

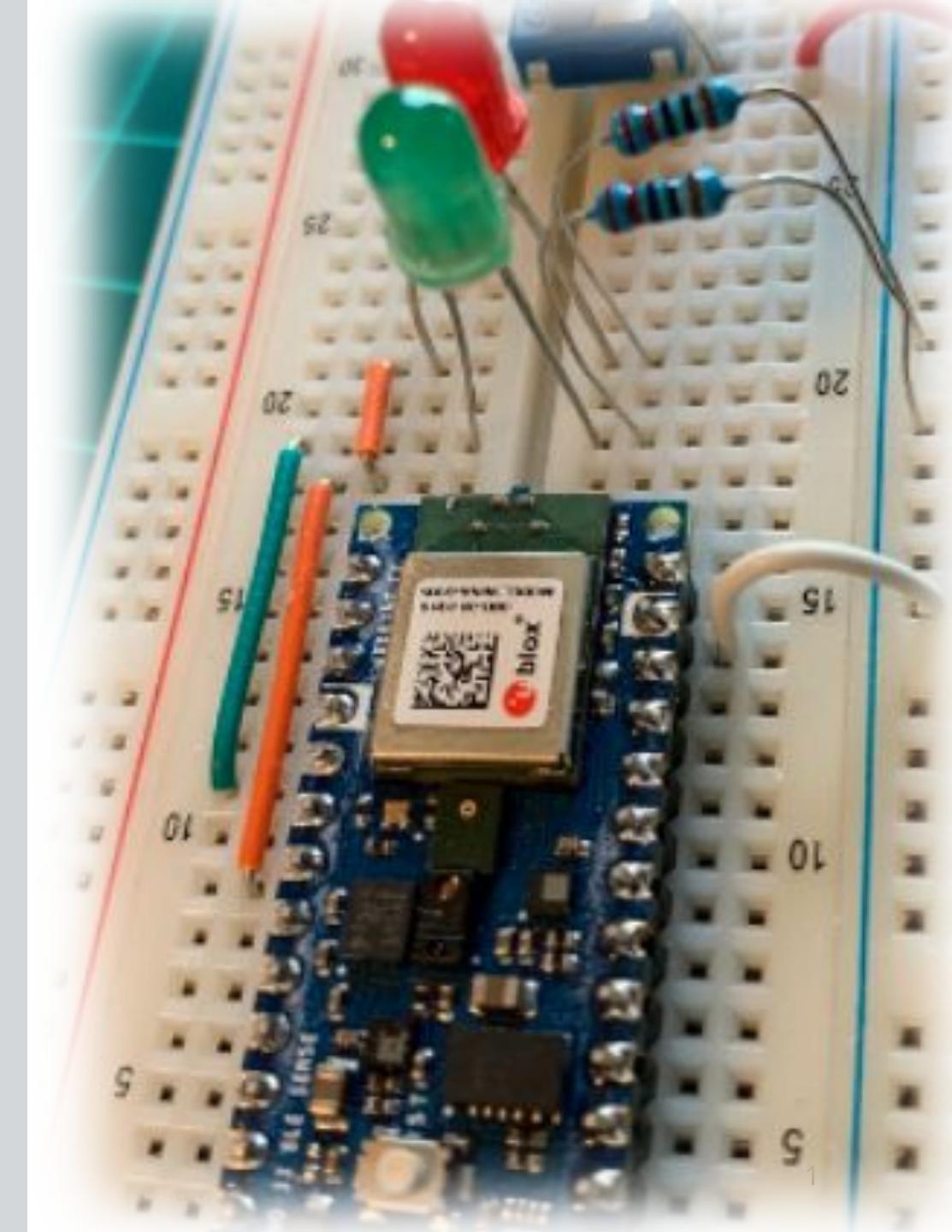
IESTI01 – TinyML

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

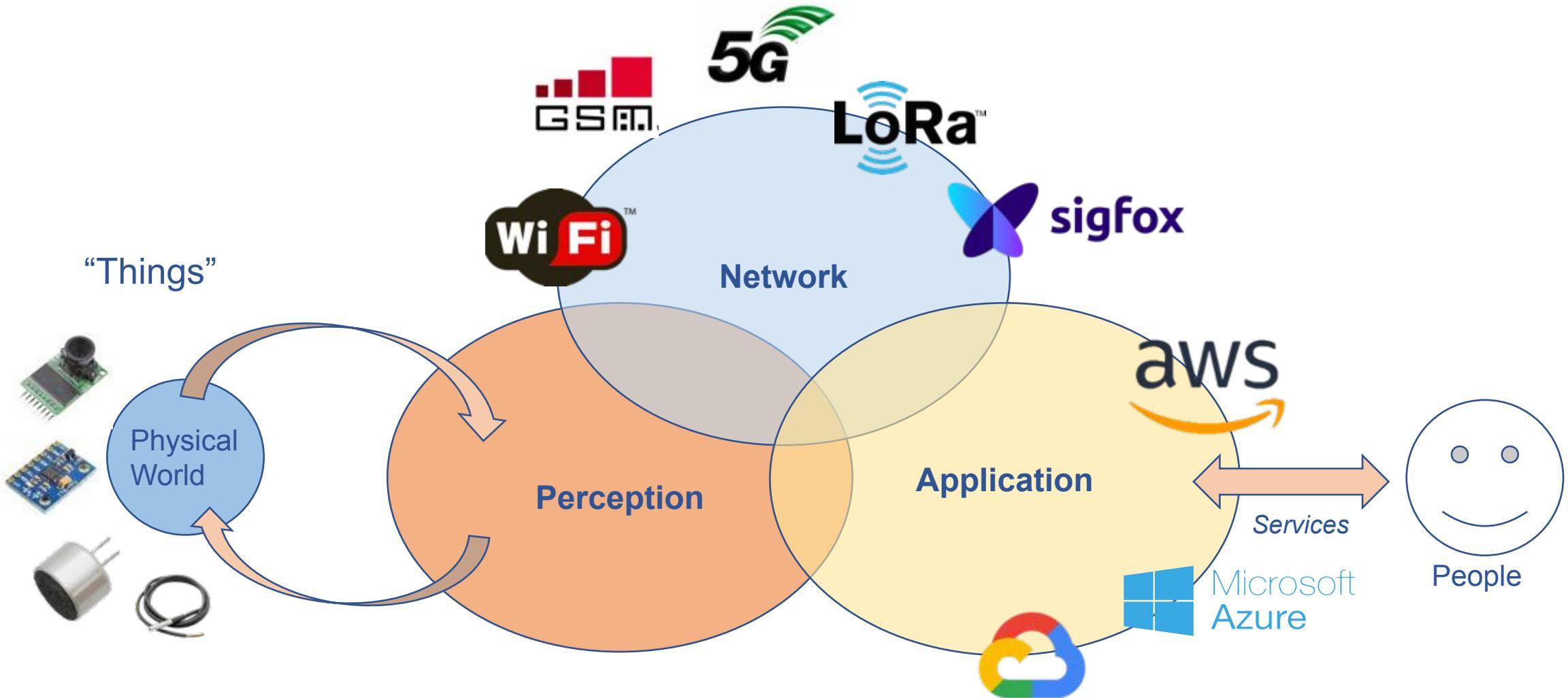
Scientific Use of Machine
Learning on Low-Power Devices
October 18-22 2021



Embedded ML

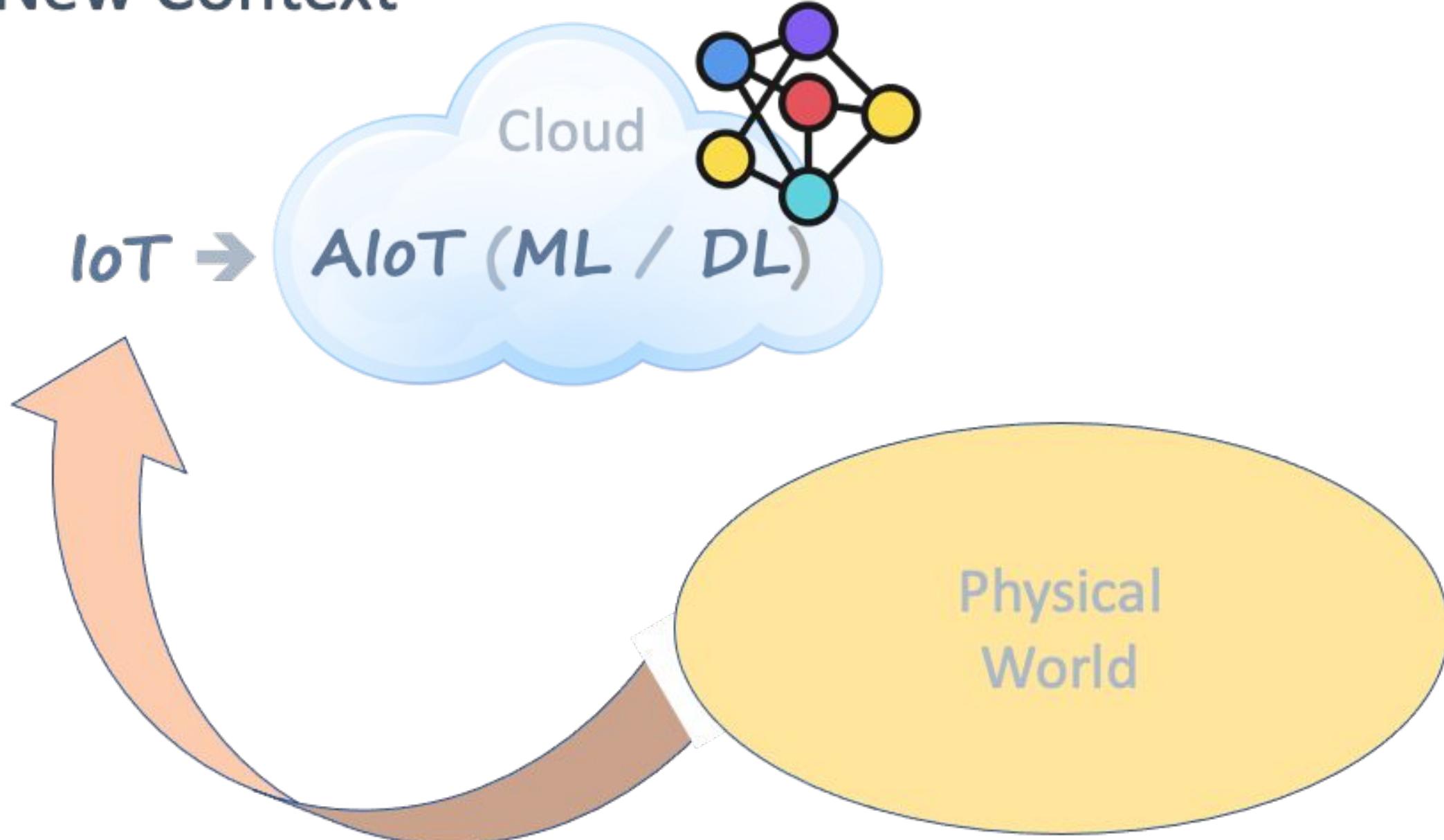
Curse Wrap-up

Classical IoT Architecture

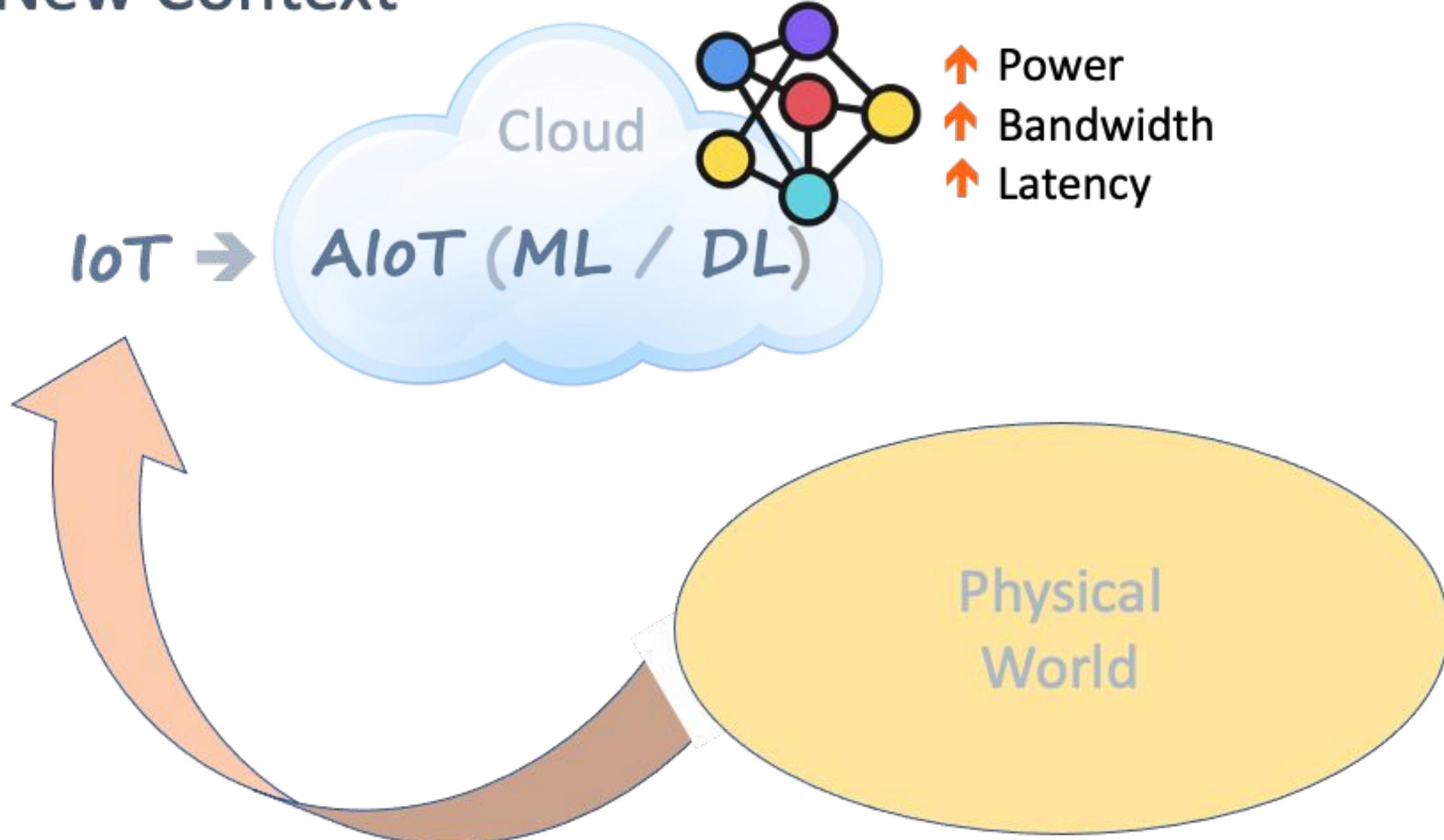


5 Quintillion bytes of data produced every day by IoT, but less than 1% is used. HBR/CISCO

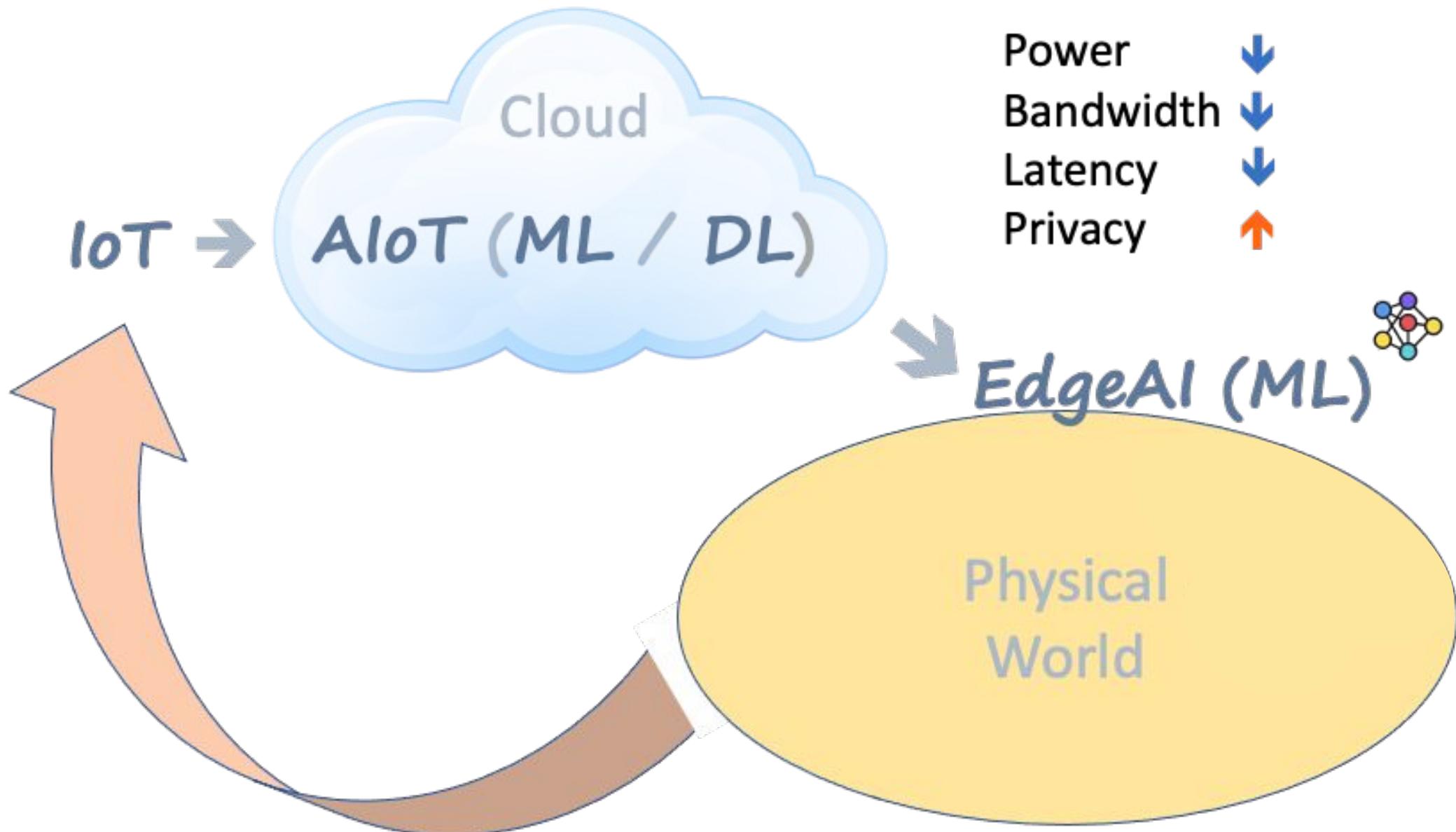
New Context



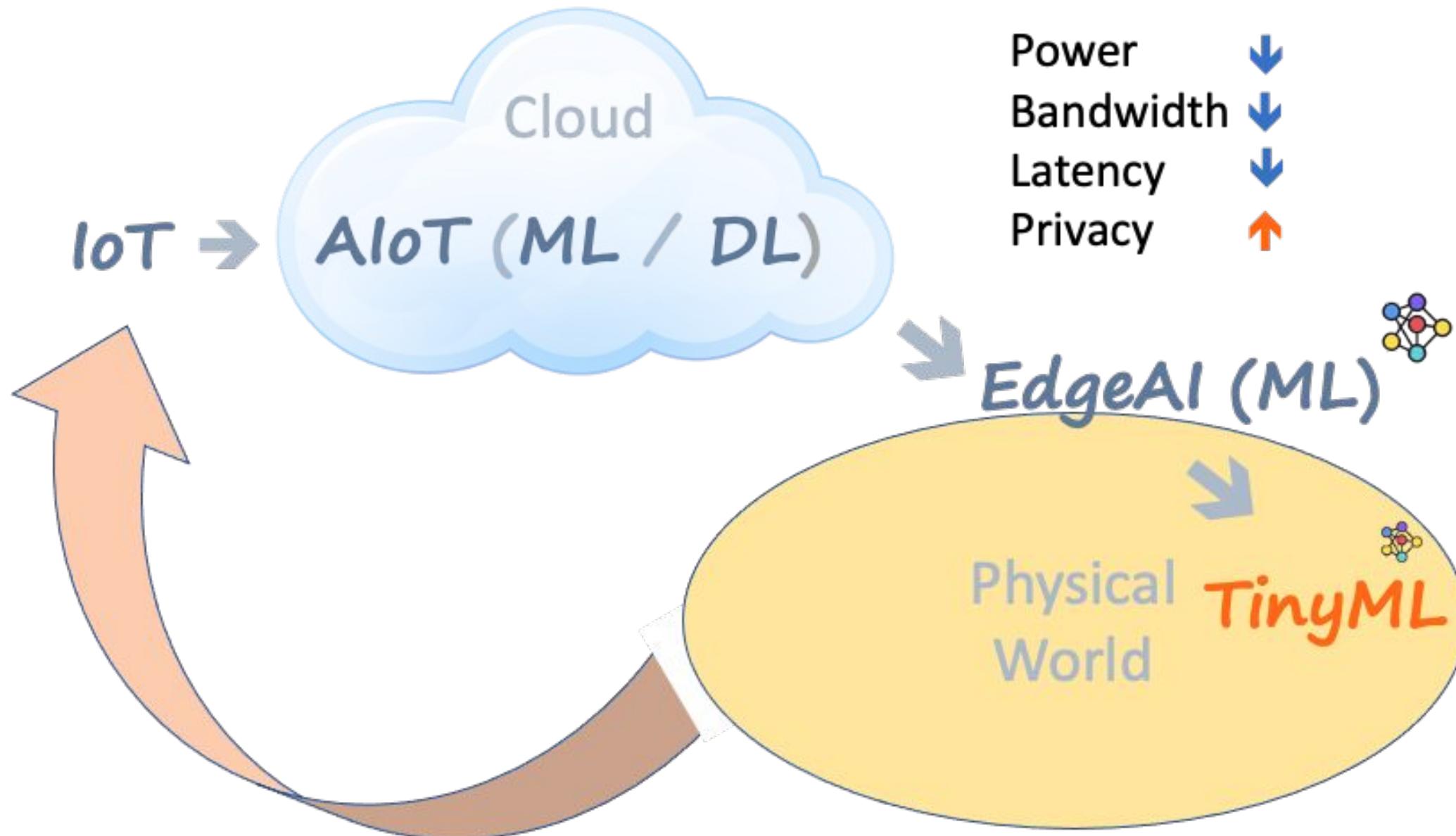
New Context



New Context



New Context



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

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

TinyML

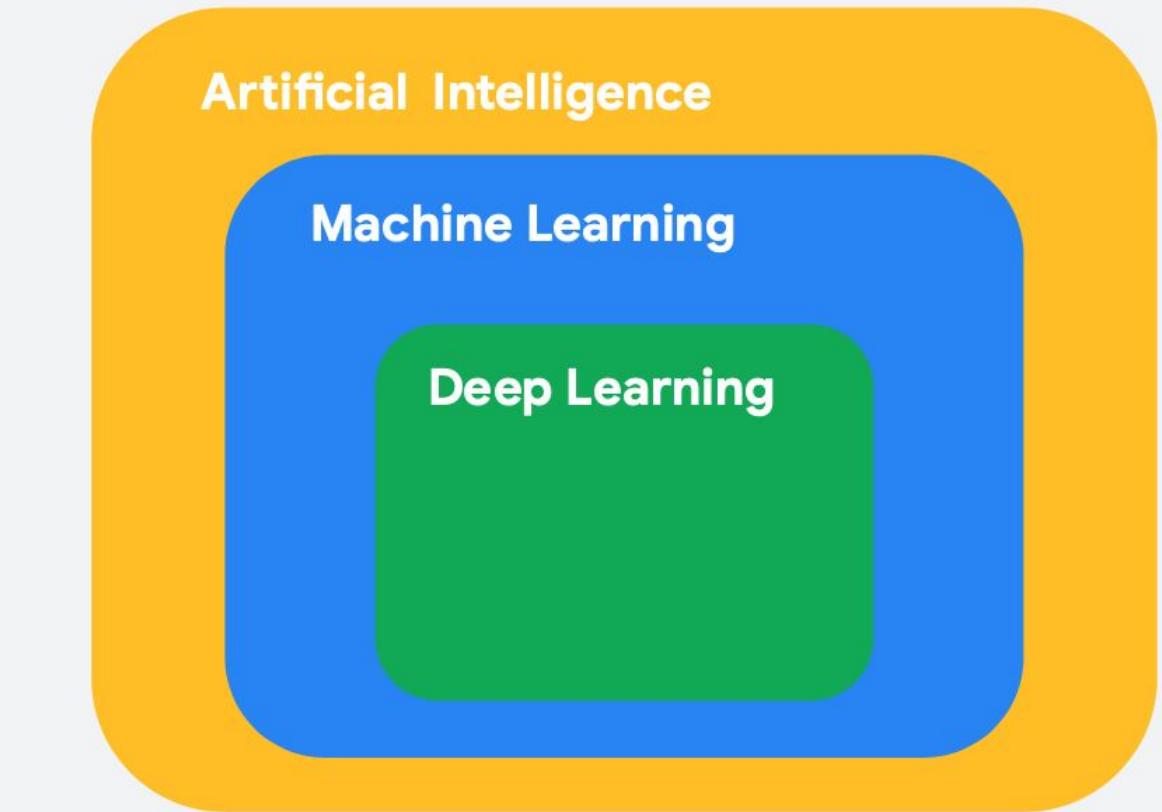


Fastest-growing field of **ML**



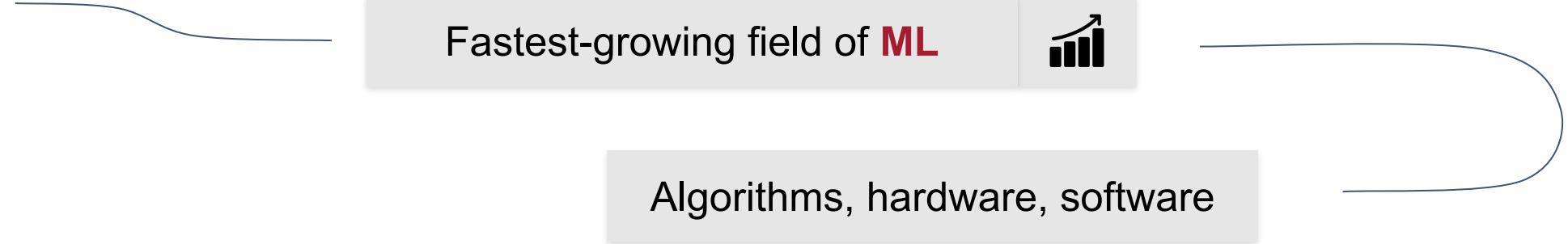
What is (**Deep**) Machine Learning?

1. Machine Learning is a subfield of Artificial Intelligence focused on developing algorithms that learn to solve problems by analyzing data for patterns
2. **Deep Learning** is a type of Machine Learning that leverages **Neural Networks** and **Big Data**



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

TinyML



Fastest-growing field of **ML**



Algorithms, hardware, software

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

TinyML

Fastest-growing field of **ML**



On-device sensor analytics



Algorithms, hardware, software

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

TinyML

Fastest-growing field of **ML**



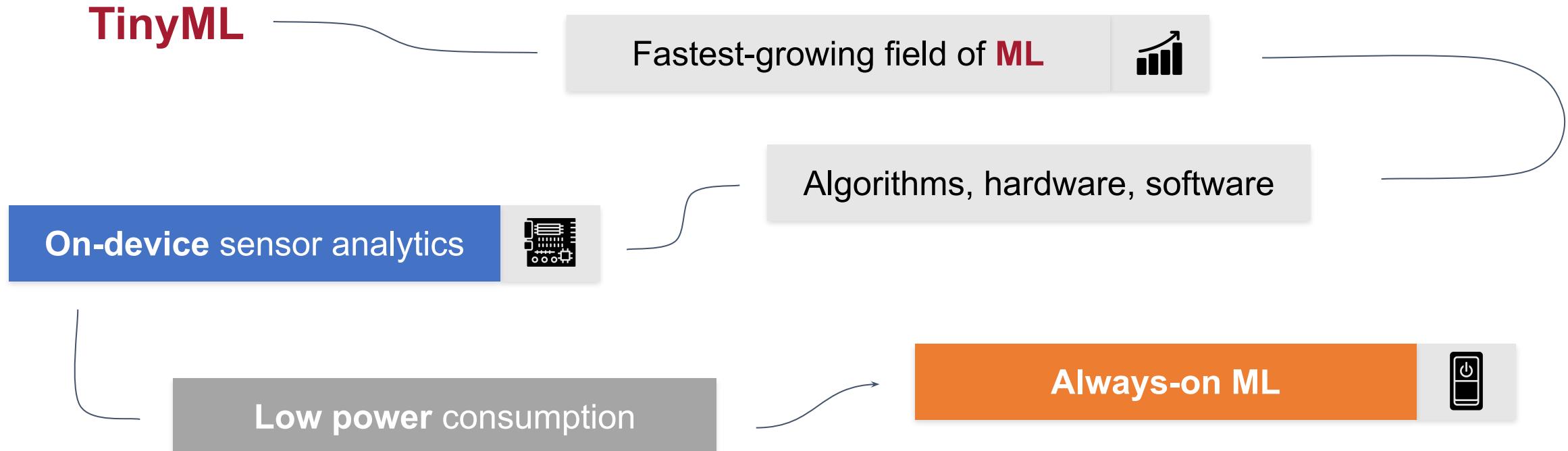
On-device sensor analytics



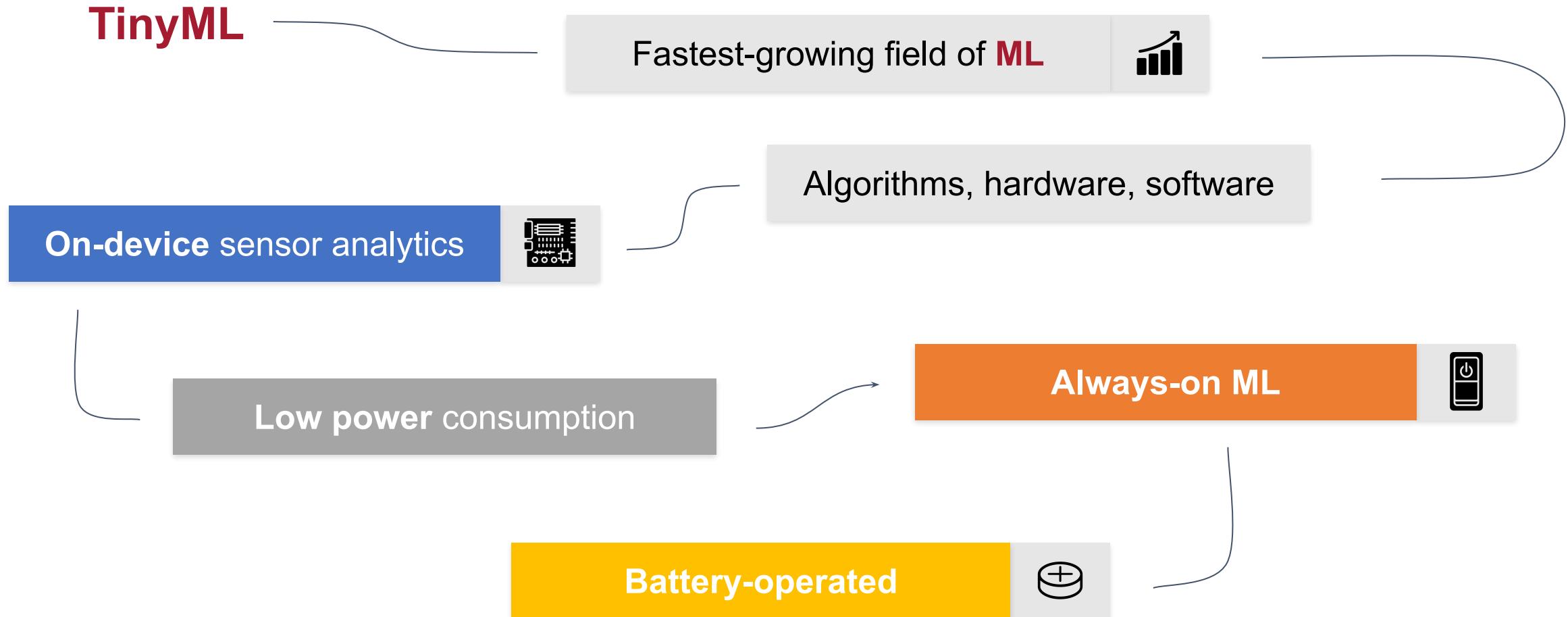
Algorithms, hardware, software

Low power consumption

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



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



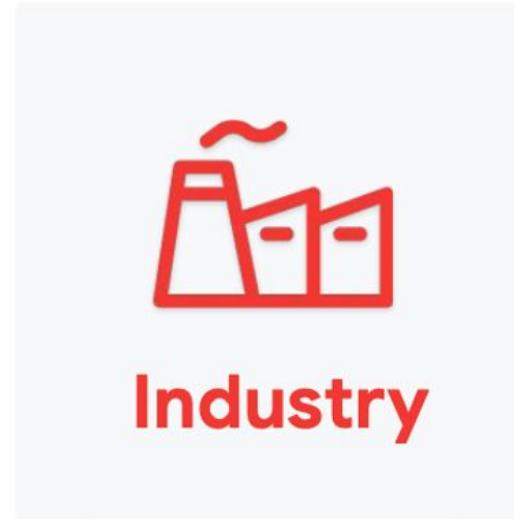
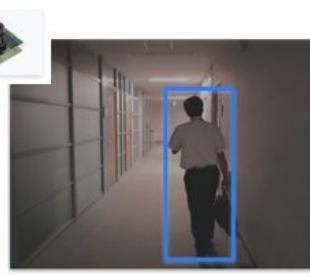
TinyML Application Areas



Home



Office



Industry



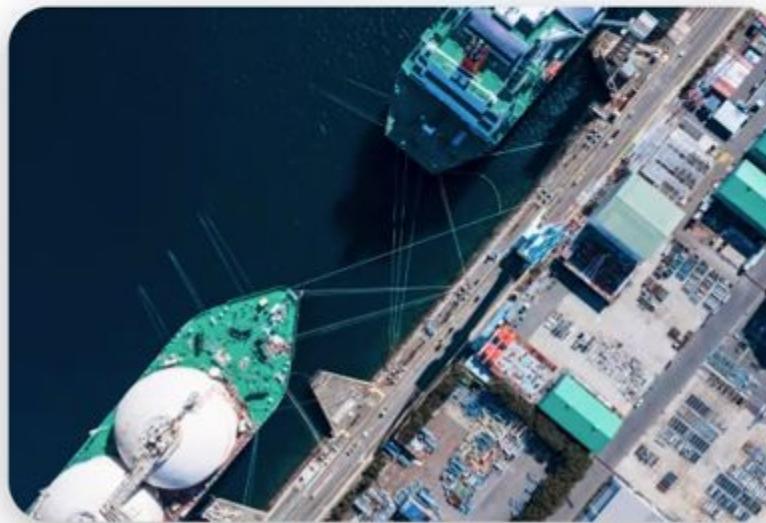
Predictive Maintenance



Motion, current, audio and camera

- Industrial
- White goods
- Infrastructure
- Automotive

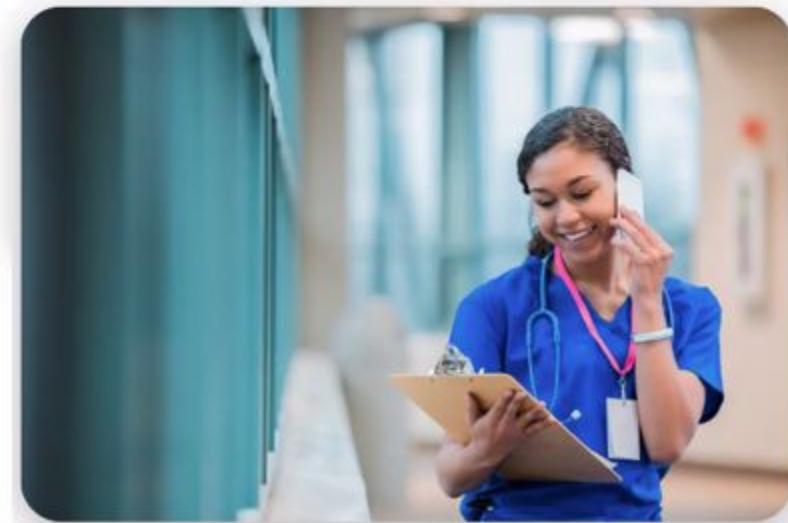
Asset Tracking & Monitoring



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

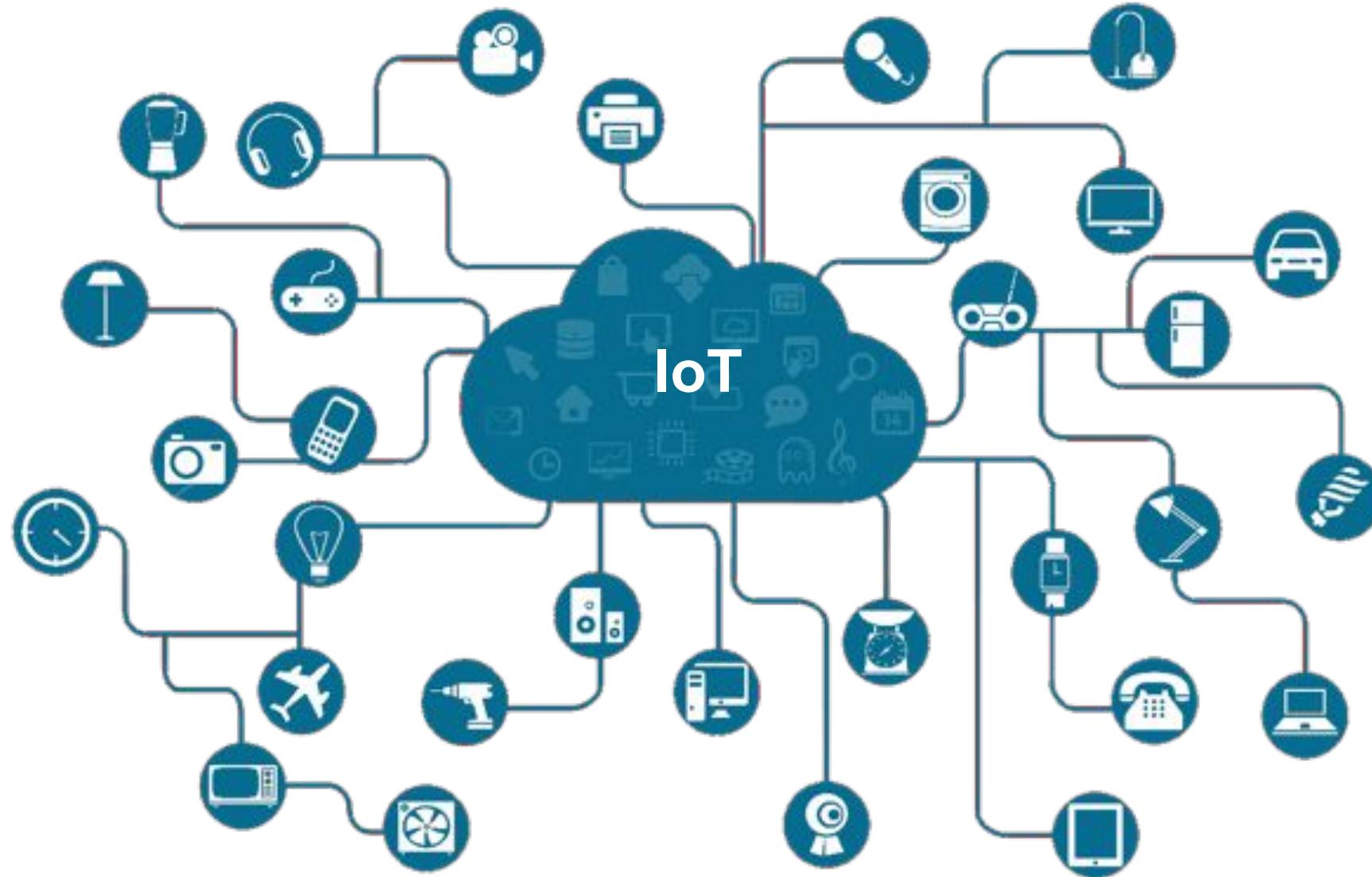
Building The World's Most Advanced [Wildlife Tracker](#).



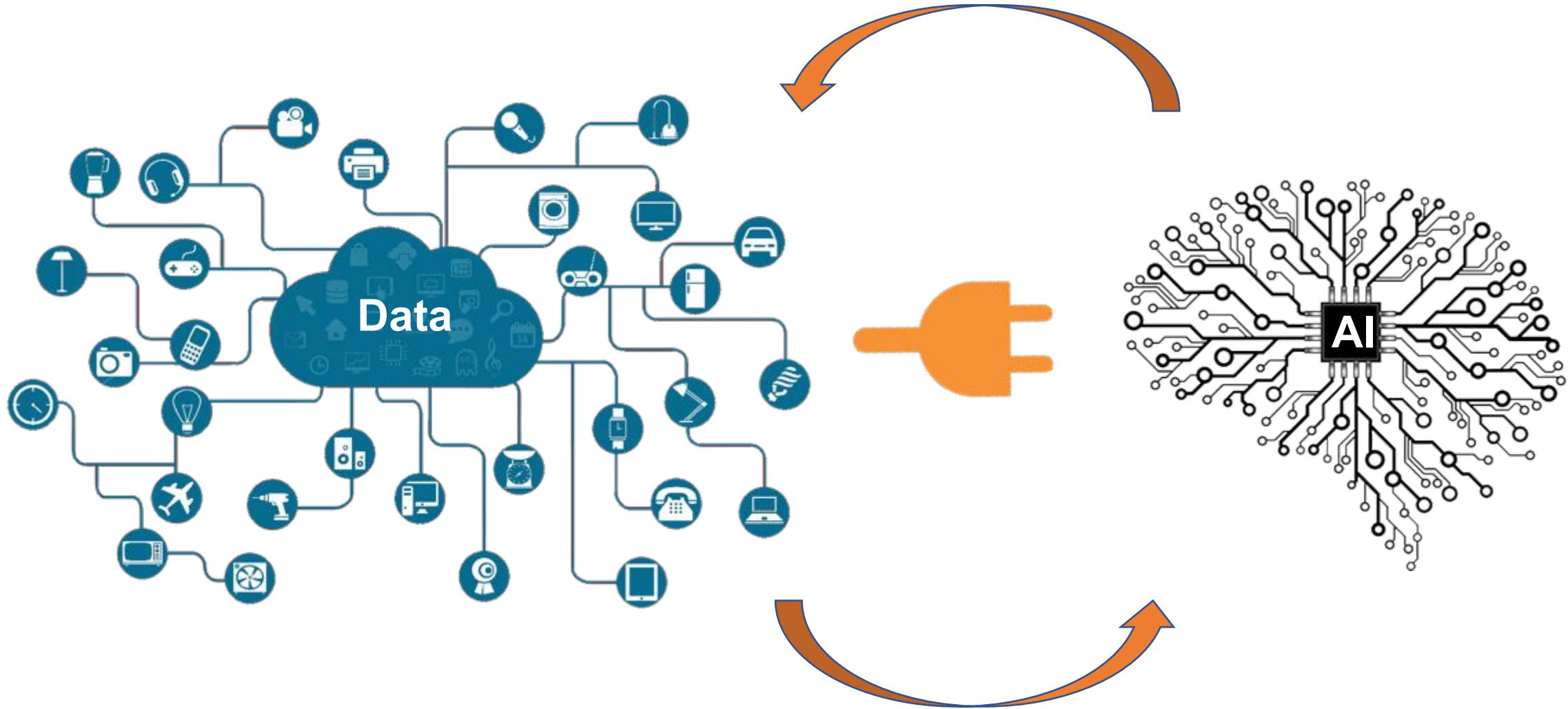
[ElephantEdge: A New Neural Wildlife Tracker,](#)
[Powered by Edge Impulse](#)



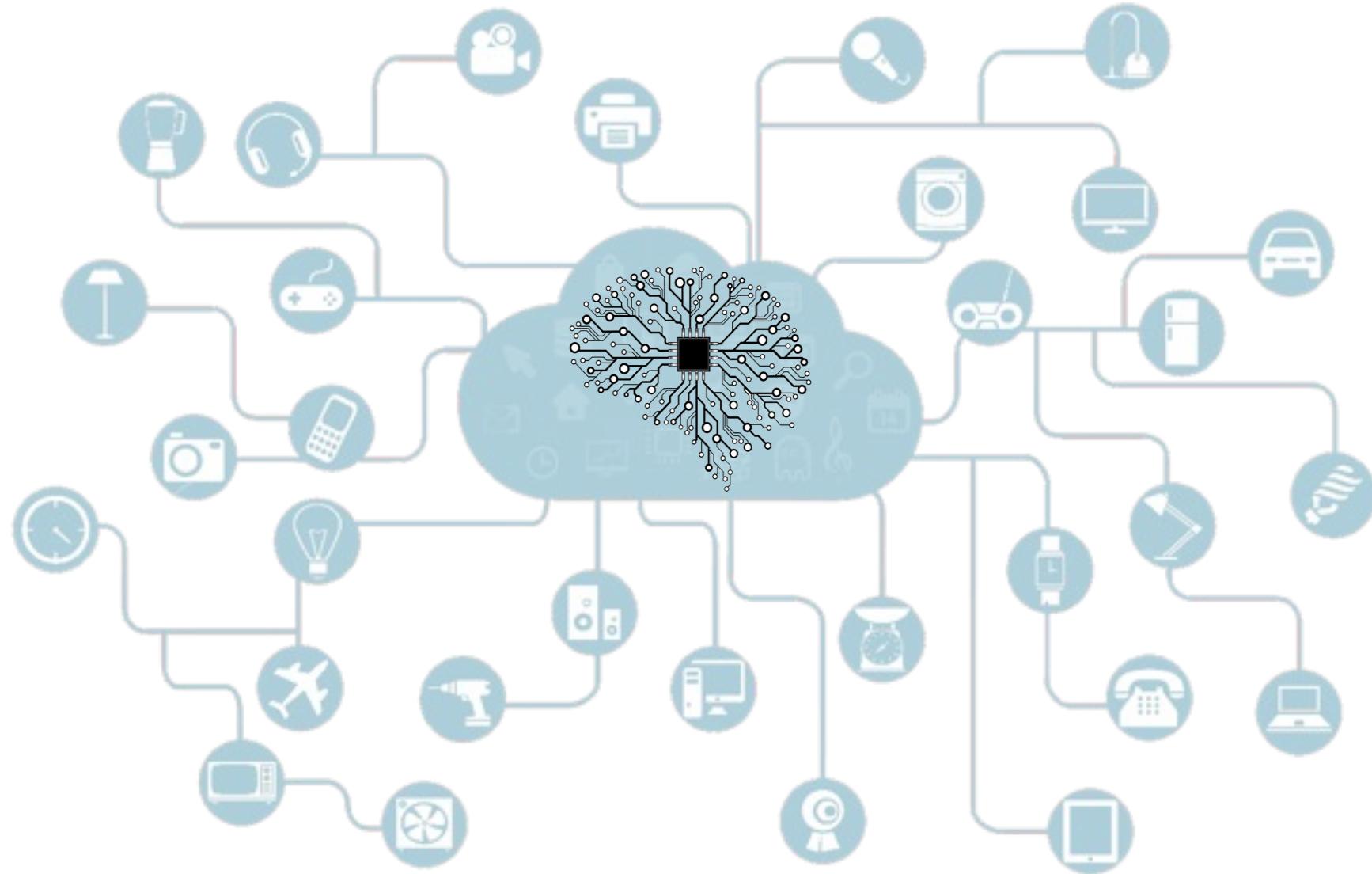
IoT - Architecture



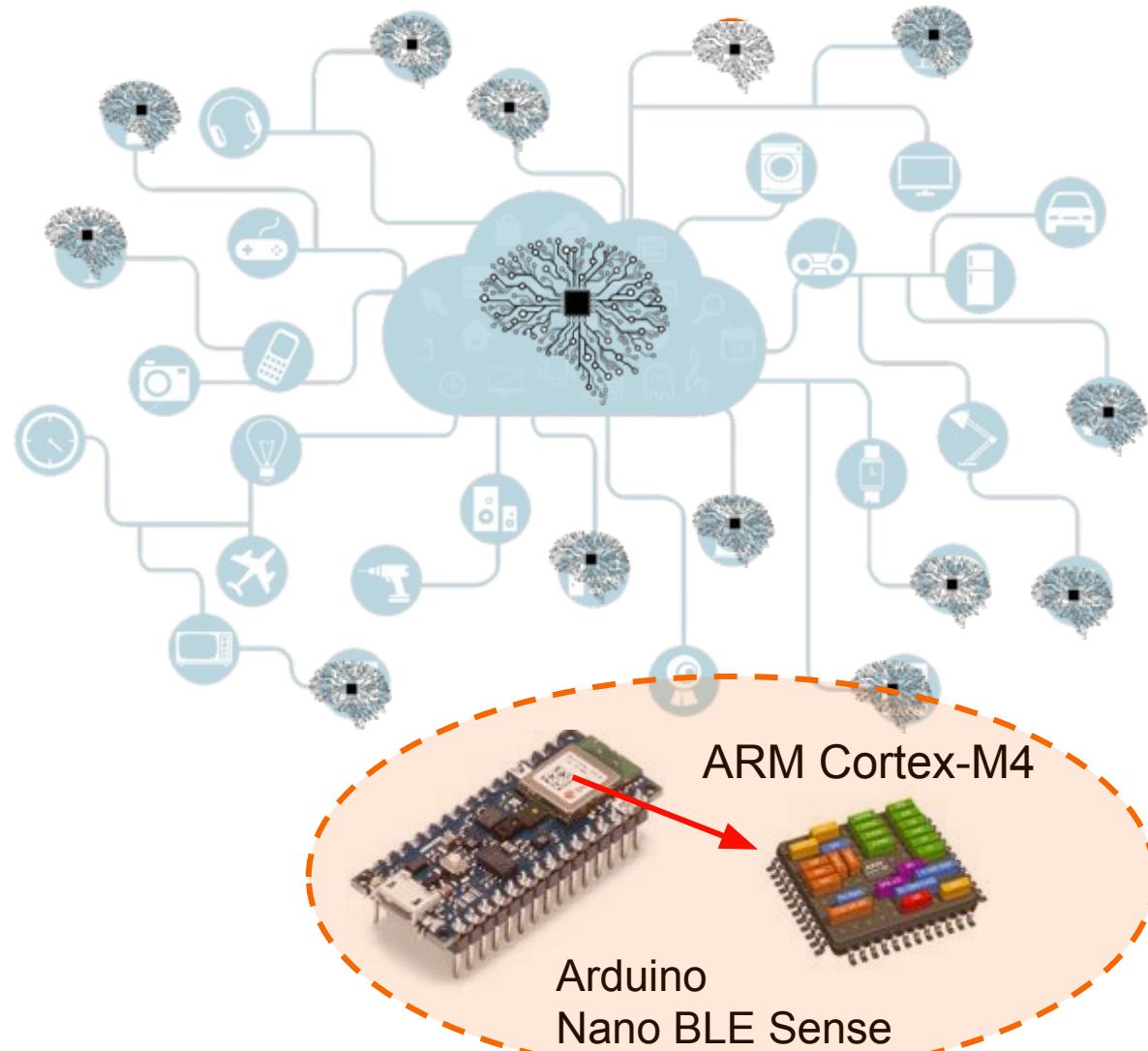
Endpoints devices → Data + AI → Value



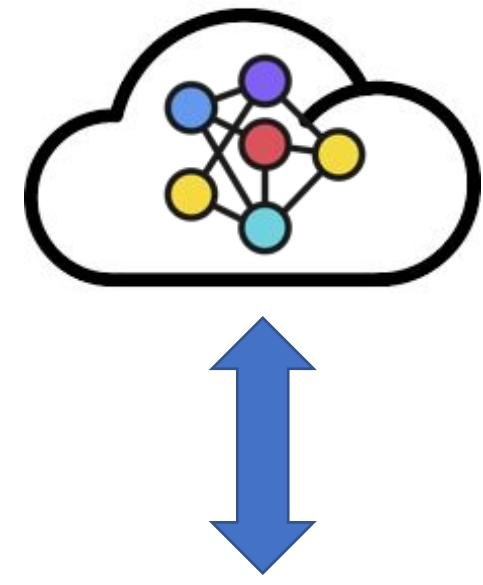
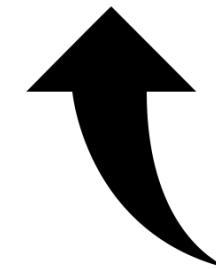
AI + IOT = Alot



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

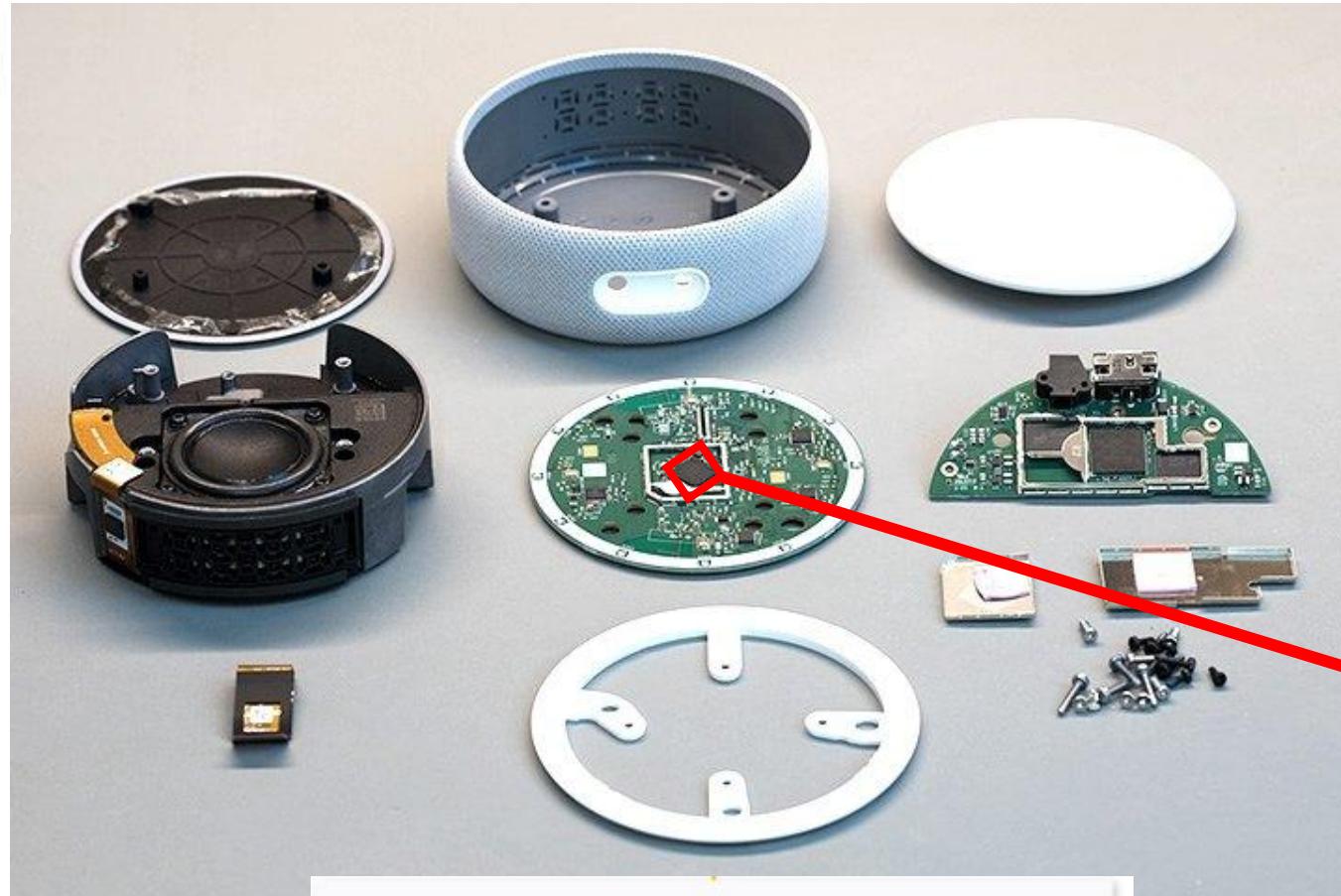


TinyML enables machine intelligence right next to the physical world



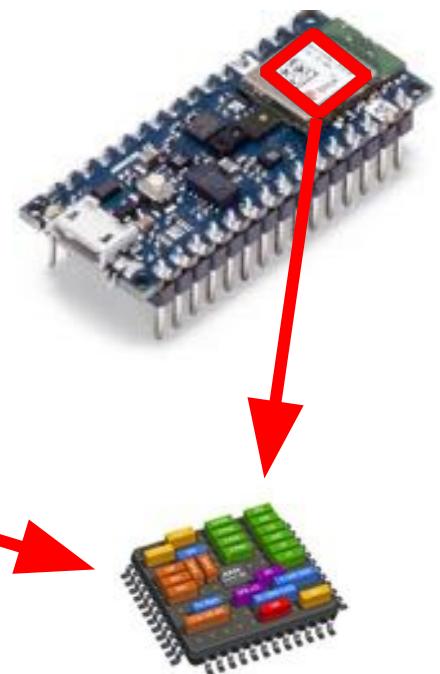
ML at microprocessor level avoid issues as Latency, Power Consuming, and Security

Echo-Dot Teardown vs Arduino Nano BLE Sense



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

Nordic nRF52840-M4

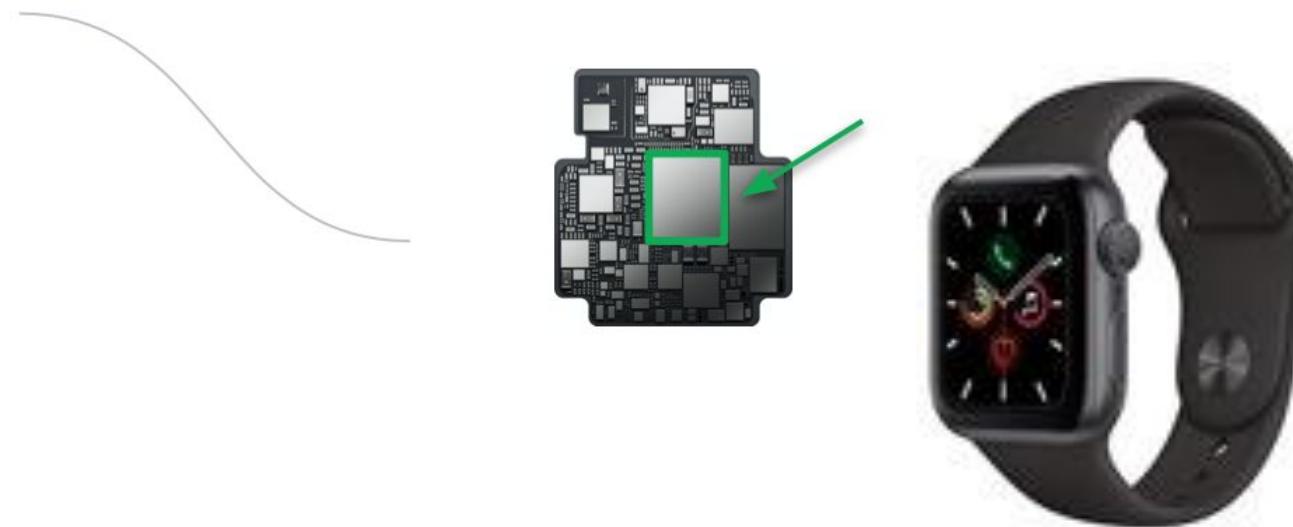


MCUs enable **TinyML**

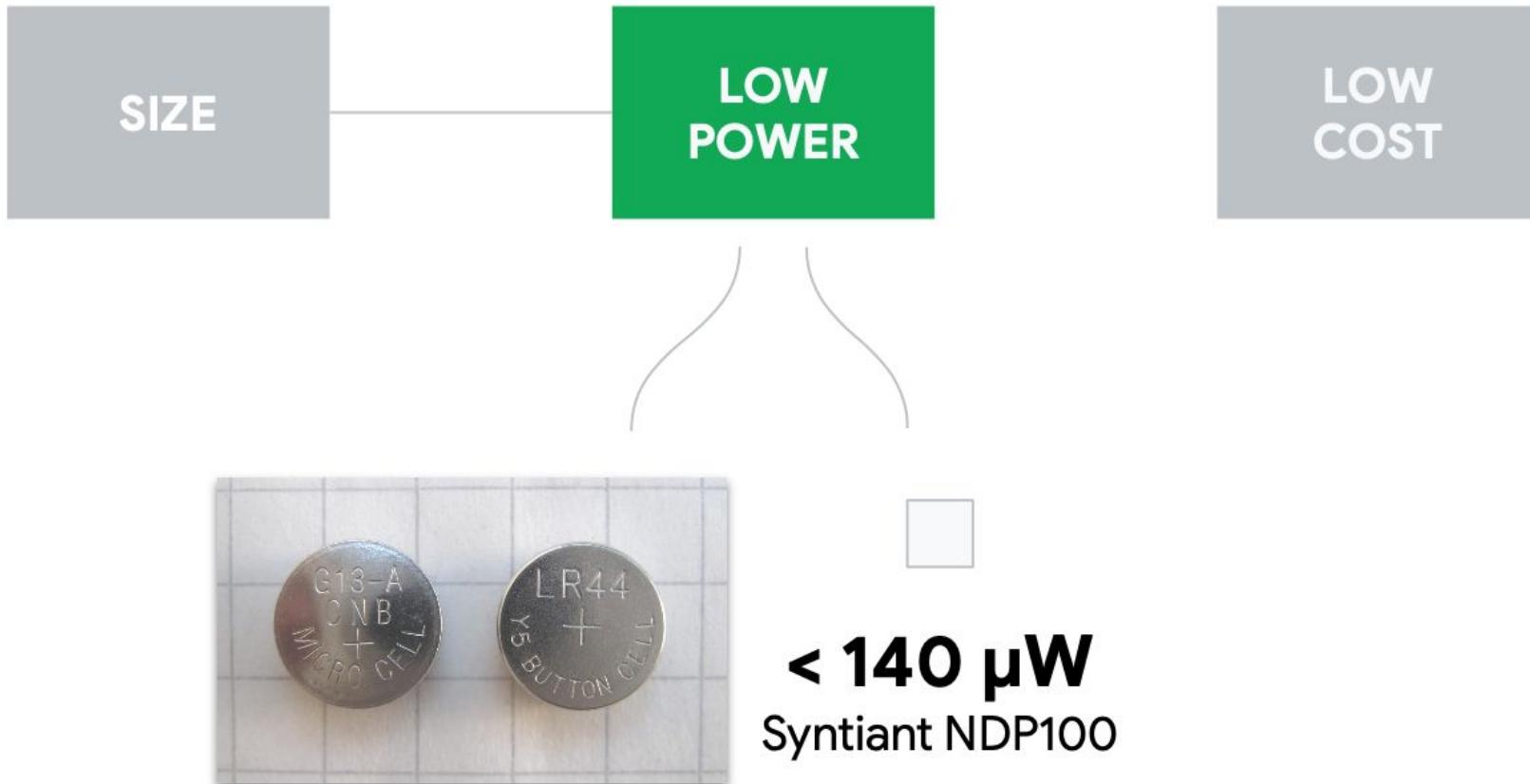
SIZE

LOW
POWER

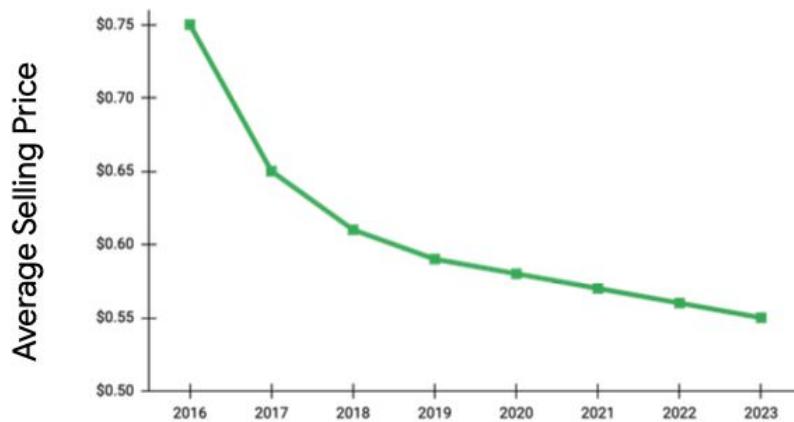
LOW
COST



MCUs enable **TinyML**



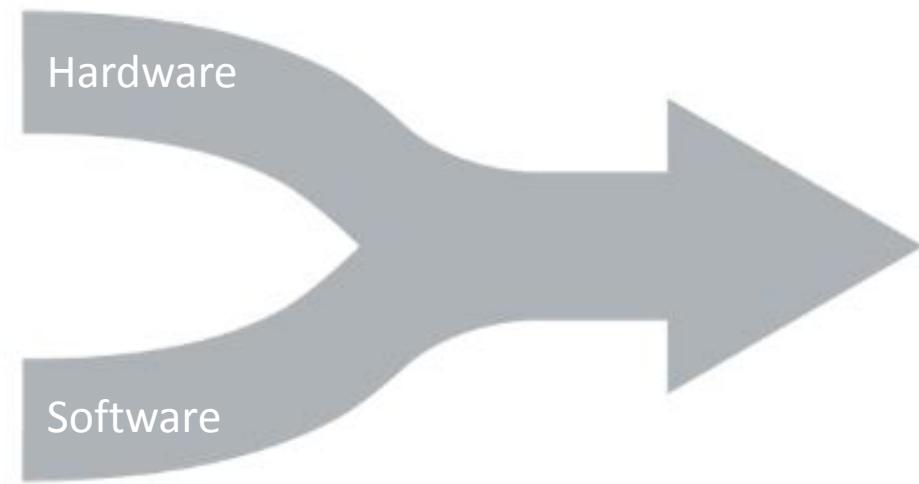
MCUs enable **TinyML**



What Makes **TinyML**?

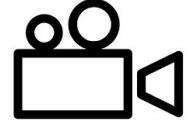
**Embedded
Systems**

**Machine
Learning**



TinyML

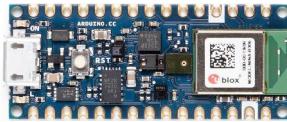
Hardware



Anomaly Detection
Sensor Classification
20 KB



Rpi-Pico
(Cortex-M0+)



Arduino Nano
(Cortex-M4)



Arduino Pro
(Cortex-M7)

Source: Edge Impulse

EdgeML

TinyML

KeyWord Spotting
Audio Classification
50 KB

Image
Classification
250 KB+



Video
Classification
2 MB+

Object Detection
Complex Voice
Processing
1 MB+



RaspberryPi
(Cortex-A)

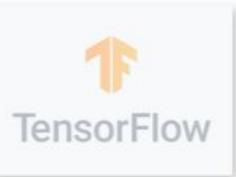


SmartPhone
(Cortex-A)



Jetson Nano
(Cortex-A + GPU)

Software



Train a model



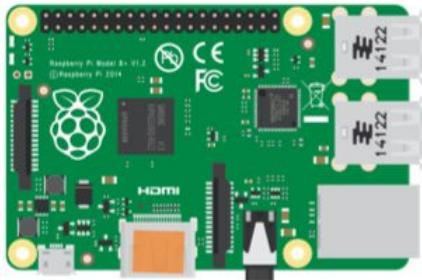
TensorFlow Lite

Convert
model

Optimize
model

Deploy
model at
Edge

Make
inferences
at Edge



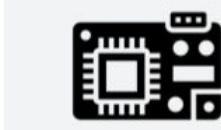
Raspberry Pi



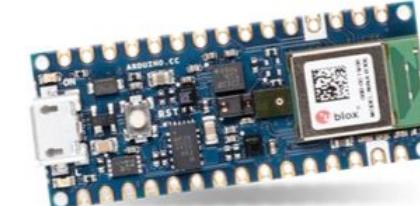
Linux



iOS



(TFL Micro)



Microcontroller

TinyML Application Examples

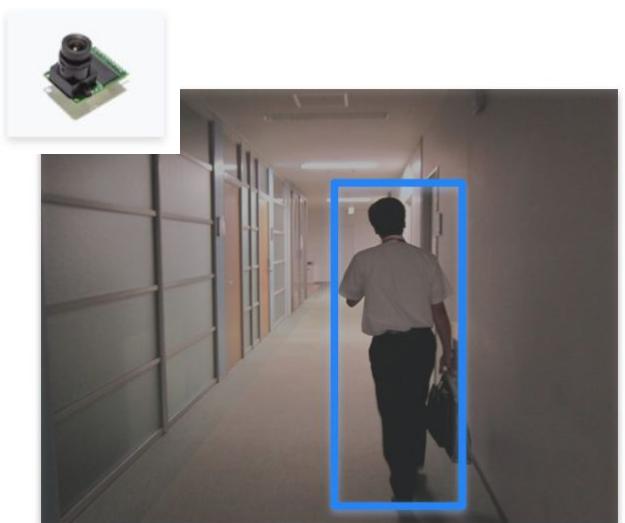
Sound



Vibration



Vision



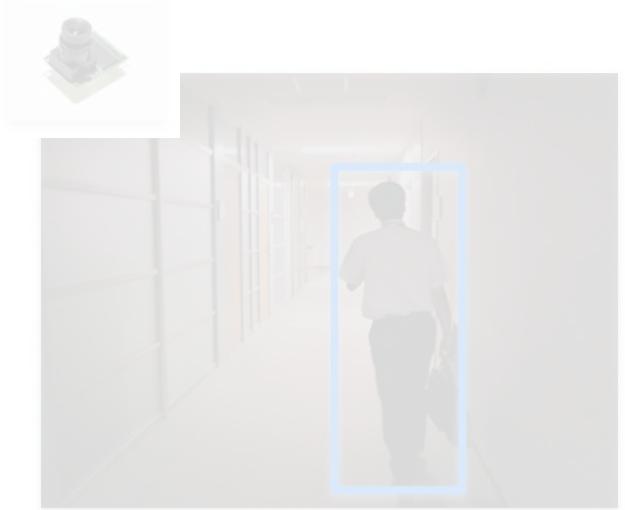
Sound



Vibration



Vision









More than just voice

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



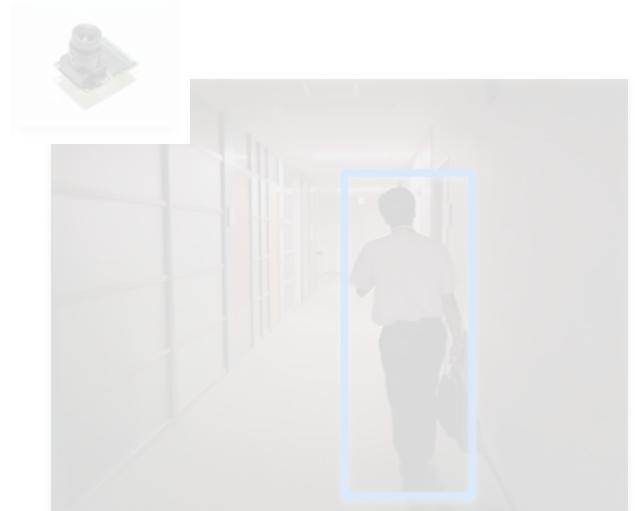
Sound



Vibration



Vision



Cow Monitoring

Using the Internet of Things for Agricultural Monitoring

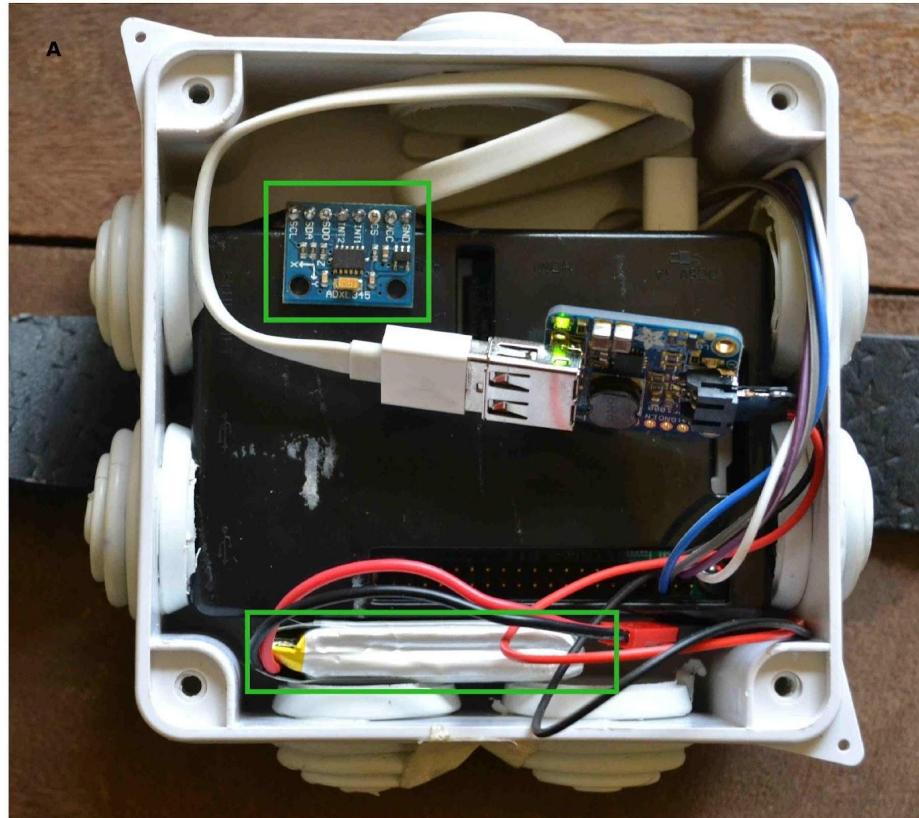
"We aim to deploy a variety of sensors for agricultural monitoring. One of the projects involves using **accelerometer sensors** to monitor activity levels in dairy cows with a view to determining when the cows are on heat or when they are sick."



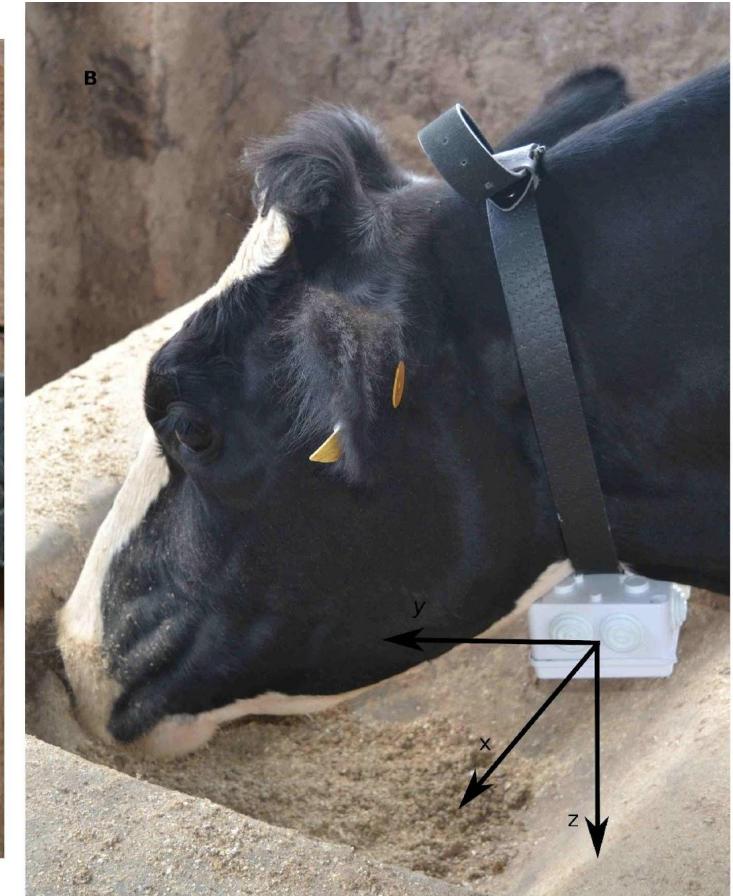
Ciira wa Maina, Ph.D.

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



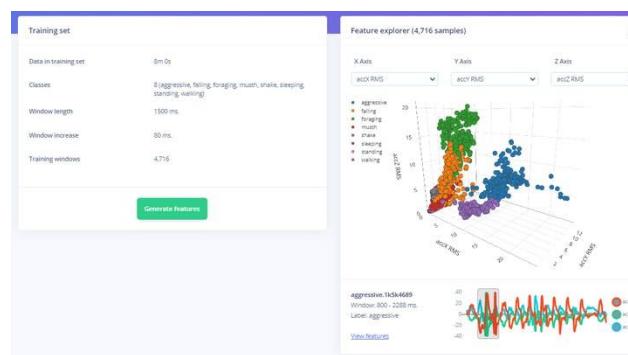
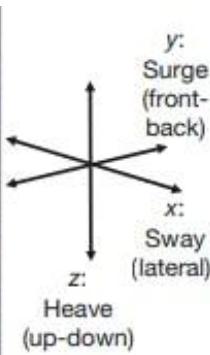
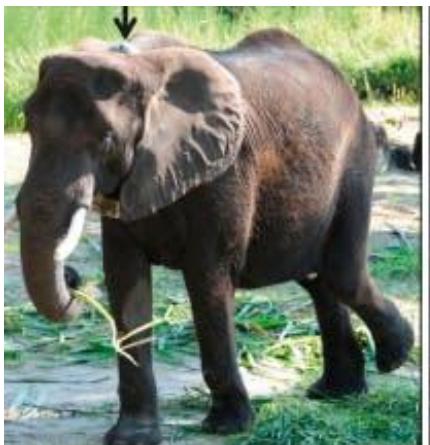
Aggressive



Standing



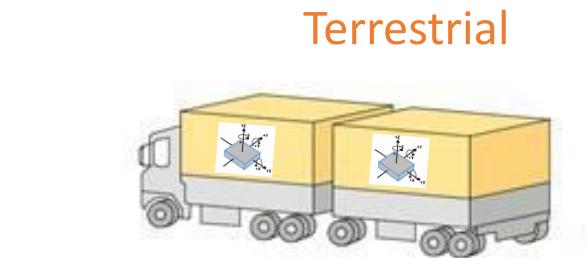
Sleeping



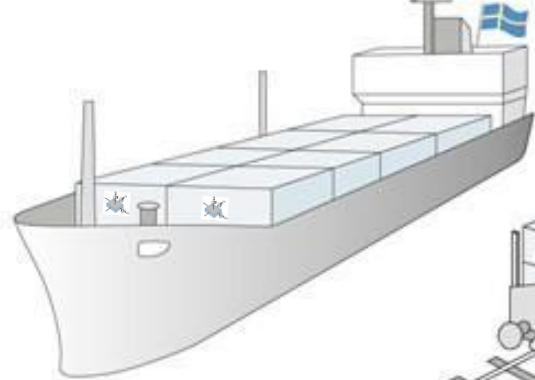
https://www.hackster.io/dhruvsheth_elect-tinyml-and-iot-based-smart-wildlife-tracker-c03e5a



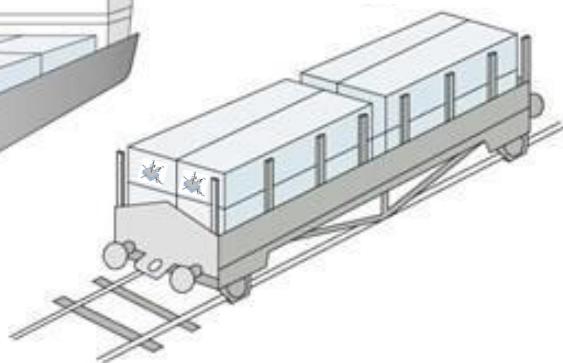
Mechanical Stresses in Transport



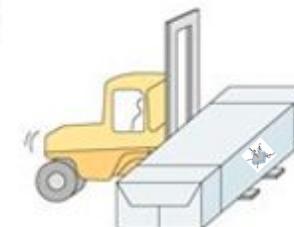
Terrestrial



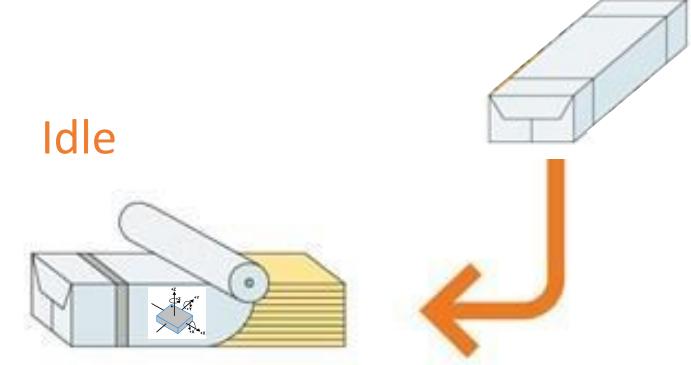
Maritime



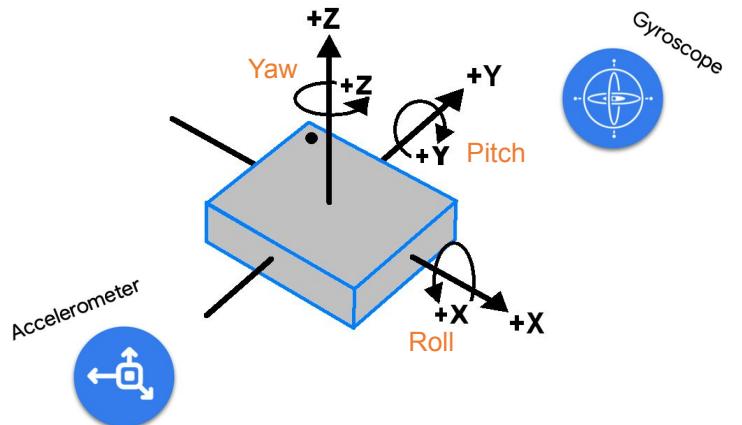
Rail



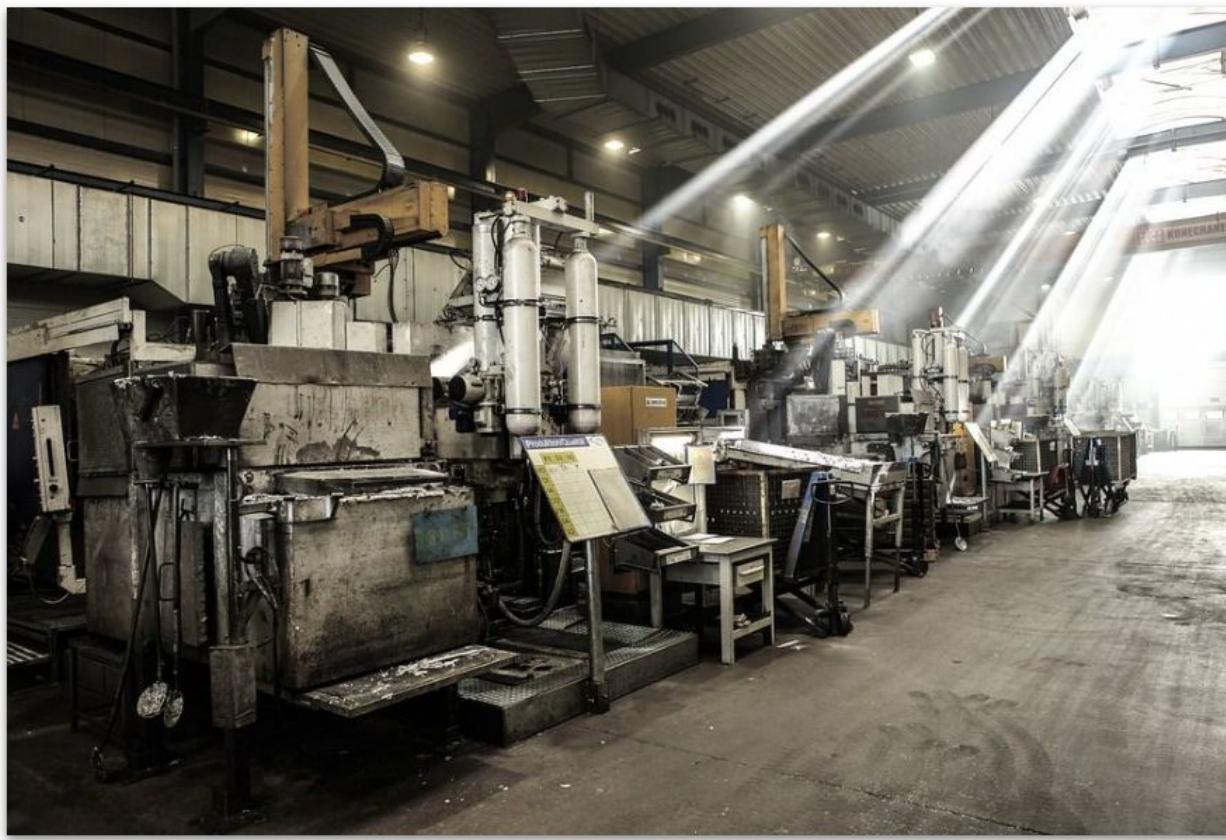
Fork-Lift



Idle



Application: Factory machinery



Ball Bearings

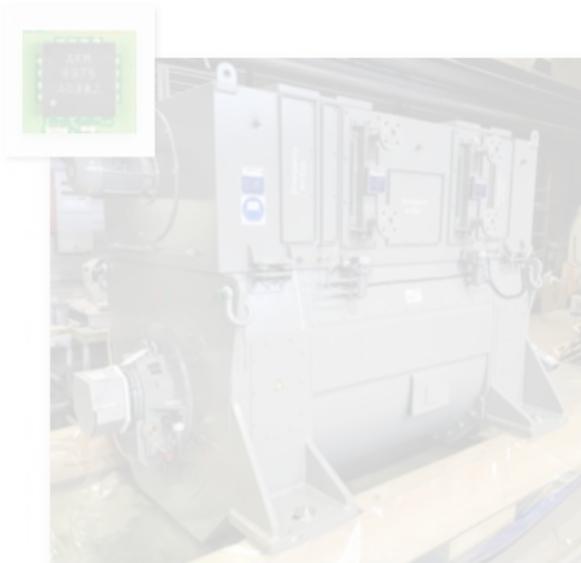


Accelerometer

Sound



Vibration



Vision

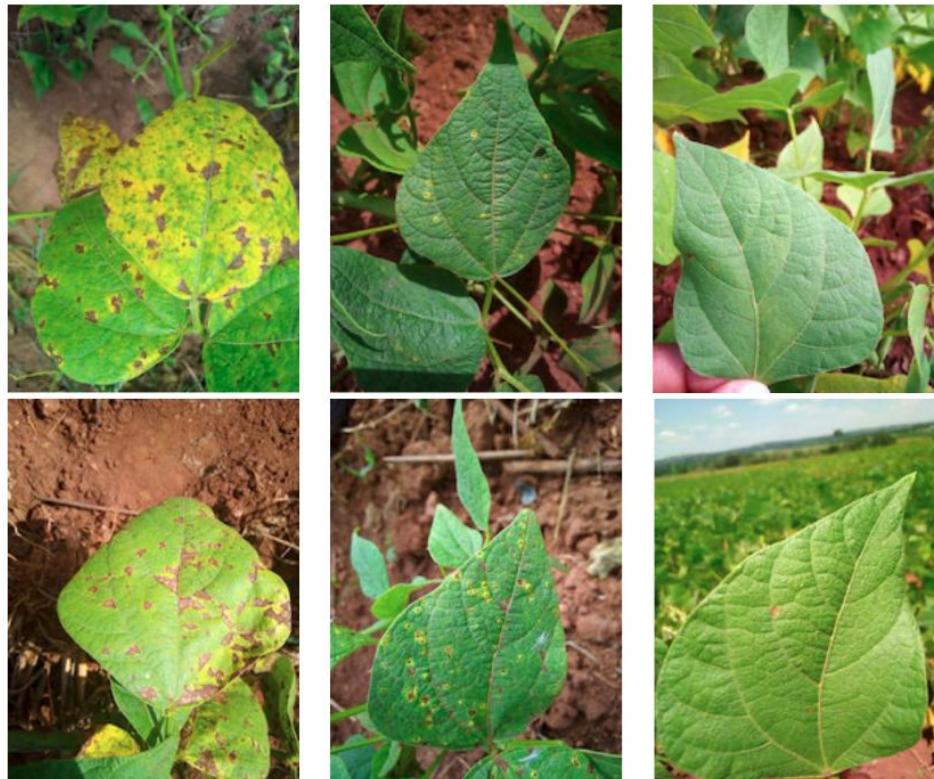


Detecting Diseases in the Bean plants



AIR Lab Makerere University

UGANDA

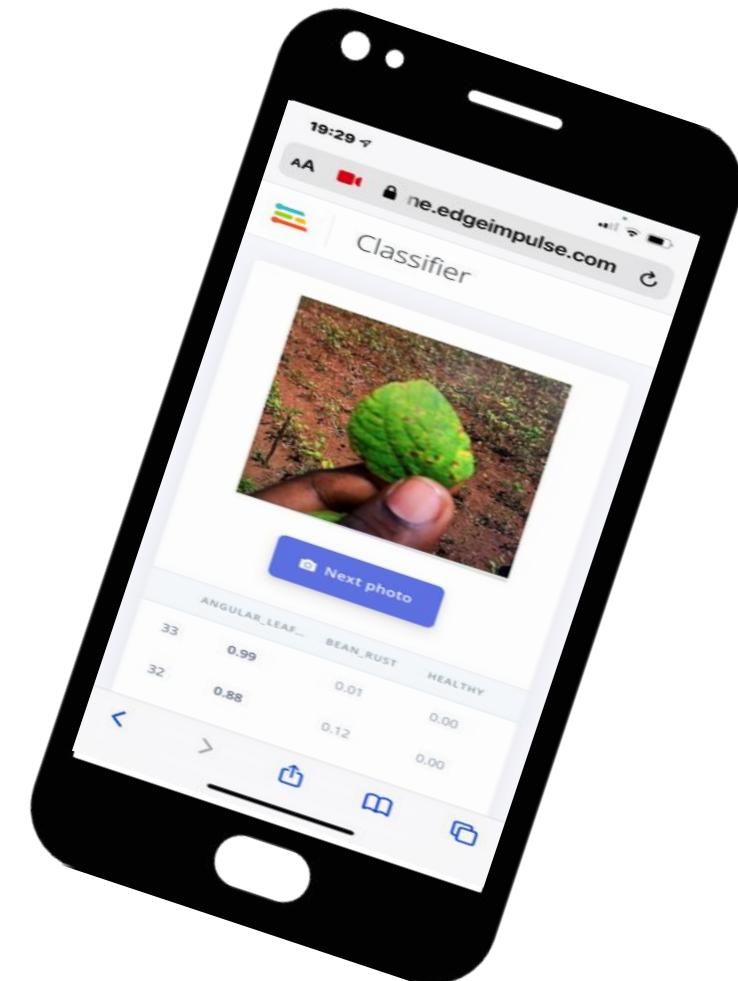


Angular Leaf Spot

Bean Rust

Healthy

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

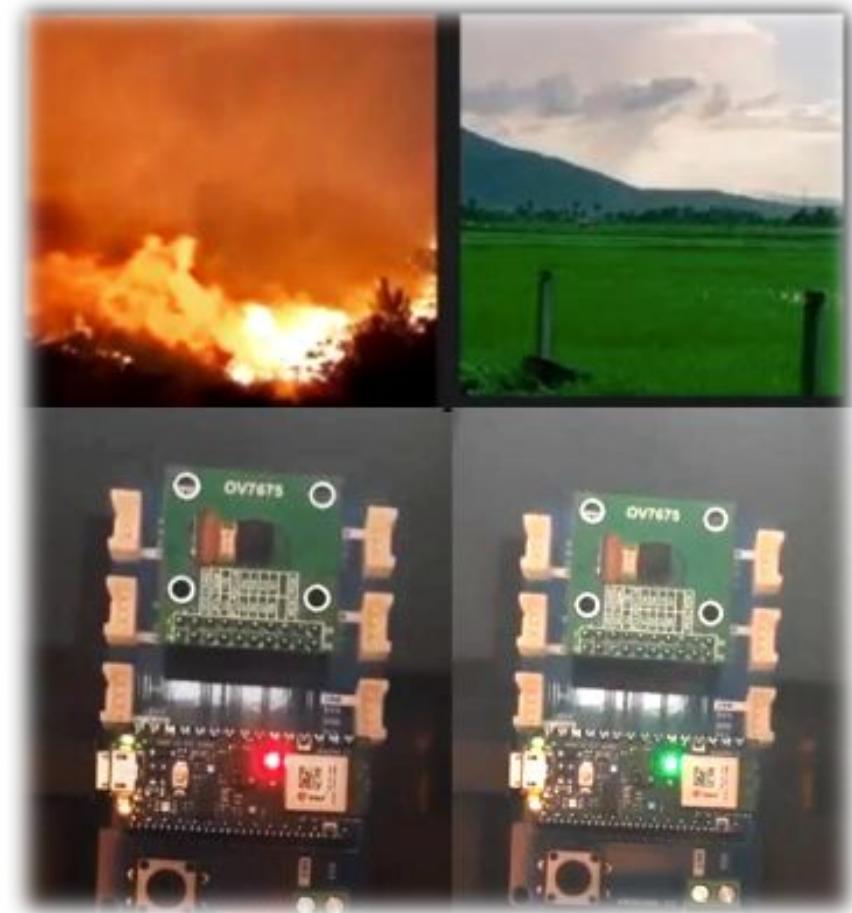


Learn the steps to build an app that detects crop diseases

Forest Fire Detection



TinyML Aerial Forest Fire Detection



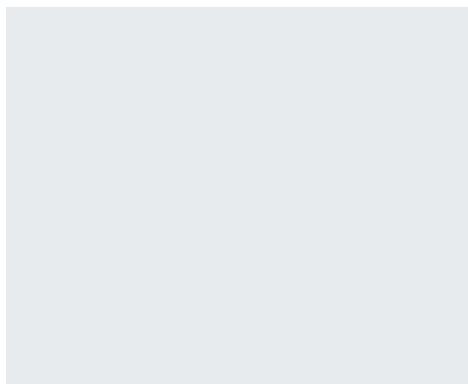
IESTI01 - Forest Fire Detection – Proof of Concept



Person Detection



Person Detection

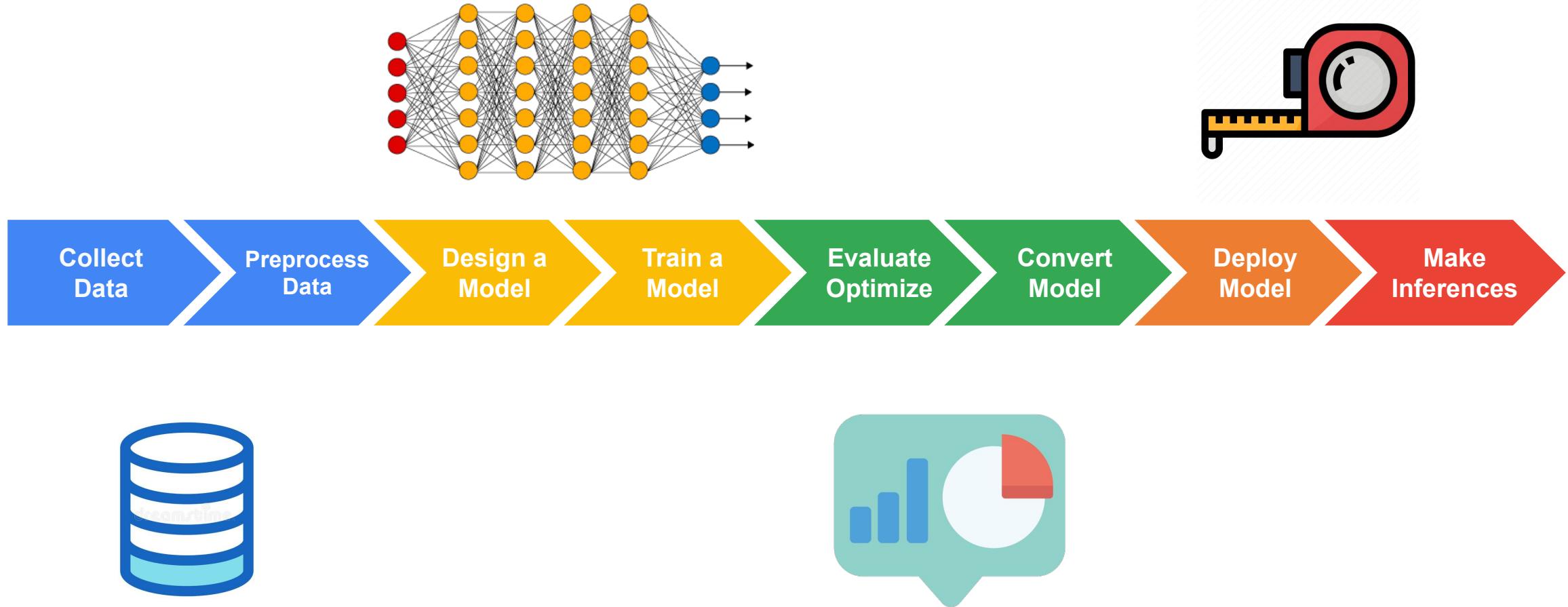


Mask Detection

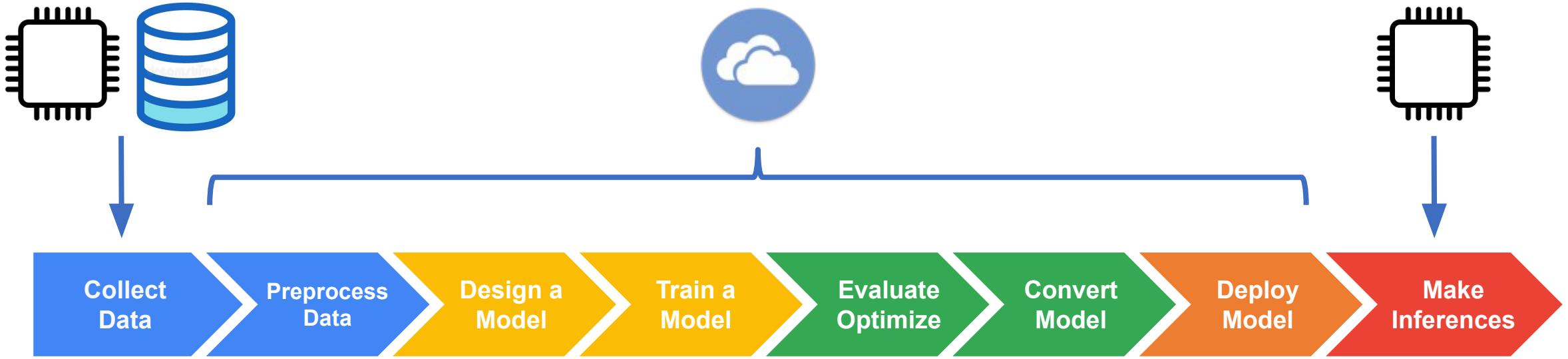


How to Train a ML Model?

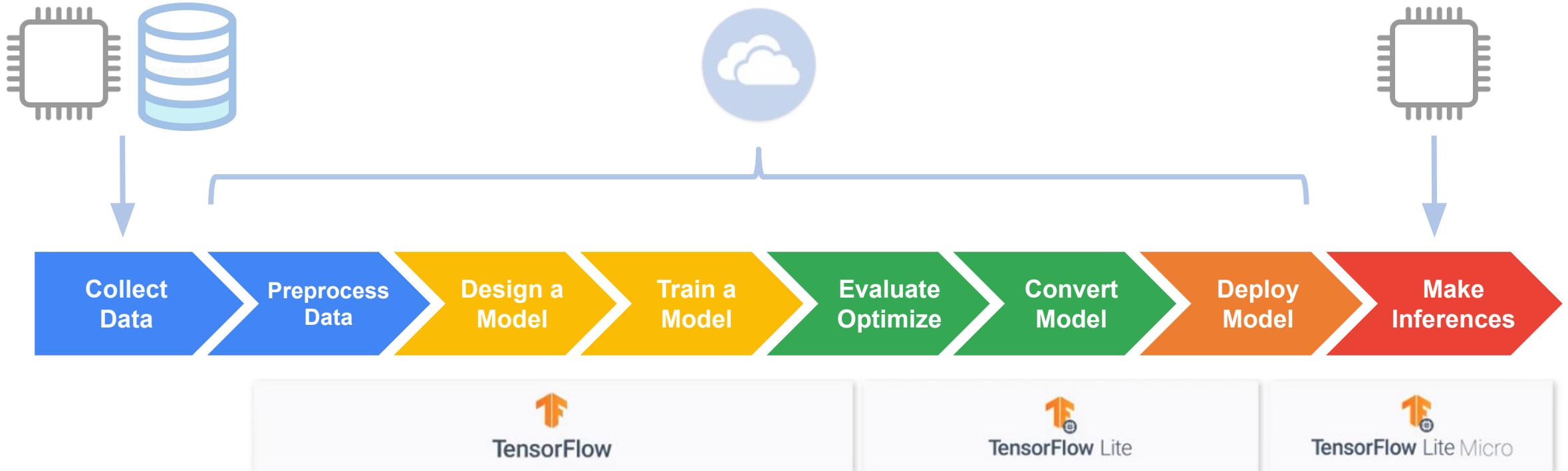
Machine Learning Workflow (“What”)



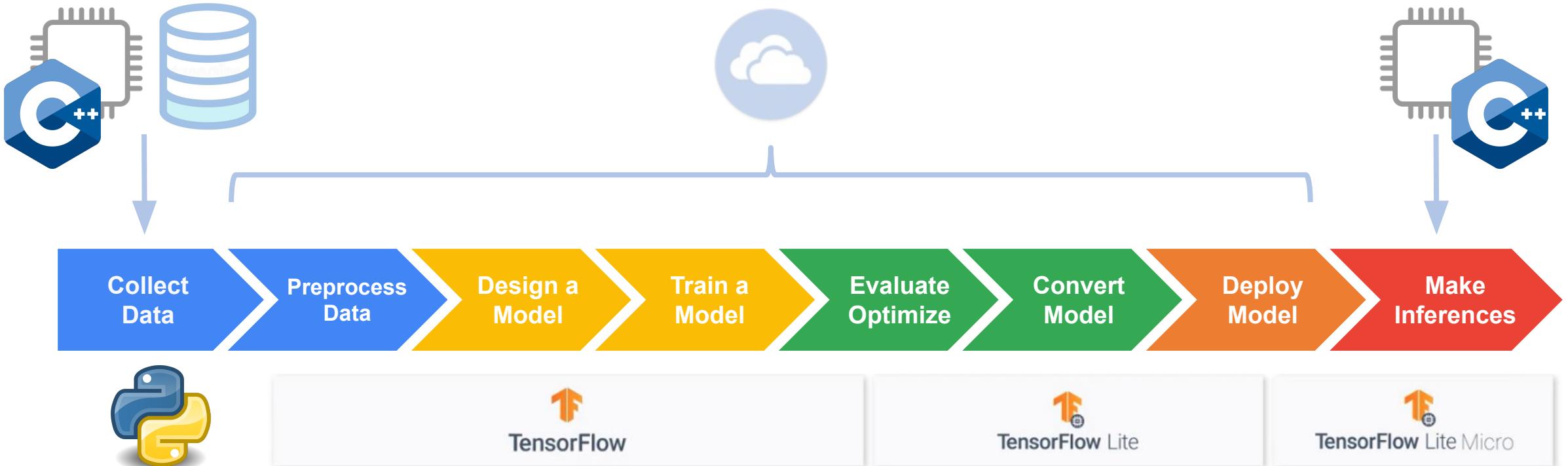
Machine Learning Workflow (“Where”)



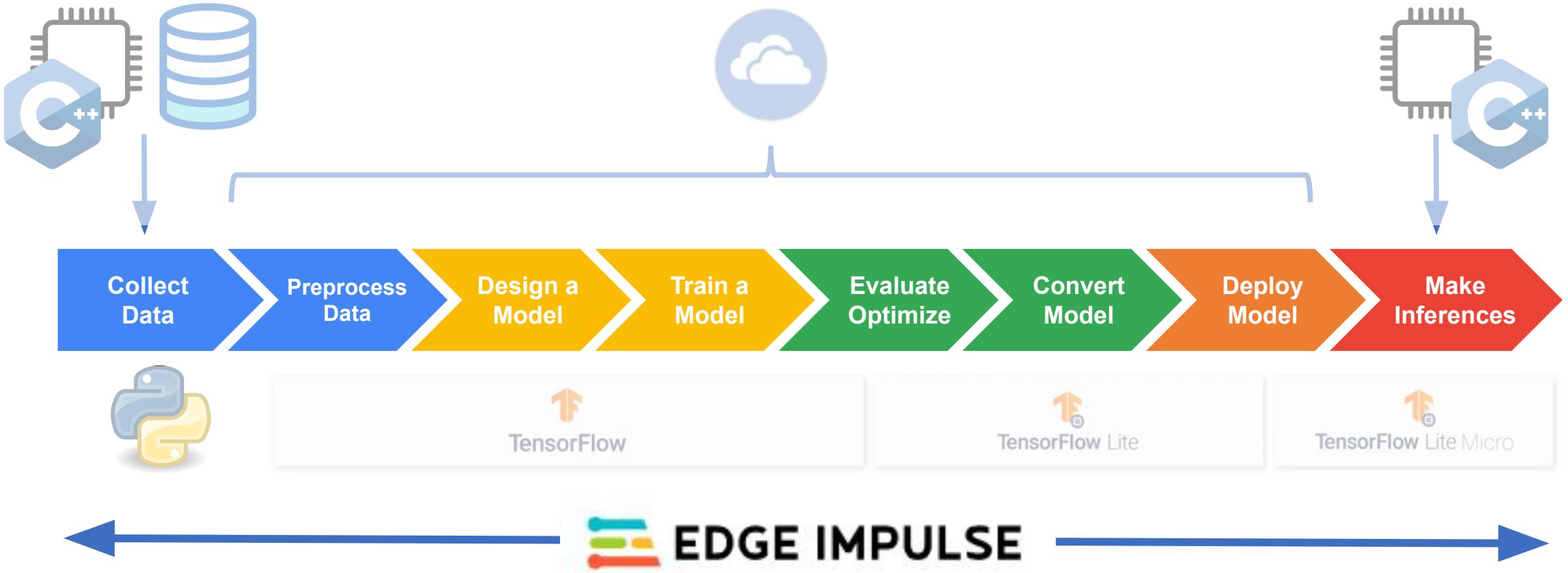
Machine Learning Workflow (“How”)



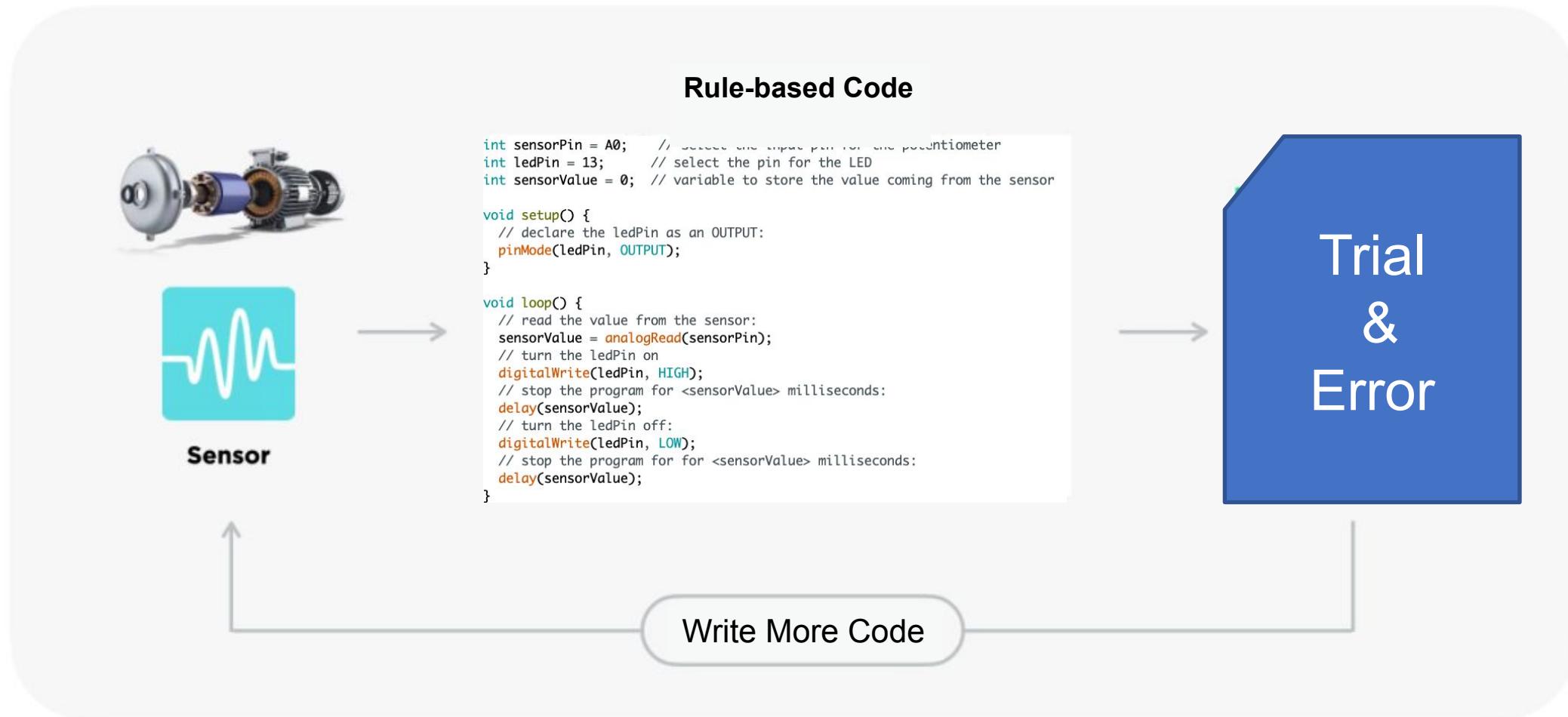
Machine Learning Workflow (“How”)



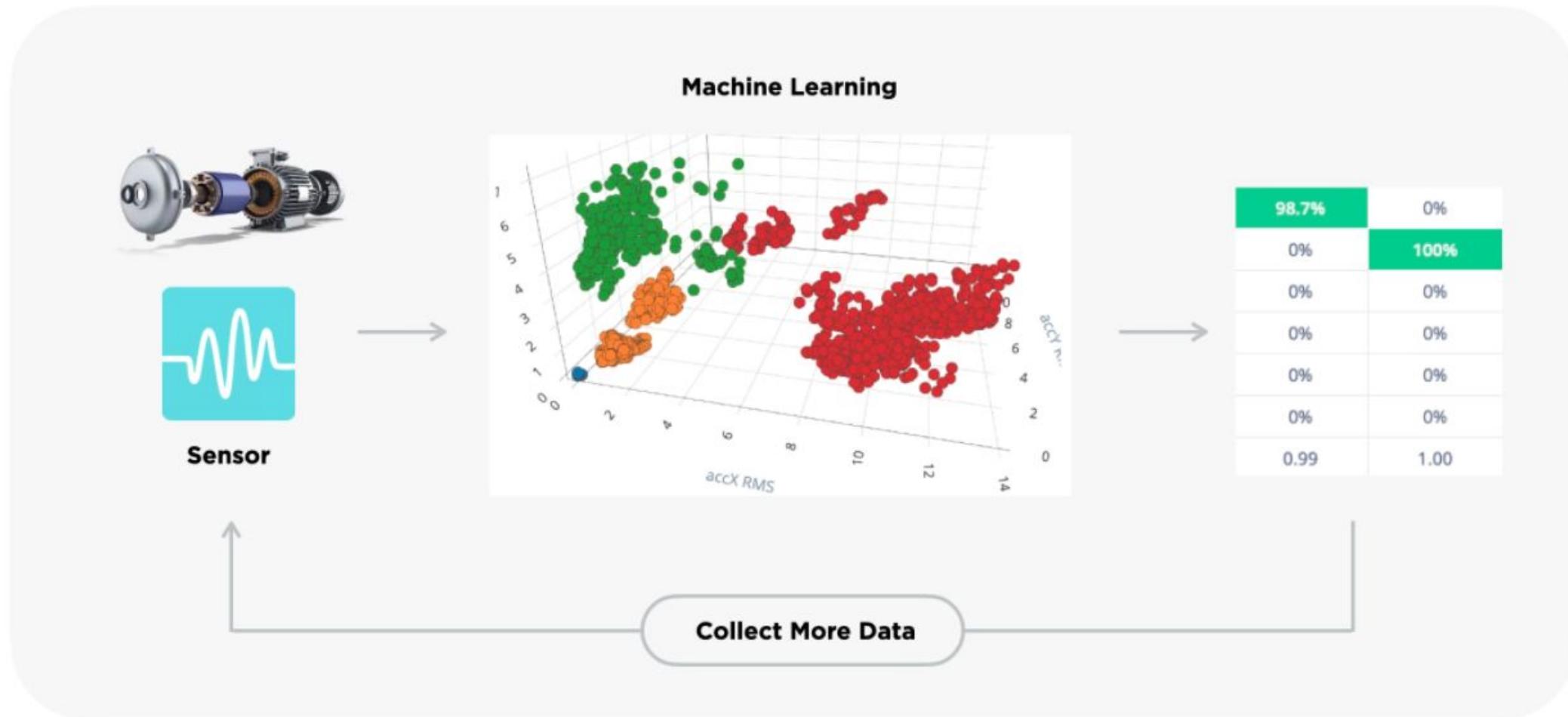
Machine Learning Workflow (“How”)

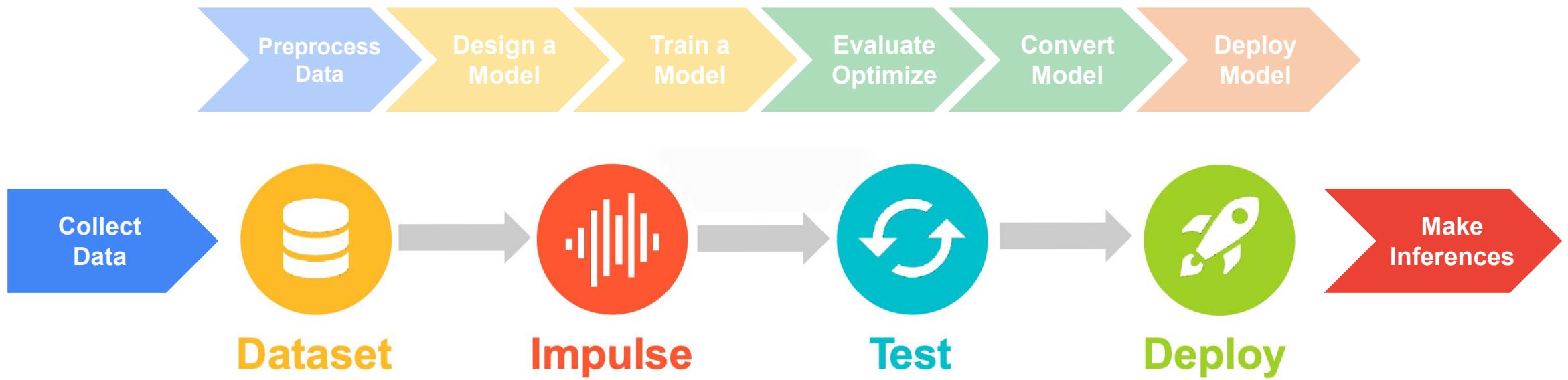


From rule-based engineering to...

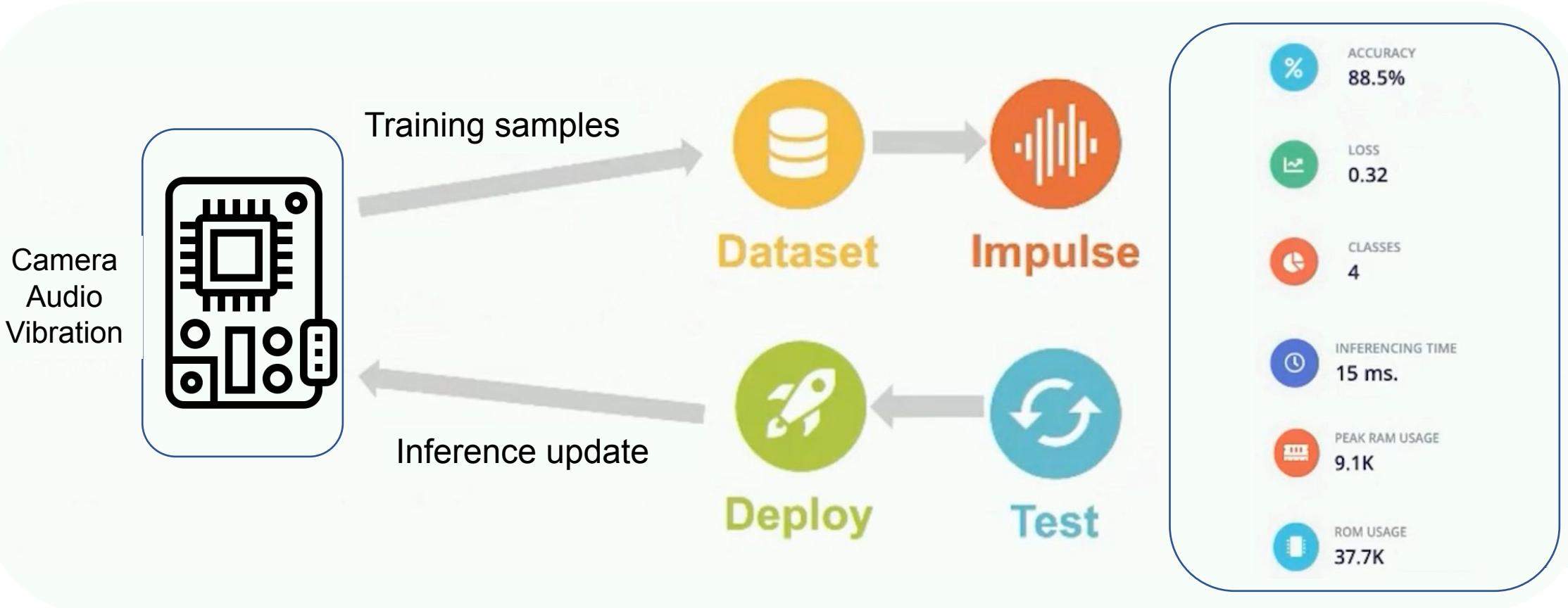


Data-driven engineering

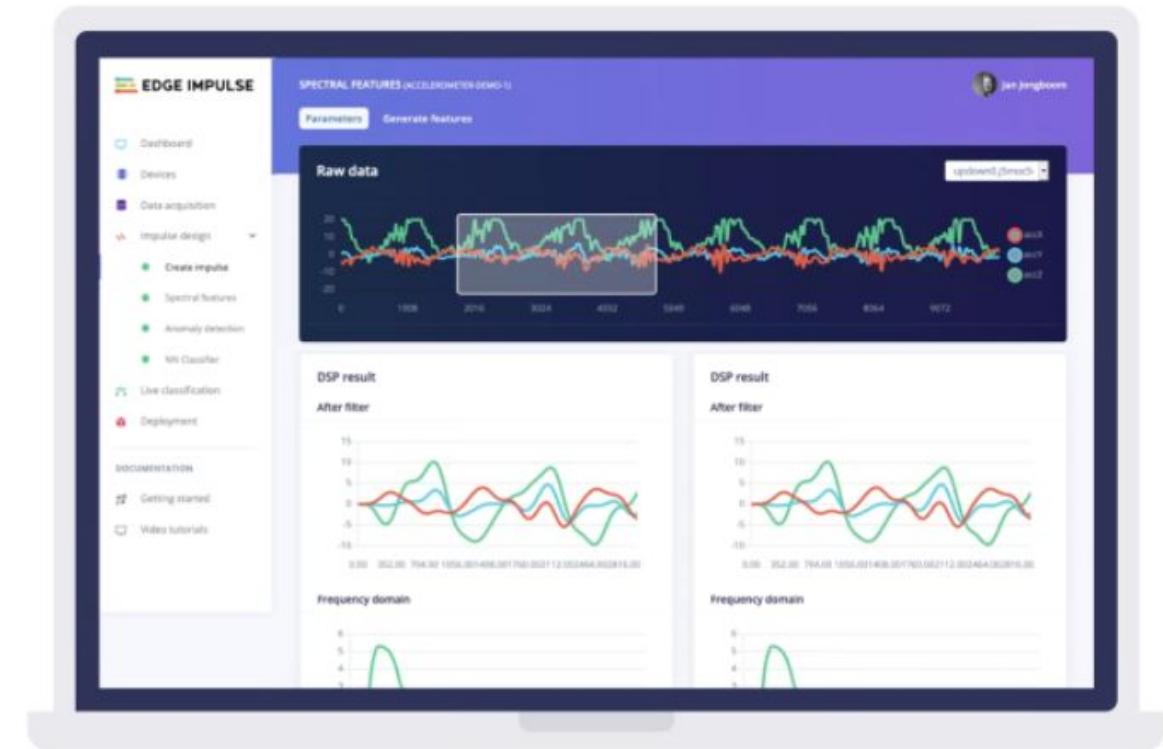
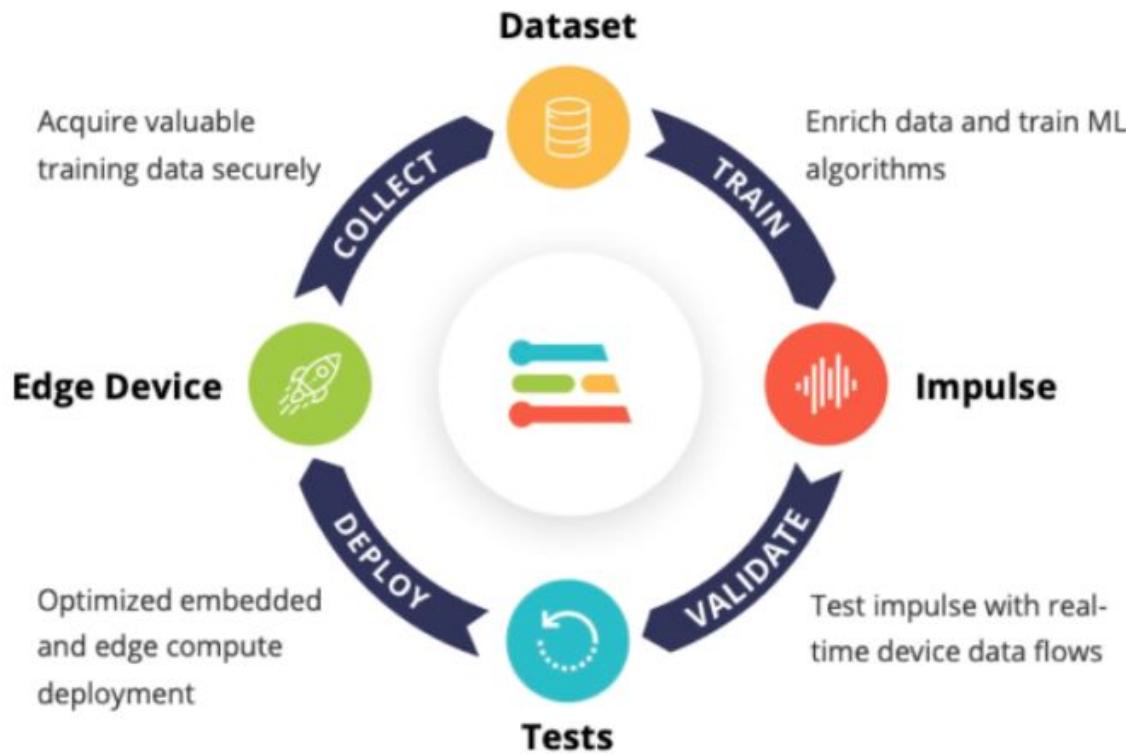




Data-driven engineering

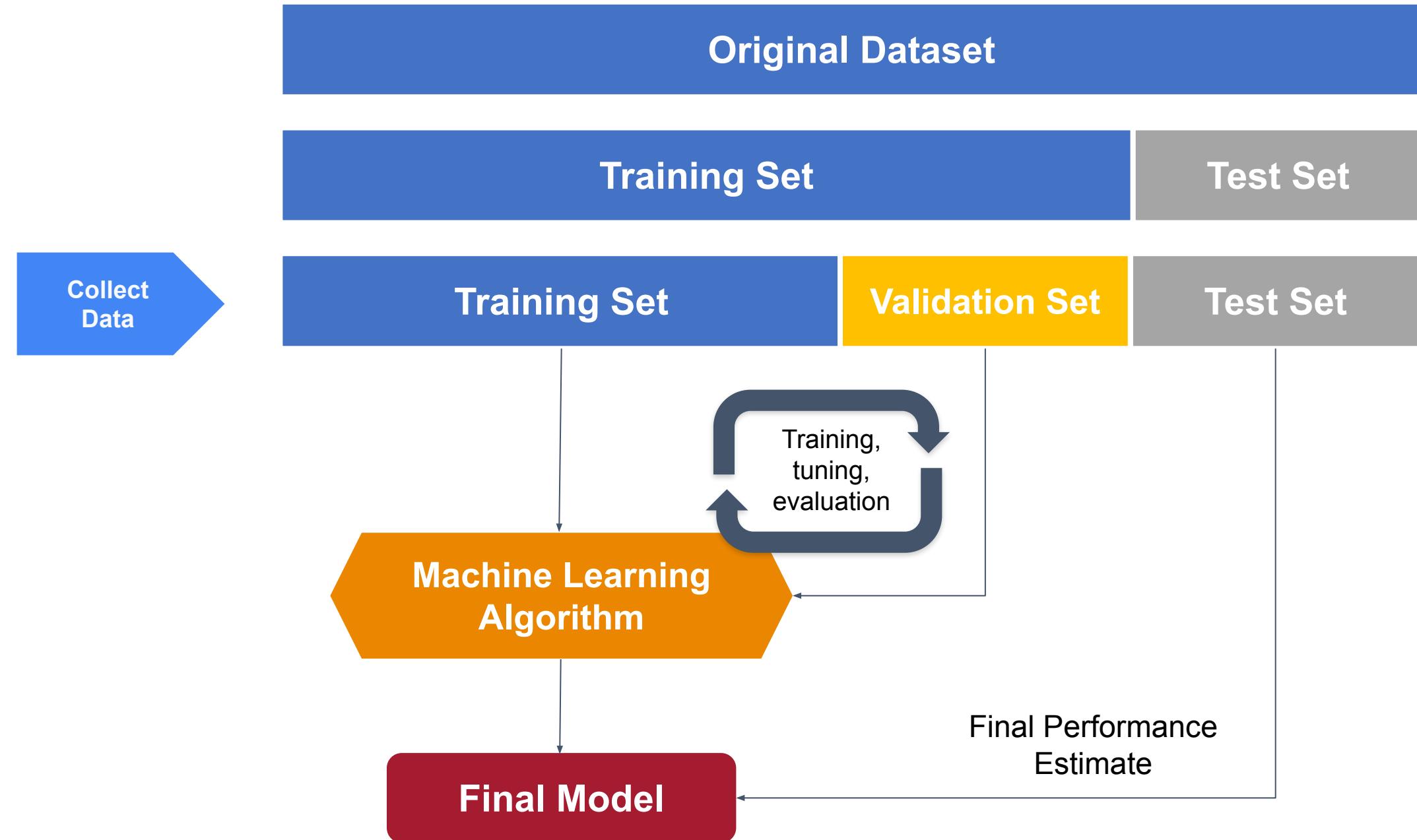


EI Studio - Embedded ML platform (“AutoML”)



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

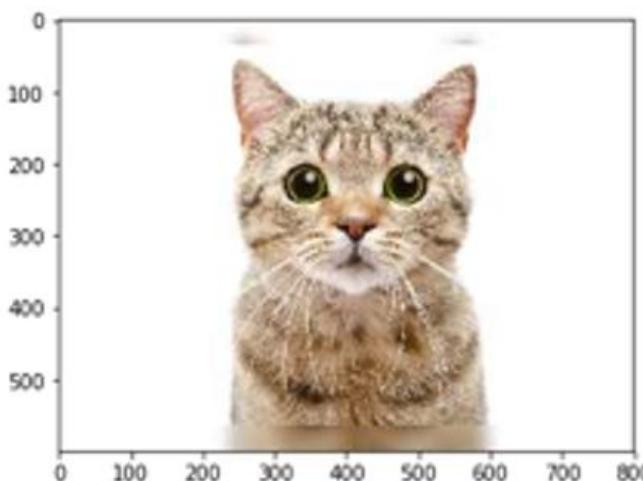




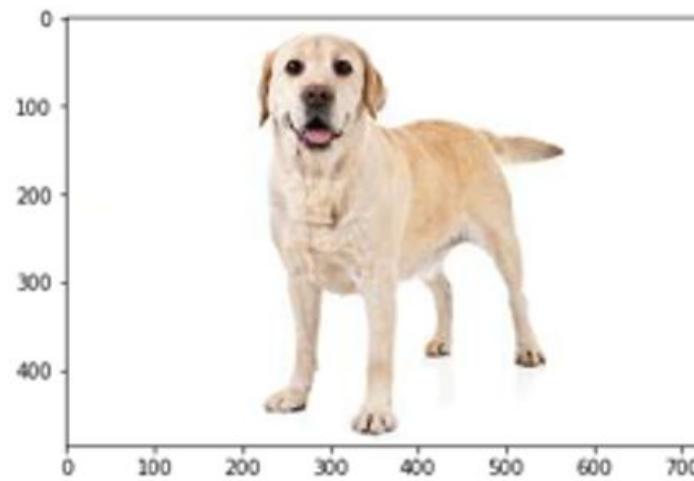
What AI really is?

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

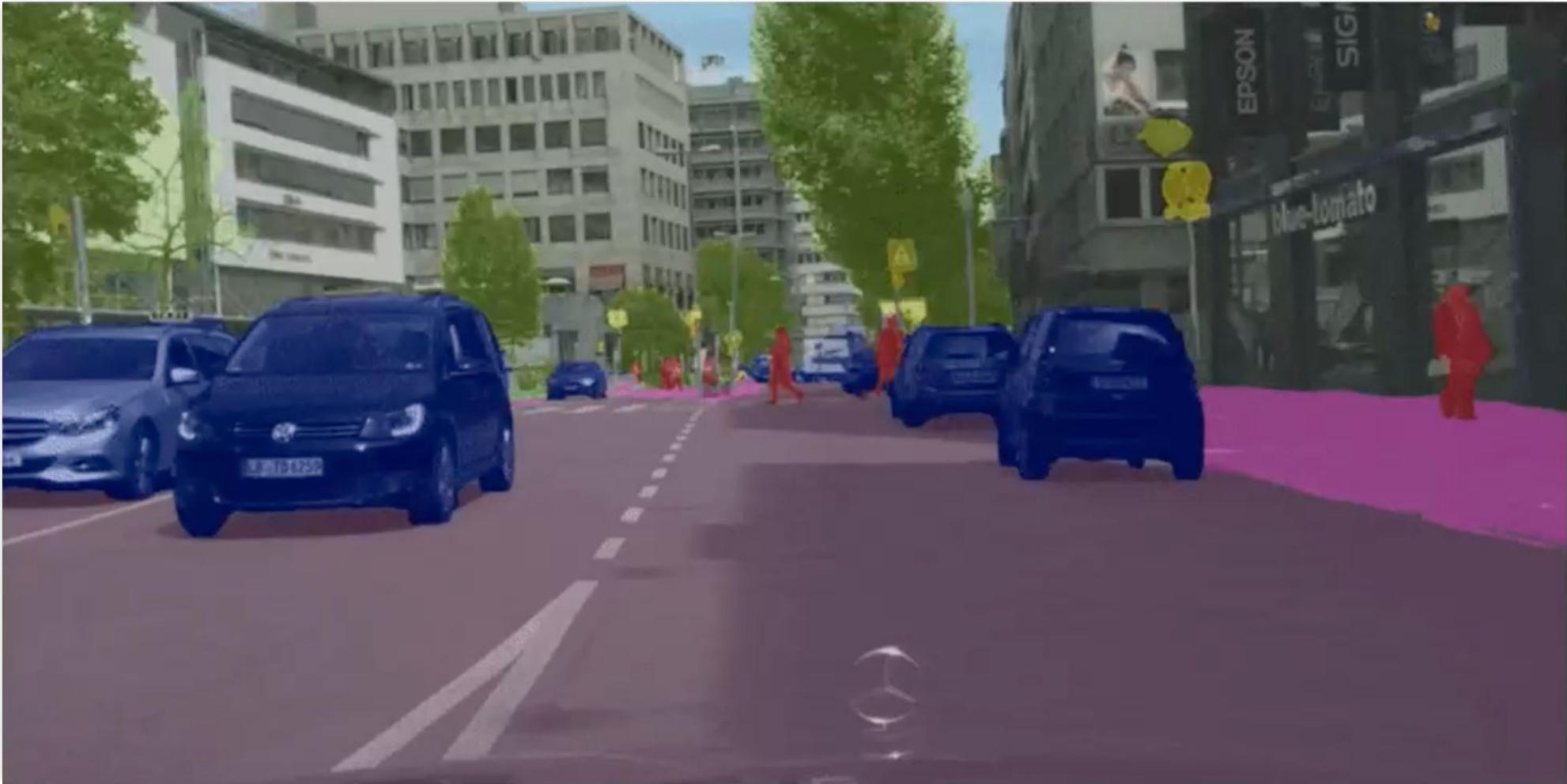


Photos

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

Live Video

Segmentation



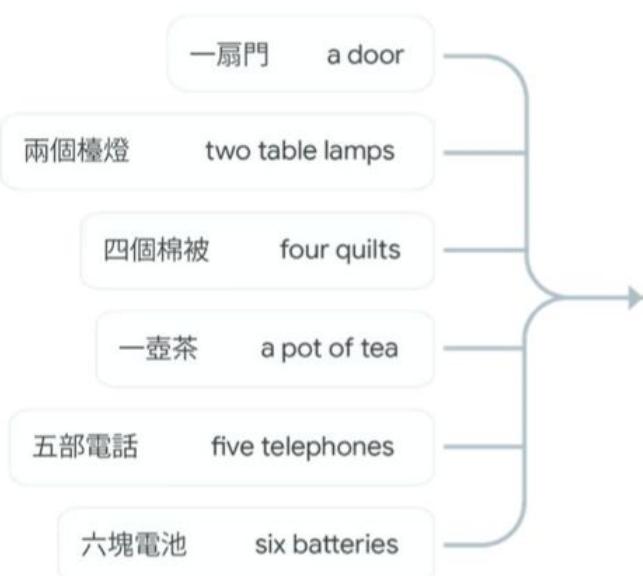
Pose Estimation



<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



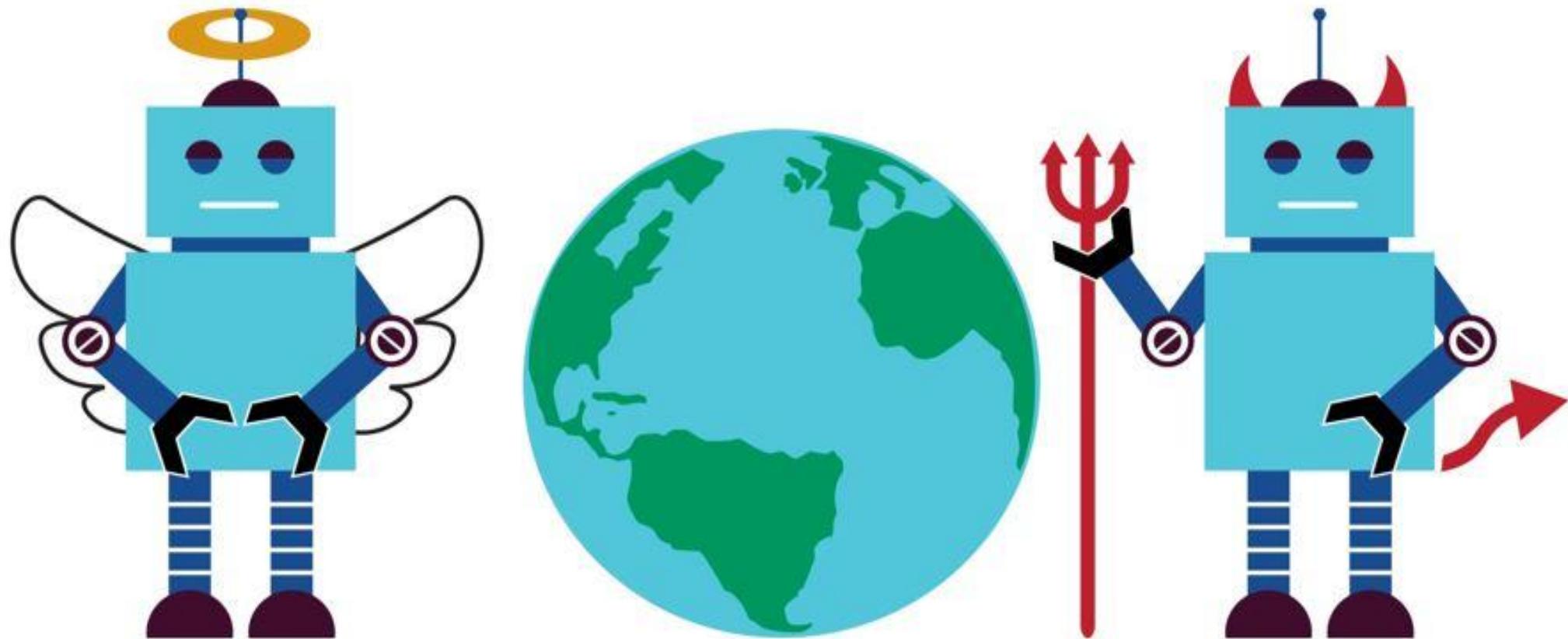
Recommendations

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