MACHINE LEARNING EM **IOT** COM **TENSORFLOW**

Alvaro Viebrantz

Google Developer Expert for IoT and Product Engineer at Leverege

aviebrantz.com

@alvaroviebrantz

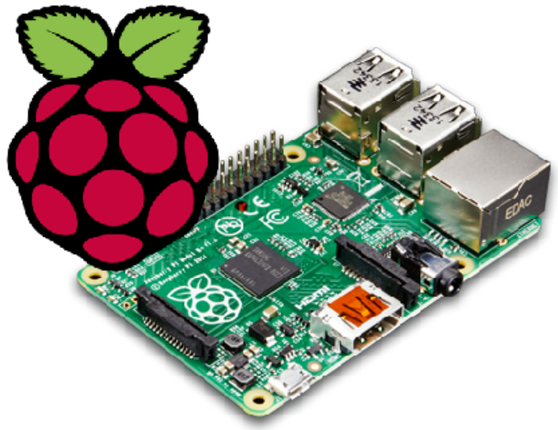
O que vamos ver hoje ?

Internet das **Coisas**

Dispositivos IoT

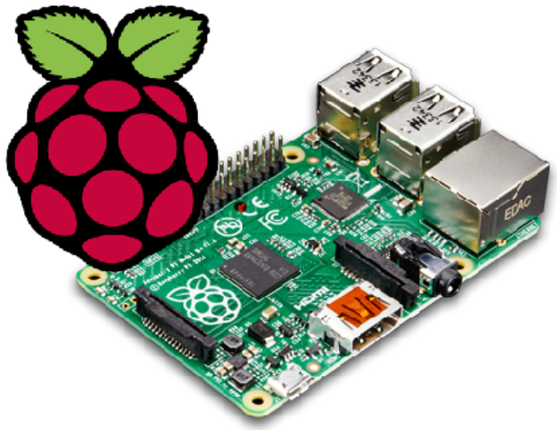
Apesar de contar, na maioria das vezes não estamos falando disso

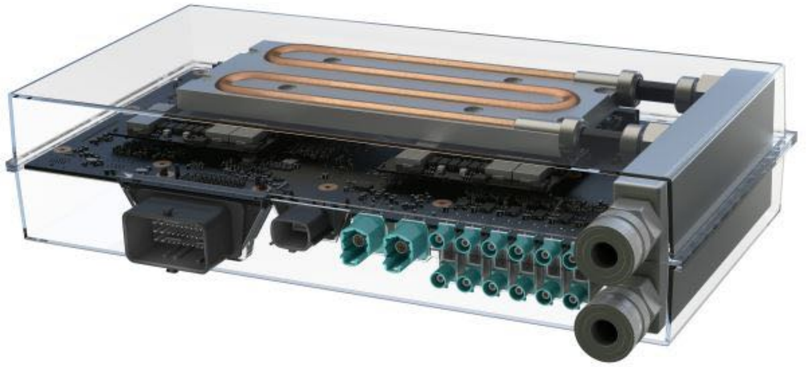
- Celulares
- Carros inteligentes
- Roteadores/Gateways
- Raspberry Pi’s e afins



Dispositivos IoT

Essa classe de dispositivos são bem mais poderosos

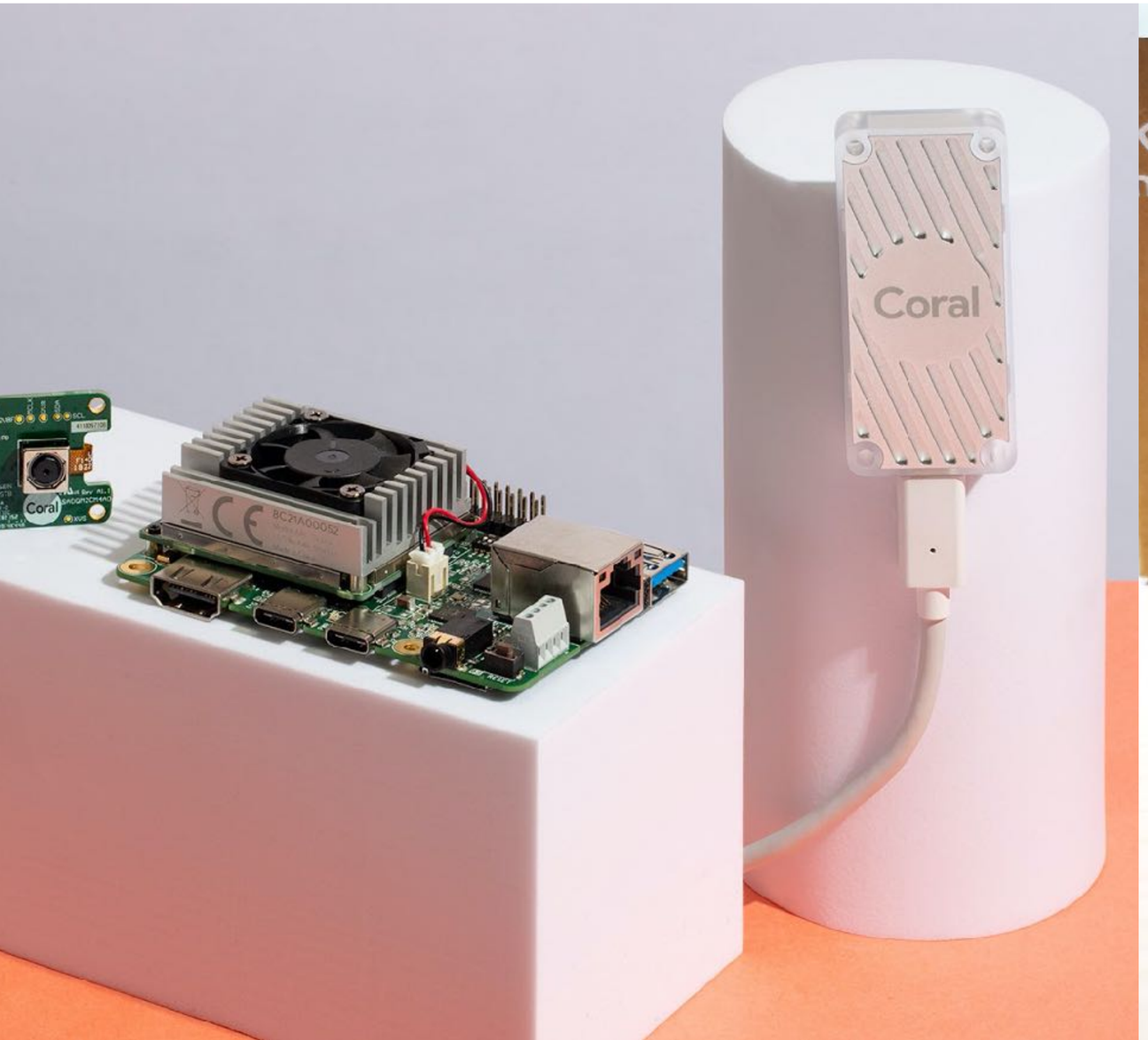




	CPU	Cores	Memory	Storage	Power Consumption	Usage under Load	Price
Raspberry Pi 3	1.2 Ghz	4	1 GB	Up to 32 GB	6W / 400 mA @idle	700 mA @load	$35
Pixel 4a	2.2 Ghz	8	6 GB	Up to 128 GB	5W / 80mA @idle	900 mA @load	$350
Google Nest Mini	1.4 Ghz	4	512 MB	4 GB	2W / 150 mA @idle	210 mA @load	$50
NVIDIA Drive PX2	1.4 Ghz	8 CPU 4 GPU	16 GB	Up to 128 GB	60 W / 16 A @idle	50 A @load	$800

Edge Devices

Performance otimizada para Machine Learning



Dispositivos IoT

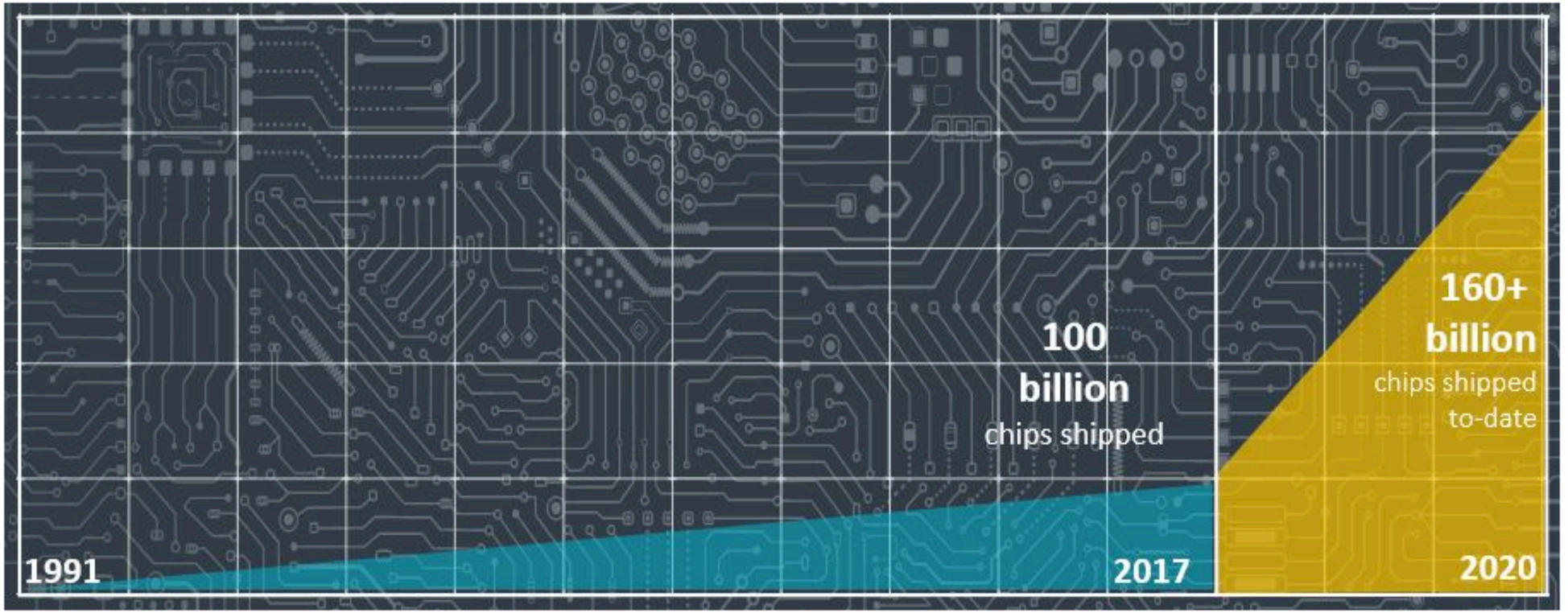
Bastante limitados em memoria, cpu e uso de bateria

- Dispositivos bem menores e mais baratos
  - Lampadas, Sensores de porta, Fechaduras Smart, Termostatos
  - Smartwatches e Fitness bands
  - Rastreadores em geral - GPS, rede celular, LoRa, etc
  - Assistentes pessoais - Alexa/Google Assistant
  - Na maioria das vezes, não tem sistema operacional nenhum

In the fourth quarter of 2019 (Arm FY Q319):

- Arm silicon partners shipped a **record 6.4 billion Arm-based chips**, the third record quarter for unit shipments in the past two years
- Arm saw growing demand for embedded intelligence in endpoint devices as demonstrated by the **record 4.2 billion Cortex-M processors** shipped

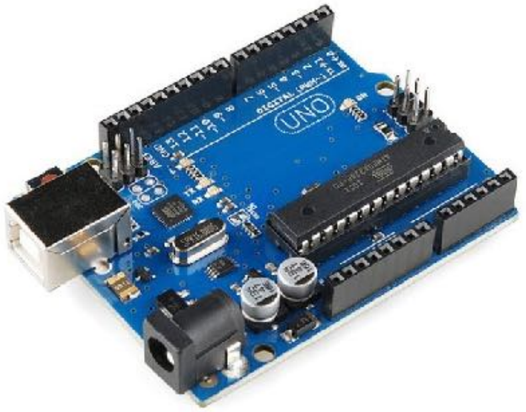
To-date, Arm partners have shipped more than **160 billion Arm-based chips**, and an average of more than **22 billion over the past three years**.



www.arm.com/company/news/2020/02/record-shipments-of-arm-based-chips-in-previous-quarter

Dispositivos IoT

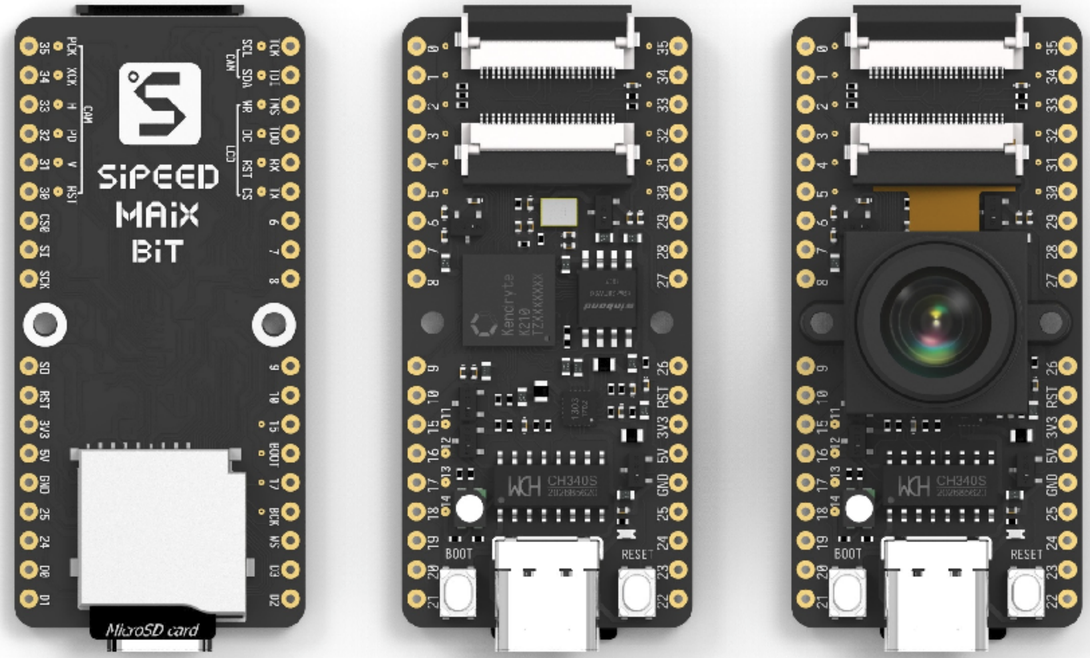
Bastante limitados em memoria, cpu e uso de bateria



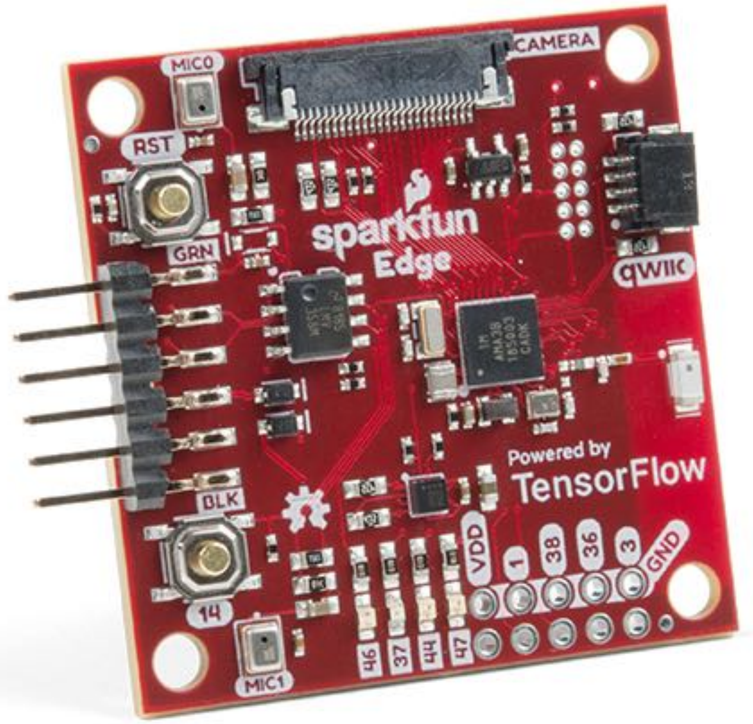
	CPU	Memory	Flash	Connectivity	GPIO	Arch	Power Consumption	Deep Sleep	Price
ATMega 328p	16 Mhz	2 Kb	32 Kb	None	24	AVR RISC 8 bit	40mA	6uA	$1.7
STM32 “Blue Pill”	72 Mhz	20 Kb	64 kb	None	32	ARM 32 bit Cortex M3	8mA	3uA	$2.3
Nordic nrf52840	64 Mhz	256 Kb	1 MiB	Ble/Zigbee/ Thread	36	ARM 32 bit Cortex M4F	16mA	2uA	$3
ESP 32	160 Mhz Dual Core	512 Kb	Up to 16MiB	Wifi/Ble	36	XTensa 32 bit	200mA	10uA	$3

Outros Edge Devices

Performance melhor para machine learning também em micro controladores



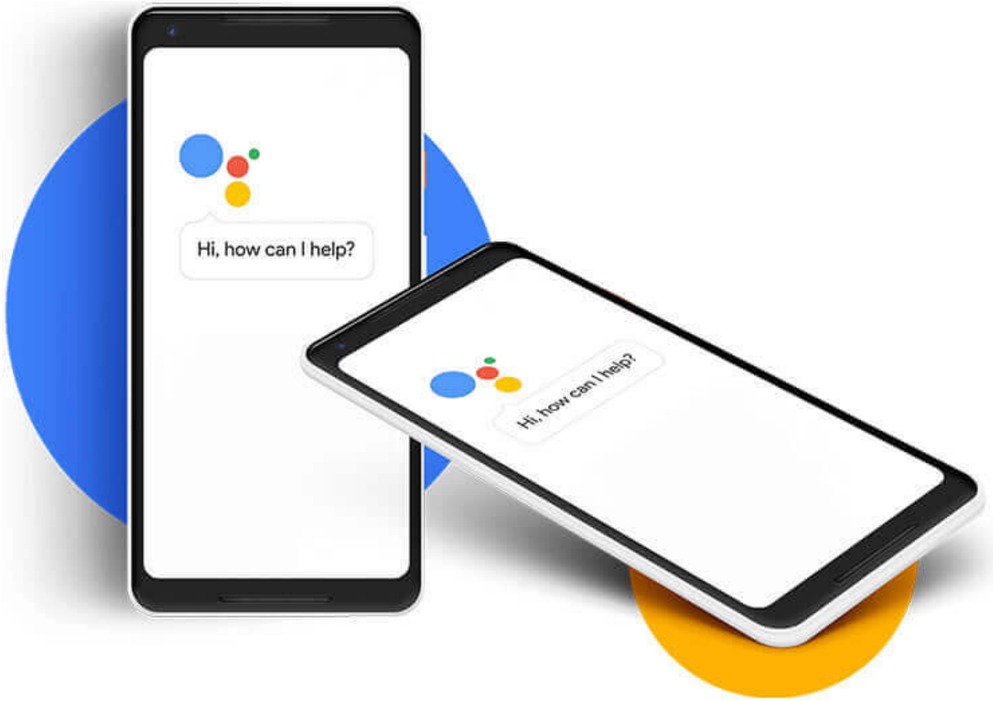
Sipeed Maix Bit



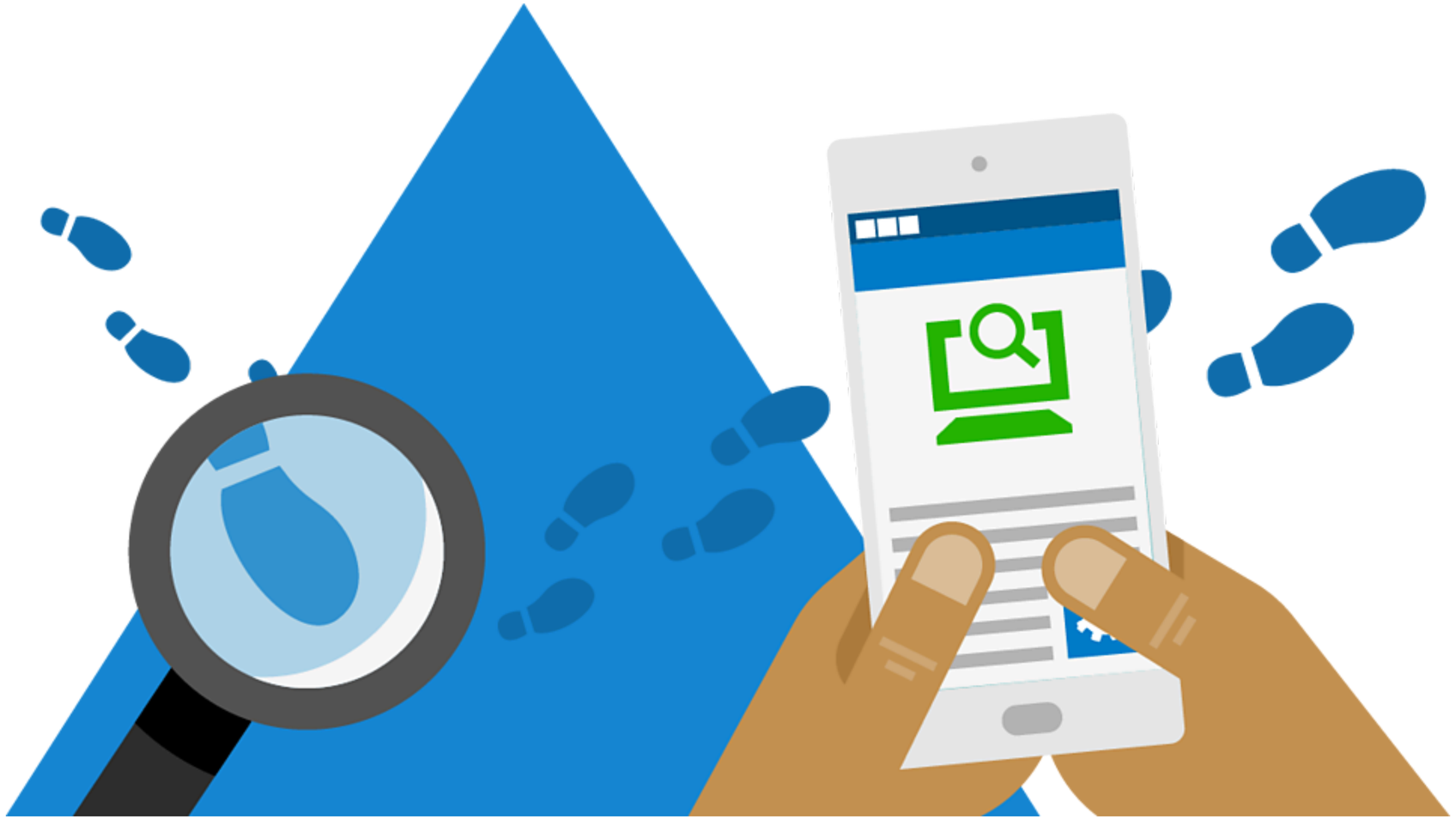
Sparkfun Edge

IoT + Machine Learning
Faz sentido ?

Banda de Rede

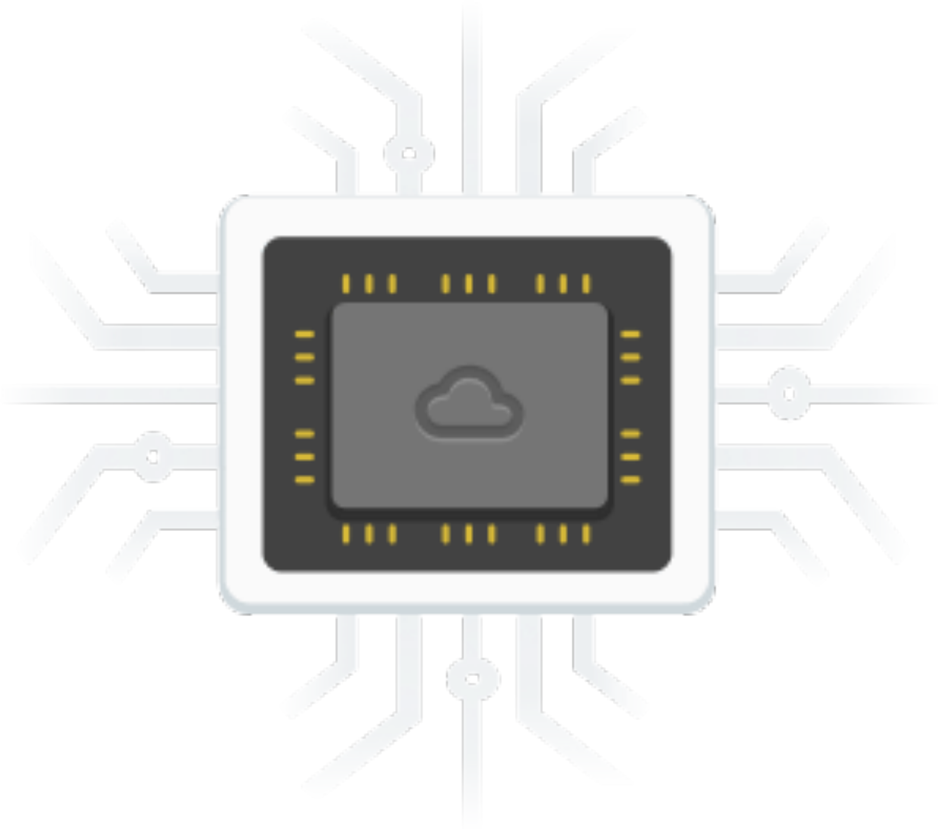


Privacidade



Latência

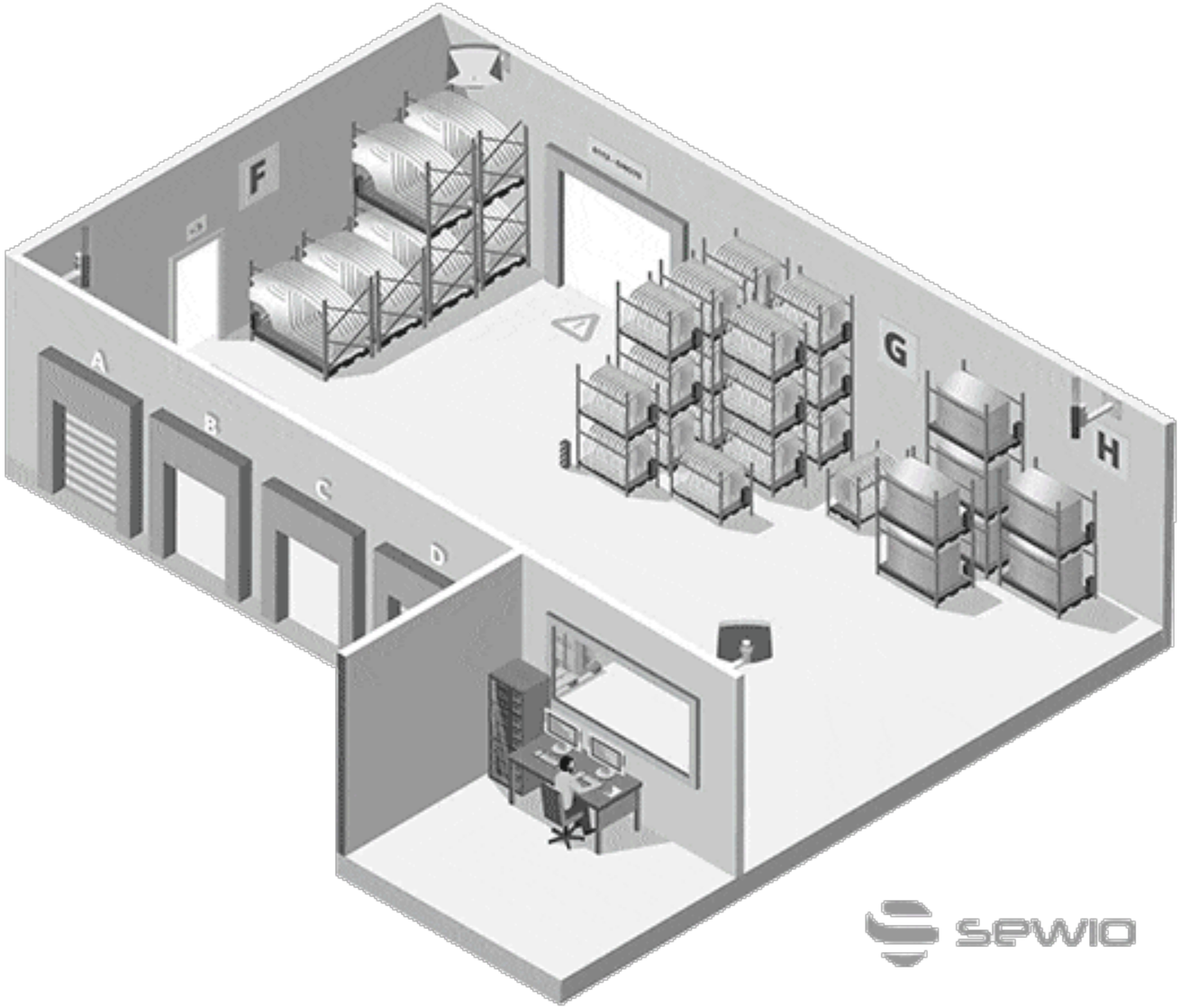
Custos



Mais casos de uso
IoT + Machine Learning

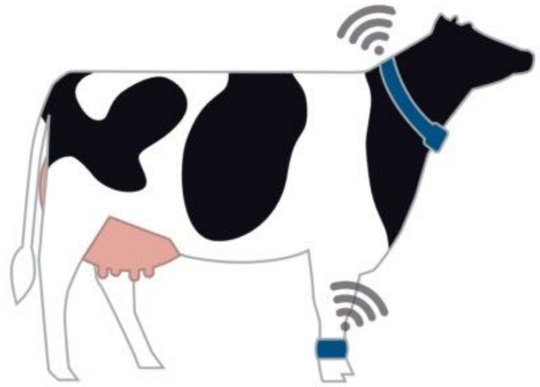
Monitoramento de ativos indoor

Dados bastante ruidosos e volumosos



Comportamento de animais

Padrões de movimento - Internet of Cows/Cattle or Internet of Horses



Farm Jenny
FOR HORSES

Problemas ambientais

Animais em extinção, queimadas e desflorestamento

Building The World's Most Advanced
Wildlife Tracker.

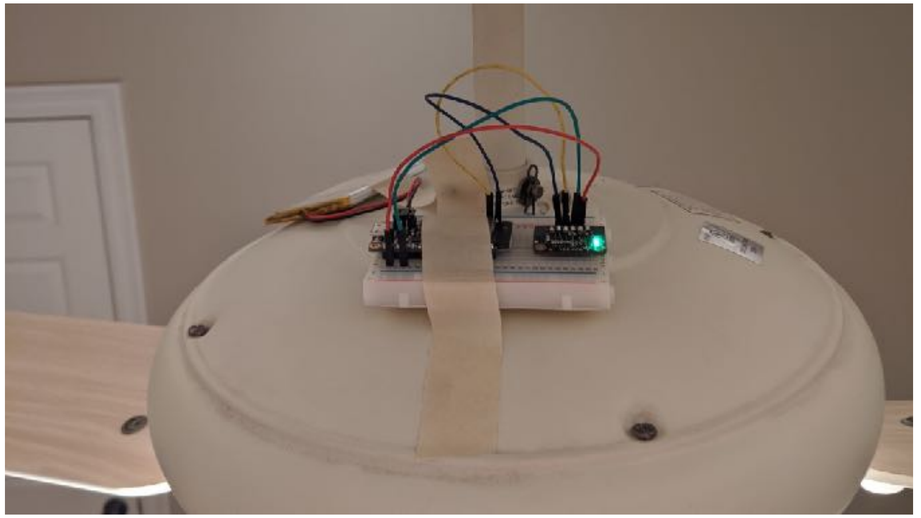
smart parks

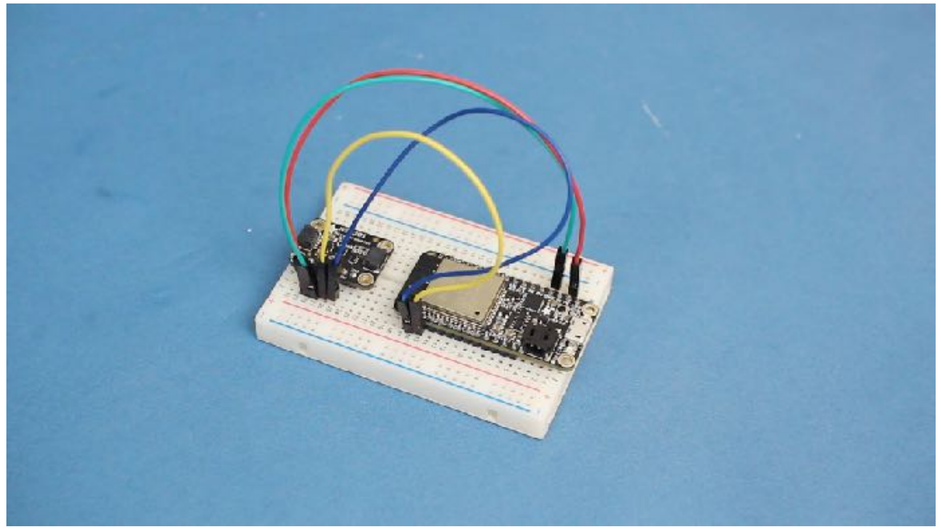
hackster.io
AN AVNET COMMUNITY

Manutenção preditiva

Padrões de vibração em motores

- Detectar anomalias no funcionamento de um equipamento
- Projeto usando um ESP32 + Accelerometro
- Diferentes modelos testados rodando no embarcado
  - Auto Encoder
  - Mahalanobis Distance
- github.com/ShawnHymel/tinyml-example-anomaly-detection

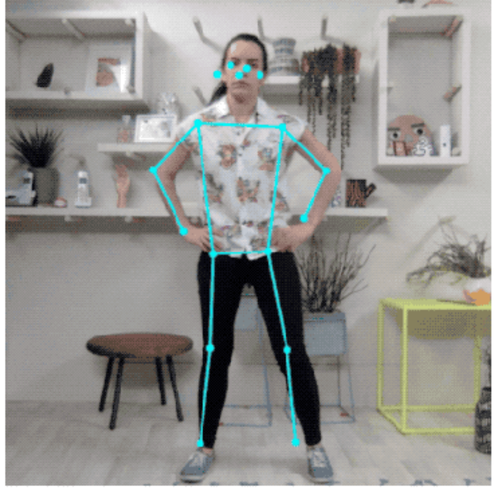


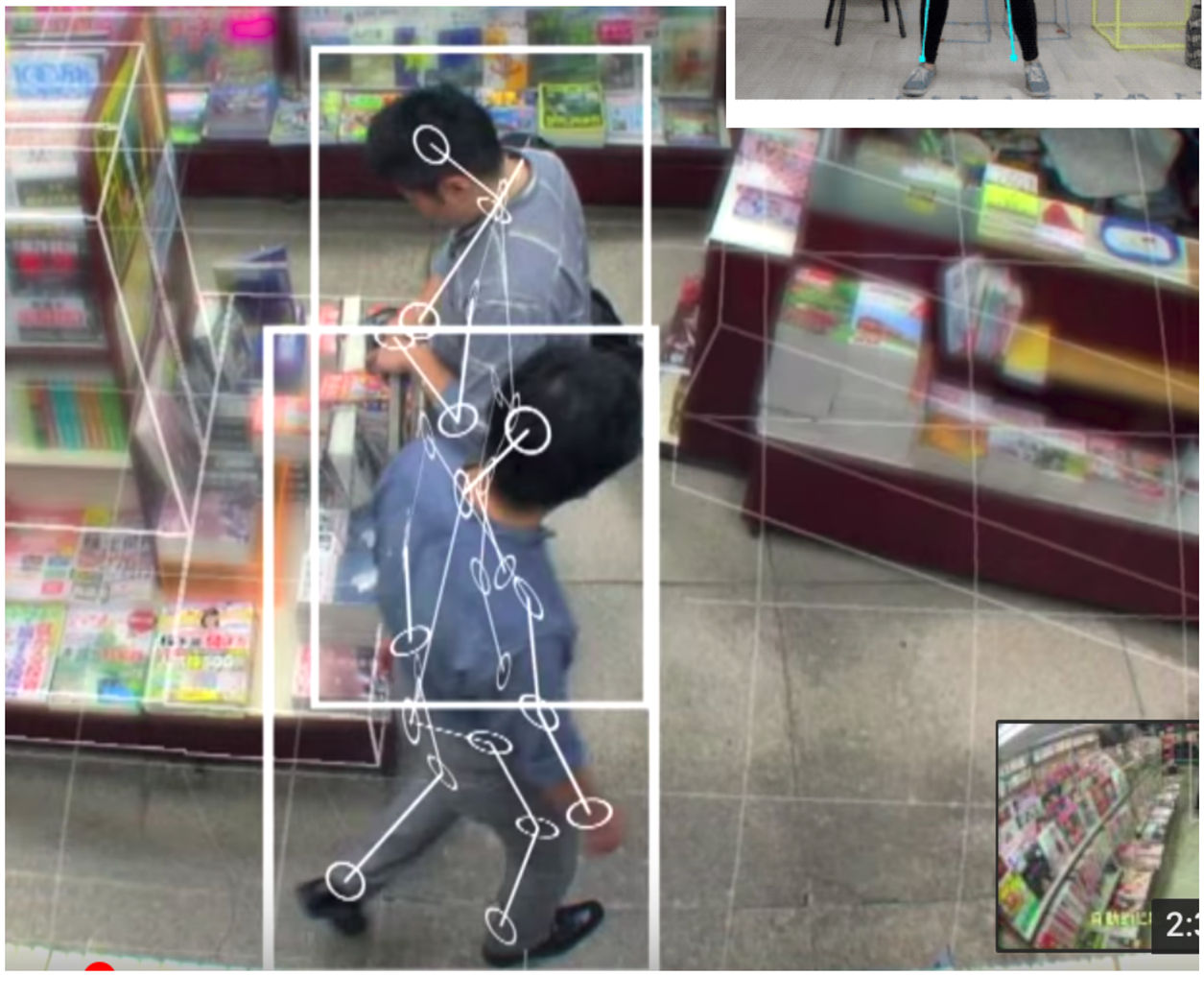


github.com/ShawnHymel/tinyml-example-anomaly-detection

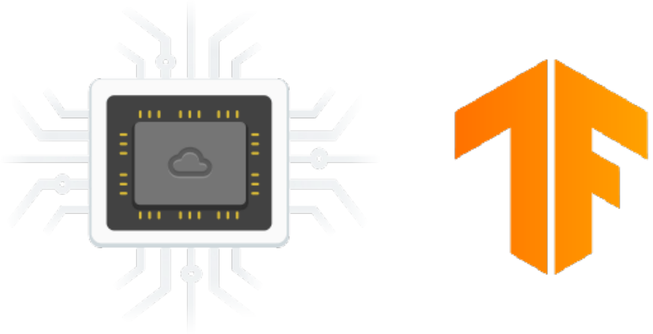
Segurança e Proteção

Detectar mascaras e possíveis acidentes no trabalho





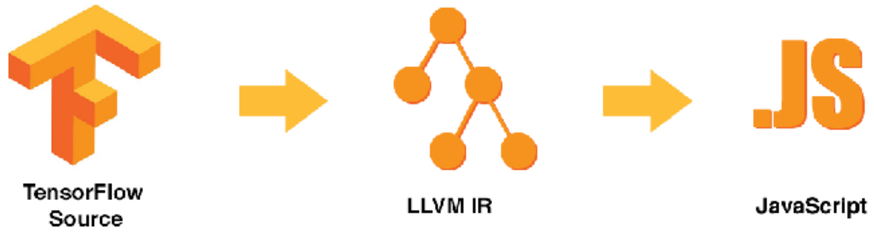
O que o **TensorFlow** oferece para **IoT** ?



TensorFlow Lite

Mobile e Internet das Coisas

- Plataformas
  - Android e iOS
  - Linux Embarcado
  - Web com TensorFlowJS
- Backend/Delegate
  - CPU
  - GPU WebGL / OpenCL / Open GL
  - iOS Core ML / Metal
  - Web Assembly
  - Edge TPU ⭐



Modelos Pré treinados

Podem ser usados sem muitas alterações

Classificação de imagens

Identifique centenas de objetos, incluindo pessoas, atividades, animais, plantas e locais.

Ver modelo →

Detecção de objetos

Detecte diversos objetos com caixa delimitadora. Sim, isso inclui cães e gatos.

Ver modelo →

Estimar poses

Estime poses para uma ou mais pessoas. Imagine as possibilidades, como festas de bonecos-palito.

Ver modelo →

Resposta inteligente

Gere sugestões de respostas para mensagens de chat.

Ver modelo →

Segmentação

Determine a forma de objetos com acurácia de localização exata e rótulos semânticos. Treinado para locais, pessoas, animais e muito mais.

Ver modelo →

Transferência de estilo

Aplique qualquer estilo a uma imagem de entrada para criar uma nova imagem artística.

Ver modelo →

Classificação de texto

Categorize texto livre em grupos predefinidos. Possíveis aplicativos: moderação de conteúdo abusivo, detecção de tom e muito mais.

Ver modelo →

Resposta a perguntas em linguagem natural

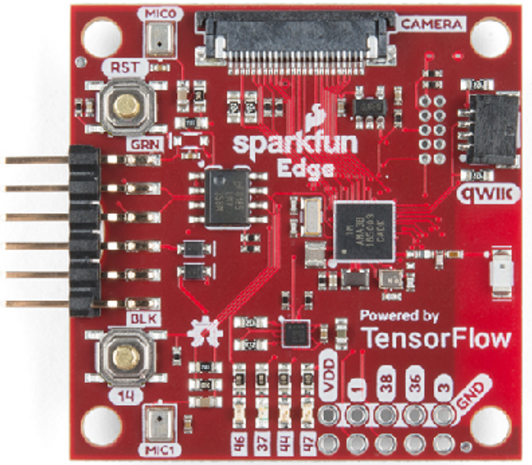
Responda a perguntas com base no conteúdo de um trecho de texto usando BERT.

Ver modelo →

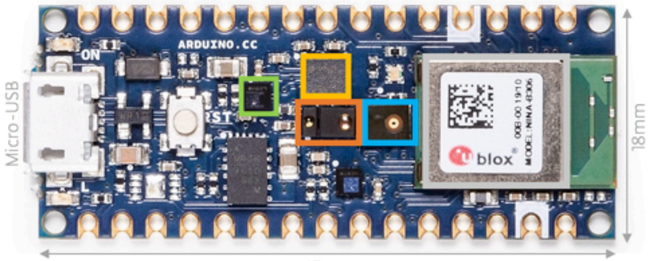
TensorFlow Lite Micro

Micro-controladores e dispositivos com 16kb de ram ou mais

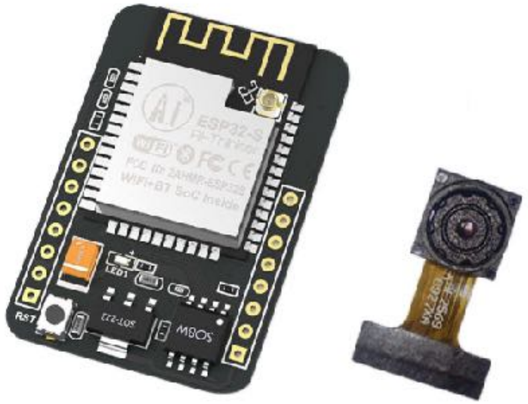
- Arquiteturas
  - Arm Cortex-M e CMSIS DSP
  - XTensa - ESP32
- Biblioteca em C/C++
- Demos
  - Detecção de hotwords - Sim/Não
  - Varinha mágica - Detecta diferentes movimentos
  - Deteção de Pessoas com Camera
- Conjuntos de instruções limitado
  - www.tensorflow.org/lite/microcontrollers/build_convert#operation_support



ARDUINO NANO 33 BLE SENSE

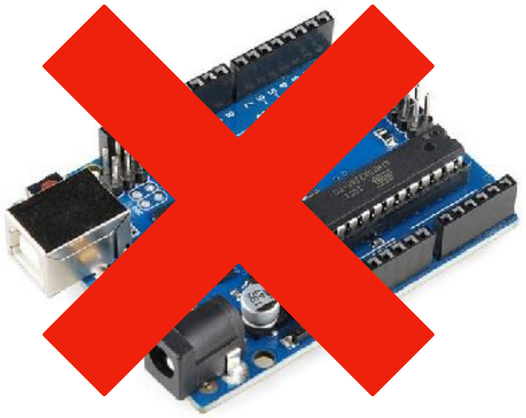


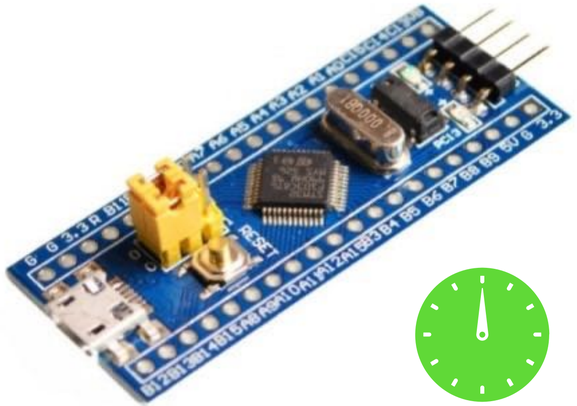
- Color, brightness, proximity and gesture sensor
- Digital microphone
- Motion, vibration and orientation sensor
- Temperature, humidity and pressure sensor
- Arm Cortex-M4 microcontroller and BLE module

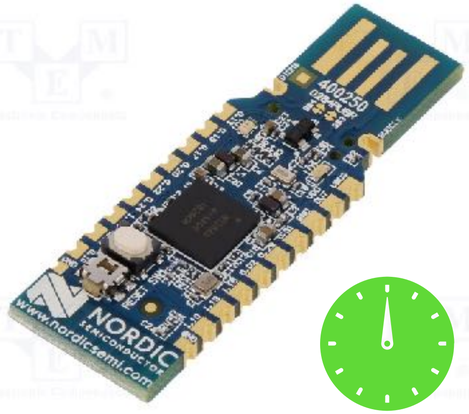


Relembrando alguns devices

Varios tem suporte ao TensorFlow Lite Micro







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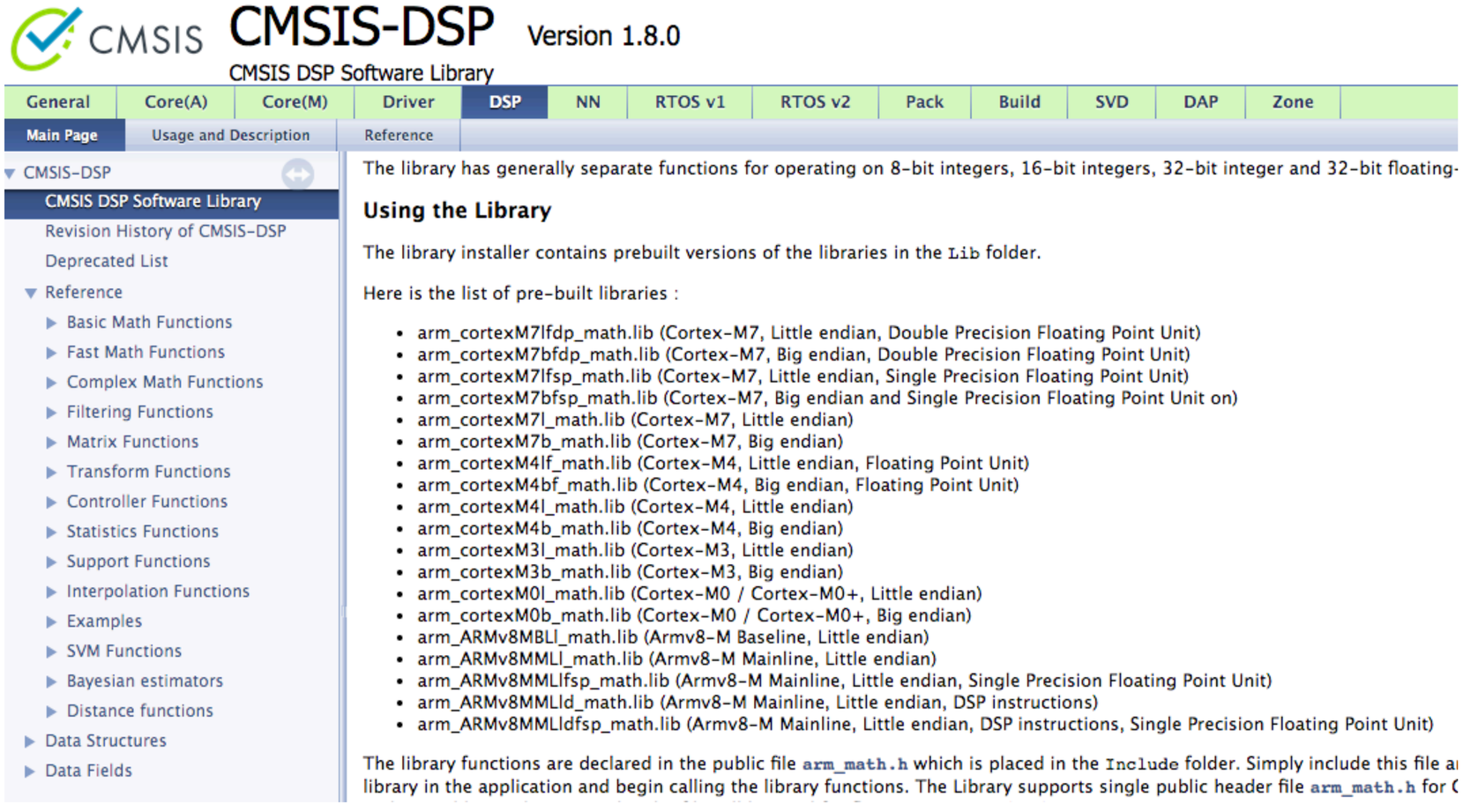
ESP 32	160 Mhz Dual Core	512 Kb	Up to 16MiB	Wifi/Ble	36	XTensa 32 bit	200mA	10uA	$3

Digital Signal Processing - DSP

Instruções otimizadas para cálculos complexos em Micro Controladores

- “GPU” para micro controladores
- Instruções especializadas para determinadas tarefas



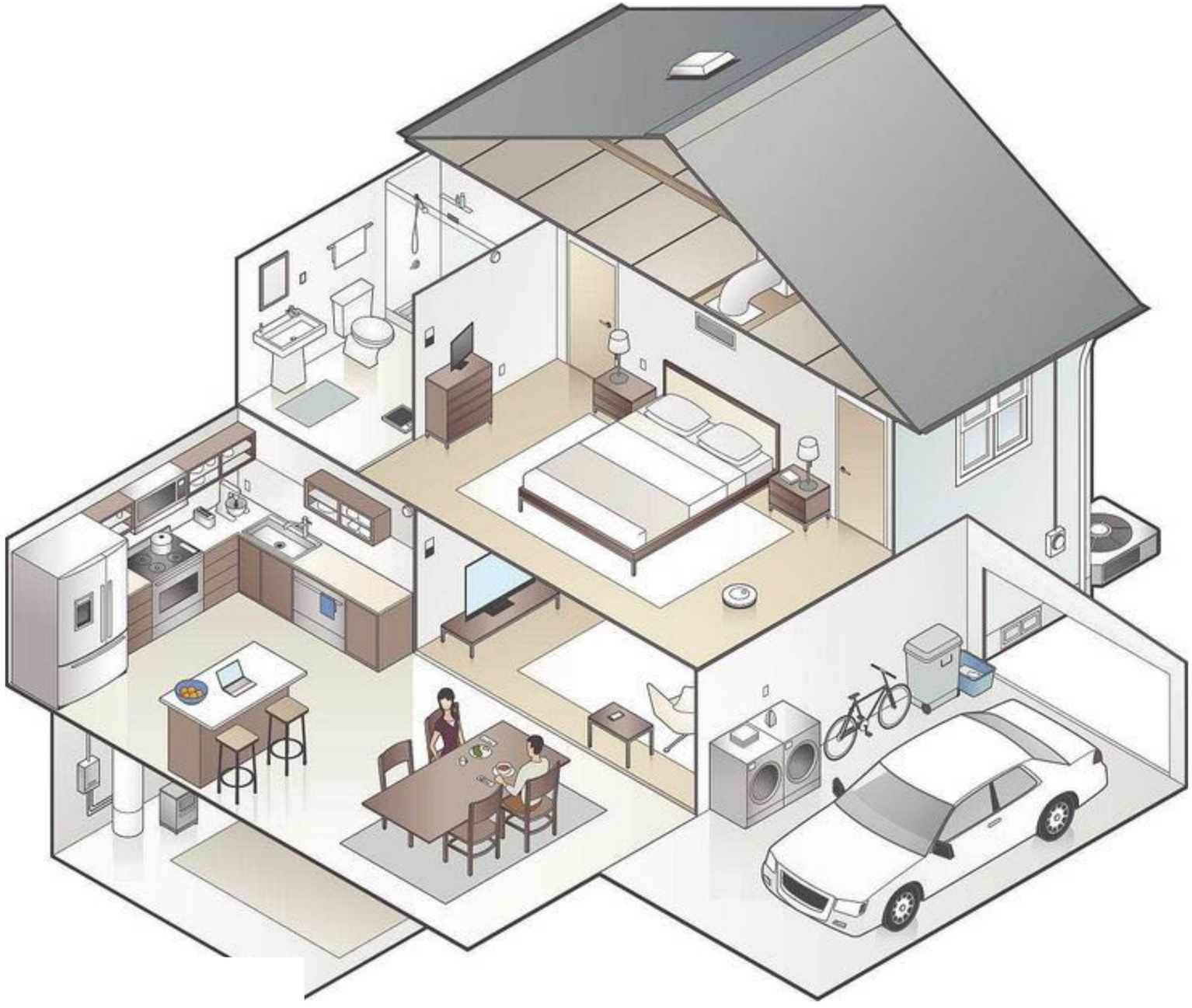
Falar é **fácil**
Vamos ver **na prática**

ATENÇÃO

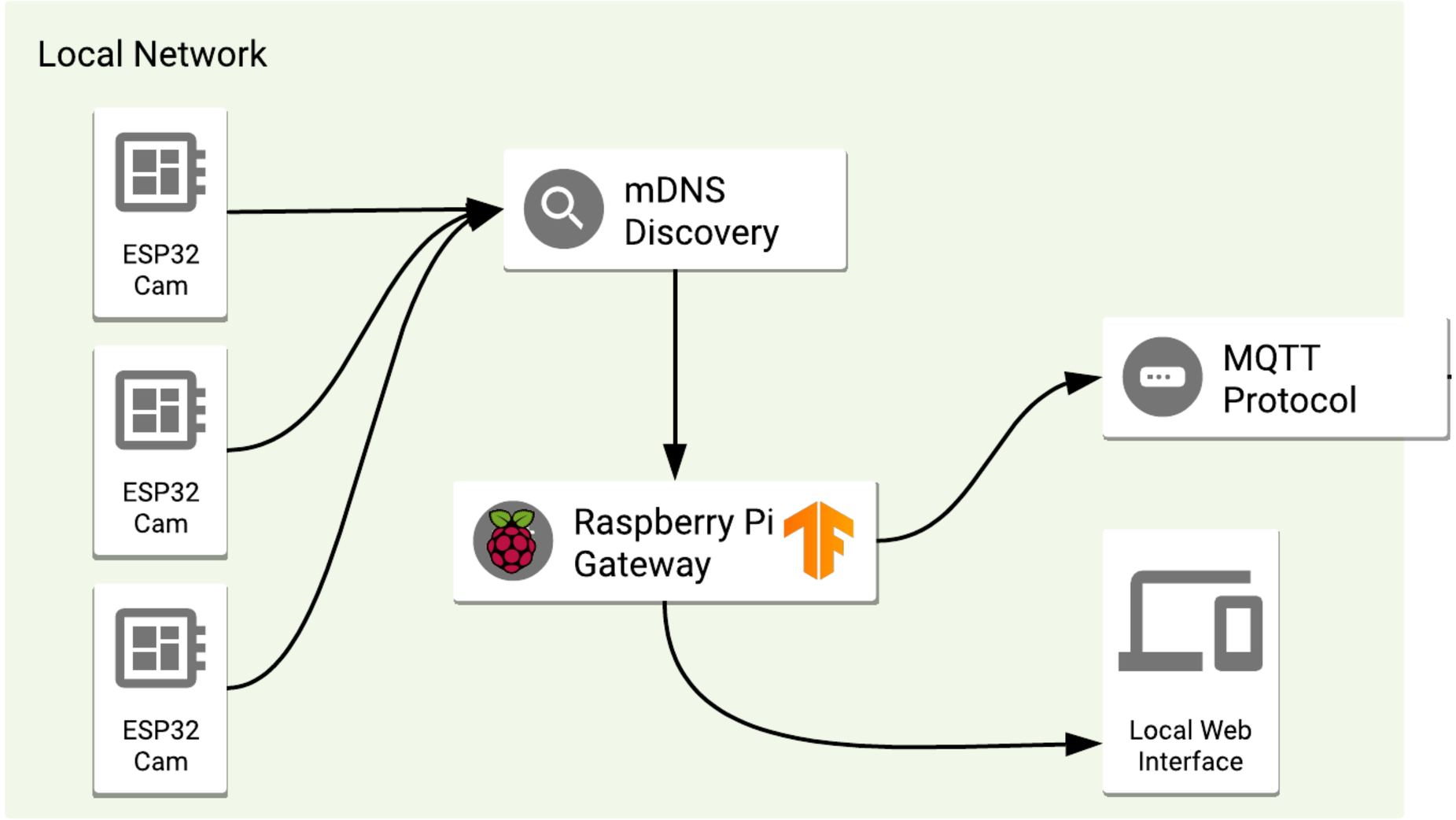
EU NÃO SOU NENHUM EXPERT EM MACHINE LEARNING

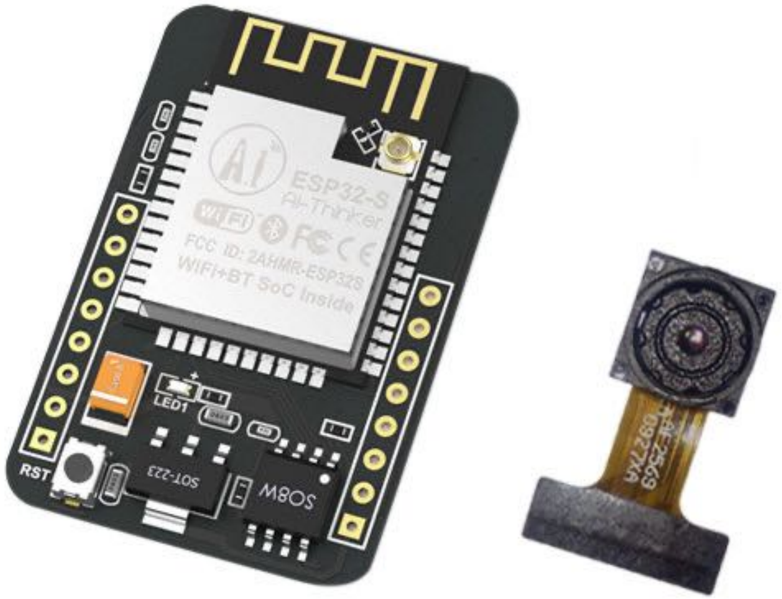
Mas talvez essa seja a **MELHOR** parte desses projetos

Monitoramento **indoor** usando **cameras** como **sensores**

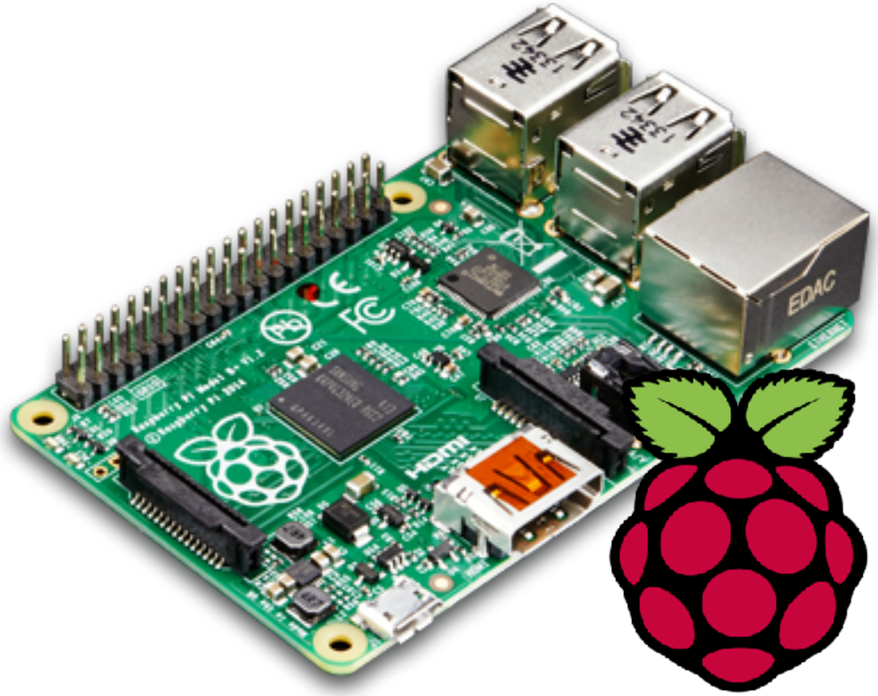


Arquitetura de Rede Local





ESP32 Cam

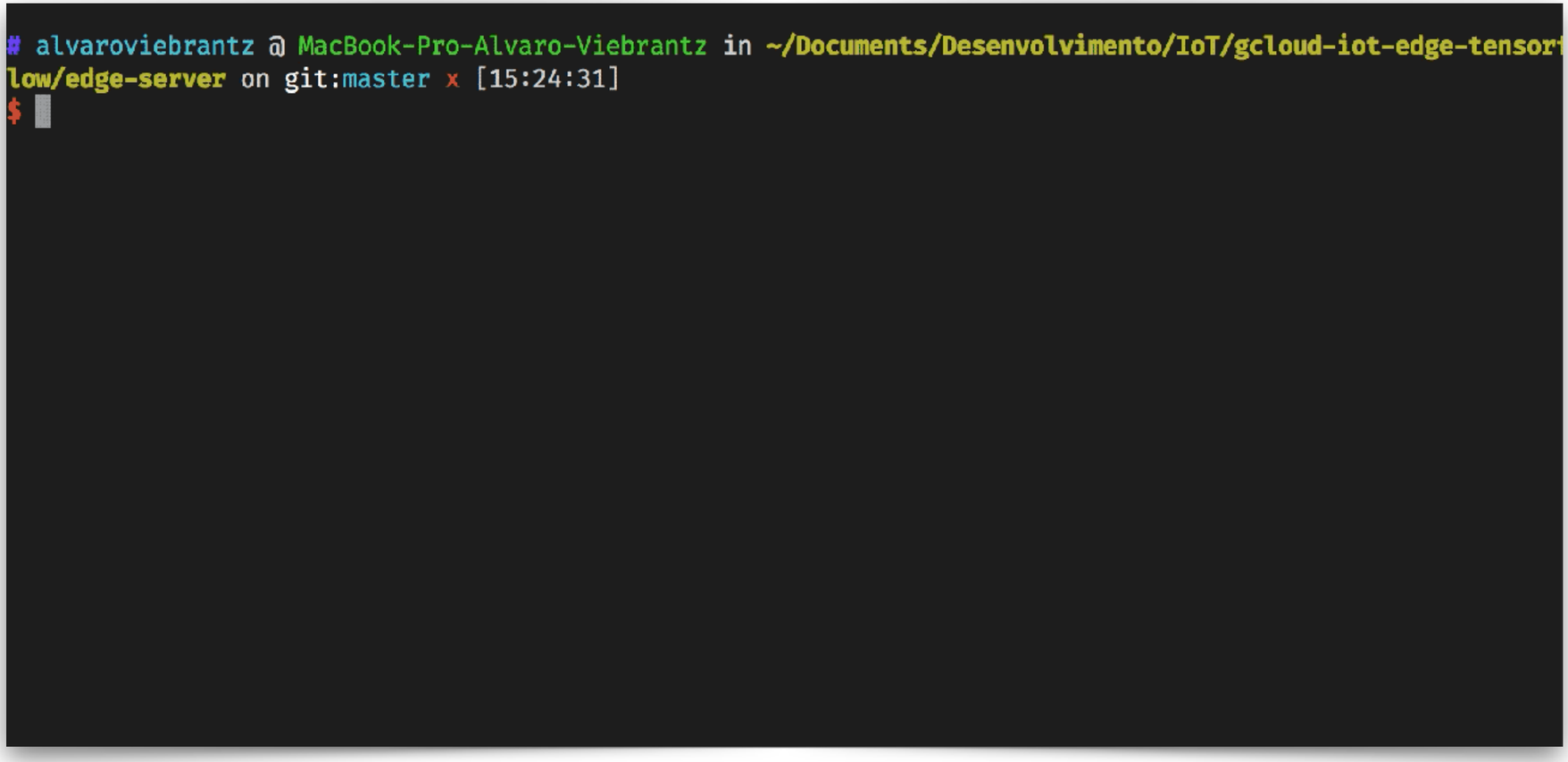


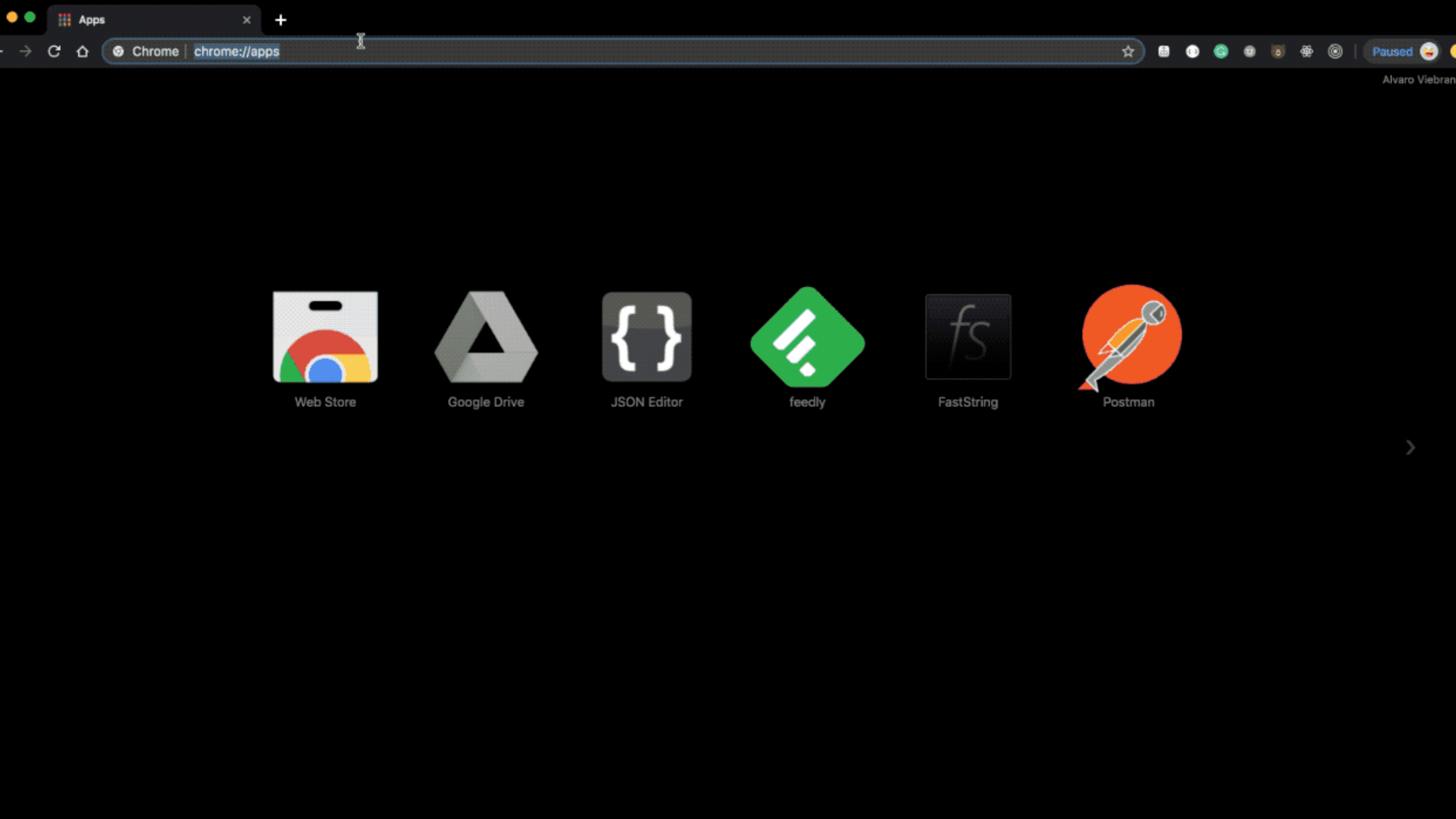
Raspberry Pi 3

Encontrando cameras locais

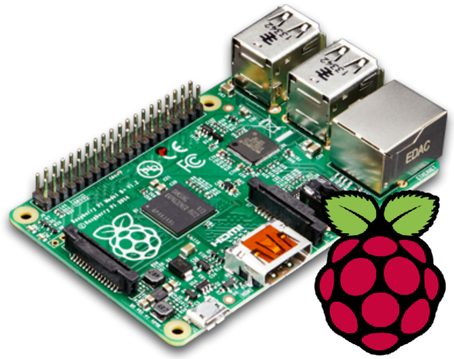
Podemos testar localmente using a ferramenta dns-sd

- http://indoor-camera-ec5d.local/jpg
- http://indoor-camera-60d8.local/jpg




Apps
Chrome
chrome://apps
Paused
Alvaro Viebran
Web Store
Google Drive
JSON Editor
feedly
FastString
Postman

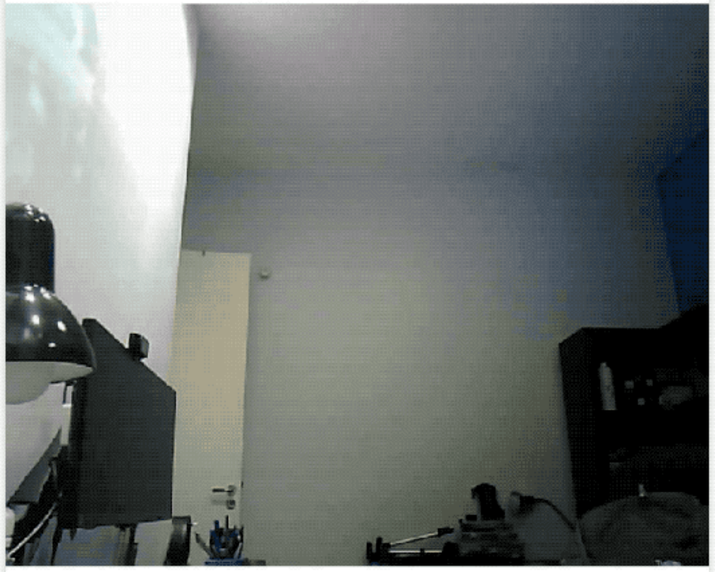
Baixar imagens, **classificar** e **enviar** classes para a **Nuvem**



IoT Edge - Local Monitor

indoor-camera-b021

5/25/2019, 6:03:51 PM



Nothing found.

indoor-camera-ec5d

6/1/2019, 12:03:58 PM

cat(1)

indoor-camera-8455

6/1/2019, 12:11:37 PM

person(1) cat(1)

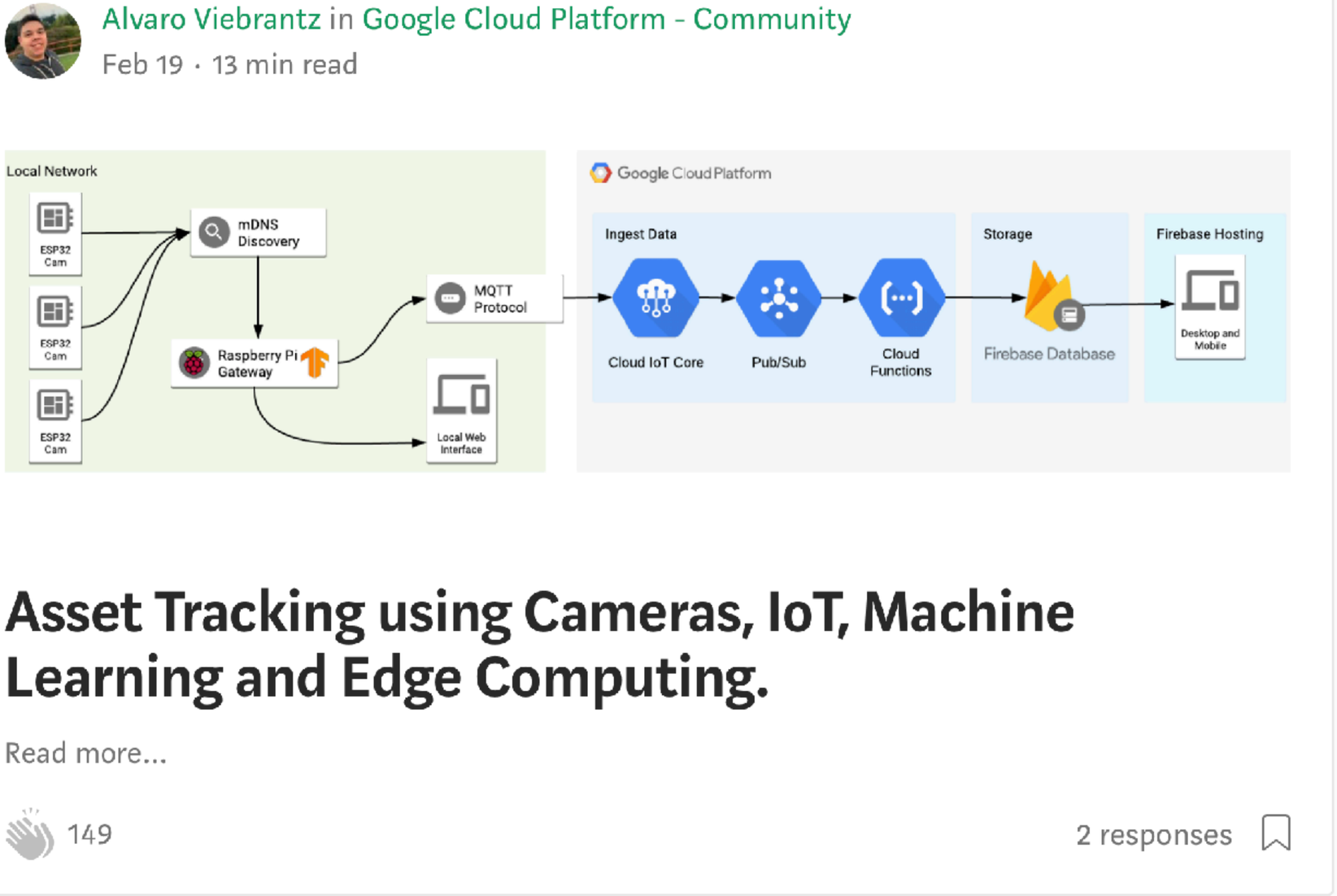
Performance

Dica - Use tfjs-node ou tfjs-node-gpu se possível

	Meu Computador	Raspberry Pi 3
TensorFlow.js Core	8 seconds per frame	45 seconds per frame
TensorFlow.js Node	200 milliseconds per frame	1 second per frame

Artigo descrevendo tudo que mostrei até agora

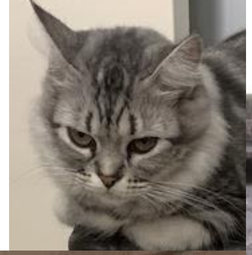
bit.ly/gcloud-iot-edge



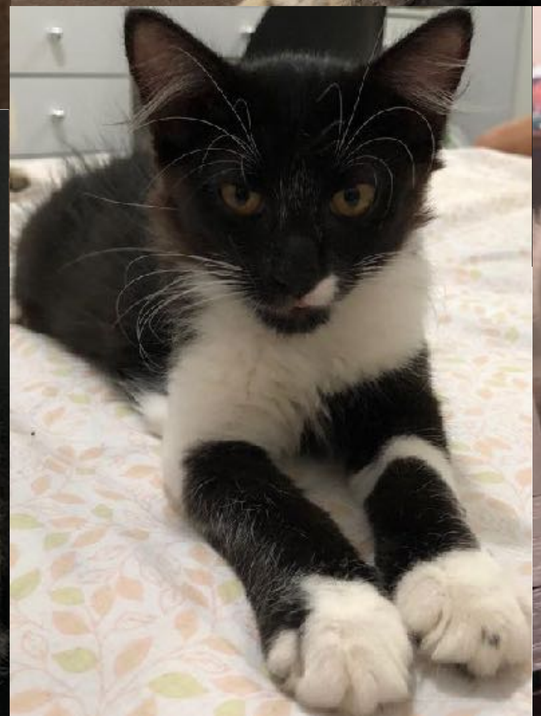
Eu amo gatos

E se eu pudesse rastrear meus gatos em casa ?







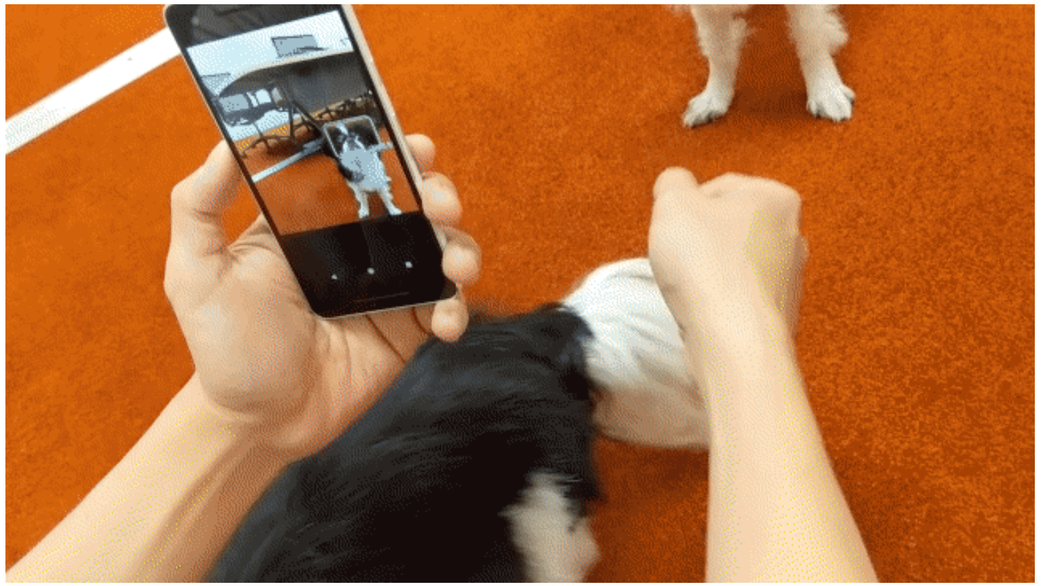
Treinando um modelo customizado

Primeira tentativa

Training and serving a realtime mobile object detector in 30 minutes with Cloud TPUs

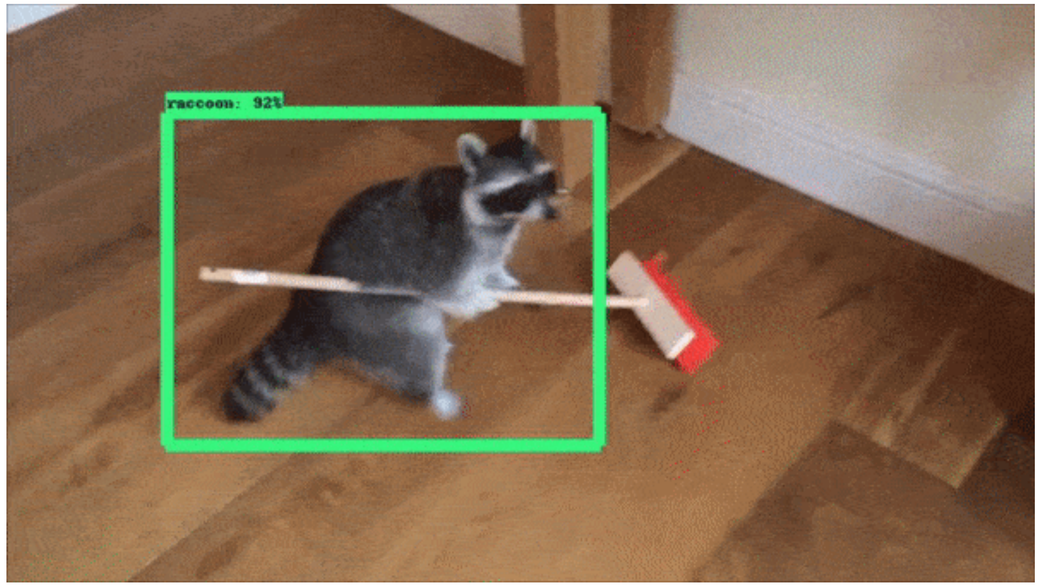
TensorFlow Follow
Jul 13, 2018 · 14 min read

By Sara Robinson, Aakanksha Chowdhery, and Jonathan Huang



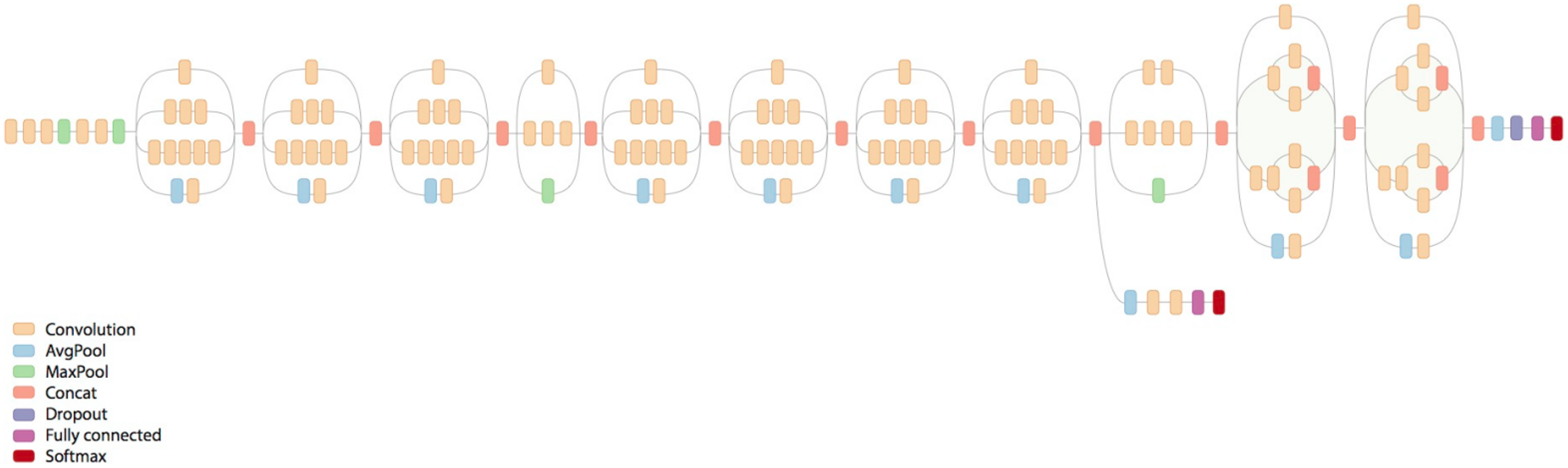
How to train your own Object Detector with TensorFlow's Object Detector API

Dat Tran Follow
Jul 28, 2017 · 8 min read



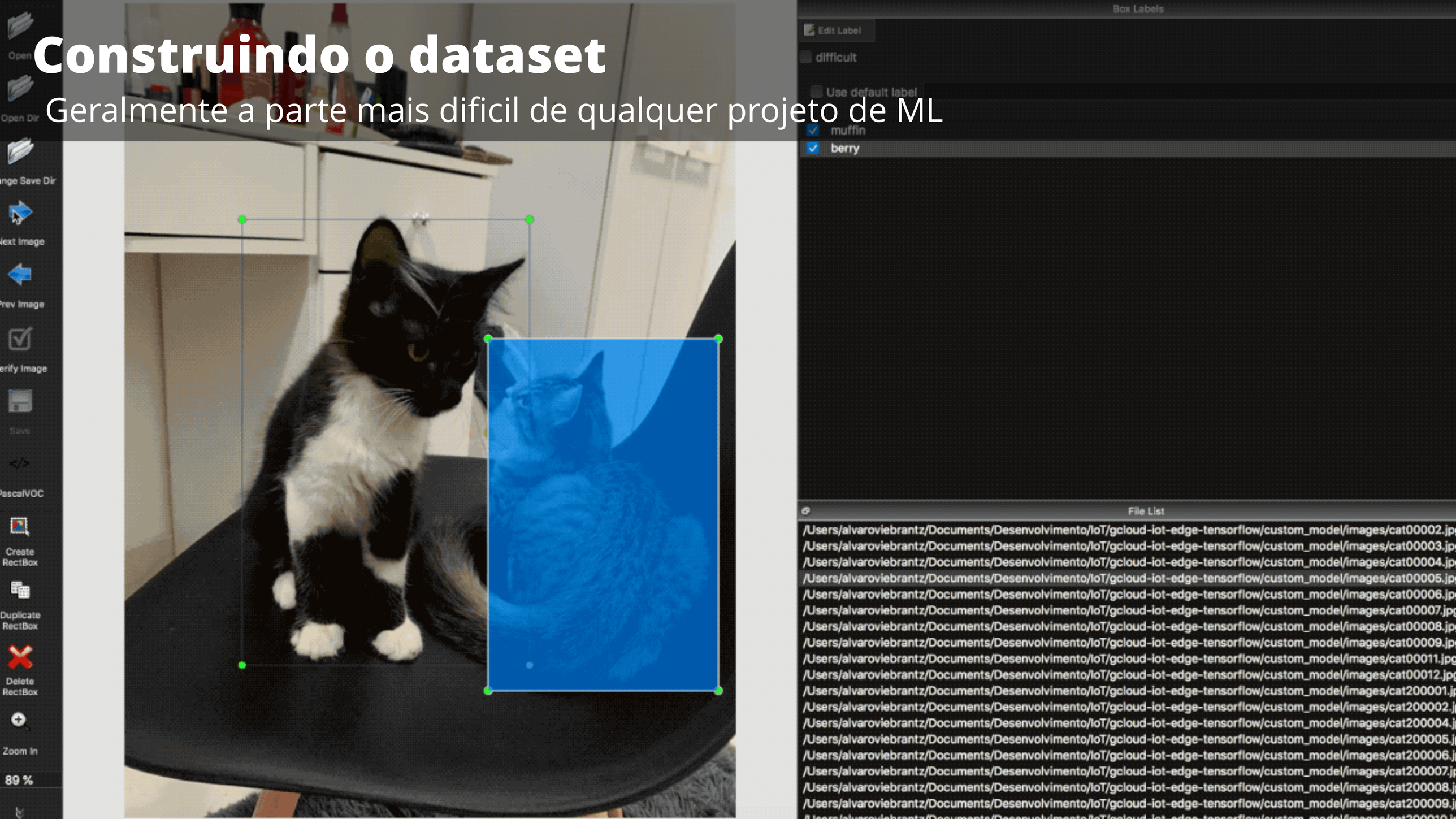
Transfer Learning

Usando modelos pré treinados para treinar novos modelos com datasets menores



Construindo o dataset

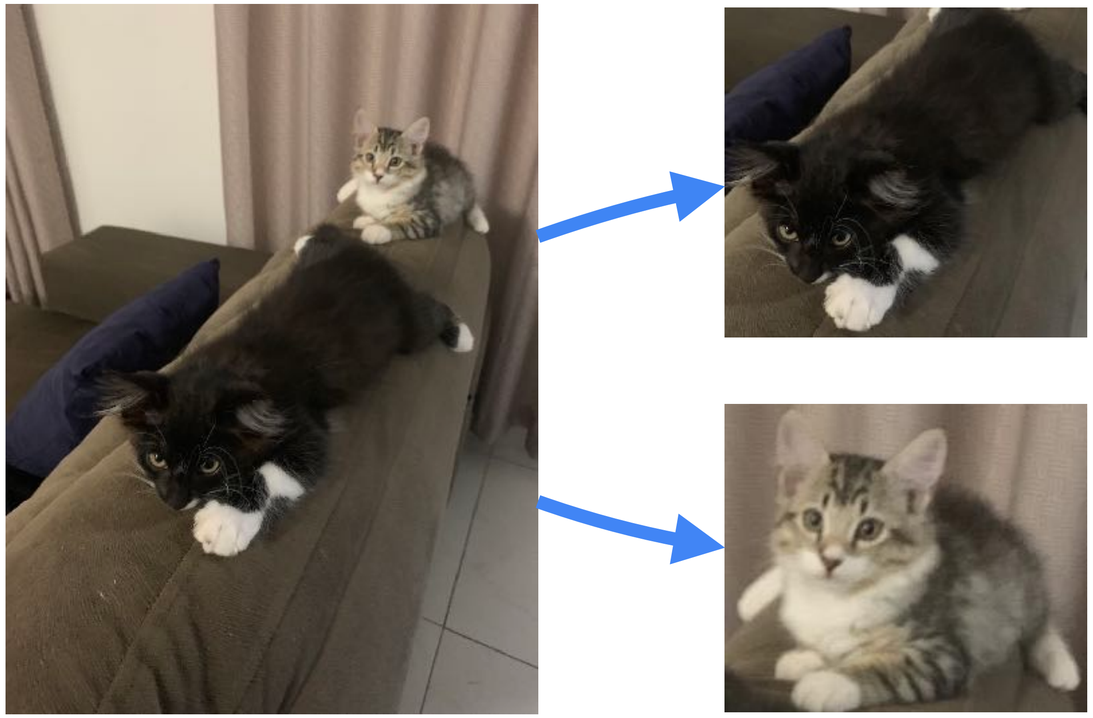
Geralmente a parte mais dificil de qualquer projeto de ML



BAIXA **ACURÁCIA** NO MEU MODELO

Treinar modelo de classificação

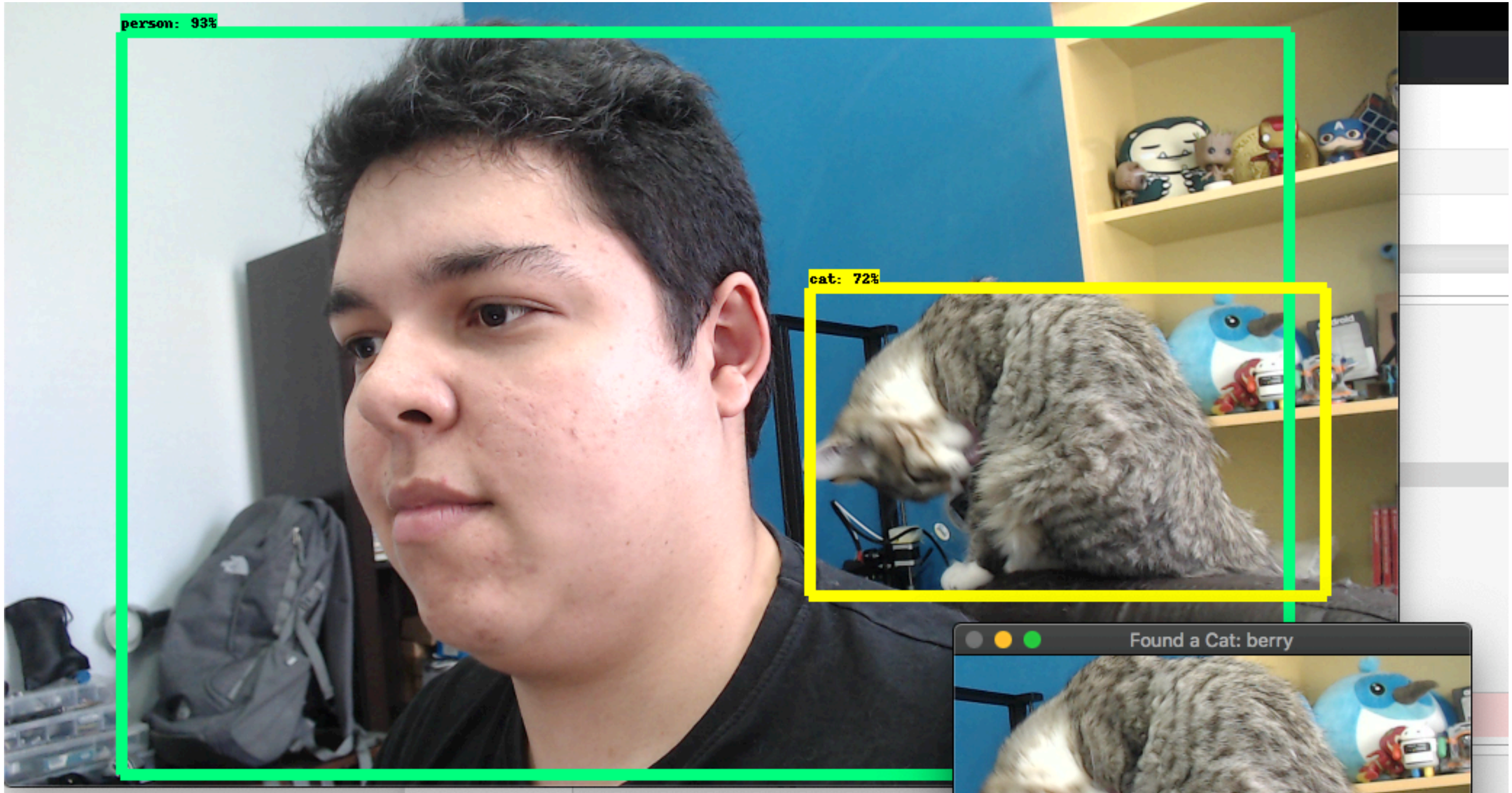
Usando o mesmo dataset




berry
jam
muffin
popcorn
raspberry

Melhor dos dois mundos

Usar um modelo pré treinado para detecção de objetos primeiro e depois o modelo customizado




```
def prepare_image(file):
    img_path = ''
    img = image.load_img(img_pa
    img_array = image.img_to_a
    img_array_expanded_dims =
    return keras.applications.
```

```
WARNING:tensorflow:From /usr/local/lib/python3.7/site-packages/tensorflow/py
ocate_with (from tensorflow.python.framework.ops) is deprecated and will be
```

IoT Edge - Local Monitor

indoor-camera-8455

6/1/2019, 12:14:29 PM

Nothing found.

Found a **cat**

✓ Found **Jam**

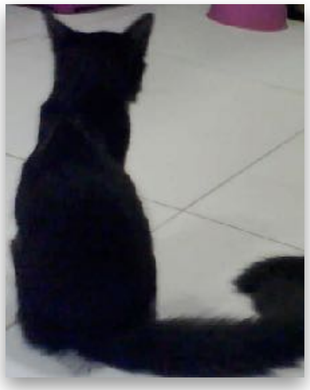
IoT Edge - Local Monitor

Found a **cat**

✅ Found **Berry**

IoT Edge - Local Monitor

✗ Found **Jam**



✓ Found **Muffin**

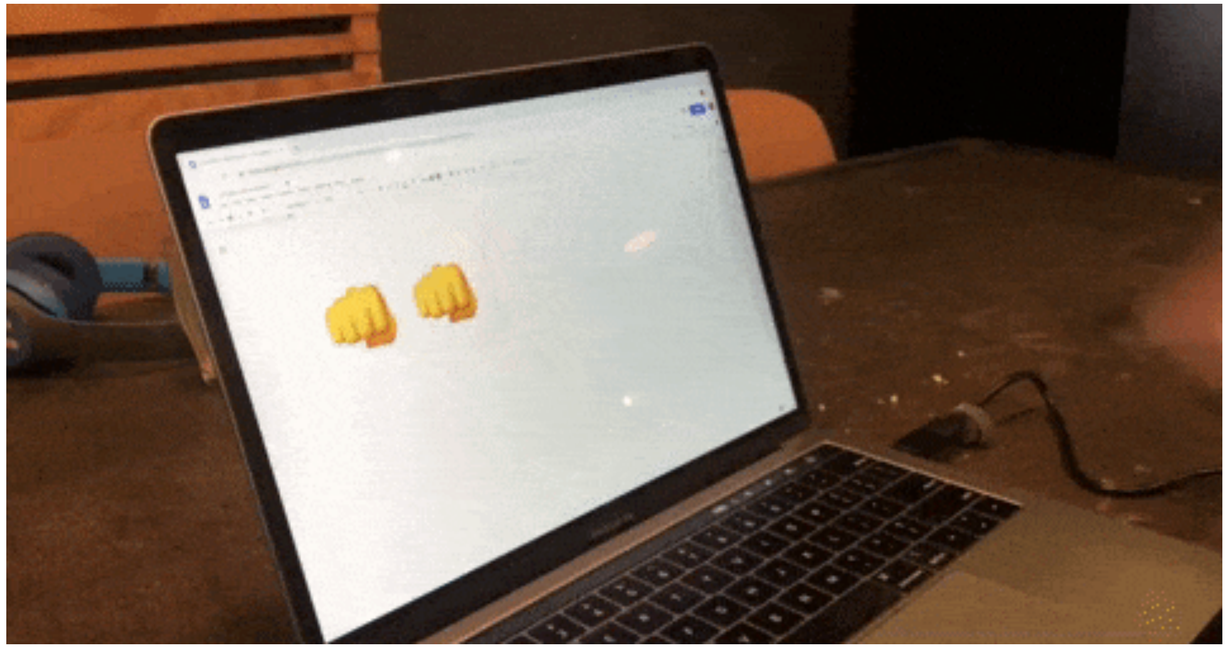
Found two **cats**

✓ Found **Berry**

Raquete de **Tênis Inteligente** 🎾

Inspirações

Outros projetos de TinyML com Tensorflow



medium.com/@devdevcharlie/play-street-fighter-with-body-movements-using-arduino-and-tensorflow-js-6b0e4734e118

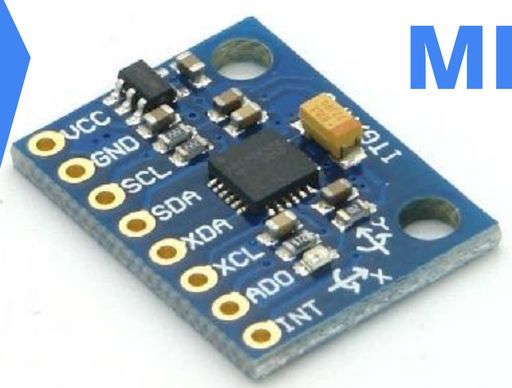
blog.arduino.cc/2019/10/15/get-started-with-machine-learning-on-arduino/

Raquete Inteligente

Classificar os diferentes movimentos do tênis - Backhand, forehand e serve

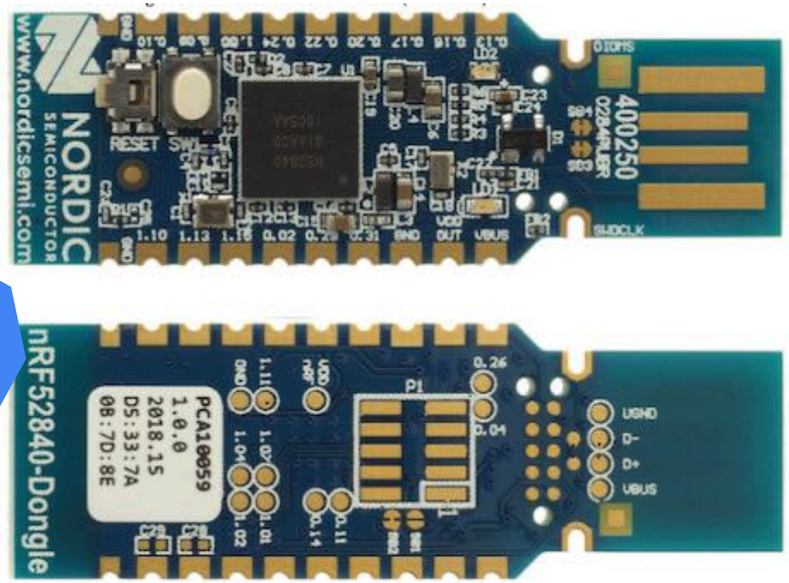
- Capturar dados de movimento
  - Acelerômetro e Giroscopio
  - Captura via Bluetooth
  - Janelas de 1 segundo de captura
    - 60*6 pontos por segundo (16ms de intervalo) = 360 de entrada
- Treinar modelo para classificar os movimentos
  - Analise espectral dos dados de movimento
  - Classificador com Redes Neurais
- Exportar modelo TFLite pra ser usado com TF Lite Micro

7$

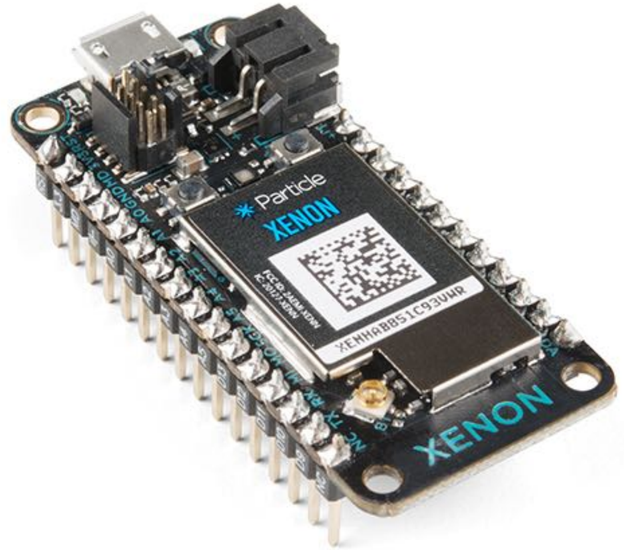


MPU6050

10$



nrf52840 Dongle



20$

Particle Xenon


ITG-MPU
nRF-52
INT
ADO
XDA
XCL
SDA
SCL
GND
VCC
USB
D+
D-
USB0


NORDIC
SEMICONDUCTOR
www.nordicsemi.com
RESET
SWDIO
SWDCLK
400250
032R/RBR


HEAD

Capturas dos dados

Captura via Web Bluetooth e envia para a platforma Edge Impulse

TinyML Tennis Capture

Connected

Clear

Dataset Label forehand

Edge Impulse API Key [redacted]

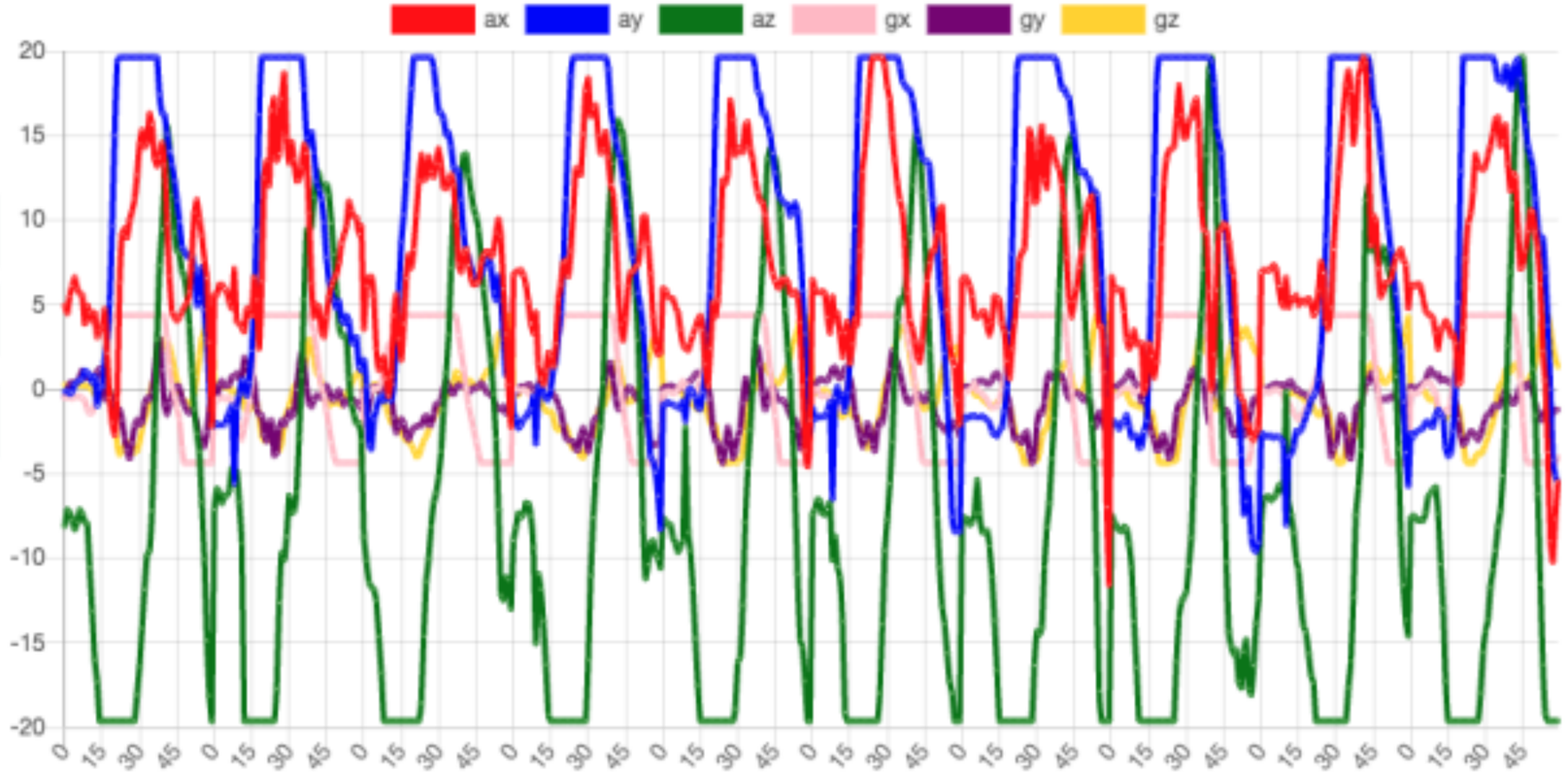
Edge Impulse HMAC Key [redacted]

Export

Send to Edge Impulse

Points : 600

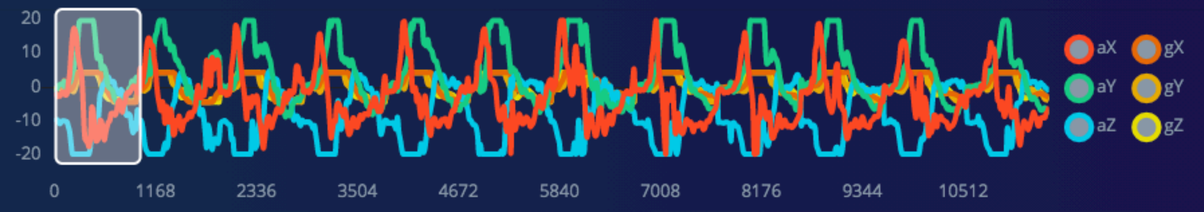
Datasets : 10



EDGE IMPULSE

Raw data

backhand.1kr8p25o (backhand)



Raw features

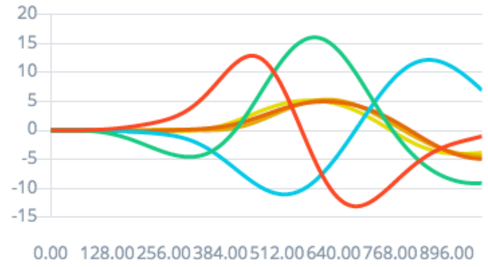
Parameters

Scaling

Scale axes 1

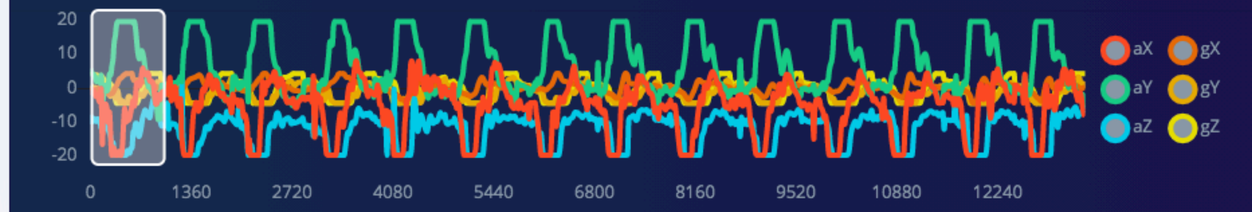
DSP result

After filter



Raw data

forehand.1kr8ue5o (forehand)



Raw features

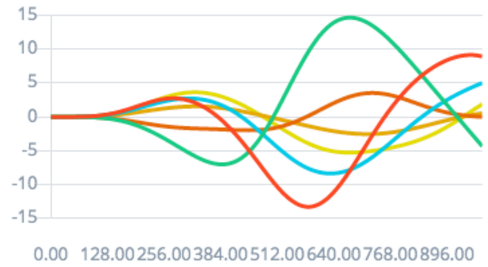
Parameters

Scaling

Scale axes 1

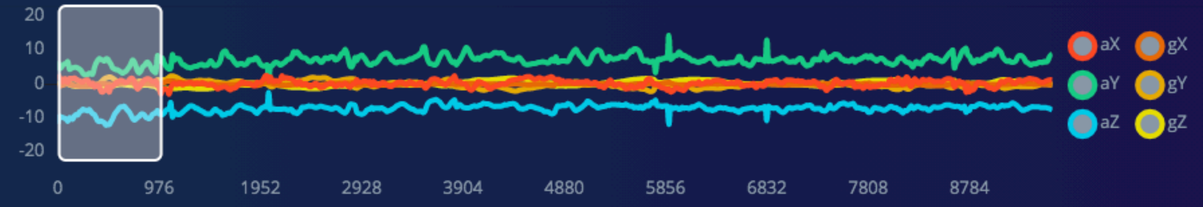
DSP result

After filter



Raw data

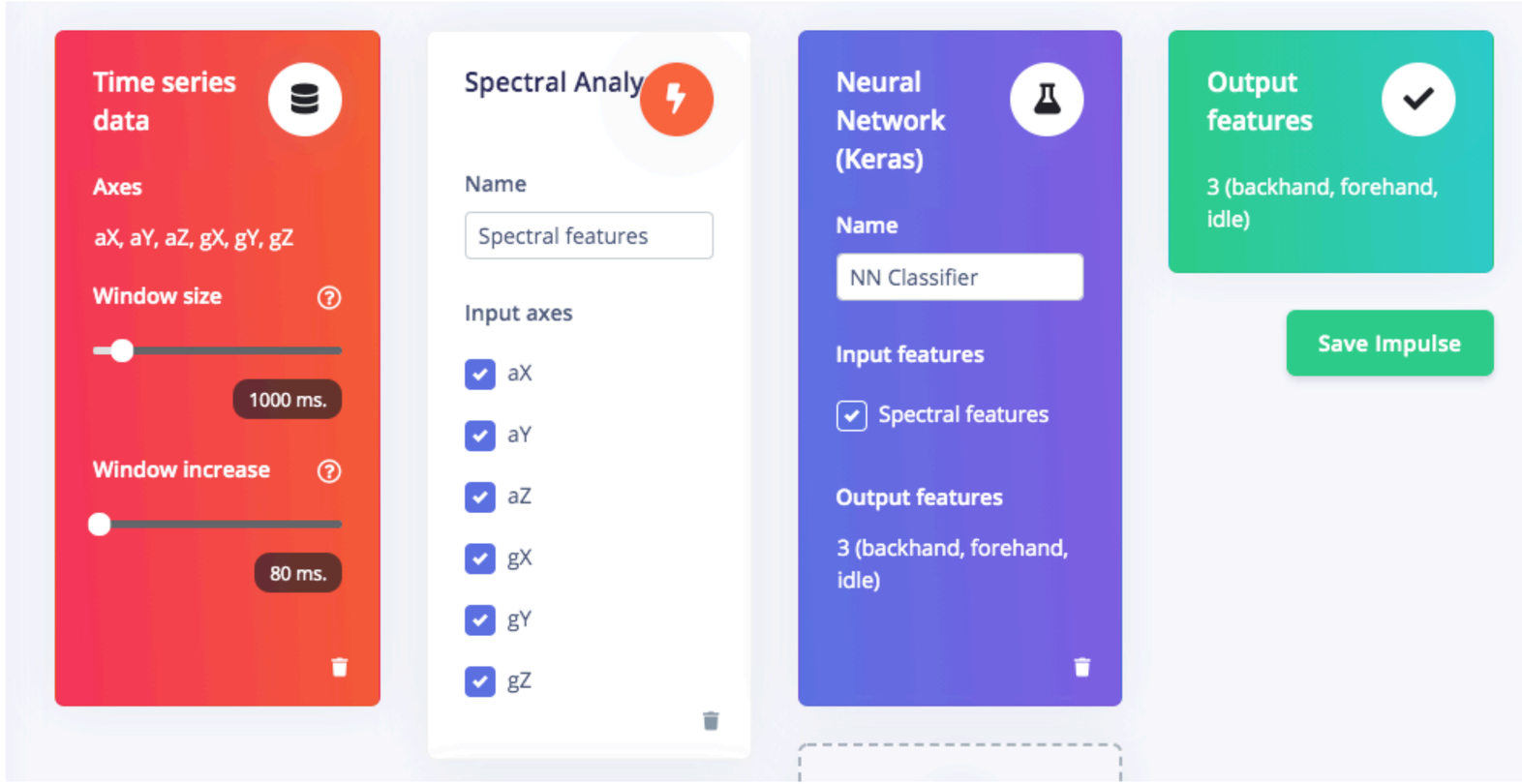
idle.1kr8r01m (idle)



Exportando o modelo

SDK da Edge Impulse usa Tensorflow Micro + DSP

- Analise espectral usa DSP
- Classificador usa TensorFlow Micro
- Estatísticas final do Modelo
  - 4kb de RAM e 28k de Flash 😍




HEAD
poly


Backhand
Led green

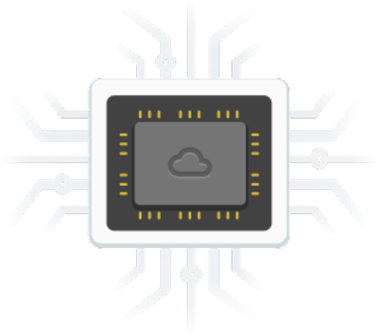
Próximos passos

Melhorar o modelo e compartilhar os dados

- Capturar mais dados
  - Serve/Saques
  - Diferentes pessoas, alturas, estilos de jogo
  - Capturar dados em jogo/treino
- Disponibilizar o dataset
- Treinar modelo apenas com TensorFlow
  - O quanto o processamento DSP faz diferença ? (provavelmente muita)
  - Usar com ESP32 - Mais acessível no Brasil

Links e Referências

- Projetos
  - github.com/alvarowolfx/gcloud-iot-edge-tensorflow
  - github.com/alvarowolfx/tinyml-smart-tennis-sensor
- Links
  - edgeimpulse.com
  - www.tensorflow.org/lite/microcontrollers
  - blog.arduino.cc/2019/10/15/get-started-with-machine-learning-on-arduino/
  - medium.com/@devdevcharlie/play-street-fighter-with-body-movements-using-arduino-and-tensorflow-js-6b0e4734e118



OBRIGADO!

AVIEBRANTZ.COM

Alvaro Viebrantz

Google Developer Expert for IoT and Product Engineer at Leverege

aviebrantz.com

@alvaroviebrantz