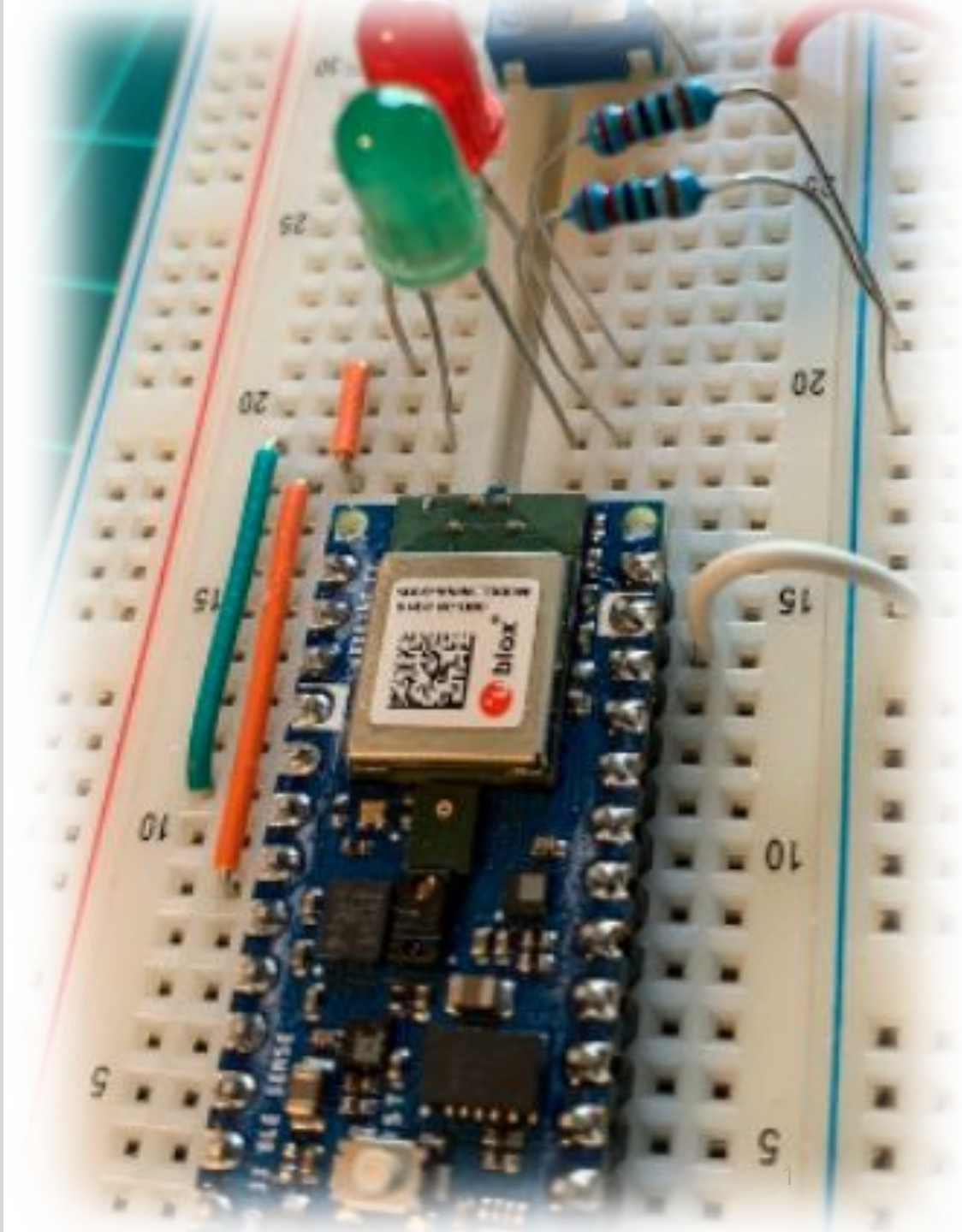
IESTI01 – TinyML

Embedded Machine Learning

28. Responsible AI & Curse Wrap-up



Prof. Marcelo Rovai
UNIFEI

Embedded ML

Curse Wrap-up

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

TinyML

Fastest-growing field of **ML**

Algorithms, hardware, software

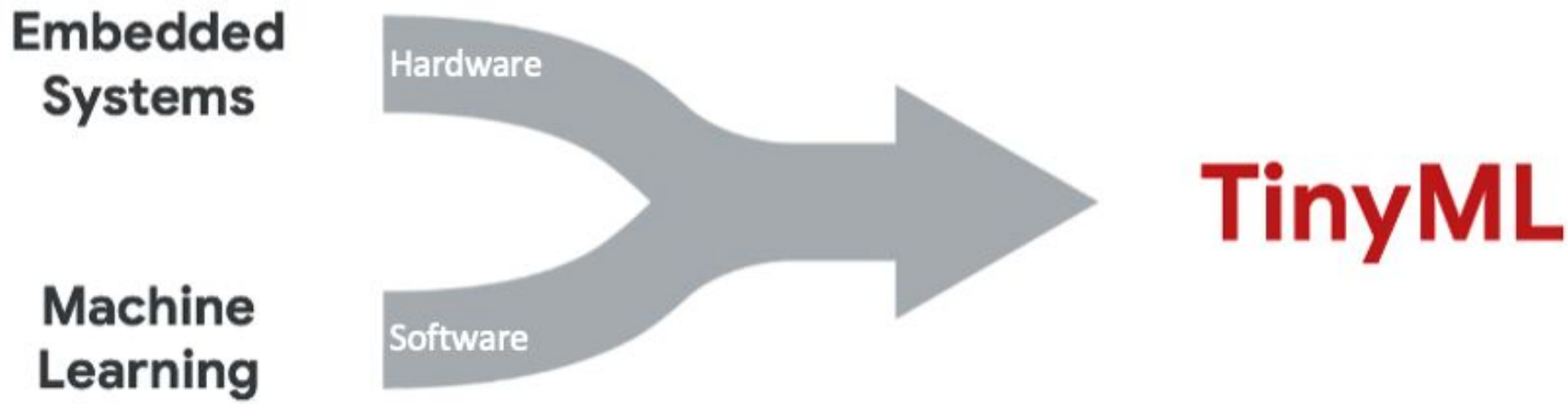
On-device sensor analytics

Low power consumption

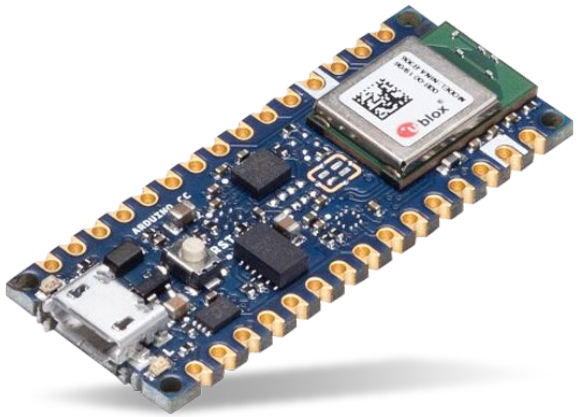
Always-on ML

Battery-operated

What Makes TinyML?



What Makes TinyML?



TensorFlow Lite

Hardware

Software

TinyML

Hardware

Power

EdgeML

TinyML

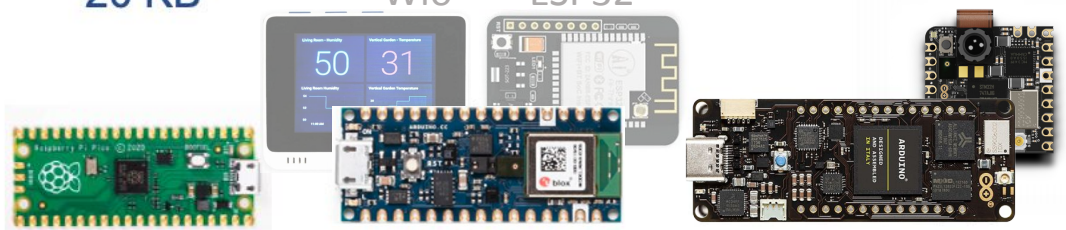
Video Classification 2 MB+

Object Detection Complex Voice Processing 1 MB+

Image Classification 250 KB+

KeyWord Spotting Audio Classification 50 KB

Anomaly Detection Sensor Classification 20 KB



Rpi-Pico (Cortex-M0+)

Arduino Nano (Cortex-M4)

Arduino Pro (Cortex-M7)

RaspberryPi SmartPhone (Cortex-A)

Jetson Nano (Cortex-A + GPU)

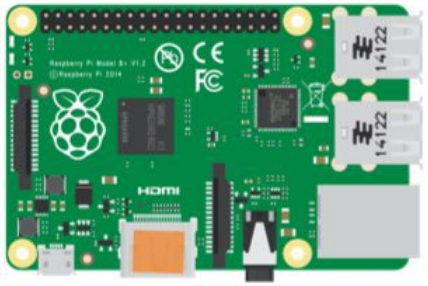
Source: Edge Impulse

Software

TensorFlow

TensorFlow Lite

Train a model → Convert model → Optimize model → Deploy model at Edge → Make inferences at Edge



Raspberry Pi

Linux

iOS

(TFL Micro)

Microcontroller

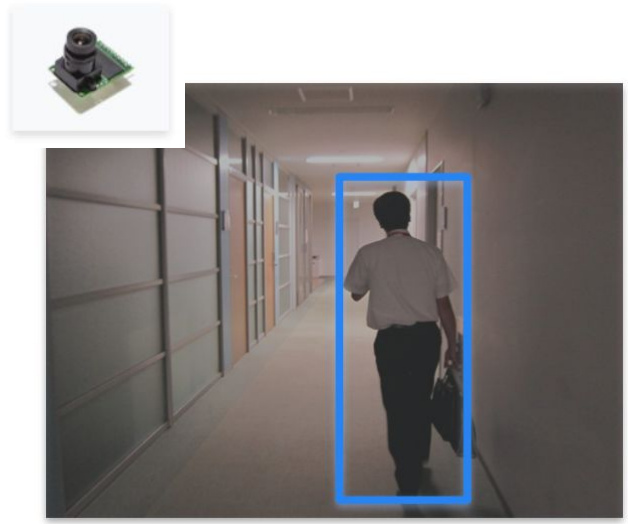
TinyML Application

Examples

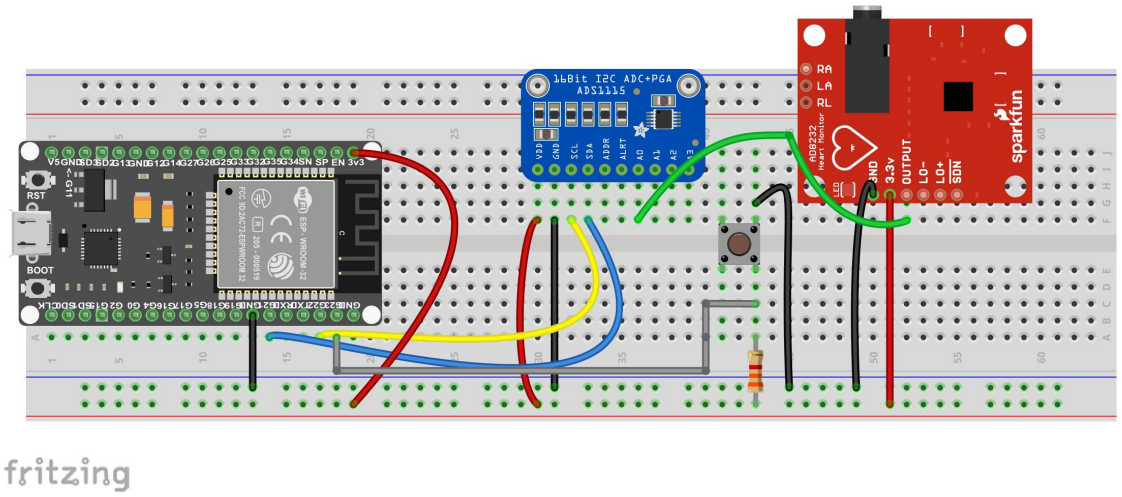
Sound

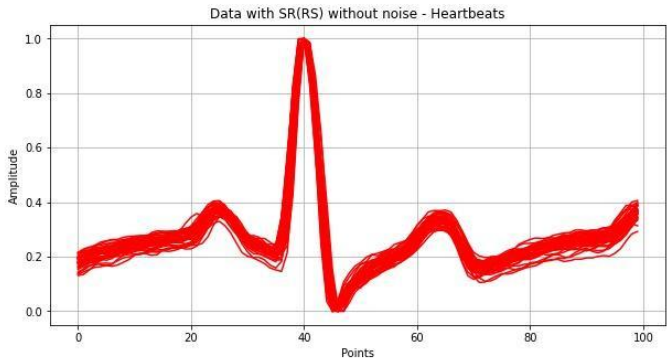
Vibration

Vision



Other **sensors**





Guilherme Silva
Engenheiro - UNIFEI

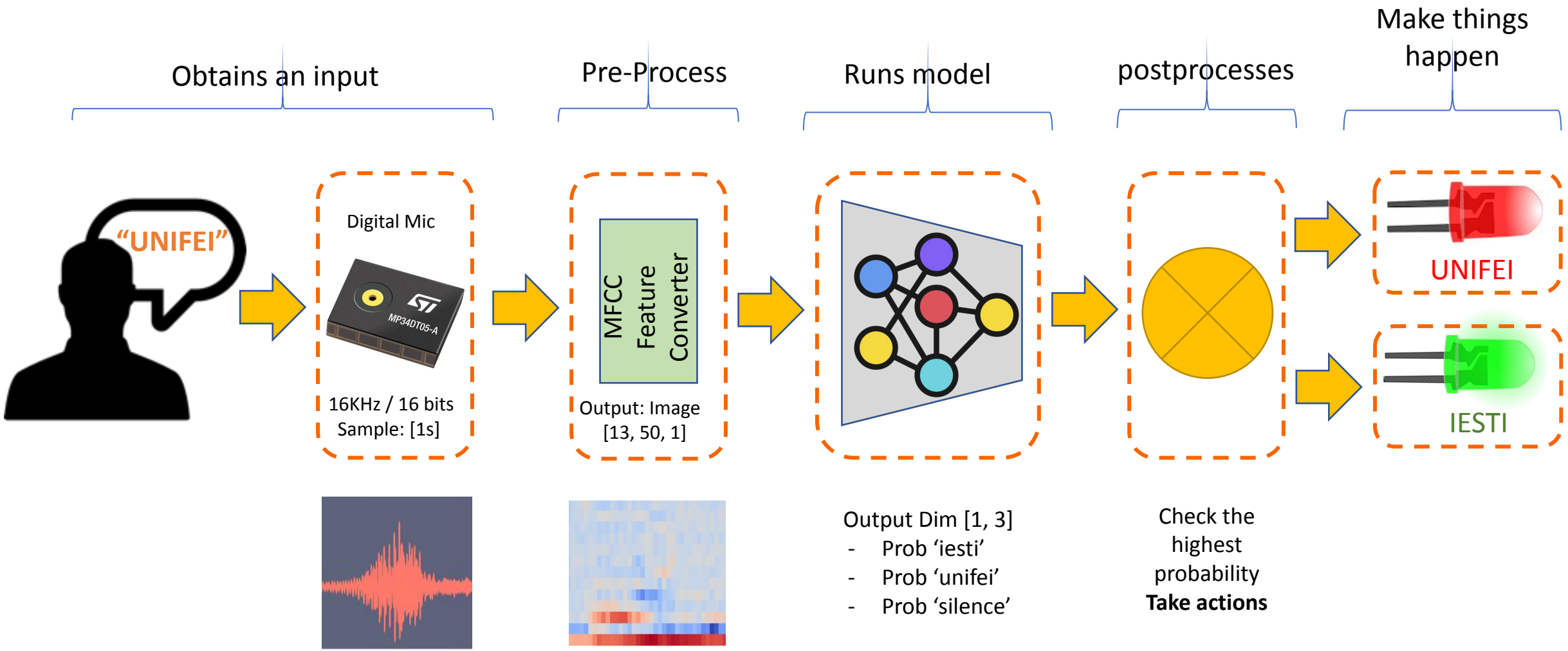
[Atrial Fibrillation Detection on ECG using TinyML
Silva et al. UNIFEI 2021]

Sound

Vibration

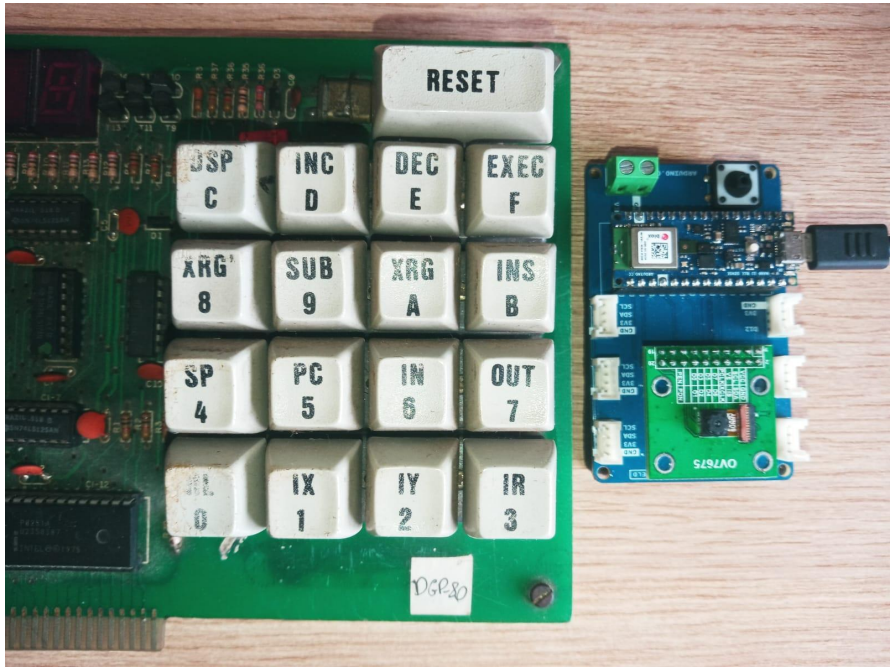
Vision

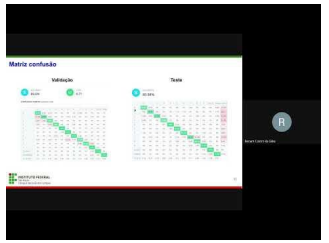
KeyWord Spotting (KWS) - Inference



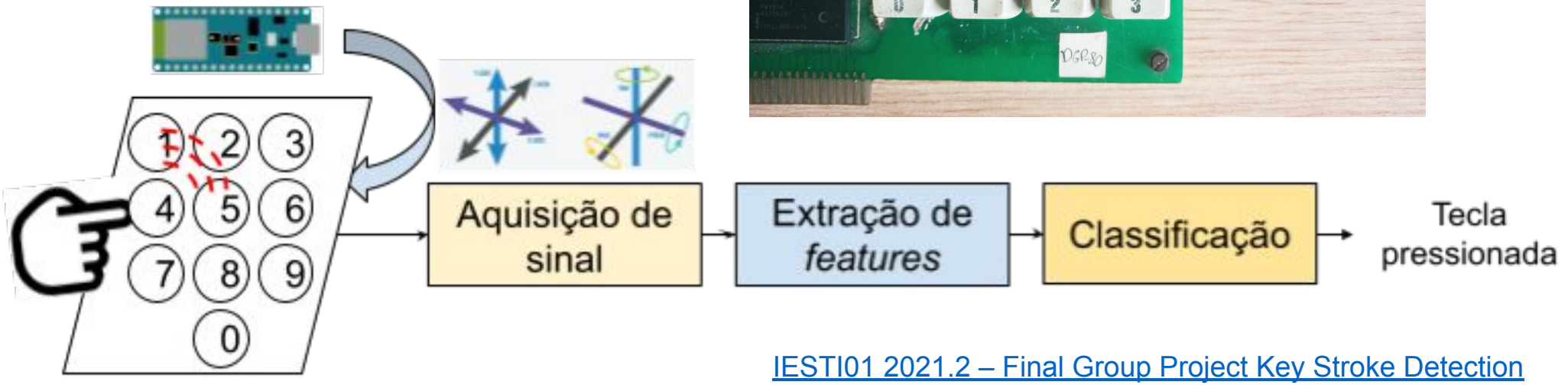
https://youtu.be/XnFYz-RSNe8

Keystroke **Sound** Detection





Renam Castro
Professor IFESP



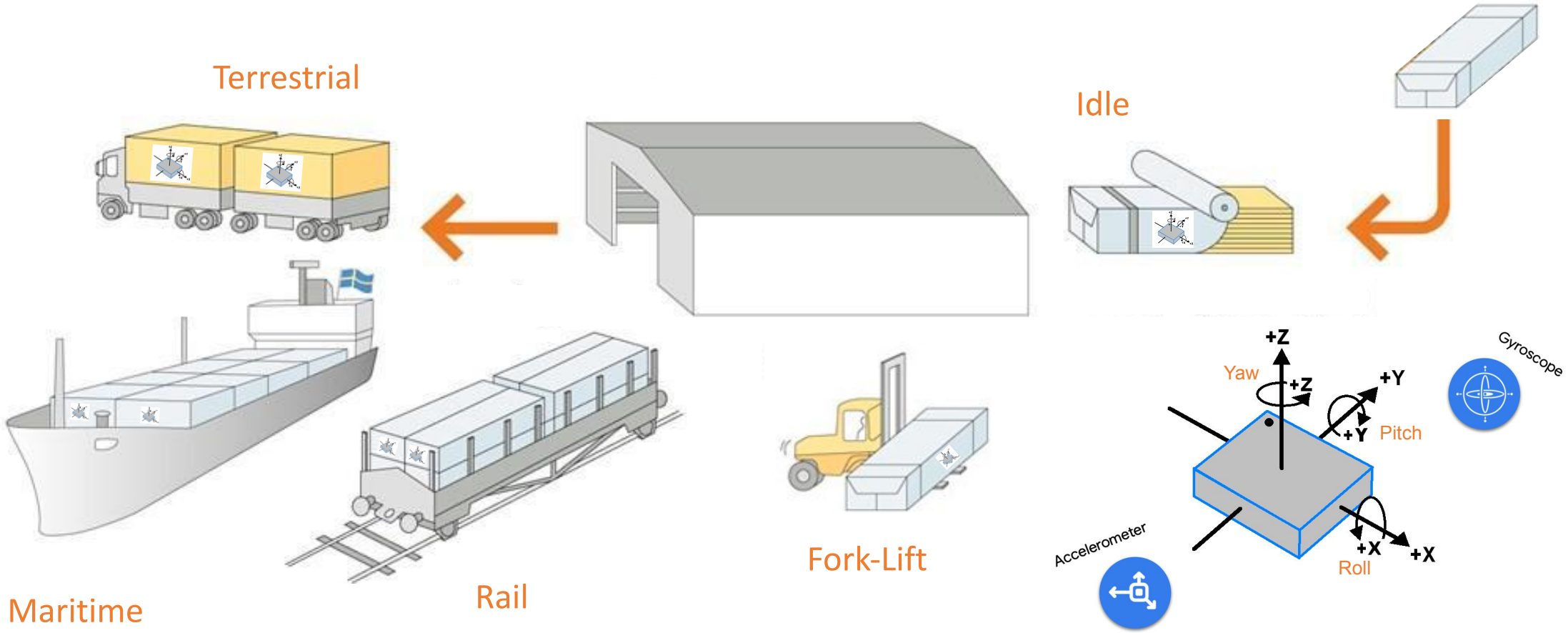
[IESTI01 2021.2 – Final Group Project Key Stroke Detection]

Sound

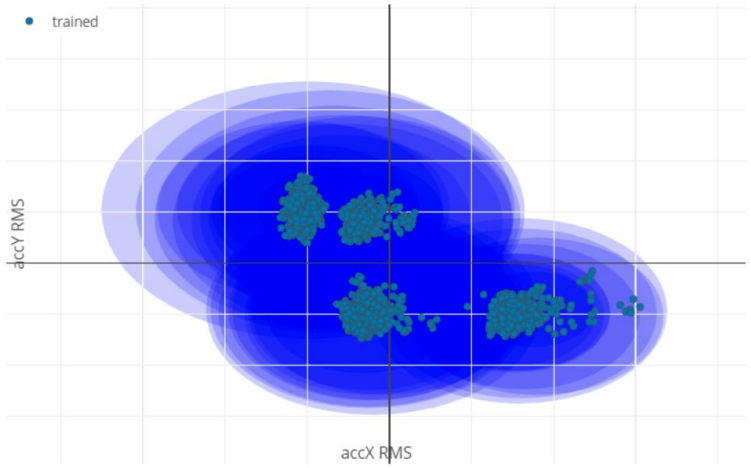
Vibration

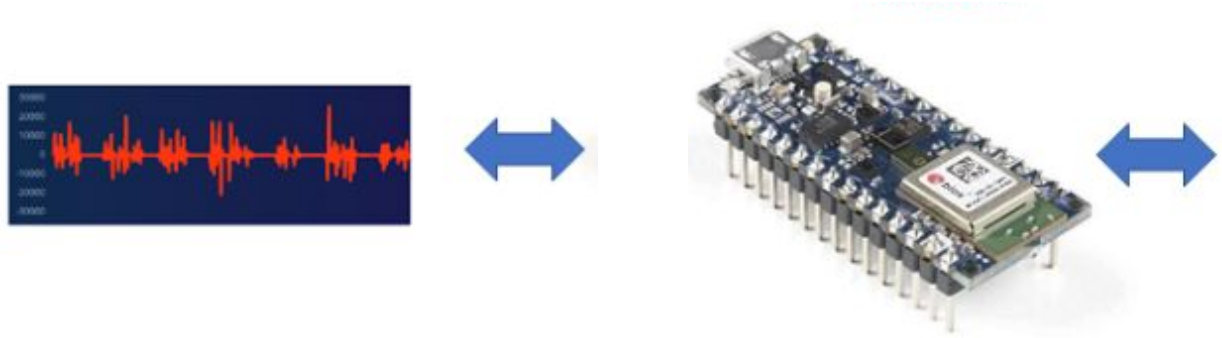
Vision

Mechanical Stresses in Transport



Industrial – Anomaly Detection



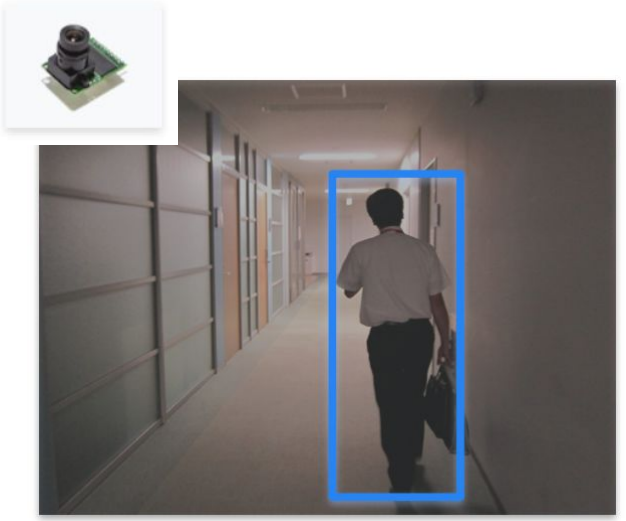


[IESTI01 2021.2 - Final Group Project: Bearing Failure Detection]

Sound

Vibration

Vision



Computer Vision Main Types

Image Classification

(**Multi-Class** Classification)

Cat: 70%

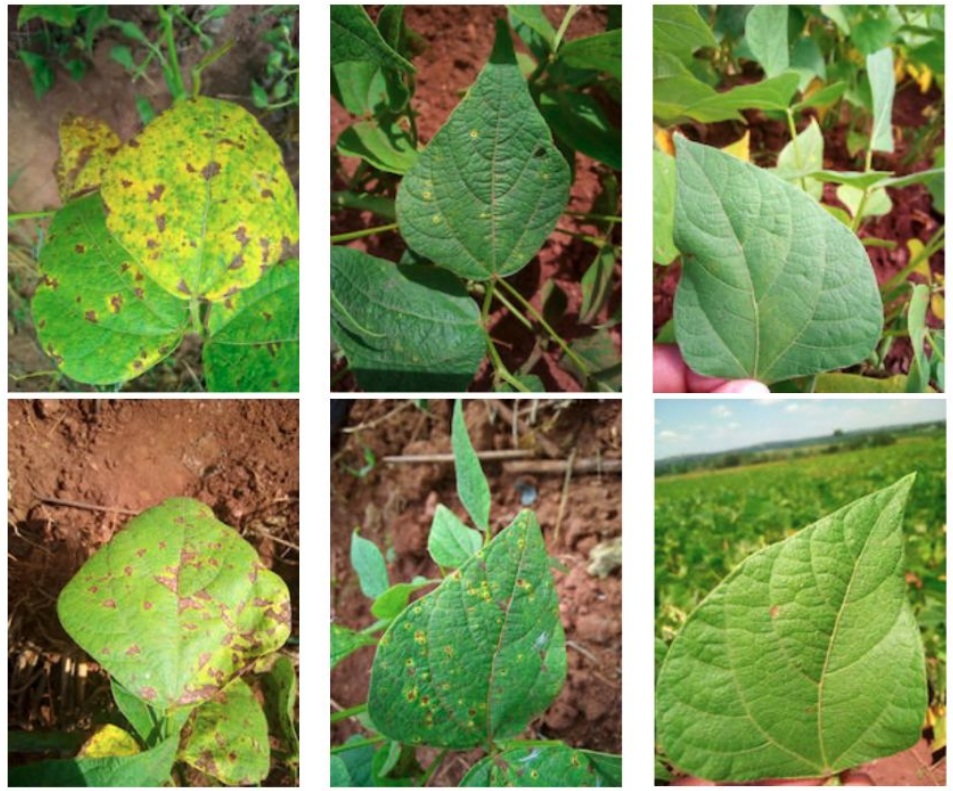
Dog: 80%

Object Detection

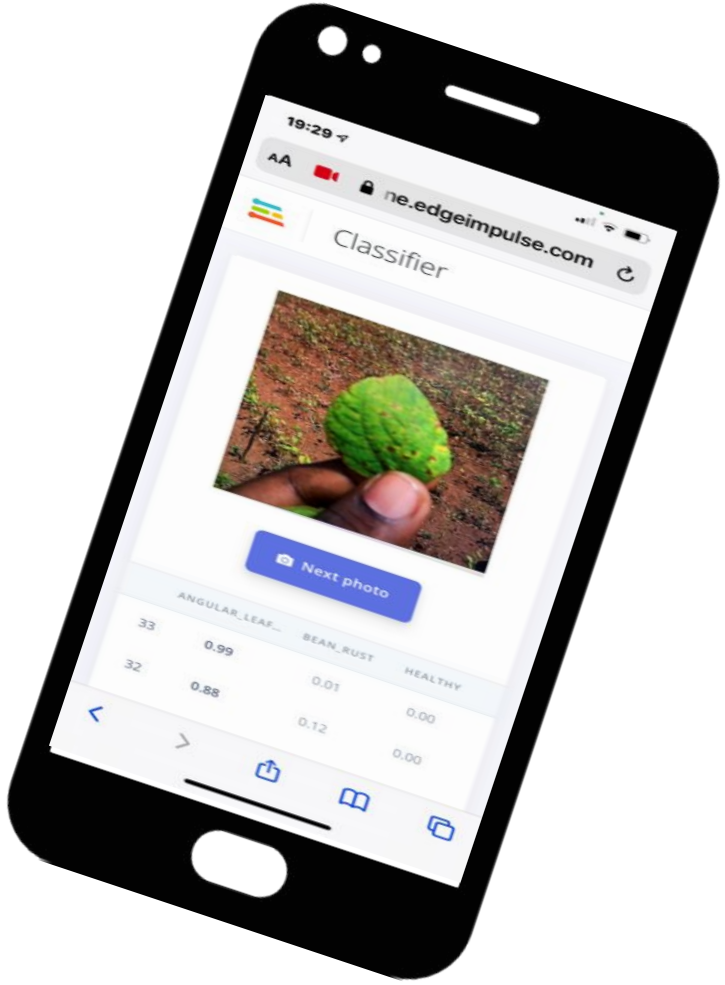
Multi-Label Classification + Object **Localization**

Detecting Diseases in the Bean plants

AIR Lab Makerere University
UGANDA



Angular Leaf Spot | Bean Rust | Healthy



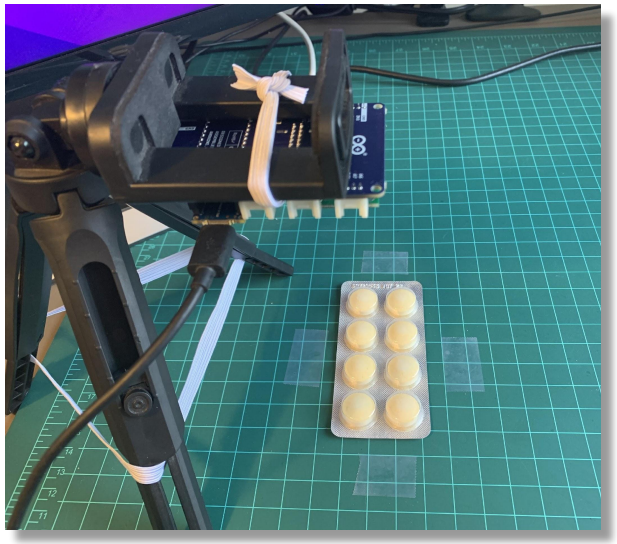
Dataset: https://github.com/AI-Lab-Makerere/ibean/

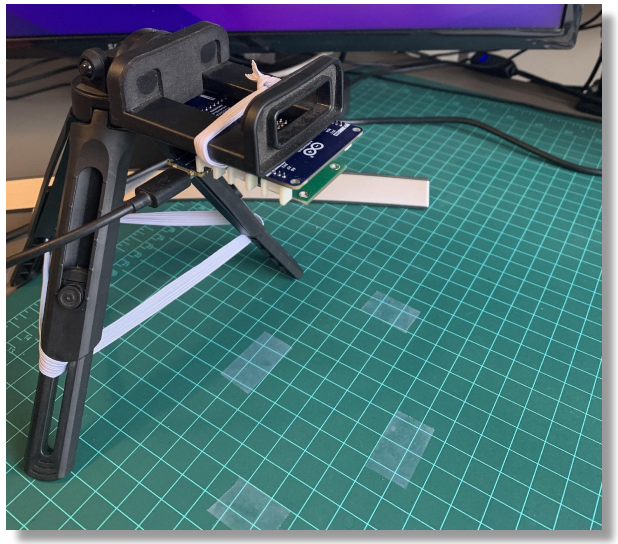
Learn the steps to build an app that detects crop diseases

Image Classification Project

Decide a Goal

- Possible Images:
  - Medicine
  - background





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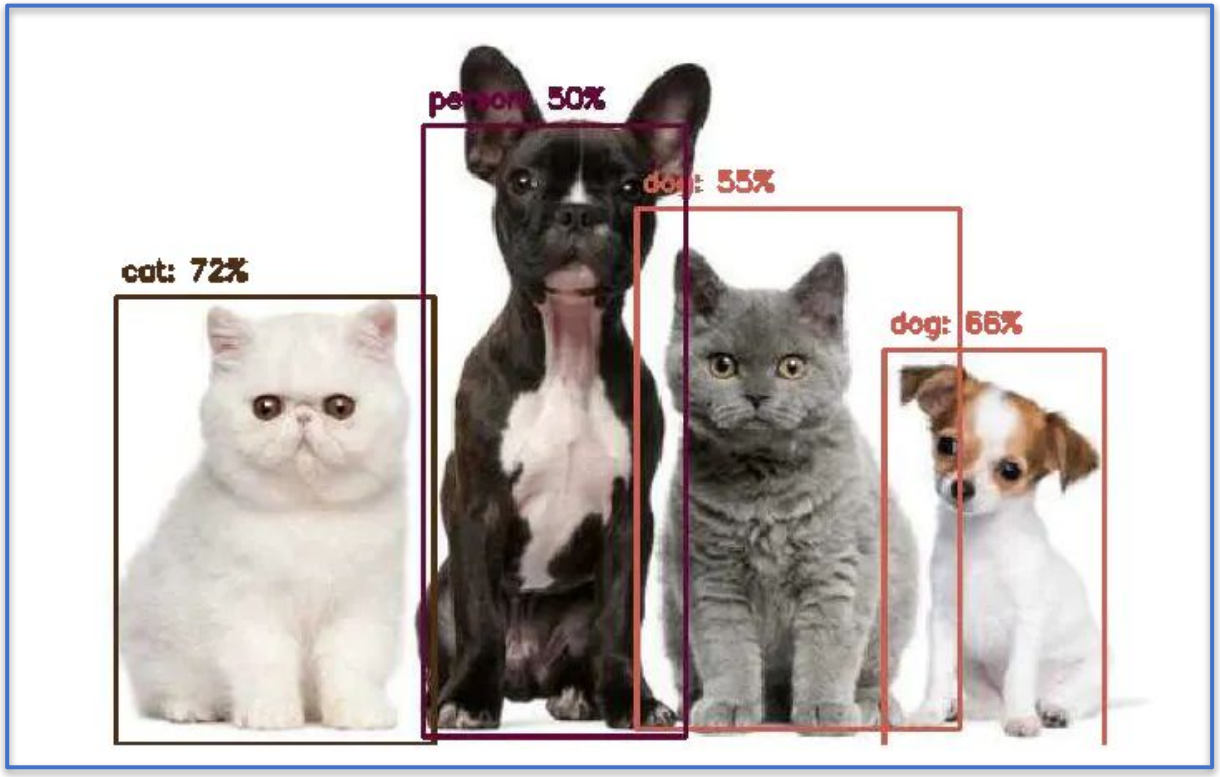
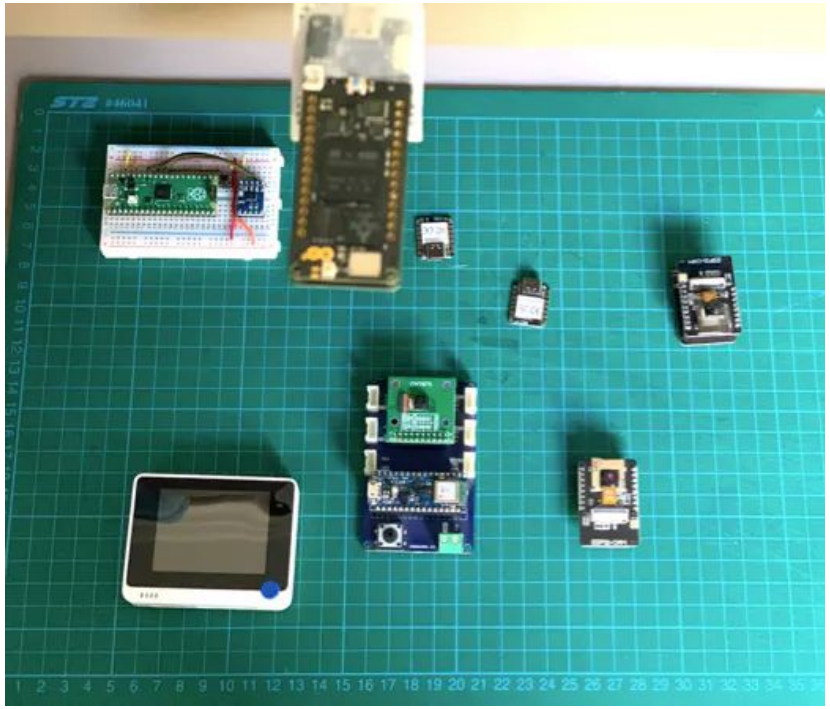
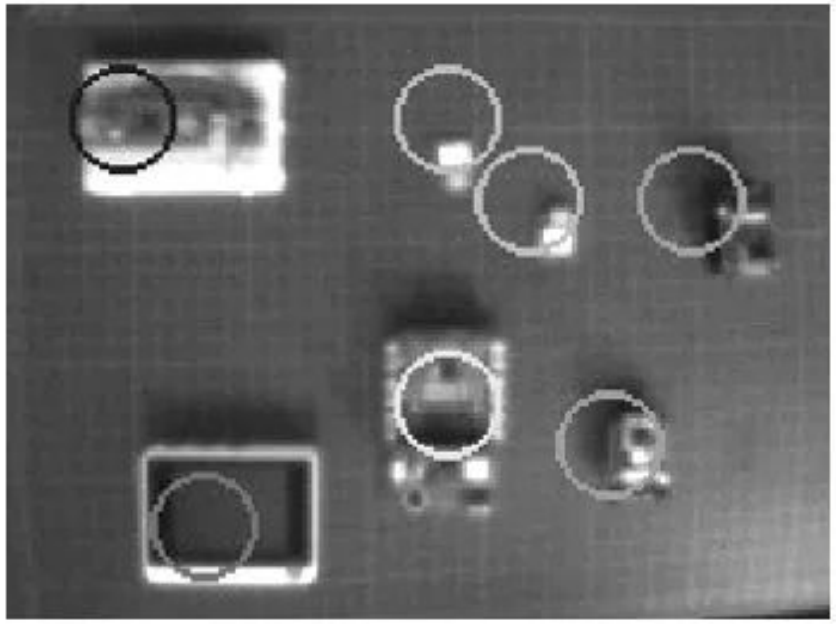
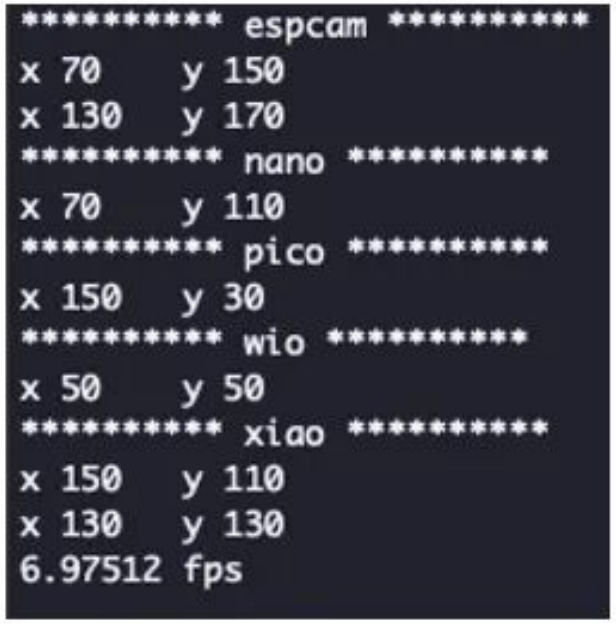


Detecting Objects using TinyML (FOMO)

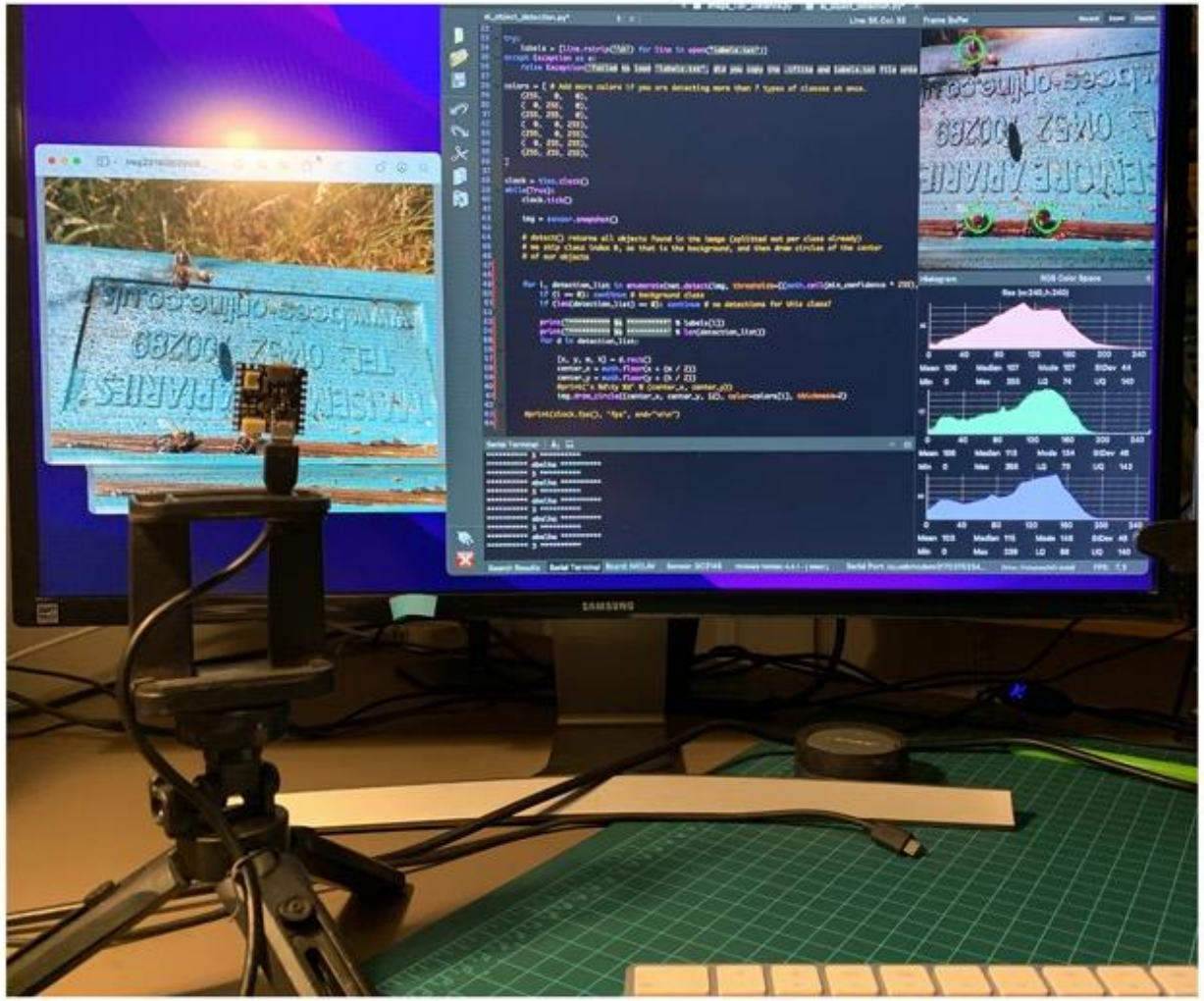


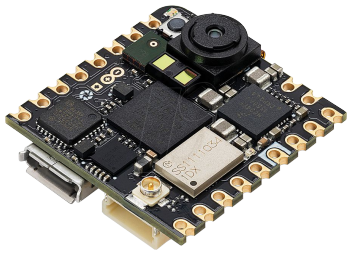




EdgeAI made simple - Exploring Image Processing (Object Detection) on microcontrollers with Arduino Portenta, Edge Impulse FOMO, and OpenMV

Detecting Objects using TinyML (FOMO)





OpenMV

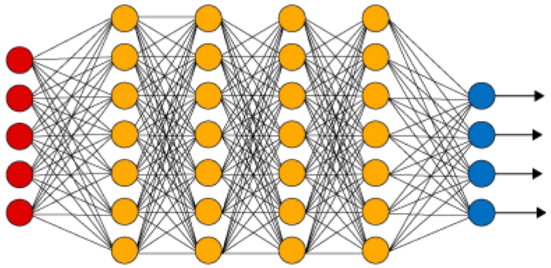
MicroPython

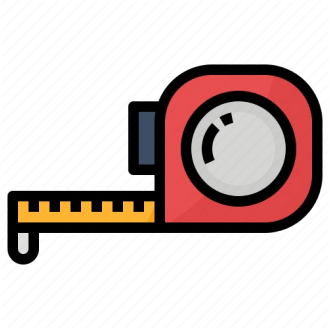
EDGE IMPULSE

https://youtu.be/jOZKxO3KnIA

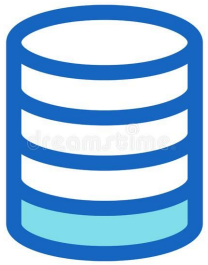
How to Train a ML Model?

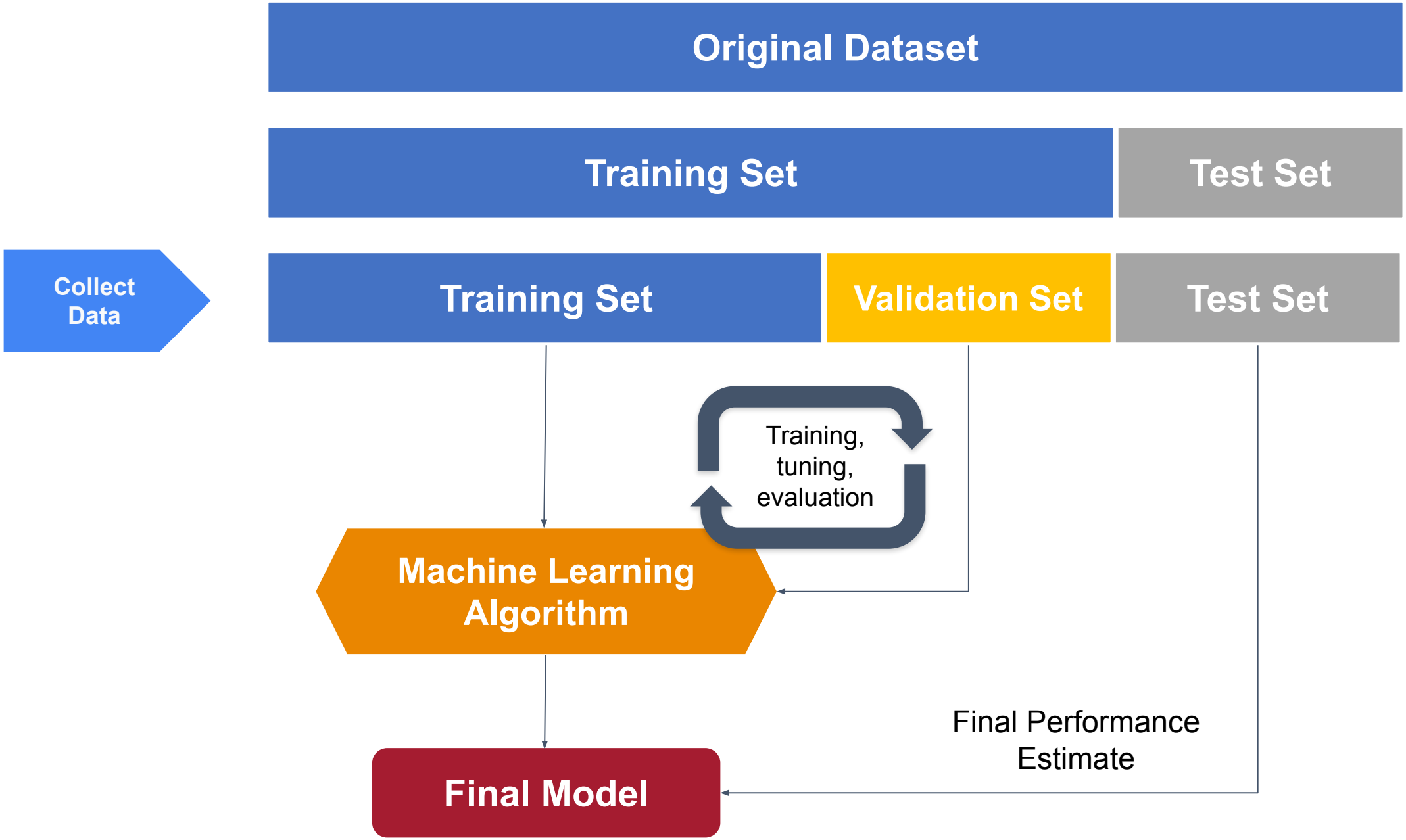
Machine Learning Workflow ("What")



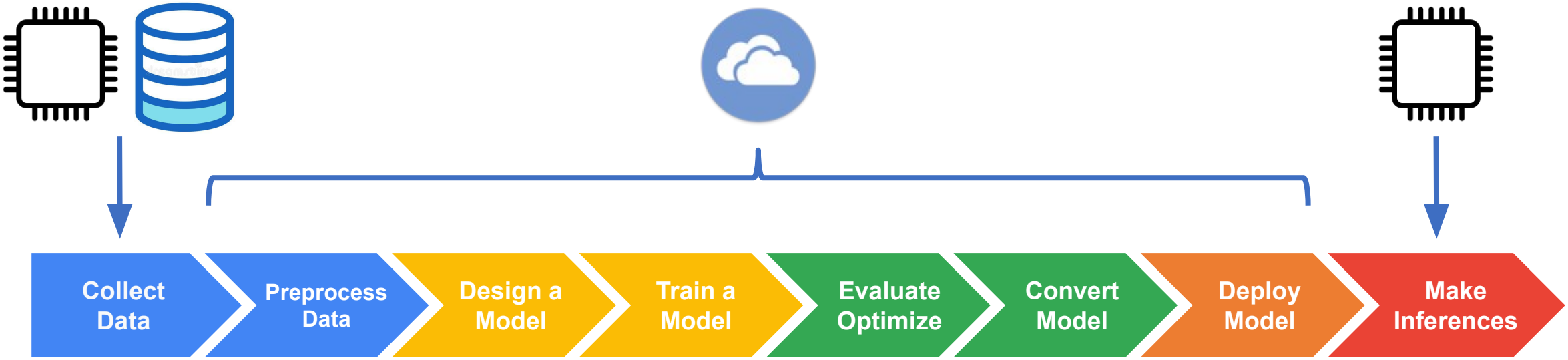


Collect Data → Preprocess Data → Design a Model → Train a Model → Evaluate Optimize → Convert Model → Deploy Model → Make Inferences

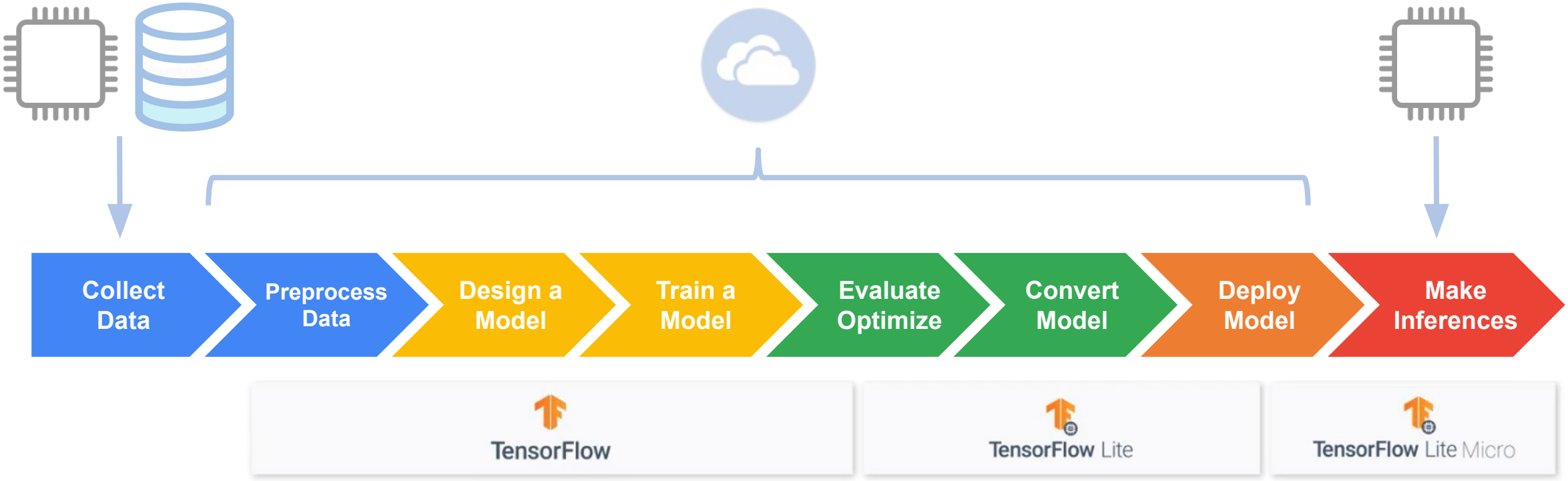



Original Dataset
Training Set
Test Set
Collect Data
Training Set
Validation Set
Test Set
Training, tuning, evaluation
Machine Learning Algorithm
Final Performance Estimate
Final Model

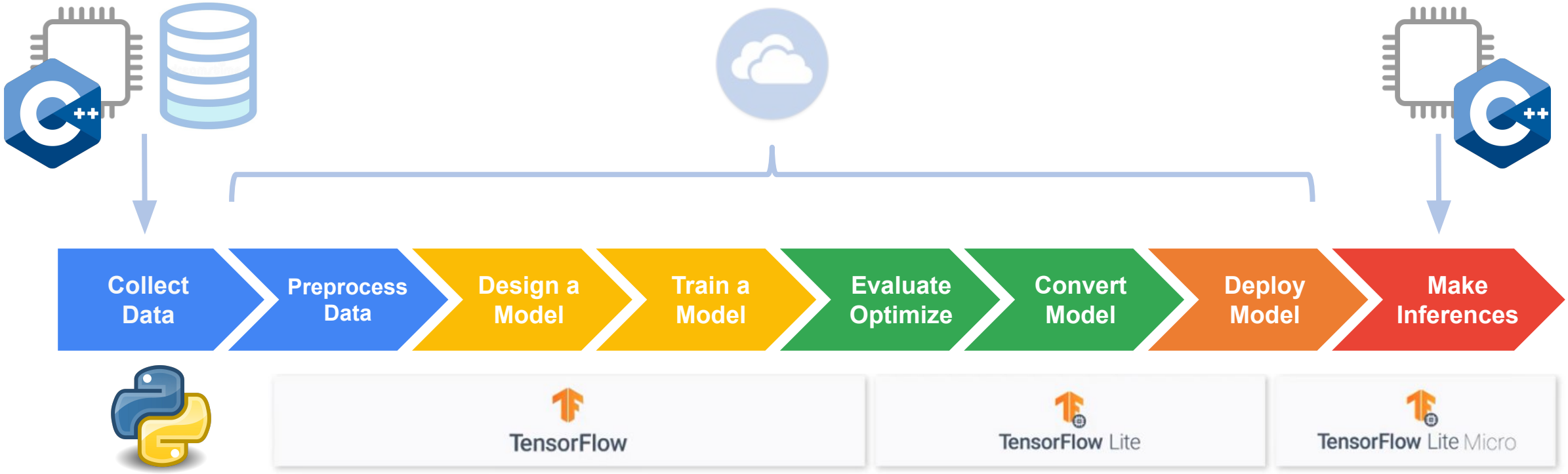
Machine Learning Workflow ("Where")



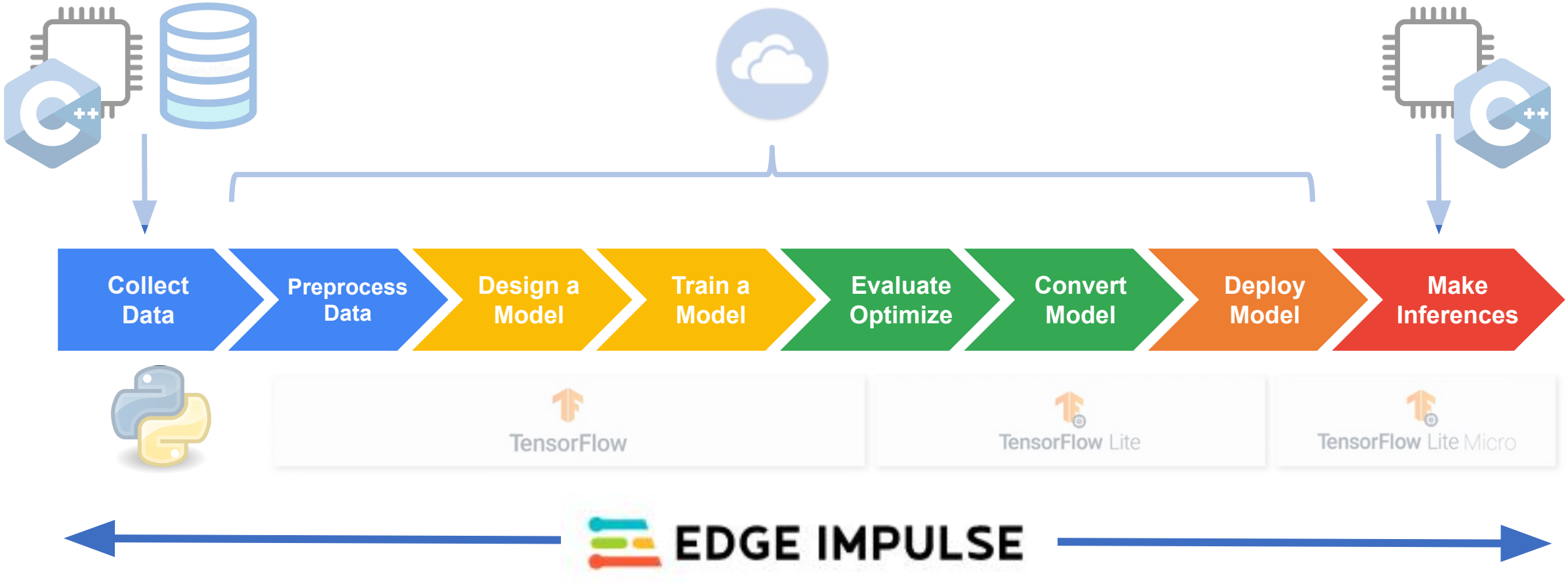
Machine Learning Workflow ("How")



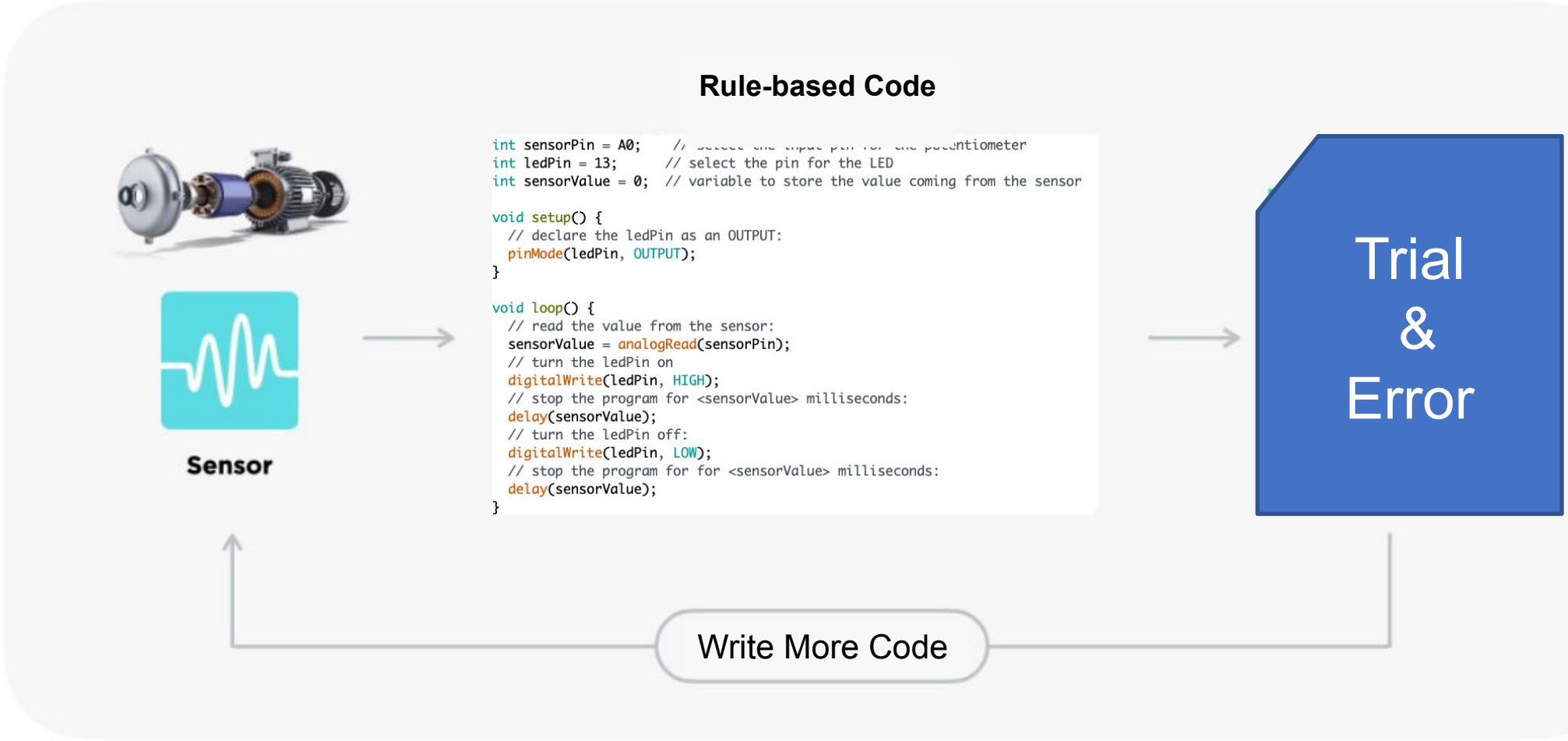
Machine Learning Workflow ("How")



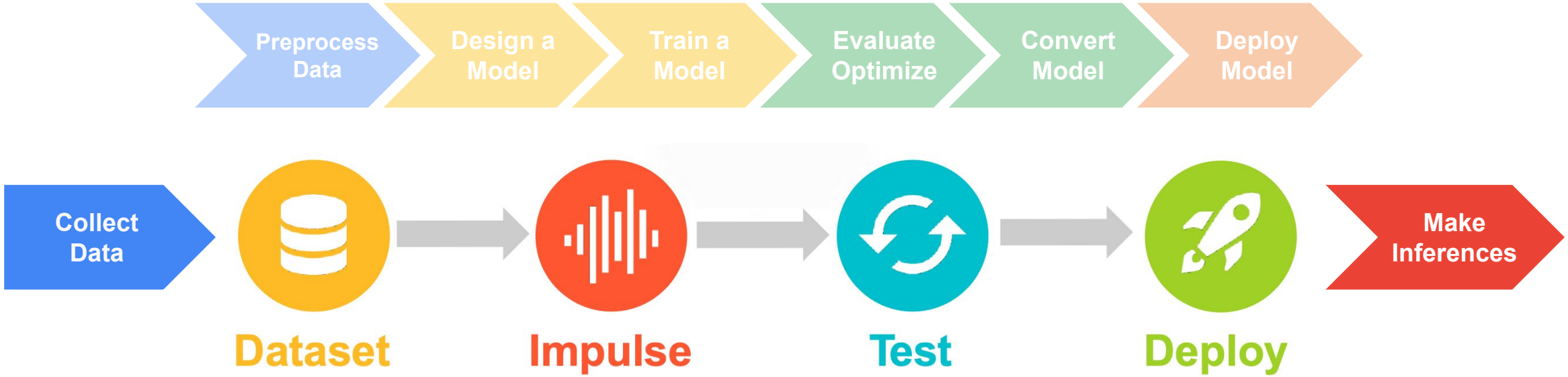
Machine Learning Workflow ("How")



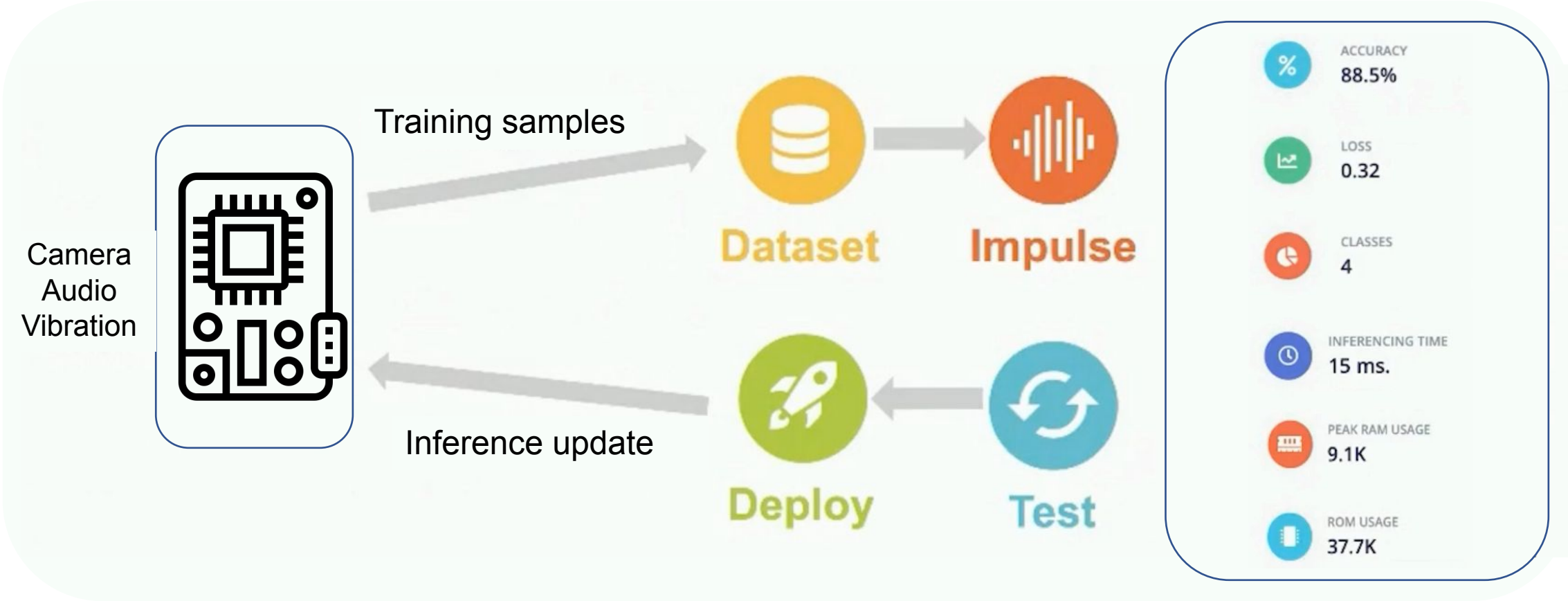
From rule-based engineering to…



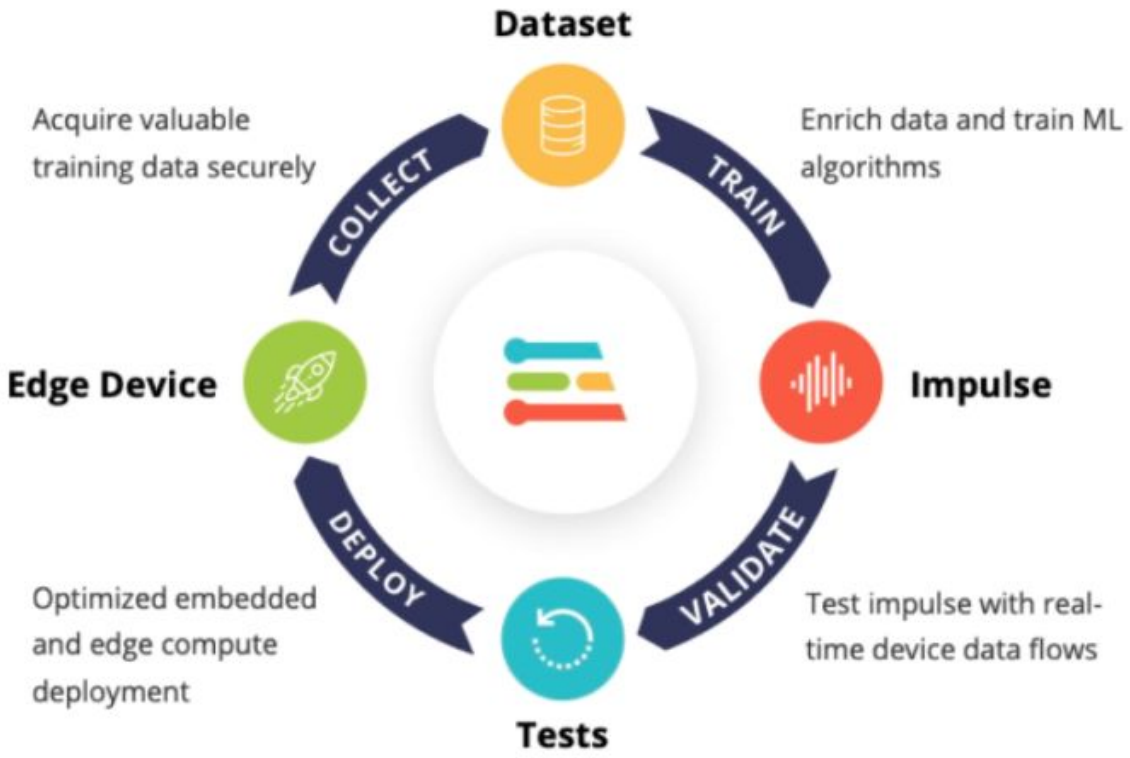
Data-driven engineering

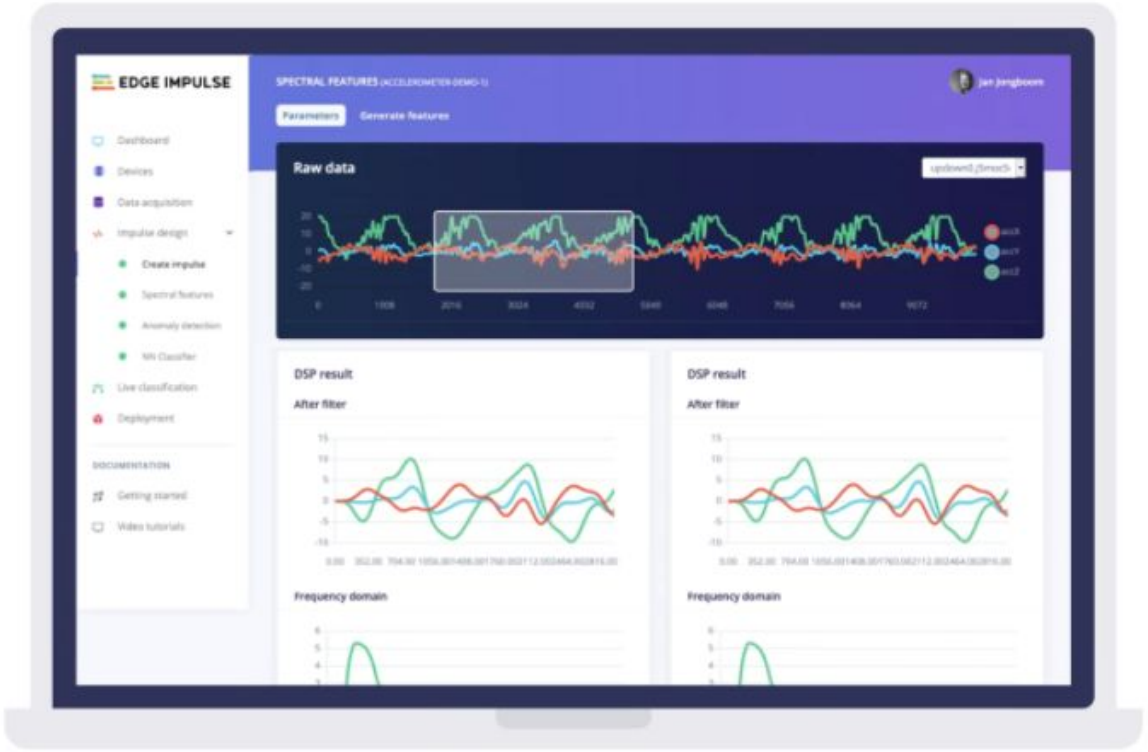

Preprocess Data
Design a Model
Train a Model
Evaluate Optimize
Convert Model
Deploy Model
Collect Data
Dataset
Impulse
Test
Deploy
Make Inferences

Data-driven engineering



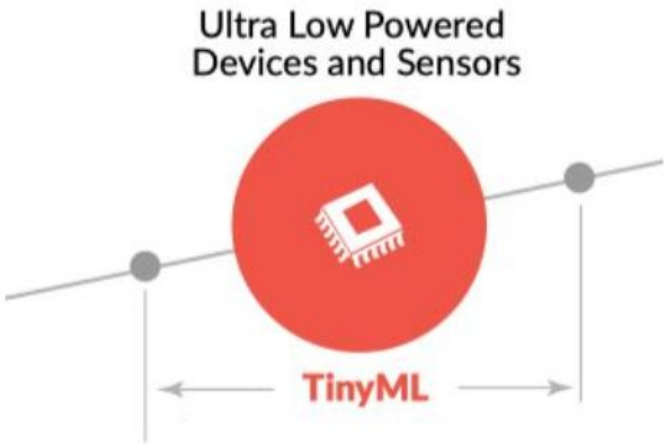
EI Studio - Embedded ML platform ("AutoML")



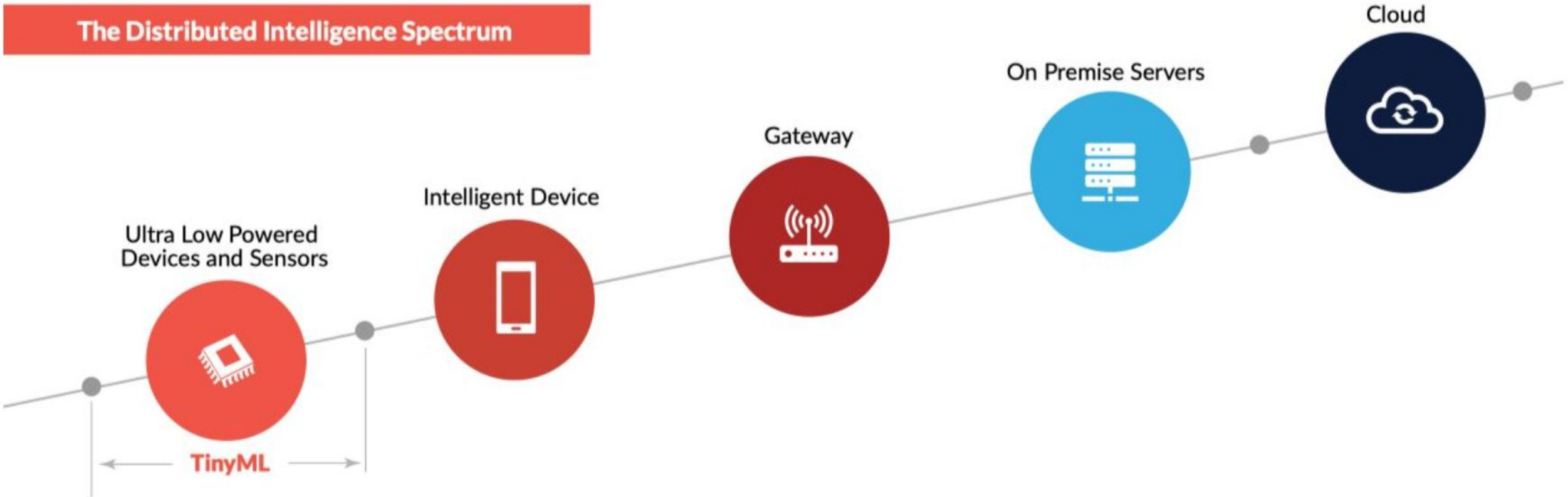


Learn more at http://edgeimpulse.com

The Future of the TinyML (Embedded ML)



Source: ABI Research: TinyML



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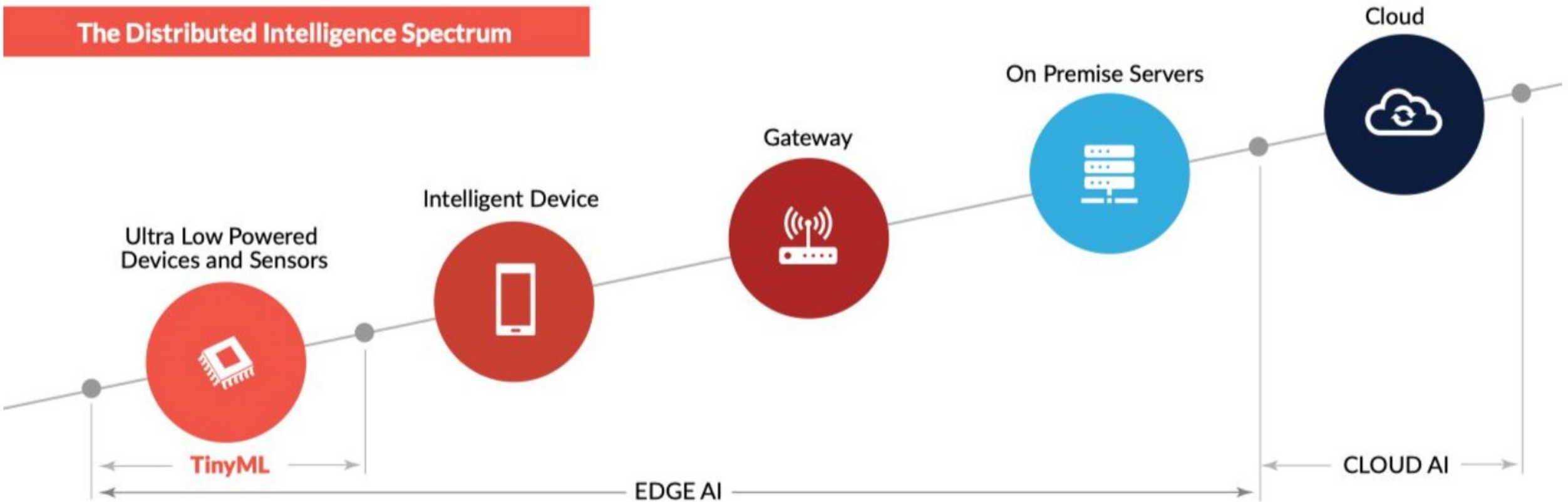
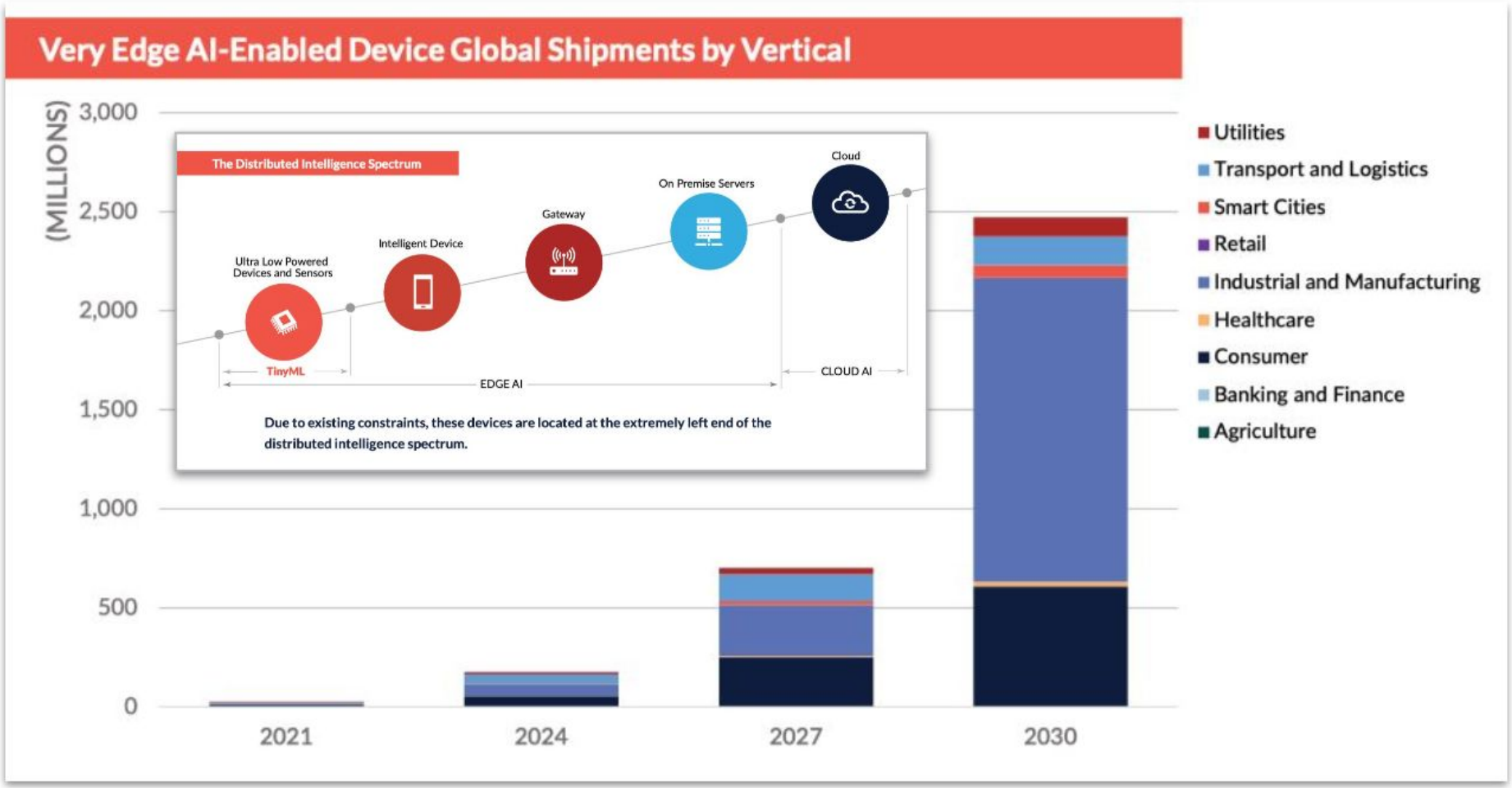


Source: ABI Research: TinyML

Massive Potential for Impact



Source: ABI Research: TinyML

Conclusion

The Future of ML is Tiny and Bright

***Vijay Janapa Reddi**, Ph. D. | Associate Professor |*
John A. Paulson School of Engineering and Applied Sciences | Harvard University |

Responsible AI

Suzan Kennedy, Ph.D.

Santa Clara University

SciTinyML Seminar - Slides

SciTinyML Seminar - Video

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/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

I want to thank Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google, Professor Vijay Janapa Reddi and Brian Plancher from Harvard, and the rest of the TinyMLedu team 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

UNIFEI