

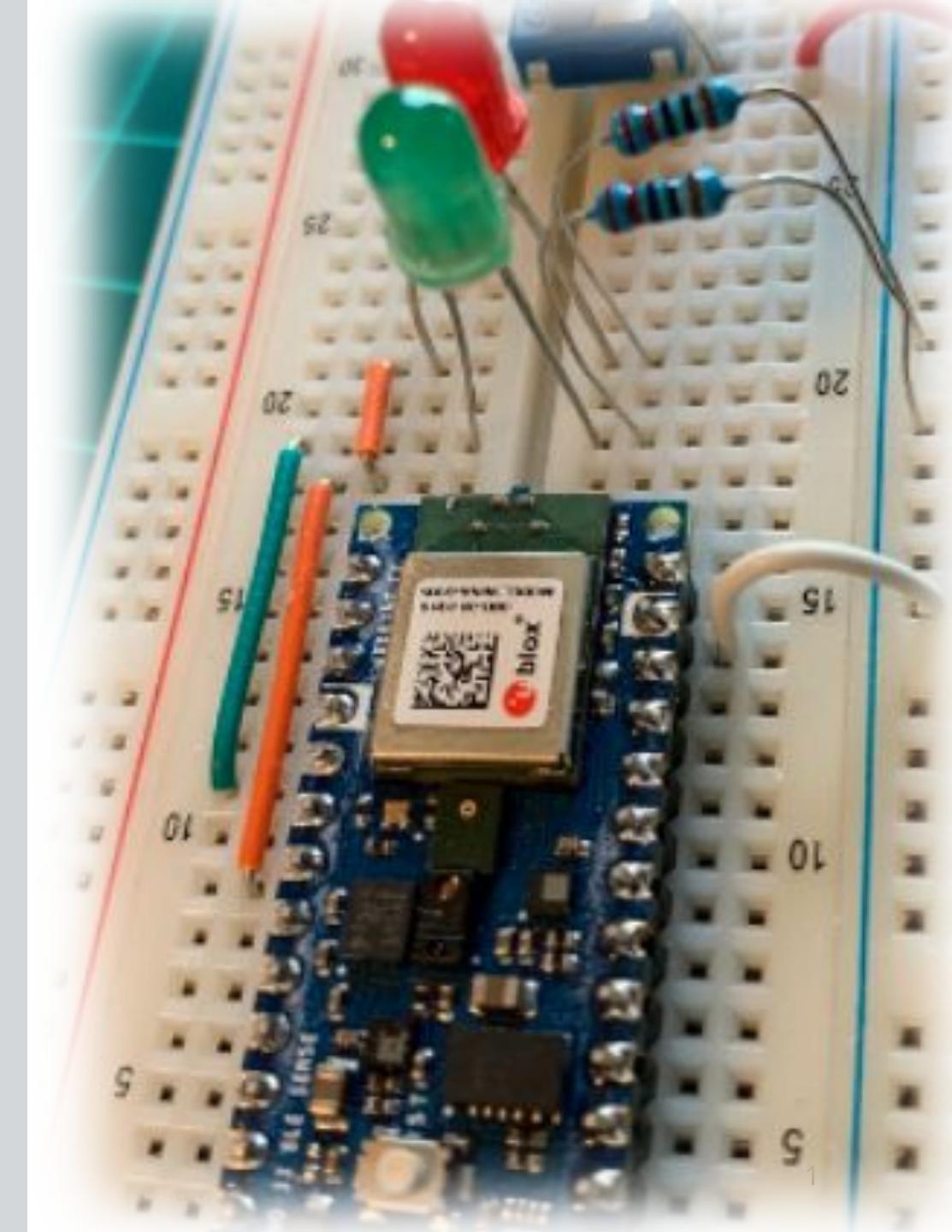
# IESTI01 – TinyML

## Embedded Machine Learning

### 28. Responsible AI & Curse Wrap-up



Prof. Marcelo Rovai  
UNIFEI



# Responsible AI

Suzan Kennedy, Ph.D.



[SciTinyML Seminar - Slides](#)



[SciTinyML Seminar - Video](#)



**SciTinyML**

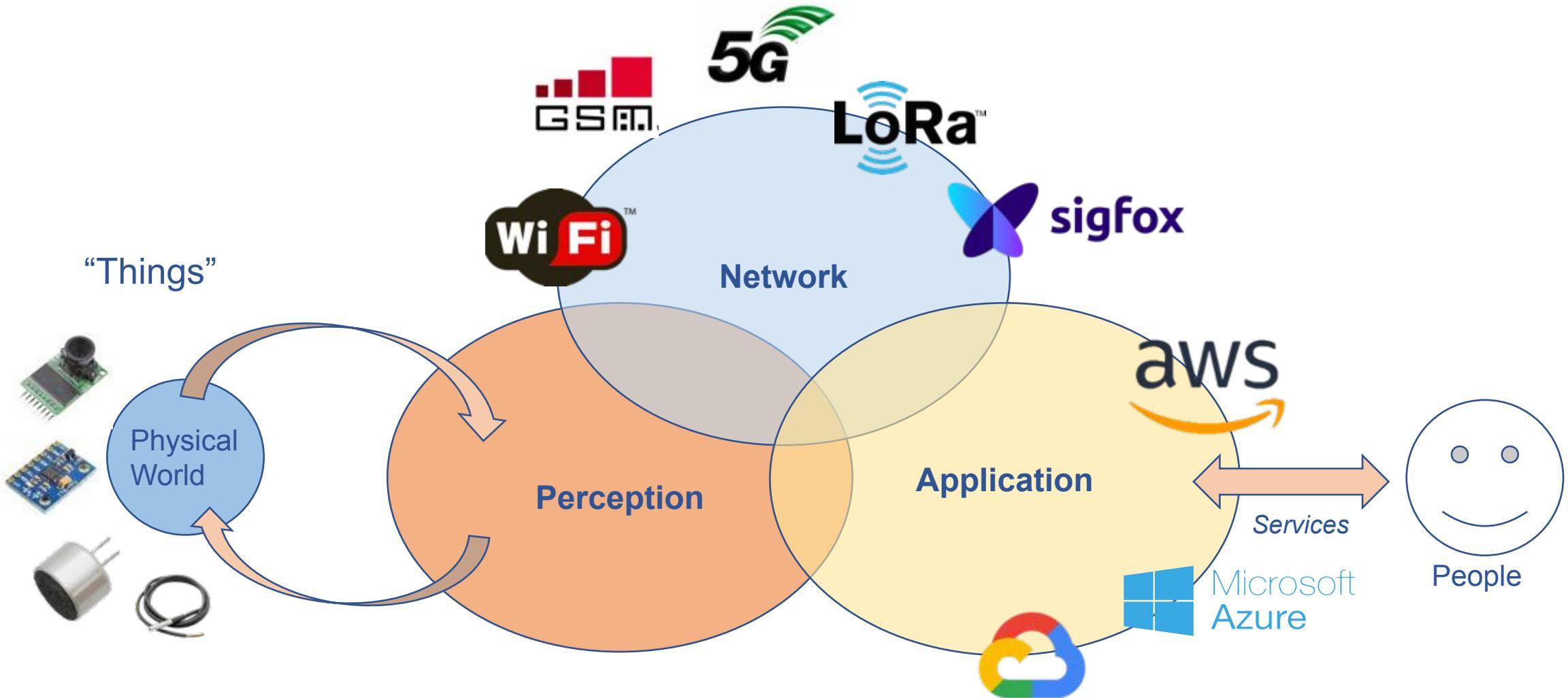
Scientific Use of Machine  
Learning on Low-Power Devices  
*October 18-22 2021*



# Embedded ML

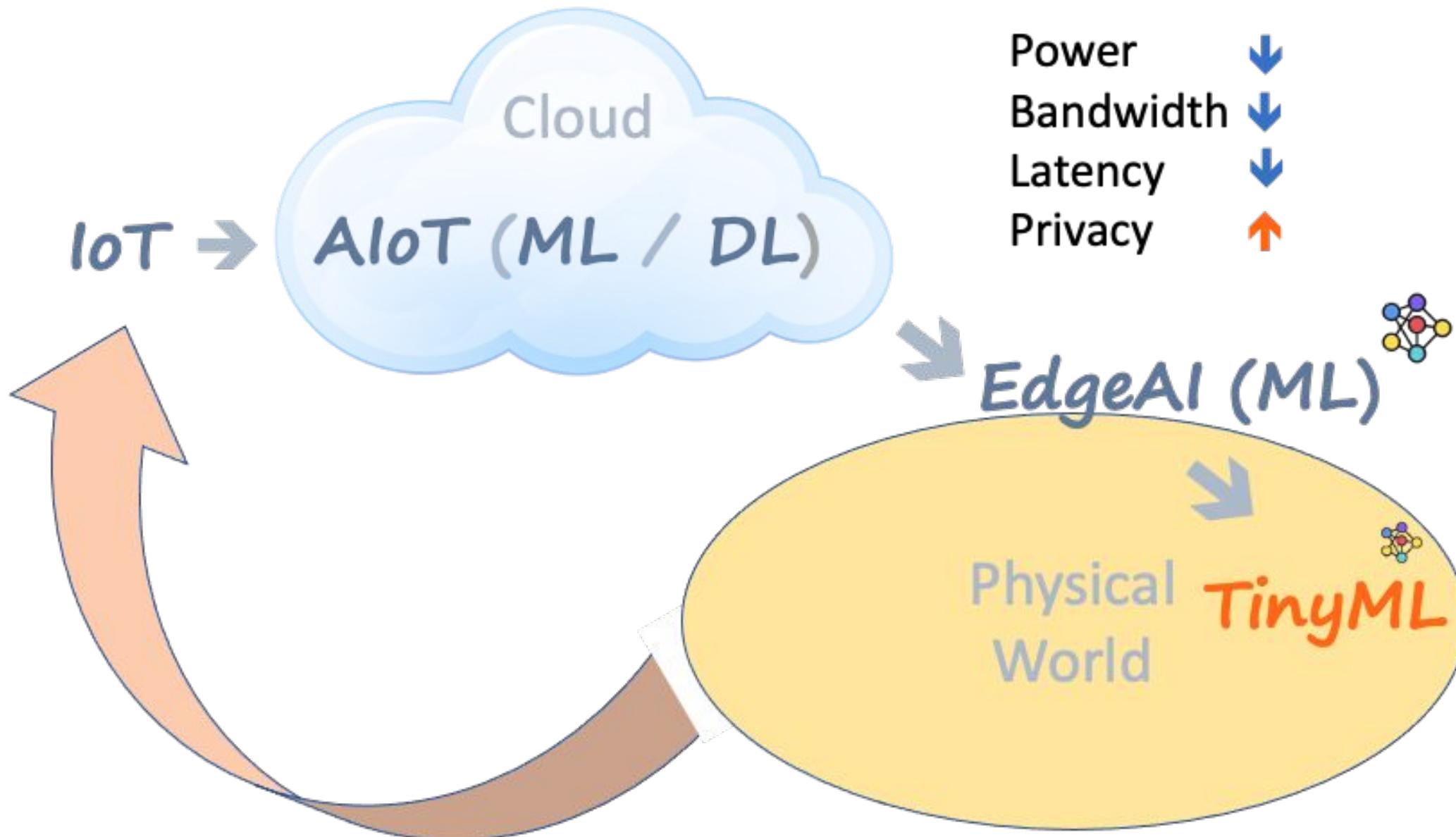
## Curse Wrap-up

# Classical IoT Architecture

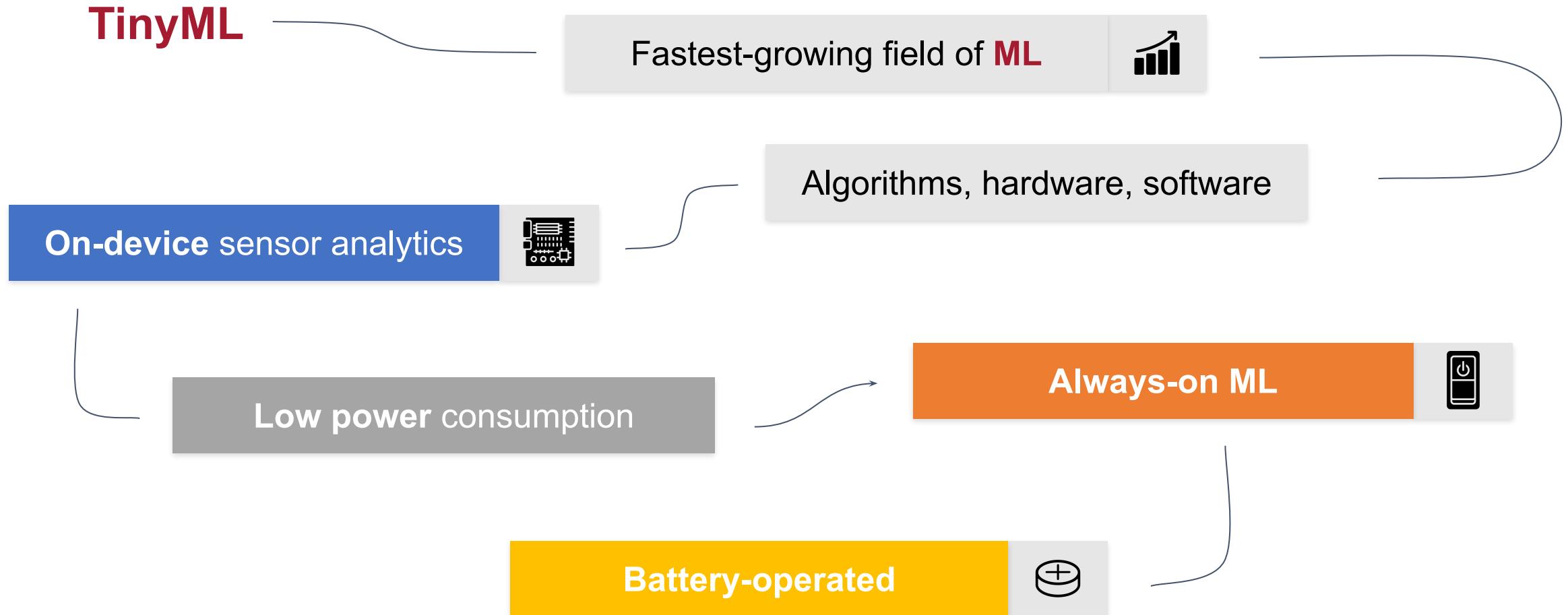


5 Quintillion bytes of data produced every day by IoT, but less than 1% is used. HBR/CISCO

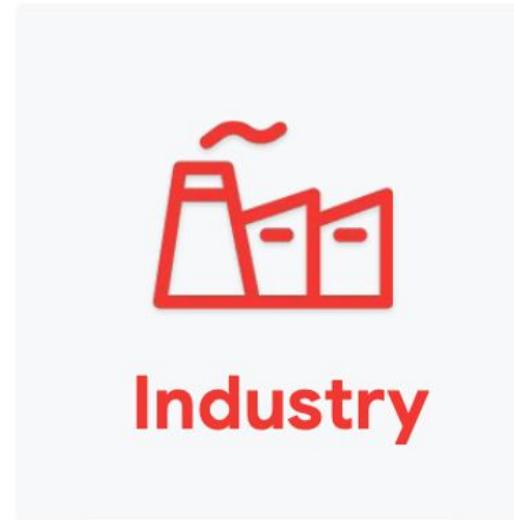
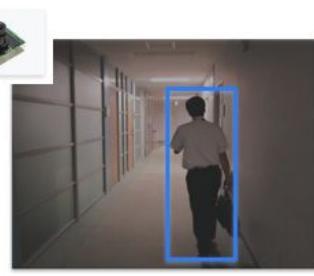
# New Context



# What is Tiny Machine Learning (**TinyML**)?



# TinyML Application Areas



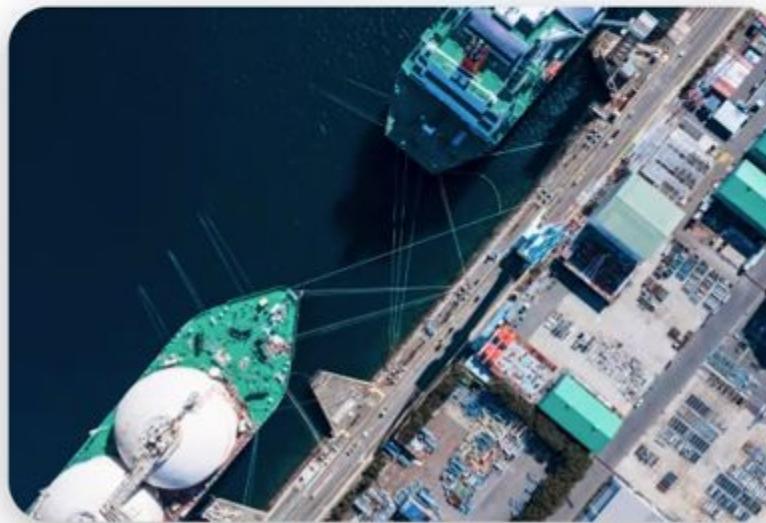
## Predictive Maintenance



Motion, current, audio and camera

- Industrial
- White goods
- Infrastructure
- Automotive

## Asset Tracking & Monitoring



Motion, temp, humidity, position, audio and camera

- Logistics
- Infrastructure
- Buildings

## Human & Animal Sensing



Motion, radar, audio, PPG, ECG

- Health
- Consumer
- Industrial

# Human and Animal Sensing examples



[Atrial Fibrillation Detection on ECG using TinyML](#)  
[Silva et al. UNIFEI 2021](#)

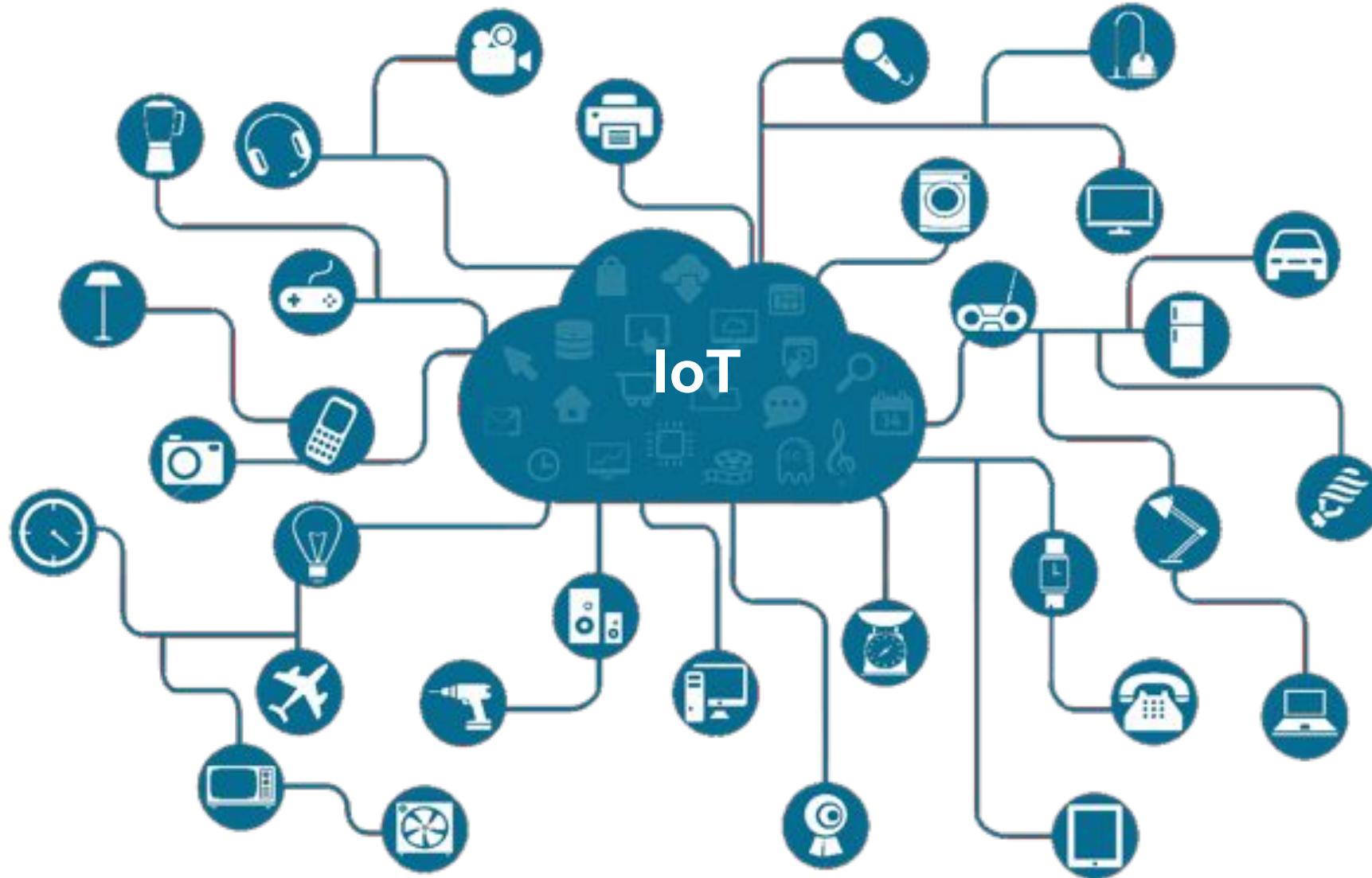
## ElephantEdge

Building The World's Most Advanced [Wildlife Tracker](#).

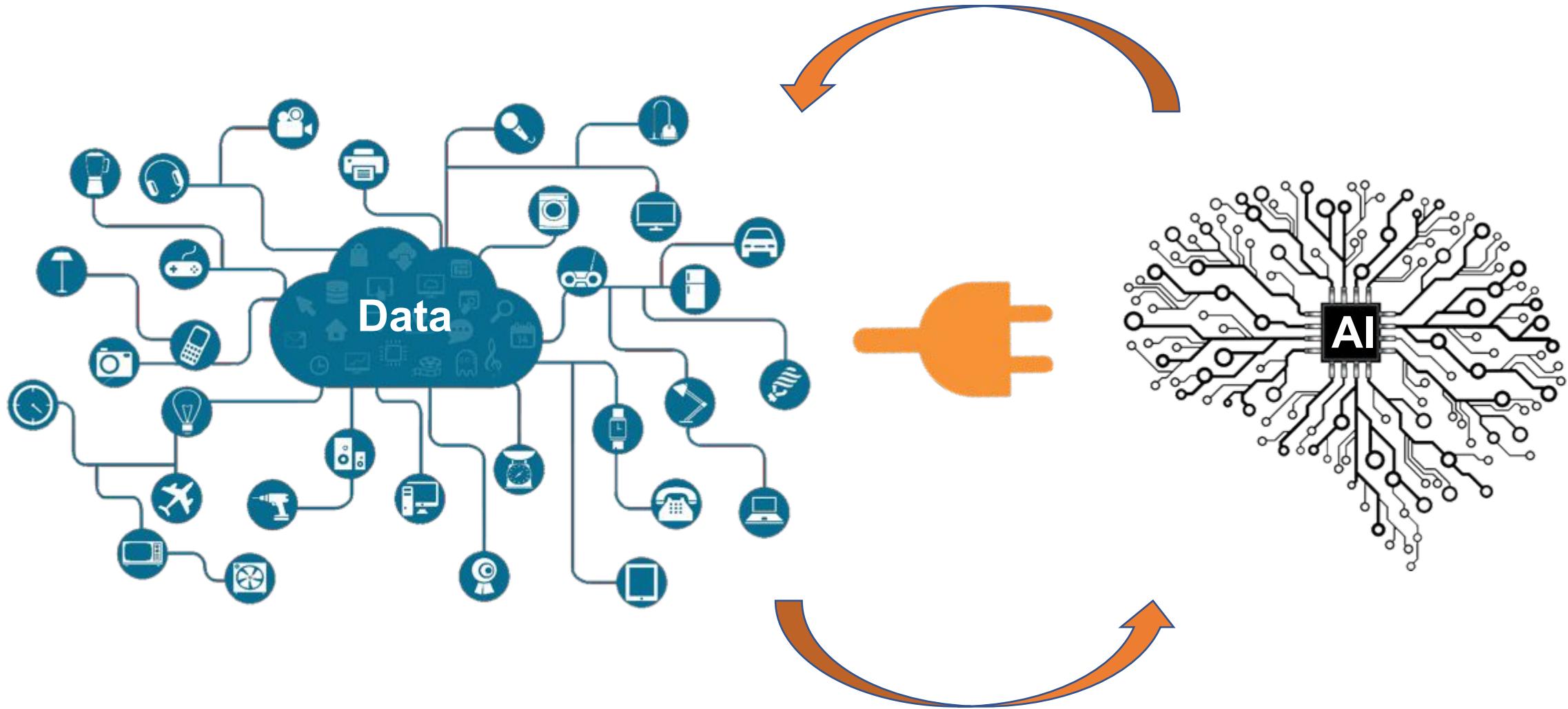


[ElephantEdge: A New Neural Wildlife Tracker,](#)  
[Powered by Edge Impulse](#)

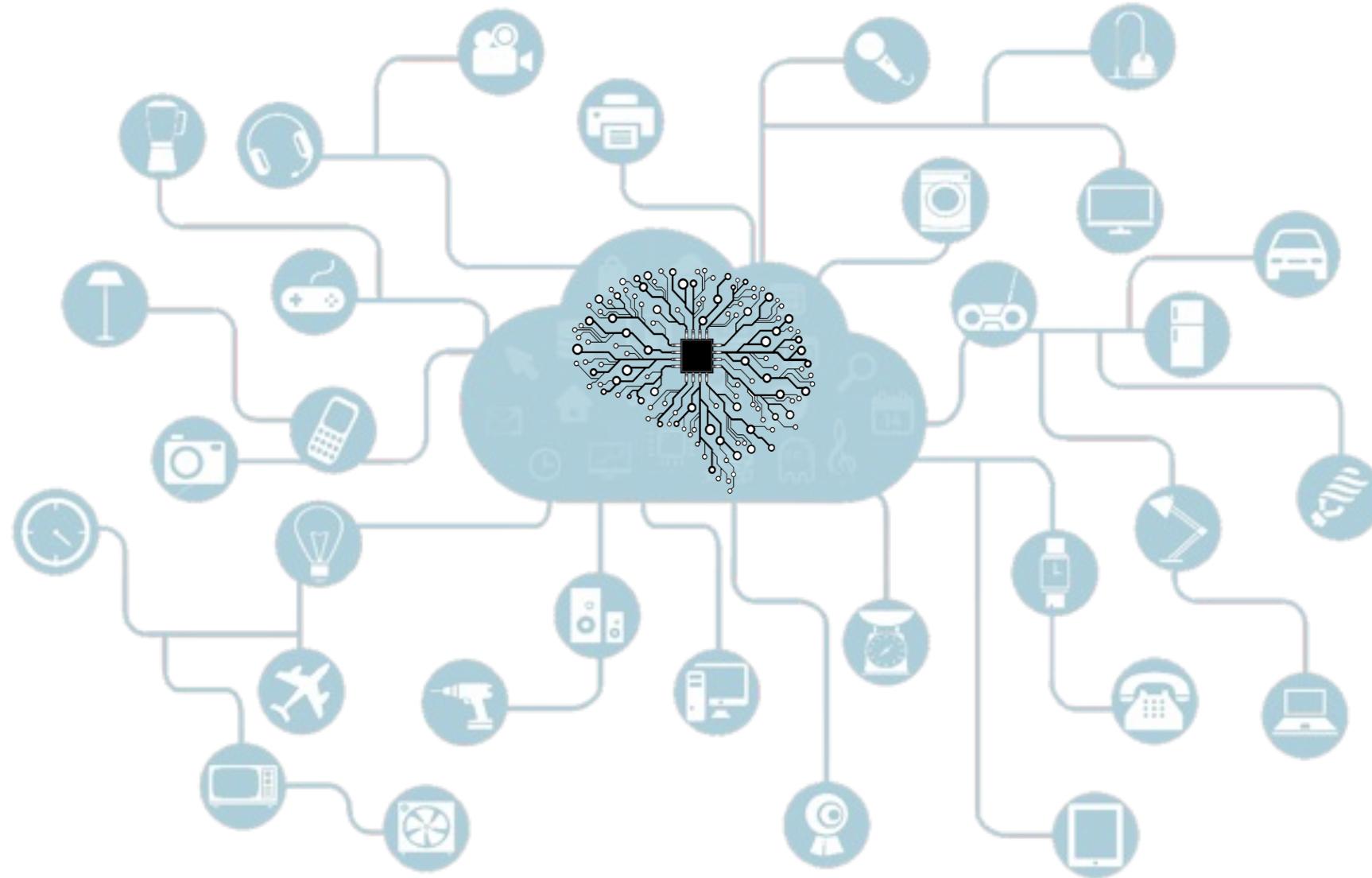
# IoT - Architecture



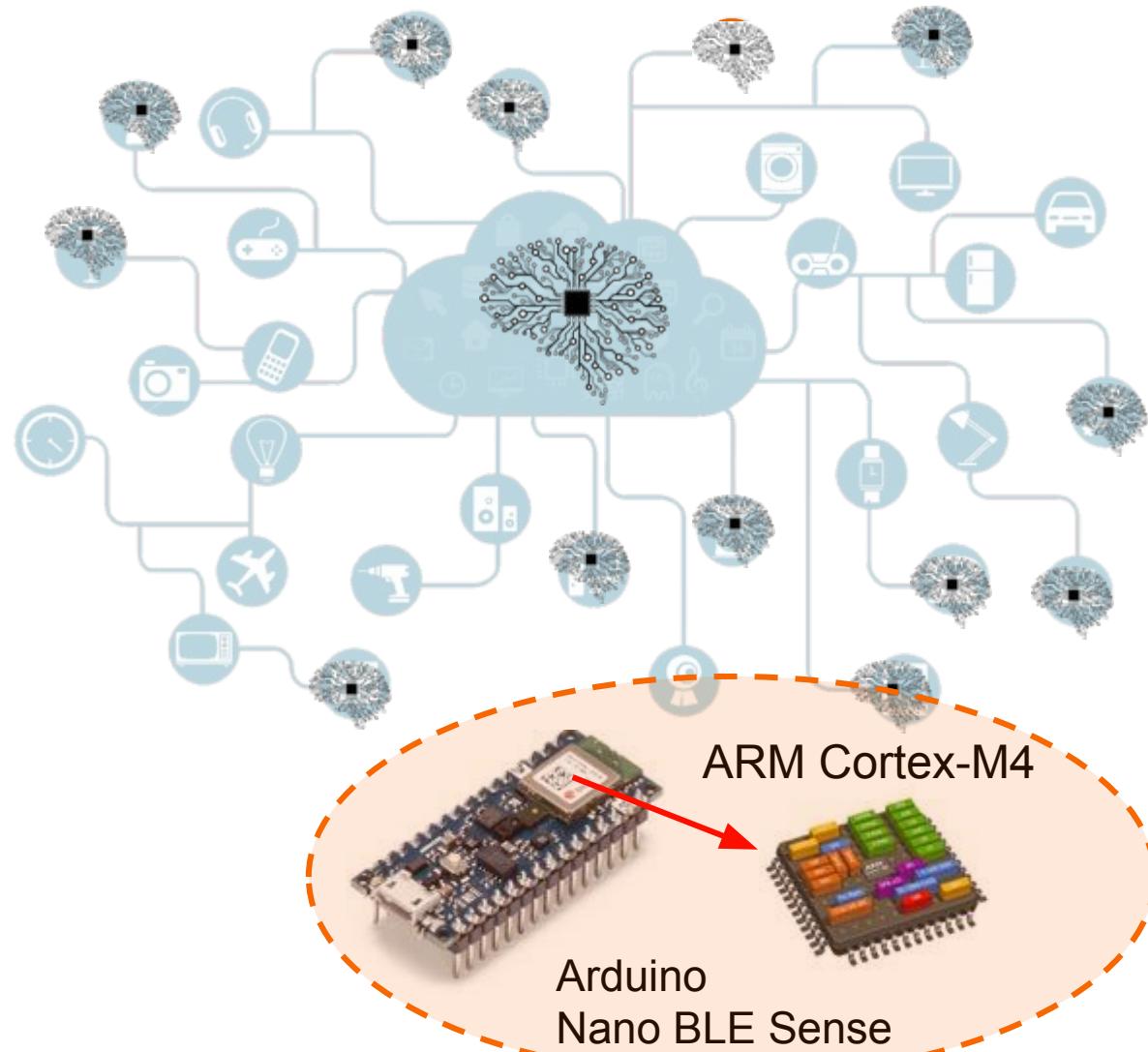
# Endpoints devices → Data + AI → Value



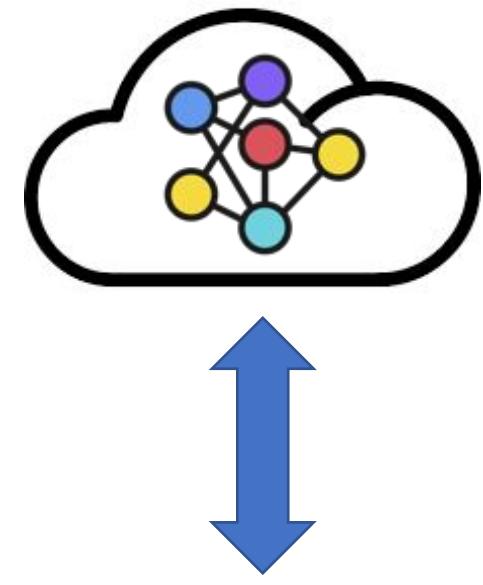
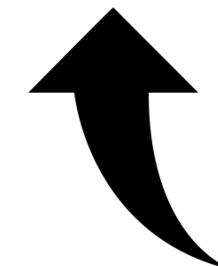
# AI + IOT = Alot



# ML (AI) at the “edge of the edge” → TinyML

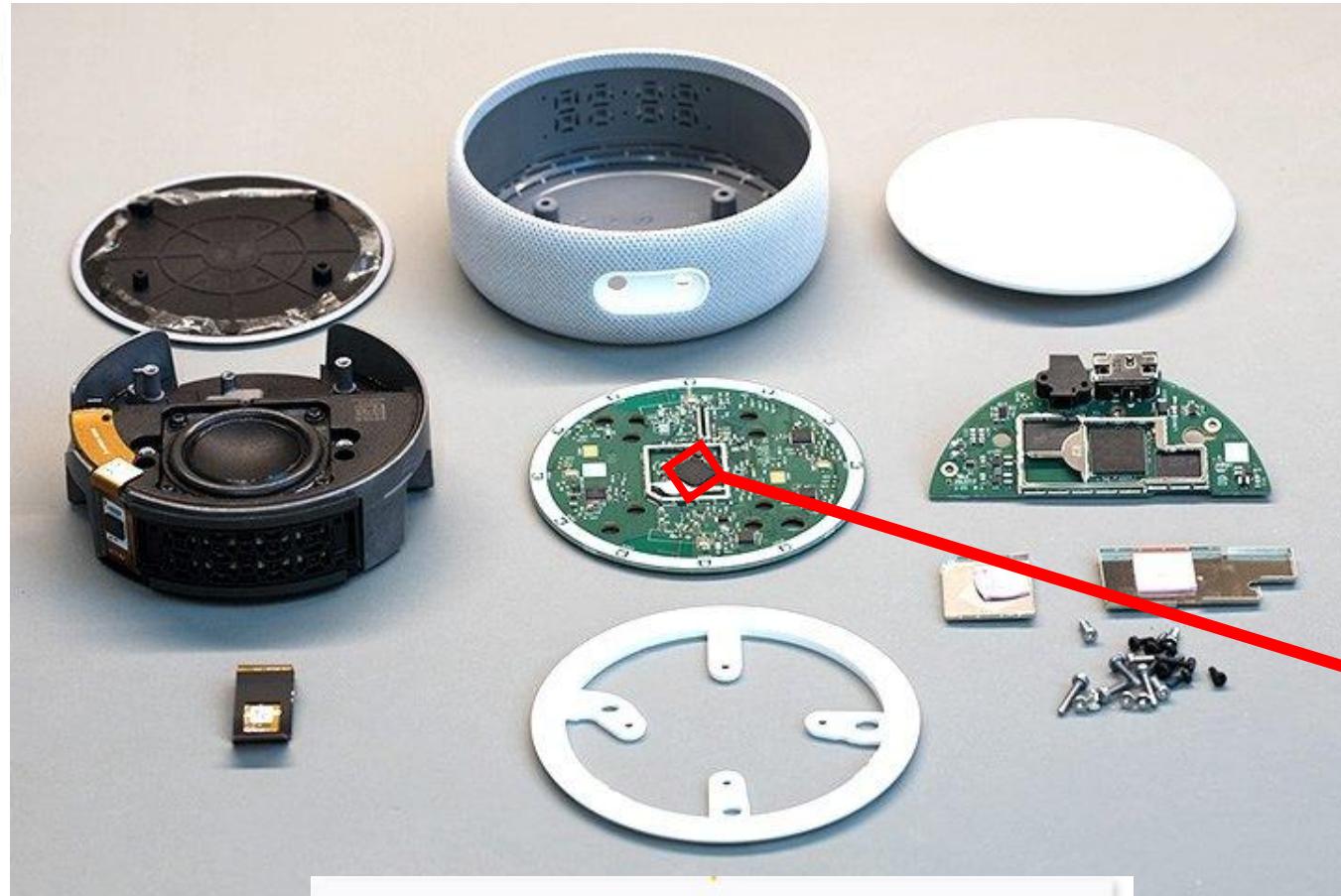


TinyML enables machine intelligence right next to the physical world



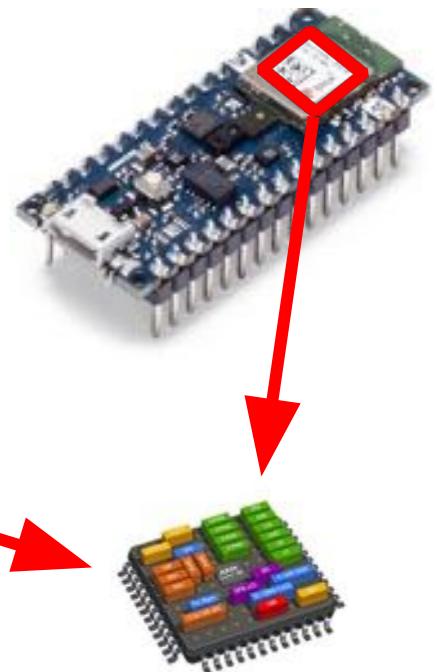
ML at microprocessor level avoid issues as Latency, Power Consuming, and Security

# Echo-Dot Teardown vs Arduino Nano BLE Sense



MediaTek 7658CSN: Wi-Fi +ARM® Cortex-R4

Nordic nRF52840-M4

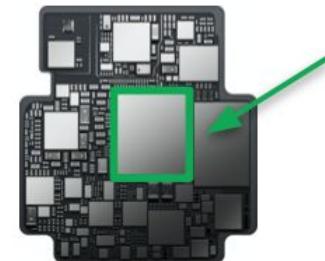


# MCUs enable **TinyML**

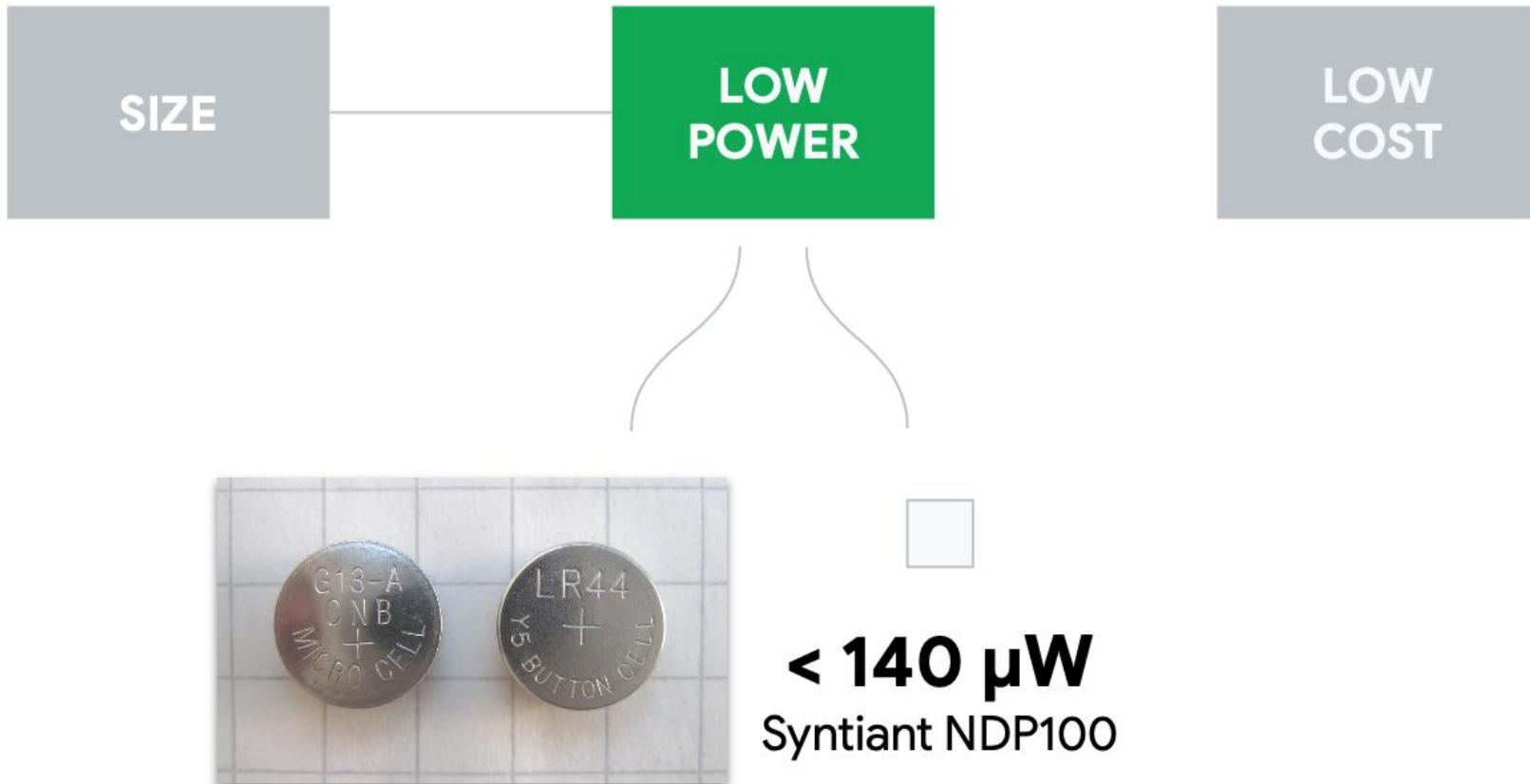
SIZE

LOW  
POWER

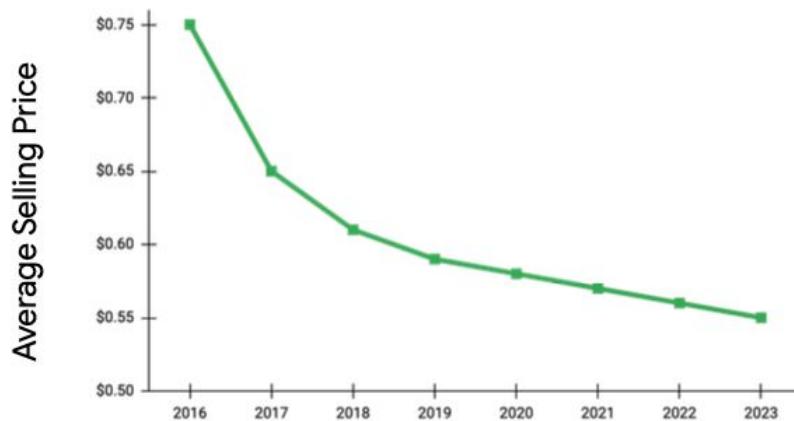
LOW  
COST



# MCUs enable **TinyML**



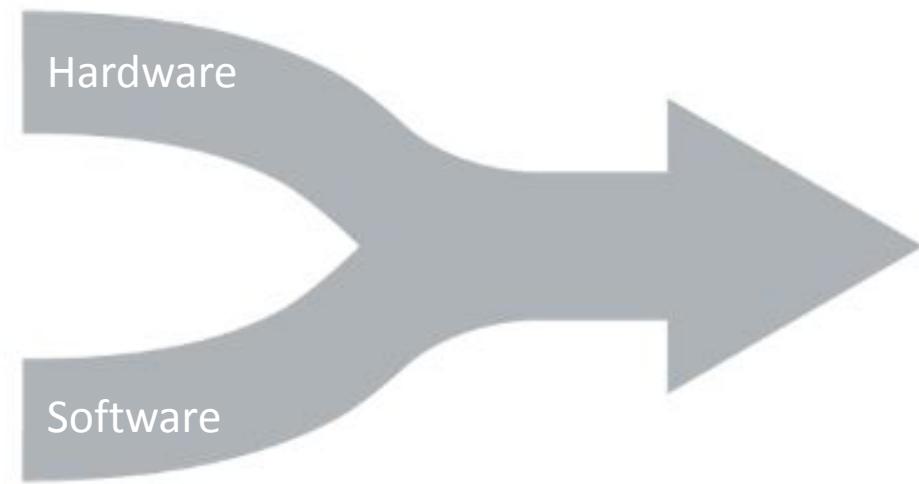
# MCUs enable **TinyML**



# What Makes **TinyML**?

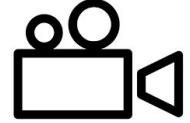
**Embedded  
Systems**

**Machine  
Learning**



**TinyML**

# Hardware



Anomaly Detection  
Sensor Classification  
20 KB



Rpi-Pico  
(Cortex-M0+)



Arduino Nano  
(Cortex-M4)



Arduino Pro  
(Cortex-M7)

Source: Edge Impulse

# EdgeML

## TinyML

Image  
Classification  
250 KB+

KeyWord Spotting  
Audio Classification  
50 KB



Object Detection  
Complex Voice  
Processing  
1 MB+



RaspberryPi  
(Cortex-A)



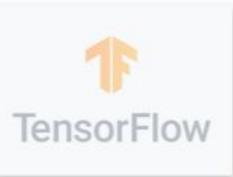
SmartPhone  
(Cortex-A)



Jetson Nano  
(Cortex-A + GPU)

Video  
Classification  
2 MB+

# Software



Train a model



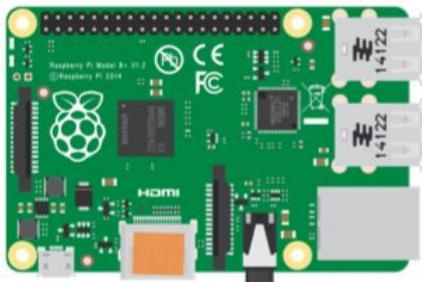
TensorFlow Lite

Convert  
model

Optimize  
model

Deploy  
model at  
Edge

Make  
inferences  
at Edge



Raspberry Pi



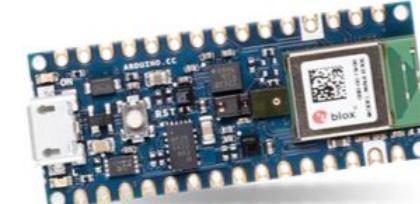
Linux



iOS



(TFL Micro)



Microcontroller

# TinyML Application Examples

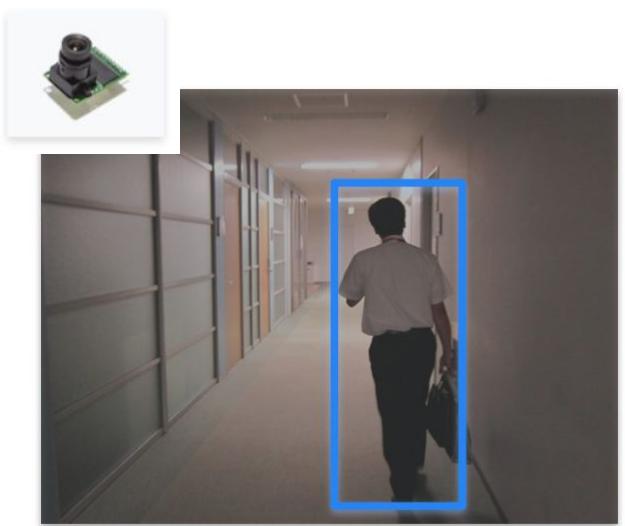
# Sound



# Vibration



# Vision



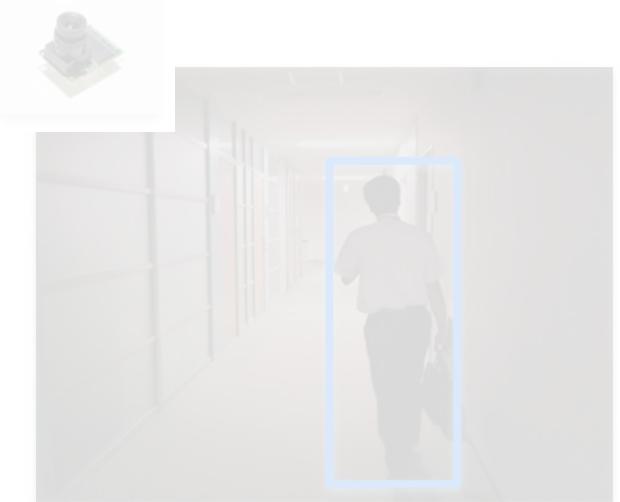
# Sound



# Vibration



# Vision



# More than just voice

- Security (Broken Glass)
- Industry (Anomaly Detection)
- Medical (Snore, Toss)
- Nature (Bee, Mosquito sound)



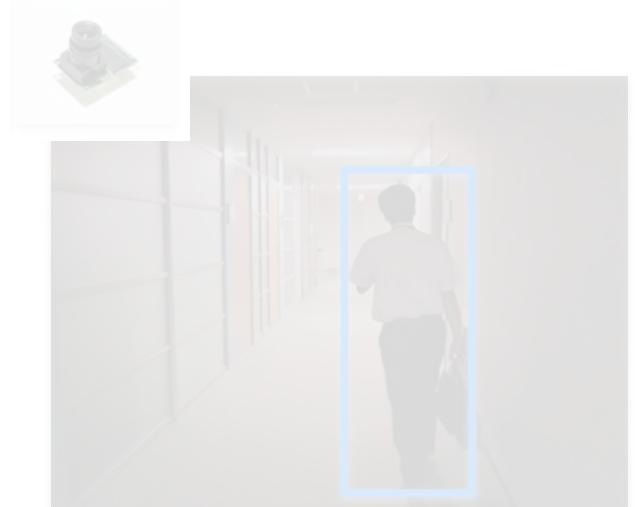
# Sound



# Vibration



# Vision



# Cow Monitoring

## Using the Internet of Things for Agricultural Monitoring

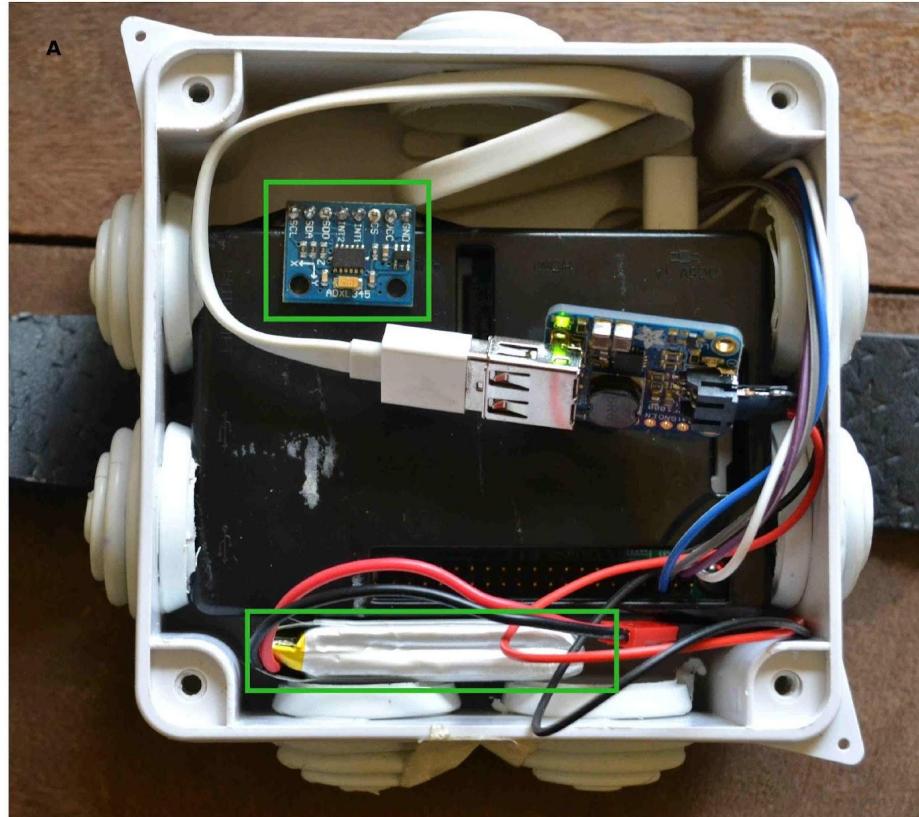
"We aim to deploy a variety of sensors for agricultural monitoring. One of the projects involves using **accelerometer sensors** to monitor activity levels in dairy cows with a view to determining when the cows are on heat or when they are sick."



Ciira wa Maina, Ph.D.

Senior Lecturer  
Department of Electrical and Electronic Engineering  
Dedan Kimathi University of Technology  
Nyeri Kenya  
Email: ciira.maina@dkut.ac.ke

Kenia



<https://sites.google.com/site/cwamainadekut/research>



# Predict and classify common Elephant behavior



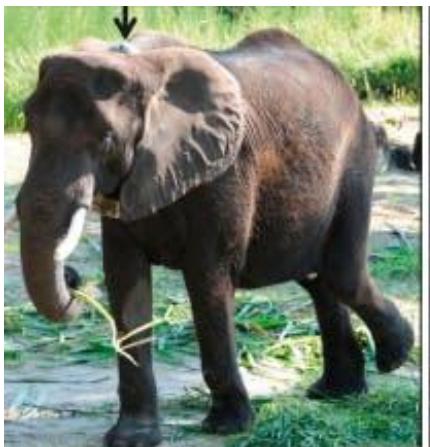
Aggressive



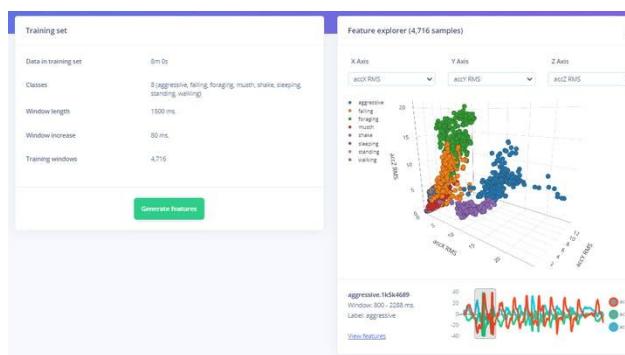
Standing



Sleeping



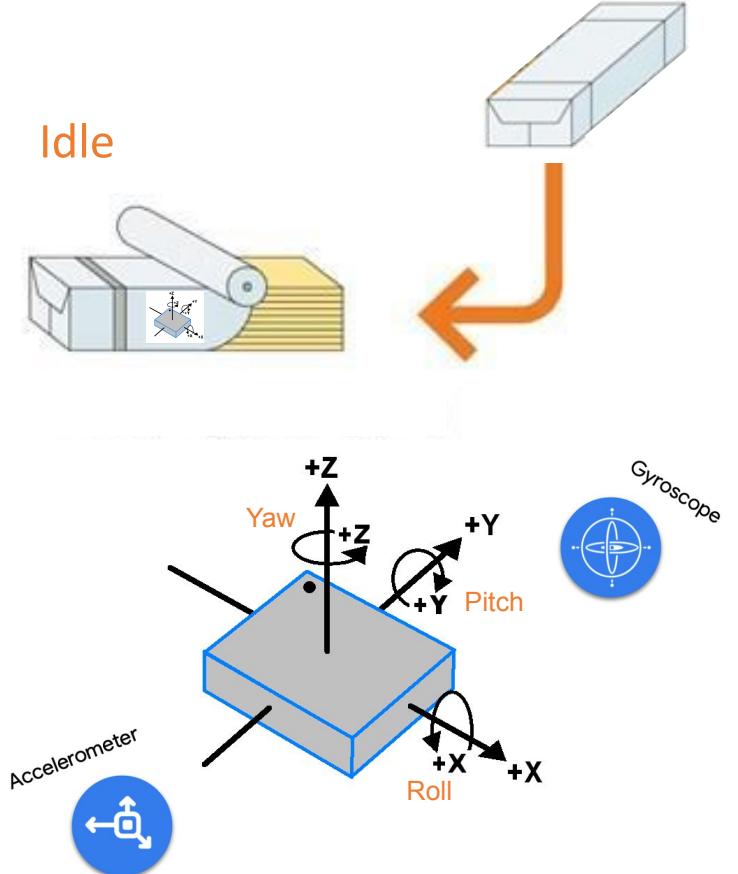
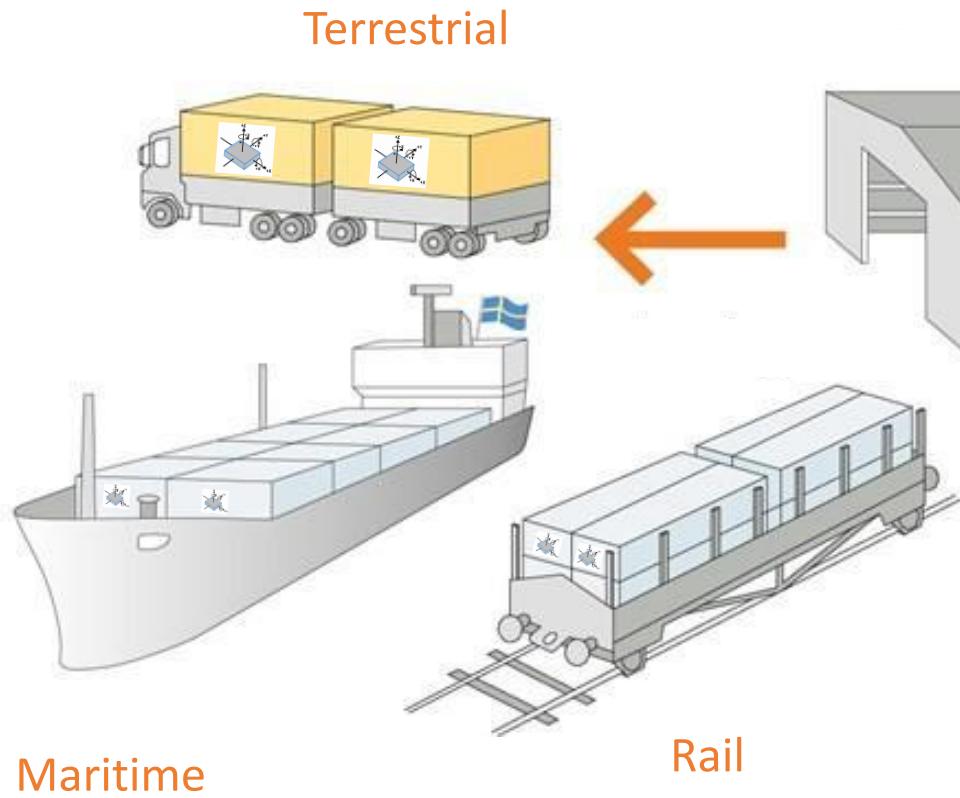
y:  
Surge  
(front-back)  
  
x:  
Sway  
(lateral)  
  
z:  
Heave  
(up-down)



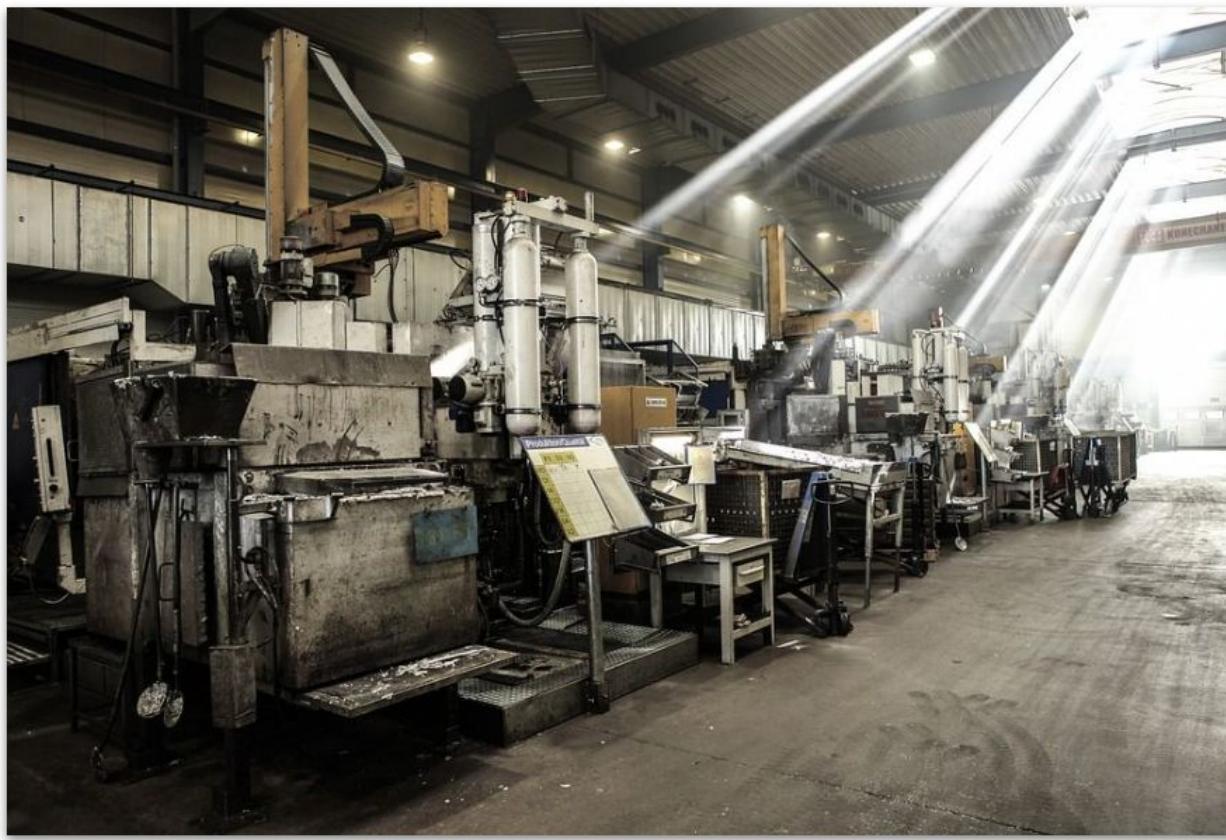
[https://www.hackster.io/dhruvsheth\\_electet-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a](https://www.hackster.io/dhruvsheth_electet-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a)



# Mechanical Stresses in Transport



# Application: Factory machinery



Ball Bearings



Accelerometer

# Sound



# Vibration



# Vision

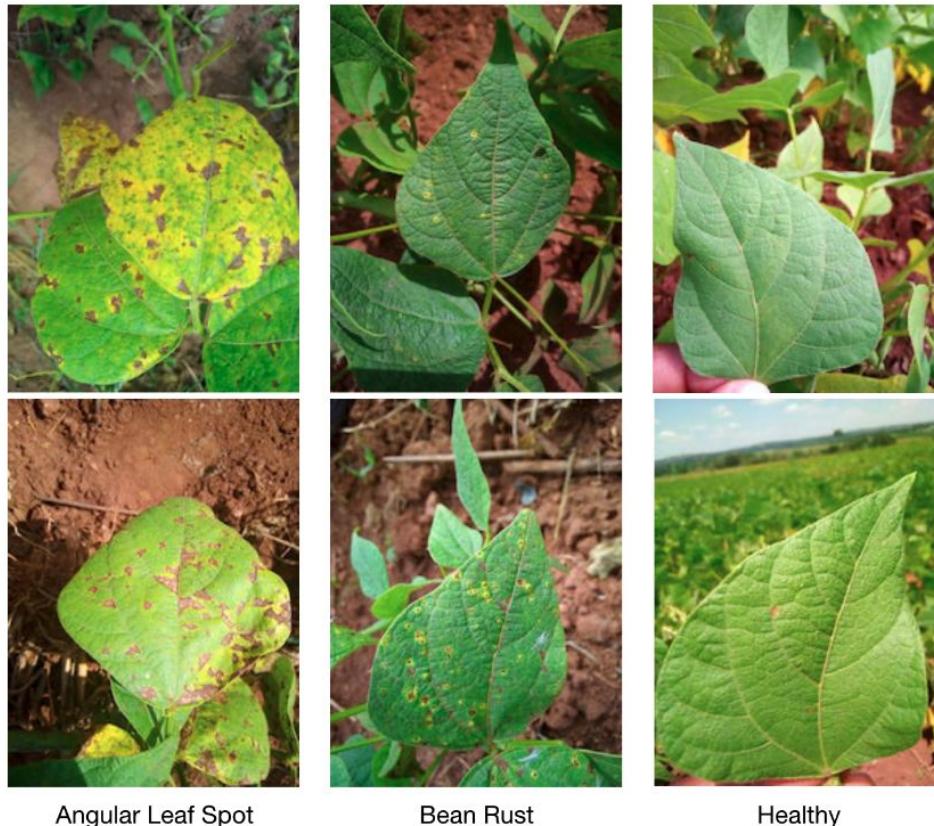


# Detecting Diseases in the Bean plants



AIR Lab Makerere University

UGANDA



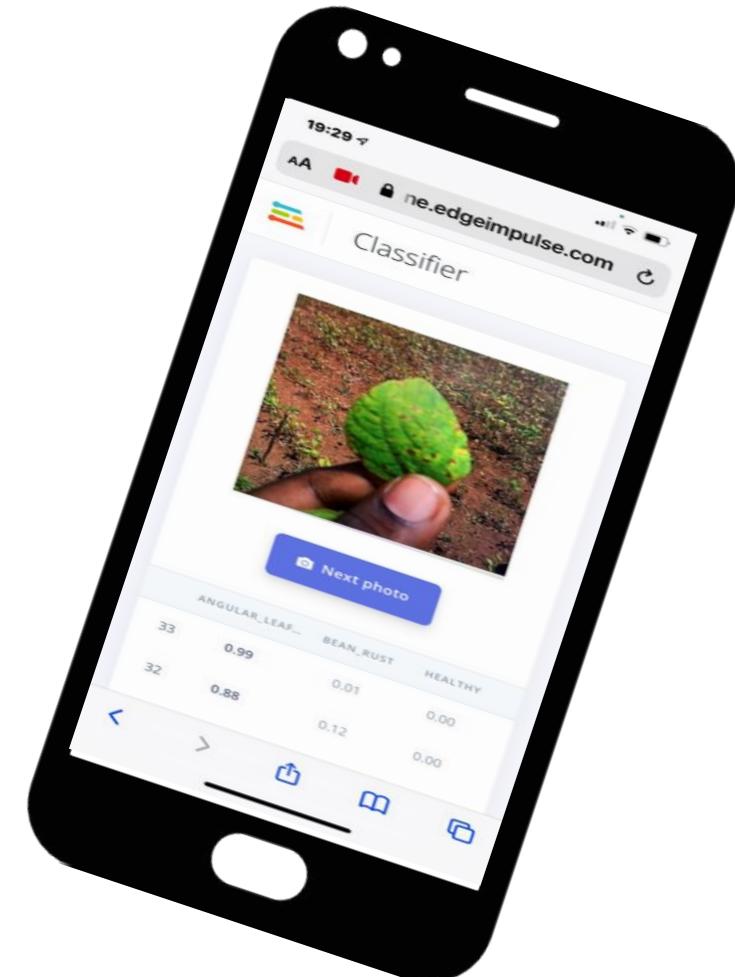
Angular Leaf Spot

Bean Rust

Healthy

Dataset: <https://github.com/AI-Lab-Makerere/ibean/>

Learn the steps to build an app that detects crop diseases

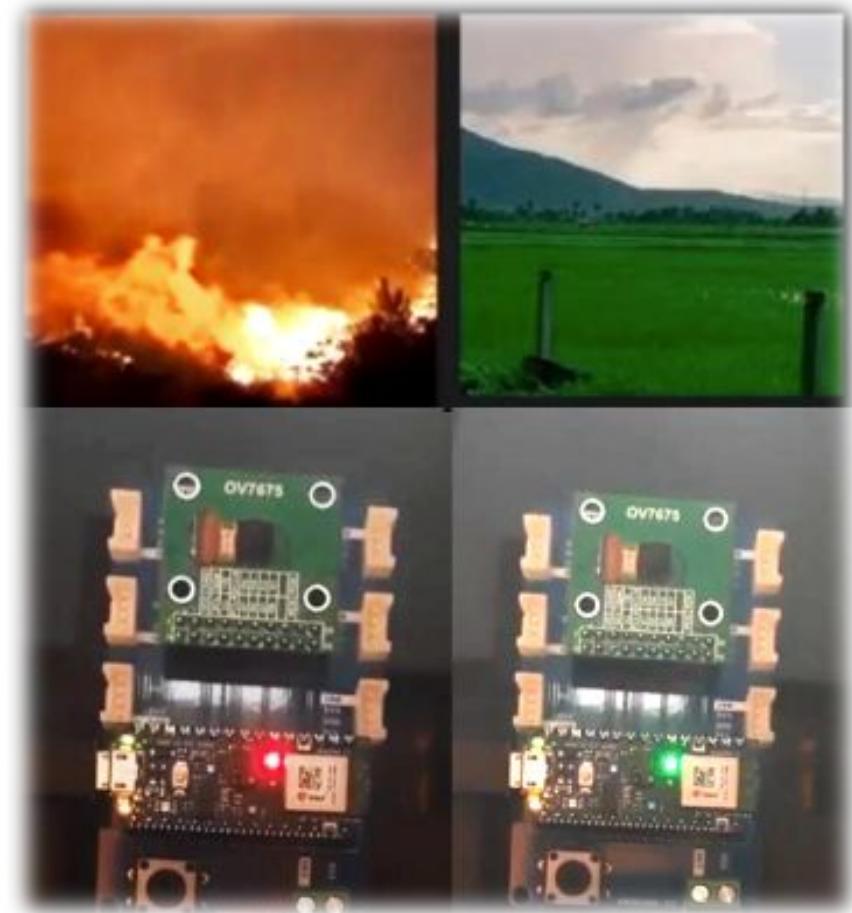


	ANGULAR LEAF SPOT	BEAN RUST	HEALTHY
33	0.99	0.01	0.00
32	0.88	0.12	0.00

# Forest Fire Detection



TinyML Aerial Forest Fire Detection

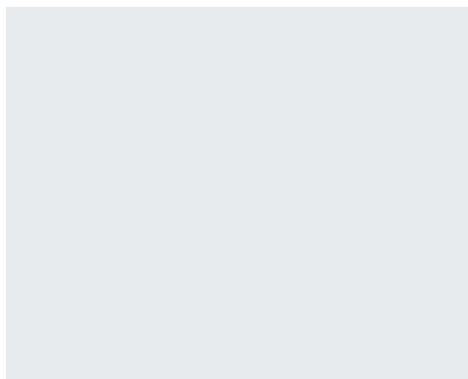


IESTI01 - Forest Fire Detection – Proof of Concept

# Person Detection



## Person Detection

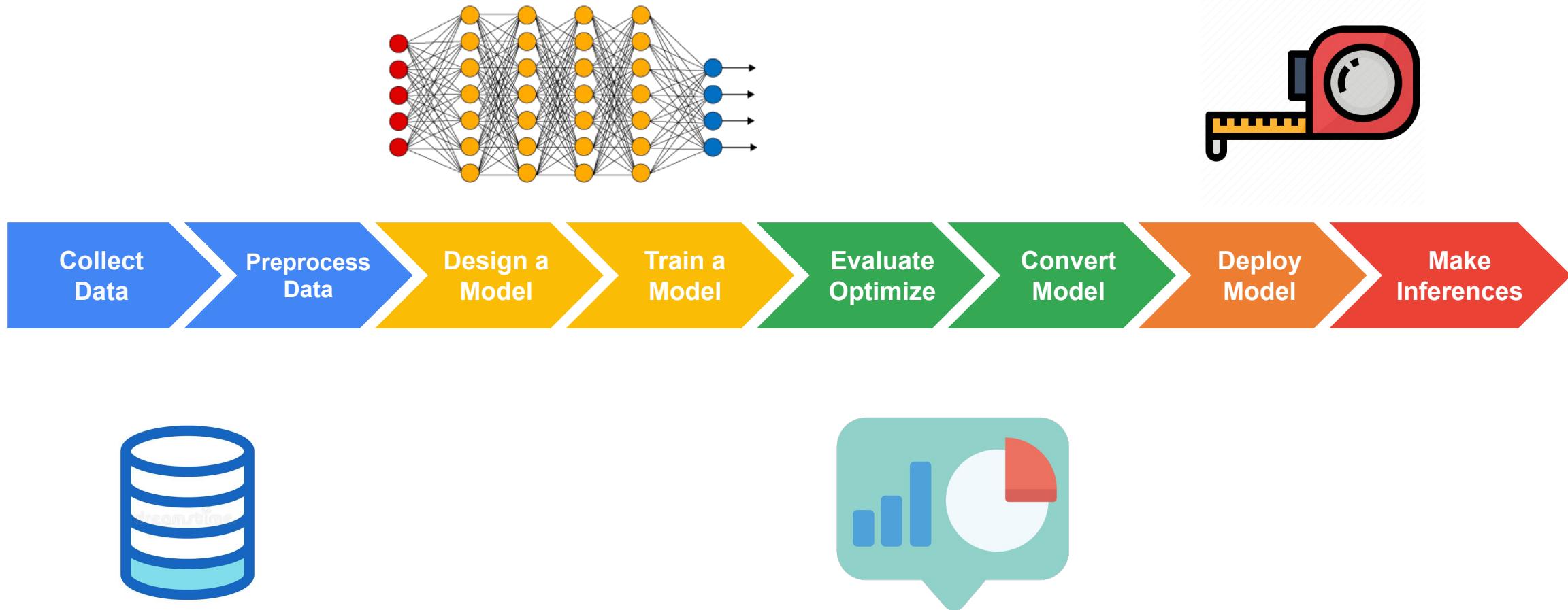


## Mask Detection

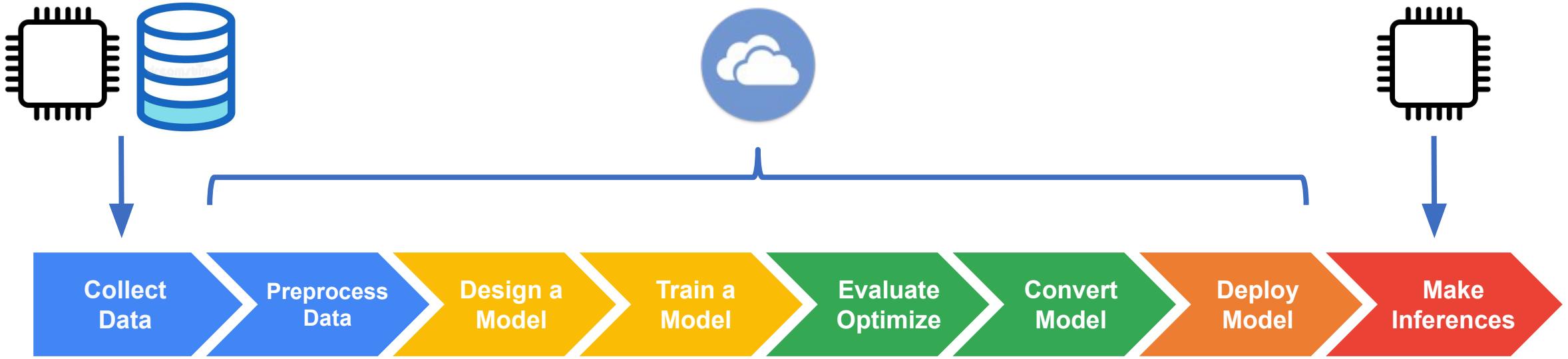


# How to Train a ML Model?

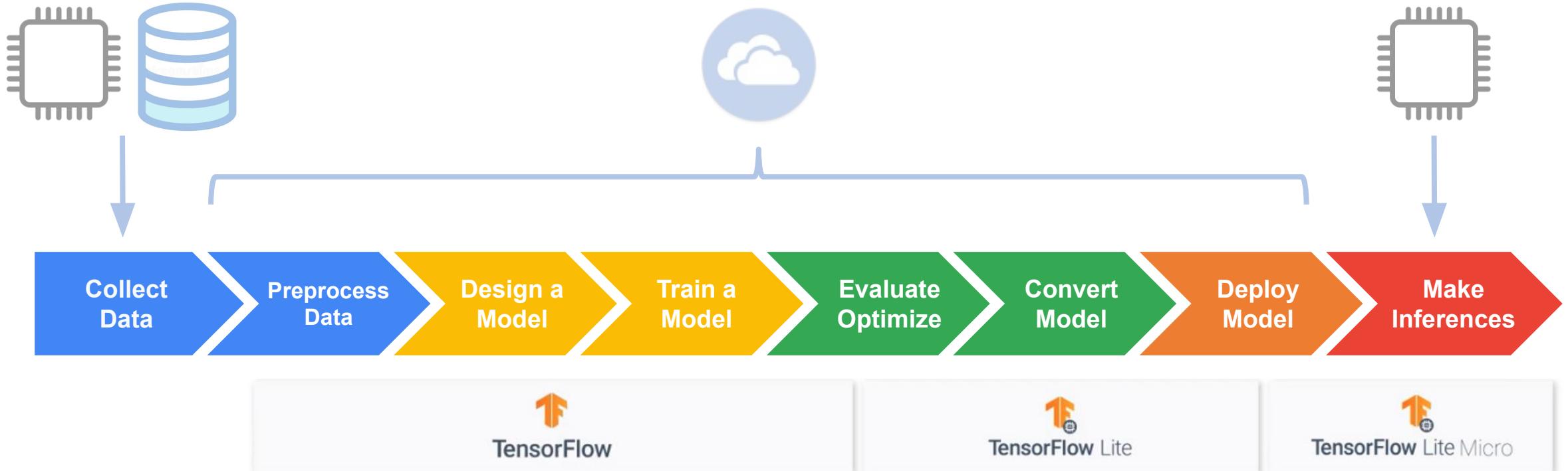
# Machine Learning Workflow (“What”)



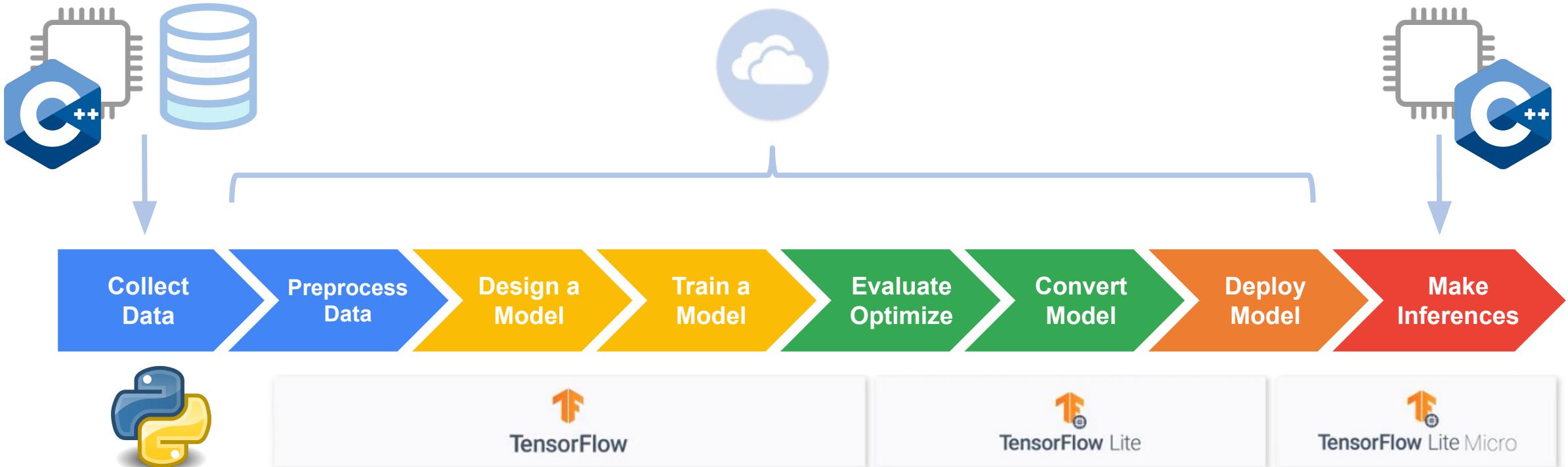
# Machine Learning Workflow (“Where”)



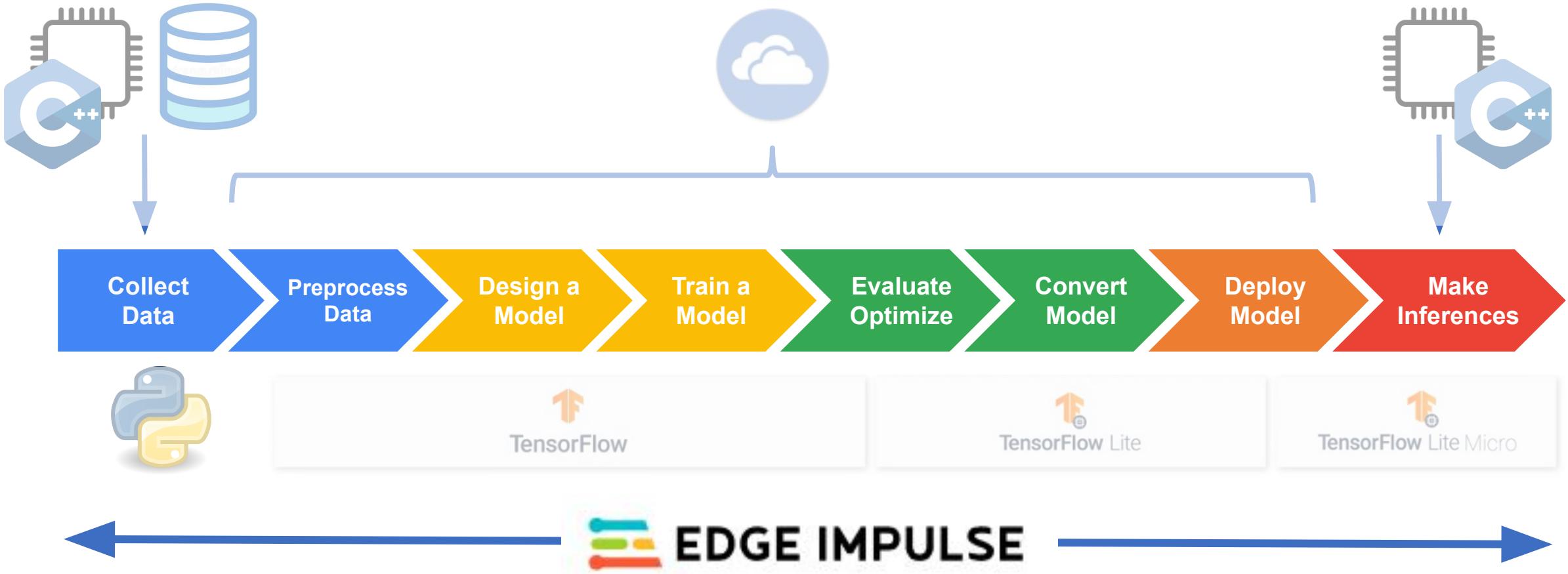
# Machine Learning Workflow (“How”)



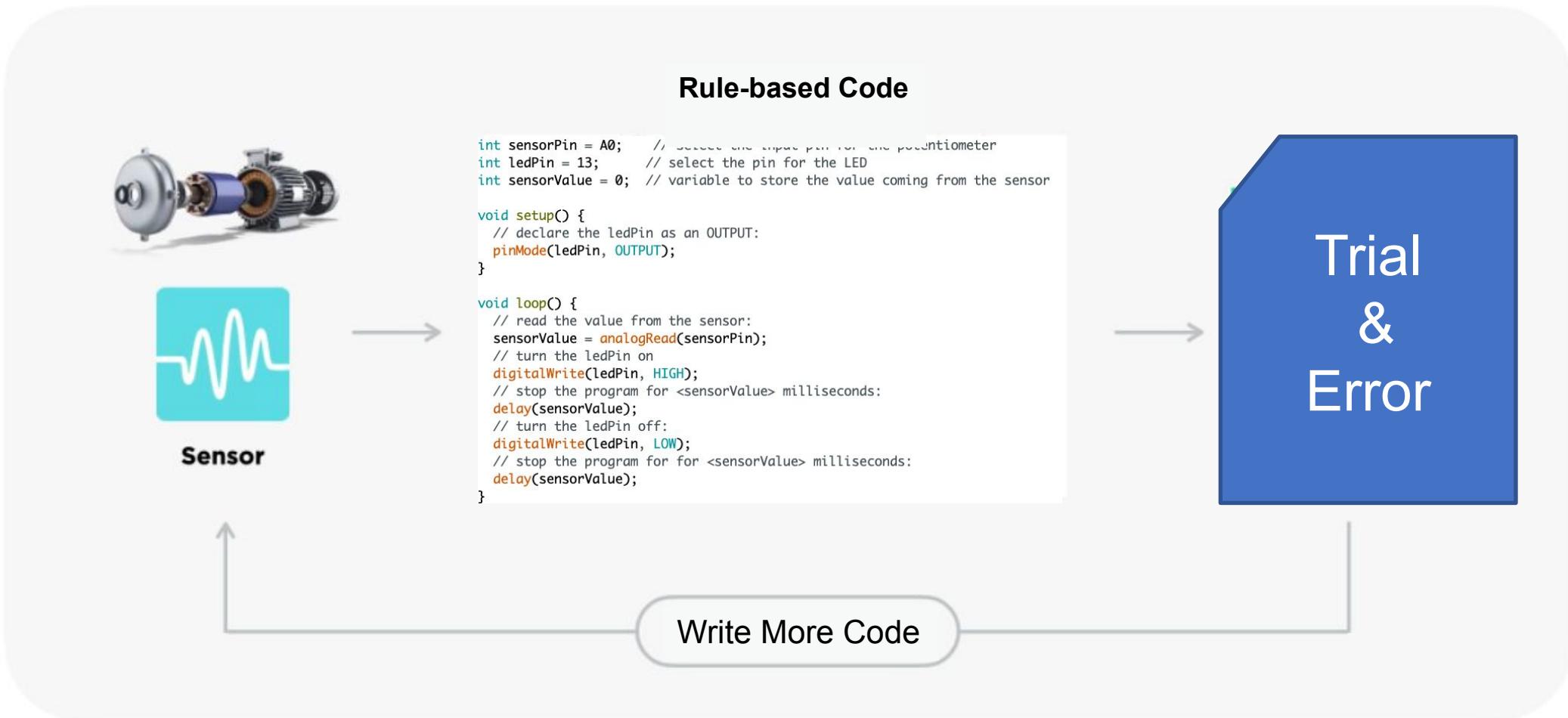
# Machine Learning Workflow (“How”)



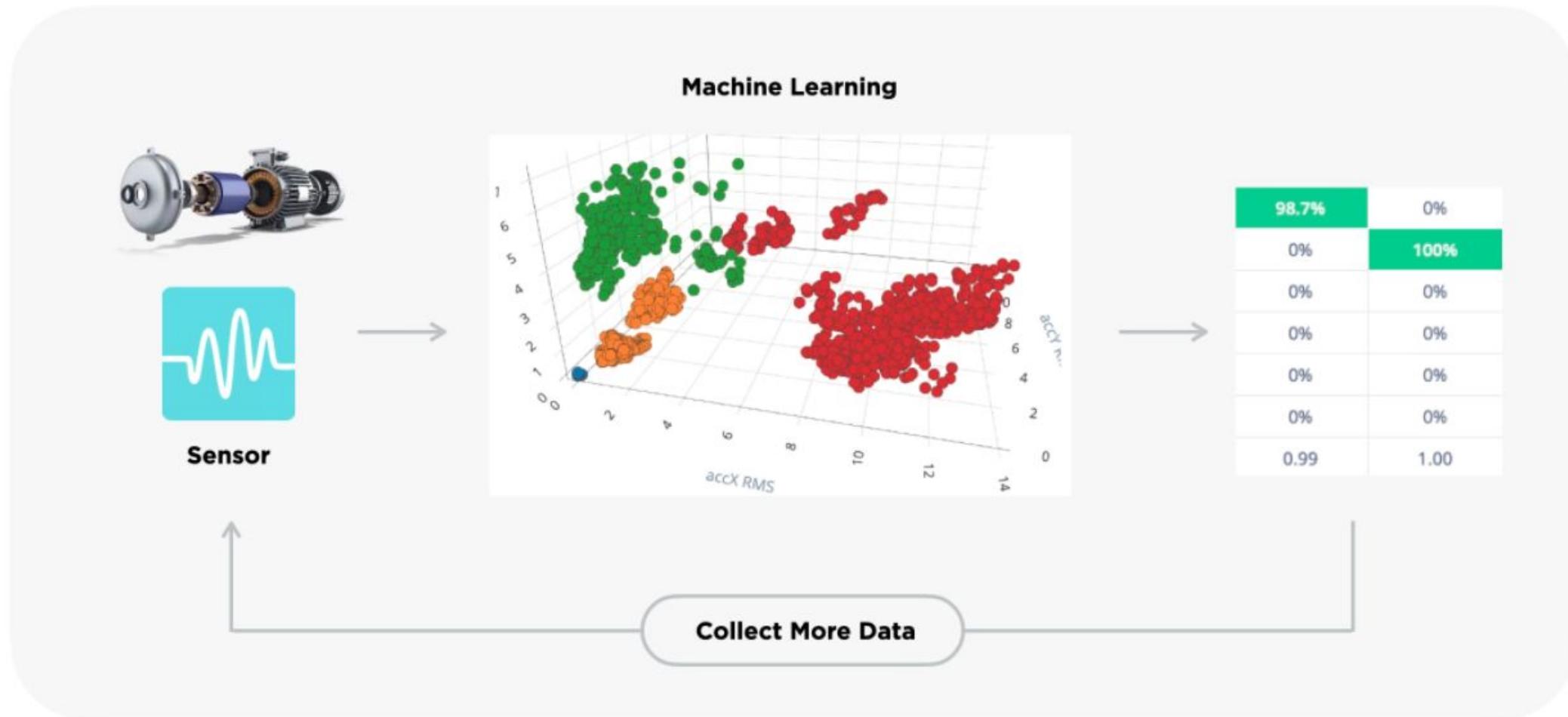
# Machine Learning Workflow (“How”)

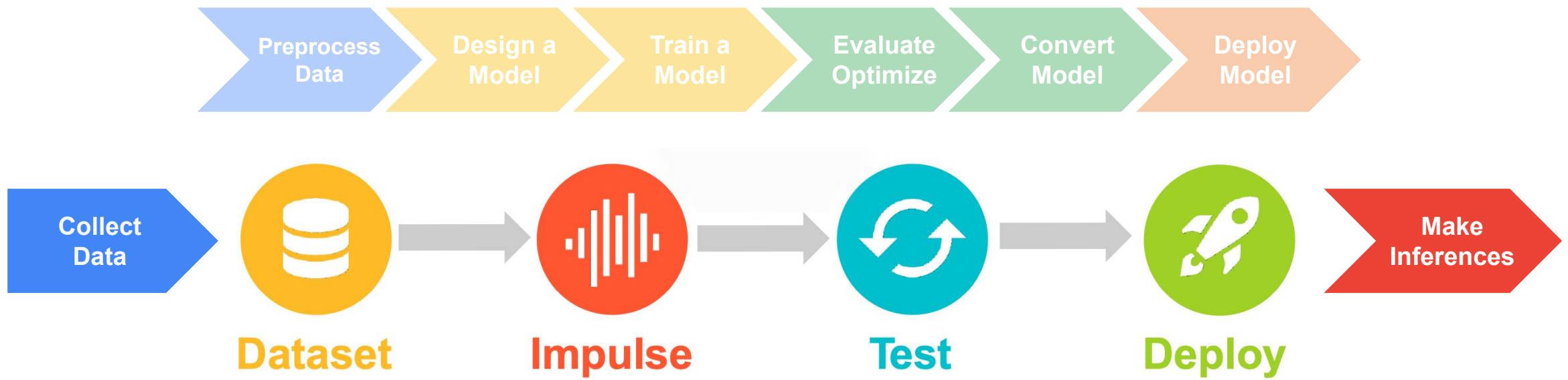


# From rule-based engineering to...

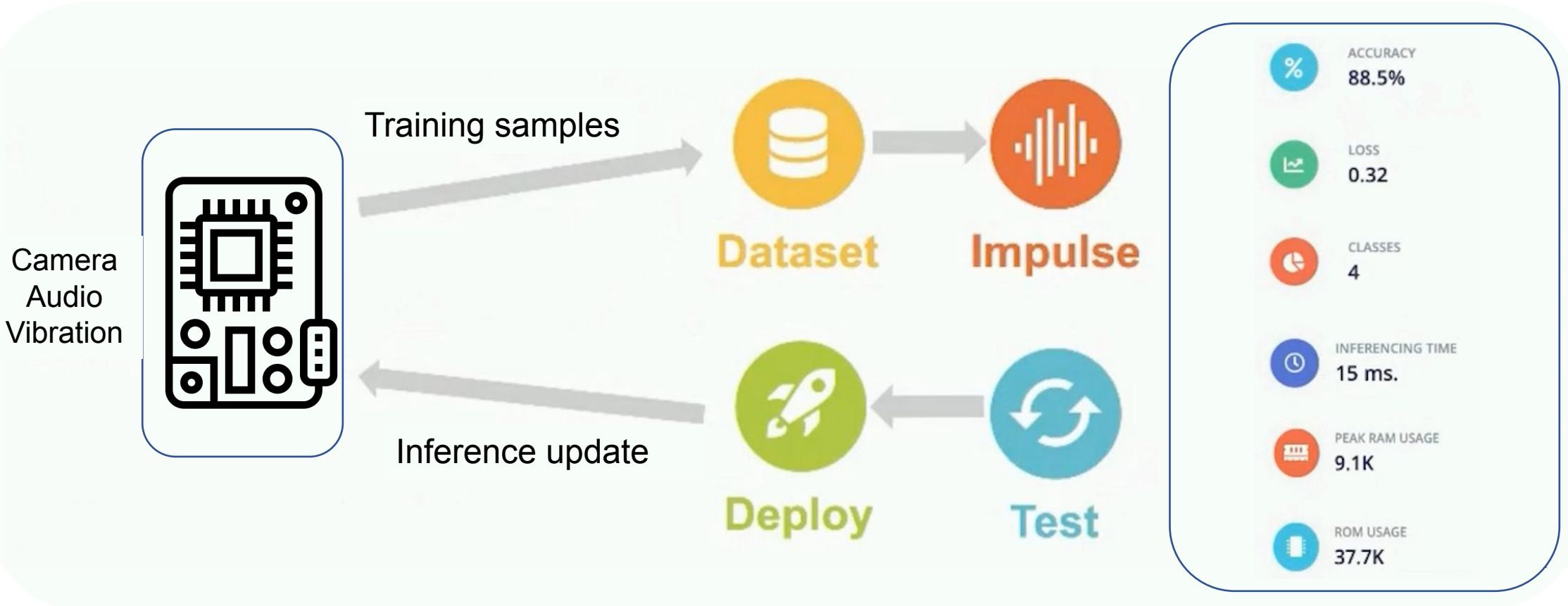


# Data-driven engineering

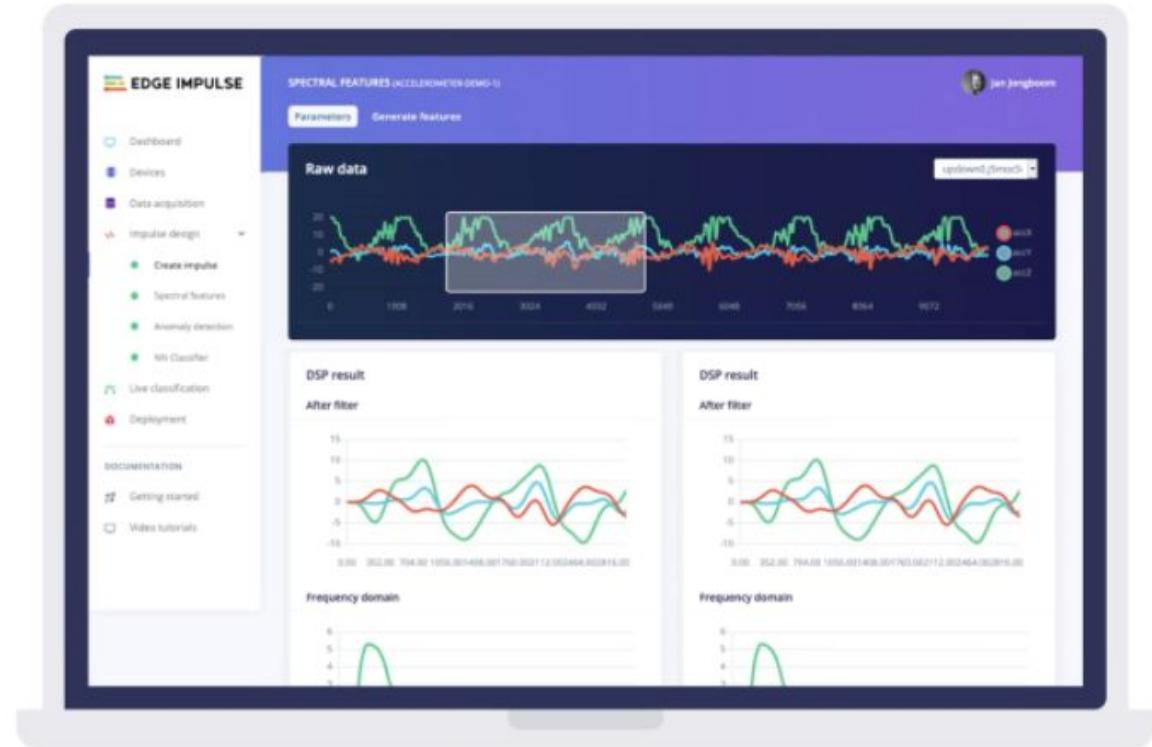
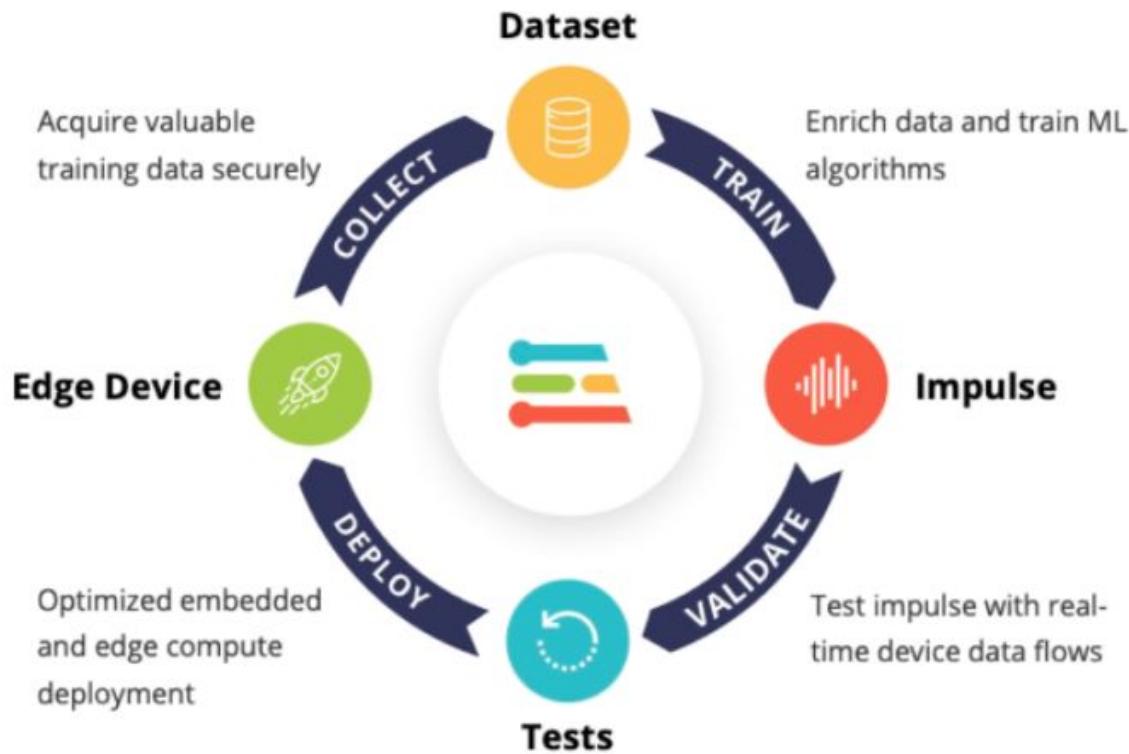




# Data-driven engineering

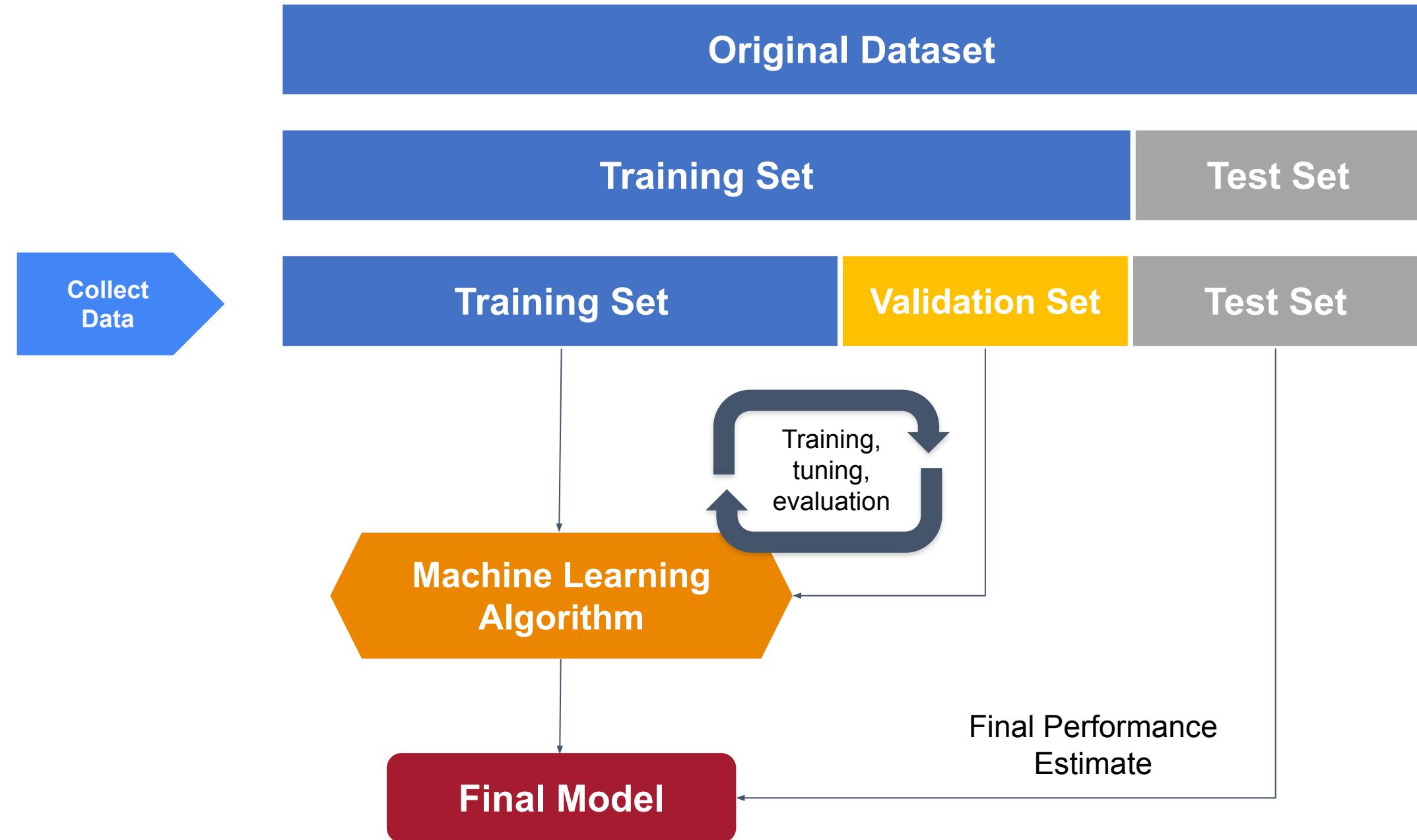


# EI Studio - Embedded ML platform (“AutoML”)



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

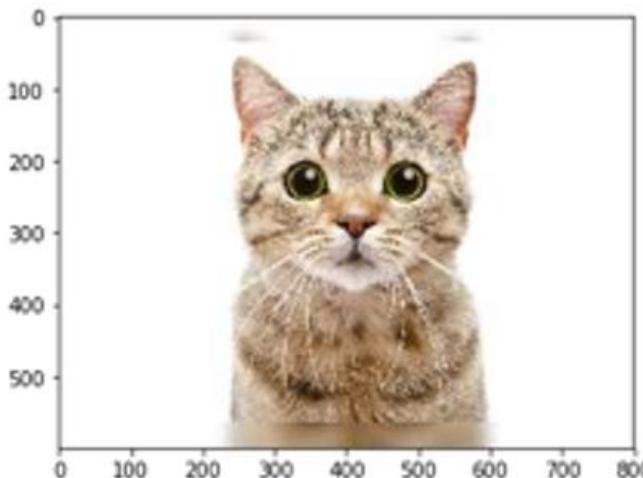




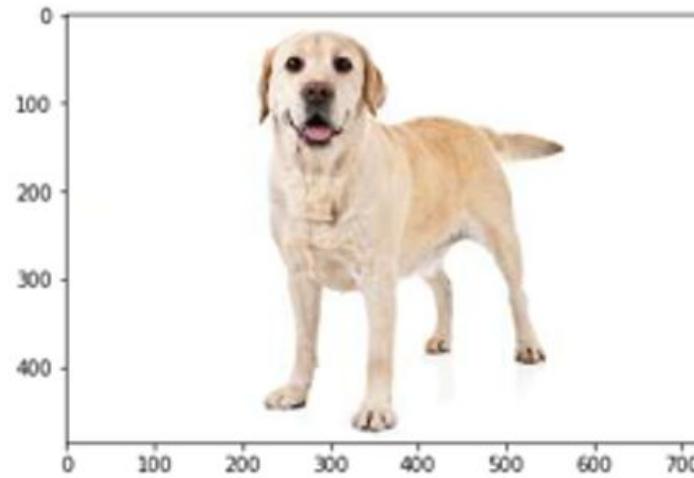
# What AI really is?

# Image Classification

[PREDICTION]	[Prob]
Egyptian cat	: 64%
tabby	: 14%
bucket	: 3%



[PREDICTION]	[Prob]
Labrador retriever	: 83%
golden retriever	: 13%
bloodhound	: 0%



[PREDICTION]	[Prob]
German shepherd	: 60%
dhole	: 16%
malinois	: 7%



<https://www.hackster.io/mjrobot/exploring-ia-at-the-edge-97588d>

# Object Detection



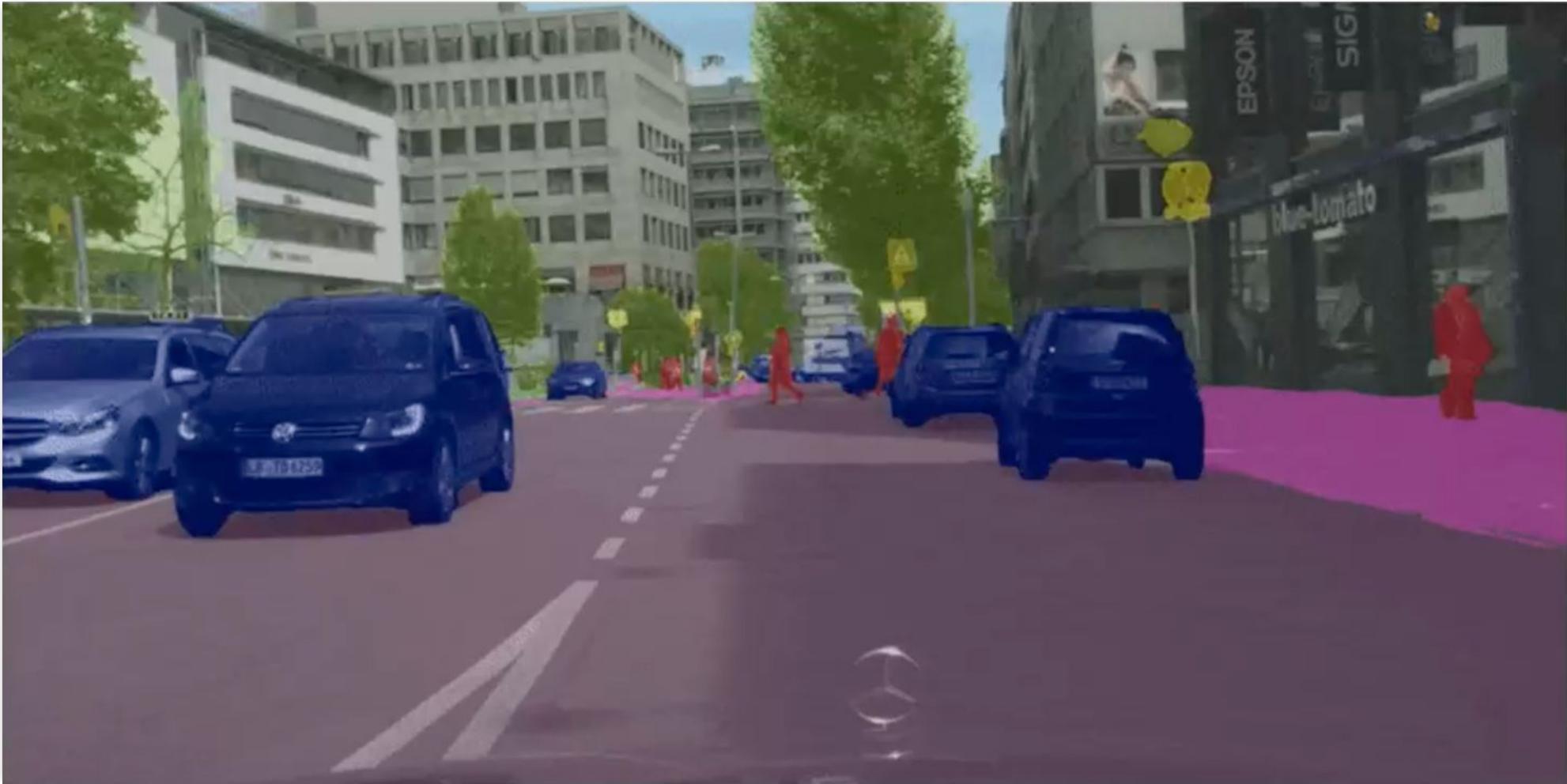
Photos

<https://www.hackster.io/mjrobot/exploring-ia-at-the-edge-97588d>



Live Video

# Segmentation



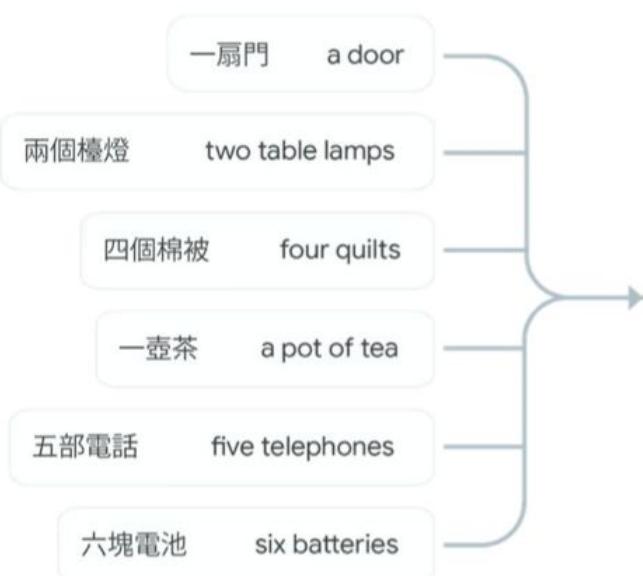
# Pose Estimation



<https://www.hackster.io/mjrobot/exploring-ia-at-the-edge-97588d>

# Machine Translation

1 Upload translated language pairs



2 Train your model



AutoML  
Translation

3 Evaluate



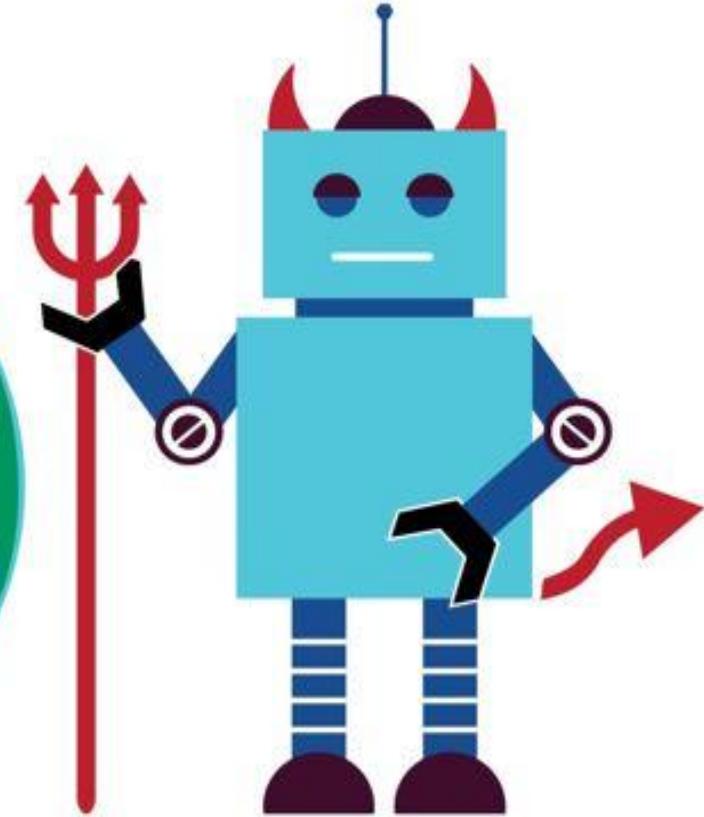
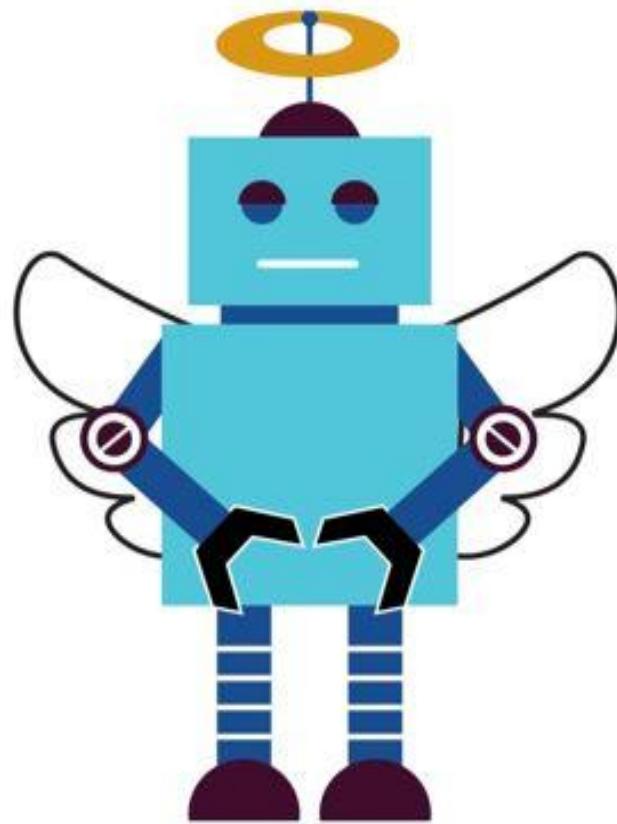
# Recommendations

General AI does not exist (yet)

# Dedicated ML Applications

- Image Classification
- Object Detection
- Pose Estimation
- Voice Recognition
- Gesture Recognition
- Anomaly Detection
- Natural Language Processing (**NLP**)

# Responsible AI



# 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 \(Coursera\)](#)
- [Text Book: "TinyML" by Pete Warden, Daniel Situnayake](#)

I want to thank [Shawn Hymel](#) and [Edge Impulse](#), [Pete Warden](#) and [Laurence Moroney](#) from Google, and especially Harvard professor [Vijay Janapa Reddi](#), Ph.D. student [Brian Plancher](#) and their staff for preparing the excellent material on TinyML that is the basis of this course at UNIFEI.

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

**Thanks**  
**And stay safe!**



**UNIFEI**