

WALC 2024

Applied AI



Computer Vision & Hands-On

Prof. Marcelo J. Rovai

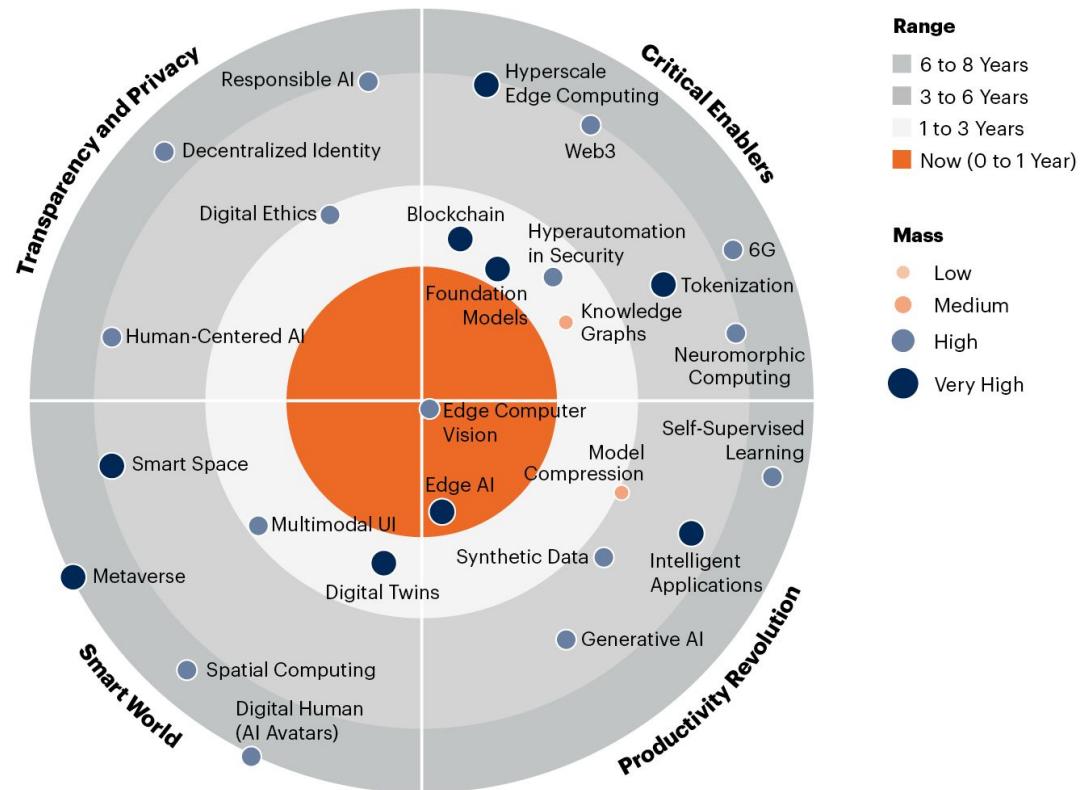
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UNIFEI - Federal University of Itajuba, Brazil
TinyML4D Academic Network Co-Chair



TINYML4D

2023 Gartner Emerging Technologies and Trends Impact Radar



gartner.com

Note: Range measures number of years it will take the technology/trend to cross over from early adopter to early majority adoption. Mass indicates how substantial the impact of the technology or trend will be on existing products and markets.

Source: Gartner
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Gartner®

Edge Computer Vision has a high impact potential, and it is for **now!**

"Visual recognition has undergone the largest changes and fastest development in the last decade, due in part to the availability of much larger labeled datasets as well as breakthroughs in deep learning."

Computer Vision: Algorithms and Applications, 2nd ed.

Computer Vision Recognition Tasks

Image Classification (Multi-Class Classification)

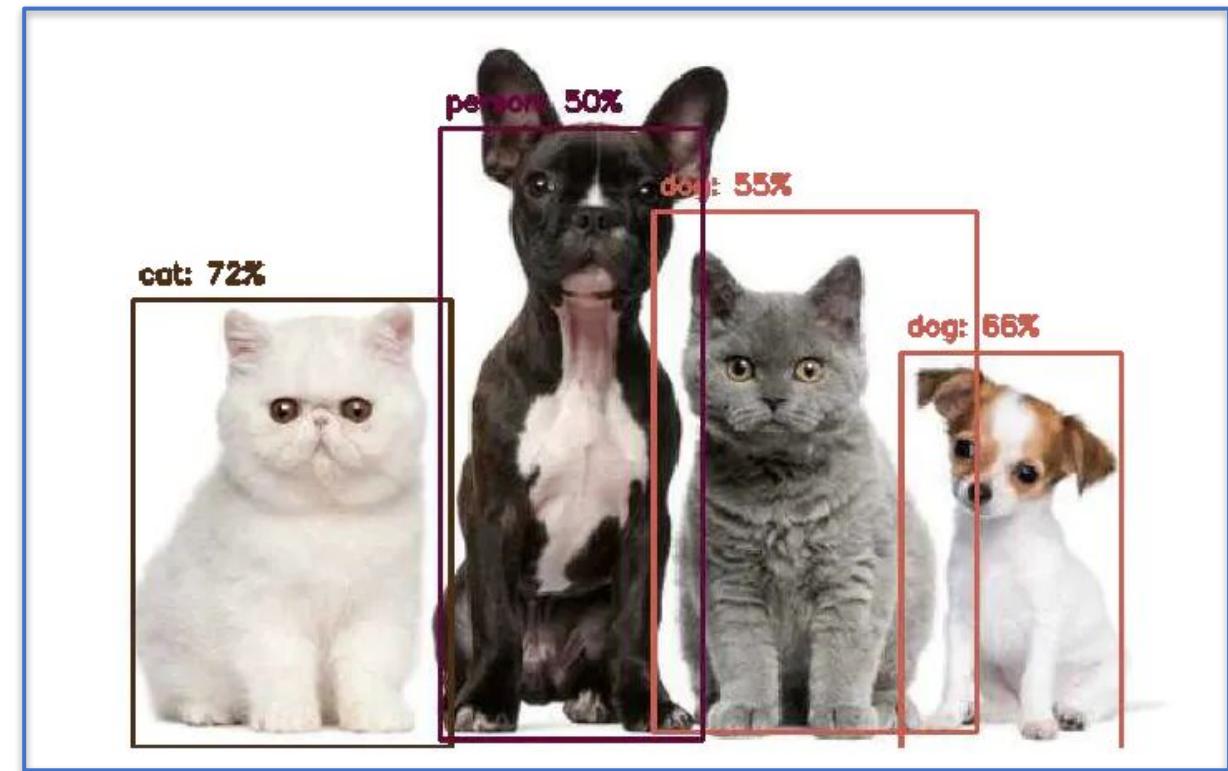


Cat: 70%



Dog: 80%

Object Detection Multi-Label Classification + Object Localization



Computer Vision Recognition Tasks

Instance Segmentation

Each pixel in an image IS CLASSIFIED into a predefined category.

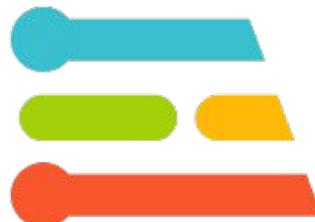


Pose Estimation

Key points (or landmarks) on the object, such as joints on a human body are detect



Image Classification Application: Design, Train, Test and Deploy



Computer Vision Recognition Tasks

Image Classification (Multi-Class Classification)



Cat: 70%



Dog: 80%

Object Detection Multi-Label Classification + Object Localization

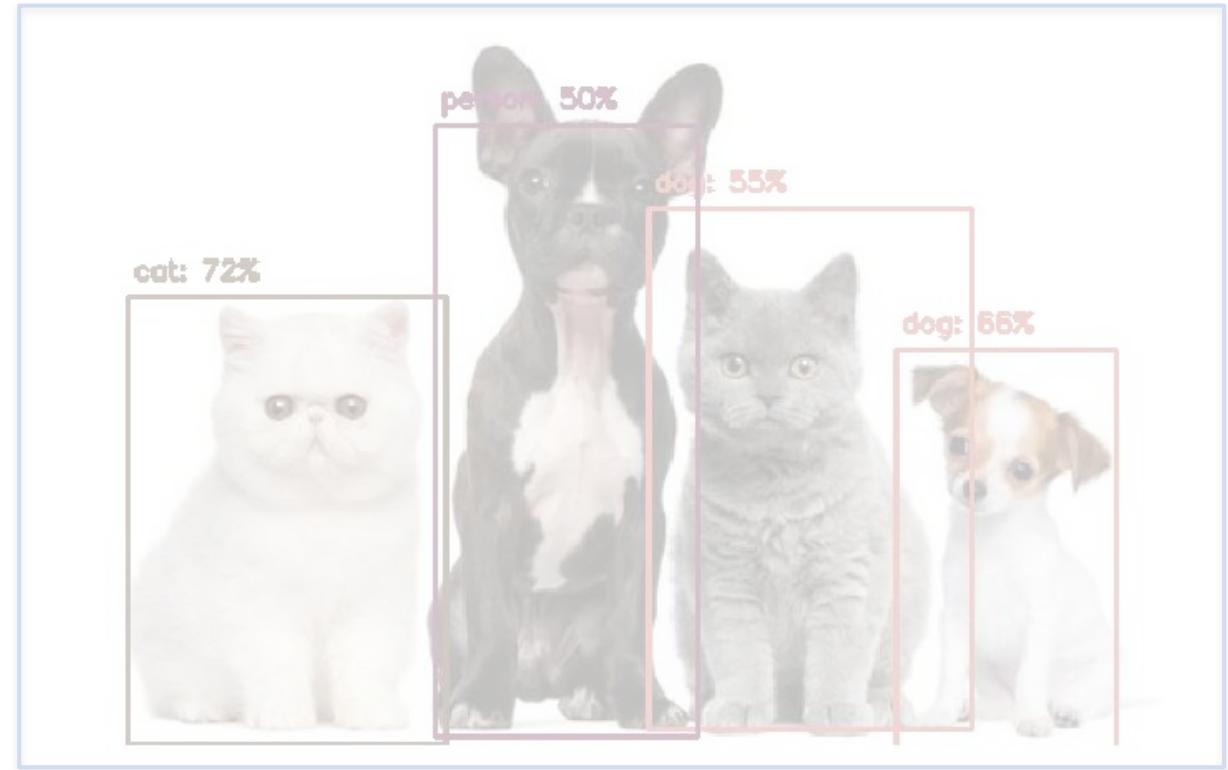
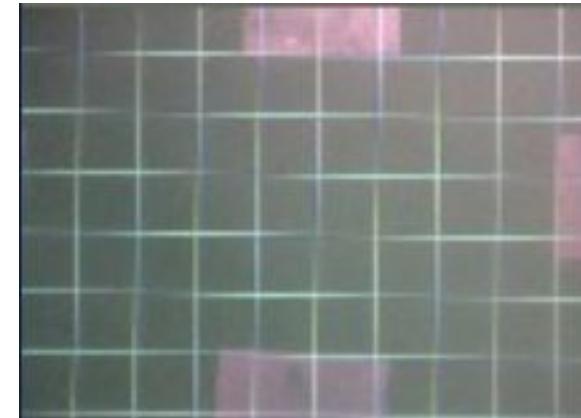


Image Classification Project 1

Decide a Goal

- Possible Images:
 - medicine
 - background



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

Image Classification Project 2

Decide a Goal

- Possible Images:
 - mug
 - background



<https://studio.edgeimpulse.com/public/139479/latest>

Image Classification Project 3

Decide a Goal

- Classes:
 - background
 - periquito
 - robot



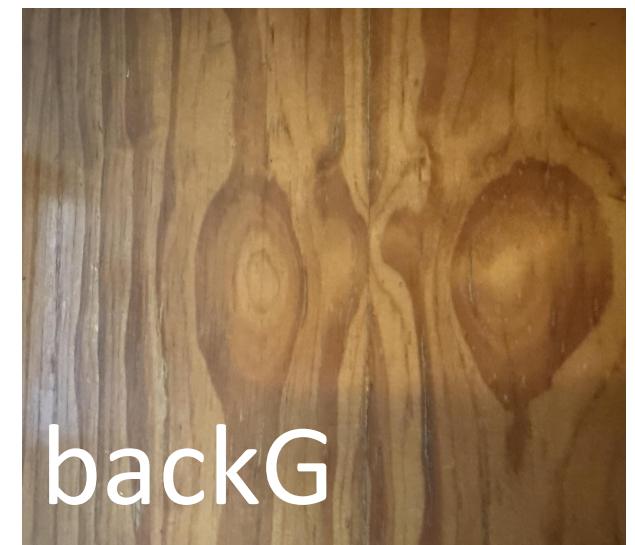
Image Classification Project 4

Medicine Classifier

Decide a Goal

Classes:

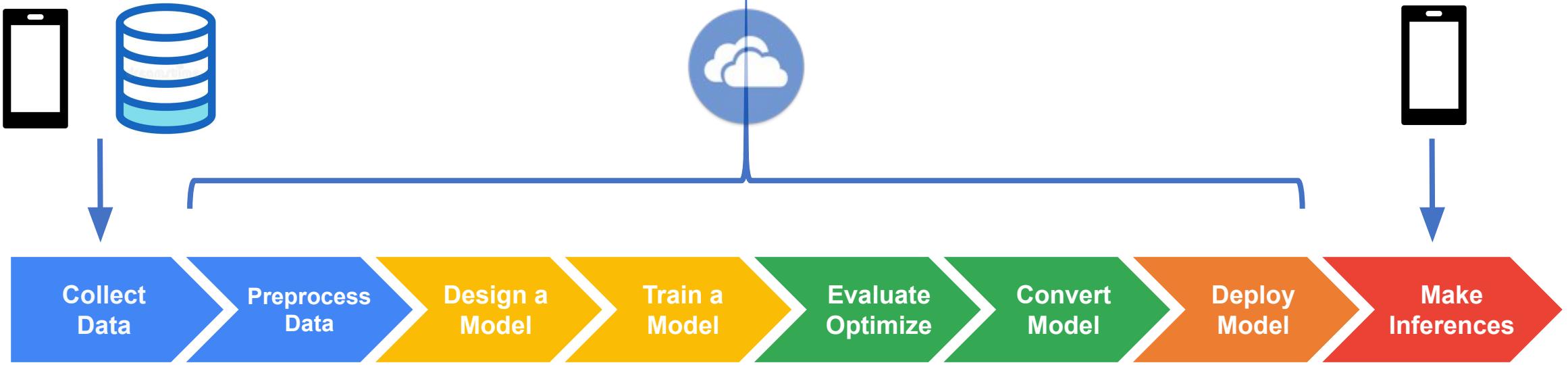
- prodR
- prodD
- prodT
- backG



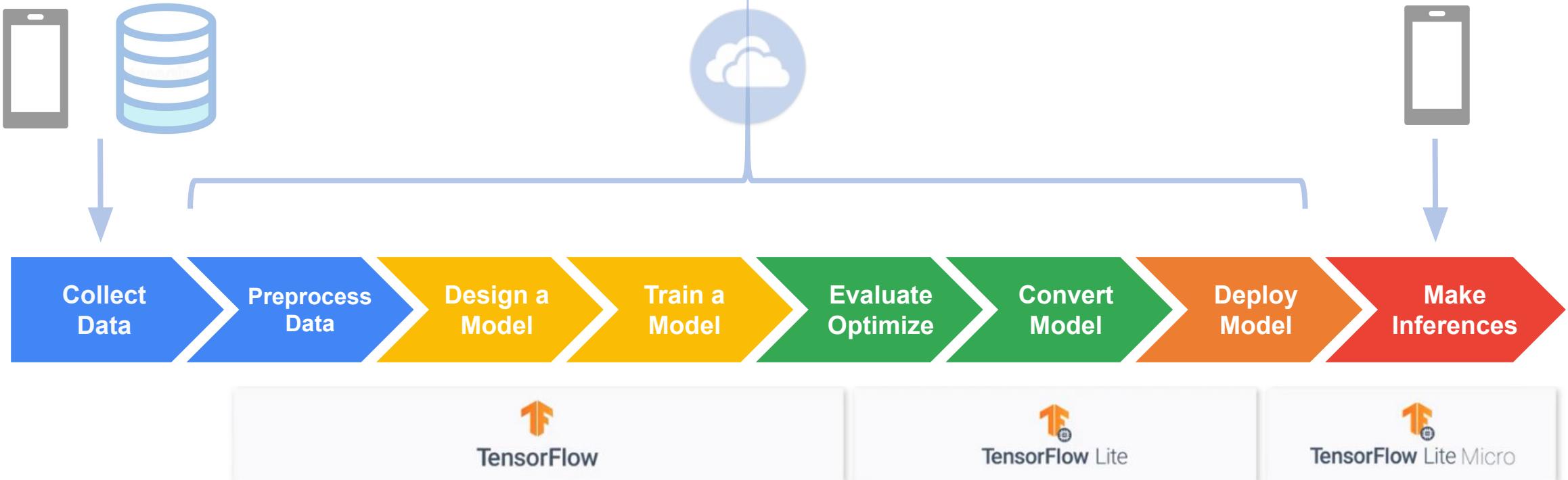
Machine Learning Workflow



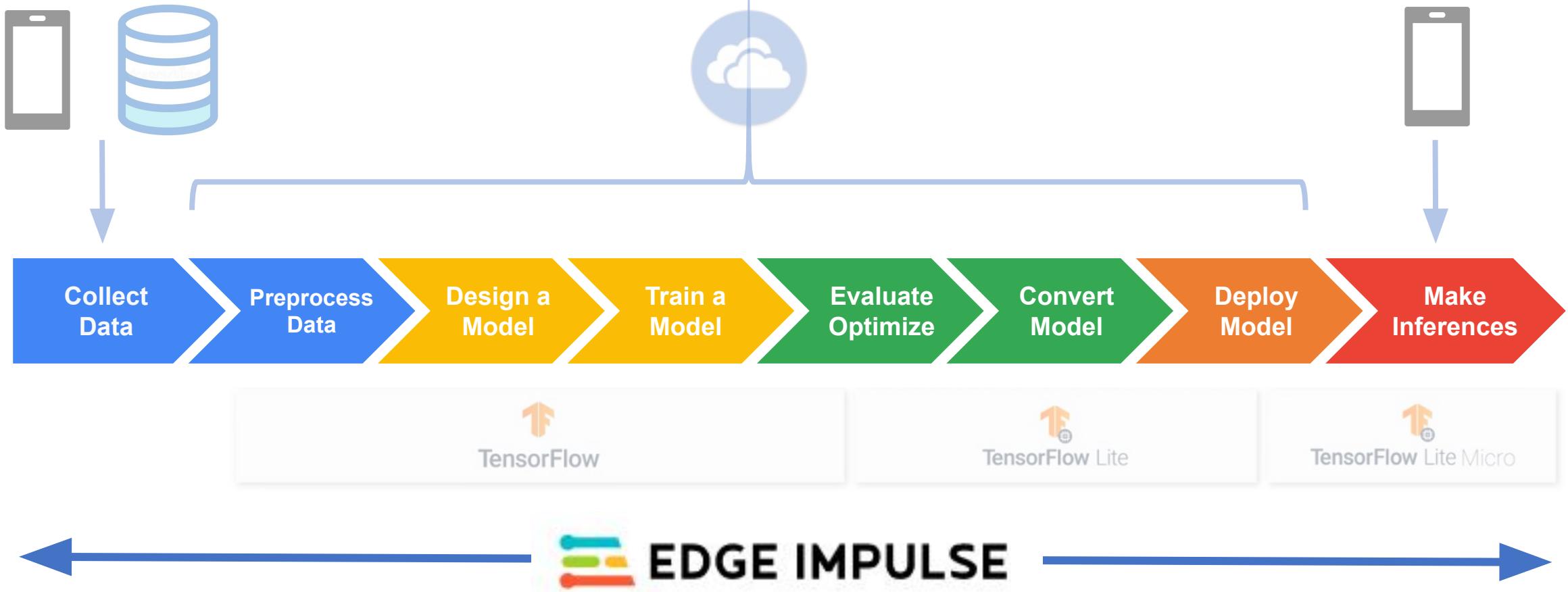
Machine Learning Workflow (“Where”)

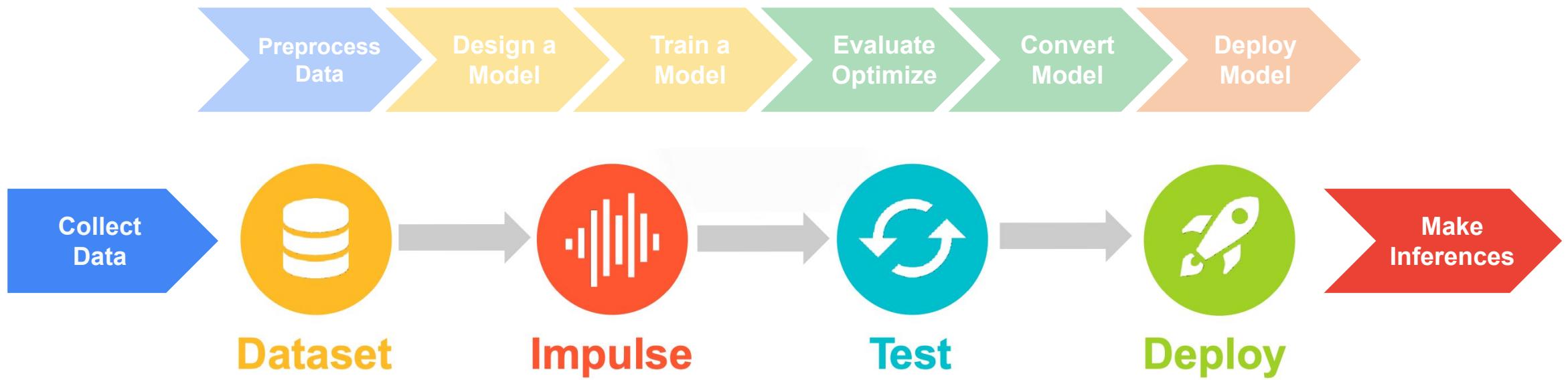


Machine Learning Workflow (“How”)

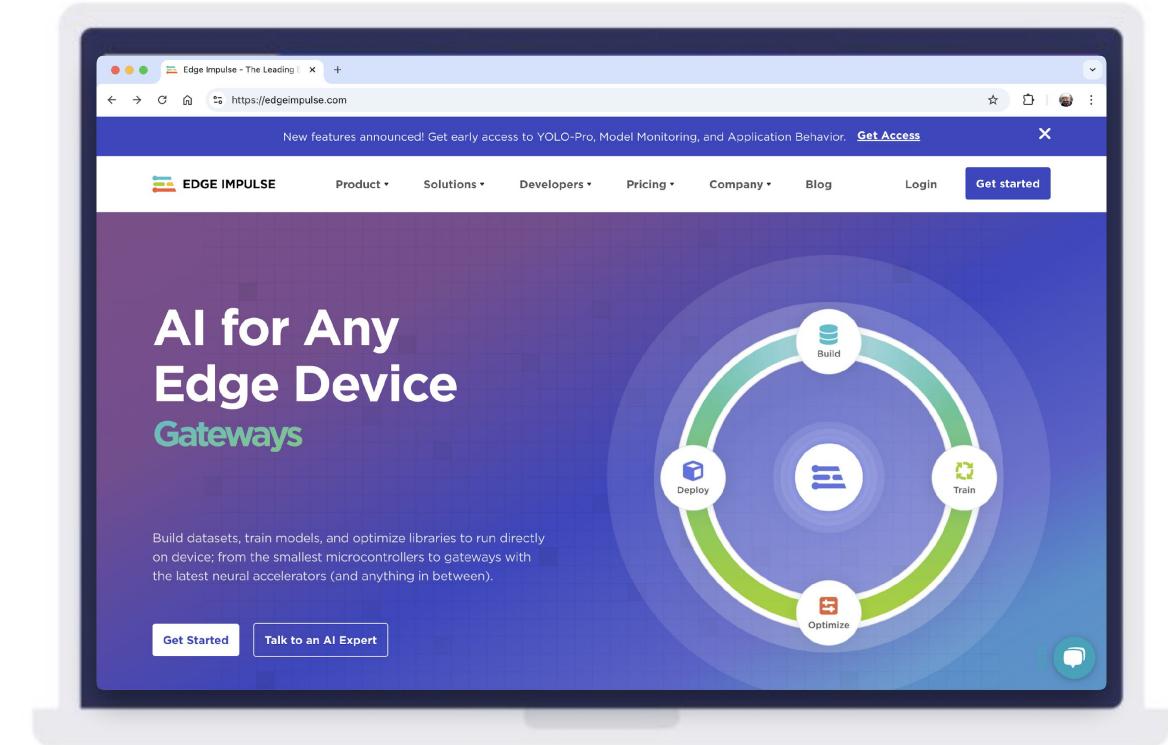
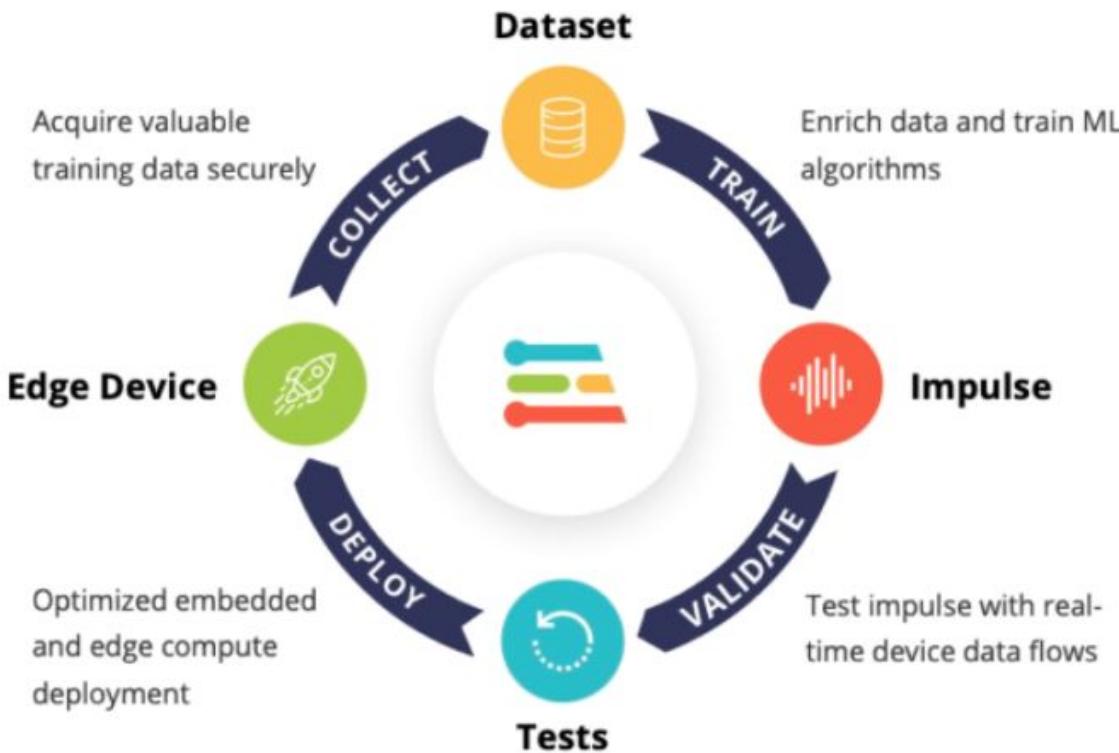


Machine Learning Workflow (“How”)





EI Studio - Embedded ML platform (“AutoML”)



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

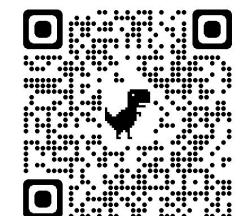


Image Classification Project

Edge Impulse Studio

<https://studio.edgeimpulse.com/public/540912/live>



The screenshot shows the homepage of the Edge Impulse website. At the top, there is a navigation bar with links for Product, Solutions, Developers, Pricing, Company, Blog, and Login. A yellow arrow labeled '1' points to the URL bar, which displays the address <https://edgeimpulse.com>. To the right of the URL bar, there is a call-to-action button labeled 'Get started' with an orange rounded rectangle around it. A yellow arrow labeled '2' points to this button. The main content area features a large purple banner with the text 'AI for Any Edge Device Gateways'. Below the banner, there is a circular diagram representing the AI development cycle, divided into four quadrants: Build (top), Train (right), Deploy (bottom-left), and Optimize (bottom-right). The text '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).' is displayed below the diagram. At the bottom left, there are two buttons: 'Get Started' and 'Talk to an AI Expert'. A small blue speech bubble icon is located at the bottom right.

New features announced! Get early access to YOLO-Pro, Model Monitoring, and Application Behavior. [Get Access](#)

EDGE IMPULSE

Product ▾ Solutions ▾ Developers ▾ Pricing ▾ Company ▾ Blog Login

Get started

AI for Any Edge Device Gateways

Build

Train

Deploy

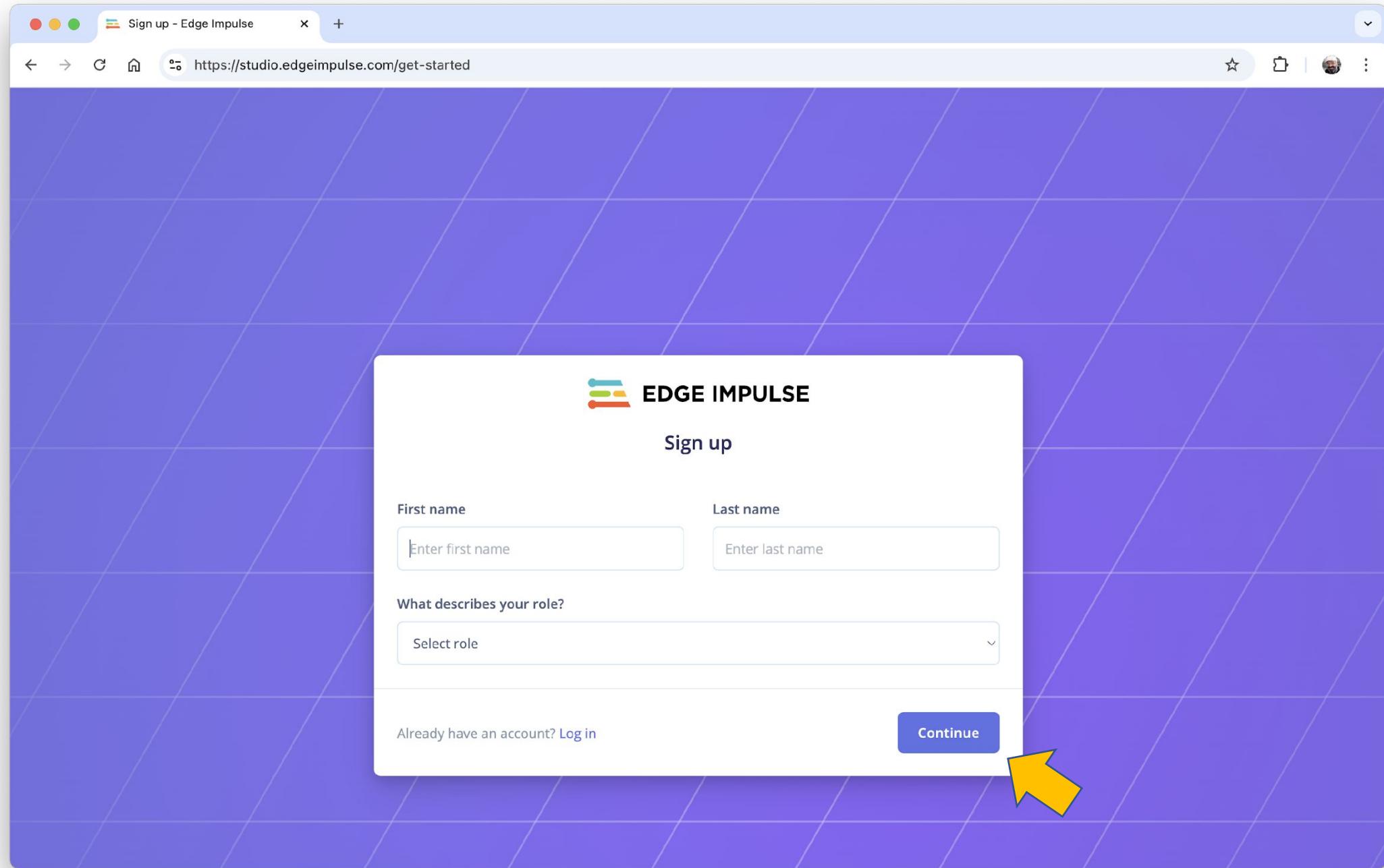
Optimize

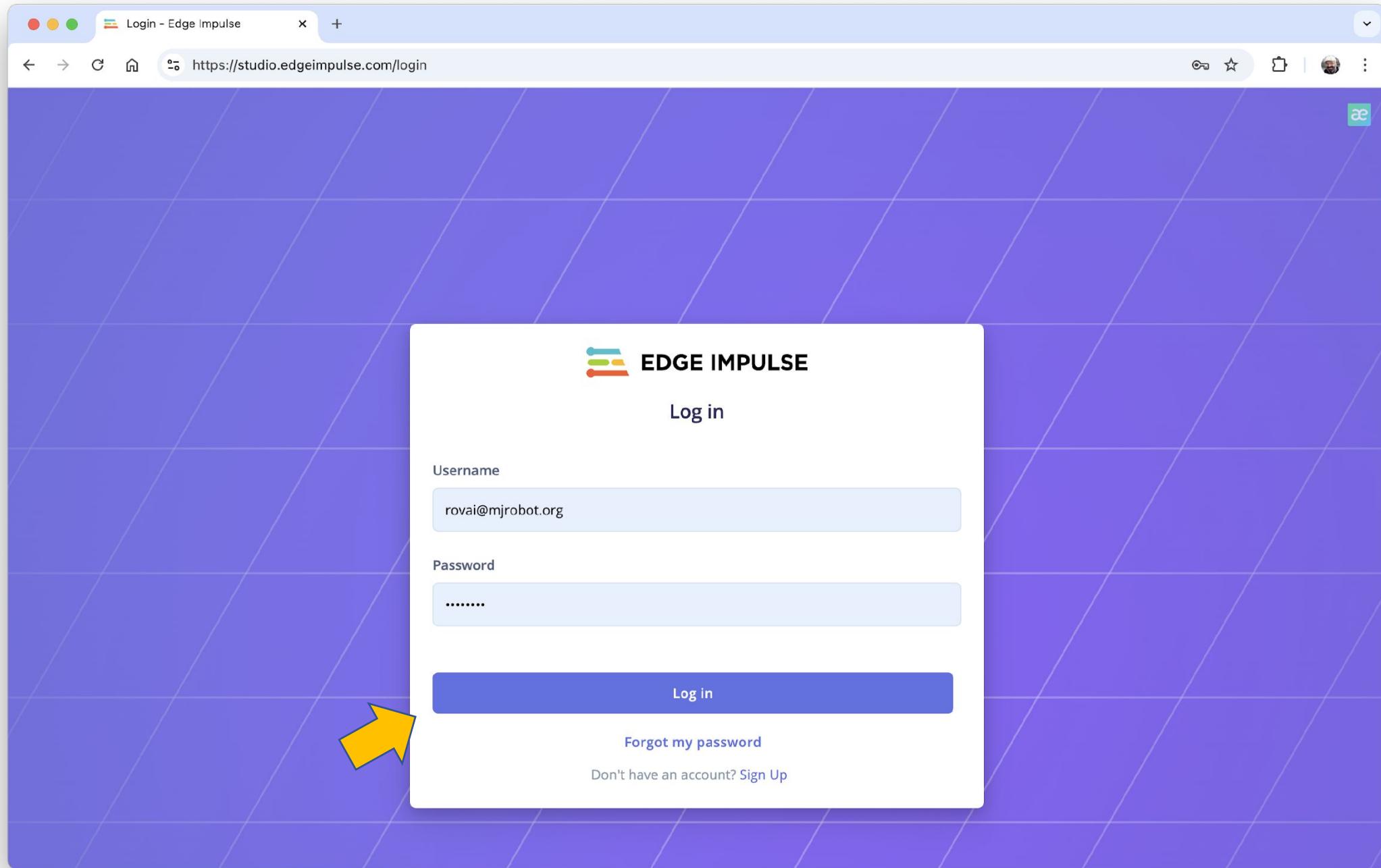
Get Started

Talk to an AI Expert

1

2





The screenshot shows the Edge Impulse web studio interface. On the left, there's a sidebar with a profile picture of a man with glasses and a beard, the text "MJRoBot (Marcelo Rovai)", and an "ENTERPRISE" badge. Below that is a "Enable MFA" section and an "Organizations" section with an "EIE" button. The main area has a purple header bar with the "EDGE IMPULSE" logo. A central modal window titled "Create a new project" is open. It contains a text input field with the placeholder "Enter the name for your new project:" containing the text "SDSU - Image Classification", which is highlighted with an orange border. Below it, there are two project type options: "Personal" (selected) and "Enterprise". The "Personal" option is described as having a 20 min job limit, 4GB or 4 hours of data, and limited collaboration. The "Enterprise" option is described as having no job or data size limits, higher performance, and custom blocks. Underneath, there's a dropdown menu set to "Edge Impulse Experts". The next section is "Choose your project setting:" with two options: "Public" (selected) and "Private". The "Public" setting is described as allowing anyone on the internet to view and clone the project under the Apache 2.0 license. The "Private" setting is described as allowing only invited users to edit and view the project. At the bottom of the modal is a green "Create new project" button. To the right of the modal, the main workspace shows a list of projects with a "Sort" dropdown and a "+ Create new project" button. A yellow arrow points from the bottom right towards the "Create new project" button.

Profile - Projects - Edge Impulse

https://studio.edgeimpulse.com/studio/profile/projects?autoredirect=1&createNewProject=1

EDGE IMPULSE

MJRoBot (Marcelo Rovai)

ENTERPRISE

Enable MFA

Multi-factor authentication is now available for all users. Set up now.

Organizations

EIE

Create a new project

Enter the name for your new project:

SDSU - Image Classification

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.

Create under organization: Edge Impulse Experts

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.

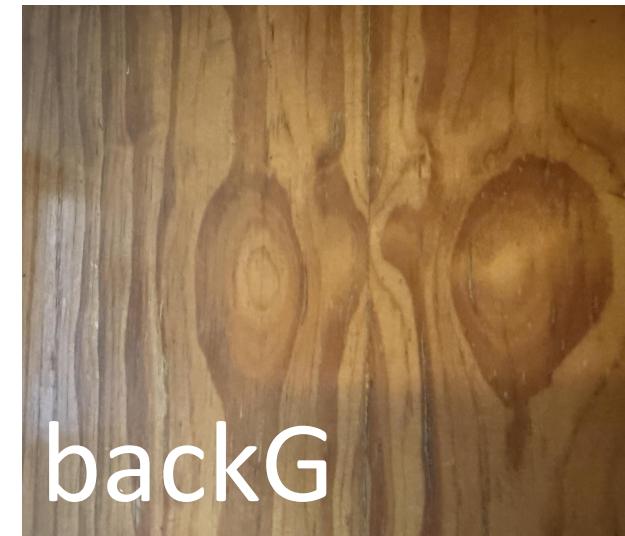
Private (0 of 2 remaining)
Only invited users can edit and view your project.

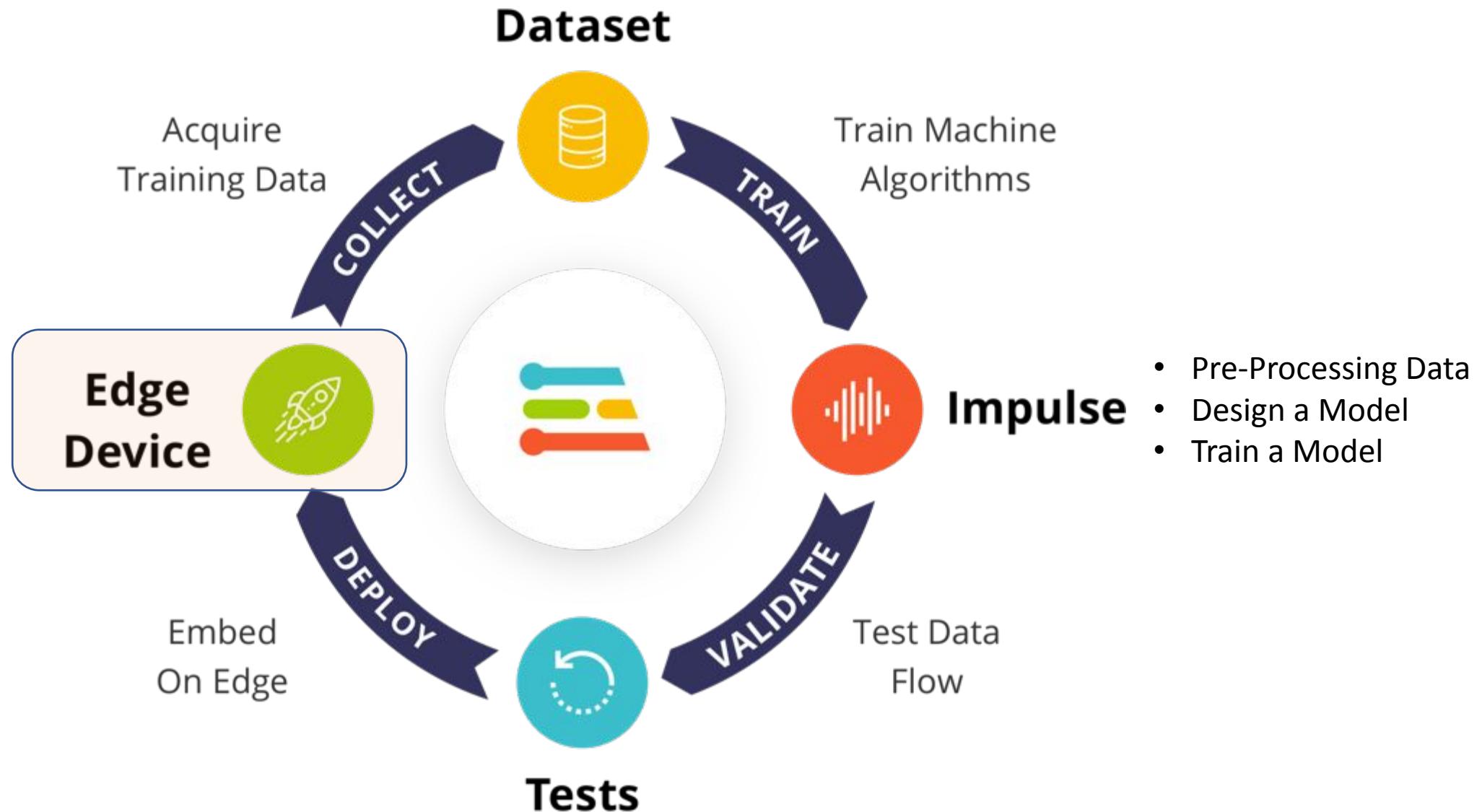
Create new project

MJRoBot (Marcelo Rovai) / video_tinyml_raw

Medicine Classifier

- Classes:
 - prodR
 - prodD
 - prodT
 - backG

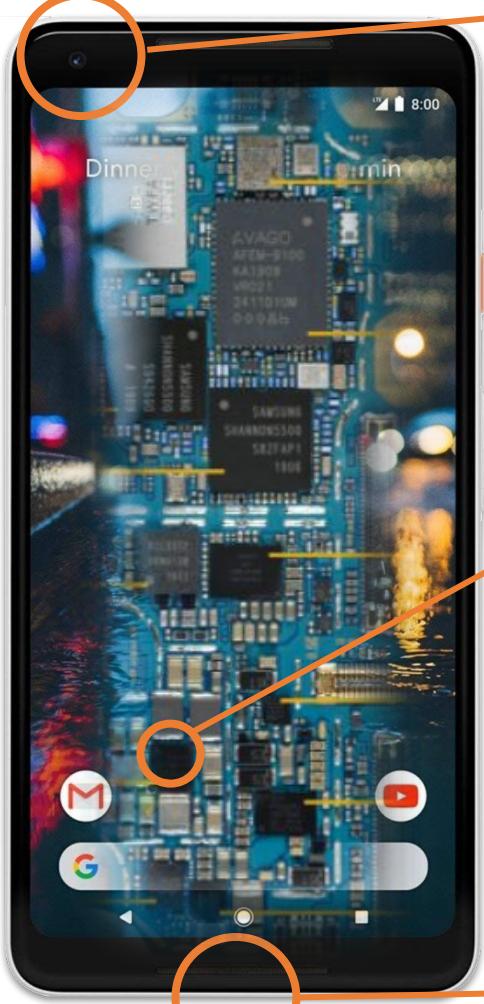




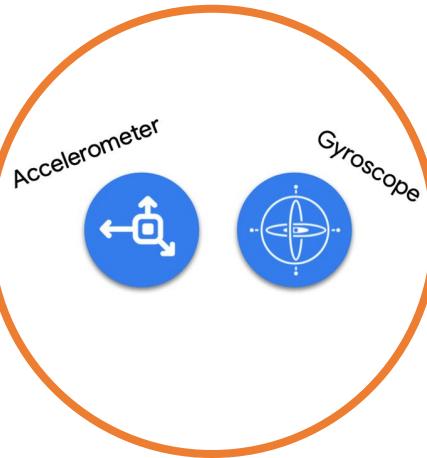
Edge Device



& Sensors



Camera



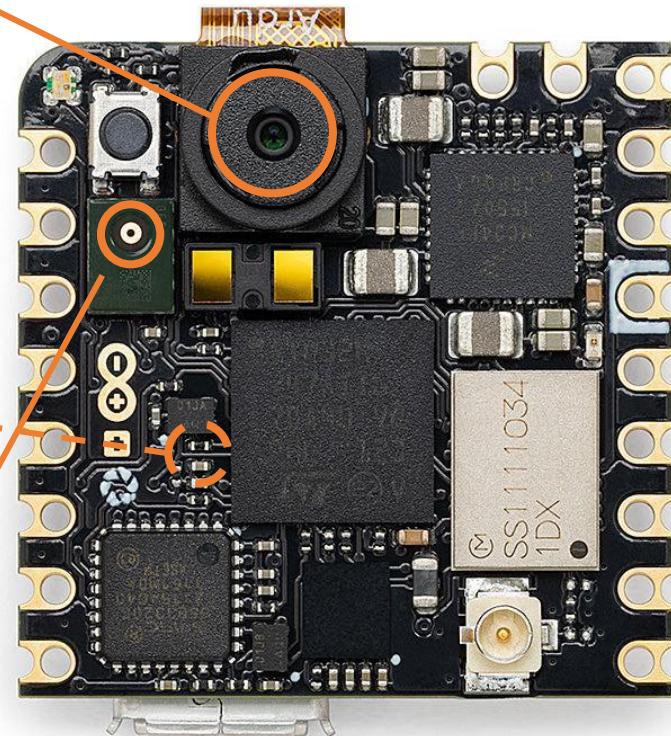
Accelerometer



Gyroscope



Microphone



The screenshot shows the Edge Impulse Studio interface for SDSU - Image Classification. The left sidebar has a 'Data acquisition' section highlighted with an orange box. The main area has tabs for Dataset, Data explorer, Data sources, and CSV Wizard. The Dataset tab shows a placeholder for adding data with a '+ Add data' button. The Collect data section contains a message: 'Connect a device to start building your dataset.' A yellow arrow points to this message. The top right shows a profile picture and the text 'Target: Raspberry Pi 5'.

SDSU - Image Classification

MJRoBot (Marcelo Rovai) / SDSU - Image Classification PERSONAL

Target: Raspberry Pi 5

EDGE IMPULSE

Dataset Data explorer Data sources | CSV Wizard

Dataset

Add data

Start building your dataset by adding some data.

+ Add data

Collect data

Connect a device to start building your dataset.

Dashboard

Devices

Data acquisition

Experiments

Impulse design

- Create impulse
- Retrain model

Live classification

Model testing

Deployment

Versioning

GETTING STARTED

Documentation

Forums

SDSU - Image Classification

https://studio.edgeimpulse.com/studio/540912/acquisition/training?page=1#collect-new-data

EDGE IMPULSE

Dashboard

Devices

Data acquisition

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GETTING STARTED

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Forums

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

+ Add data

edgeimpulse.com

CINEMA VÍDEO FOTO RETRATO ESPAC

EDGE IMPULSE

Dashboard

Devices

Data acquisition

Experiments

Impulse design

- Create impulse
- Retrain model

Live classification

Model testing

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Versioning

GETTING STARTED

Documentation

Forums

Accelerometer

16:48 Camera

smartphone.edgeimpulse.com

Data collection

Device "phone_m23dz5xi" is now connected

Get started!

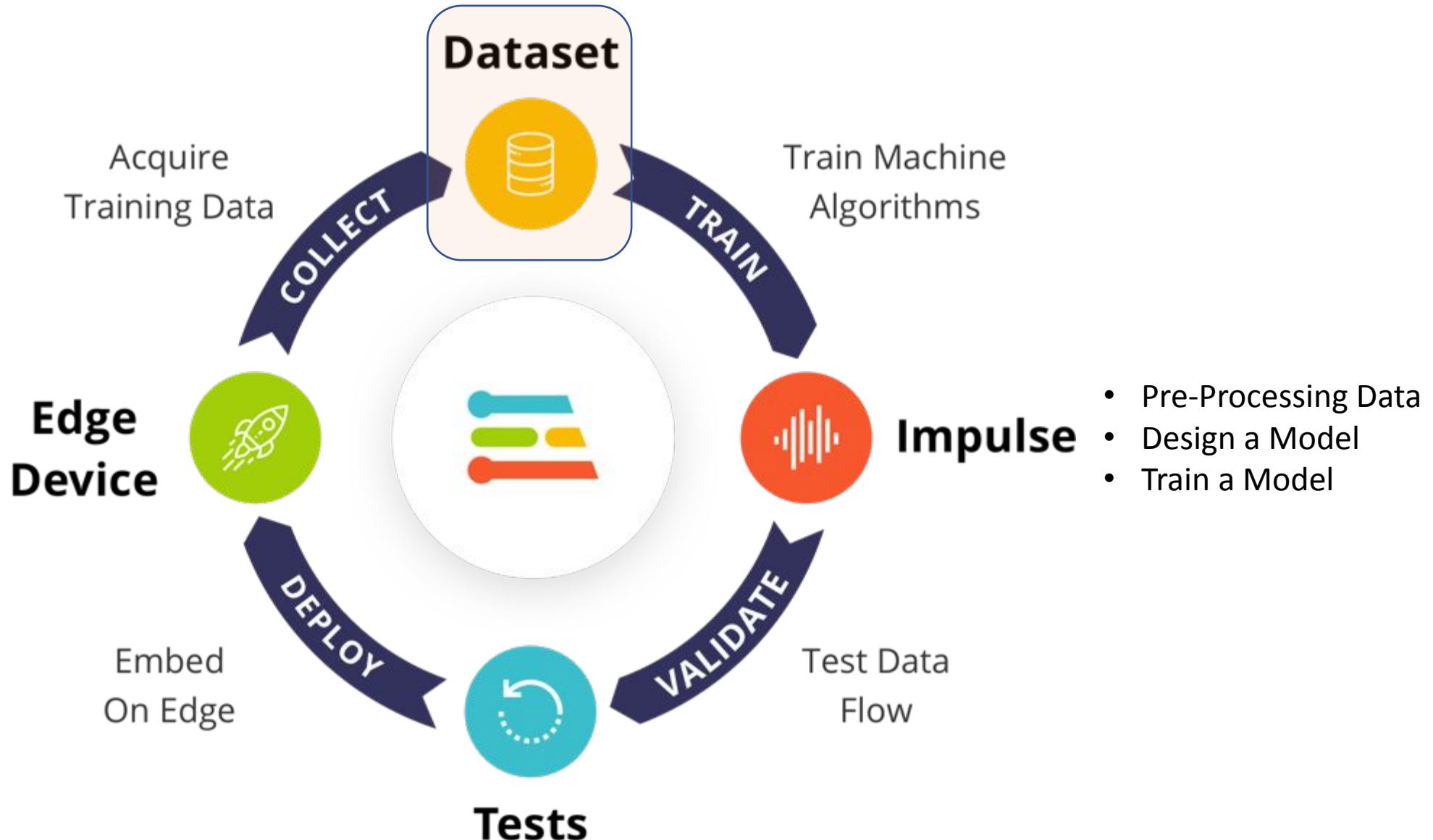
Back

Collecting images?

Collecting audio?

Collecting motion?

27



SDSU - Image Classification - +

https://studio.edgeimpulse.com/studio/540912/acquisition/training?page=1

EDGE IMPULSE

MJRoBot (Marcelo Rovai) / SDSU - Image Classification PERSONAL

Target: Raspberry Pi 5

Dataset Data explorer Data sources | CSV Wizard

DATA COLLECTED 1 items TRAIN / TEST SPLIT 100% / 0% ⚠️

Collect data

device to start building your dataset.

Dataset

Training (1) Test (0)

SAMPLE NAME unknown.sakut99q

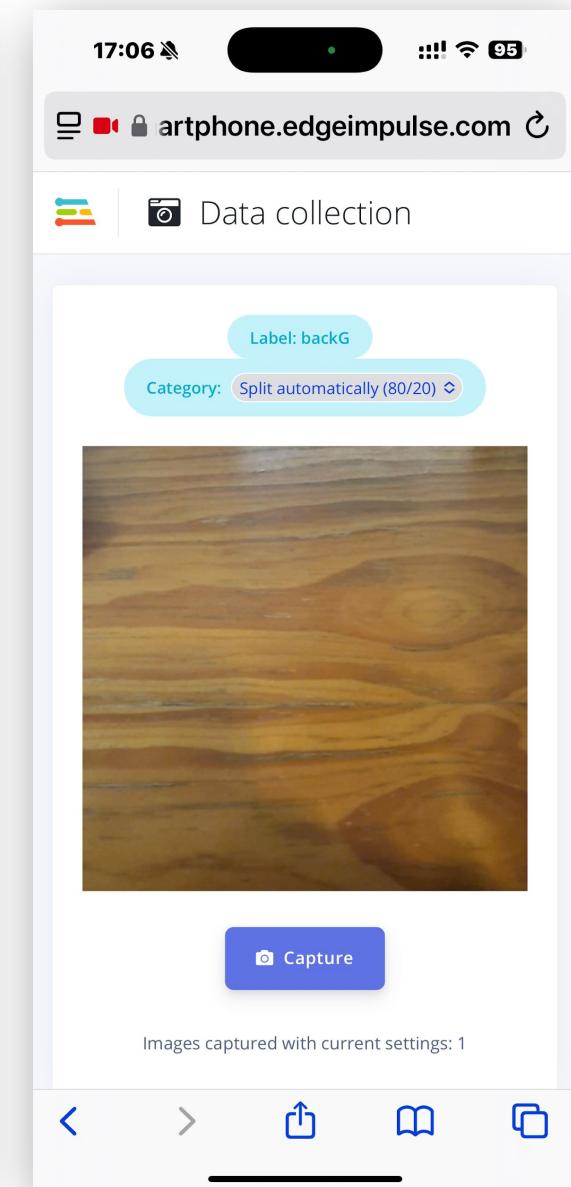
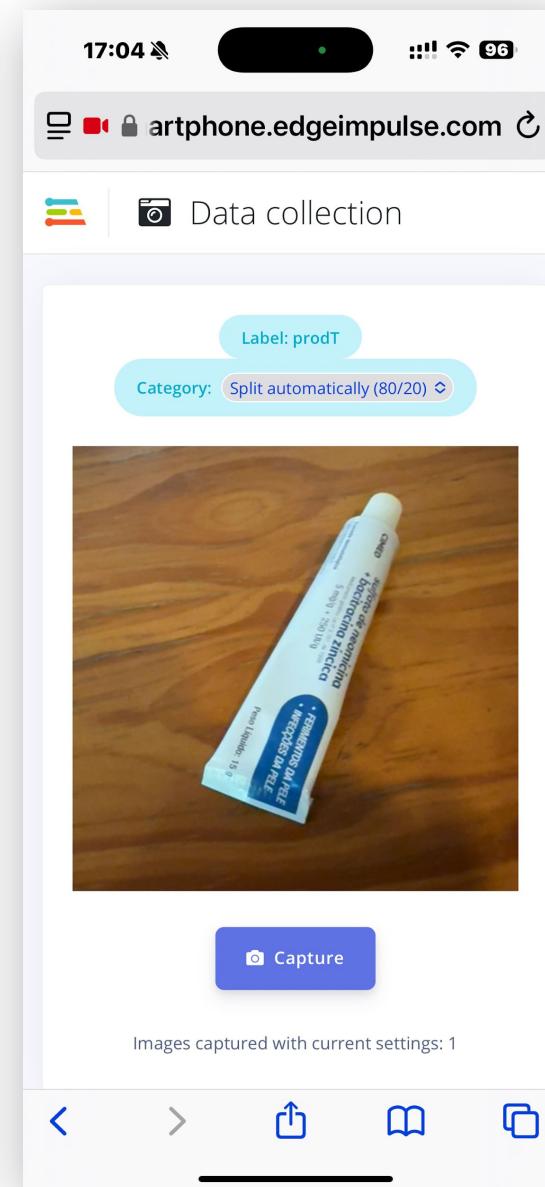
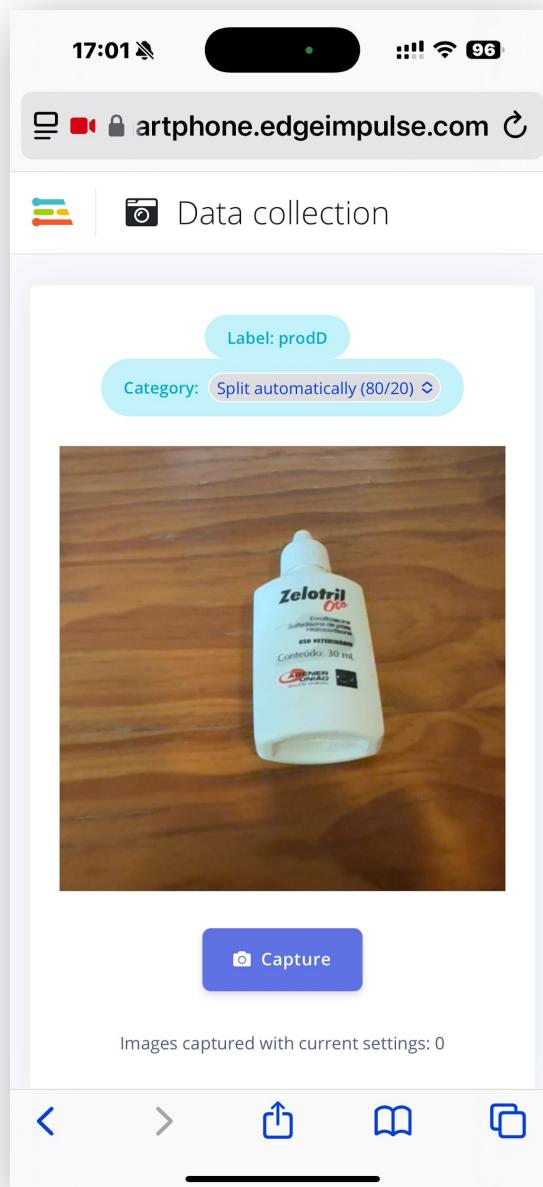
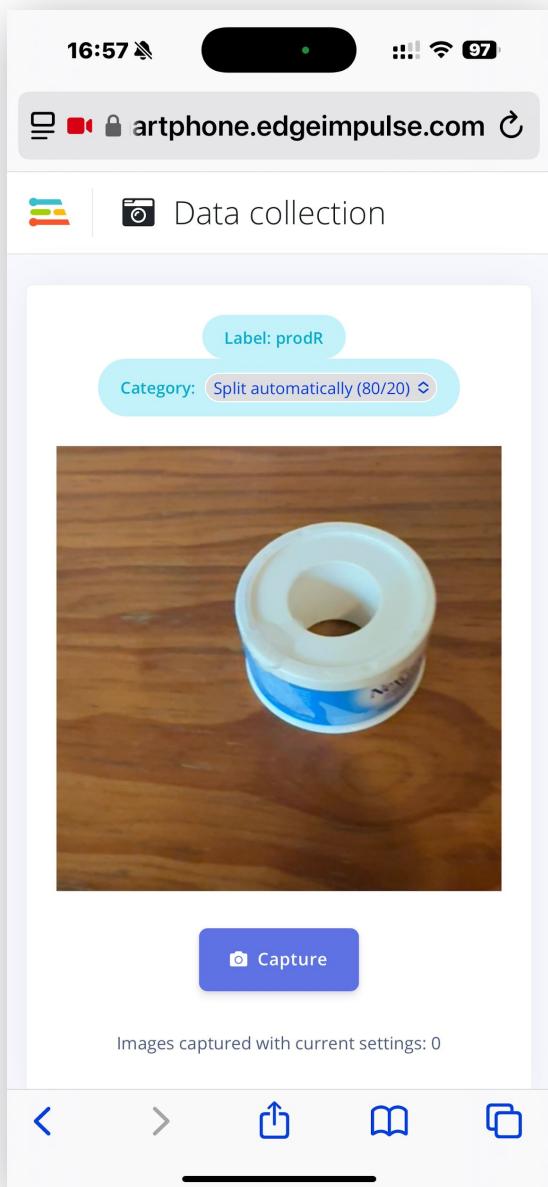
IMAGE DATA DETECTED!

Are you building an object detection project?

You can change this choice under "Dashboard > Labeling method".

Yes No

.5akut99q



Collect Data

The screenshot shows the Edge Impulse Studio interface for SDSU - Image Classification. On the left, a sidebar titled "Collect Data" lists navigation options: Dashboard, Devices, Data acquisition, Experiments, Impulse design (with sub-options Create impulse, Retrain model, Live classification, Model testing, Deployment), Versioning, GETTING STARTED (Documentation, Forums), and a plus sign icon. The main area is titled "Dataset" and displays a summary: "DATA COLLECTED 200 items" with a pie chart icon, and "TRAIN / TEST SPLIT 83% / 17%" with a warning icon. Below this, a "Dataset" section shows two tabs: "Training (166)" and "Test (34)". Six images of a white tube labeled "prodT" are listed under the training tab, each with its file name and label. To the right, a large image shows a white tube labeled "prodT.5akvinki" on a wooden surface, with the text "RAW DATA prodT.5akvinki" above it. The top right corner shows a user profile for MJRoBot (Marcelo Rovai) and a "Target: Raspberry Pi 5" indicator.

SDSU - Image Classification

https://studio.edgeimpulse.com/studio/540912/acquisition/training?page=5

MJRoBot (Marcelo Rovai) / SDSU - Image Classification PERSONAL

Target: Raspberry Pi 5

EDGE IMPULSE

Dataset Data explorer Data sources | CSV Wizard

DATA COLLECTED
200 items

TRAIN / TEST SPLIT
83% / 17%

Collect data

Connect a device to start building your dataset.

Dataset

Training (166) Test (34)

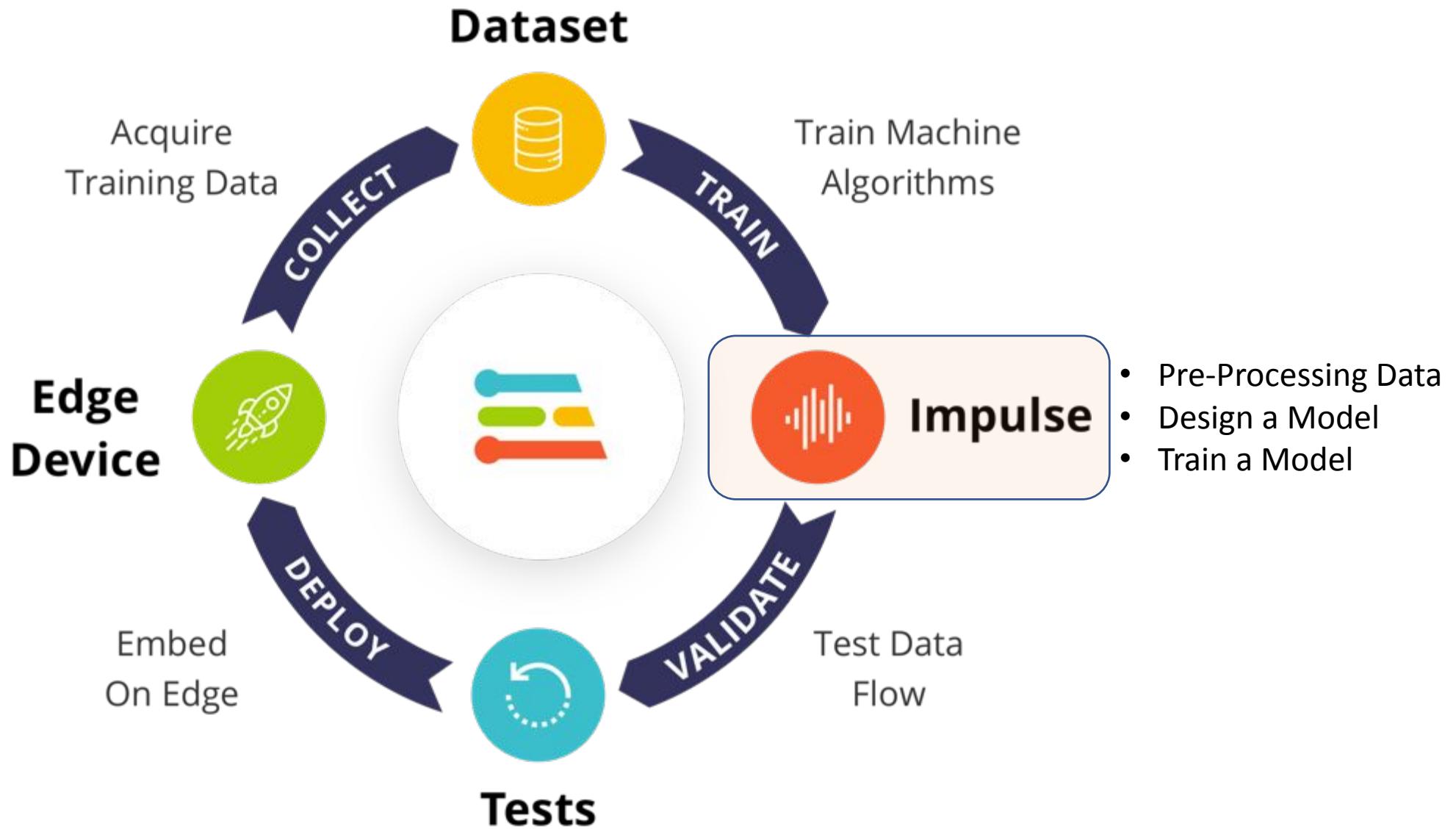
prodT.5akvir3n prodT.5akvinki prodT.5akvind1

prodT.5akvijc3 prodT.5akviifr prodT.5akvih1t

prodT.5akvinki

RAW DATA

?



SDSU - Image Classification

https://studio.edgeimpulse.com/studio/540912/impulse/1/create-impulse

MJRoBot (Marcelo Rovai) / SDSU - Image Classification PERSONAL

Target: Raspberry Pi 5

EDGE IMPULSE

Impulse #1

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

Image data

Input axes

image

Image ... Image h...

96 96

Resize mode

S ↗

Image

Name

Transfer Learning (Images)

Name

Transfer learning

Input axes (1)

Image

Output features

5 (backG, prodD, prodR, prodT, unknown)

Save Impulse

?

Dashboard

Devices

Data acquisition

Experiments

Impulse design

- Create impulse

Retrain model

Live classification

Model testing

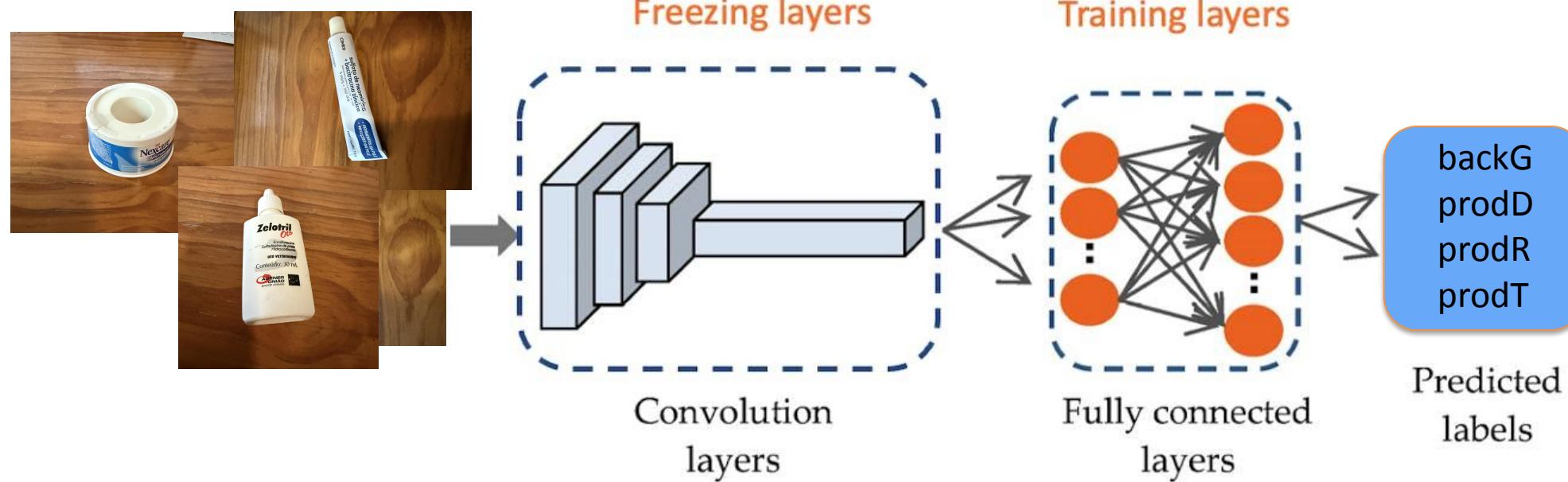
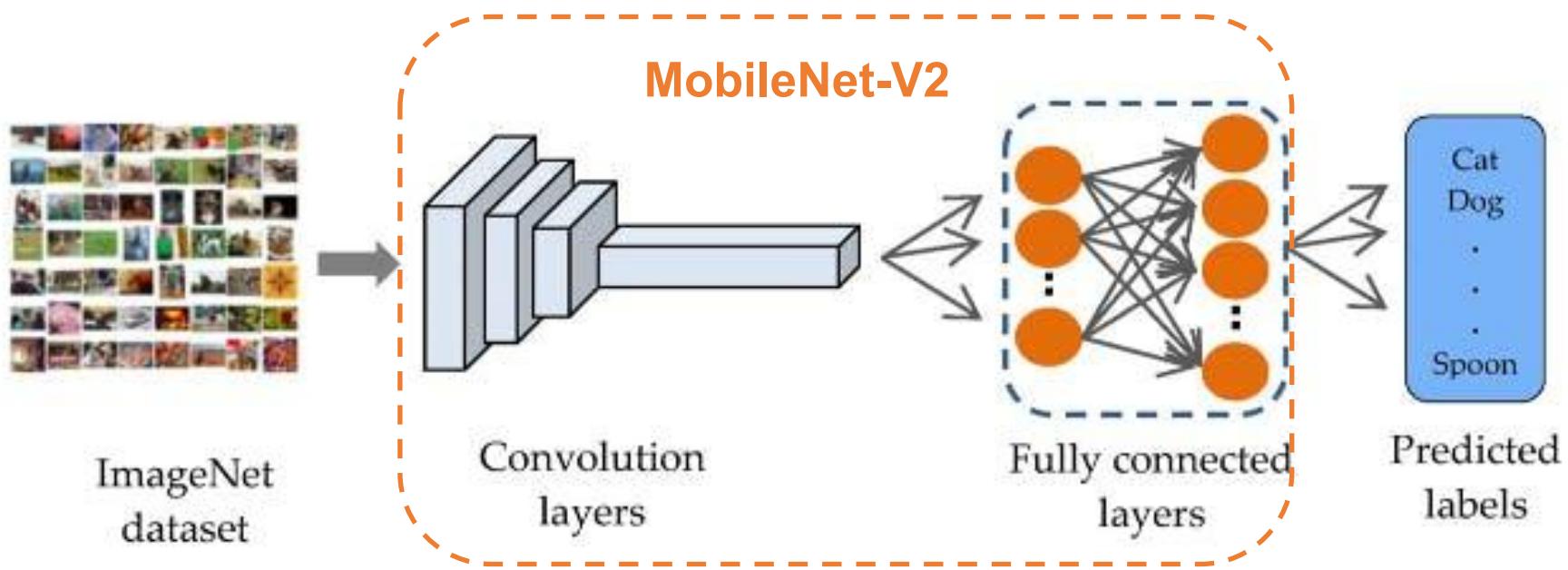
Deployment

Versioning

GETTING STARTED

Documentation

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Preprocess Data

SDSU - Image Classification - X +

https://studio.edgeimpulse.com/studio/540912/impulse/1/dsp/image/2

MJRoBot (Marcelo Rovai) / SDSU - Image Classification PERSONAL Target: Raspberry Pi 5

EDGE IMPULSE

Parameters Generate features

Raw data Show: prodD prodD.5akvf5fd (prc)

Raw features 

DSP result Image **96x96x3 = 27,648**

Processed features 

Parameters

Image

Color depth **RGB**

Save parameters

GETTING STARTED

A yellow arrow points from the text "Preprocess Data" to the "Save parameters" button.

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Preprocess Data

SDSU - Image Classification - https://studio.edgeimpulse.com/studio/540912/impulse/1/dsp/image/2/generate-features

EDGE IMPULSE

Parameters **Generate features**

Training set

Data in training set: 166 items
Classes: 4 (backG, prodD, prodR, prodT)

Generate features

Feature generation output (0)

Creating job... OK (ID: 25038003)
Scheduling job in cluster...
Container image pulled!
Job started
Fetching info for data items...
Fetching info for data items OK

Scheduling job in cluster...
Container image pulled!
Job started
Creating windows from files...
[1/1] Creating windows from files...
[1/1] Creating windows from files...

Feature explorer

Legend: backG (blue), prodD (orange), prodR (green), prodT (red)

On-device performance

PROCESSING TIME: 1 ms. PEAK RAM USAGE: 4 KB

Documentation

Neural Network settings

Hyperparameters

Training settings

Number of training cycles ②

20

Use learned optimizer ②



Learning rate ②

0.0005

Training processor ②

CPU



Data augmentation ②



Advanced training settings

Validation set size ②

20

%

Split train/validation set on metadata key ②



Batch size ②

32

Auto-weight classes ②



Profile int8 model ②



Neural network architecture

Model Design

Input layer (27,648 features)



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

Choose a different model

Output layer (4 classes)

Save & train



Last training performance (validation set)



ACCURACY
85.3%



LOSS
0.43

Confusion matrix (validation set)

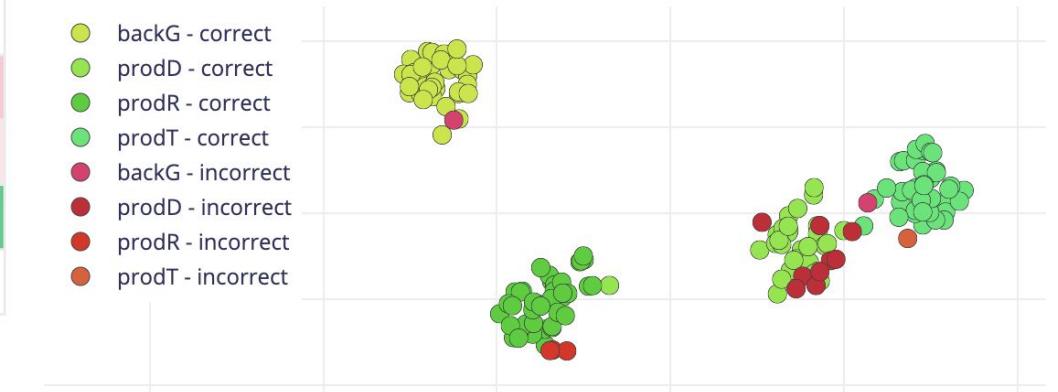
	BACKG	PRODD	PRODR	PRODT
BACKG	77.8%	11.1%	11.1%	0%
PRODD	0%	71.4%	0%	28.6%
PRODR	0%	0%	85.7%	14.3%
PRODT	0%	0%	0%	100%
F1 SCORE	0.88	0.77	0.86	0.88

Metrics (validation set)

METRIC	VALUE
Area under ROC Curve ⓘ	0.98
Weighted average Precision ⓘ	0.87
Weighted average Recall ⓘ	0.85
Weighted average F1 score ⓘ	0.85

Data explorer (full training set) ⓘ

- backG - correct
- prodD - correct
- prodR - correct
- prodT - correct
- backG - incorrect
- prodD - incorrect
- prodR - incorrect
- prodT - incorrect



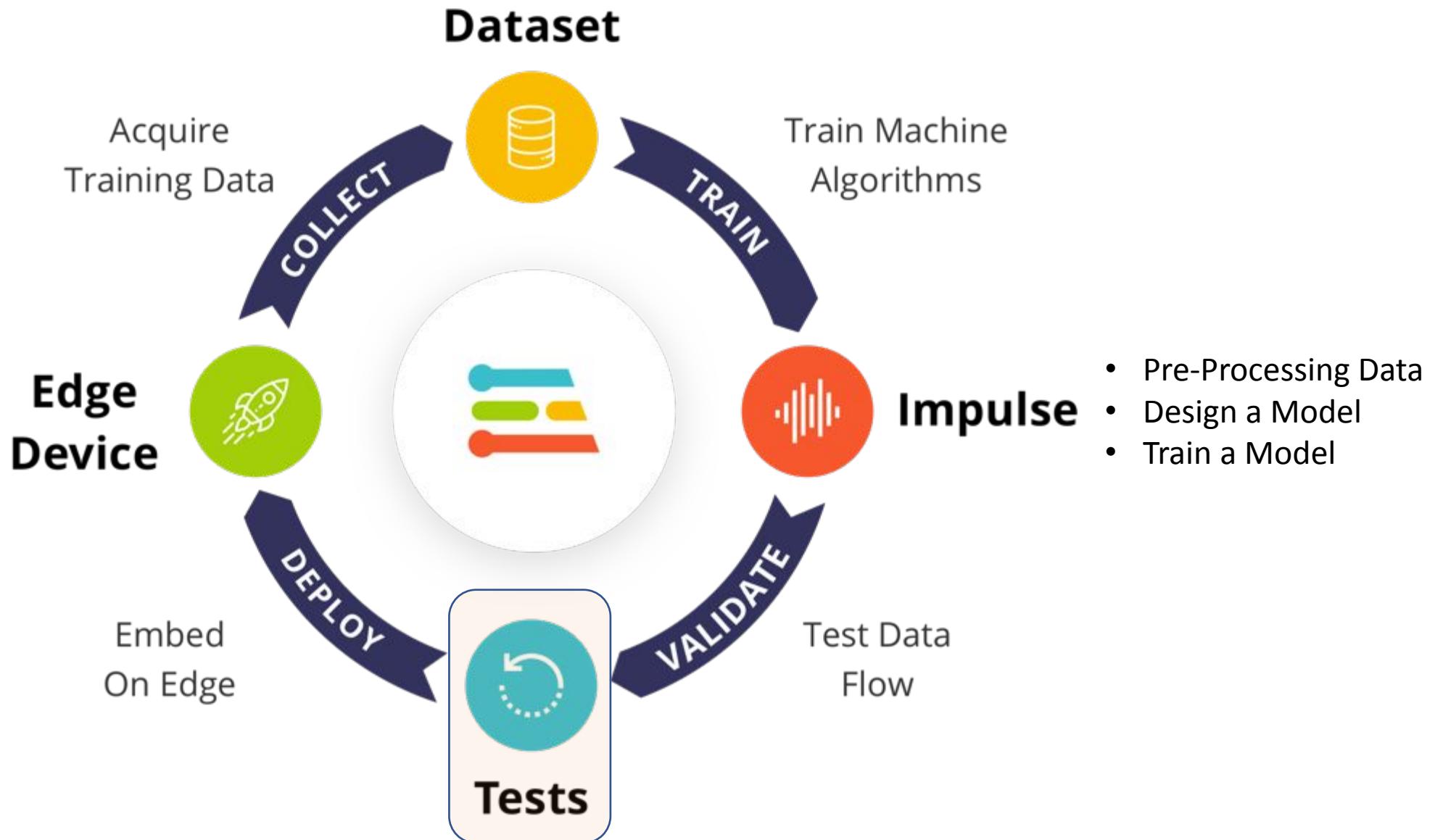
The screenshot shows the Edge Impulse Studio interface for SDSU - Image Classification. The left sidebar has a yellow arrow pointing right labeled "Design a Model" and another yellow arrow pointing right labeled "Train a Model". The main area is divided into two main sections:

- Neural Network settings** (highlighted with an orange circle):
 - Training settings**: Number of training cycles (20), Use learned optimizer (unchecked), Learning rate (0.0005), Training processor (CPU), Data augmentation (checked).
 - Advanced training settings**
 - 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 (4 classes).
- Training output**: Converts TensorFlow Lite int8 quantized model..., Attached to job 25038061..., Loading data for profiling..., Loading data for profiling OK, Creating embeddings... [0/166] Creating embeddings..., [166/166] Creating embeddings..., Creating embeddings OK (took 5 seconds), Calculating performance metrics..., Calculating inferencing time..., INFO: Created TensorFlow Lite XNNPACK delegate for CPU, Calculating inferencing time OK, Calculating float32 accuracy...

Model (highlighted with an orange circle): Model version: Quantized (int8). Last training performance (validation set): Accuracy 85.3%, Loss 0.43. Confusion matrix (validation set):

	BACKG	PRODD	PRODR	PRODT
BACKG	77.8%	11.1%	11.1%	0%
PRODD	0%	71.4%	0%	28.6%
PRODR	0%	0%	85.7%	14.3%
PRODT	0%	0%	0%	100%
F1 SCORE	0.88	0.77	0.86	0.88

Metrics (validation set): METRIC VALUE
Area under ROC Curve 0.98



Evaluate Optimize

SDSU - Image Classification - <https://studio.edgeimpulse.com/studio/540912/impulse/1/validation>

Test data

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

SAMPLE NAME	EXPECTED OUTCOME	ACCURACY	RESULT	⋮
backG.5akvm3dv	backG	100%	1 backG	⋮
backG.5akvm0es	backG	100%	1 backG	⋮
backG.5akvlvkq	backG	100%	1 backG	⋮
backG.5akvlsrf	backG	100%	1 backG	⋮
backG.5akvlpnrm	backG	100%	1 backG	⋮
backG.5akvlfes	backG	100%	1 backG	⋮
backG.5akvlb4n	backG	100%	1 backG	⋮
backG.5akvkrcc	backG	0%	1 uncertain	⋮
backG.5akvkmq6	backG	100%	1 backG	⋮
backG.5akvkktr	backG	100%	1 backG	⋮
prodT.5akviphm	prodT	0%	1 prodD	⋮

Model testing output

Classifying data for float32 model...
Scheduling job in cluster...
Container image pulled!
Job started
INFO: Created TensorFlow Lite XNNPACK delegate for CPU.

Classifying data for Transfer learning OK

Generating model testing summary...
Finished generating model testing summary

Job completed (success)

Results Model version: [②](#) [Unoptimized \(float32\) ▾](#)

ACCURACY 88.24%

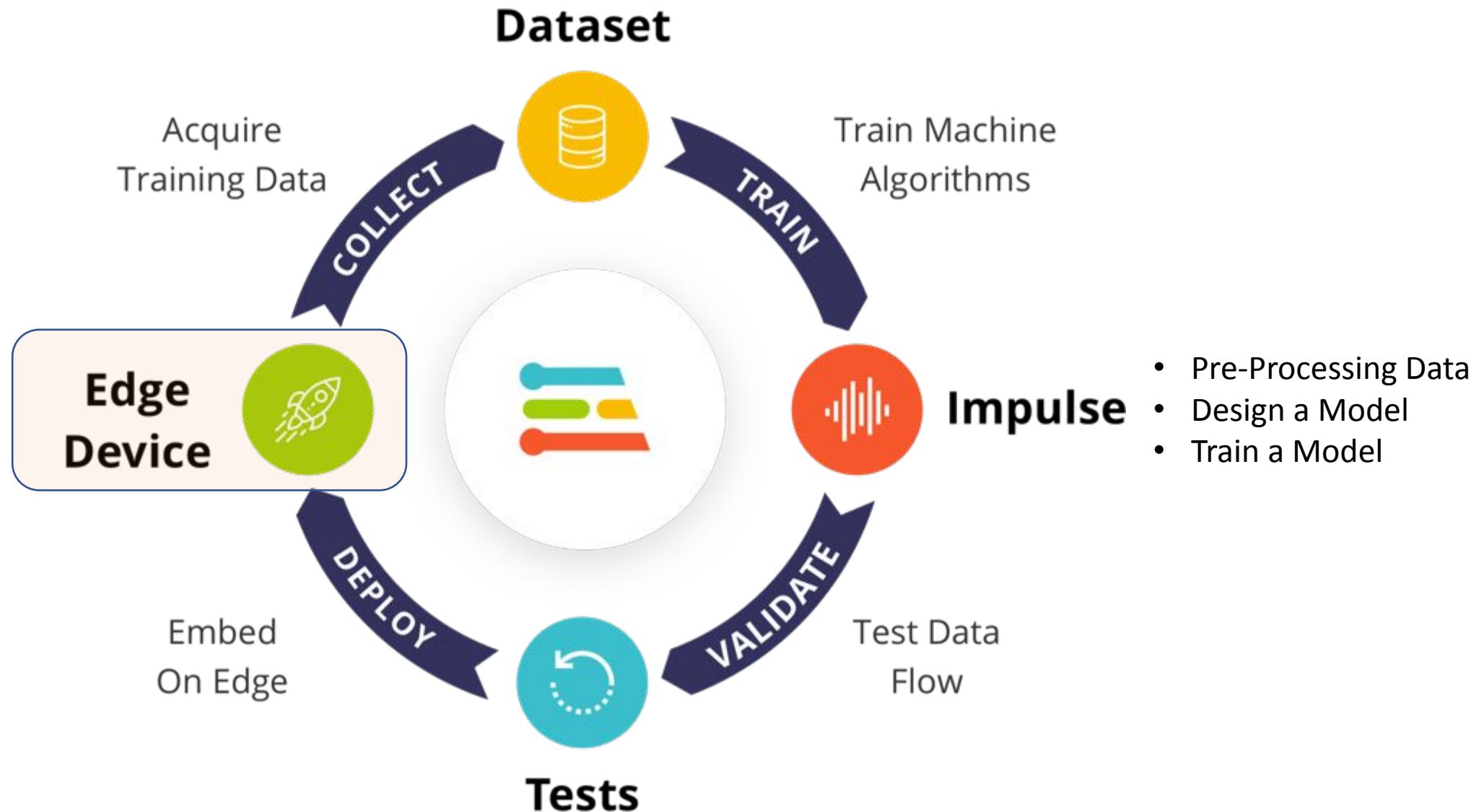
Metrics for Transfer learning

METRIC	VALUE
Area under ROC Curve ②	1.00
Weighted average Precision ②	0.95
Weighted average Recall ②	0.94
Weighted average F1 score ②	0.94

Confusion matrix

	BACKG	PRODD	PRODR	PRODT	UNCERTAIN
BACKG	90%	0%	0%	0%	10%
PRODD	0%	87.5%	0%	0%	12.5%
PRODR	0%	0%	85.7%	0%	14.3%
PRODT	0%	11.1%	0%	88.9%	0%
F1 SCORE	0.95	0.88	0.92	0.94	

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Deploy Model

SDSU - Image Classification - X + https://studio.edgeimpulse.com/studio/540912/impulse/1/deployment

EDGE IMPULSE MJRoBot (Marcelo Rovai) / SDSU - Image Classification PERSONAL Target: Raspberry Pi 5

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

DEFAULT DEPLOYMENT

C++ library

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

MODEL OPTIMIZATIONS

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

EON™ Compiler

Same accuracy, 17% less RAM, 14% less ROM.

Quantized (int8) Selected ✓

	IMAGE	TRANSFER LEARNING	TOTAL
LATENCY	1 ms.	4 ms.	5 ms.
RAM	4.0K	334.7K	334.7K
FLASH	-	585.8K	-
ACCURACY			-

Unoptimized (float32) Select

	IMAGE	TRANSFER LEARNING	TOTAL
LATENCY	1 ms.	2 ms.	3 ms.
RAM	4.0K	893.7K	893.7K
FLASH	-	1.6M	-
ACCURACY			88.24%

To compare model accuracy, run model testing for all available optimizations. [Run model testing](#)

Run this model

Scan QR code or launch in browser to test your prototype



Launch in browser

Make
Inferences

Inference – Real World

prodR
Time per inference: 1 ms.

	BACKG	PRODD	PRODR	PRODT
3...	0.00	0.02	0.98	0.00

< >

prodT
Time per inference: 1 ms.

	BACKG	PRODD	PRODR	PRODT
3...	0.00	0.01	0.00	0.99

< >

prodD
Time per inference: 1 ms.

	BACKG	PRODD	PRODR	PRODT
3...	0.00	1.00	0.00	0.00

< >

backG
Time per inference: 1 ms.

	BACKG	PRODD	PRODR	PRODT
4...	1.00	0.00	0.00	0.00

< >

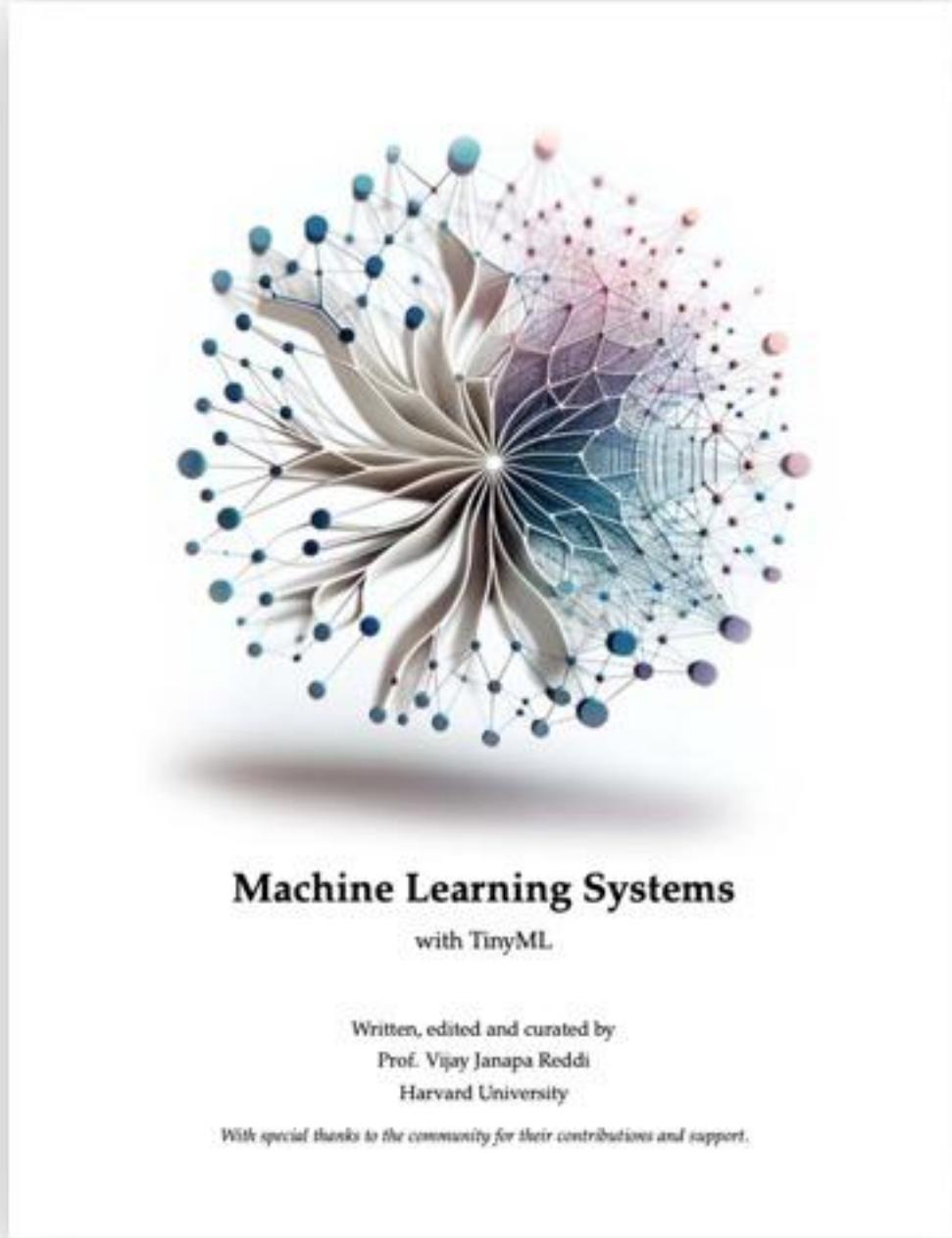
uncertain
Time per inference: 1 ms.

	BACKG	PRODD	PRODR	PRODT
7...	0.05	0.38	0.54	0.03

< >

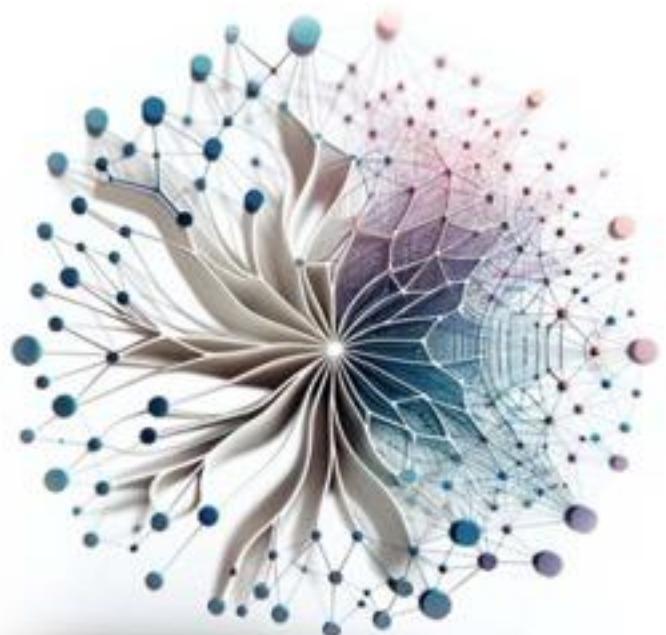
Object Detection Application: Design, Train, Test and Deploy





Nicla Vision

XIAO ESP32S3



Machine Learning Systems

with TinyML

Written, edited and curated by

Prof. Vijay Janapa Reddi

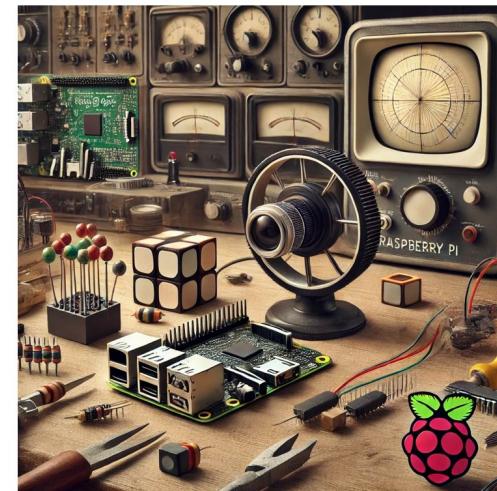
Harvard University

With special thanks to the community for their contributions and support.



Raspberry Pi > Object Detection

Object Detection



Raspberry Pi

FOMO

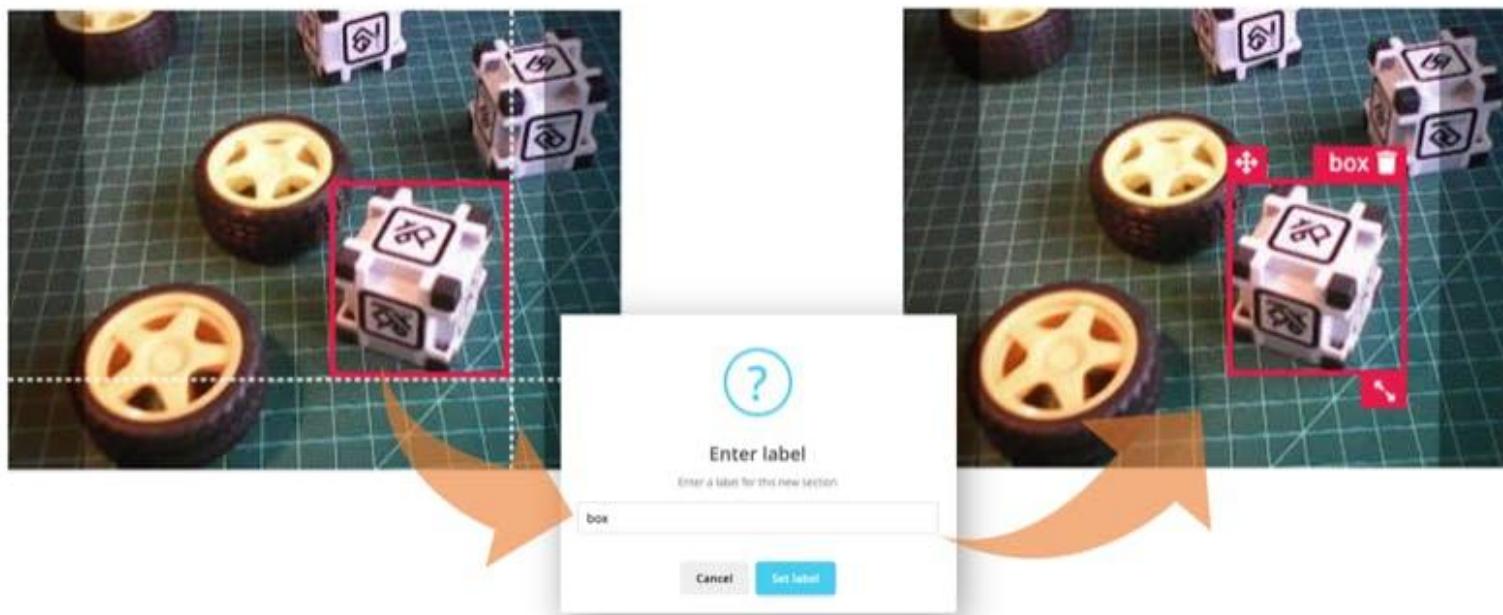
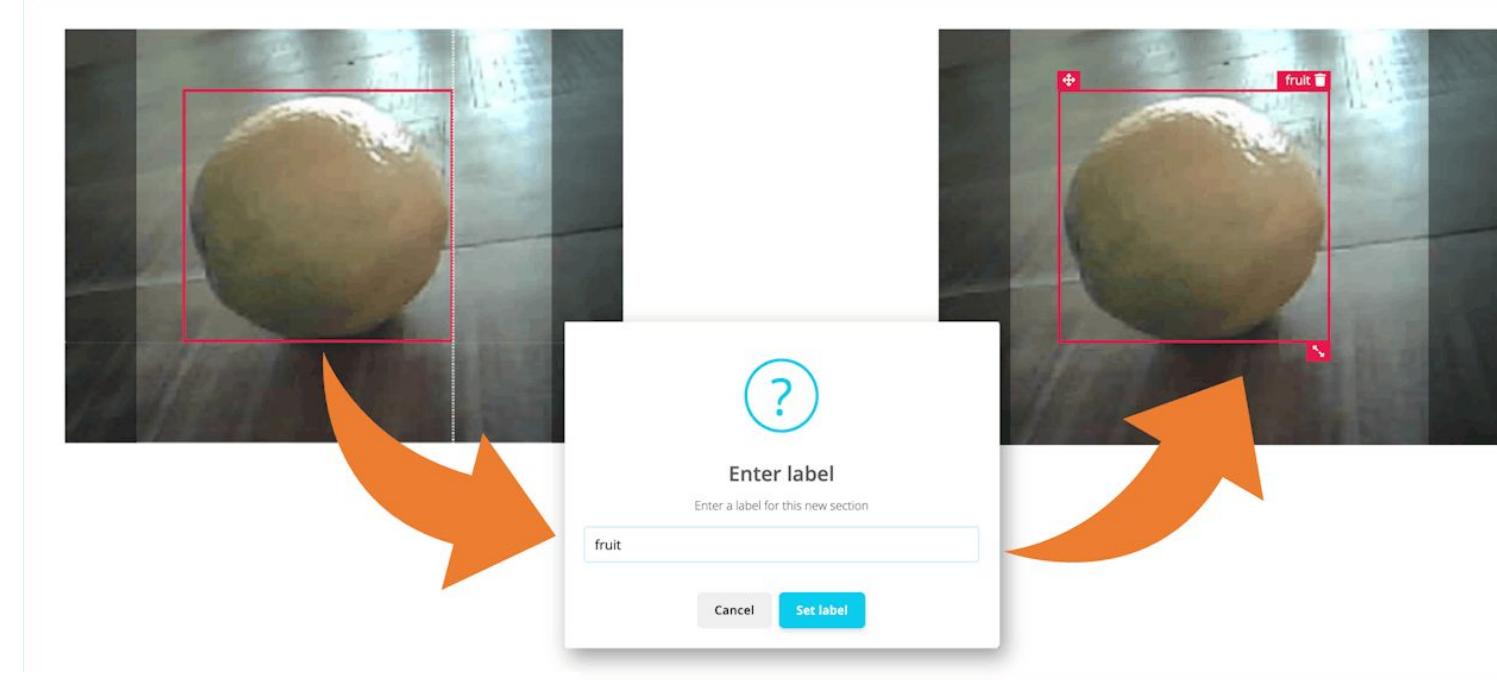
Object Detection model

Labeling

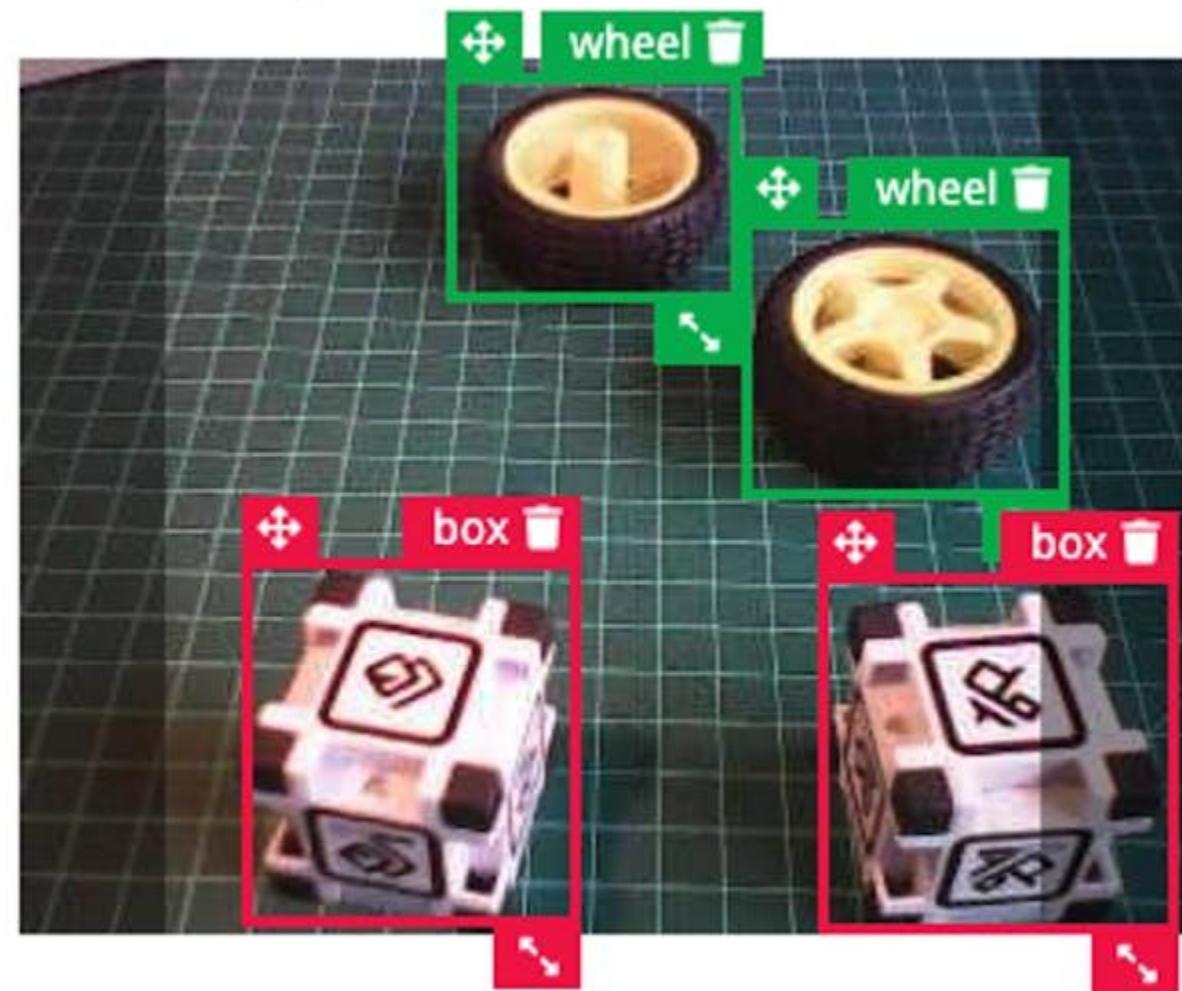
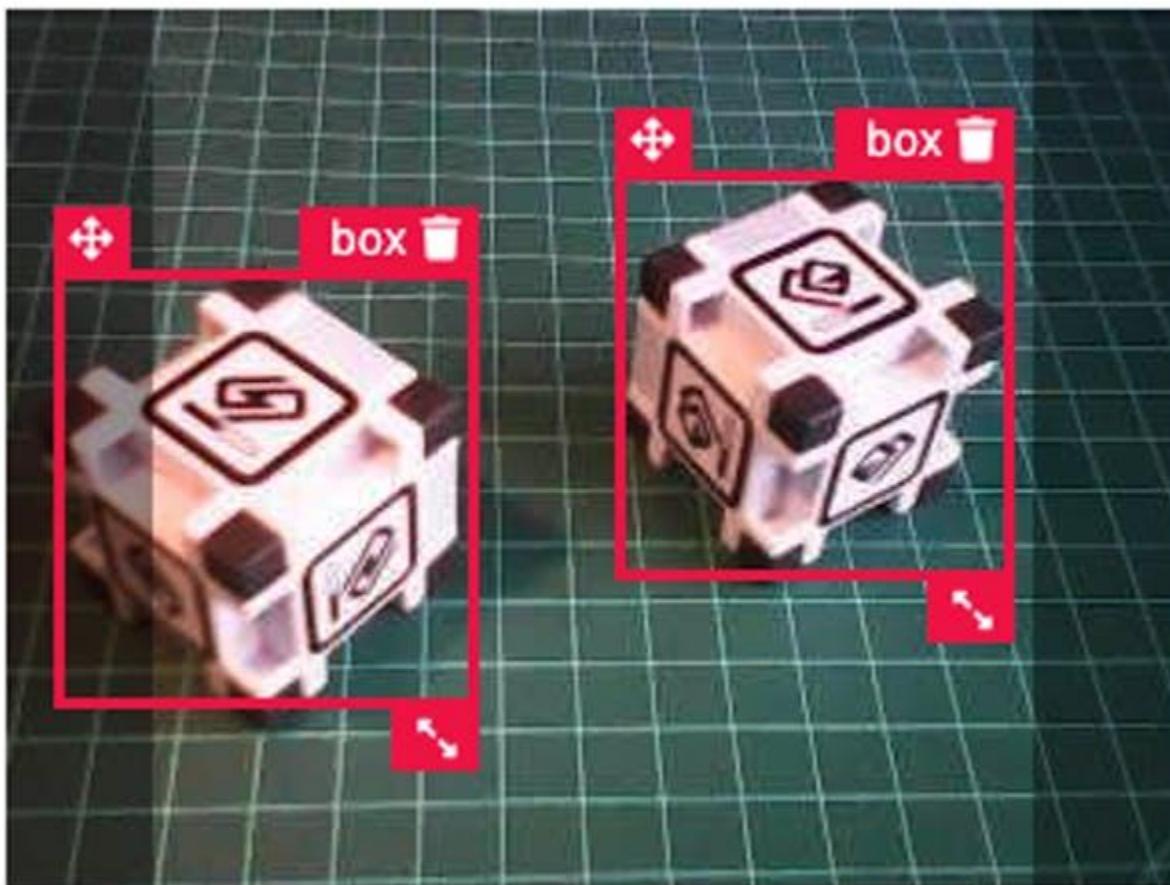
The screenshot shows the Edge Impulse web interface for dataset management. The main navigation bar includes 'Dataset', 'Data sources', and 'Labeling queue (47)', with the 'Labeling queue' tab highlighted by an orange arrow. The left sidebar lists various project management and documentation links. The central area displays a 'Dataset' table with columns for 'Training (47)' and 'Test (0)'. The table lists 10 sample entries, each with a timestamp of 'Today, 15:27:09'. To the right of the table is a 'RAW DATA' section showing a timestamp '20231128151645' and a small image of two green objects on a surface. Below this is a 'Metadata' section stating 'No metadata.'

SAMPLE NAME	LABELS	ADDED	LENGTH
20231128151645	-	Today, 15:27:09	-
20231128150613	-	Today, 15:27:09	-
20231128150604	-	Today, 15:27:09	-
20231128150833	-	Today, 15:27:09	-
20231128150600	-	Today, 15:27:09	-
20231128150855	-	Today, 15:27:09	-
20231128150458	-	Today, 15:27:09	-
20231128150713	-	Today, 15:27:09	-
20231128150908	-	Today, 15:27:09	-

Labeling



Labeling



XIAO-ESP32S3-Sense-Objec X +

studio.edgeimpulse.com/studio/315759/create-impulse

EDGE IMPULSE

MJRoBot (Marcelo Rovai) / XIAO-ESP32S3-Sense-Object_Detection

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

Image data

Input axes
image

Image width 96 **Image height** 96

Resize mode
Squash

For object detection use a square image size, e.g. 96x96, 160x160 or 320x320.

Image

Name Image

Input axes (1)
 image

Object Detection (Images)

Name Object detection

Input features
 Image

Output features
2 (bug, fruit)

Save Impulse

Add a processing block

Add a learning block

?

Dashboard

Devices

Data acquisition

Impulse design

- Create impulse
- Image
- Object detection

EON Tuner

Retrain model

Live classification

Model testing

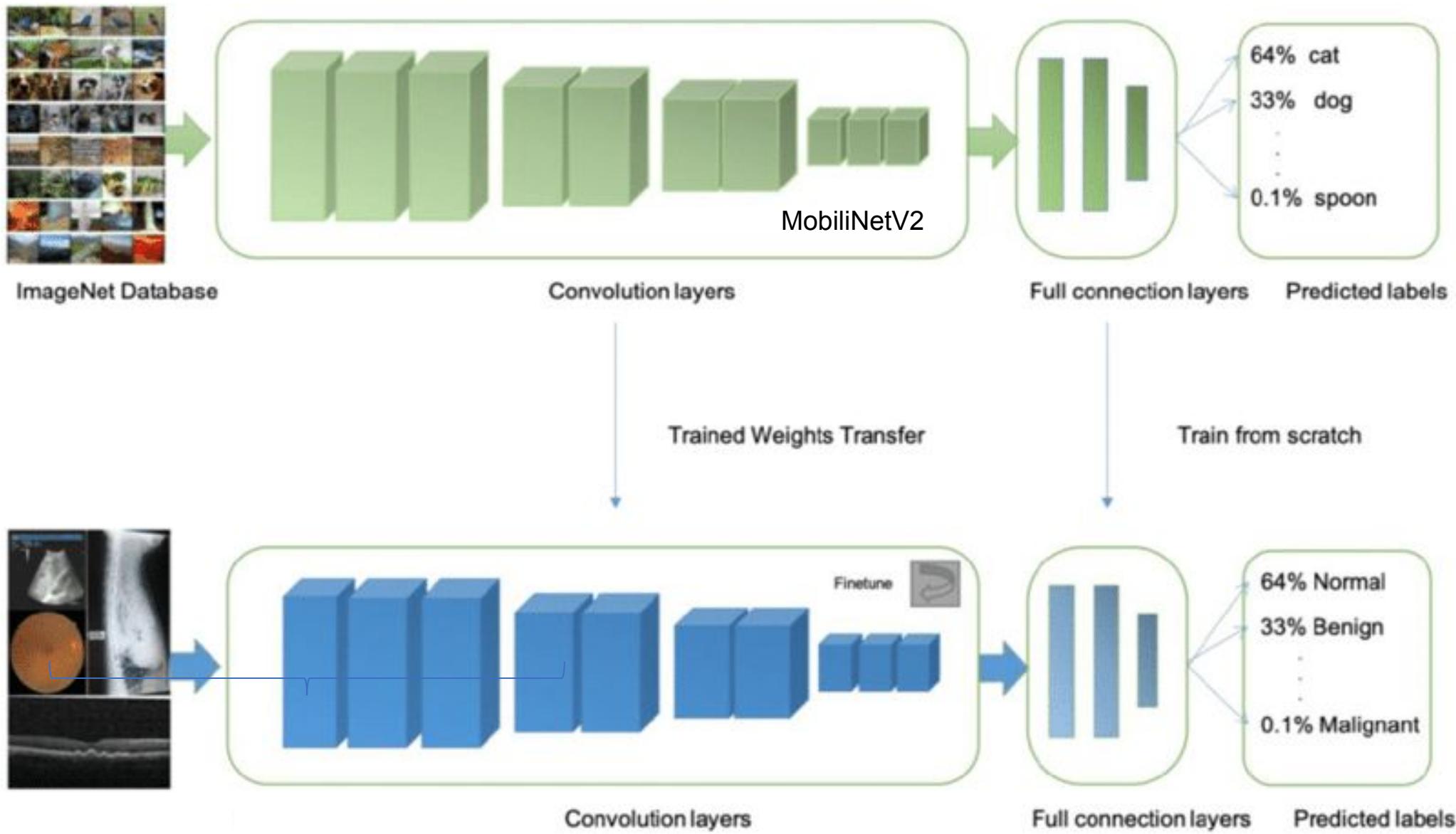
Versioning

Deployment

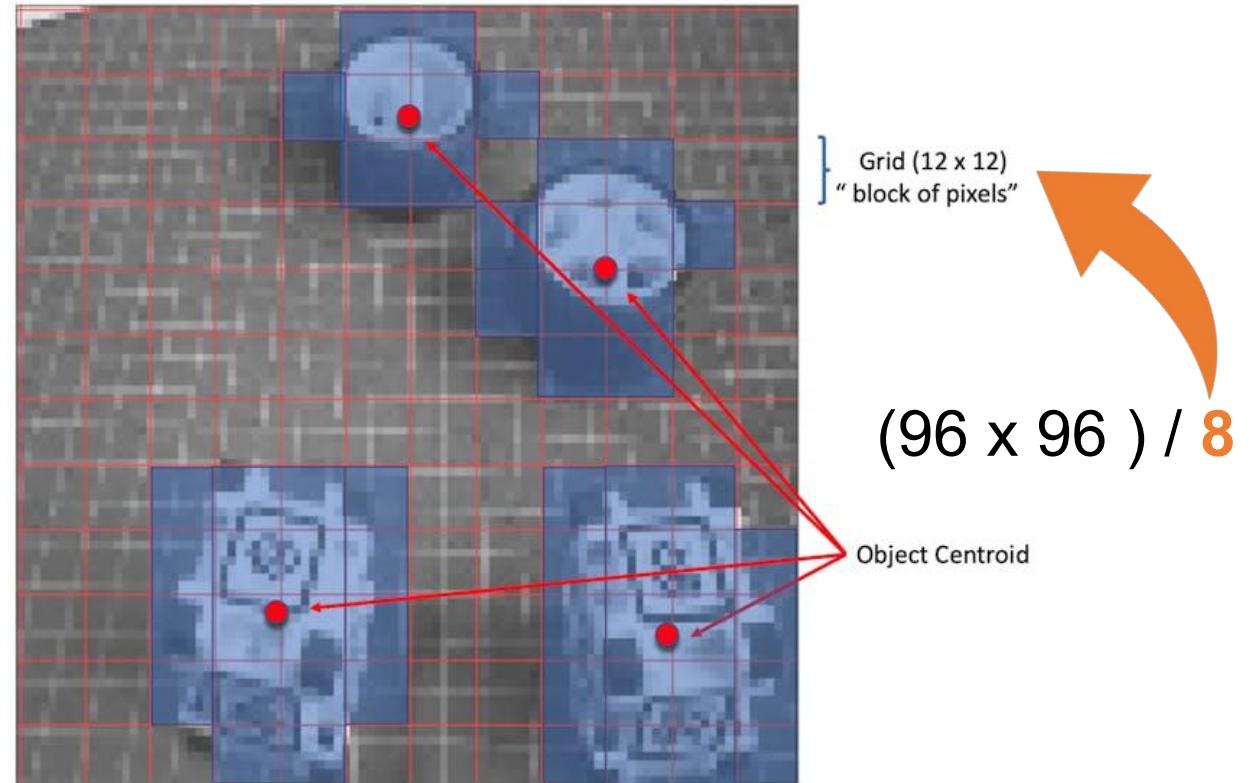
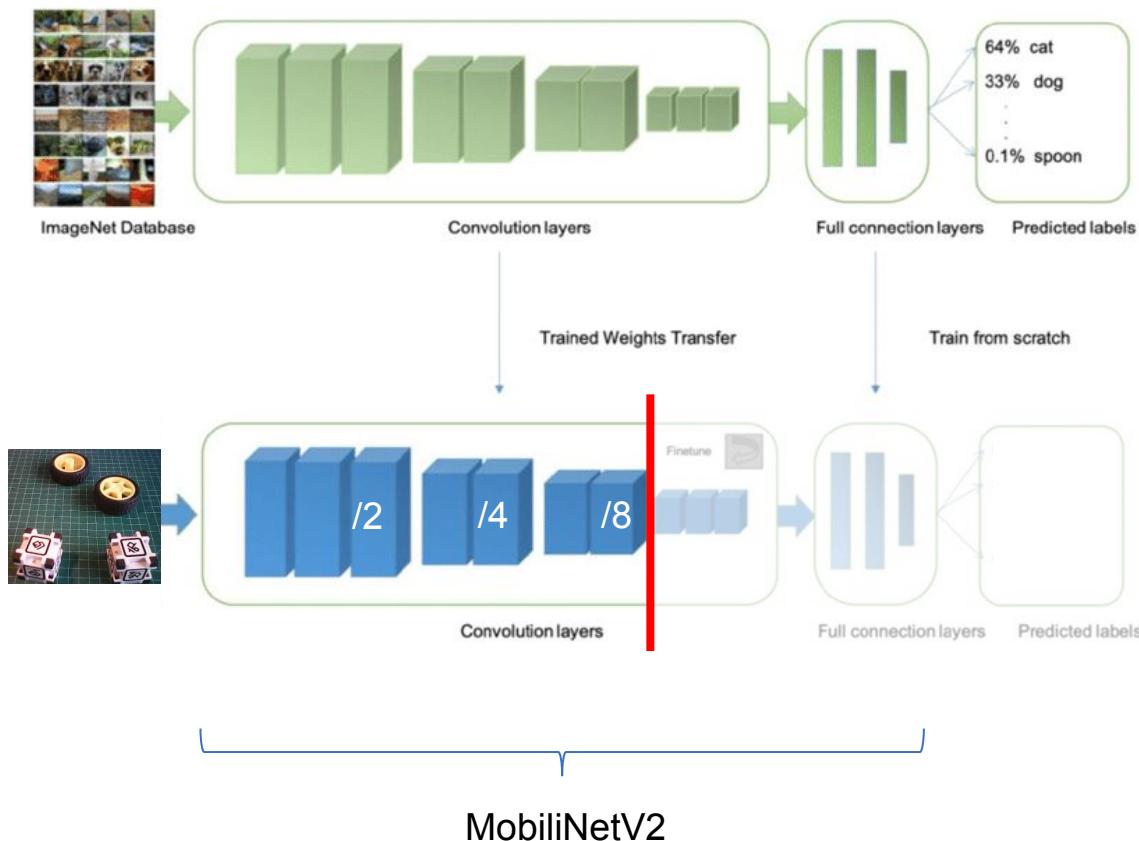
GETTING STARTED

Documentation

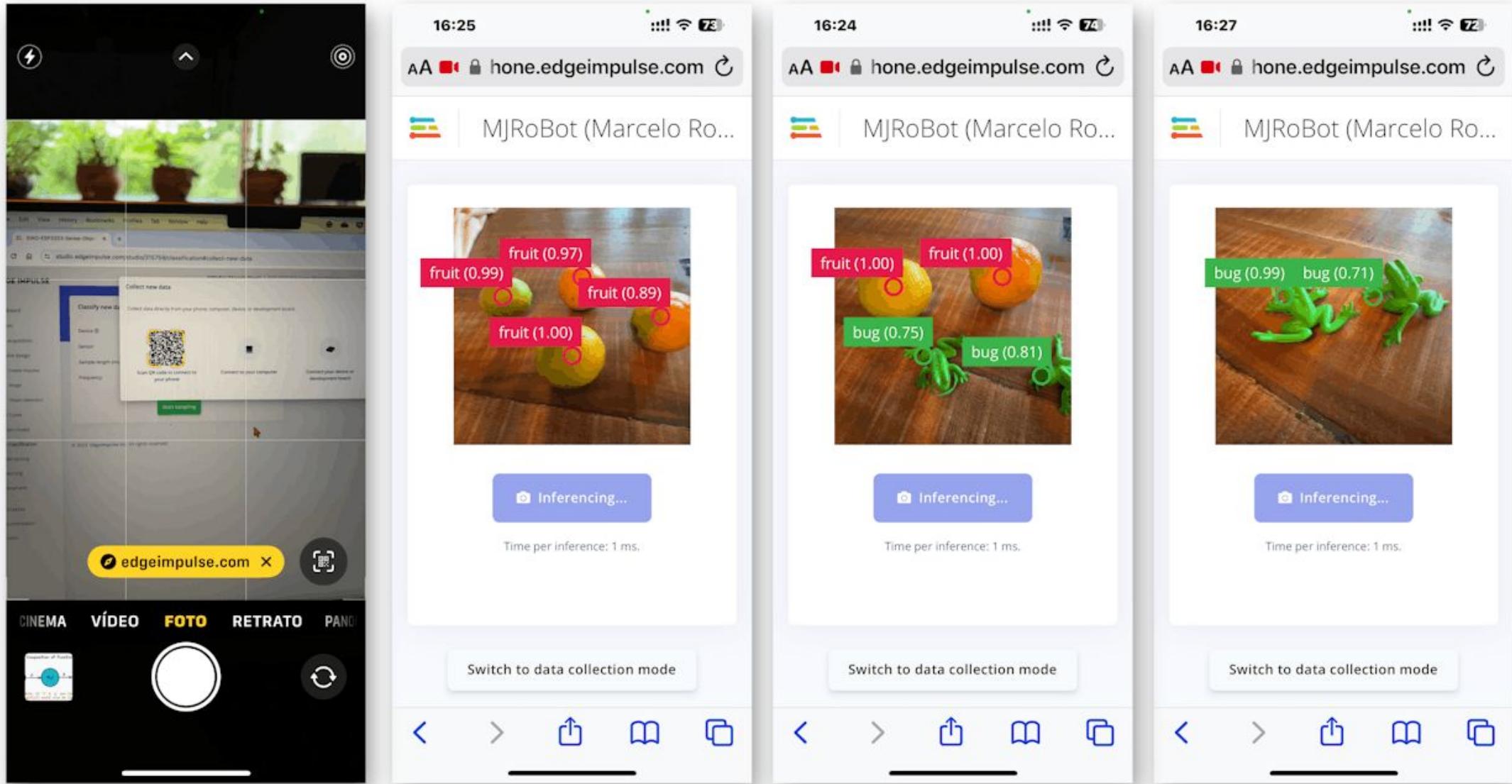
Forums



Model: FOMO



Inference Test



Deploy



esp32_camera | Arduino IDE 2.2.1

XIAO_ESP32S3

```
esp32_camera.ino

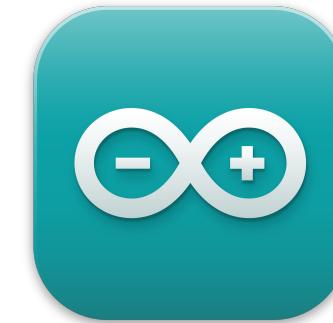
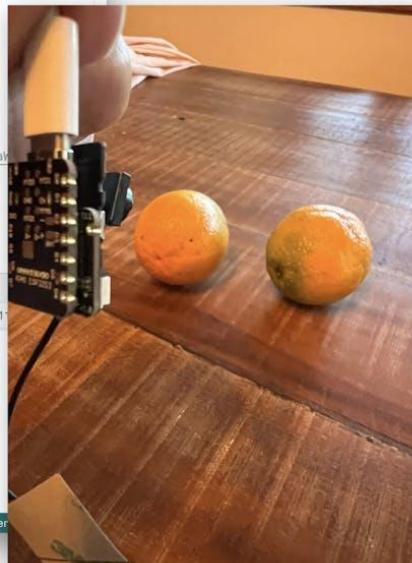
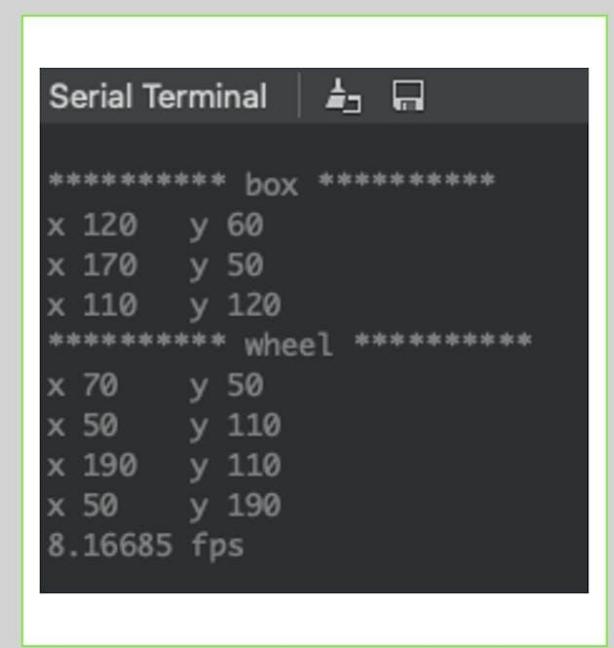
18 * LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
19 * OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE
20 * SOFTWARE.
21 */
22
23 /* Includes ----- */
24 #include <XIAO-ESP32S3-Sense-Object_Detection_inferencing.h>
25 #include "edge-impulse-sdk/dsp/image/image.hpp"
26
27 #include "esp_camera.h"
28
29 // Select camera model - find more camera models in camera_pins.h file here
30 // https://github.com/espressif/arduino-esp32/blob/master/libraries/ESP32/examples/Camera/Camera
31
32 #define PWDN_GPIO_NUM      -1
33 #define RESET_GPIO_NUM     -1
34 #define XCLK_GPIO_NUM       10
35 #define SIOD_GPIO_NUM       40
36 #define STOC_GPIO_NUM       39

Serial Monitor x Output

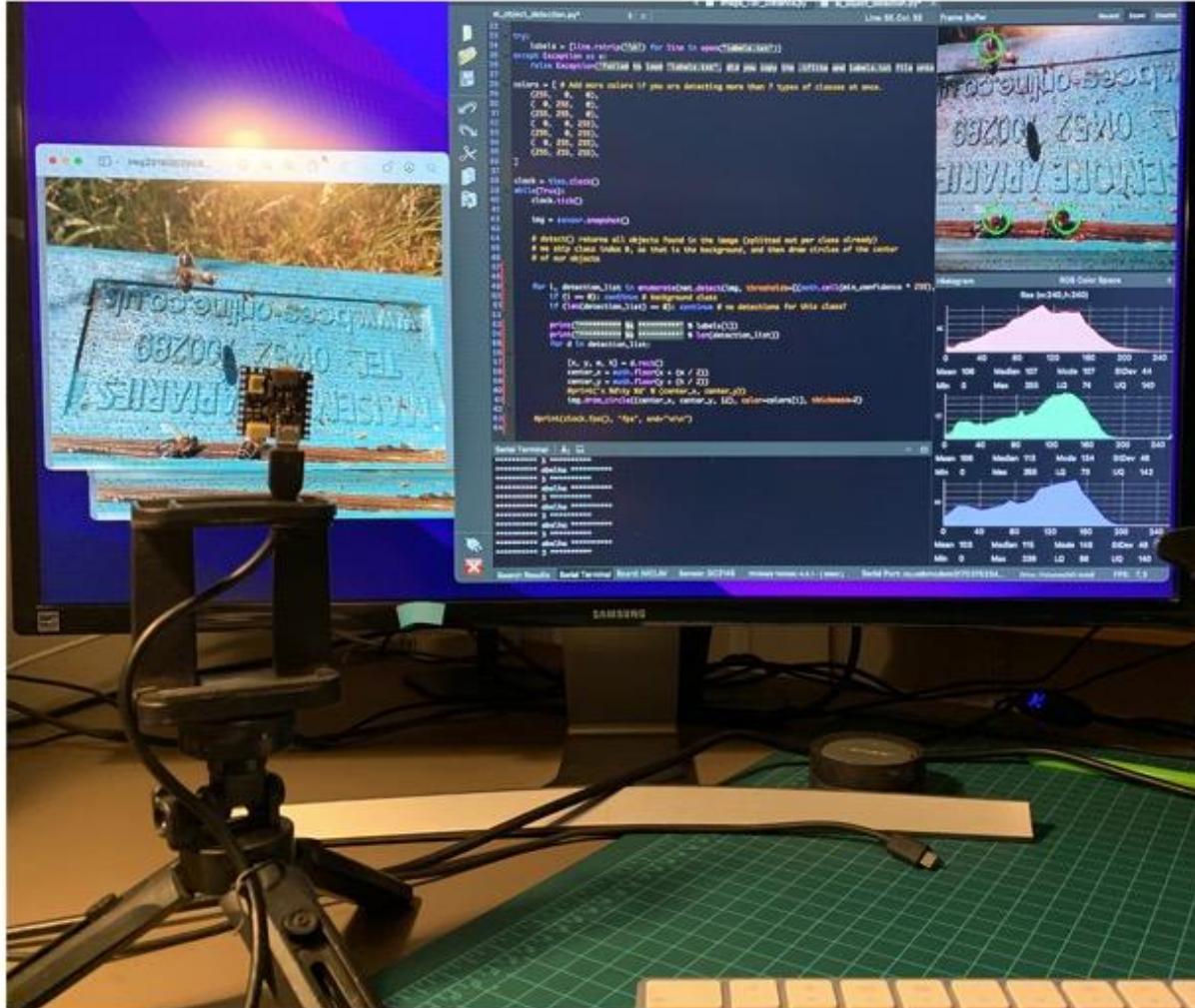
Message (Enter to send message to 'XIAO_ESP32S3' on '/dev/cu.usbmodem2101')
Both NL & CR 1

fruit (0.566406) [ x: 56, y: 32, width: 8, height: 8 ]
Predictions (DSP: 4 ms., Classification: 143 ms., Anomaly: 0 ms.):
No objects found
Predictions (DSP: 4 ms., Classification: 143 ms., Anomaly: 0 ms.):
fruit (0.582031) [ x: 48, y: 32, width: 8, height: 8 ]
fruit (0.773438) [ x: 80, y: 32, width: 8, height: 8 ]
Predictions (DSP: 4 ms., Classification: 143 ms., Anomaly: 0 ms.):
fruit (0.550781) [ x: 64, y: 16, width: 8, height: 8 ]
Predictions (DSP: 4 ms., Classification: 143 ms., Anomaly: 0 ms.):
fruit (0.722656) [ x: 64, y: 16, width: 8, height: 8 ]
```

Ln 48, Col 29 XIAO_ESP32S3 on /dev/cu.usbmodem2101



Detecting Objects using TinyML (FOMO)



MicroPython



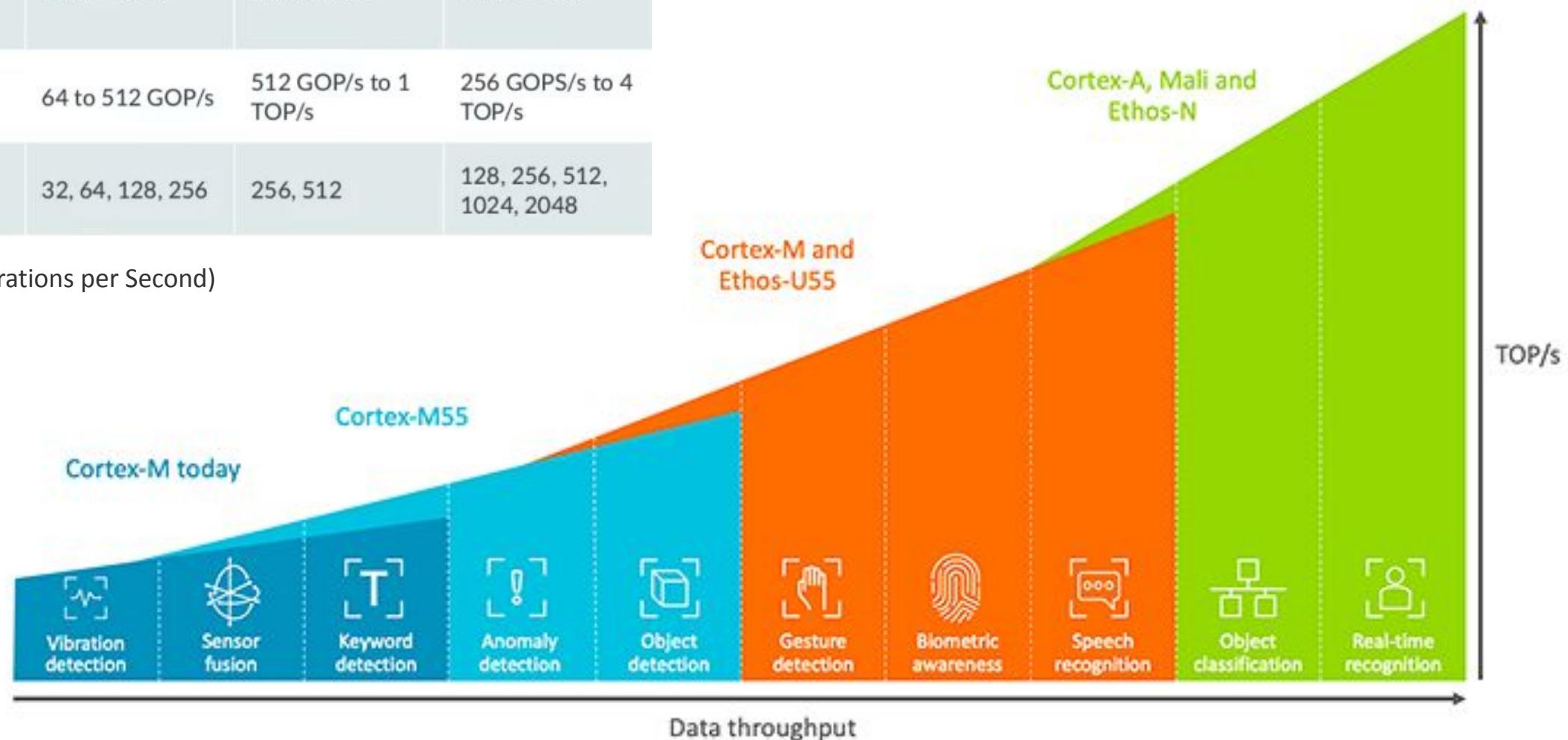
microNPU

a neural network unit for TinyML

ML- optimized Solutions

	Ethos-U55	Ethos-U65	Ethos-U85
Performance (At 1 GHz)	64 to 512 GOP/s	512 GOP/s to 1 TOP/s	256 GOPS/s to 4 TOP/s
MACs (8x8)	32, 64, 128, 256	256, 512	128, 256, 512, 1024, 2048

TOPS (Tera Operations per Second)

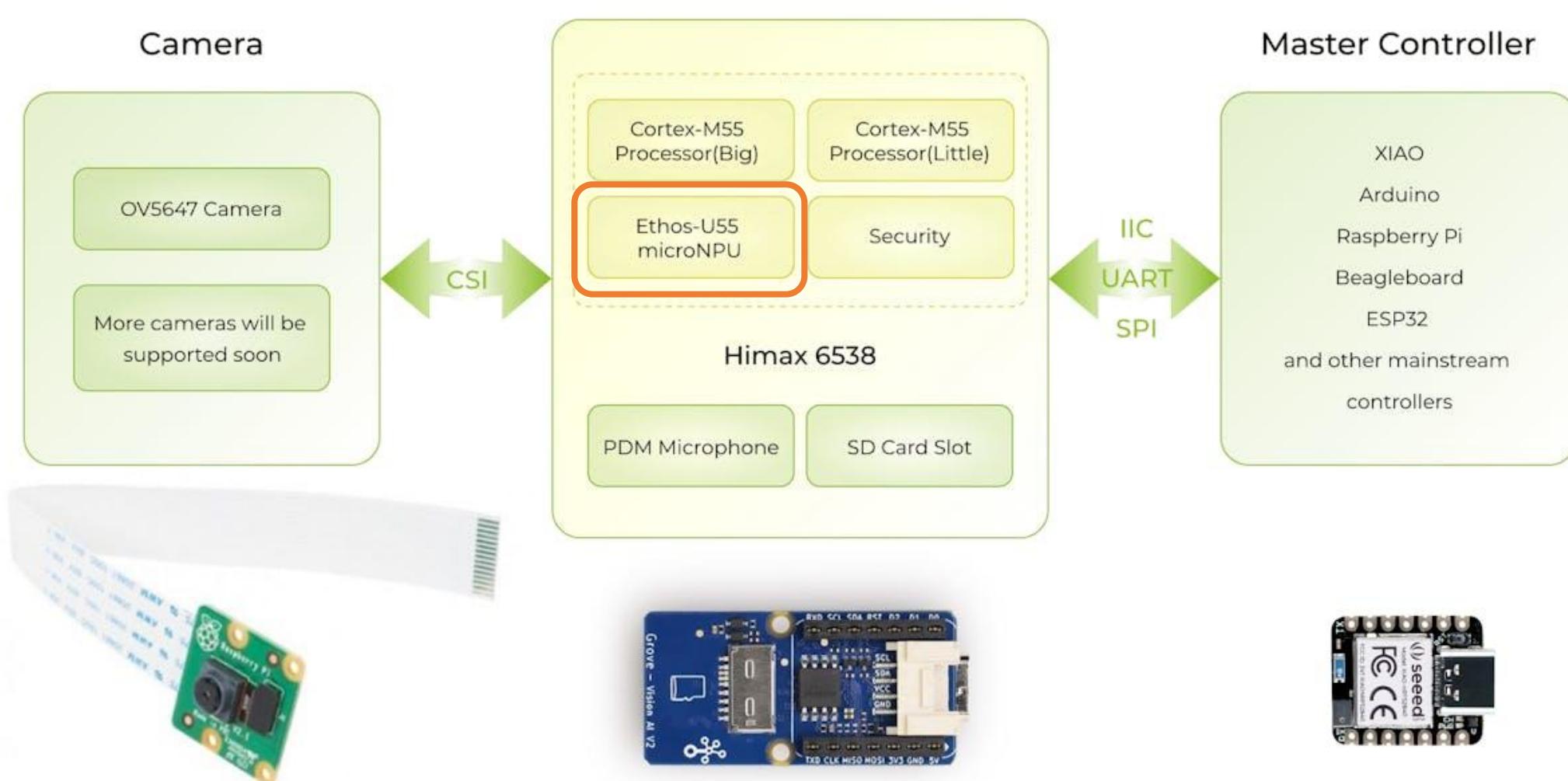


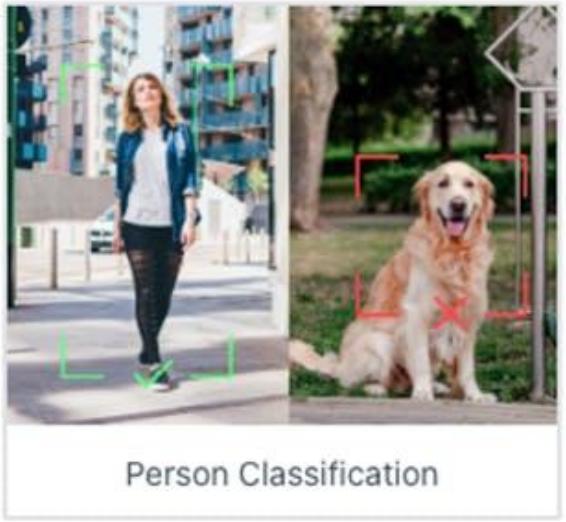


Computer Vision at the Edge with Grove Vision AI Module V2

Exploring Computer Vision applications such as Image Classification, Object Detection, and Pose estimation.

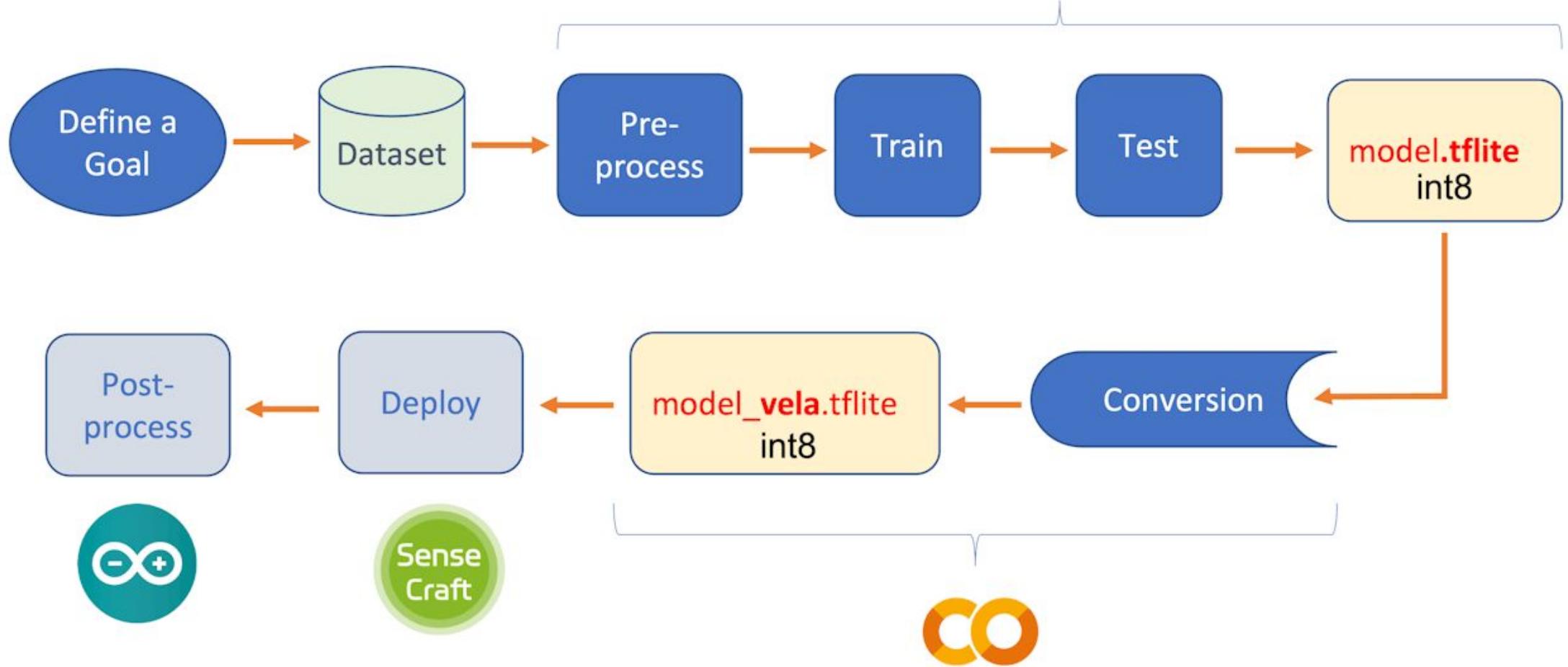
Grove Vision AI v2







EDGE IMPULSE





Classification: 687 ms

1.5 FPS



ESP - CAM
Xtensa LX6
240 MHz

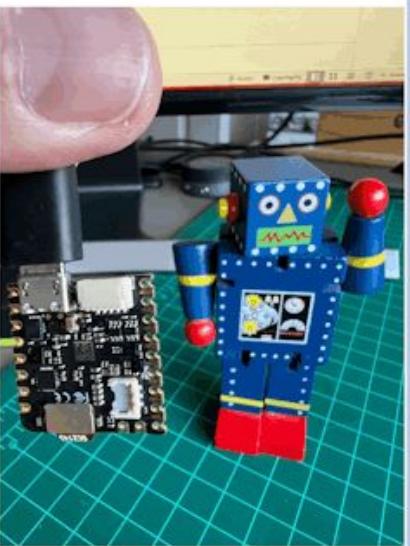


Classification: 142 ms

7.0 FPS



XIAO ESP32S3
Xtensa LX7
240 MHz

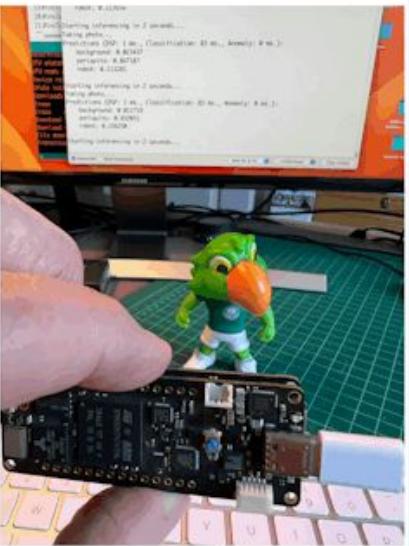


Classification: 86 ms

11.6 FPS



Nicla-Vision
ARM M7
480 MHz



Classification: 83 ms

12.0 FPS



Portenta H7
ARM M7
480 MHz



Classification: 6 ms

167 FPS



Grove Vision AI V2
ARM Ethus-U55
400 MHz

450mW

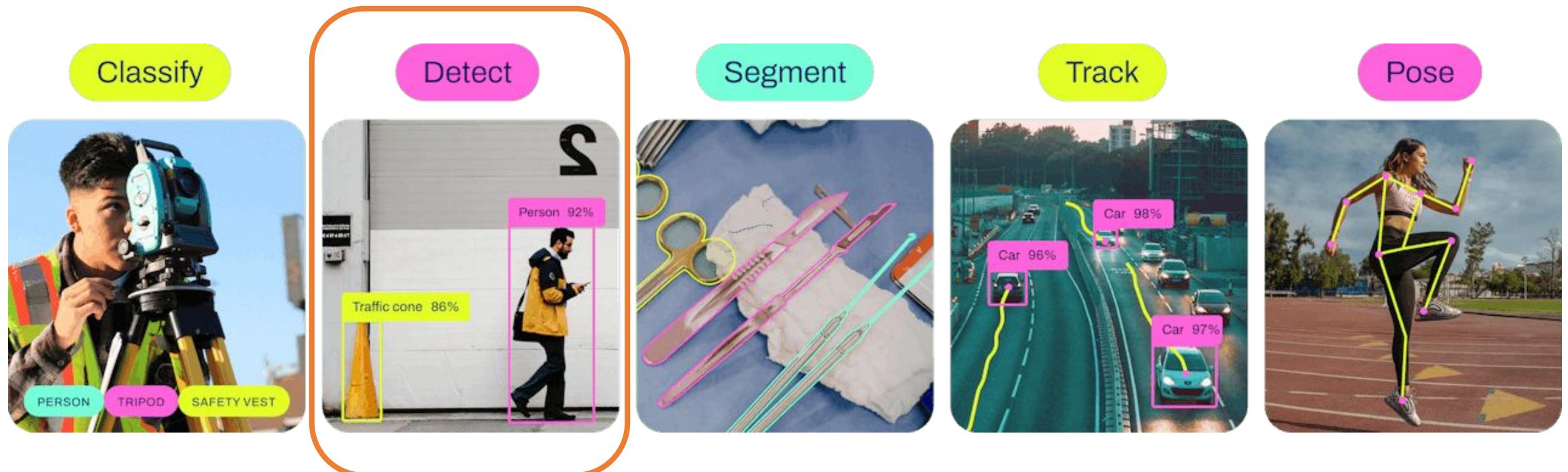
590mW

350mW

YOLO

Object Detection Model for Bee Counting

Ultralytics YOLO (You Only Look Once)



Real-time **object detection** systems that identify and classify many objects **very fast** in a single image pass.



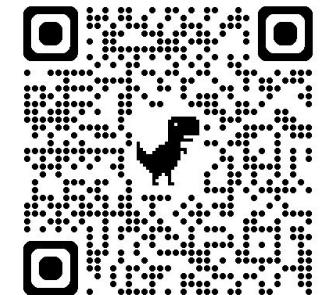
hackster.io

AN AVNET COMMUNITY



BuzzTech: Machine Learning at the Edge

Deploying YOLOv8 on Raspberry Pi Zero 2W for Real-Time Bee Counting at the Hive Entrance.



Goal: Estimate the number of bees

Number of objects: 15 bees

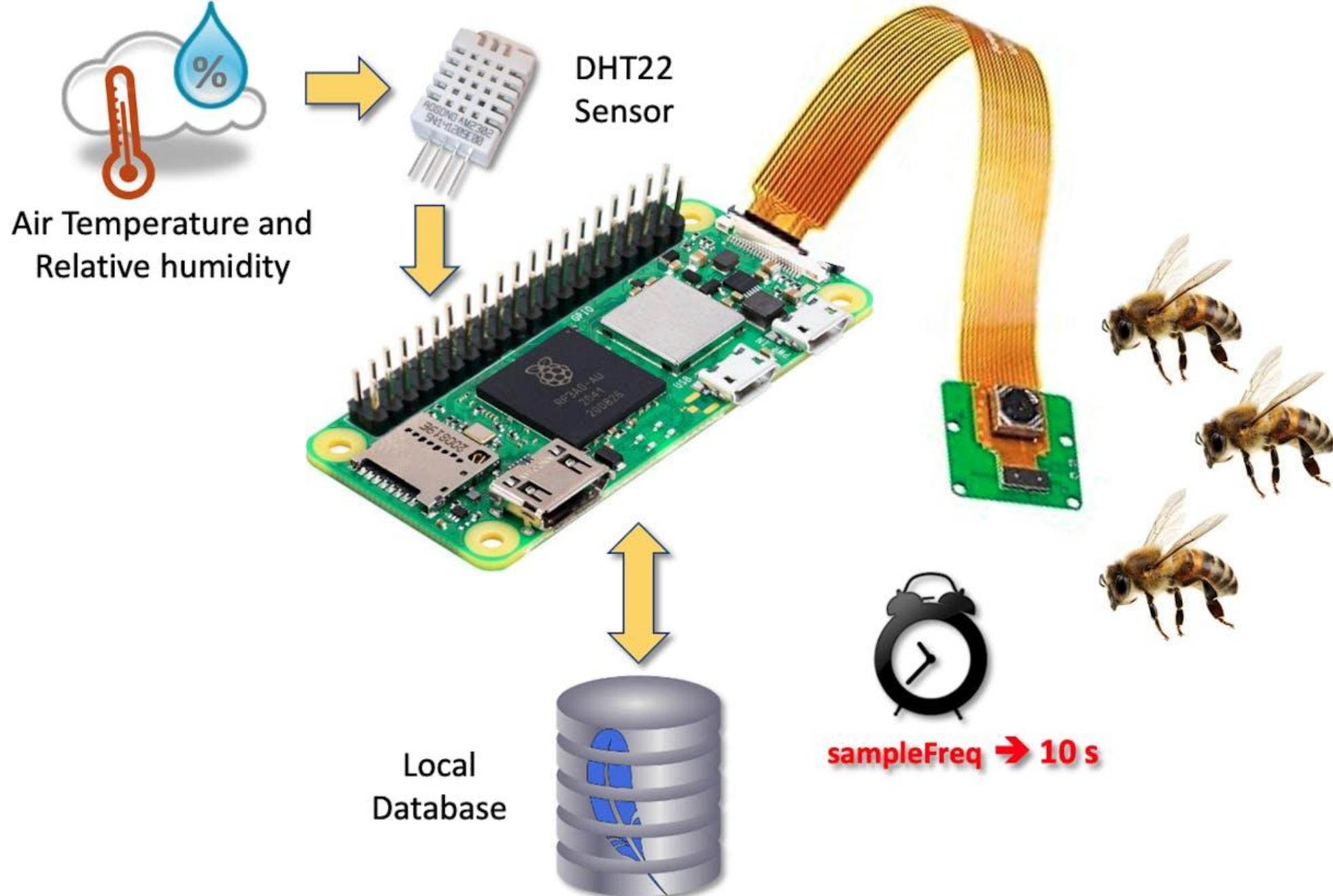


Number of objects: 36 bees



Number of objects: 28 bees





Create Project

https://app.roboflow.com/marcelo-rovali-riila/create

roboflow

Let's create your project.

Marcelo Rovai > New Public Project

Project Name: Bees_on_Hive_Landing_boards

License: CC BY 4.0

Annotation Group: bees

Project Type:

- Object Detection**: Identify objects and their positions with bounding boxes.
Best For: # Counting, % Tracking
- Classification**: Assign labels to the entire image.
Classification Type: Multi-Label (selected), Single-Label
Best For: Filtering, Content Moderation
- Instance Segmentation**: Detect multiple objects and their actual shape.
Best For: Measurements, Odd Shapes
- Keypoint Detection**: Identify keypoints ("skeletons") to subjects.
Best For: Pose Estimation

Show More ↓

Cancel Create Public Project

Bees_on_Hive_landing_board

https://app.roboflow.com/marcelo-rovali-riila/bees_on_hive_landing_boards/images/34IC4TuHjkC5VtUNSKxC?queryText=&pageSize=50&startingIndex=0&browseQuer... ☆

BEES_ON_HIVE_LANDING_BOARDS > ANNOTATE
20230711b6510.jpg

Annotations
Group: bees-4uet
CLASSES LAYERS
bee 26

Annotation Editor
bee
Delete Save (Enter)

1 bee

Options ▾

Labels Attributes Comments History Raw Data

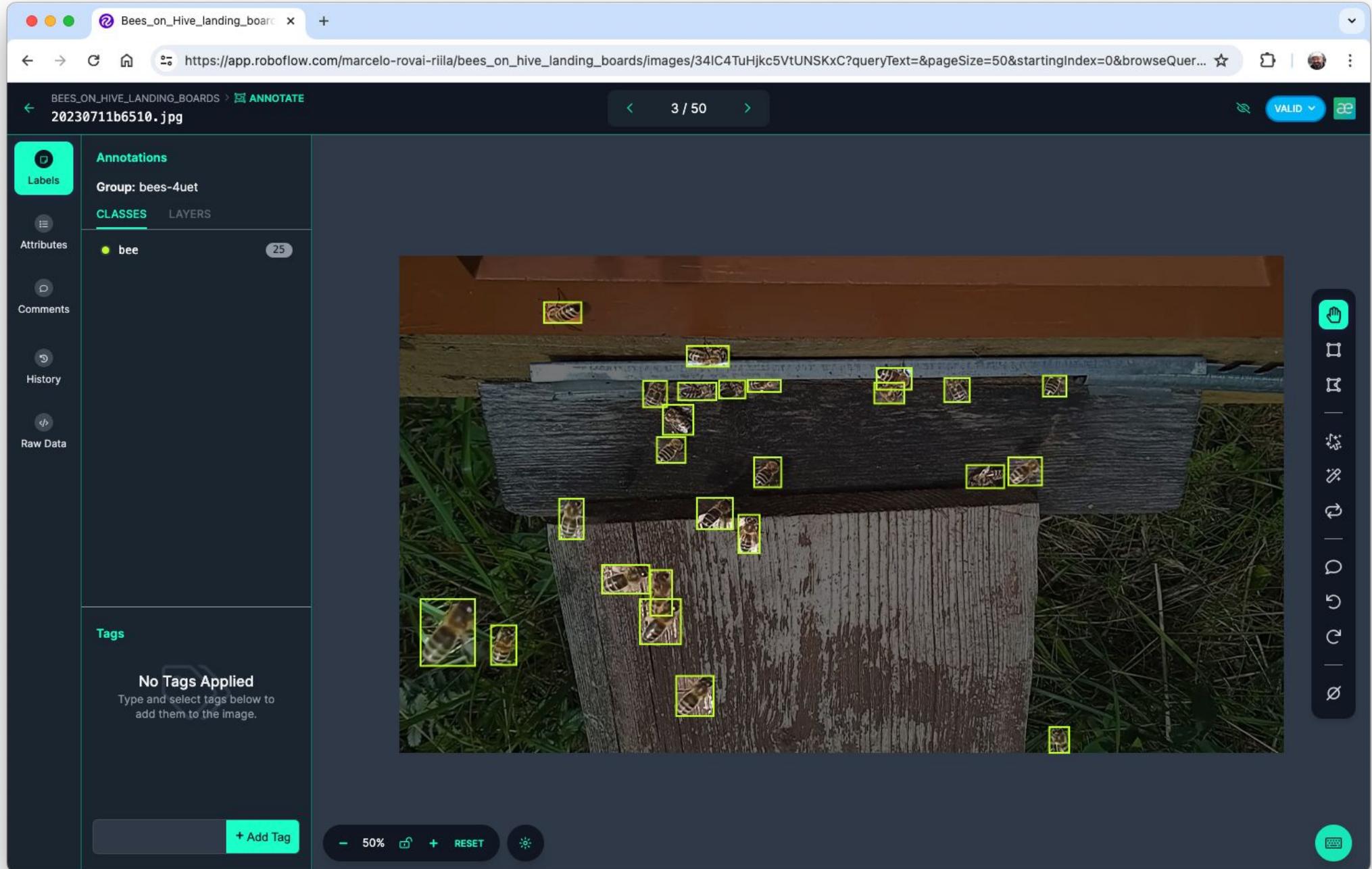
Tags
No Tags Applied
Type and select tags below to add them to the image.

+ Add Tag - 50% + RESET

VALID ae

Hand Selection Tool

Image: A photograph of a wooden beehive entrance. Bees are visible flying around and landing on the dark wooden boards. Several bees are highlighted with green bounding boxes. An annotation editor window is open, showing the class 'bee' selected. The main interface shows the image with many bees detected and labeled. A sidebar on the right contains various annotation tools like selection, cropping, and erasing.



yolov8_beans_on_hive_landing_board.ipynb

File Edit View Insert Runtime Tools Help All changes saved

Comment Share Gemini

RAM Disk Gemini

Files

{x} content datasets Bees_on_Hive_landing_b... test images labels train images labels valid images labels README.dataset.txt README.roboflow.txt data.yaml

+ Code + Text

```
[ ] 1 from ultralytics import YOLO  
2  
3 from IPython.display import display, Image
```

Dataset

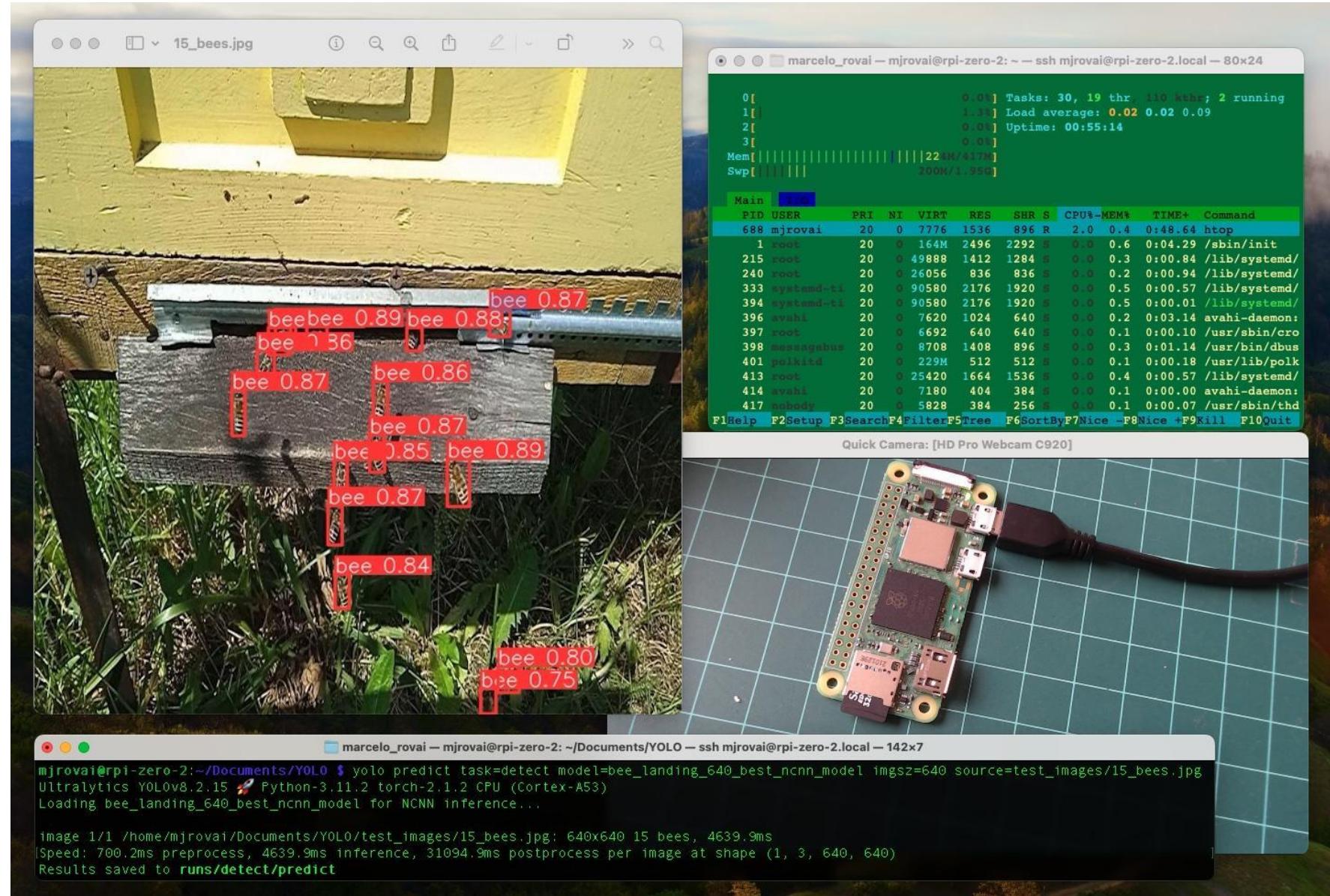
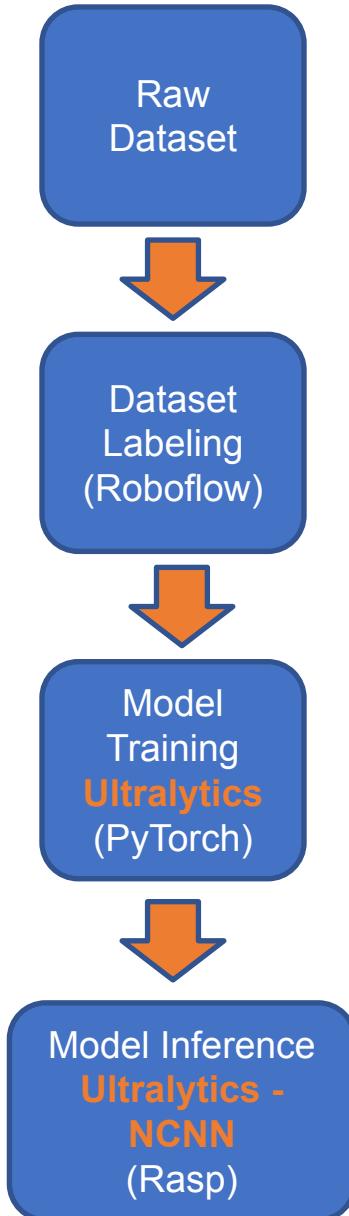
```
1 !mkdir {HOME}/datasets  
2 %cd {HOME}/datasets  
3  
4 !pip install roboflow --quiet  
5  
6 from roboflow import Roboflow  
7 rf = Roboflow(api_key="YOUR KEY HERE")  
8 project = rf.workspace("marcelo-rovai-riila").project("bees_on_hive_landing_boards")  
9 version = project.version(1)  
10 dataset = version.download("yolov8")  
11
```

```
/content/datasets
```

```
75.5/75.5 kB 3.6 MB/s eta 0:00:00  
158.3/158.3 kB 7.7 MB/s eta 0:00:00  
178.7/178.7 kB 8.3 MB/s eta 0:00:00  
58.8/58.8 kB 6.9 MB/s eta 0:00:00  
49.1/49.1 MB 16.7 MB/s eta 0:00:00  
54.5/54.5 kB 7.1 MB/s eta 0:00:00
```

```
loading Roboflow workspace...  
loading Roboflow project...  
Dependency ultralytics==8.0.196 is required but found version=8.2.23, to fix: 'pip install ultralytics==8.0.196'  
Downloading Dataset Version Zip in Bees_on_Hive_landing_boards-1 to yolov8:: 100%|██████████| 1597328/1597328 [00:09<00:00]  
Extracting Dataset Version Zip to Bees_on_Hive_landing_boards-1 in yolov8:: 100%|██████████| 32468/32468 [00:09<00:00]
```

50s completed at 8:46AM



Questions?

