

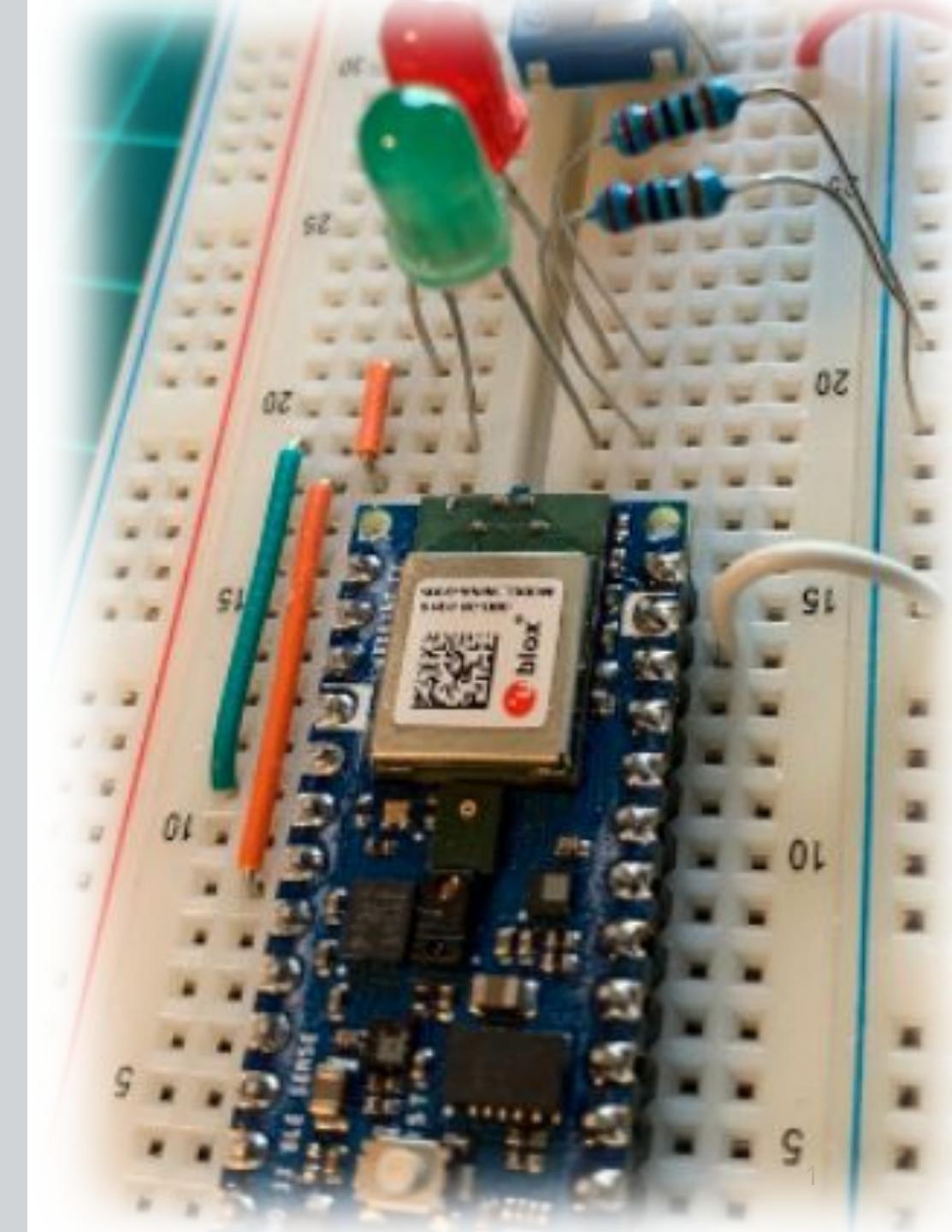
# IESTI01 – TinyML

## Embedded Machine Learning

### 12. Introduction to Edge Impulse – CNN with Cifar-10



Prof. Marcelo Rovai  
UNIFEI

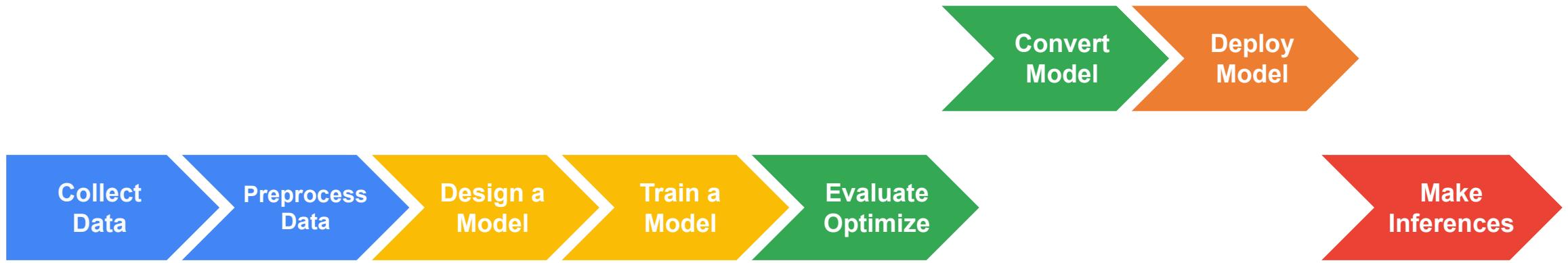


# Embedded Machine Learning (TinyML) Workflow Review

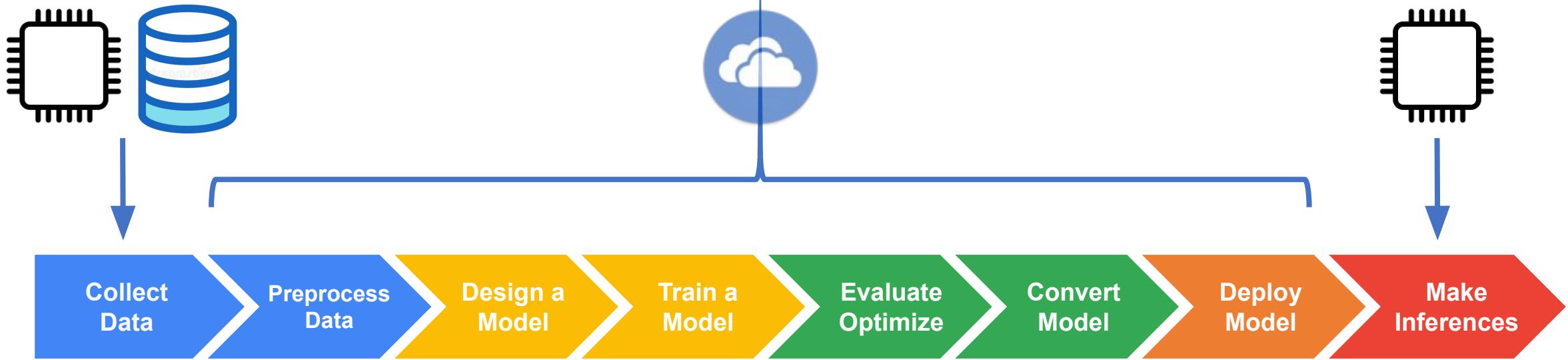
# Machine Learning Workflow



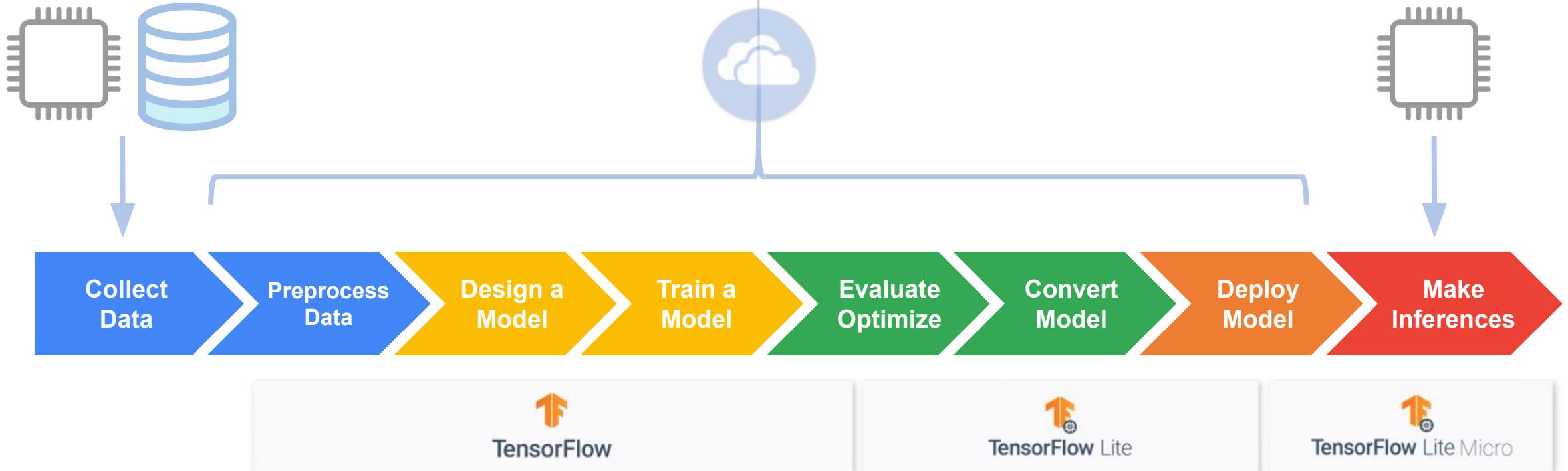
# Tiny Machine Learning Workflow (“What”)



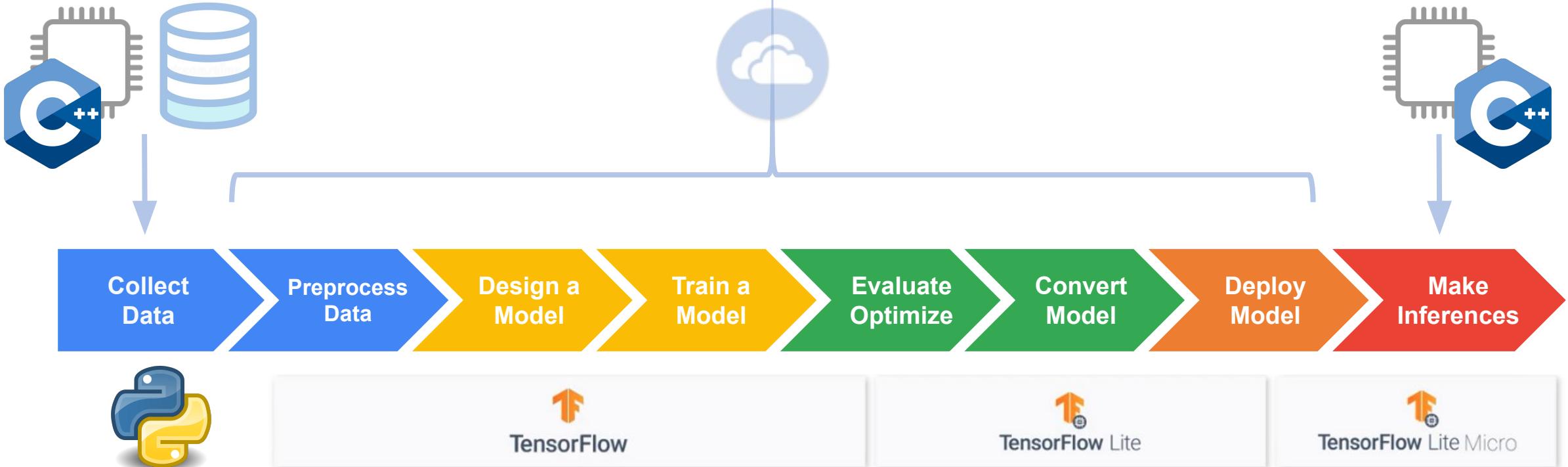
# Tiny Machine Learning Workflow (“Where”)



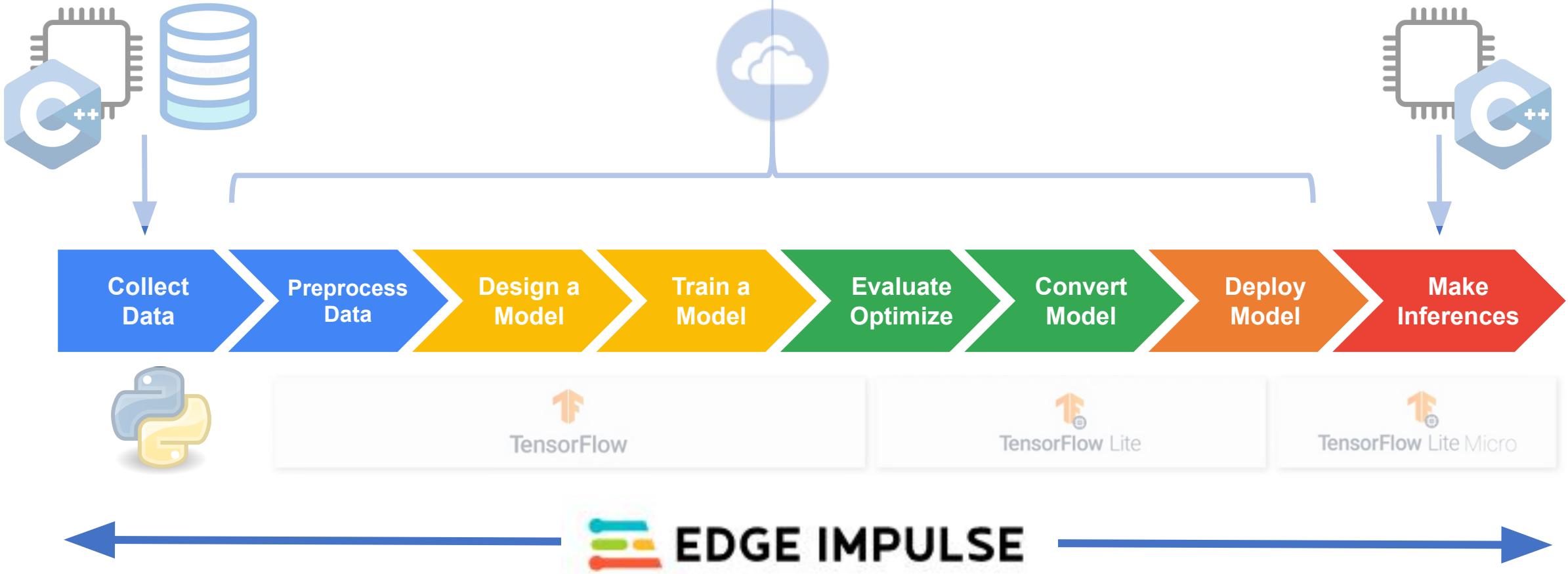
# Machine Learning Workflow (“How”)

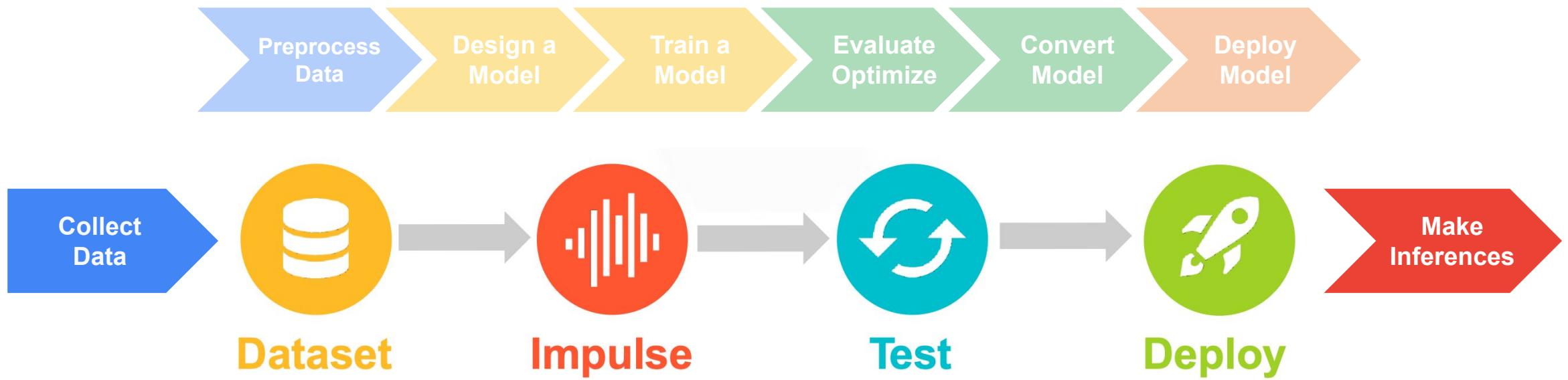


# Machine Learning Workflow (“How”)

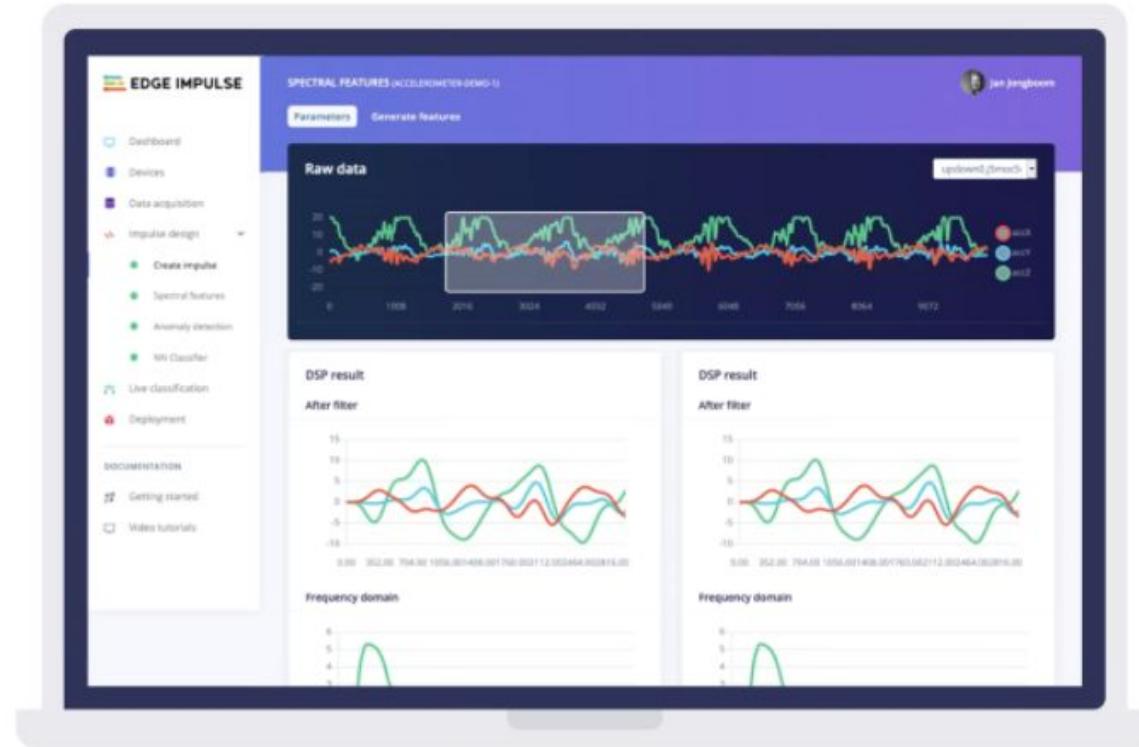
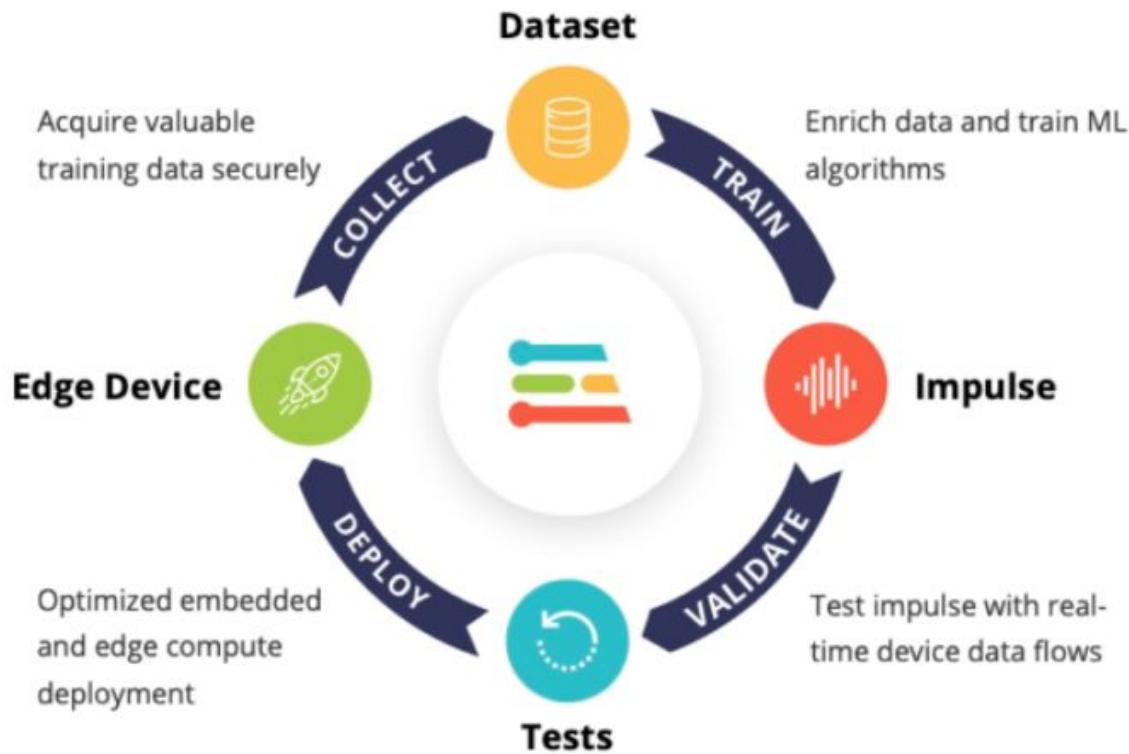


# Machine Learning Workflow (“How”)





# EI Studio - Embedded ML platform (“AutoML”)



Learn more at <http://edgeimpulse.com>

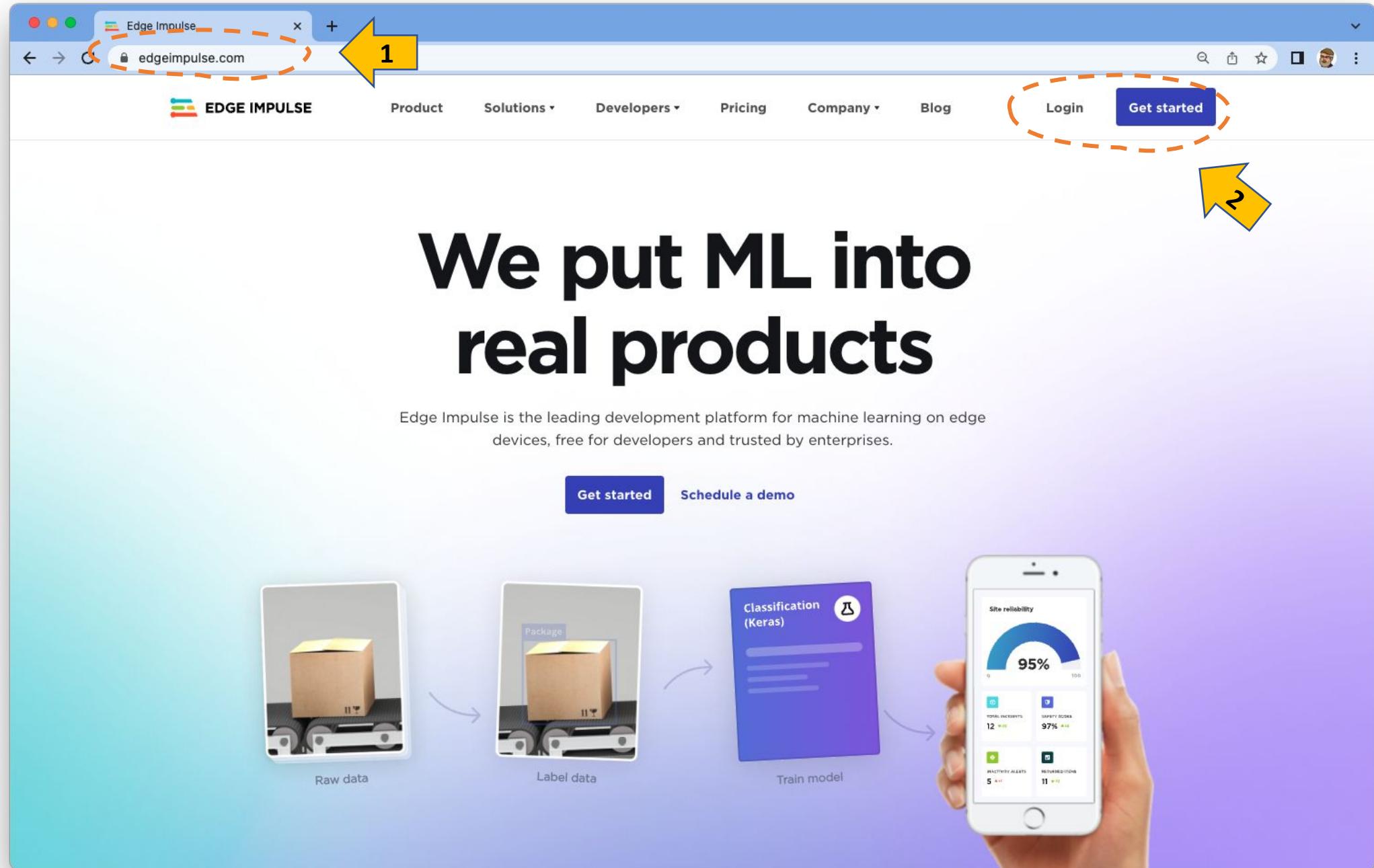


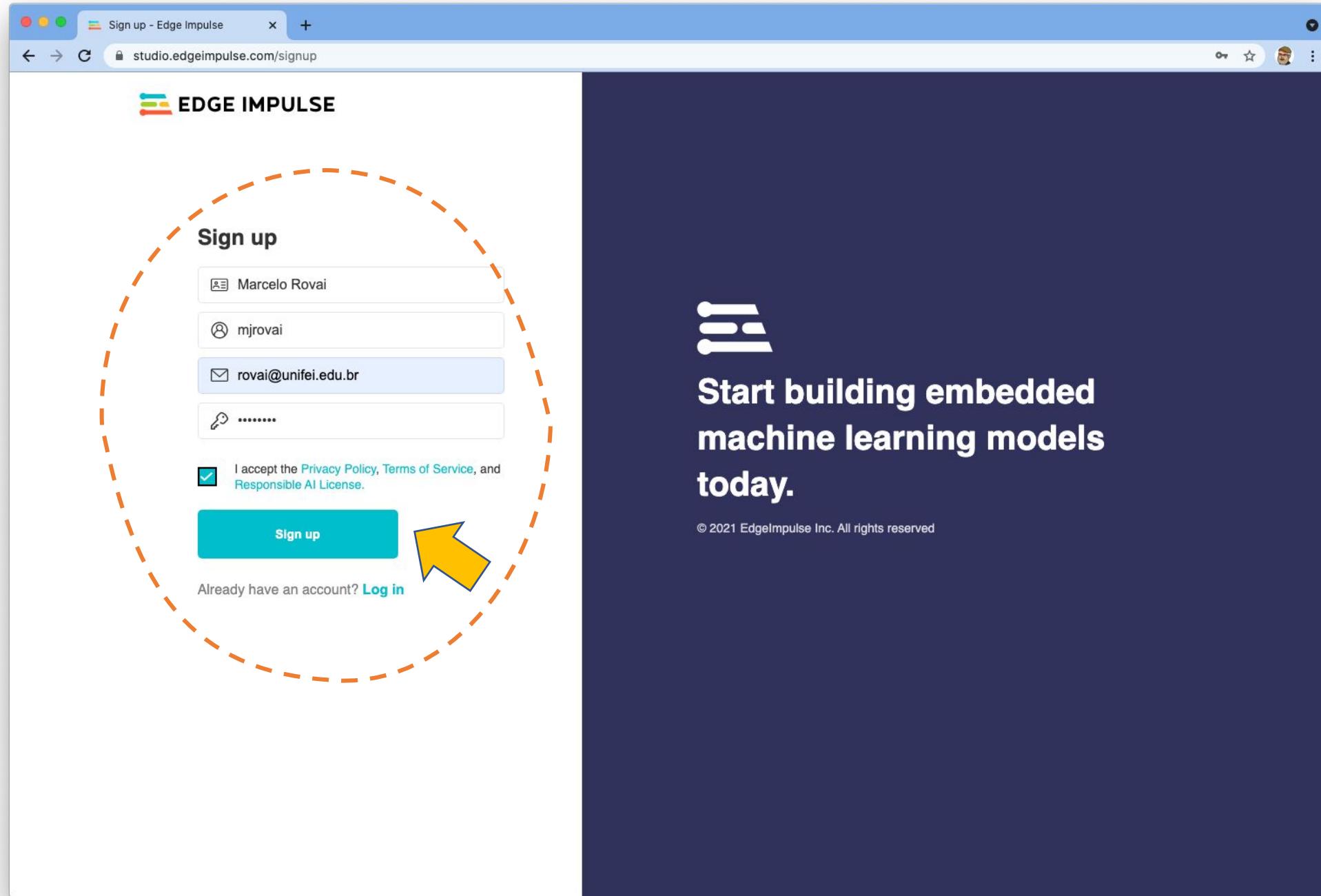
# Cifar10

# Edge Impulse Studio



Dataset: <https://github.com/YoongiKim/CIFAR-10-images>





A screenshot of a web browser window showing the Edge Impulse sign-up success page. The URL in the address bar is `studio.edgeimpulse.com/studio/signup-success`. The page features a white header with the Edge Impulse logo and a dark blue footer. The main content area on the left displays a success message and a button to build a model, while the right side has a large call-to-action text.

Sign up successful!

Thanks Marcelo Rovai!

You have successfully signed up for Edge Impulse.

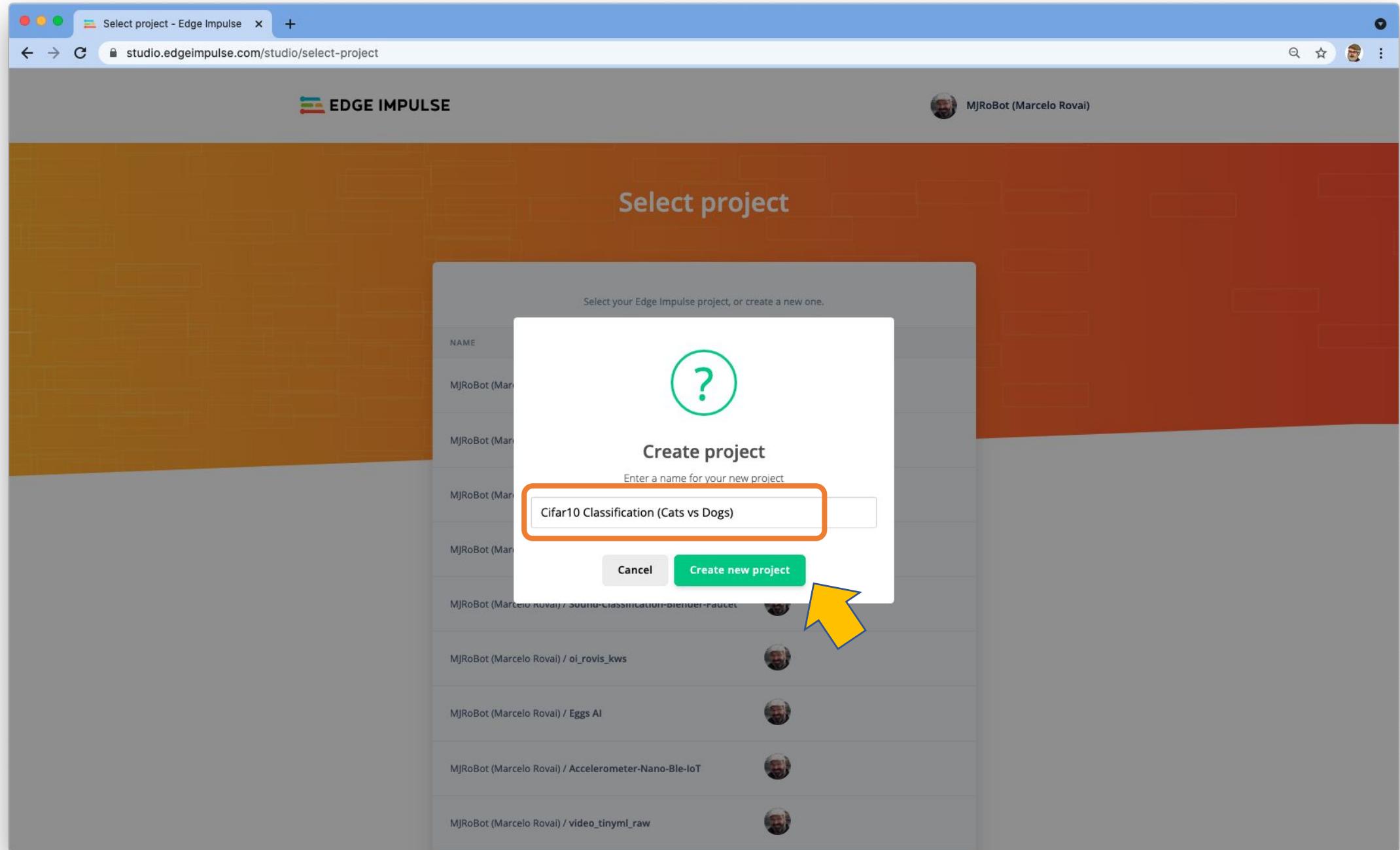
 Click here to build your first ML model!

[Re-send activation email](#)



**Start building embedded machine learning models today.**

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Select project - Edge Impulse

studio.edgeimpulse.com/studio/select-project

MJRoBot (Marcelo Rovai)

# Select project

Select your Edge Impulse project, or create a new one.

NAME	COLLABORATORS
MJRoBot (Marcelo Rovai) / Cifar10 Classification (Cats vs Dogs)	
MJRoBot (Marcelo Rovai) / SoundClassification-Blender-Faucet	
MJRoBot (Marcelo Rovai) / ol_rovis_kws	
MJRoBot (Marcelo Rovai) / Eggs AI	
MJRoBot (Marcelo Rovai) / Accelerometer-Nano-Ble-IoT	
MJRoBot (Marcelo Rovai) / video_tinyml_raw	

**Created project**

Successfully created project "Cifar10 Classification (Cats vs Dogs)"

OK

A yellow arrow points from the bottom left towards the "OK" button on the modal dialog.

Dashboard - Cifar10 Classifica  +    

← → C  studio.edgeimpulse.com/studio/51076

**EDGE IMPULSE**

Project info Keys Export

MJRoBot (Marcelo Rovai)

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

GETTING STARTED Documentation Forums

# MJRoBot (Marcelo Rovai) / Cifar10 Classification (Cats vs Dogs)

This is your Edge Impulse project.

Welcome to your new Edge Impulse project!

You're ready to add real intelligence to your edge devices. Let's set up your project. What type of data are you dealing with?

**Creating your first impulse**

**Acquire data**

Accelerometer data Analyze movement of your device in real-time to predict machine failure, detect human gestures, or monitor rotating machines.

Audio Listen to what's happening around you to create voice interfaces, listen to keywords, detect audible events, or to hear what's happening around your device.

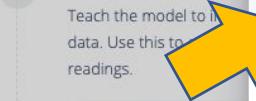
Images Add sight to your sensors with image classification or object detection - to detect humans and animals, monitor production lines or track objects.

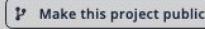
Something else Different sensor? No problem! You can collect and import data from any sensor, from environmental sensors to radars - and deploy your trained model back to virtually any device.

I know what I'm doing, hide this wizard!

**Deploy**

Package the complete impulse up, from signal processing code to trained model, and deploy it on your device. This ensures that the impulse runs with low latency and without requiring a network connection.

Sharing Your project is private. 

Summary DEVICES CONNECTED 0 DATA COLLECTED

Collaborators MJRoBot (Marcelo Rovai) OWNER

Project info

Dashboard - Cifar10 Classifica x +

studio.edgeimpulse.com/studio/51076

EDGE IMPULSE

Project info Keys Export

MJRoBot (Marcelo Rovai)

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

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# MJRoBot (Marcelo Rovai) / Cifar10 Classification (Cats vs Dogs)

This is your Edge Impulse project.

Welcome to your new Edge Impulse project!

Great! What do you want to detect?

**Creating your first impulse**

**Acquire data**

Every Machine Learning Project needs data. You can collect it from a development board or your smartphone.

**LET'S COLLECT SOME DATA**

**Design an impulse**

Teach the model to interpret the data. Use this to categorize sensor readings.

**GETTING STARTED: CONCEPT**

**GETTING STARTED: RESULTS**

**GETTING STARTED: ADVICE**

I know what I'm doing, hide this wizard!

**Deploy**

Package the complete impulse up, from signal processing code to trained model, and deploy it on your device. This ensures that the impulse runs with low latency and without requiring a network connection.

**DEPLOY YOUR MODEL**

Sharing

Your project is private.

**Make this project public**

Summary

DEVICES CONNECTED 0

DATA COLLECTED -

Collaborators

MJRoBot (Marcelo Rovai) OWNER

Project info



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Dashboard - Cifar10 Classifica +

studio.edgeimpulse.com/studio/51076

EDGE IMPULSE

Project info Keys Export

MJRoBot (Marcelo Rovai)

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GETTING STARTED Documentation Forums

# MJRoBot (Marcelo Rovai) / Cifar10 Classification (Cats vs Dogs)

This is your Edge Impulse project.

Welcome to your new Edge Impulse project!

Great! Here's how you can get started with image classification:

**Connect a development board**

Get started with real hardware from Arduino, OpenMV, Eta Compute, Himax, Raspberry Pi or NVIDIA to quickly build a custom image dataset.

[Connect your development board](#)

**Acquire data**

Every Machine Learning project needs data. You can collect it using a development board or your smartphone.

[LET'S COLLECT SOME DATA](#)

**Import existing data**

If you already have images in JPG or PNG file format, you can upload it to Edge Impulse through the web interface or using the Edge Impulse CLI.

[Go to the uploader](#)

**Design an impulse**

Teach the model to interpret your sensor data. Use this to categorize sensor readings.

[GETTING STARTED: CONCEPTS](#) [GETTING STARTED: RESULTS](#) [GETTING STARTED: ADVICE](#)

**Tutorial: adding sight to your sensors**

Follow our end-to-end tutorial to collect data, train a model, and deploy it back to your device to analyze images in realtime.

[Read the tutorial](#)

I know what I'm doing, hide this wizard!

[Let's get started!](#)

**Deploy**

Package the complete impulse up, from signal processing code to trained model, and deploy it on your device. This ensures that the impulse runs with low latency and without requiring a network connection.

[DEPLOY YOUR MODEL](#)

Sharing

Your project is private.

[Make this project public](#)

Summary

DEVICES CONNECTED 0

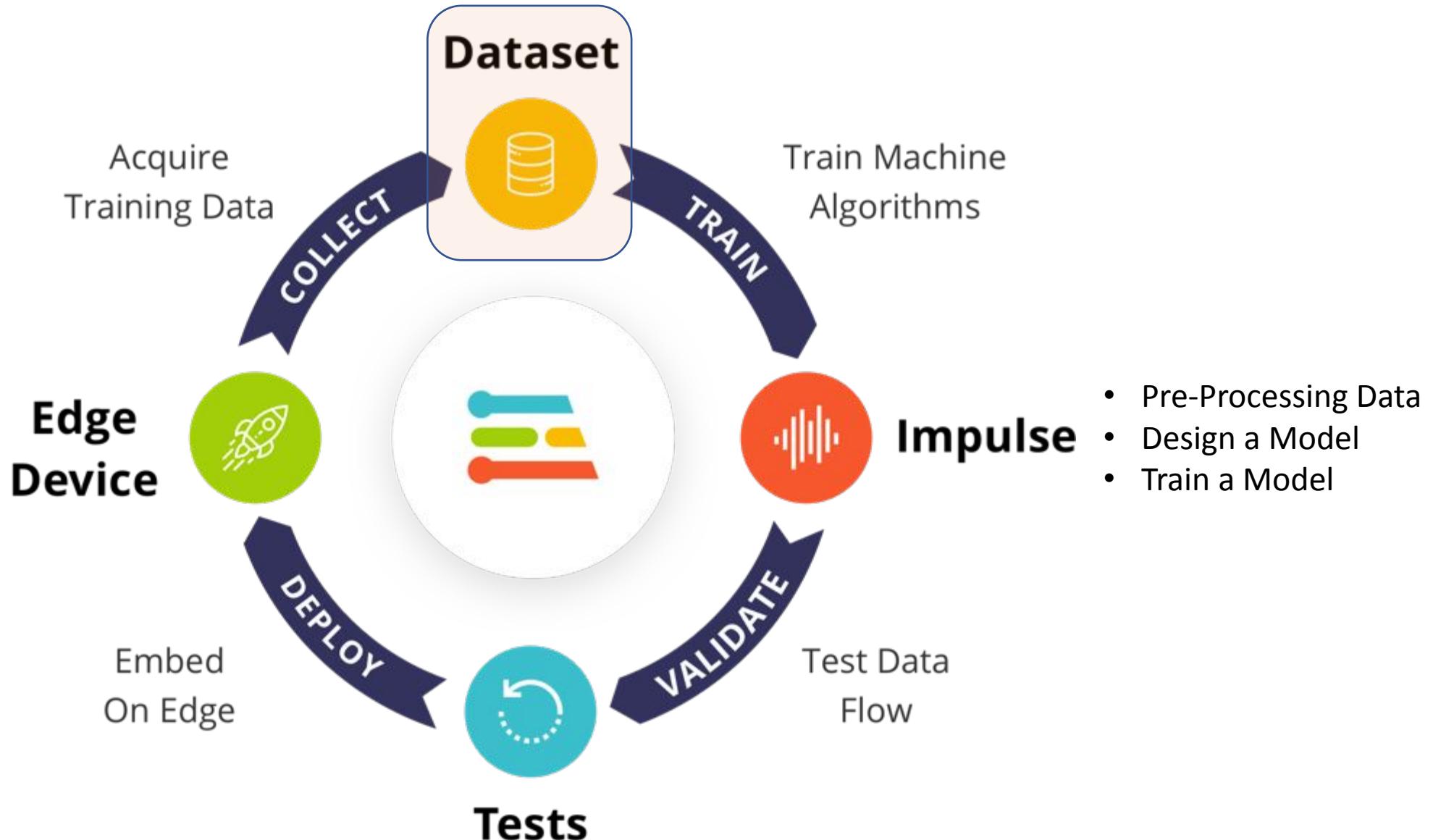
DATA COLLECTED -

Collaborators

MJRoBot (Marcelo Rovai) OWNER

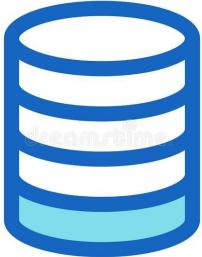
Project info

https://studio.edgeimpulse.com/studio/51076/upload

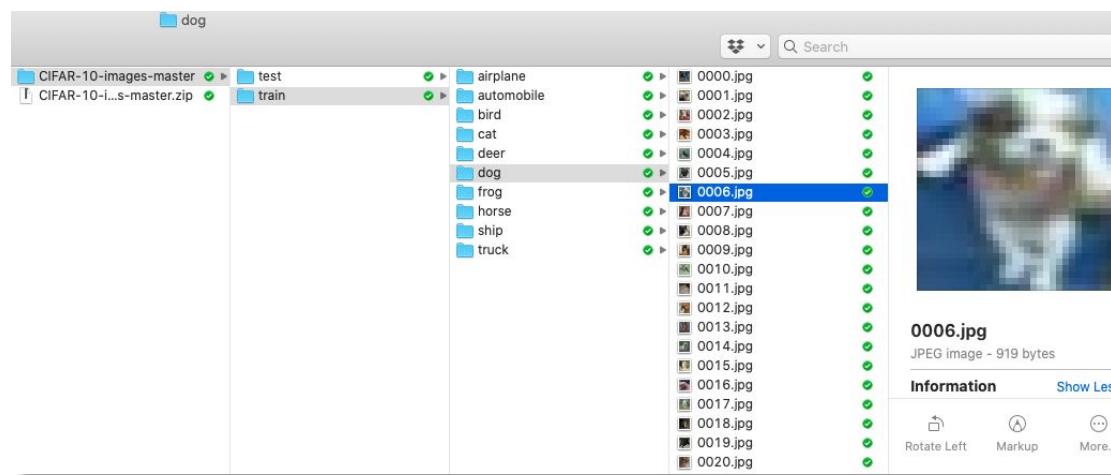


# Download Dataset

<https://github.com/YoongiKim/CIFAR-10-images>



The screenshot shows a GitHub repository page for 'CIFAR-10-images'. At the top, there are buttons for 'Code' (highlighted with an orange box), 'Go to file', and 'Add file'. Below the buttons, there's a 'Clone' section with 'HTTPS' selected, showing the URL 'https://github.com/YoongiKim/CIFAR-10-images'. There are also links for 'Open with GitHub Desktop' and 'Download ZIP'. A large yellow arrow points from the monitor icon up to this 'Download ZIP' button. The main content area displays the repository's README.md file, which contains the text 'CIFAR-10 raw jpeg images' and 'You can just clone this repository to use dataset.'



## Collect Data

Upload data - Cifar10\_Image\_C

stUDIO.edgeimpulse.com/studio/51070/upload

EDGE IMPULSE

Dashboard

Devices

Data acquisition

Impulse design

- Create impulse
- Image
- NN Classifier

EON Tuner

Retrain model

Live classification

Model testing

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UPLOAD DATA (CIFAR10\_IMAGE\_CLASSIFICATION)

Upload existing data

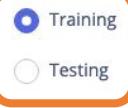
You can upload existing data to your project in the [Data Acquisition Format](#) (CBOR, JSON, CSV), or as WAV, JPG or PNG files.

Select files 

No file chosen

Upload into category

Automatically split between training and testing ?

Training 

Testing

Label

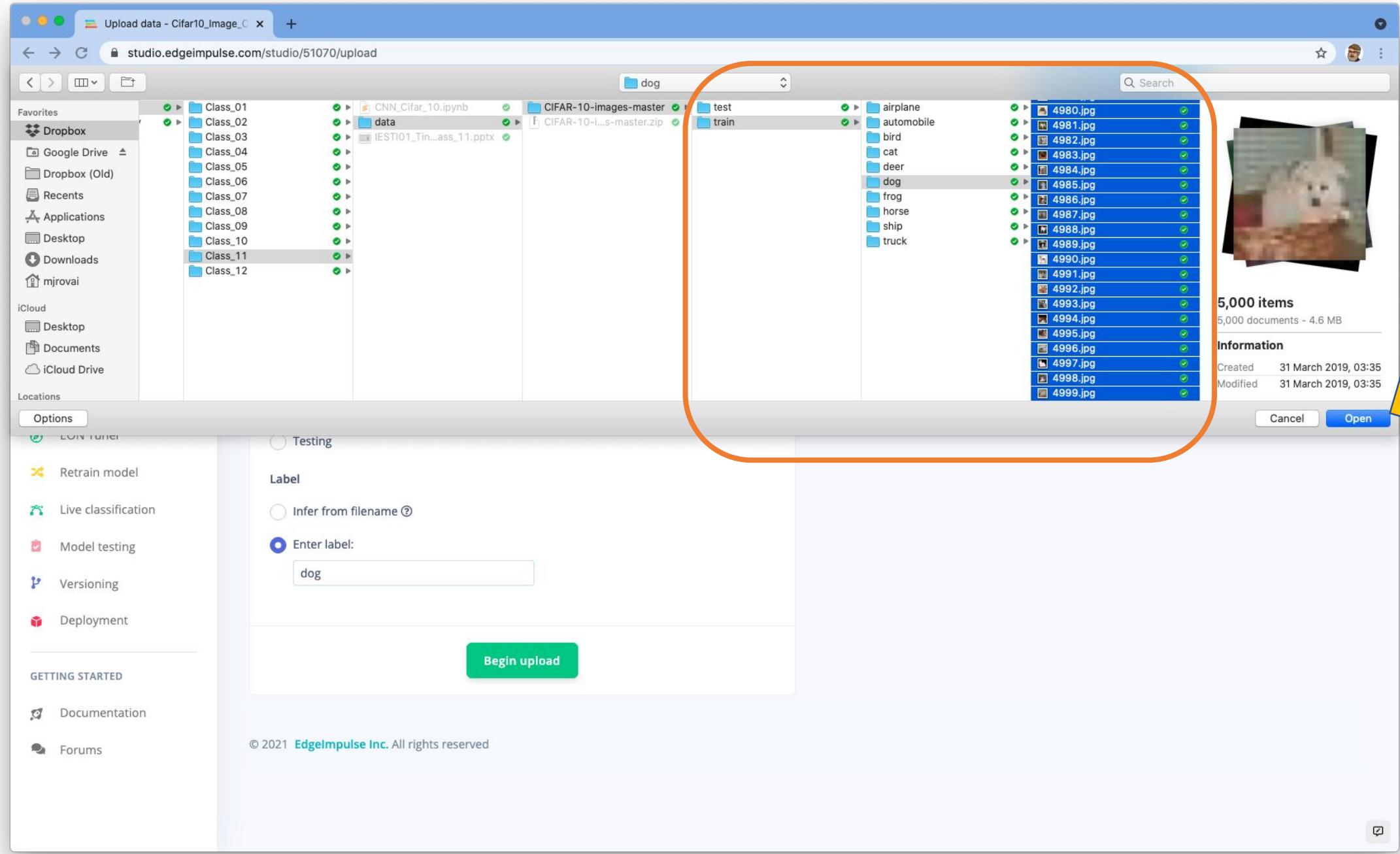
Infer from filename ?

Enter label: 

dog

Begin upload

MJRoBot (Marcelo Rovai)



## Collect Data

Upload data - Cifar10\_Image\_C

stUDIO.edgeimpulse.com/studio/51070/upload

EDGE IMPULSE

MJRoBot (Marcelo Rovai)

Dashboard

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UPLOAD DATA (CIFAR10\_IMAGE\_CLASSIFICATION)

Upload existing data

You can upload existing data to your project in the [Data Acquisition Format](#) (CBOR, JSON, CSV), or as WAV, JPG or PNG files.

Select files

5000 files

Upload into category

Automatically split between training and testing ?

Training

Testing

Label

Infer from filename ?

Enter label:

dog

**Collect Data**

EDGE IMPULSE

Training data Test data

Did you know? You can capture data from any device or development board, or upload your existing datasets - [Show options](#)

DATA COLLECTED  
10,000 items

TRAIN / TEST SPLIT  
83% / 17%

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
4999.jpg.2hfb34u0	dog	Today, 11:14:02	-
4997.jpg.2hfb34n1	dog	Today, 11:14:01	-
4991.jpg.2hfb34mm	dog	Today, 11:14:01	-
4993.jpg.2hfb34n8	dog	Today, 11:14:01	-
4996.jpg.2hfb34o3	dog	Today, 11:14:01	-
4987.jpg.2hfb34ni	dog	Today, 11:14:01	-
4995.jpg.2hfb34nq	dog	Today, 11:14:01	-
4988.jpg.2hfb34mh	dog	Today, 11:14:01	-
4990.jpg.2hfb34n8	dog	Today, 11:14:01	-
4989.jpg.2hfb34n8	dog	Today, 11:14:01	-
4992.jpg.2hfb34nq	dog	Today, 11:14:01	-
4994.jpg.2hfb34mr	dog	Today, 11:14:01	-

RAW DATA  
**4999.jpg.2hfb34u0**

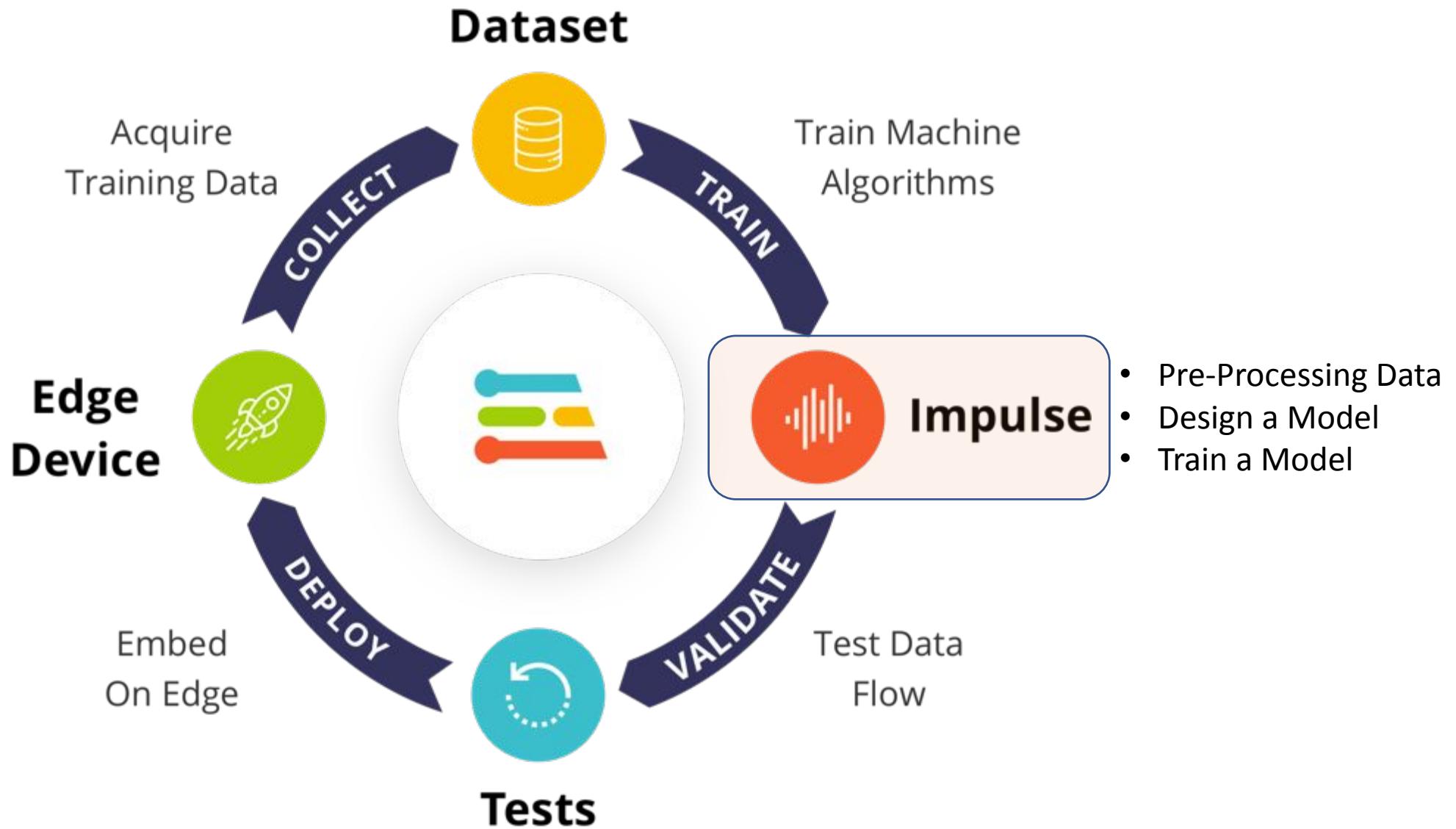


Record new data [Connect using WebUSB](#)

No devices connected to the remote management API.

Dashboard Devices Data acquisition Impulse design Create impulse Image NN Classifier EON Tuner Retrain model Live classification Model testing Versioning Deployment Documentation Forums

studio.edgeimpulse.com/studio/511/position/training?page=1



Create impulse - Cifar10\_Image

studio.edgeimpulse.com/studio/51070/create-impulse

EDGE IMPULSE

CREATE IMPULSE (CIFAR10\_IMAGE\_CLASSIFICATION)

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

Image data

Axes

Image width: 32      Image height: 32

Resize mode: Fit longest axis

For optimal accuracy with transfer learning blocks, use a 96x96 or 160x160 image size.

Image

Name: Image

Input axes:  image

Classification (Keras)

Name: NN Classifier

Input features:  Image

Output features: 2 (cat, dog)

Output features

2 (cat, dog)

Save impulse

Image width and height fields highlighted with a blue border.

Yellow arrow pointing to the "Save impulse" button.

Dashboard

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**Preprocess Data**

Image - Cifar10\_Image\_Classifi x +

studio.edgeimpulse.com/studio/51070/dsp/image/3

EDGE IMPULSE

IMAGE (CIFAR10\_IMAGE\_CLASSIFICATION)

#1 Click to set a description for this version

Parameters Generate features

Raw data

4999.jpg.2hfb34u0 (dog)

Raw features

0xa9aaa4, 0xafb0aa, 0xabaca6, 0xa9aaa4, 0xaebl8, 0xabaee5, 0xa6a9a0, 0xabaee5, 0xabaee3, 0xaaad...

Parameters

Image

Color depth

RGB

Save parameters

DSP result

Image

Processed features

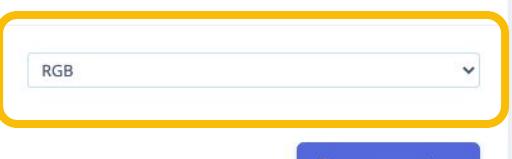
0.6627, 0.6667, 0.6431, 0.6863, 0.6902, 0.6667, 0.6706, 0.6745, 0.6510, 0.6627, 0.6667, 0.6431, ...

On-device performance

PROCESSING TIME 9 ms.

PEAK RAM USAGE 4 KB

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**Preprocess Data**

Image - Cifar10\_Image\_Classifi x +

studio.edgeimpulse.com/studio/51070/dsp/image/3/generate-features

EDGE IMPULSE

IMAGE (CIFAR10\_IMAGE\_CLASSIFICATION)  
#1 Click to set a description for this version

Parameters Generate features

Training set

Data in training set 10,000 items

Classes 2 (cat, dog)

Generate features

Feature explorer (10,000 samples) ②

X Axis Y Axis Z Axis

Visualization layer 1 Visualization layer 2 Visualization layer 3

cat dog

8.5  
8  
7.5  
7  
6.5  
6  
5.5  
5  
4.5  
4  
3.5  
3  
2.5  
2  
1.5  
1  
0.5  
0

Visualization layer 3  
Visualization layer 2  
Visualization layer 1

On-device performance ②

PROCESSING TIME 9 ms.

PEAK RAM USAGE 4 KB

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MJRoBot (Marcelo Rovai)

EDGE IMPULSE

NN CLASSIFIER (CIFAR10\_IMAGE\_CLASSIFICATION)  
#2 ▾ Model - Same as done in class (IESTI01) ★ Primary version

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Neural Network settings

Training settings

Number of training cycles ①  Learning rate ①

Neural network architecture

Input layer (3,072 features)

2D conv / pool layer (32 filters, 3 kernel size, 1 layer)

2D conv / pool layer (64 filters, 3 kernel size, 1 layer)

Flatten layer

Dense layer (64 neurons)

Add an extra layer

Output layer (2 features)

Start training

Training output

Model version: ② Quantized (int8)

Model

Last training performance (validation set)

ACCURACY 74.4% LOSS 0.56

Confusion matrix (validation set)

	CAT	DOG
CAT	80.6%	19.4%
DOG	32.1%	67.9%
F1 SCORE	0.76	0.72

Feature explorer (full training set) ③

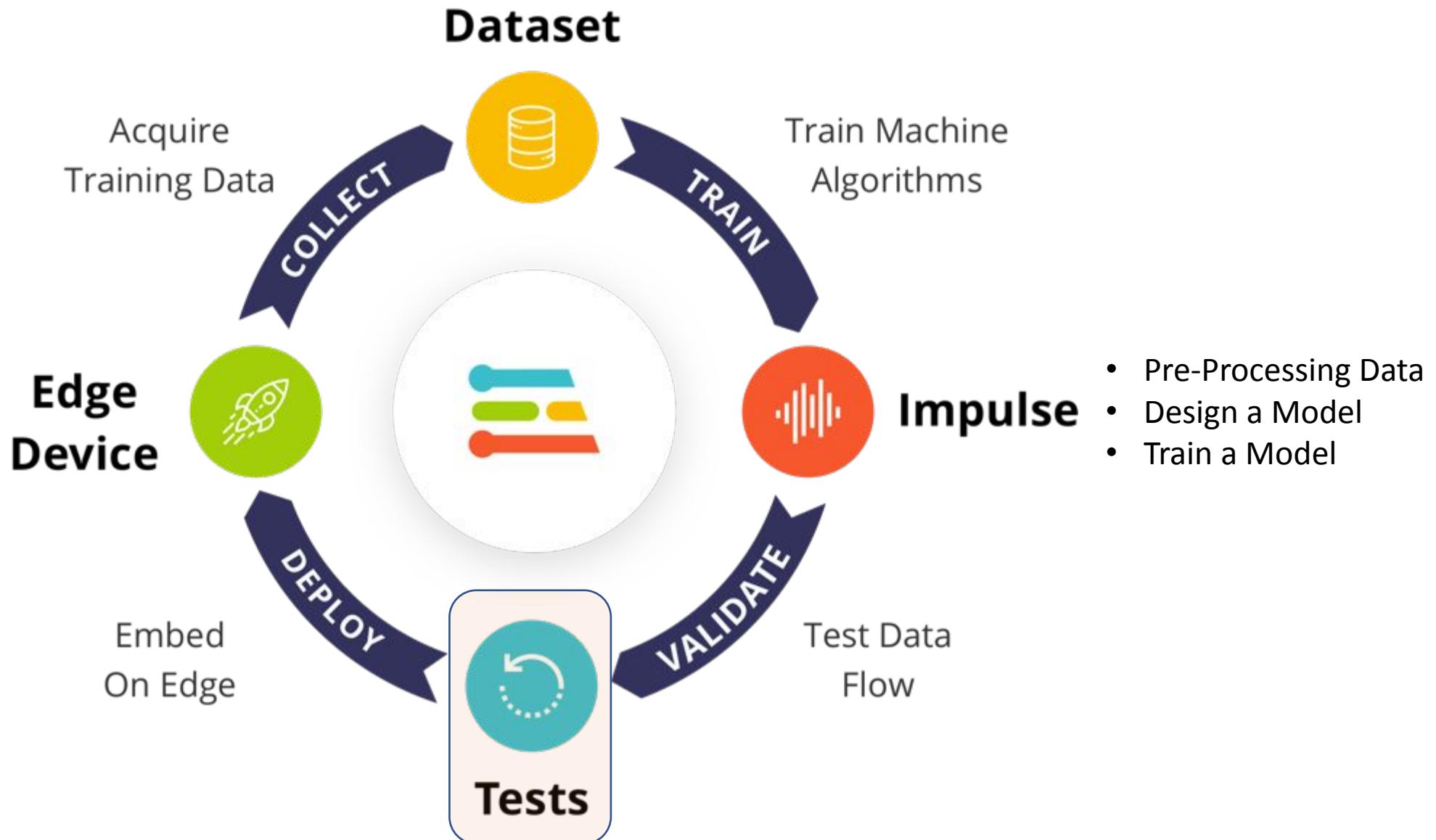
cat - correct  
dog - correct  
cat - incorrect  
dog - incorrect

Visualization layer 3  
Visualization layer 2  
Visualization layer 1

On-device performance ④

INFERENCING TIME 838 ms. PEAK RAM USAGE 44.7K FLASH USAGE 308.2K

30



Model testing - Cifar10\_Image... Upload data - Cifar10 Classific... | +

studio.edgeimpulse.com/studio/51070/validation

**EDGE IMPULSE**

- Dashboard
- Devices
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  - Create impulse
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**Evaluate Optimize**

### Test data

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

SAMPLE NAME	EXPECTED OUTCOME	LENGTH	ACCURACY	RESULT	⋮
testing.2hfe5uat	testing	-		1 cat	⋮
0999.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0997.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0998.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0996.jpg.2hfb7a...	cat	-	0%	1 uncertain	⋮
0993.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0995.jpg.2hfb7a...	cat	-	0%	1 dog	⋮
0991.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0994.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0992.jpg.2hfb7a...	cat	-	100%	1 cat	⋮
0990.jpg.2hfb79...	cat	-	100%	1 cat	⋮
0988.jpg.2hfb79...	cat	-	100%	1 cat	⋮
0985.jpg.2hfb79...	cat	-	0%	1 uncertain	⋮

**Model testing output**

Classifying data for NN classifier...  
 Copying features from processing blocks...  
 Copying features from DSP block...  
 Copying features from DSP block OK  
 Copying features from processing blocks OK

Classifying data for float32 model...  
 Scheduling job in cluster...  
 Job started  
 Classifying data for NN Classifier OK

Job completed

**Model testing results**

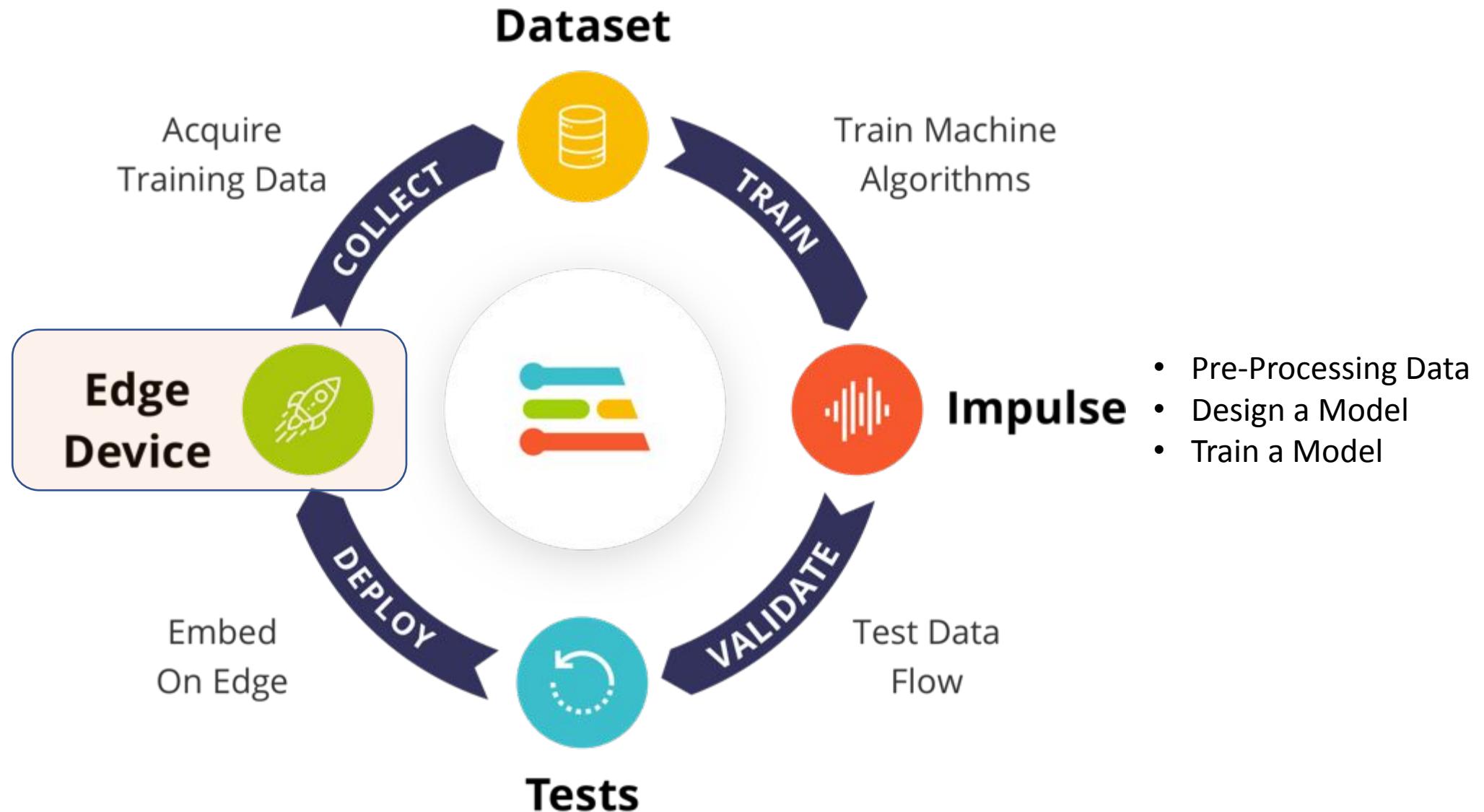
ACCURACY **64.95%** %

	CAT	DOG	UNCERTAIN
CAT	67.7%	16%	16.3%
DOG	21.2%	62.2%	16.6%
F1 SCORE	0.72	0.70	

**Feature explorer** ⓘ

Legend:

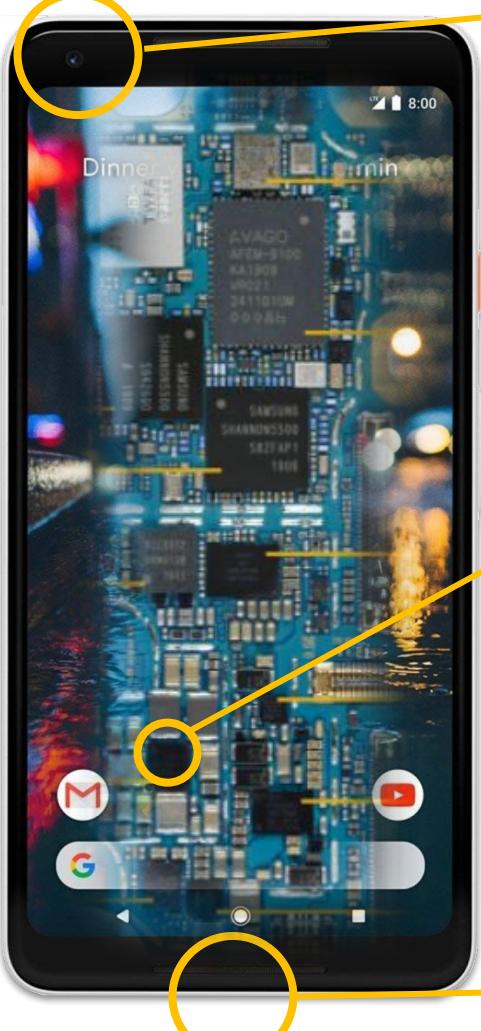
- cat - correct
- dog - correct
- cat - incorrect
- dog - incorrect
- testing



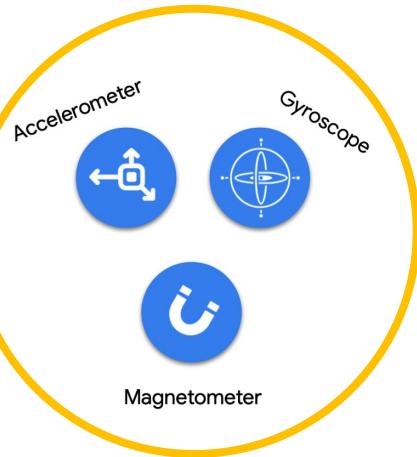
# Edge Device



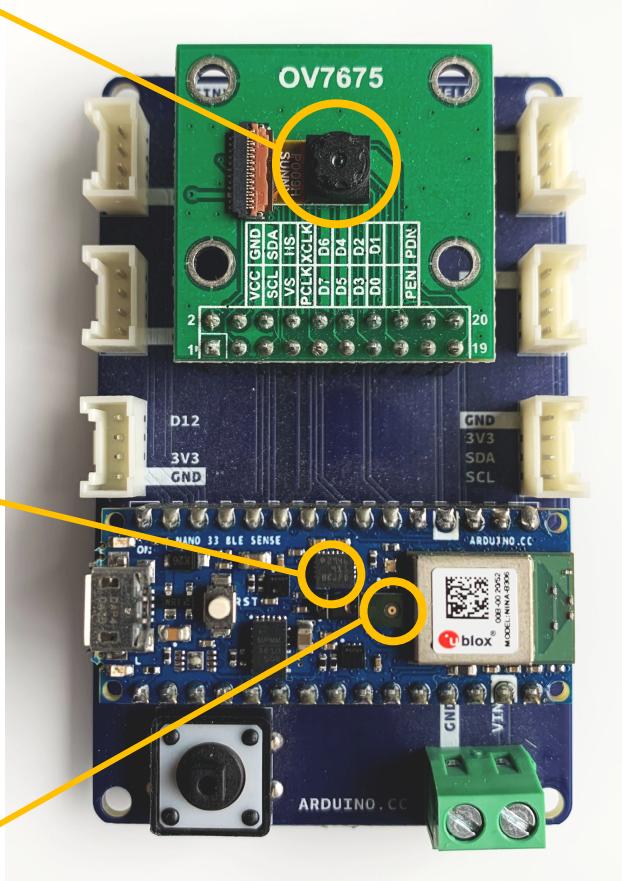
& Sensors



Camera



Microphone



**Devices - TinyML4D - Project**

DEVICES (TINYML4D - PROJECT SETUP)

Your projects

Collect data

These are the ways you can collect data:

- Connect a fully supported development board
- Use your mobile phone
- Use your computer
- Data from any device with the data forwarder
- Upload data
- Integrate with your cloud

You can collect data from development boards, from your own devices, or by uploading an existing dataset.

Get started with real hardware from a wide range of silicon vendors - fully supported by Edge Impulse.

Use your mobile phone to capture movement, audio or images, and even run your trained model locally. No app required.

Capture audio or images from your webcam or microphone, or from an external audio device.

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

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

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

Show QR code

Collect data

Show docs

Go to the uploader

Contact us

Connect a new device

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Marcelo Rovai

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Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

DEVICES (TINYML4D - PROJECT SETUP)

Your devices

+ Connect a new device

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

Collect data

You can collect data from any smartphone. From your smartphone go to [this URL](#), or scan the QR code below.



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Dashboard

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Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

Devices

Your devices

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

NAME	ID	TYPE	SENSORS	REMO...	LAST SEEN
phone_kq6ray4k	phone_kq6ray4k	MOBILE CLIENT	Accelerometer, Microphone	...	Today, 12:06:04

+ Connect a new device

Collect data

Device phone\_kq6ray4k is now connected

Get started!

smartphone.edgeimpulse.com 12:07 22% Camera Wi-Fi

Data collection

Connected as phone\_kq6ray4k

You can collect data from this

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Devices - TinyML4D - Project

studio.edgeimpulse.com/studio/49268/devices

EDGE IMPULSE

DEVICES (TINYML4D - PROJECT SETUP)

Marcelo Rovai

Your devices

+ Connect a new device

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

NAME	ID	TYPE	SENSORS	REMO...	LAST SEEN
phone_kq6ray4k	phone_kq6ray4k	MOBILE_CLIENT	Accelerometer, Microph...	●	Today, 12:06:04

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Dashboard

Devices (highlighted with orange dashed box)

Data acquisition

Impulse design

- Create impulse

Retrain model

Live classification

Model testing

Versioning

Deployment

GETTING STARTED

Documentation

Forums

Camera 12:07 22%

smartphone.edgeimpulse.com

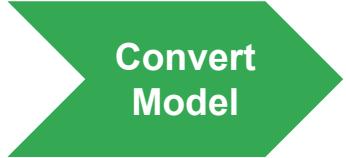
Data collection

Connected as phone\_kq6ray4k

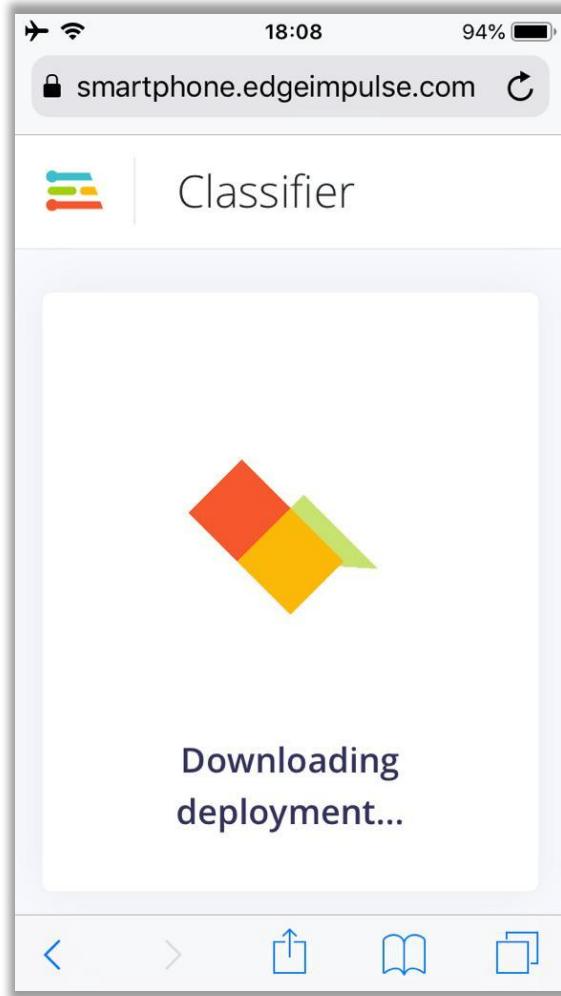
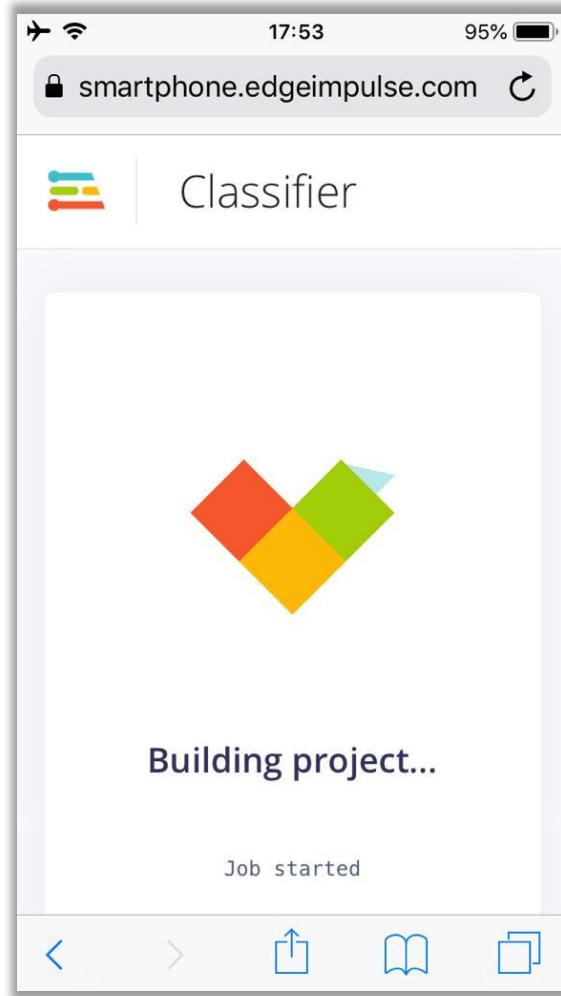
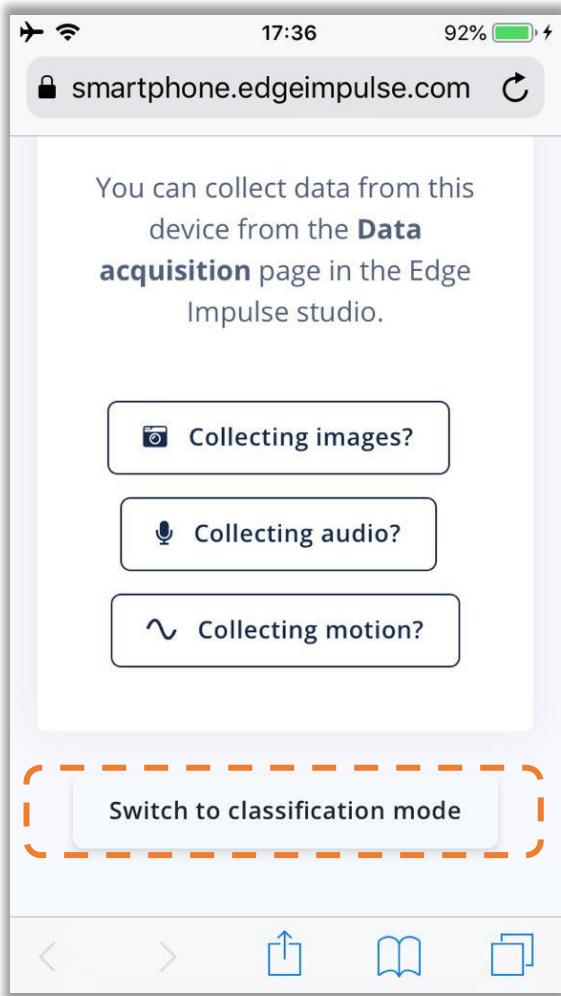
You can collect data from this

< >

A yellow arrow points from the "Connected as phone\_kq6ray4k" text in the smartphone window back towards the "Devices" section of the main Edge Impulse studio window.



## Convert Model



## Make Inferences

The figure displays four sequential screenshots of a mobile application interface, illustrating the process of making inferences on images using a classifier. The interface includes a header bar with the URL [ne.edgeimpulse.com](https://ne.edgeimpulse.com), a camera icon, signal strength, battery level, and a refresh button.

**Screenshot 1 (11:58):** Shows a Beagle dog running. The classifier results table shows:

	CAT	DOG
16	0.03	0.97
15	0.49	0.51

**Screenshot 2 (11:59):** Shows a white dog with brown spots. The classifier results table shows:

	CAT	DOG
17	0.00	1.00
16	0.03	0.97

**Screenshot 3 (12:04):** Shows a fluffy light-colored cat. The classifier results table shows:

	CAT	DOG
39	0.94	0.06
38	0.98	0.02

**Screenshot 4 (12:04):** Shows a woman with a cat head. The classifier results table shows:

	CAT	DOG
40	0.64	0.36
39	0.94	0.06

Each screenshot includes a "Next photo" button at the bottom center and standard iOS navigation icons (back, forward, share, etc.) at the bottom.

# EI Studio “under the hood” Code Time!

ei-cifar10\_image\_classification-nn-classifier-explained.ipynb



EDGE IMPULSE

NN CLASSIFIER (CIFAR10\_IMAGE\_CLASSIFICATION)

#2 ▾ Model - Same as done in class (IESTI01) ★ Primary version

**Neural Network settings**

**Training settings**

**Neural network architecture**

```

1 import tensorflow as tf
2 from tensorflow.keras.models import Sequential
3 from tensorflow.keras.layers import Dense, InputLayer, Dropout, Conv2D, Flatten,
4     Reshape, MaxPooling1D, MaxPooling2D, BatchNormalization, TimeDistributed
5
6 # model architecture
7 model = Sequential()
8 model.add(Conv2D(32, kernel_size=3, activation='relu', kernel_constraint=tf.keras
    .constraints.MaxNorm(1), padding='same'))
9 model.add(MaxPooling2D(pool_size=2, strides=2, padding='same'))
10 model.add(Conv2D(64, kernel_size=3, activation='relu', kernel_constraint=tf.keras
    .constraints.MaxNorm(1), padding='same'))
11 model.add(MaxPooling2D(pool_size=2, strides=2, padding='same'))
12 model.add(Flatten())
13 model.add(Dense(64, activation='relu',
    activity_regularizer=tf.keras.regularizers.l1(0.0001)))
14 model.add(Dense(classes, activation='softmax', name='y_pred'))
15
16 # this controls the learning rate
17 opt = Adam(lr=0.0005, beta_1=0.9, beta_2=0.999)
18 # this controls the batch size, or you can manipulate the tf.data.Dataset objects
19 # yourself
20 BATCH_SIZE = 32
21 train_dataset = train_dataset.batch(BATCH_SIZE, drop_remainder=False)
22 validation_dataset = validation_dataset.batch(BATCH_SIZE, drop_remainder=False)
23 callbacks.append(BatchLoggerCallback(BATCH_SIZE, train_sample_count))
24
25 # train the neural network
26 model.compile(loss='categorical_crossentropy', optimizer=opt, metrics=['accuracy'])

```

**Start training**

**Training output**

**Model**

Model version: ② Quantized (int8)

Last training performance (validation set)

ACCURACY 74.4%

LOSS 0.56

Confusion matrix (validation set)

	CAT	DOG
CAT	80.6%	19.4%
DOG	32.1%	67.9%
F1 SCORE	0.76	0.72

Feature explorer (full training set) ②

- cat - correct
- dog - correct
- cat - incorrect
- dog - incorrect

On-device performance ②

INFERENCING TIME 1,048 ms.

PEAK RAM USAGE 44.7K

FLASH USAGE 308.2K

NN Classifier - Cifar10\_Image... X Upload data - Cifar10 Classific... X computer icon - Pesquisa Go... X +

studio.edgeimpulse.com/studio/51070/learning/keras/6

EDGE IMPULSE

NN CLASSIFIER (CIFAR10\_IMAGE\_CLASSIFICATION)  
#2 ▾ Model - Same as done in class (IESTI01) ★ Primary version

MJRoBot (Marcelo Rovai)

Neural Network settings

Training settings

Number of training cycles ②

Learning rate ②

Switch to Keras (expert mode)

Edit as iPython notebook

Training output

Model

Last training performance (validation set)

ACCURACY 74.4%

LOSS 0.56

Confusion matrix (validation set)

	CAT	DOG
CAT	80.6%	19.4%
DOG	32.1%	67.9%
F1 SCORE	0.76	0.72

Feature explorer (full training set) ②

cat - correct  
dog - correct  
cat - incorrect  
dog - incorrect

Visualization layer 3

Visualization layer 2

On-device performance ②

INFERENCING TIME 1,048 ms.

PEAK RAM USAGE 44.7K

FLASH USAGE 308.2K

https://studio.edgeimpulse.com/v1/api/51070/training/keras/6/ipynb

A context menu is displayed over the learning rate slider, containing two items: "Switch to Keras (expert mode)" and "Edit as iPython notebook".

# Reading Material

# Main references

- [Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning](#)
- [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](#)
- Fundamentals textbook: “[Deep Learning with Python](#)” by François Chollet
- Applications & Deploy textbook: “[TinyML](#)” by Pete Warden, Daniel Situnayake
- Deploy textbook “[TinyML Cookbook](#)” by Gian Marco Iodice

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The IESTI01 course is part of the [TinyML4D](#), an initiative to make TinyML education available to everyone globally.

Thanks



UNIFEI