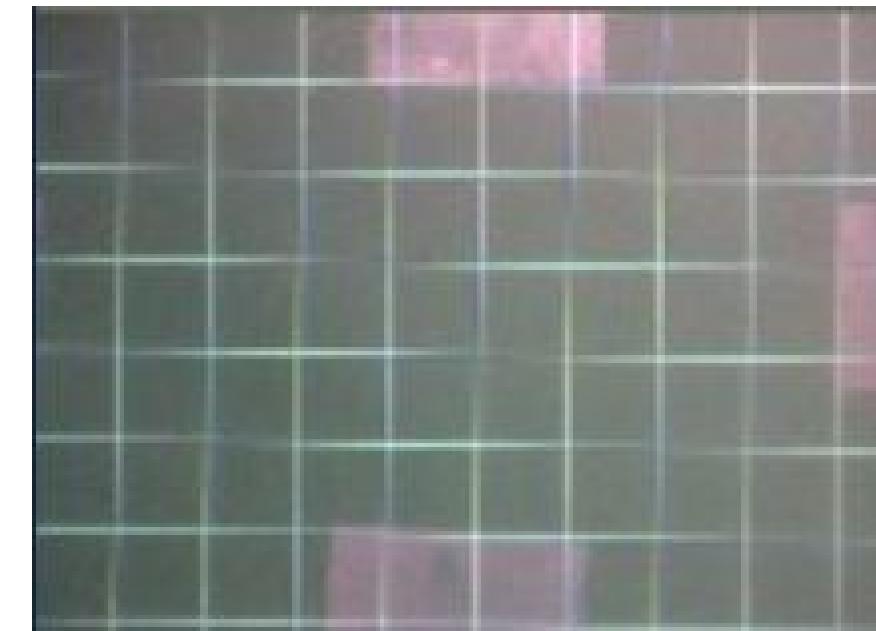


Deep Learning at the Edge Simplifies Package Inspection

# Image Classification Project 1



- Possible Images:
  - medicine
  - background

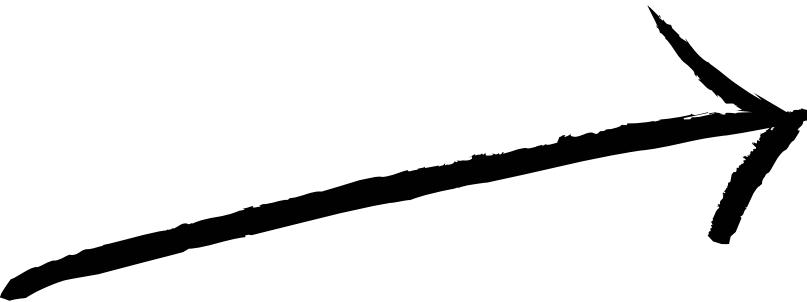


<https://studio.edgeimpulse.com/public/114253/latest>

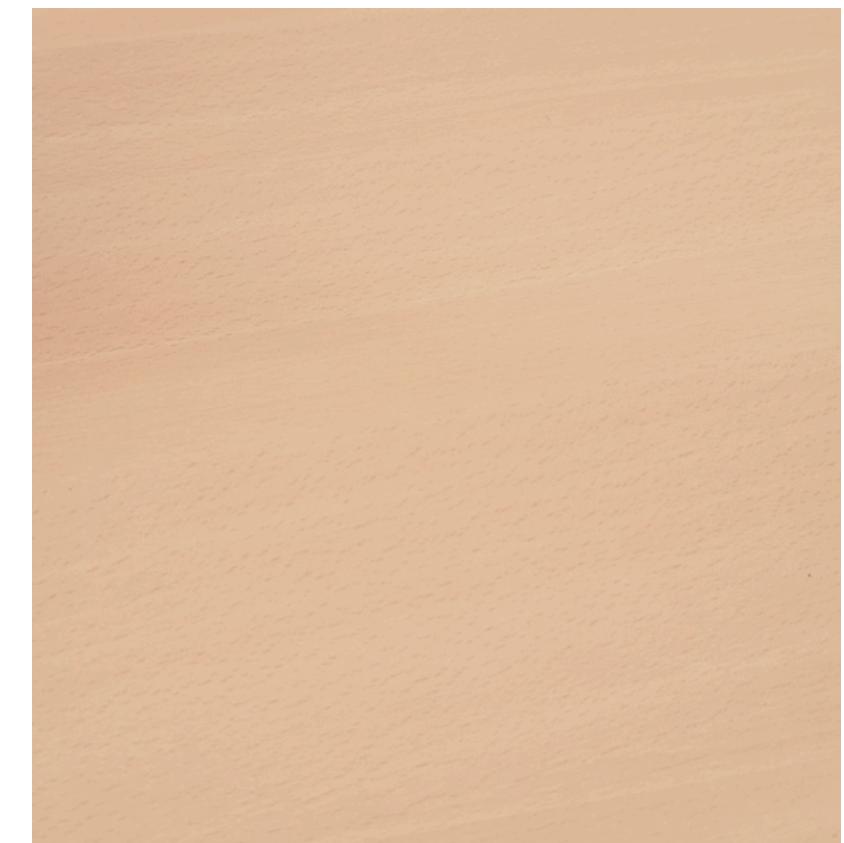
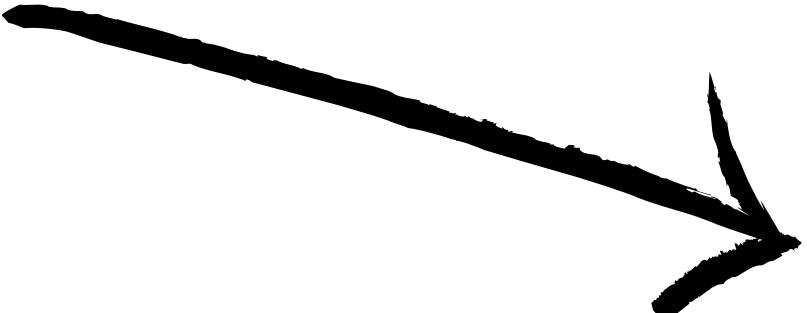
# Image Classification Project 2



- Possible Images:  
Tomatodo



- background



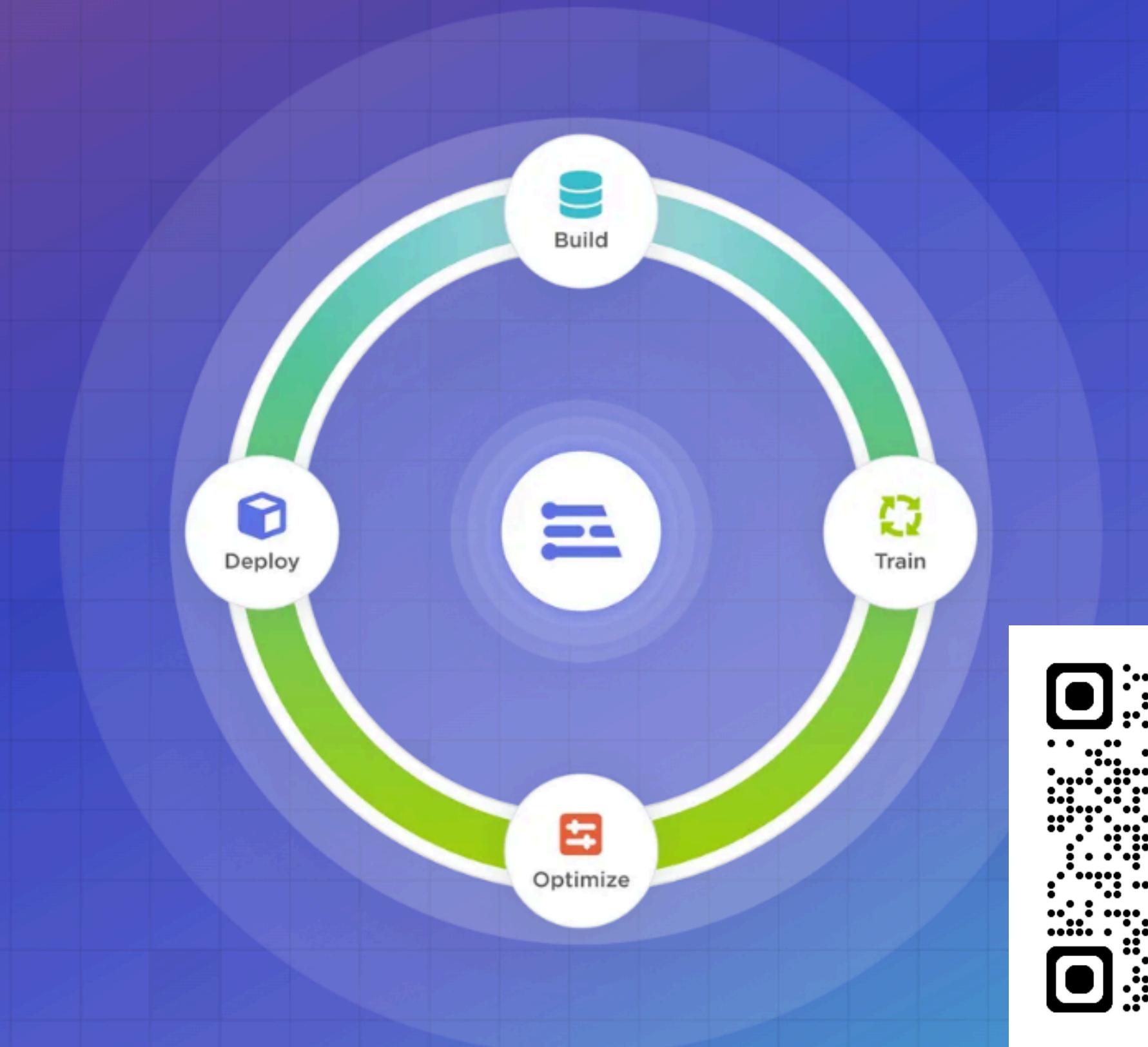
# AI for Any Edge Device

## Docker Containers

Build datasets, train models, and optimize libraries to run directly on device; from the smallest microcontrollers to gateways with the latest neural accelerators (and anything in between).

[Get Started](#)

[Talk to an AI Expert](#)





# smarciniegas

COMMUNITY

## Organizations

Allow anyone on your team to collaborate on multiple datasets, automation, and models in a shared workspace.

[Try Enterprise free](#)

### Create a new project

Enter the name for your new project:

Choose your project type:

Personal  
20 min job limit, 4GB or 4 hours of data, limited collaboration.

Enterprise  
No job or data size limits, higher performance, custom blocks.

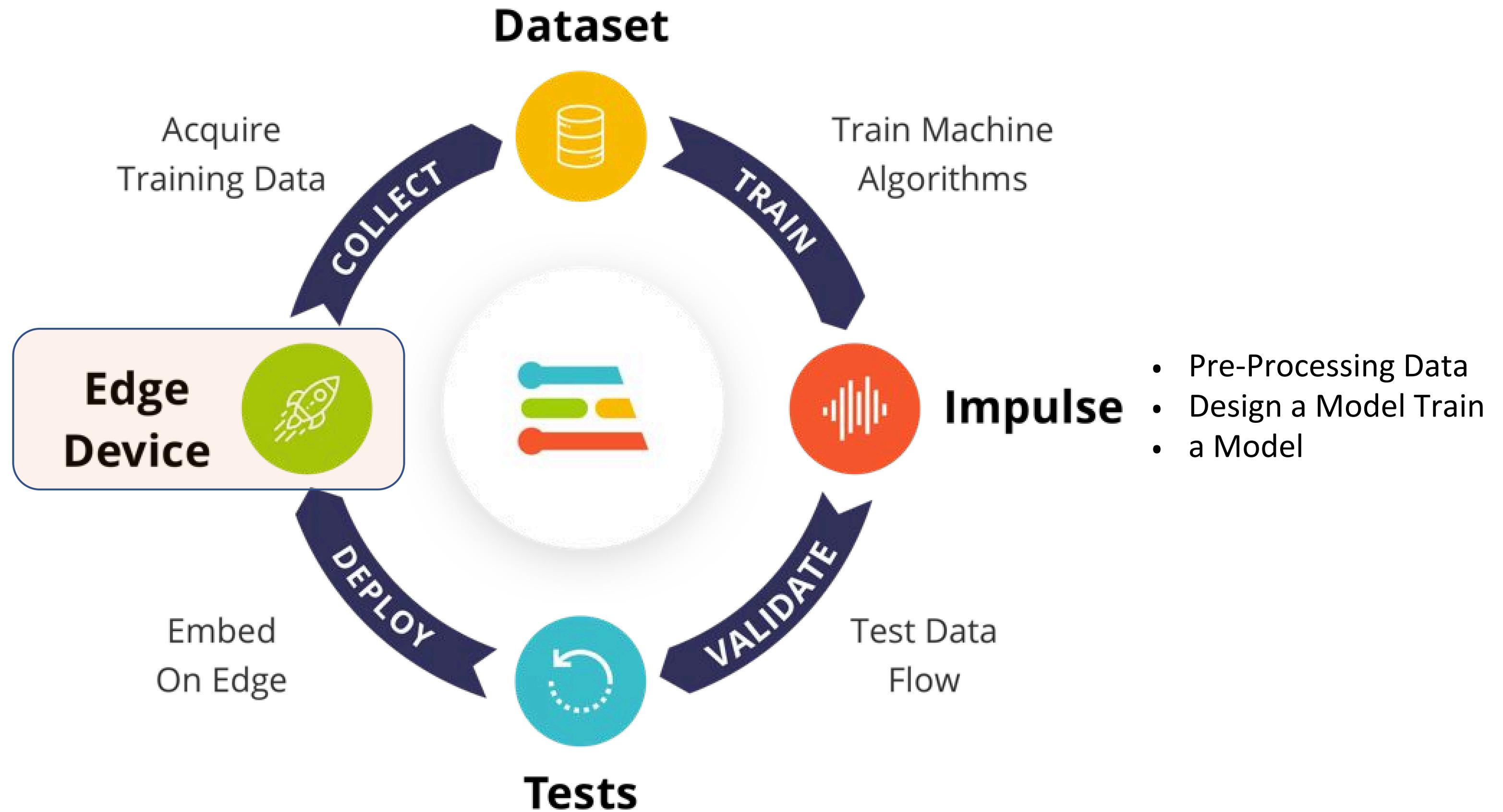
Choose your project setting:

Public  
Anyone on the internet can view and clone this project under the licence: [Apache 2.0](#). Only invited users will be able to edit.

Private (0 of 2 remaining)  
Only invited users can edit and view your project.

 Want full-feature access and unlimited projects? [Try Enterprise free](#).

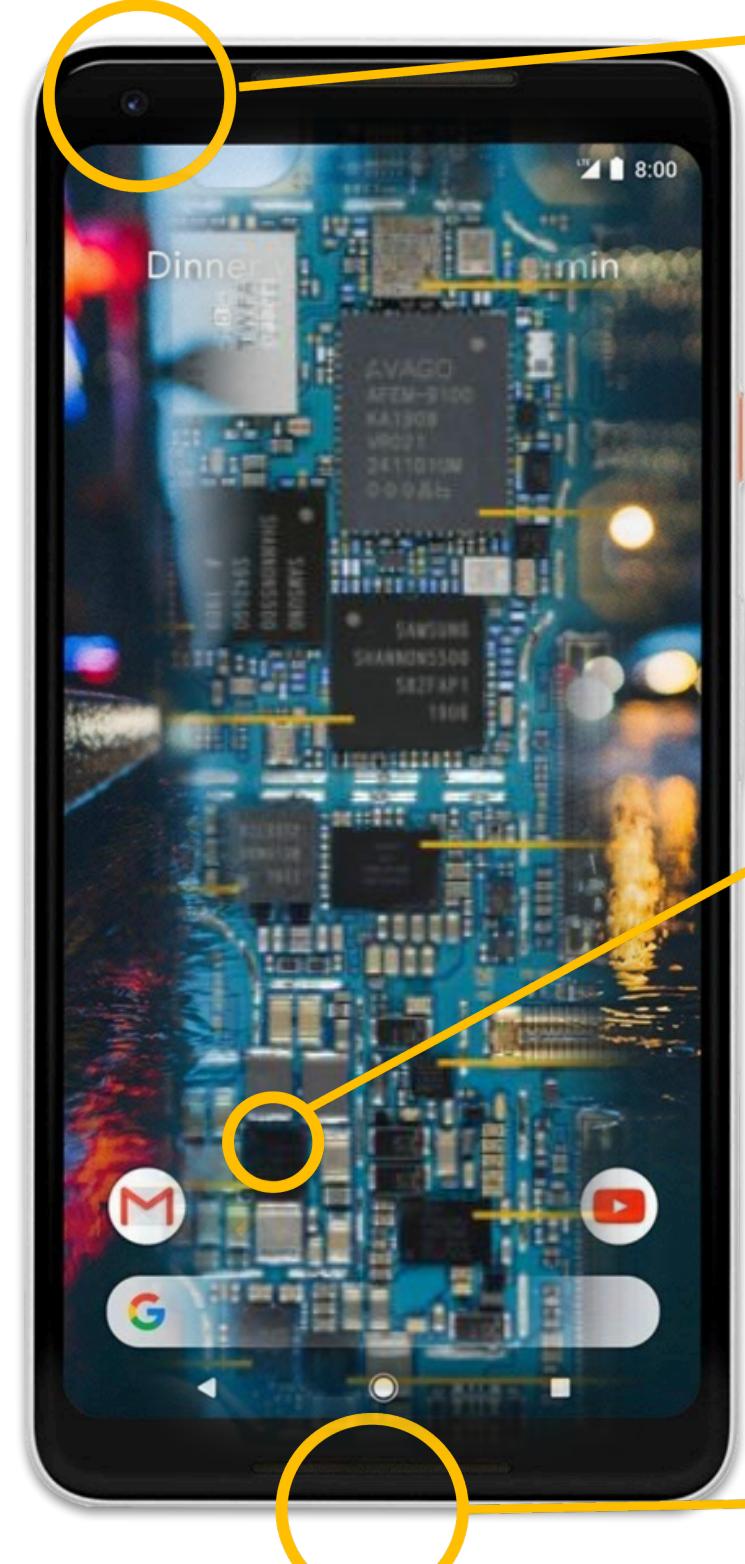
[Create new project](#)



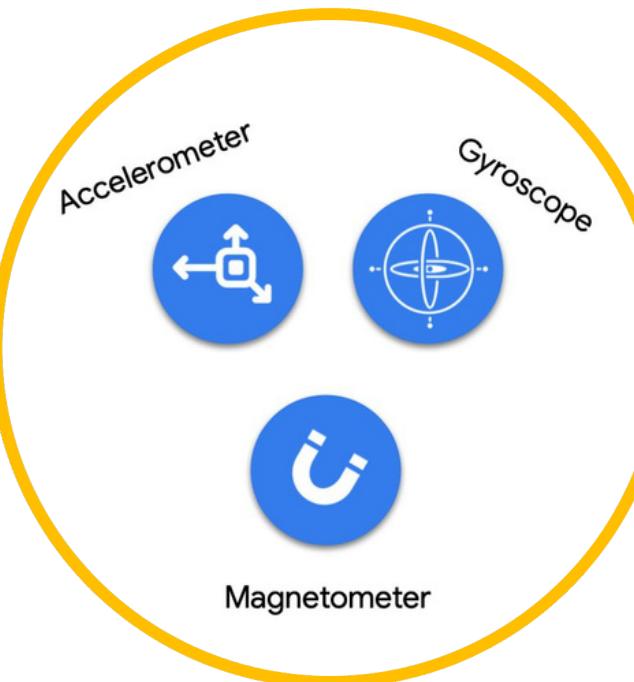
# Edge Device



& Sensors



Camera



Accelerometer



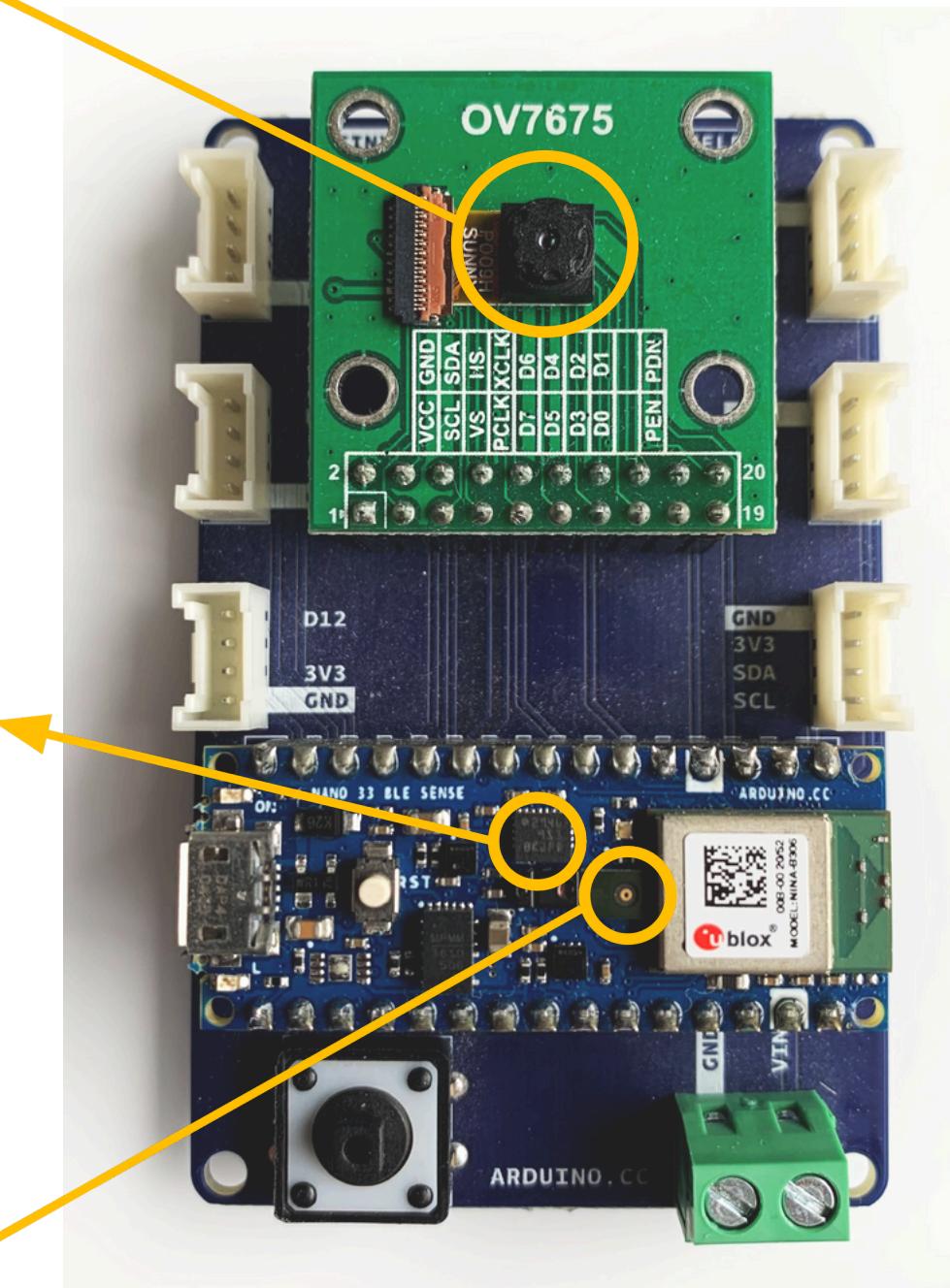
Gyroscope



Magnetometer



Microphone





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

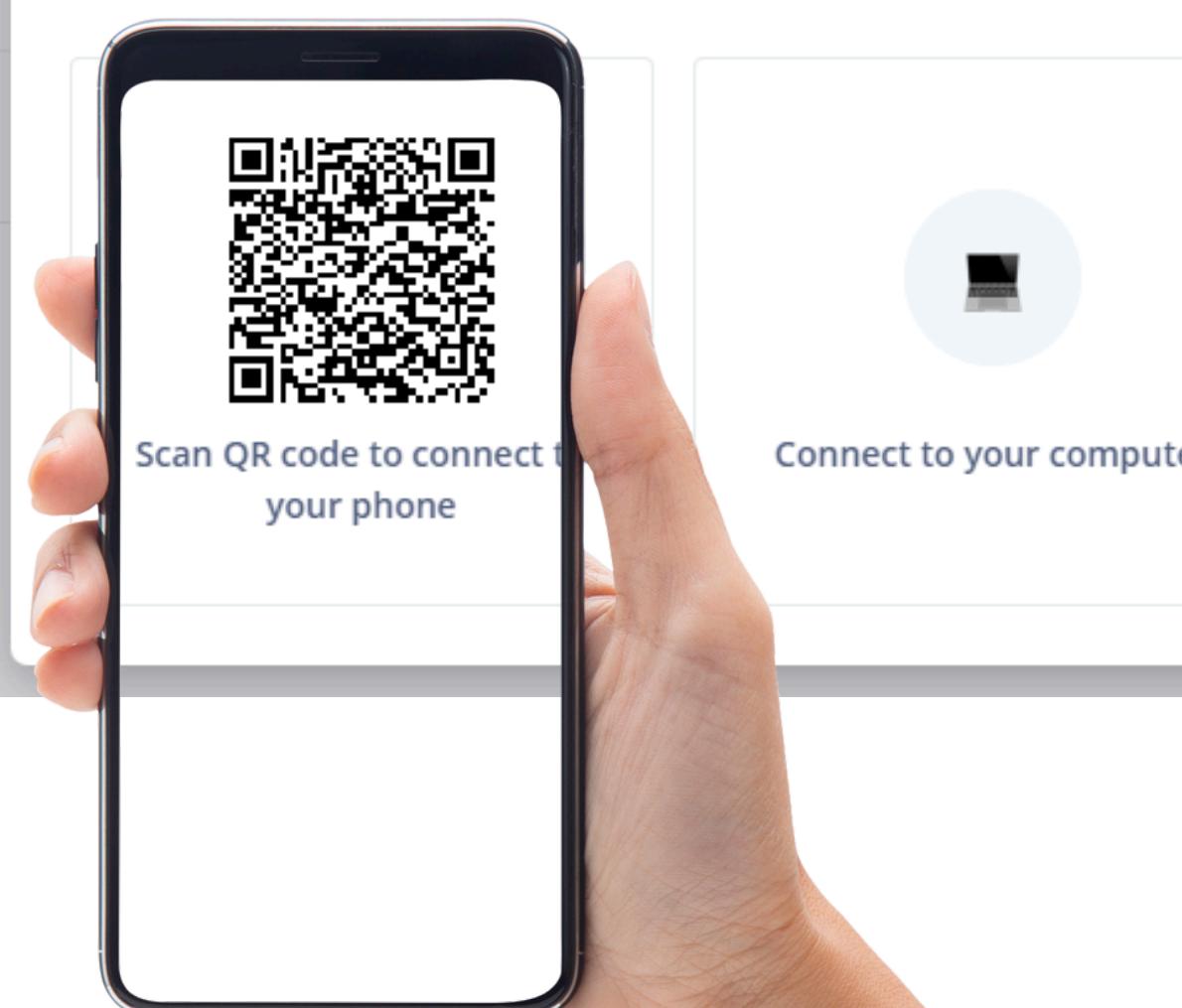
Connect to your computer

Connect your device or development board

Target: Cortex-M4F 80MHz

+ Connect a new device

SDK.



**EDGE IMPULSE**

Dashboard

Devices

Data acquisition

Experiments

EON Tuner

Impulse design

- Create impulse
- Image
- Transfer learning

Collect new data

Device "phone\_m3djsdgk" is now connected

Go to 'Data acquisition' to collect data from this device.

Get started!

Back

Target: Cortex-M4F 80MHz

+ Connect a new device

SDK.

PE

OBILE

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?



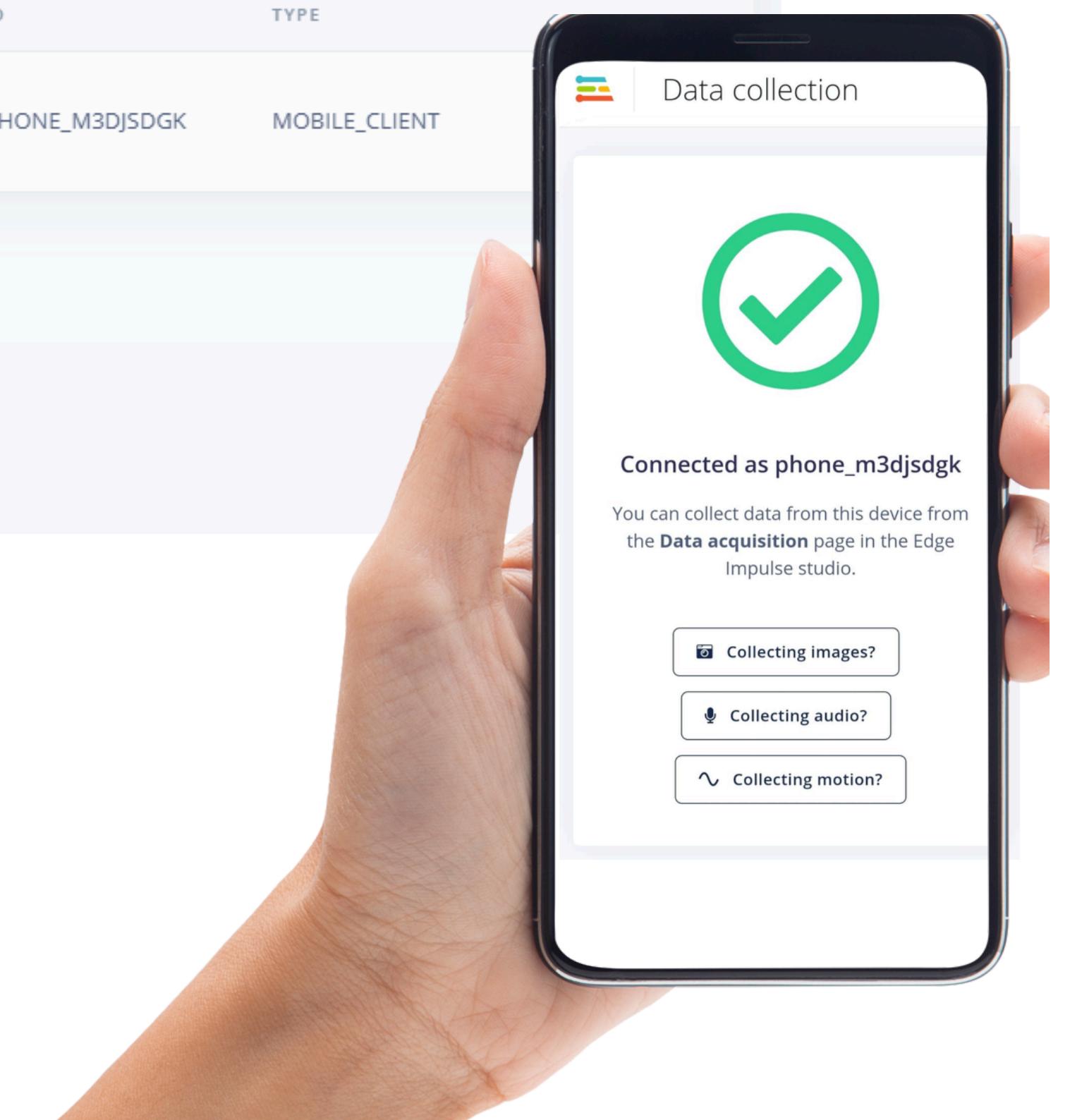
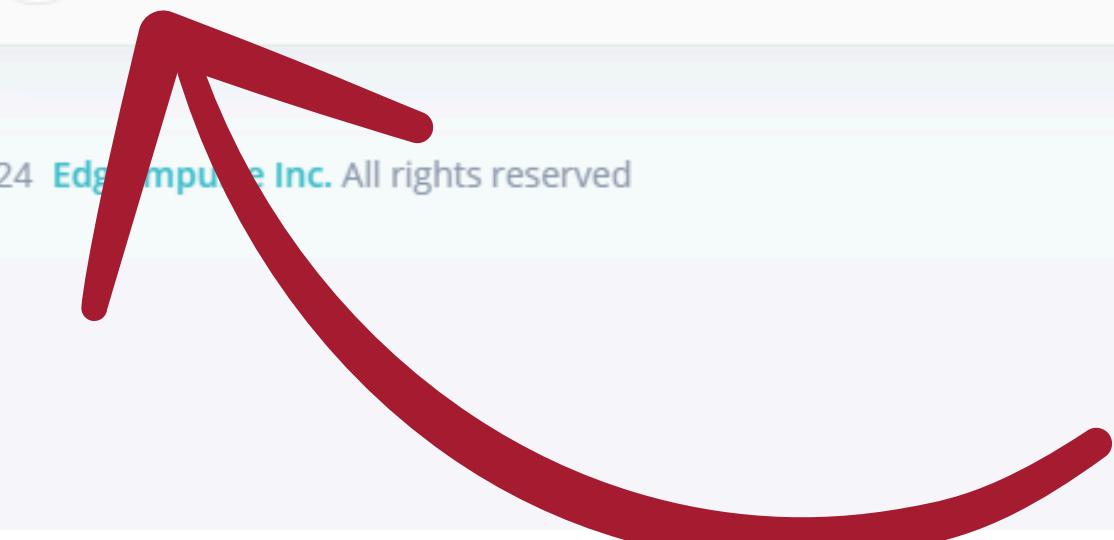
- Dashboard
- Devices
- Data acquisition
- Experiments
- EON Tuner
- Impulse design
  - Create impulse
  - Image
  - Transfer learning
- Retrain model

## Your devices

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

DEVICE	ID	TYPE
phone_m3djsdgk Connected to data acquisition (Accelerometer, Microphone, Camera, Positional)	PHONE_M3DJS DGK	MOBILE_CLIENT

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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



Permission required

[Give access to the camera](#)

[Switch to classification mode](#)



Data collection

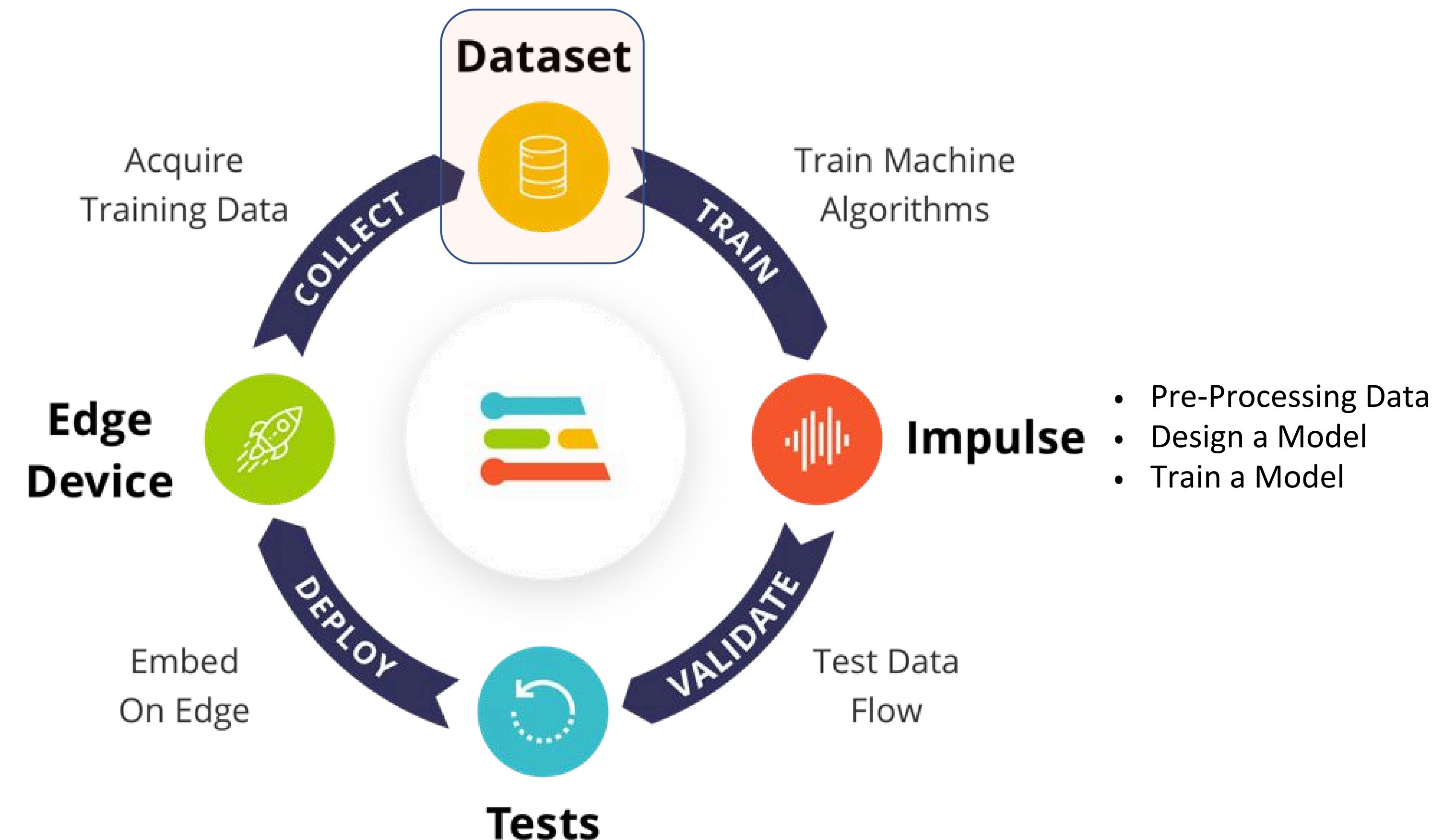
Label: Tomatodo

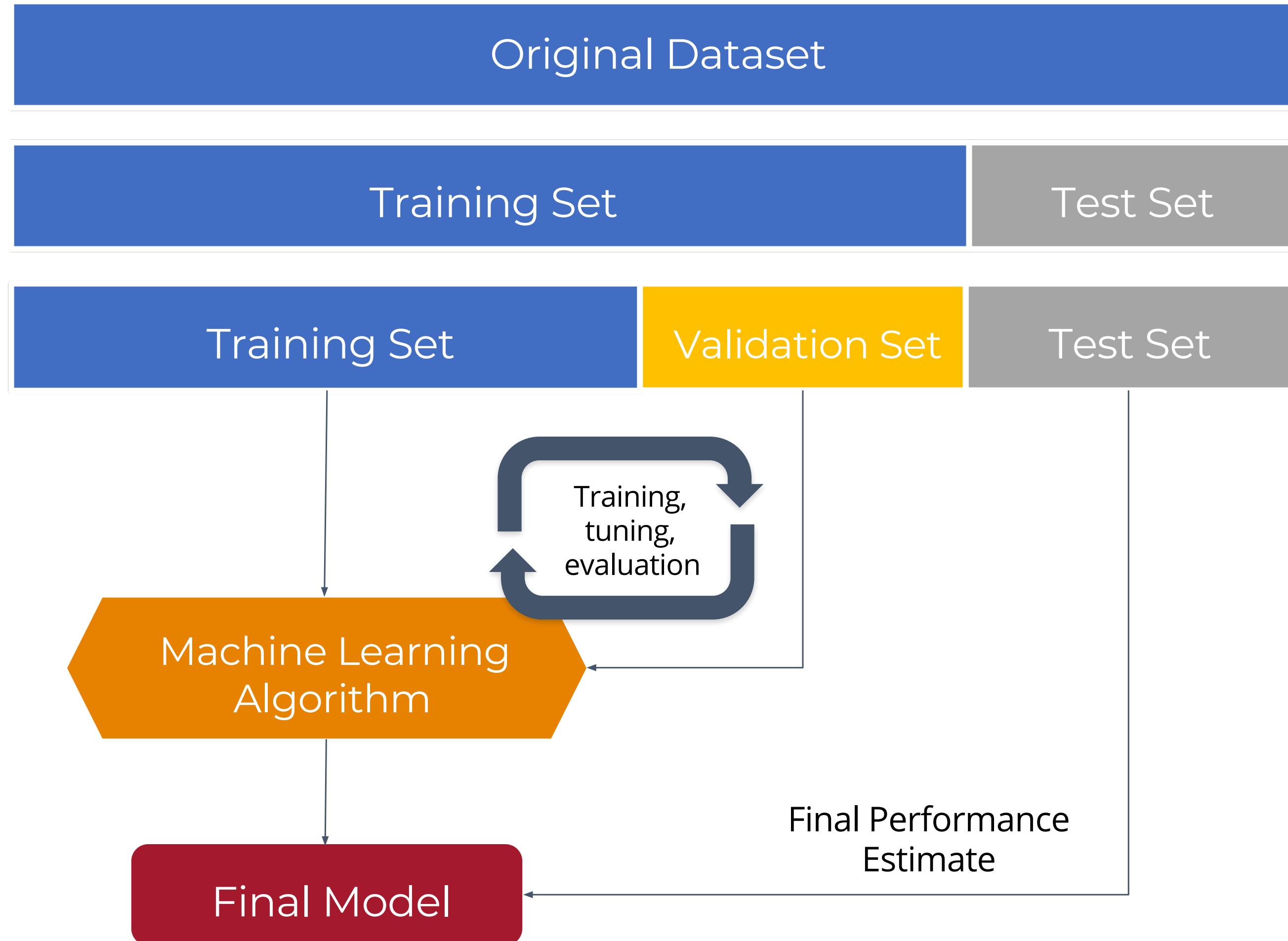
Category: Split automatically (80/20) ▾



Capture

Images captured with current settings: 0





[Dashboard](#)[Devices](#)[Data acquisition](#)[Experiments](#)[EON Tuner](#)[Impulse design](#)[Create impulse](#)[Image](#)[Transfer learning](#)[Retrain model](#)[Live classification](#)[Model testing](#)[Dataset](#)[Data explorer](#)[Data sources](#)[CSV Wizard](#)

DATA COLLECTED

242 items



TRAIN / TEST SP...

81% / 1...



## Dataset

[Upload](#) [Cloud](#) [Download](#)[Training \(196\)](#)[Test \(46\)](#)[Edit](#) [Filter](#) [Select All](#) [Delete](#)

SAMPLE NAME

LABEL

ADDED

piso.3sk85h00

piso

mar 29 2023...

⋮

piso.3sk85gcr

piso

mar 29 2023...

⋮

piso.3sk85ftl

piso

mar 29 2023...

⋮

piso.3sk85flf

piso

mar 29 2023...

⋮

piso.3sk85fff

piso

mar 29 2023...

⋮

## Collect data

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

### RAW DATA

**Click on a sample to load...**



## Impulse #1



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

Dashboard

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Deployment

## Image data



## Input axes

image

Image wid...

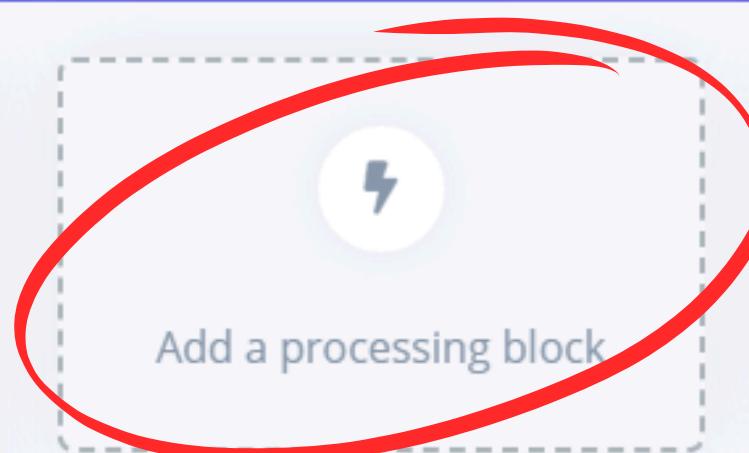
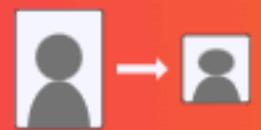
Image hei...

96

96

## Resize mode

Squas ▾



Add a learning block

## Output features



Save Impulse



Dashboard

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emarsinigas / Clasificación imágenes puercos - project

Target: Cortex-M4F 80MHz



## ⚡ Add a processing block

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

DESCRIPTION	AUTHOR	RECOMMENDED
<b>Image</b> OFFICIALLY SUPPORTED Preprocess and normalize image data, and optionally reduce the color depth.	Edge Impulse	★ <a href="#">Add</a>
<b>Raw Data</b> OFFICIALLY SUPPORTED Use data without pre-processing. Useful if you want to use deep learning to learn features.	Edge Impulse	<a href="#">Add</a>

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

[Add custom block](#)

[Cancel](#)

Output features



[Save Impulse](#)



Dashboard

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## Add a learning block

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

DESCRIPTION	AUTHOR	RECOMMENDED
-------------	--------	-------------

Transfer Learning (Images) OFFICIALLY SUPPORTED

Fine tune a pre-trained image classification model on your data. Good performance even with relatively small image datasets.

Edge Impulse



Add

Classification OFFICIALLY SUPPORTED

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

Edge Impulse

Add

Regression OFFICIALLY SUPPORTED

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

Edge Impulse

Add

Classification - BrainChip Akida™ OFFICIALLY SUPPORTED

Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio. Only works with BrainChip AKD1000 MINI PCIe board.

BrainChip

Add

Transfer Learning (Images) - BrainChip Akida™ OFFICIALLY SUPPORTED

Fine tune a pre-trained image classification model on your data. Good

Output  
features



Save Impulse



## 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

Experiments

EON Tuner

Impulse design

Create impulse

Image

Transfer learning

Retrain model

Live classification

Model testing

Deployment

**Image data**

**Input axes**

image

Image width: 96      Image height: 96

**Resize mode**

Squa

**Image**

Name: Image

Input axes (1):  image

**Transfer Learning (Images)**

Name: Transfer learning

**Input features**

Image

**Output features**

2 (piso, tomatodo)

**Output features**

2 (piso, tomatodo)



- Dashboard
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- EON Tuner
- Impulse design
  - Create impulse
  - Image
  - Transfer learning
- Retrain model
- Live classification
- Model testing
- Deployment
- Versioning

### Upgrade Plan

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

[View plans](#)[Parameters](#) [Generate features](#)

### Raw data

Show: All labels

tomatodo.3sk7fok6 (tor



### Raw features

```
0x46504f, 0x5b6766, 0x63706c, 0x6c7773, 0x6d7771, 0x6c7571, 0x616a66, 0x5f6560, 0x4a4b46, 0x494c4a, 0x5f6d6c,...
```

### Parameters

#### Image

Color depth

[Save parameters](#)

### DSP result

#### Image



#### Processed features

```
0.3016, 0.3894, 0.4222, 0.4520, 0.4523, 0.4465, 0.4033, 0.3868, 0.2907, 0.2936, 0.4106, 0.3974, 0.3723, 0.374...
```

### On-device performance

PROCESSING TIME  
7 ms.

PEAK RAM USAGE  
4 KB



[Dashboard](#)[Devices](#)[Data acquisition](#)[Experiments](#)[EON Tuner](#)[Impulse design](#)[Create impulse](#)[Image](#)[Transfer learning](#)[Retrain model](#)[Live classification](#)[Model testing](#)

### Upgrade Plan

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

[View plans](#)[Parameters](#) [Generate features](#)

### Training set

Data in training set 196 items

Classes 2 (piso, tomatodo)

[Generate features](#)

### Feature generation output

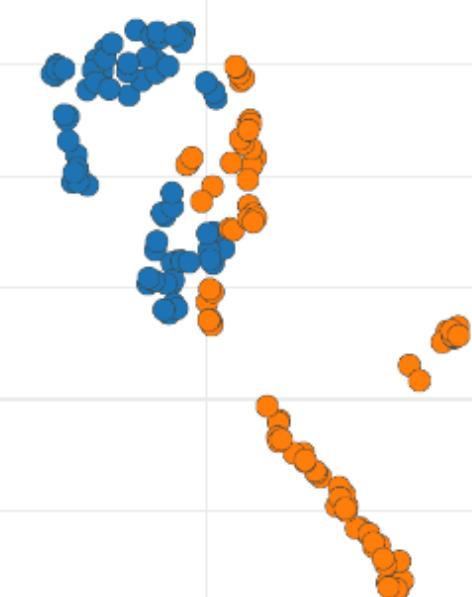
[\(0\)](#)

```
Container image pulled!
Job started
Reducing dimensions for visualizations...
UMAP( verbose=True)
Mon Nov 11 22:14:00 2024 Construct fuzzy simplicial set
Mon Nov 11 22:14:00 2024 Finding Nearest Neighbors
Mon Nov 11 22:14:02 2024 Finished Nearest Neighbor Search
Mon Nov 11 22:14:04 2024 Construct embedding
Epochs completed: 100% 500/500 [00:02<00:00, 182.60it/s]
Mon Nov 11 22:14:07 2024 Finished embedding
Writing output files...
Writing output files OK
Reducing dimensions for visualizations OK (took 9045ms.)
```

Job completed (success)

### Feature explorer

piso  
tomatodo



### On-device performance



PROCESSING TIME  
7 ms.



PEAK RAM USAGE  
4 KB



# MobileNet

Es una red neuronal convolucional diseñada específicamente para dispositivos móviles y embebidos

Está optimizada para tener un buen balance entre eficiencia y precisión

## MODEL

MobileNetV1 96x96 0.25

OFFICIALLY SUPPORTED

A pre-trained multi-layer convolutional network designed to efficiently classify images. Uses around 105.9K RAM and 301.6K ROM with default settings and optimizations.

MobileNetV1 96x96 0.2

OFFICIALLY SUPPORTED

Uses around 83.1K RAM and 218.3K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.

MobileNetV1 96x96 0.1

OFFICIALLY SUPPORTED

Uses around 53.2K RAM and 101K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.

MobileNetV2 96x96 0.35

OFFICIALLY SUPPORTED

Uses around 296.8K RAM and 575.2K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.

**96x96**

Indica el tamaño de entrada de las imágenes

Significa que las imágenes deben ser de 96 píxeles de ancho por 96 píxeles de alto

**0.35**

Es el factor de multiplicador de anchura

Va de 0 a 1, donde números más pequeños indican redes más ligeras

Este factor ayuda a reducir el tamaño del modelo y la cantidad de cálculos necesarios

Modelo	RAM	ROM	Tamaño de entrada	Soporte de color
MobileNetV1 96x96 0.25	105.9K	301.6K	96x96	RGB y escala de grises
MobileNetV1 96x96 0.2	83.1K	218.3K	96x96	RGB y escala de grises
MobileNetV1 96x96 0.1	53.2K	101K	96x96	RGB y escala de grises
MobileNetV2 96x96 0.35	296.8K	575.2K	96x96	RGB y escala de grises
MobileNetV2 96x96 0.1	270.2K	212.3K	96x96	RGB y escala de grises
MobileNetV2 96x96 0.05	265.3K	162.4K	96x96	RGB y escala de grises
MobileNetV2 160x160 1.0	1.3M	2.6M	160x160	Solo RGB
MobileNetV2 160x160 0.75	1.3M	1.7M	160x160	Solo RGB
MobileNetV2 160x160 0.5	700.7K	982.4K	160x160	Solo RGB
MobileNetV2 160x160 0.35	683.3K	658.4K	160x160	Solo RGB

[Dashboard](#)[Devices](#)[Data acquisition](#)[Experiments](#)[EON Tuner](#)[Impulse design](#)[Create impulse](#)[Image](#)[Transfer learning](#)[Retrain model](#)[Live classification](#)[Model testing](#)[Deployment](#)[Versioning](#)**GETTING STARTED**[Documentation](#)[Forums](#)[Upgrade Plan](#)

Get access to higher job limits.

**Neural Network settings****Training settings**Number of training cycles ?Use learned optimizer ?Learning rate ?Training processor ?Data augmentation ?**Advanced training settings****Neural network architecture**

MobileNetV1

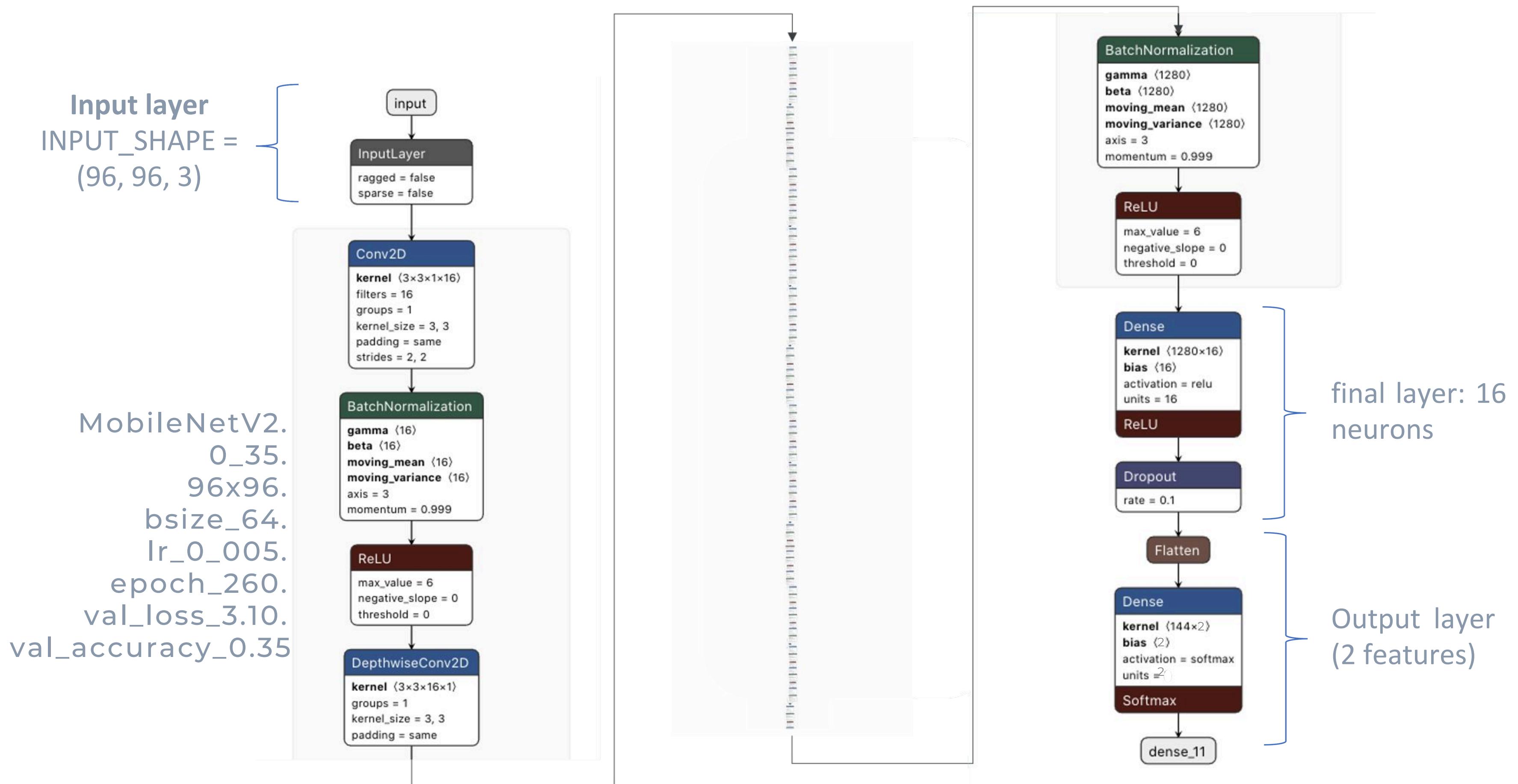
MODEL	AUTHOR	
MobileNetV1 96x96 0.25 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
A pre-trained multi-layer convolutional network designed to efficiently classify images. Uses around 105.9K RAM and 301.6K ROM with default settings and optimizations.		
MobileNetV1 96x96 0.2 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 83.1K RAM and 218.3K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.		
MobileNetV1 96x96 0.1 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 53.2K RAM and 101K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.		
MobileNetV2 96x96 0.35 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 296.8K RAM and 575.2K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.		
MobileNetV2 96x96 0.1 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 270.2K RAM and 212.3K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.		
MobileNetV2 96x96 0.05 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 265.3K RAM and 162.4K ROM with default settings and optimizations. Works best with 96x96 input size. Supports both RGB and grayscale.		
MobileNetV2 160x160 1.0 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 1.3M RAM and 2.6M ROM with default settings and optimizations. Works best with 160x160 input size. Supports RGB only.		
MobileNetV2 160x160 0.75 <small>OFFICIALLY SUPPORTED</small>	Edge Impulse	<a href="#">Add</a>
Uses around 1.3M RAM and 1.7M ROM with default settings and optimizations.		

**Choose a different model**

Did you know? You can customize your model through the Expert view (click on to switch), or can even bring your own model (in PyTorch, Keras or scikit-learn).



# MobileNetV2 96x96 0.35



### Neural Network settings

**Training settings**

Number of training cycles ②

Learning rate ②

Validation set size ②  %

Auto-balance dataset ②

Data augmentation ②

**Neural network architecture**

**Input layer (27,648 features)**



MobileNetV2 96x96 0.35 (final layer: 16 neurons, 0.1 dropout)

Choose a different model

**Output layer (2 classes)**

**Start training**

### Neural Network settings

**Training settings**

Validation set size ②  %

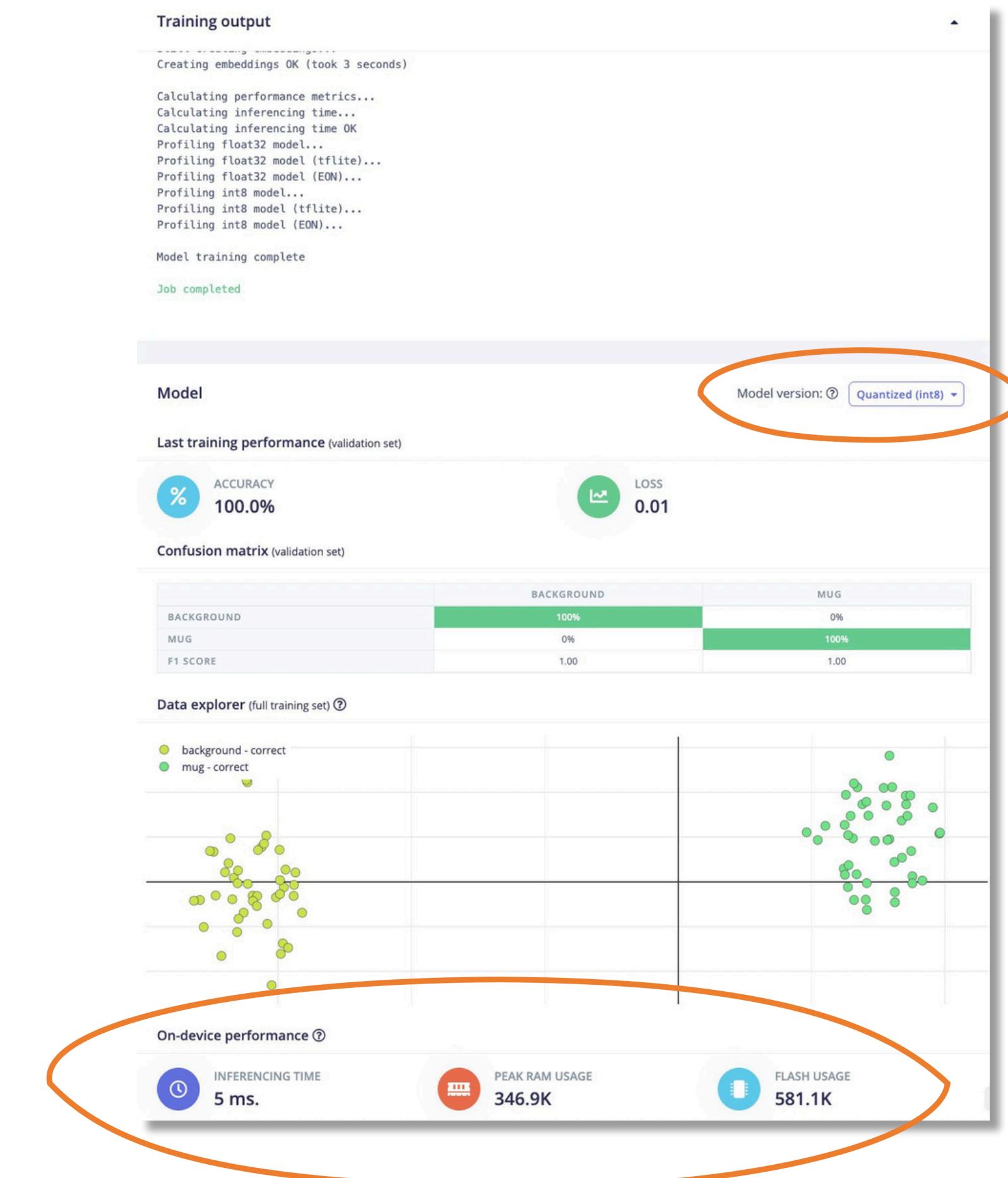
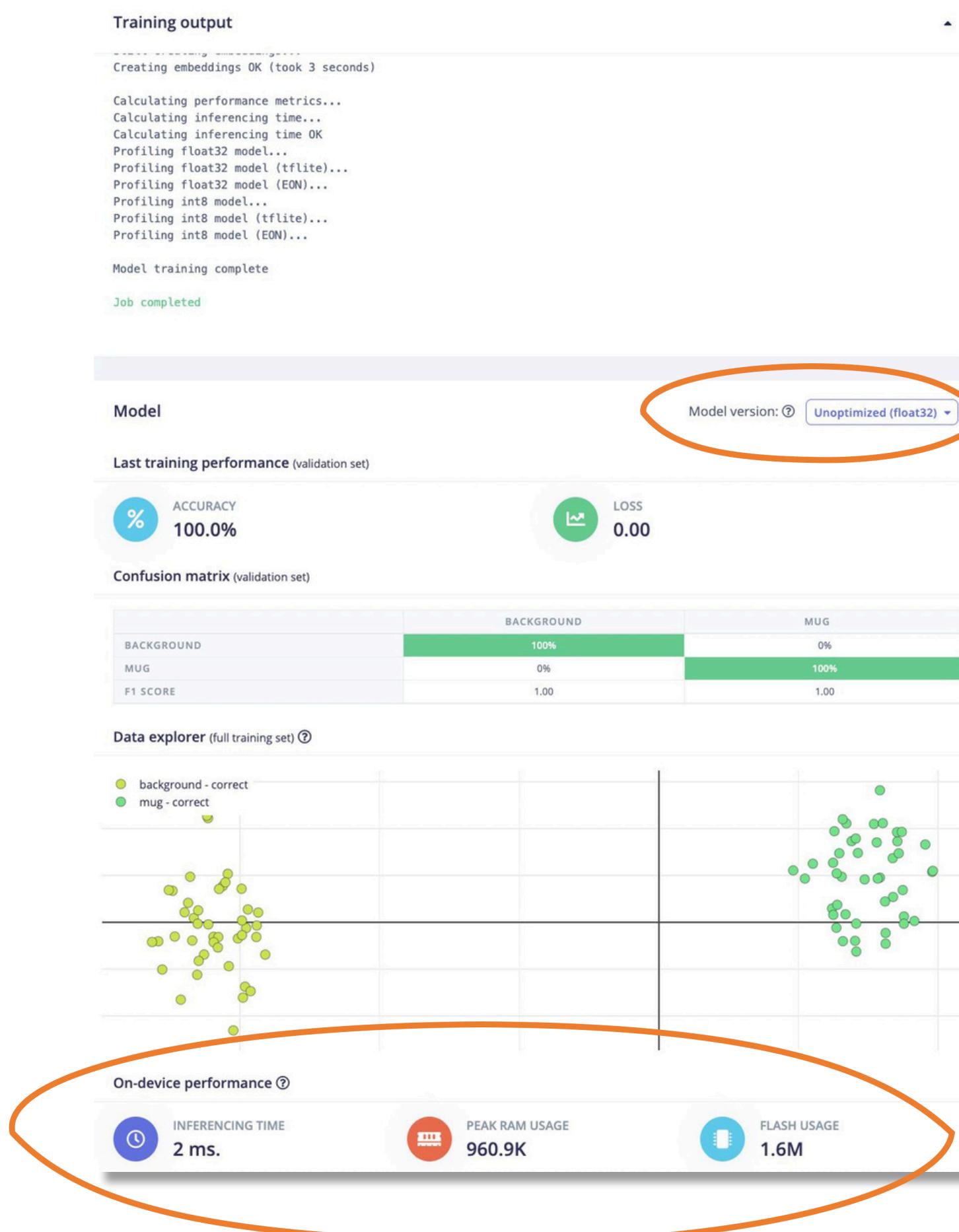
**Neural network architecture**

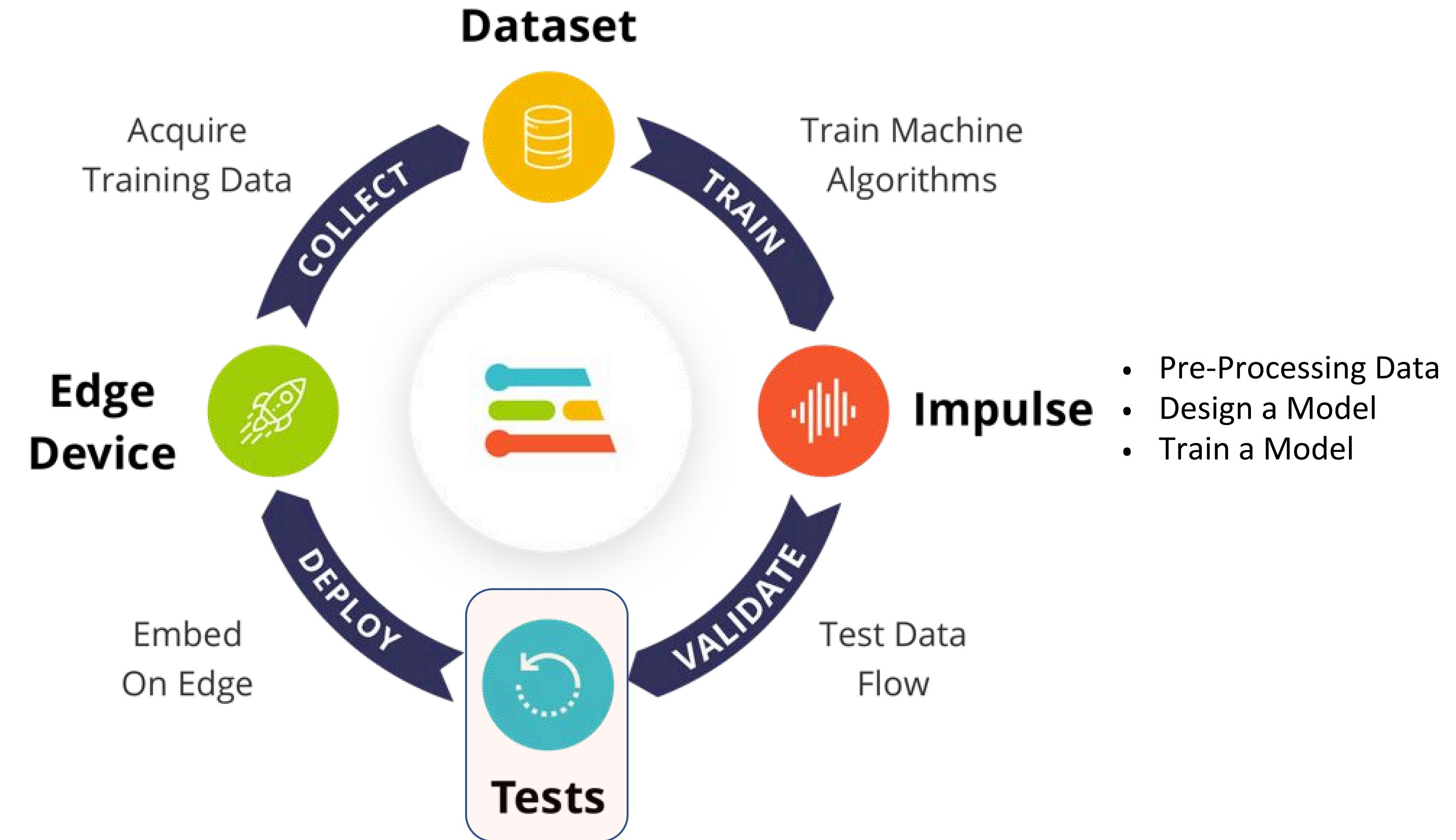
```

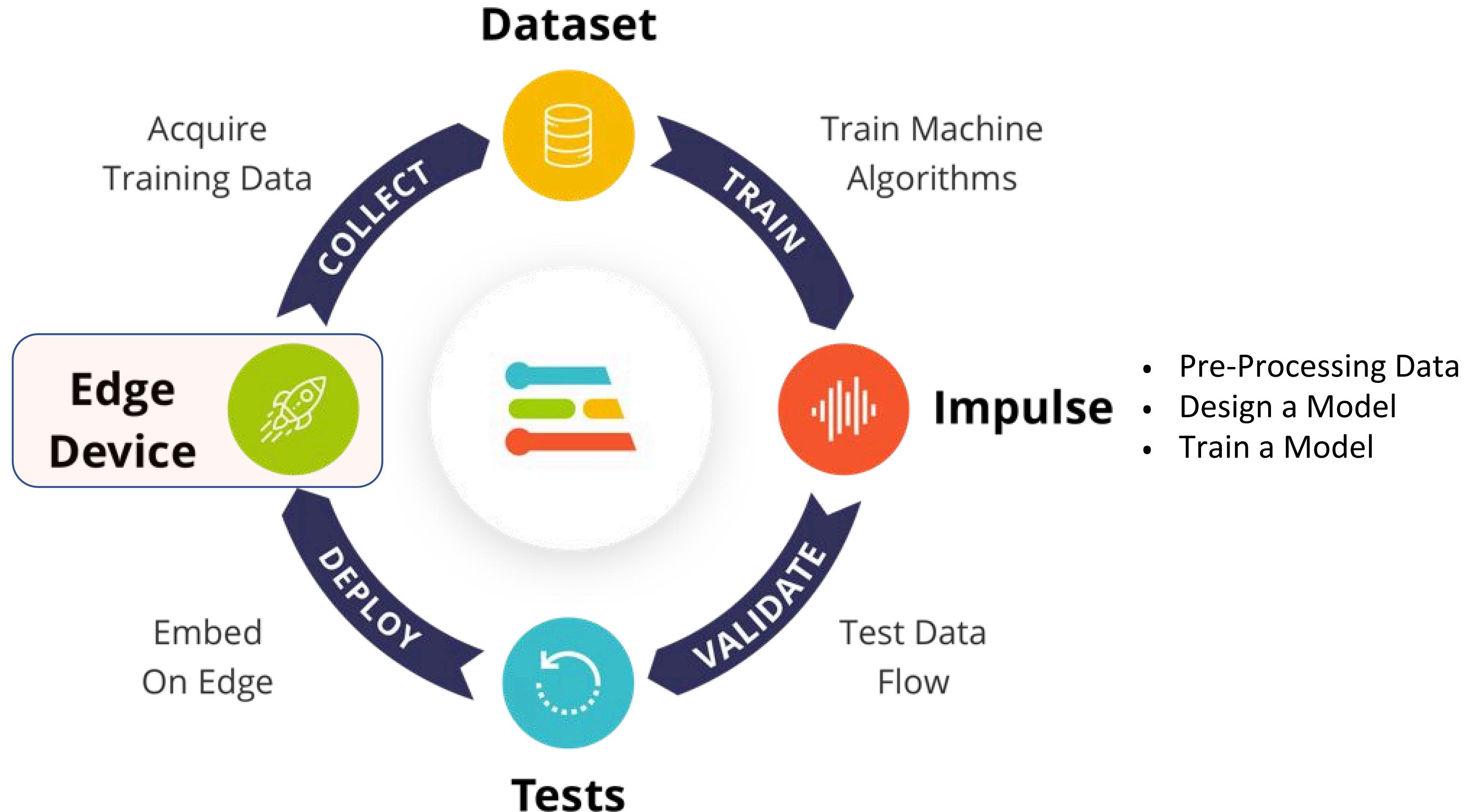
49
50
51 # Implements the data augmentation policy
52 def augment_image(image, label):
53     # Flips the image randomly
54     image = tf.image.random_flip_left_right(image)
55
56     # Increase the image size, then randomly crop it down to
57     # the original dimensions
58     resize_factor = random.uniform(1, 1.2)
59     new_height = math.floor(resize_factor * INPUT_SHAPE[0])
60     new_width = math.floor(resize_factor * INPUT_SHAPE[1])
61     image = tf.image.resize_with_crop_or_pad(image, new_height, new_width)
62     image = tf.image.random_crop(image, size=INPUT_SHAPE)
63
64     # Vary the brightness of the image
65     image = tf.image.random_brightness(image, max_delta=0.2)
66
67     return image, label
68
69 train_dataset = train_dataset.map(augment_image, num_parallel_calls=tf.data
    .AUTOTUNE)
70
71 BATCH_SIZE = 32
72 EPOCHS = args.epochs or 20
73 LEARNING_RATE = args.learning_rate or 0.0005
74 train_dataset = train_dataset.batch(BATCH_SIZE, drop_remainder=False)
75 validation_dataset = validation_dataset.batch(BATCH_SIZE, drop_remainder
    =False)
76 callbacks.append(BatchLoggerCallback(BATCH_SIZE, train_sample_count, epochs
    =EPOCHS))

```

**Start training**







- Dashboard
- Devices
- Data acquisition
- Experiments
- EON Tuner
- Impulse design ▼
  - Create impulse
  - Image
  - Transfer learning
- Retrain model
- Live classification
- Model testing
- Deployment
- Versioning

## Upgrade Plan

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

[View plans](#)

## Run this model

### Configure your deployment

You can deploy your impulse to any device. This makes the model run without an interi with minimal power consumption. [Read more.](#)



Search deployment options



#### DEFAULT DEPLOYMENT

##### Arduino library

An Arduino library with examples that runs on most Arm-based Arduino d

Scan QR code or launch in browser to test your prototype



[Launch in browser](#)

#### MODEL OPTIMIZATIONS

Model optimizations can increase on-device performance but may reduce accuracy



##### EON™ Compiler

Same accuracy, 17% less RAM, 15% less ROM.

#### Quantized (int8)

Selected ✓

	IMAGE	TRANSFER LEARNING	TOTAL
LATENCY	7 ms.	1061 ms.	<b>1068 ms.</b>
RAM	4,0K	334,6K	<b>334,6K</b>
FLASH	-	585,3K	-
ACCURACY			-

#### Unoptimized (float32)

Select

	IMAGE	TRANSFER LEARNING	TOTAL
LATENCY	7 ms.	1462 ms.	<b>1469 ms.</b>
RAM	4,0K	893,7K	<b>893,7K</b>
FLASH	-	1,6M	-

 Dashboard Devices Data acquisition Experiments EON Tuner Impulse design Create impulse Image Transfer learning Retrain model Live classification Model testing Deployment Versioning

## Configure your deployment

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.](#)



Search deployment options

**C++ library**

A portable C++ library with no external dependencies, which can be compiled with any modern C++ compiler.

**Arduino library**

An Arduino library with examples that runs on most Arm-based Arduino development boards.

**BrainChip MetaTF Model**

A MetaTF converted model (.fbz) for use with the BrainChip Akida™ runtime.

**Cube.MX CMSIS-PACK**

A STM32Cube.MX CMSIS-PACK, for fast inferencing on many ST MCUs.

**Custom block**

A ZIP file containing everything your custom deploy block will receive.

**DRP-AI Library**

Generate machine learning models to use the DRP-AI accelerator on Renesas RZ/ products.

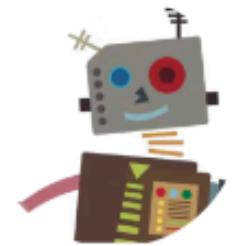
Selected

LATENCY

7 ms

1061 ms

1068 ms



# MJRoBot (Marcelo Rovai)

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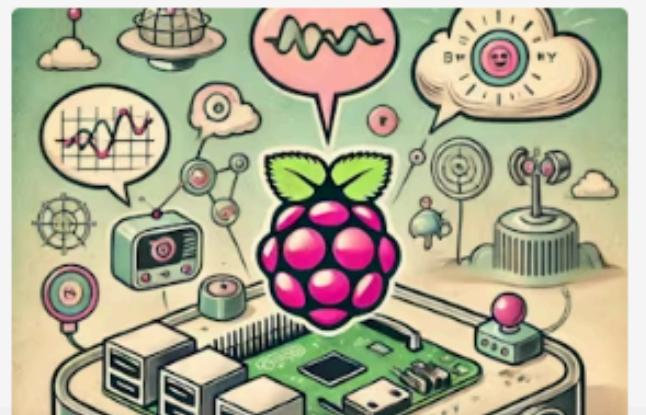
Professor, Engineer, MBA, Master in Data Science. Writes about Electronics with a focus on Physical Computing, IoT, ML, TinyML and Robotics.

**Joined**

October 2016

**Location**

Santiago, Chile

**Projects**

# 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