



INSTITUTO FEDERAL
SÃO PAULO
Câmpus Cubatão

IFSP- TinyML: Aprendizado de Máquina Embarcado

Introdução ao Edge Impulse

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O que é Tiny Machine Learning (TinyML)?

- TinyML é o conjunto de tecnologias em ML e sistemas embarcados para fazer uso de aplicações inteligentes em dispositivos de consumo reduzido.
- É comum que esses dispositivos possuam limitação de memória e recursos computacionais, todavia, esses dispositivos utilizam sensores para monitorar o ambiente físico, e agem por meio das decisões tomadas por algoritmos de ML.
- No TinyML, ML e a plataforma de implementação precisam trabalhar juntas para garantir uma boa aplicação de TinyML.

O que é Edge Impulse?

- O Edge Impulse é uma plataforma proposta para o aprendizado de máquina, e prepara os desenvolvedores para a criação e otimização de soluções com dados reais.
- Facilita e agiliza a parte de criar e implantar aplicativos de Machine Learning (ML) incorporados, e por isso, torna os dispositivos mais inteligentes.

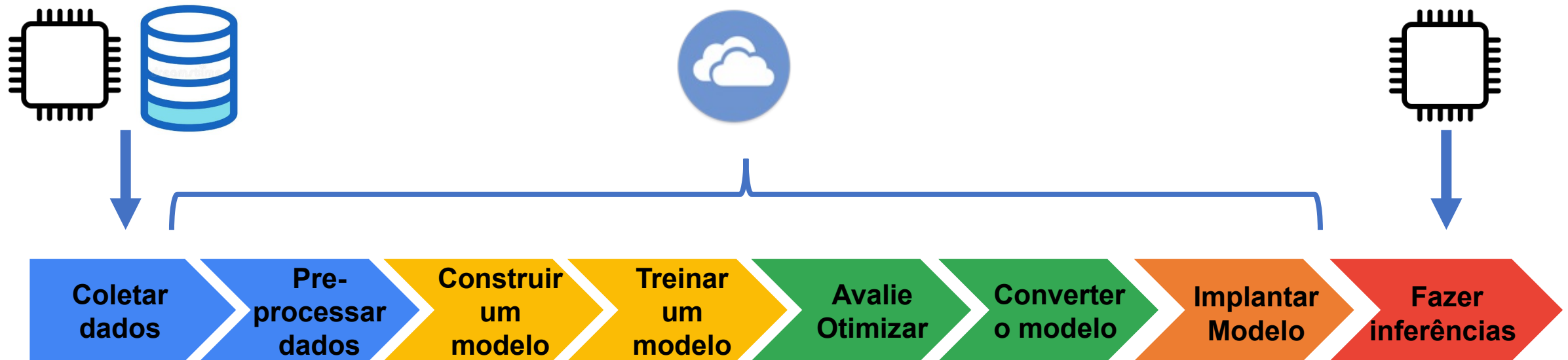
Fluxo de trabalho do Machine Learning



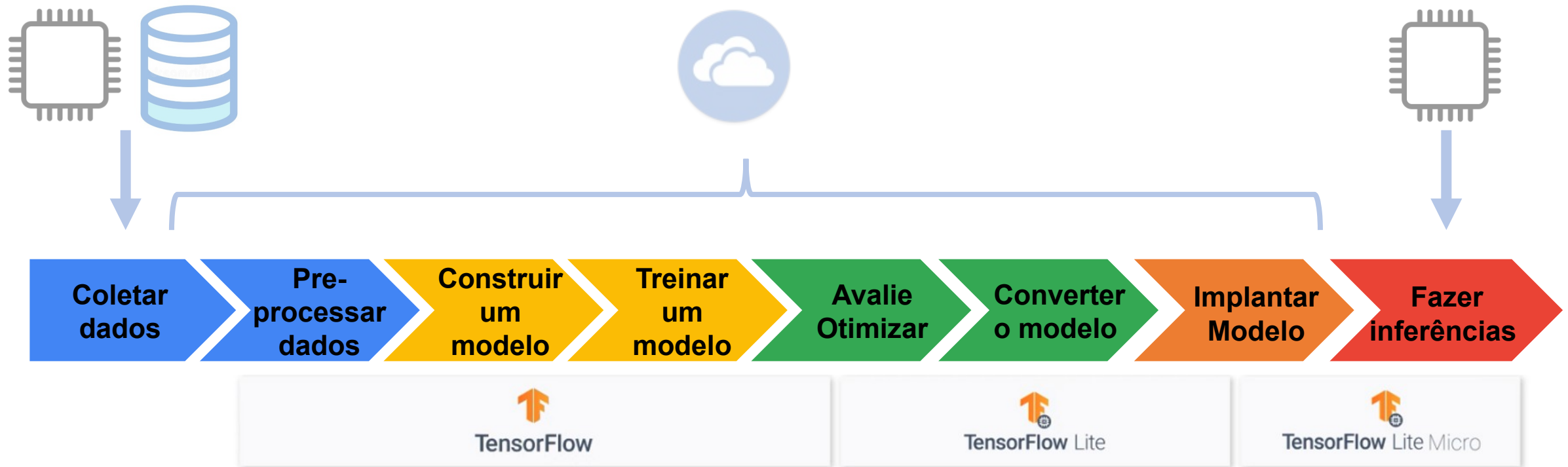
Tiny Fluxo de trabalho do Machine Learning (“O Que”)



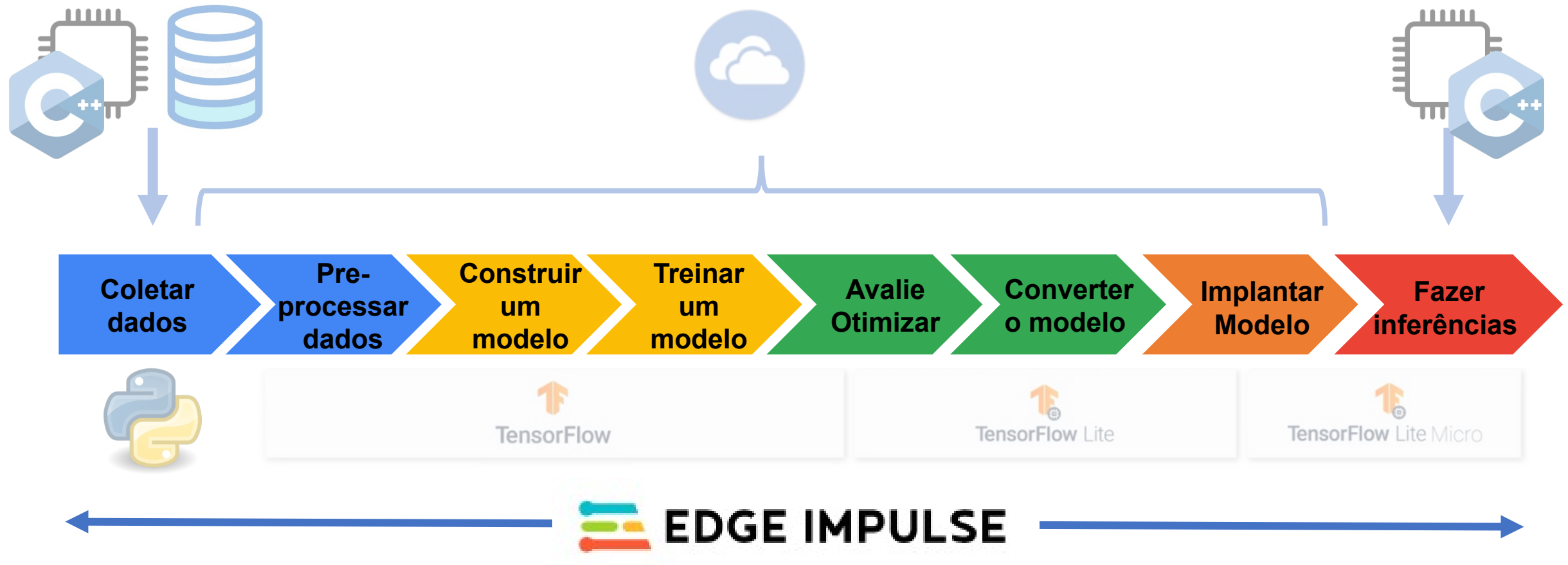
Fluxo de trabalho do Machine Learning (“Onde”)



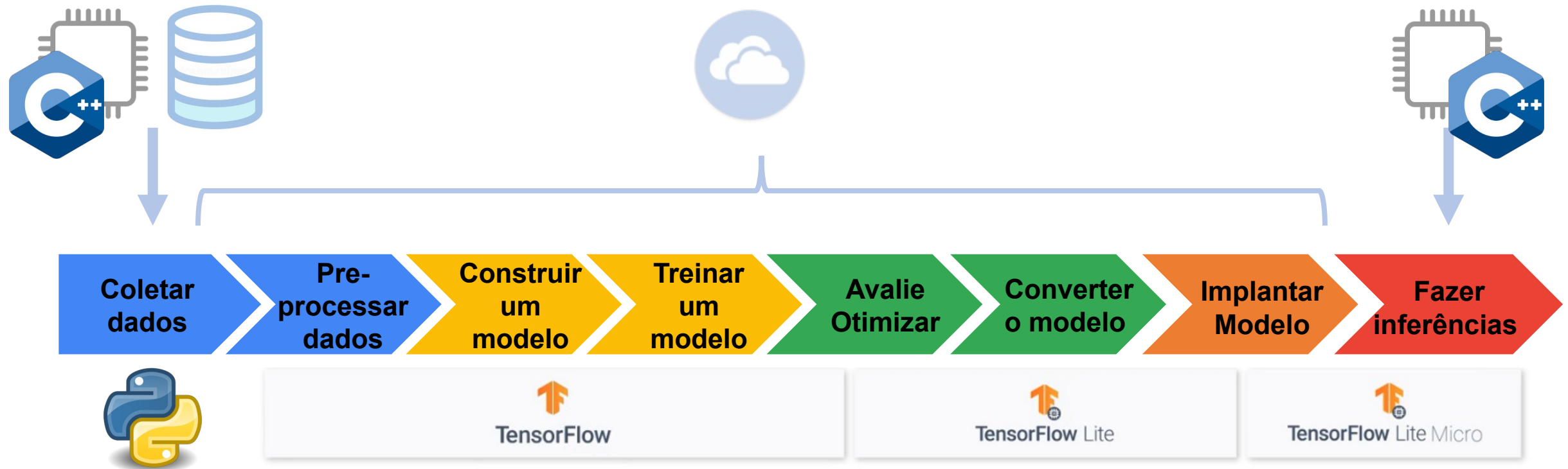
Fluxo de trabalho do Machine Learning (“Como”)

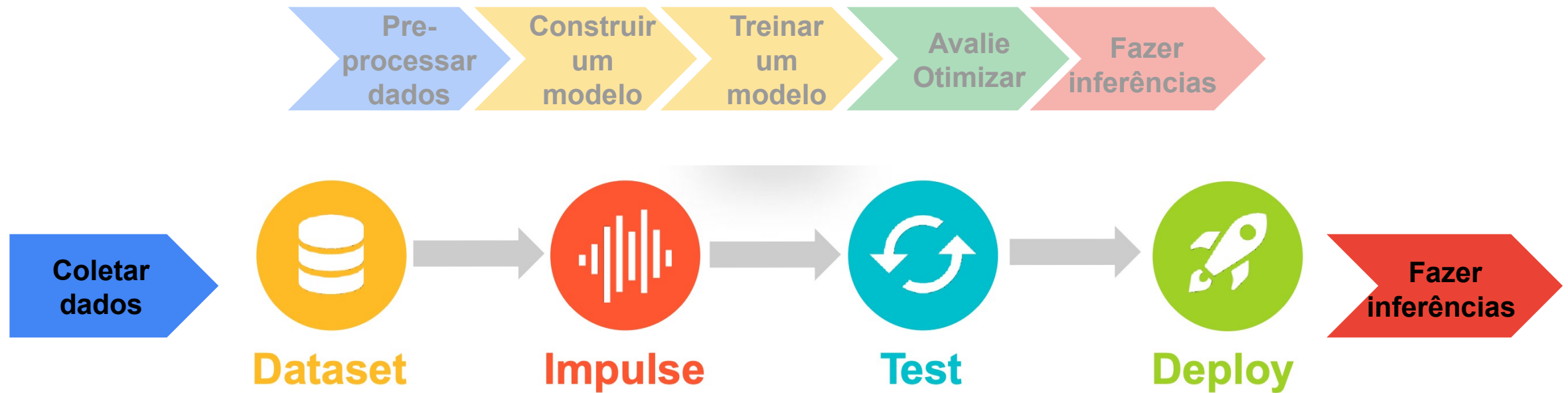


Fluxo de trabalho do Machine Learning (“Como”)



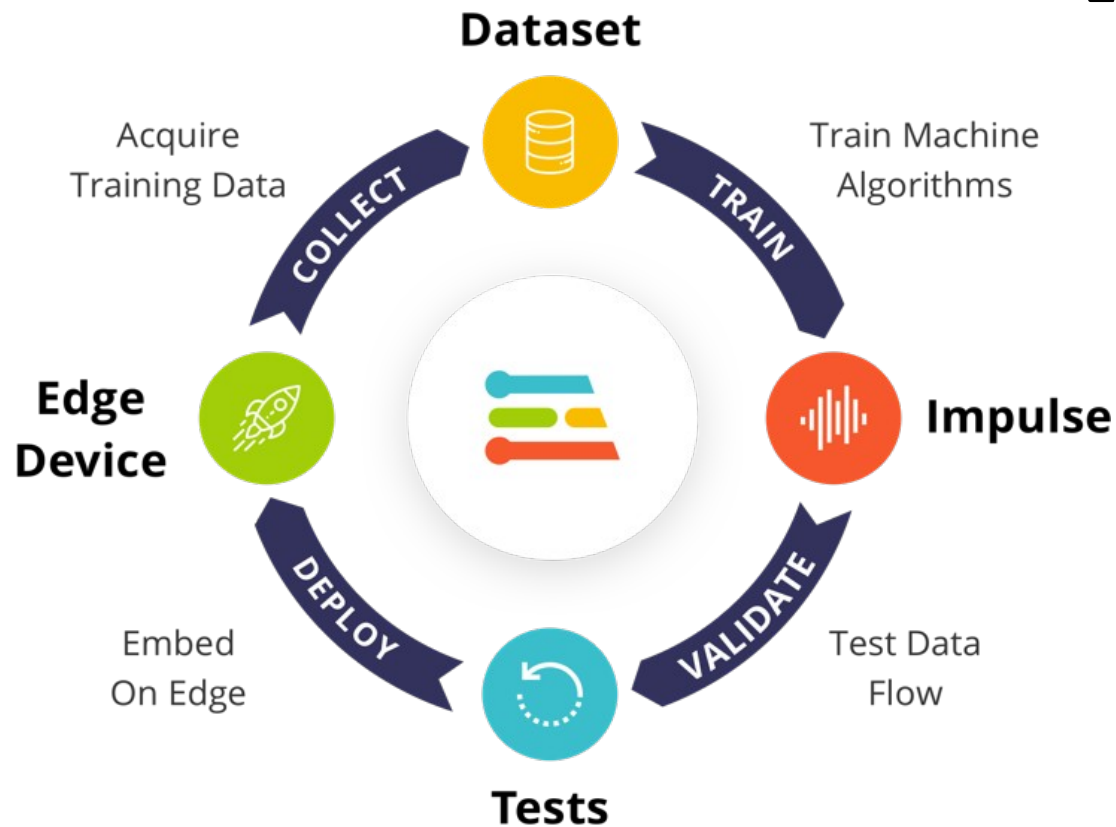
Fluxo de trabalho do Machine Learning (“Como”)

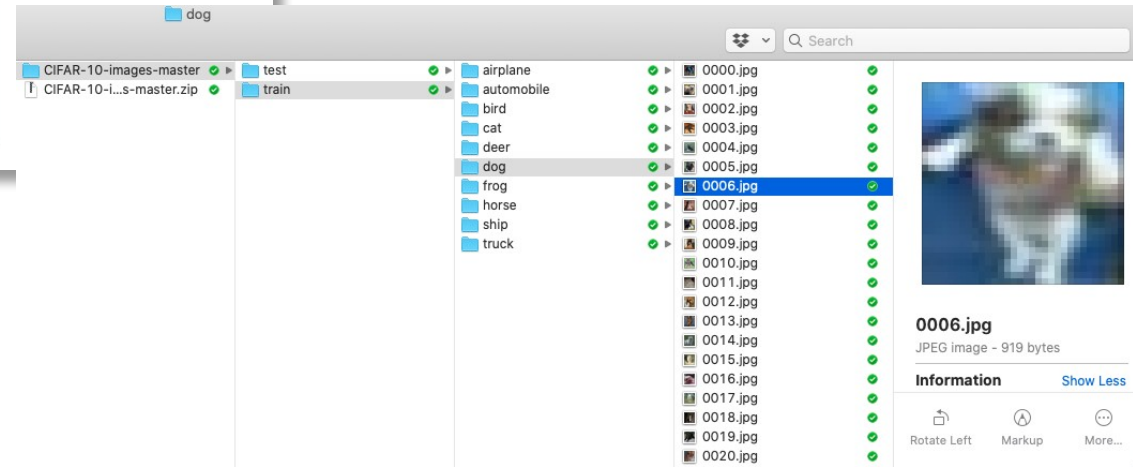
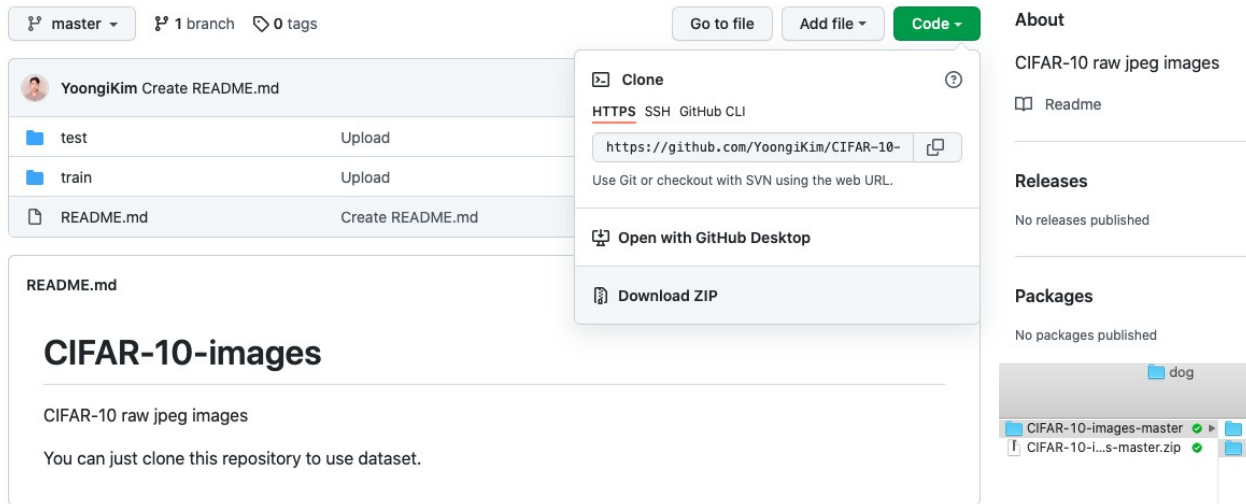




Acessando a plataforma Edge Impulse

Link: <https://www.edgeimpulse.com/>





Acessando o GitHub

Link Dataset:

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



Edge Impulse

edgeimpulse.com

EDGE IMPULSE

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Login **1 Get started**

We put ML into real products

Edge Impulse is the leading development platform for machine learning on edge devices, free for developers and trusted by enterprises.

Get started Schedule a demo

Raw data → Label data → Train model →

Classification (Keras)

Site reliability

95%

TOTAL INCIDENTS: 12

SAFETY SCORE: 97%

INACTIVITY ALERTS: 5

DEFERRATIONS: 11



Sign up - Edge Impulse

studio.edgeimpulse.com/signup

EDGE IMPULSE

Sign up

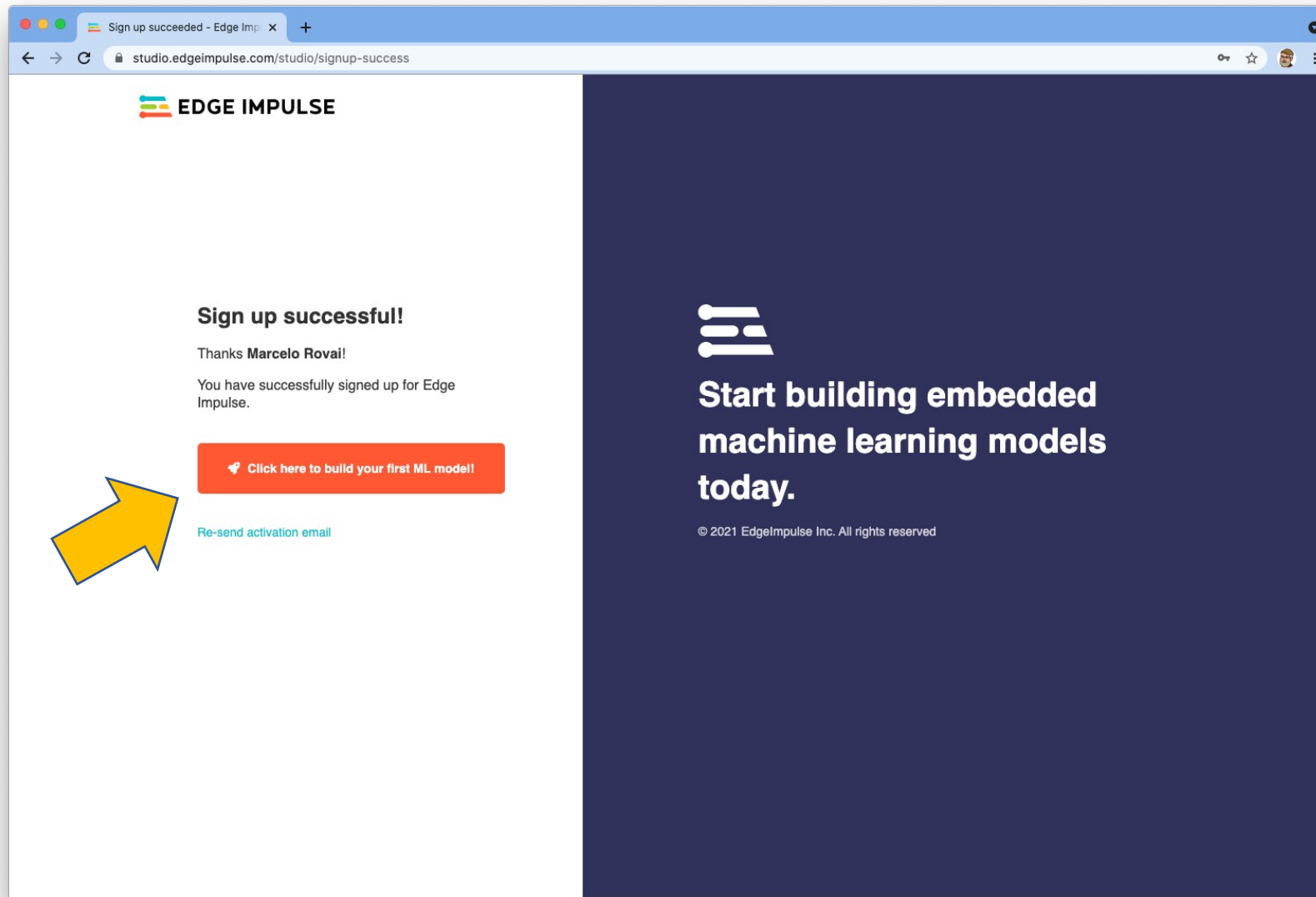
☒ I accept the [Privacy Policy](#), [Terms of Service](#), and [Responsible AI License](#).

Sign up

Already have an account? [Log in](#)

Start building embedded machine learning models today.

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The screenshot shows the Edge Impulse Studio interface. At the top, there's a navigation bar with 'Projects' and 'Custom ML blocks' tabs. Below this, on the left, is a user profile card for 'Amanda'. The main area is titled 'Projects' and contains a list of projects:

- Amanda / Amanda_Trindade-project-1
- Amanda / RedeNeural-Projeto01
- Amanda / Aulateste-Projeto01
- Amanda / TesteProjeto01
- Amanda / Projeto01
- Amanda / ReconhecimentoProjeto01

A red circle highlights the '+ Create new project' button located at the top right of the project list.



Projects - Edge Impulse

studio.edgeimpulse.com/studio/profile/projects

EDGE IMPULSE

A

Create a new project

Enter the name for your new project:

Detecção de automóveis

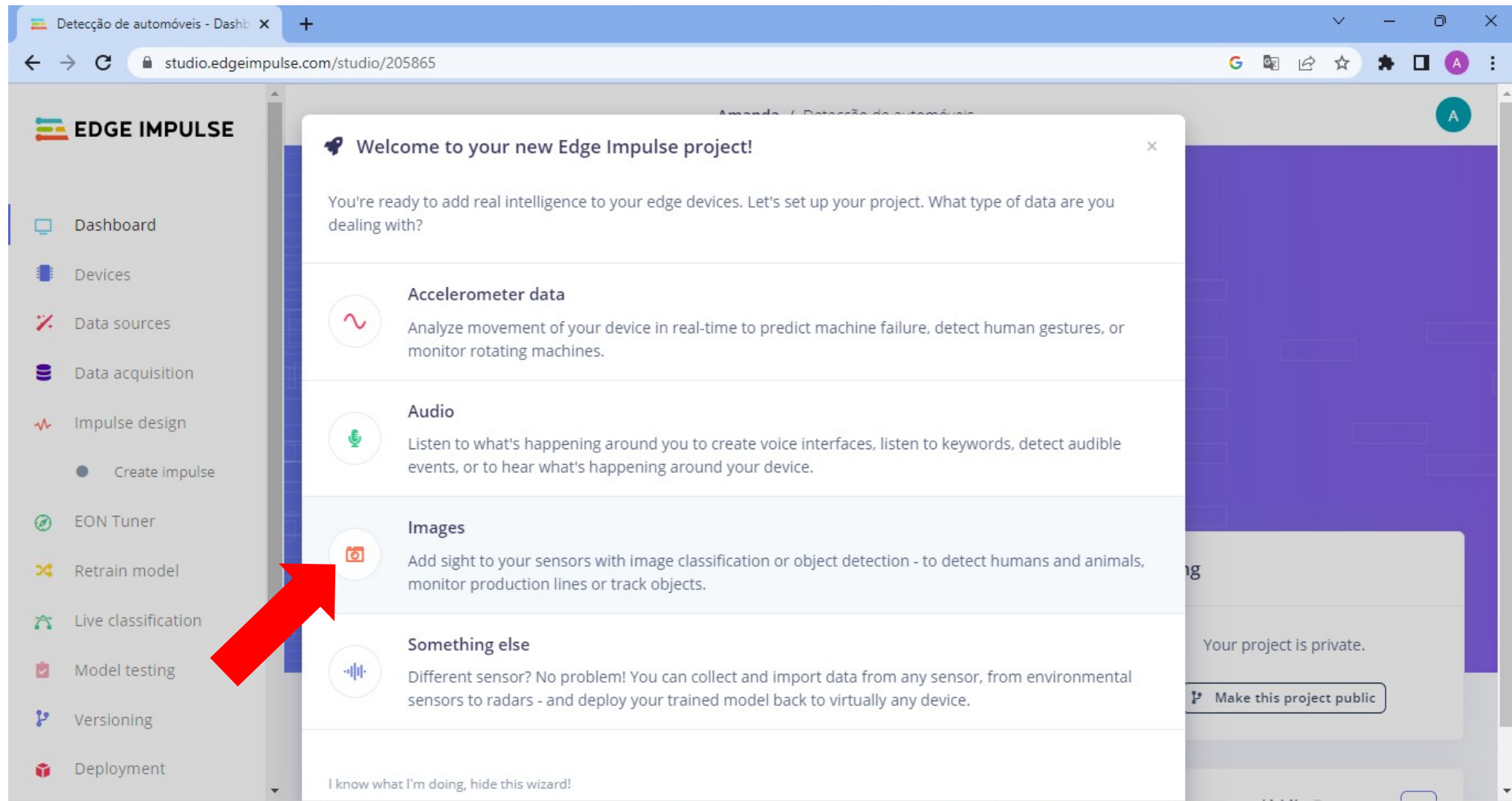
Choose your project type:

☒ **Developer**
20 min job limit, 4GB or 4 hours of data, limited collaboration.

☐ **Enterprise**
No job or data size limits, higher performance, custom blocks. [Learn more](#)

Create new project

A Amanda / ReconhecimentoProjeto01





The screenshot shows the Edge Impulse Studio web interface. A modal window titled "Welcome to your new Edge Impulse project!" is displayed in the center. The modal contains the following sections:

- 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 a wide range of fully supported hardware targets to quickly build a custom image dataset.
[Connect your development board](#)
- 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](#) (This button is circled in red in the image)
- 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](#)

At the bottom of the modal, there is a green button labeled "Let's get started!".

The background of the interface shows a sidebar with navigation options: Dashboard, Devices, Data sources, Data acquisition, Impulse design, Create impulse, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The URL in the browser address bar is <https://studio.edgeimpulse.com/studio/205865/upload>.



Detecção de automóveis - Upload x +

studio.edgeimpulse.com/studio/205865/upload

EDGE IMPULSE

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

GETTING STARTED

Upload existing data

You can upload existing data to your project in the Data Acquisition Format (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files.

Select files

Escolher arquivos 126 arquivos

Upload into category

☐ Automatically split between training and testing ?

☒ Training

☐ Testing

Label

☐ Infer from filename ?

☐ Leave data unlabeled ?

☒ Enter label:

Car

Begin upload



Detecção de automóveis - Data x Detecção de Automóveis (Projeto x +

studio.edgeimpulse.com/studio/205878/acquisition/training?page=1#

EDGE IMPULSE

Amanda / Detecção de Automóveis (Projeto 01)

Training data | Test data | Data explorer | Upload data | CSV Wizard | Export data

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

DATA COLLECTED
161 items

TRAIN / TEST SPLIT
100% / 0% ⚠

Record new data [Connect using WebUSB](#)

No devices connected to the remote management API.

RAW DATA
Click on a sample to load...

Collected data

| SAMPLE NAME | LABEL | ADDED |
|-------------|-------|-----------------|
| 0019 | Car | Today, 17:08:19 |
| 0017 | Car | Today, 17:08:19 |
| 0018 | Car | Today, 17:08:18 |
| 0160 | Car | Today, 17:08:18 |
| 0159 | Car | Today, 17:08:18 |
| 0158 | Car | Today, 17:08:18 |

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



The screenshot displays the Edge Impulse Studio web interface in a browser. The left sidebar contains a navigation menu with options: Dashboard, Devices, Data sources, Data acquisition, Impulse design, Create impulse, Image, Classifier, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main content area is titled 'Upload existing data' and includes instructions on supported file formats (CBOR, JSON, CSV, WAV, JPG, PNG, AVI, MP4). It features a 'Select files' section with a button 'Escolher arquivos' and a status 'Nenhum arquivo escolhido'. Below this is the 'Upload into category' section with radio buttons for 'Automatically split between training and testing', 'Training' (selected), and 'Testing'. The 'Label' section has radio buttons for 'Infer from filename', 'Leave data unlabeled', and 'Enter label:' (selected). A text input field next to 'Enter label:' contains the word 'Truck'. At the bottom of the main area, a green 'Begin upload' button is circled in red. A blue speech bubble points to the 'Truck' label with the text 'Repetir o processo para as imagens de caminhão.'

Detecção de automóveis - Data x Detecção de Automóveis (Projeto x +

studio.edgeimpulse.com/studio/205878/upload

EDGE IMPULSE

Dashboard

Devices

Data sources

Data acquisition

Impulse design

Create impulse

Image

Classifier

EON Tuner

Retrain model

Live classification

Model testing

Versioning

Deployment

Upload existing data

You can upload existing data to your project in the [Data Acquisition Format](#) (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files.

Select files

Escolher arquivos Nenhum arquivo escolhido

Upload into category

☐ Automatically split between training and testing ?

☒ Training

☐ Testing

Label

☐ Infer from filename ?

☐ Leave data unlabeled ?

☒ Enter label:

Truck

Begin upload

Repetir o processo para as imagens de caminhão.



Detecção de automóveis - Data x Detecção de Automóveis (Projeto) x

studio.edgeimpulse.com/studio/205878/upload

EDGE IMPULSE

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

Upload existing data

You can upload existing data to your project in the [Data Acquisition Format](#) (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files.

Select files

Escolher arquivos Nenhum arquivo escolhido

Upload into category

- ☐ Automatically split between training and testing ?
- ☐ Training
- ☒ Testing

Label

- ☐ Infer from filename ?
- ☐ Leave data unlabeled ?
- ☒ Enter label:

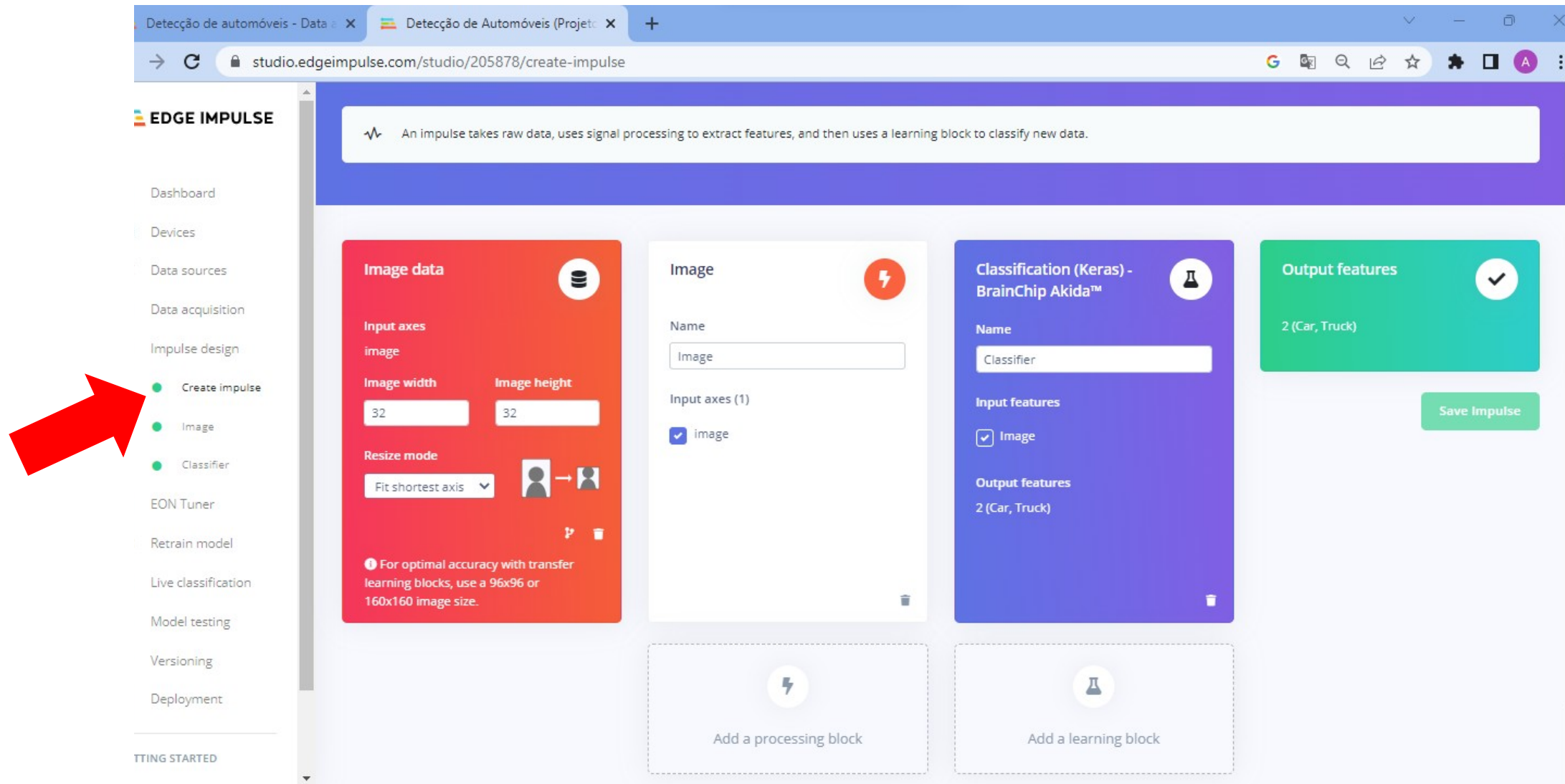
Begin upload

Trocar “Training” por “Testing”, e realizar a mesma sequência de passos.

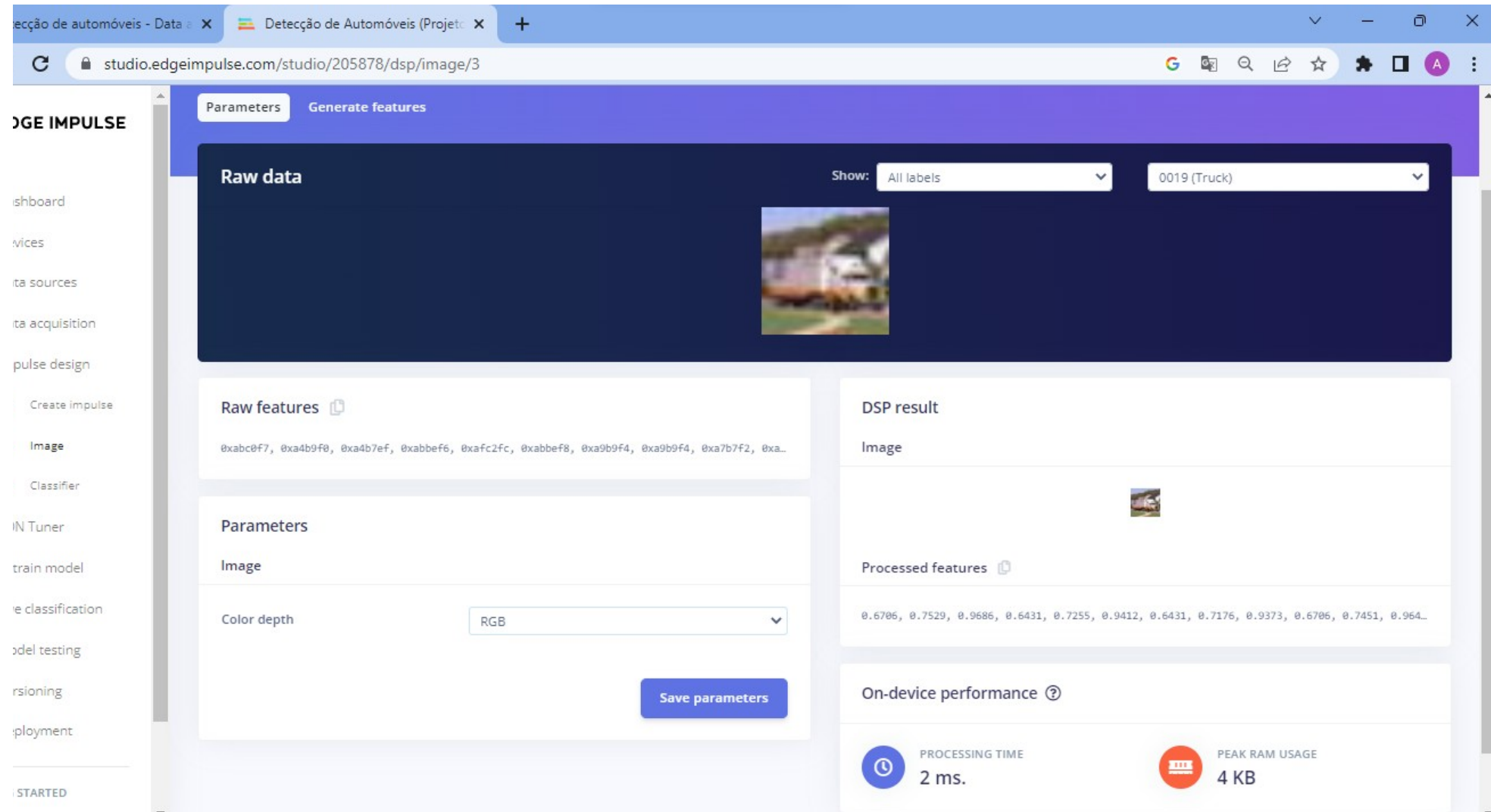


The screenshot shows the Edge Impulse Studio web interface in a browser. The browser tabs include 'Detecção de automóveis - Data' and 'Detecção de Automóveis (Projeto)'. The address bar shows 'studio.edgeimpulse.com/studio/205878/upload'. The left sidebar contains the 'EDGE IMPULSE' logo and a list of navigation items: Dashboard, Devices, Data sources, Data acquisition (highlighted), Impulse design, Create impulse, Image, Classifier, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main content area is titled 'Upload existing data' and includes the following sections:

- Upload existing data**: A heading followed by the text: 'You can upload existing data to your project in the [Data Acquisition Format](#) (CBOR, JSON, CSV), or as WAV, JPG, PNG, AVI or MP4 files.'
- Select files**: A section with a button labeled 'Escolher arquivos' and the text 'Nenhum arquivo escolhido'.
- Upload into category**: A section with three radio button options: 'Automatically split between training and testing ?' (unselected), 'Training' (unselected), and 'Testing' (selected).
- Label**: A section with three radio button options: 'Infer from filename ?' (unselected), 'Leave data unlabeled ?' (unselected), and 'Enter label:' (selected). Below this is a text input field containing the word 'Truck'.
- Begin upload**: A green button at the bottom of the form, which is circled in red.



The screenshot shows the Edge Impulse Studio web interface. The browser address bar displays `studio.edgeimpulse.com/studio/205878/create-impulse`. The left sidebar contains a navigation menu with the following items: Dashboard, Devices, Data sources, Data acquisition, Impulse design, **Create impulse** (highlighted with a red arrow), Image, Classifier, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main workspace is titled "An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data." and contains four blocks in a sequence: 1. **Image data** (red block): Input axes set to "image", Image width and height both set to 32, and Resize mode set to "Fit shortest axis". A note at the bottom states: "For optimal accuracy with transfer learning blocks, use a 96x96 or 160x160 image size." 2. **Image** (white block): Name set to "Image", and Input axes (1) set to "image". 3. **Classification (Keras) - BrainChip Akida™** (purple block): Name set to "Classifier", Input features set to "Image", and Output features set to "2 (Car, Truck)". 4. **Output features** (green block): Output features set to "2 (Car, Truck)". A "Save Impulse" button is located to the right of the Output features block. At the bottom of the workspace, there are two dashed boxes: "Add a processing block" and "Add a learning block".





The screenshot displays the Edge Impulse Studio web interface in a browser. The URL bar shows `studio.edgeimpulse.com/studio/205878/learning/keras-akida/7`. The left sidebar contains a navigation menu with the following items: Dashboard, Devices, Data sources, Data acquisition, Impulse design, Create impulse, Image, Classifier (highlighted), EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main workspace is titled "Auto-balance dataset (?)". Below this, the "Neural network architecture" section shows a vertical stack of layers: "Input layer (3,072 features)" (purple), "2D conv / pool layer (32 filters, 3 kernel size, 1 layer)", "2D conv / pool layer (16 filters, 3 kernel size, 1 layer)", "Flatten layer", "Dropout (rate 0.25)", "Add an extra layer" (dashed box), and "Output layer (2 classes)" (dark blue). At the bottom of this stack is a green "Training..." button, which is circled in red. A notification box in the top right corner displays the message: "Splitting data into training and validation sets... Splitting data into training and validation sets OK".

Detecção de automóveis - Data x Detecção de Automóveis (Projeto) x

studio.edgeimpulse.com/studio/205878/learning/keras-akida/7

EDGE IMPULSE

- Dashboard
- Devices
- Data sources
- Data acquisition
- Impulse design
- Create impulse
- Image
- Classifier
- ON Tuner
- Retrain model
- Live classification
- Model testing
- Exporting
- Deployment
- GETTING STARTED
- Documentation
- Projects

Neural Network settings

Training settings

Number of training cycles: 10

Learning rate: 0.0005

Validation set size: 20 %

Auto-balance dataset: ☐

Neural network architecture

Input layer (3,072 features)

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

2D conv / pool layer (16 filters, 3 kernel size, 1 layer)

Flatten layer

Dropout (rate 0.25)

Add an extra layer

Output layer (2 classes)

[Start training](#)

studio.edgeimpulse.com/studio/205878/validation

Training output

Model version: Quantized (akida)

Last training performance (validation set)

ACCURACY: 69.2% LOSS: 6.87

Confusion matrix (validation set)

| | CAR | TRUCK |
|----------|-------|-------|
| CAR | 76.3% | 23.3% |
| TRUCK | 27.1% | 62.9% |
| F1 SCORE | 0.70 | 0.69 |

Data explorer (full training set)

● Car - correct
● Truck - correct
● Car - incorrect
● Truck - incorrect

On-device performance

INFERRING TIME: - PEAK RAM USAGE: N/A FLASH USAGE: 8,1K

Essa será a tela gerada.



The screenshot shows the Edge Impulse Studio interface in a web browser. The browser tabs include 'Detecção de automóveis - Data' and 'Detecção de Automóveis (Projeto)'. The address bar shows the URL 'studio.edgeimpulse.com/studio/205878/validation'. The user is logged in as 'Amanda'.

The left sidebar contains the following menu items: Dashboard, Devices, Data sources, Data acquisition, Impulse design, Create impulse, Image, Classifier, EON Tuner, Retrain model, **Model testing** (highlighted with a red circle), Versioning, and Deployment.

The main content area is titled 'Amanda / Detecção de Automóveis (Projeto 01)'. It features a 'Test data' section with a 'Classify all' button (highlighted with a red circle) and a 'Model testing output' section. The 'Test data' section includes a table with the following columns: SAMPLE NA..., EXPECTED OUT..., LENG..., ACCURACY, and RESULT.

| SAMPLE NA... | EXPECTED OUT... | LENG... | ACCURACY | RESULT |
|--------------|-----------------|---------|----------|--------|
| 0019 | Truck | - | | ... |
| 0018 | Truck | - | | ... |
| 0017 | Truck | - | | ... |
| 0016 | Truck | - | | ... |
| 0160 | Truck | - | | ... |
| 0158 | Truck | - | | ... |
| 0150 | Truck | - | | ... |



The screenshot displays the Edge Impulse Studio web interface. On the left is a sidebar with navigation options: Dashboard, Devices, Data sources, Data acquisition, Impulse design, EON Tuner, Retrain model, Live classification, **Model testing** (highlighted with a red circle), Versioning, and Deployment. The main area is divided into two panels. The left panel shows a table of validation data:

| ID | Label | Confidence | Uncertainty |
|------|-------|------------|-------------|
| 0016 | Truck | 0% | 1 uncertain |
| 0160 | Truck | 0% | 1 uncertain |
| 0158 | Truck | 0% | 1 uncertain |

The right panel, titled "Model testing results", shows an overall accuracy of 42.55%. Below this is a confusion matrix table:

| | CAR | TRUCK | UNCERTAIN |
|----------|-------|-------|-----------|
| CAR | 43.5% | 16.8% | 39.8% |
| TRUCK | 14.9% | 41.6% | 43.5% |
| F1 SCORE | 0.55 | 0.53 | |

Below the table is a "Feature explorer" scatter plot showing data points categorized by color: Car - correct (yellow), Truck - correct (green), Car - incorrect (purple), and Truck - incorrect (orange). A blue speech bubble with the text "Essa será a tela gerada." points to the "Model testing" option in the sidebar.



The screenshot shows the Edge Impulse Studio interface at the URL <https://studio.edgeimpulse.com/studio/205878/deployment>. The left sidebar contains a menu with the following items: Data sources, Data acquisition, Impulse design, Create impulse, Image, Classifier, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment (circled in red). Below the menu is a 'GETTING STARTED' section with links to Documentation and Forums. The main content area displays deployment options. Under 'Linux', there are three cards: 'Linux (AArch64 with AKD1000 MINI PCIe)', 'Linux (x86_64 with AKD1000 MINI PCIe)', and 'Linux (RZ/V2L)'. Below these are two more cards: 'Linux (TI TDA4VM)' and 'Custom firmware'. A section titled 'Run your impulse directly' includes the text 'Run this impulse directly on your mobile phone or computer, no app required.' and two cards: 'Computer' and 'Mobile phone' (indicated by a red arrow). At the bottom of the main content area is a green 'Build' button, which is circled in red. The footer of the page shows the copyright notice '© 2023 EdgeImpulse Inc. All rights reserved.'



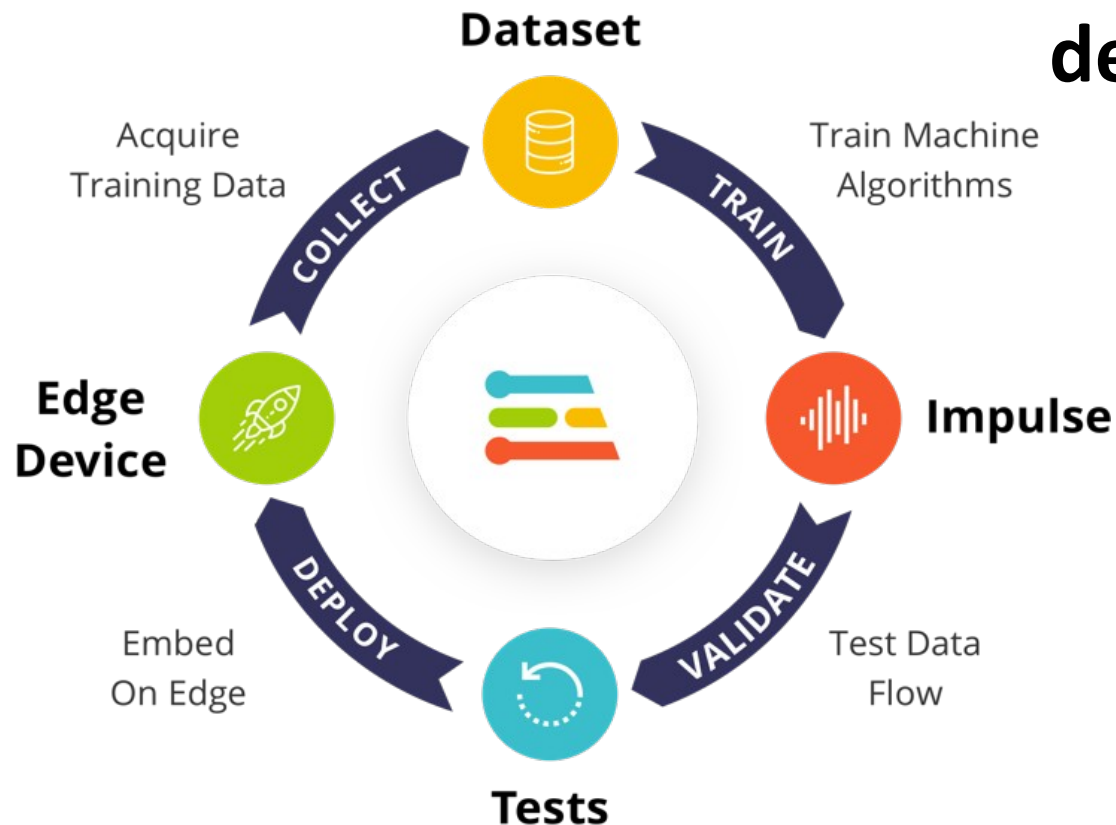
The screenshot shows the Edge Impulse Studio web interface in a browser. The address bar displays `studio.edgeimpulse.com/studio/205878/deployment`. On the left, a sidebar menu lists various tools: Dashboard, Devices, Data sources, Data acquisition, Impulse design (with sub-items: Create impulse, Image, Classifier), EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main content area shows deployment options for Linux (AARCH64, x86_64, and RZ/V2L). A white modal box is centered on the screen with the title "Scan this QR code". Inside the modal, it says "To run your impulse on your mobile phone, click [here](#) or scan the QR code." and displays a large QR code. At the bottom of the modal, there is a copyright notice: "© 2023 EdgeImpulse Inc. All rights reserved."

Edge Impulse

Através desse link você abrirá um documento que contém todos os detalhes da plataforma Edge Impulse.

Link:

<https://docs.edgeimpulse.com/docs/>



Getting Started

Welcome to Edge Impulse! We enable developers to create the next generation device solutions with **embedded Machine Learning**. In the documentation you'll find **tutorials** and **API documentation**. For support, visit the **forums**.

 Export as PDF

[Copy link](#)

❖ If you're new to the idea of embedded machine learning, or machine learning in general, you may enjoy our quick guide: [What is embedded ML, anyway?](#)

Get started with any device

Follow these three steps to build your first embedded Machine Learning model - no worries, you can use almost any device to get started.

1. You'll need some data:

- ## Data sources

Data acquisition >

Data explorer



Powered By **GitBook**

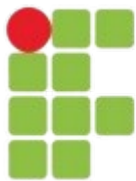
Clique aqui
para baixar o
documento
em PDF.

Link: <https://docs.edgeimpulse.com/docs/>

- [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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O curso IFSP01_TinyML é parte do [TinyML4D](#), uma iniciativa para tornar o aprendizado sobre TinyML disponível para todos em todo o mundo.



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