EdgeAI
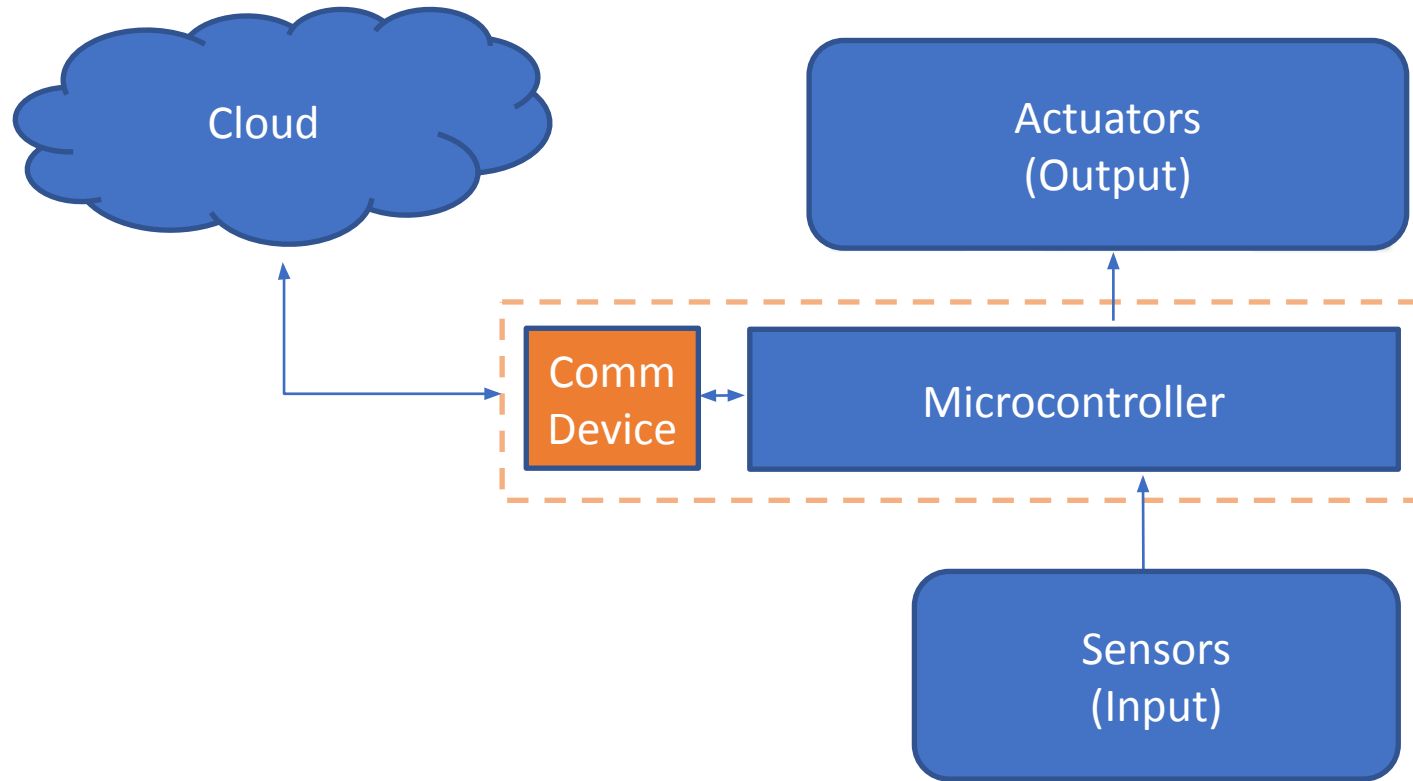Artificial intelligence at the edge
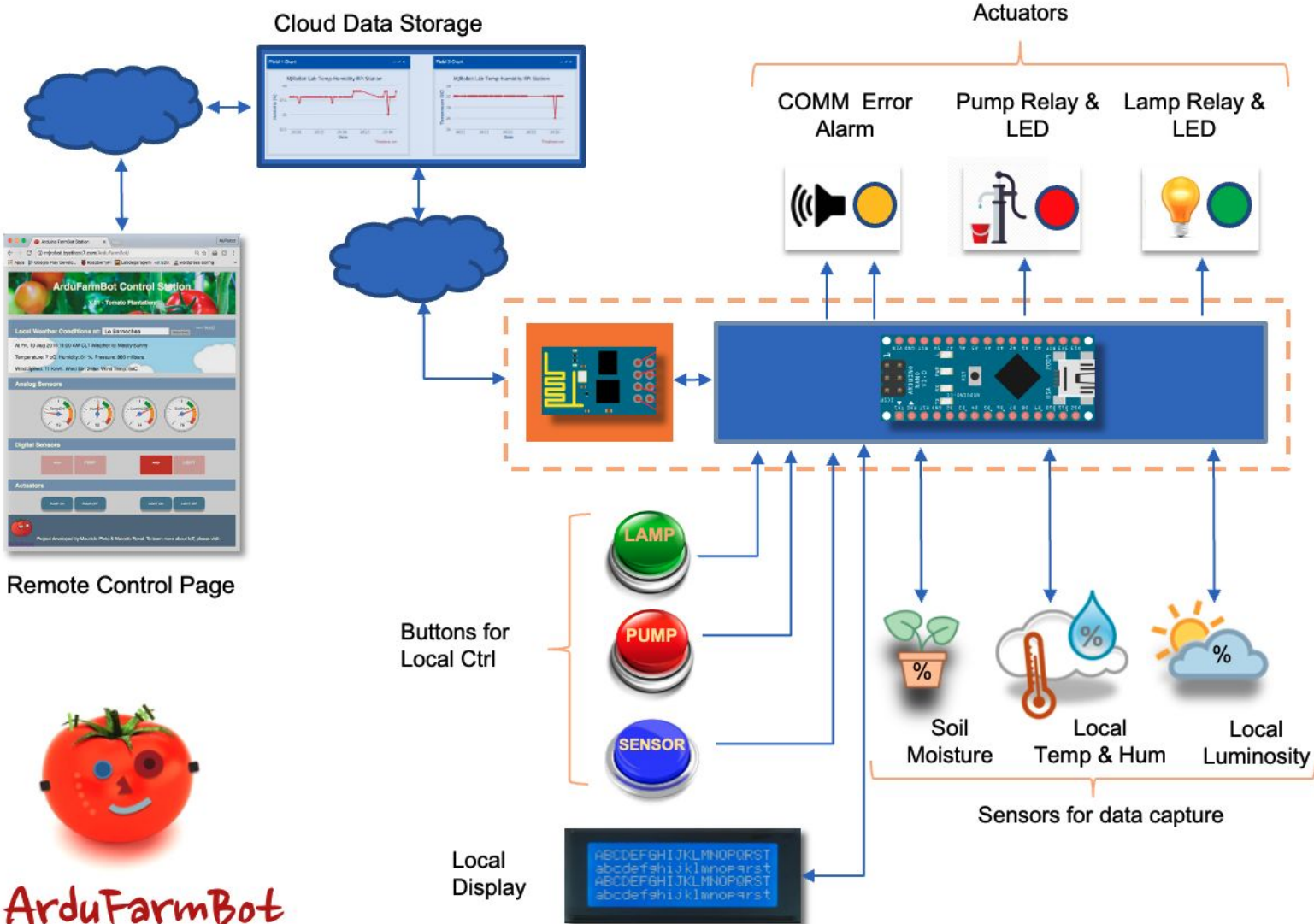
Bringing intelligence to sensors

Marcelo Rovai

Guilherme Silva

Renam Castro

João Yamashita

TUDO
SOBRE
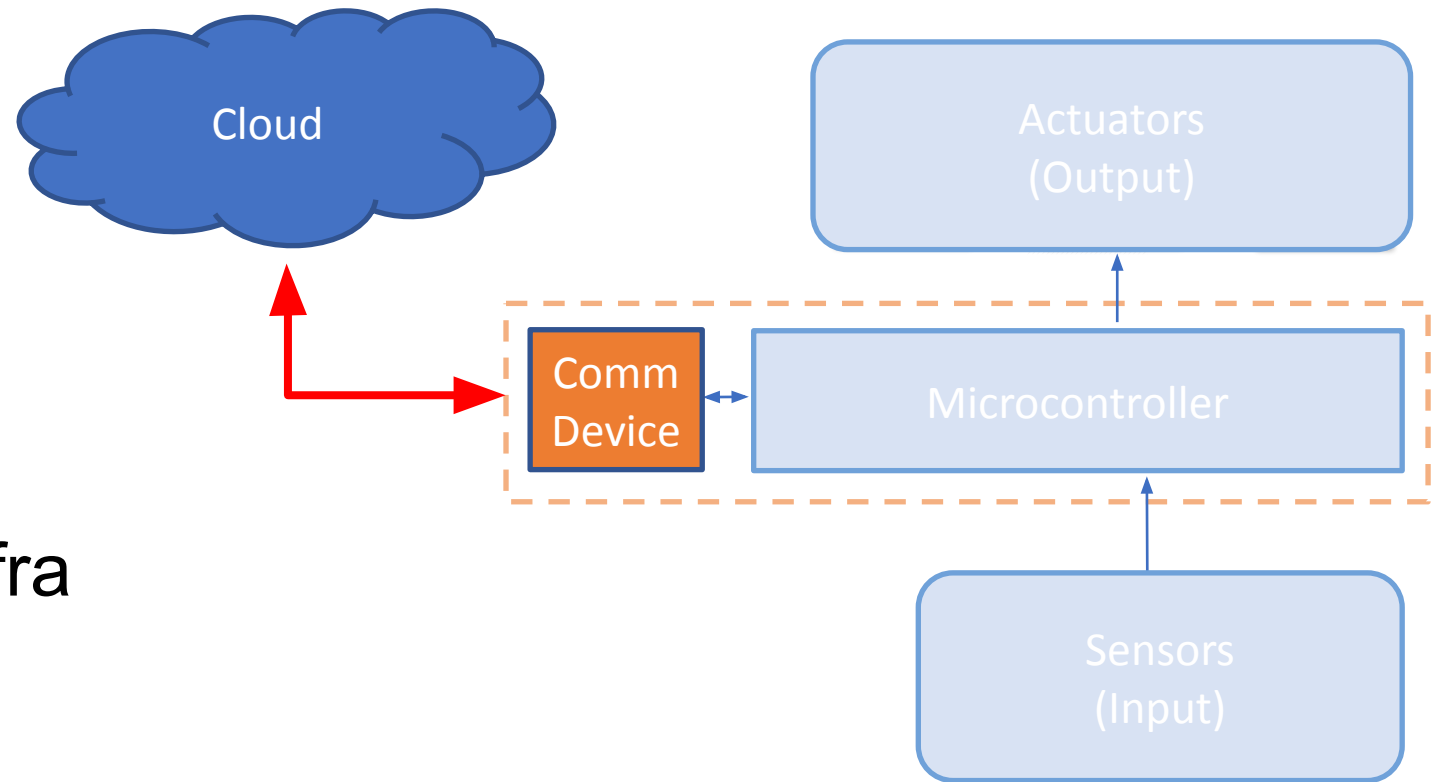iot

Typical IoT Project
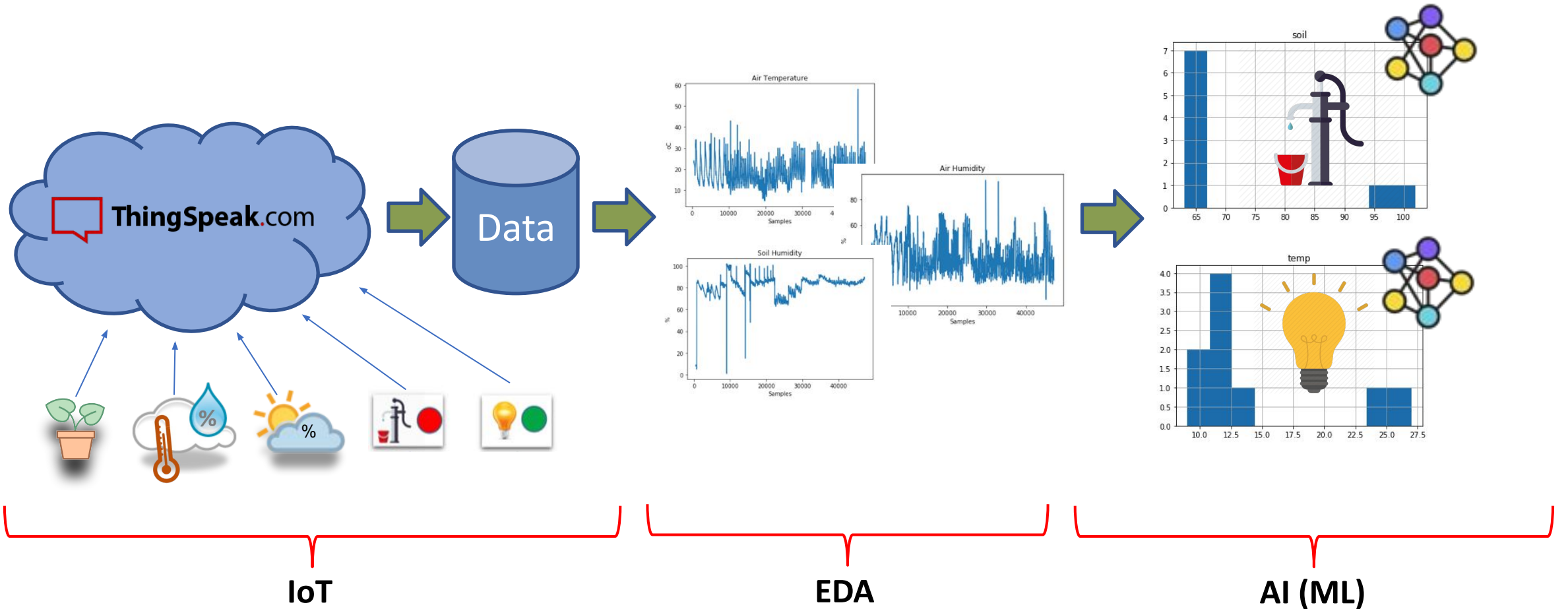
Typical IoT Project

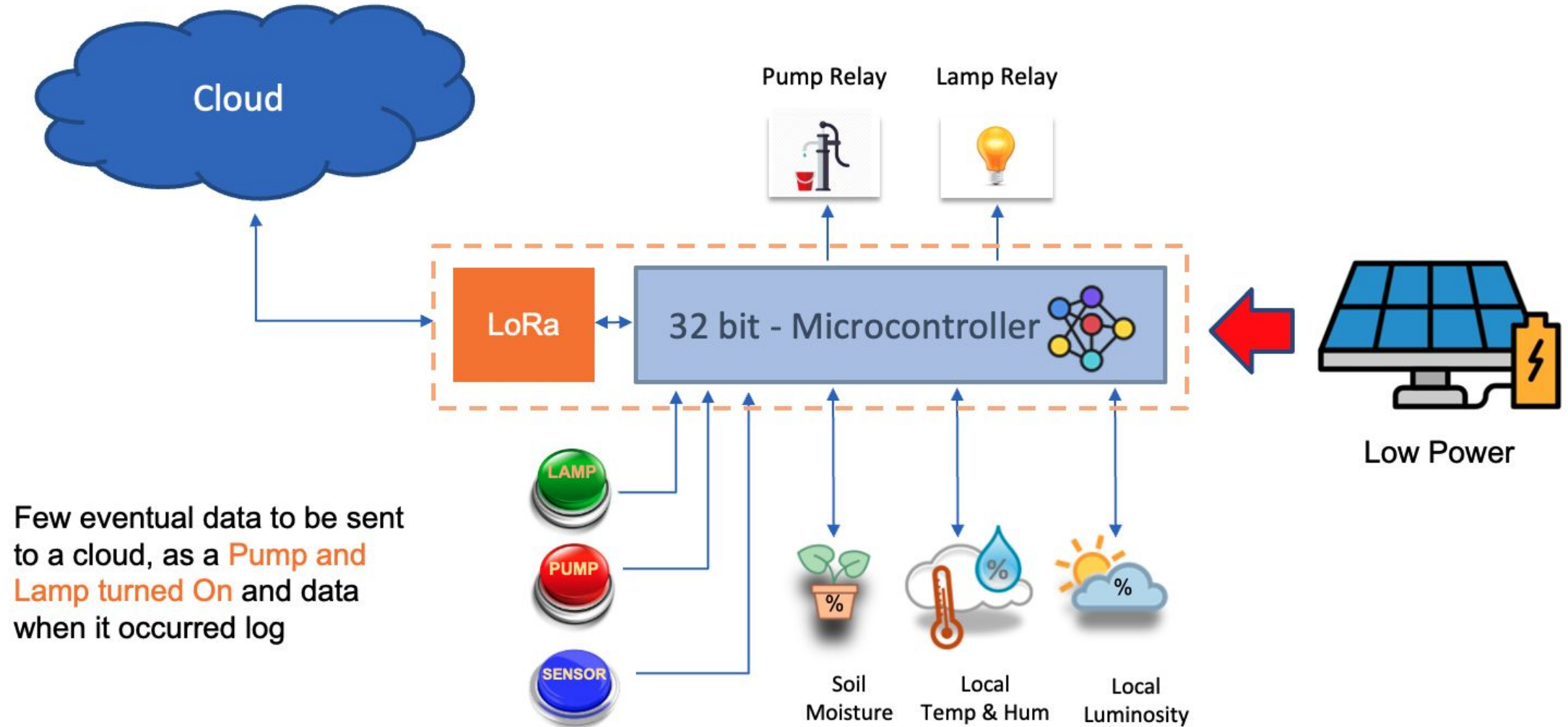Cloud Data Storage

Actuators

COMM Error Alarm · Pump Relay & LED · Lamp Relay & LED

Remote Control Page

ArduFarmBot

Buttons for Local Ctrl

LAMP · PUMP · SENSOR

Soil Moisture · Local Temp & Hum · Local Luminosity

Sensors for data capture

Local Display

https://www.hackster.io/mjrobot/ardufarmbot-part-2-remote-station-an-iot-implementation-6ccc29

Typical IoT Project Issues

✔ Power
✔ Connectivity
  ✔ Bandwidth
  ✔ Latency
  ✔ Complex Infra

Cloud

Actuators
(Output)

Comm
Device

Microcontroller

Sensors
(Input)

ArduFarmBot AIoT Project

IoT   EDA   AI (ML)

https://github.com/Mjrovai/Python4DS/tree/master/ArduFarmBot_Data_Analysis

Typical EdgeAI(ML) Project

Few eventual data to be sent to a cloud, as a Pump and Lamp turned On and data when it occurred log
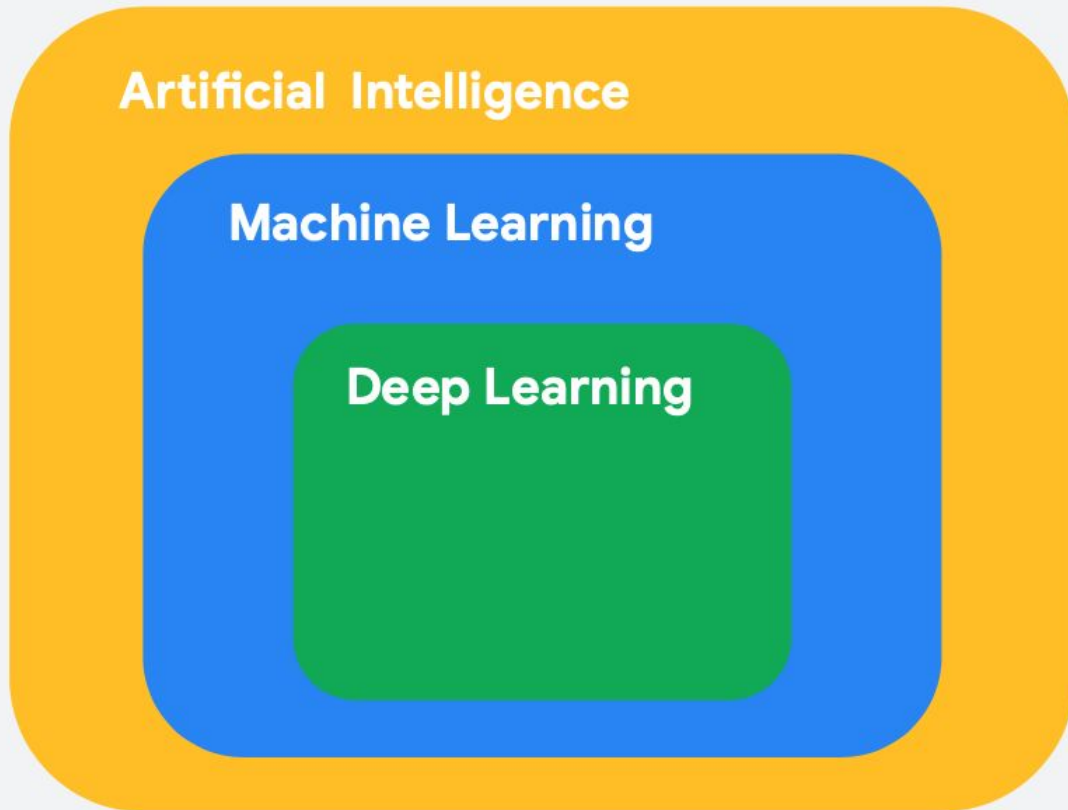
AI: Any technique that enables computers to mimic human behavior

ML: Ability to learn without explicitly being programed
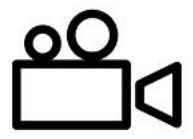
DL: Extract patterns from data using neural networks

Edge AI (or Edge ML) is the processing of Artificial Intelligence algorithms on edge, that is, on users' devices. The concept derives from **Edge Computing**, which starts from the same premise: data is stored, processed, and managed directly at the Internet of Things (IoT) endpoints.

TinyML is a subset of EdgeML, where sensors are generating data with ultra-low power consumption (batteries), so that we can ultimately deploy machine learning continuously ("always on devices")

Hardware

Power

TinyML

EdgeML

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
(Cortex-A)

SmartPhone

Jetson Nano
(Cortex-A + GPU)
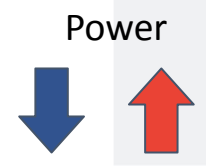
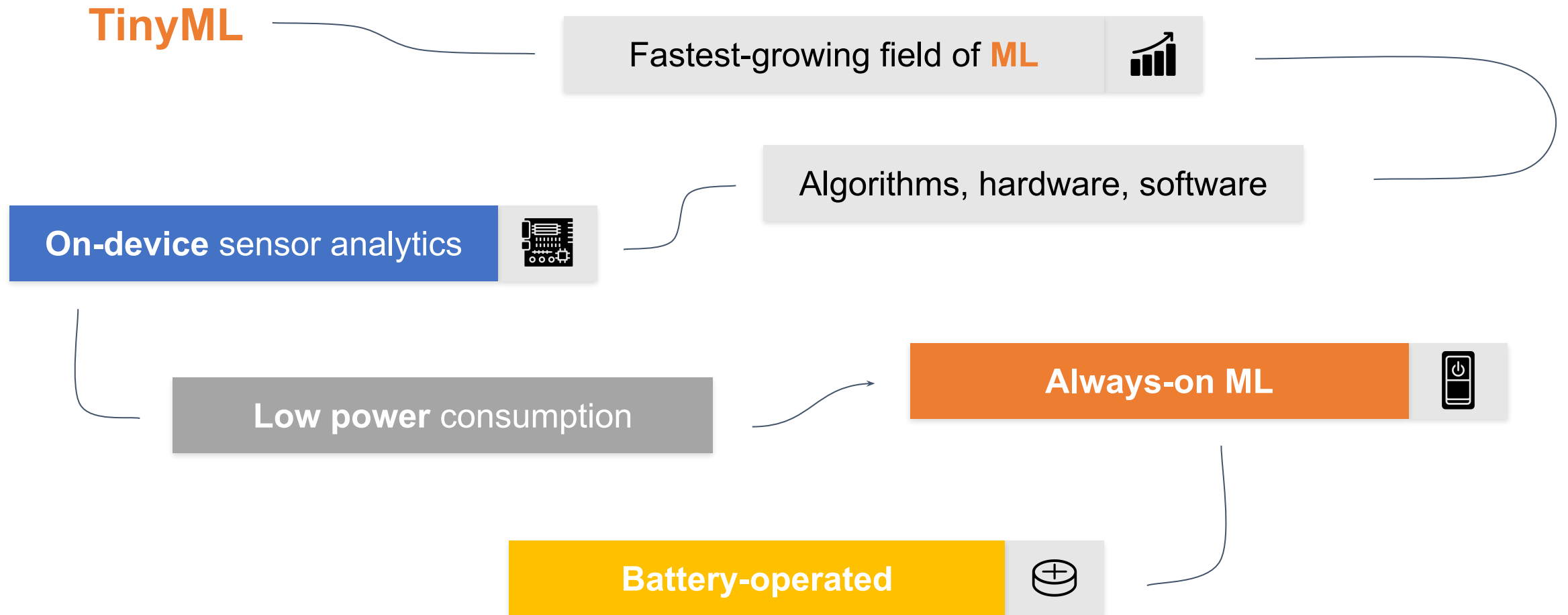# What is Tiny Machine Learning (TinyML)?

TinyML

Fastest-growing field of **ML**

Algorithms, hardware, software

On-device sensor analytics

Low power consumption

Always-on ML

Battery-operated

TinyML Application
Examples

Predictive Maintenance

Motion, current, audio and camera

→ **Industrial**

→ White goods

→ Infrastructure

→ Automotive

Asset Tracking & Monitoring

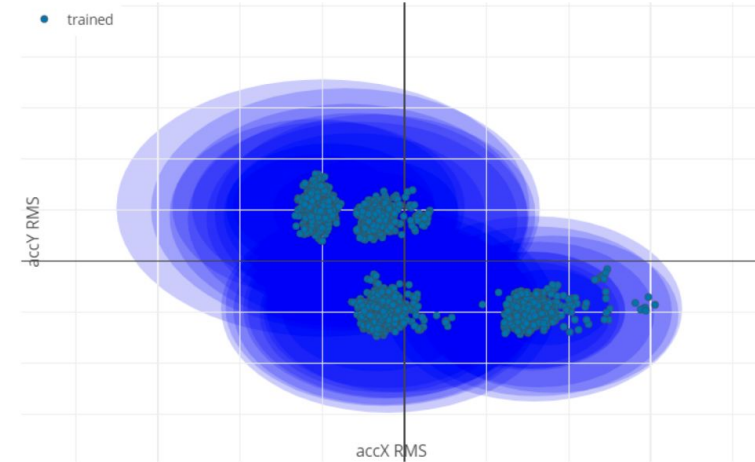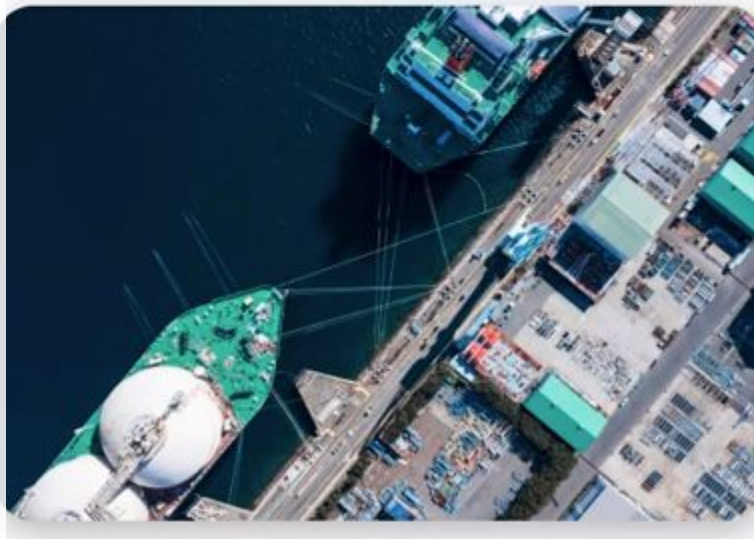Motion, temp, humidity, position, audio and camera

→ Logistics

→ Infrastructure
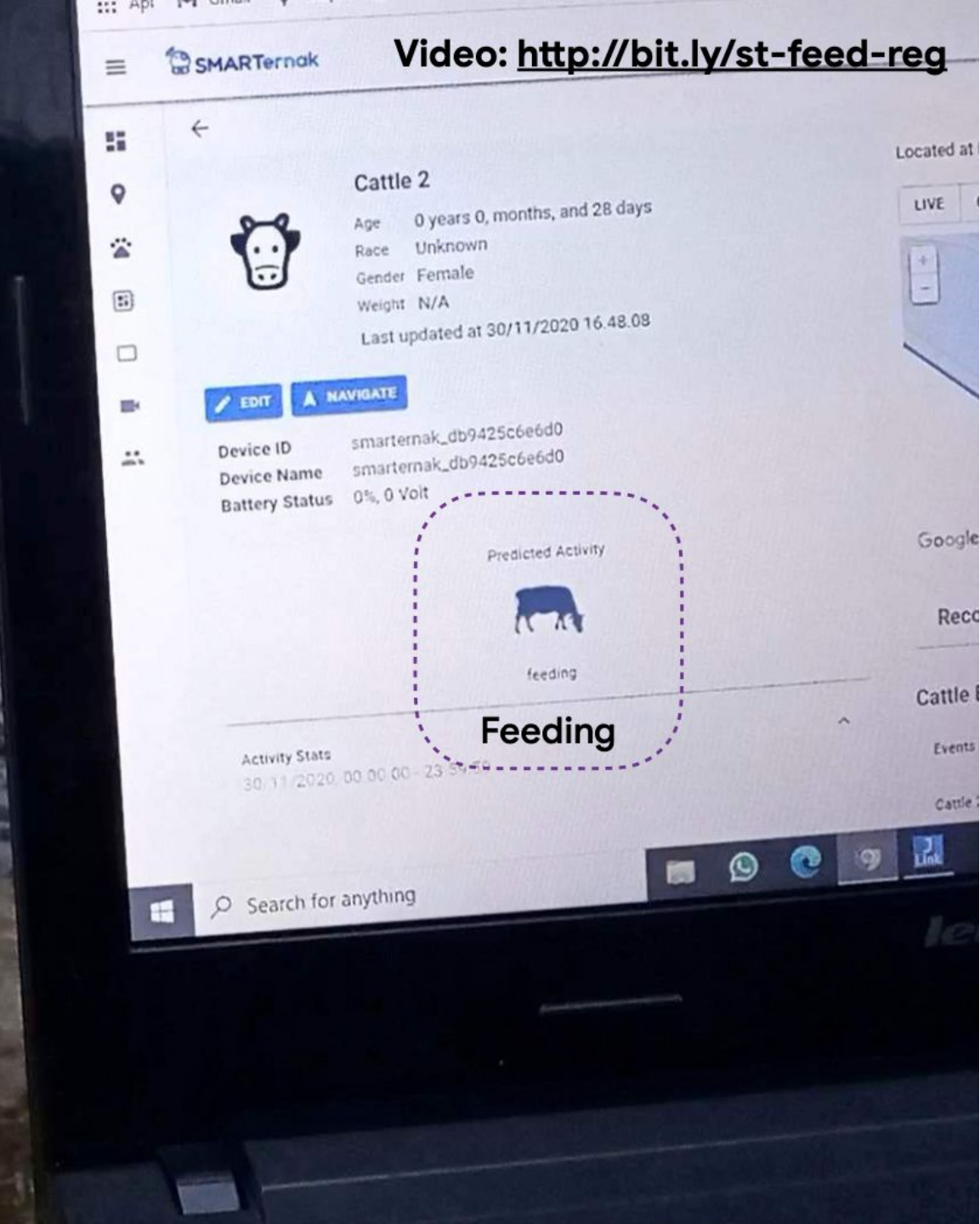
→ Buildings

→ Agriculture

Human & Animal Sensing

Motion, radar, audio, PPG, ECG

→ Health

→ Consumer

→ Industrial

EDGE IMPULSE

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Industry – Anomaly Detection

IESTI01 2021.2 - Final Group Project: Bearing Failure Detection

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

→ **Agriculture**

Human & Animal Sensing

Motion, radar, audio, PPG, ECG

→ Health

→ Consumer

→ Industrial

EDGE IMPULSE

Agriculture – Smart Farm - Animal Behavior
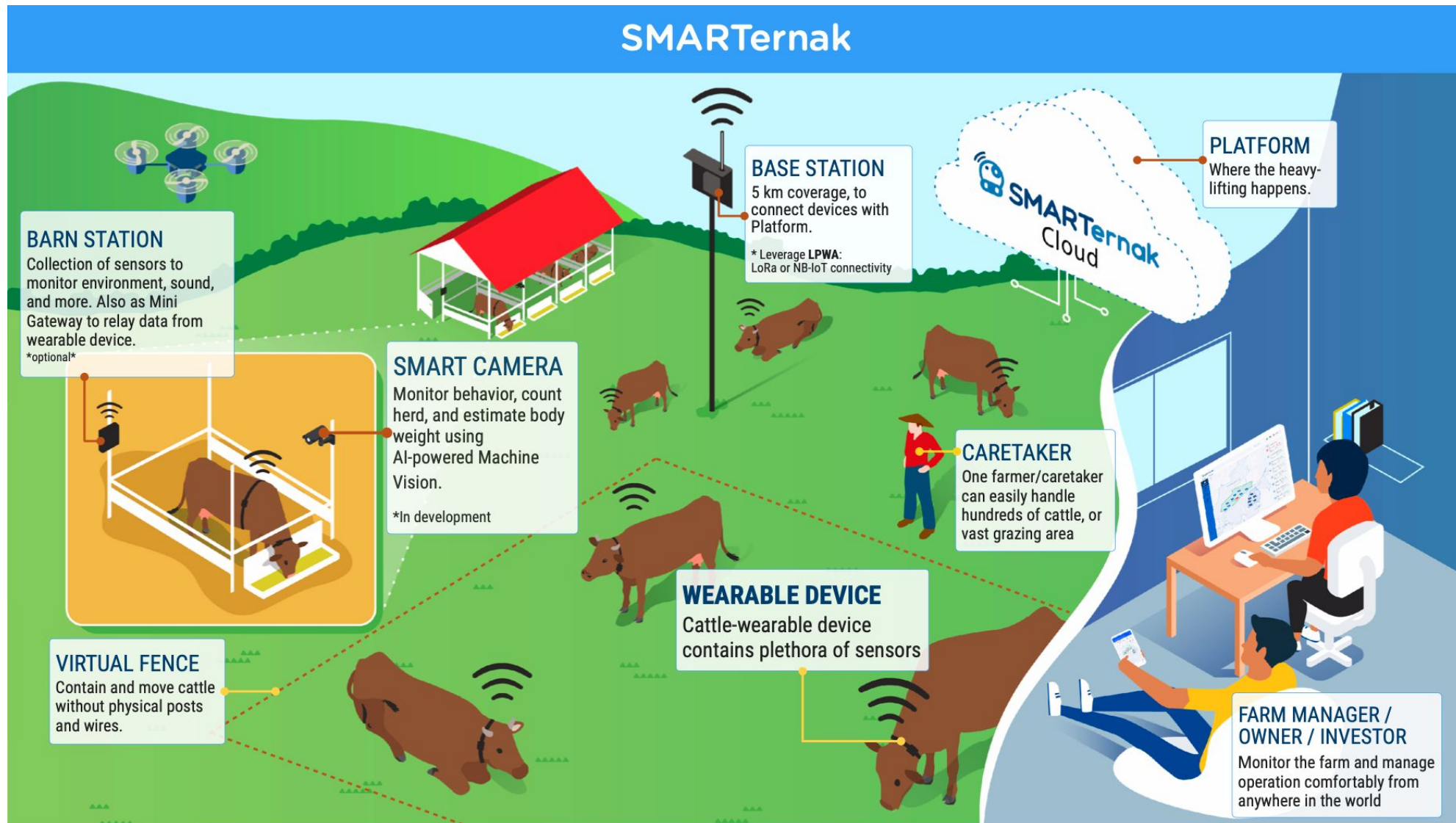
On-device Activity Prediction

Video: http://bit.ly/st-feed-reg

Predictive Maintenance

Motion, current, audio and camera

→ Industrial

→ White goods

→ Infrastructure

→ Automotive

Asset Tracking & Monitoring

Motion, temp, humidity, position, audio and camera

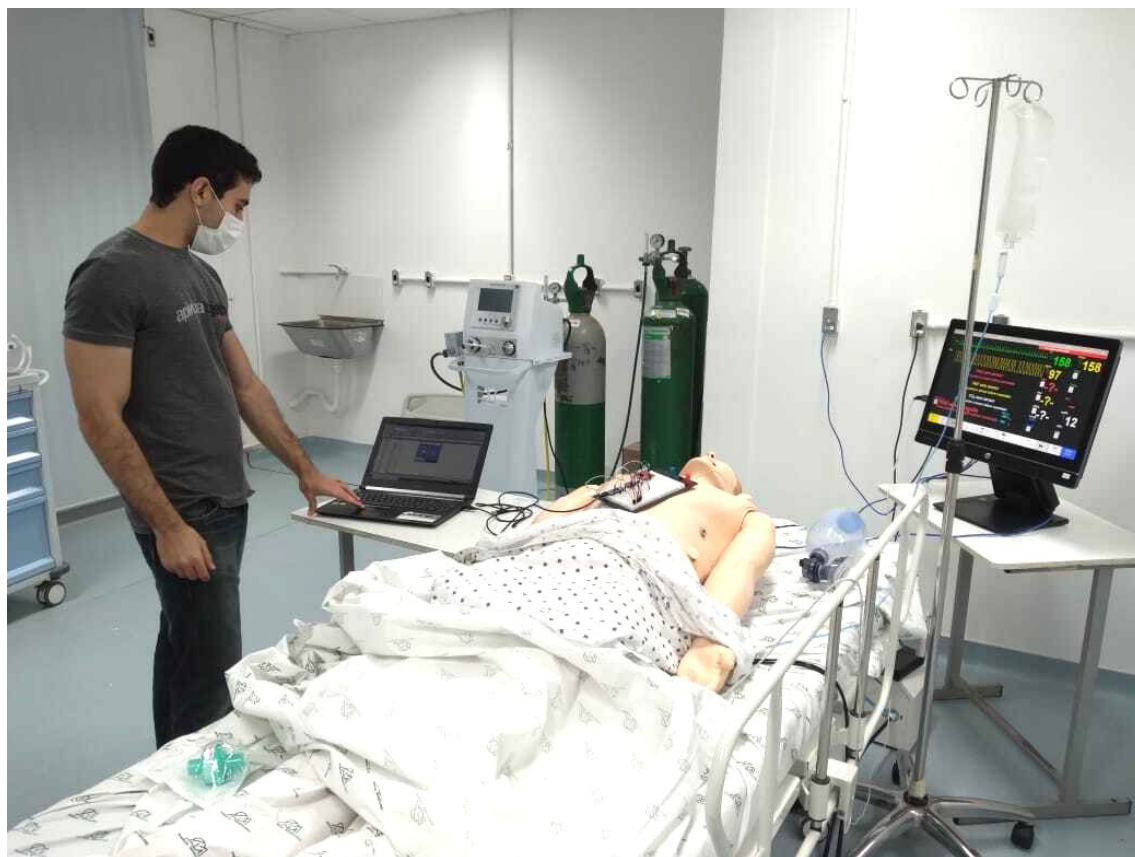→ Logistics

→ Infrastructure
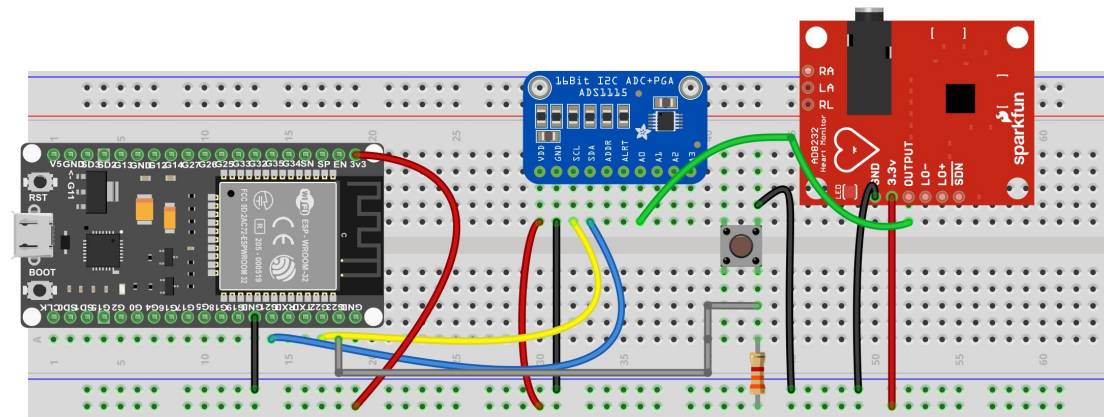
→ Buildings

→ Agriculture

Human & Animal Sensing

Motion, radar, audio, PPG, ECG
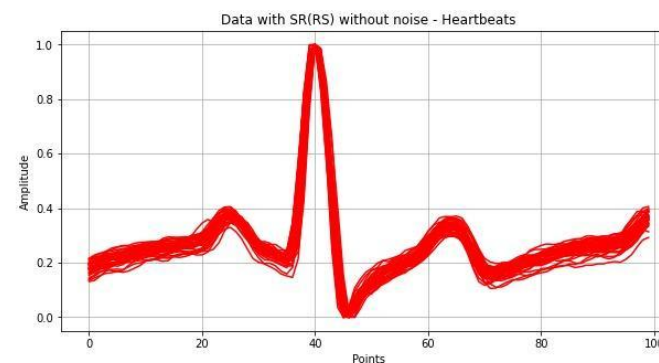
→ **Health**

→ Consumer

→ Industrial

EDGE IMPULSE

Health - Human Sensing

Data with SR(RS) without noise - Heartbeats

Guilherme Silva
Engenheiro - UNIFEI

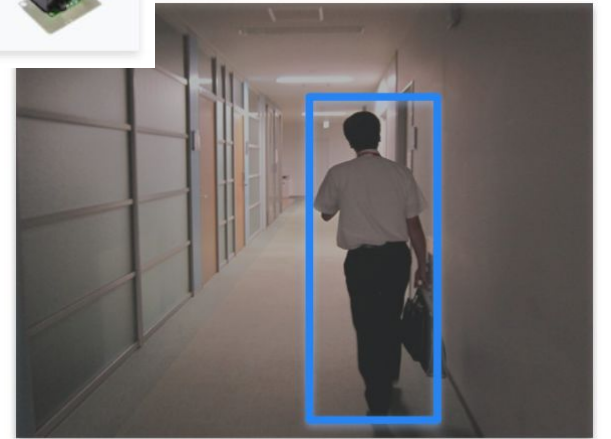Atrial Fibrillation Detection on ECG using TinyML
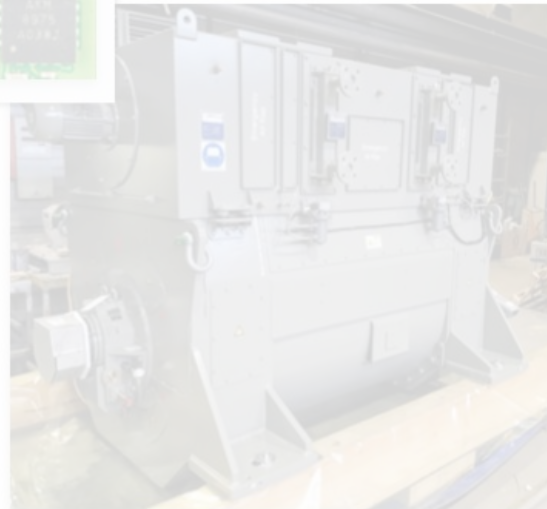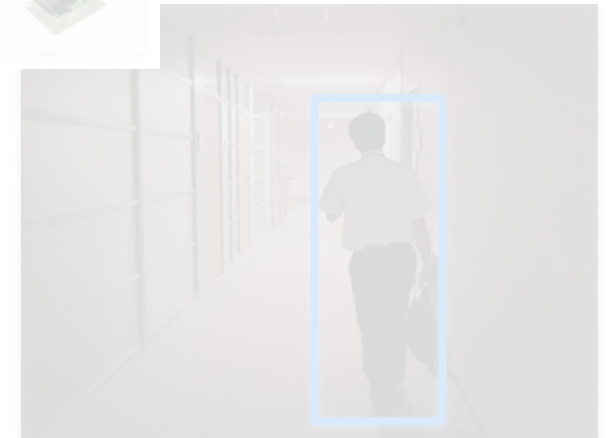Silva et al. UNIFEI 2021

Sound

Vibration

Vision

Sound

Vibration

Vision

More than just voice

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

    * Smart Beehive monitoring systems

Classifying mosquito wingbeat sound using TinyML

Moez Altayeb
University of Khartoum, Sudan
ICTP, Trieste, Italy
mohedahmed@hotmail.com

Marcelo Rovai
Universidade Federal de Itajubá
Itajubá, Brazil
rovai@unifei.edu.br

Marco Zennaro
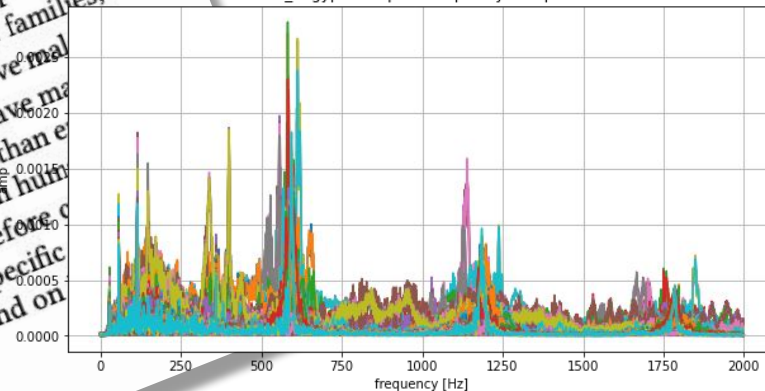ICTP
Trieste, Italy
mzennaro@ictp.it

ABSTRACT

Every year more than one billion people are infected and more than one million people die from vector-borne diseases including malaria, dengue, zika and chikungunya. Mosquitoes are the best known disease vector and are geographically spread worldwide. It is important to raise awareness of mosquito proliferation by monitoring their incidence, especially in poor regions. Acoustic detection of mosquitoes has been studied for long and ML can be used to automatically identify mosquito species by their wingbeat. We present a prototype solution based on an openly available dataset, on the Edge Impulse platform and on three commercially-available TinyML devices. The proposed solution is low-power, low-cost and can run without human intervention in resource-constrained areas. This insect monitoring system can reach a global scale.
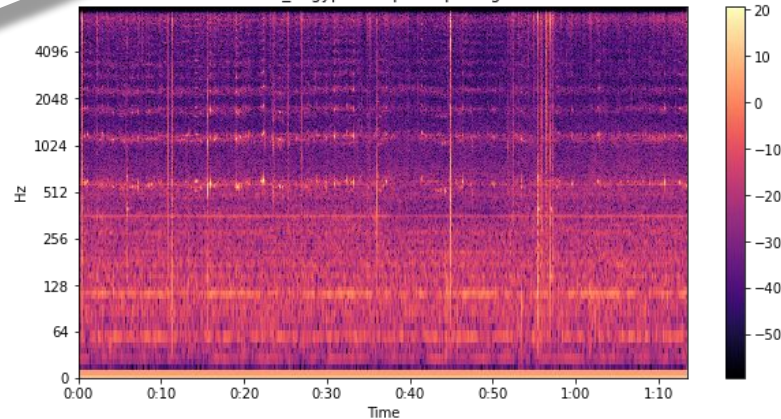
affected. People from poor communities with little access to health care and clean water sources are also at risk. Although anti-malarial drugs exist, there's currently no malaria vaccine. Vector-borne diseases also exacerbate poverty. Illness prevent people from working and supporting themselves and their families, impeding economic development. Countries with intensive mal... have much lower income levels than those that don't have ma... Countries affected by malaria turn to control rather than e... tion. Vector control means decreasing contact between hum... disease carriers on an area-by-area basis. It is therefore o... be able to detect the presence of mosquitoes in a specific... paper presents an approach based on TinyML and on... embedded devices.
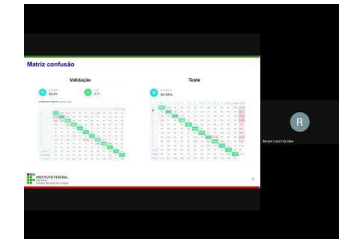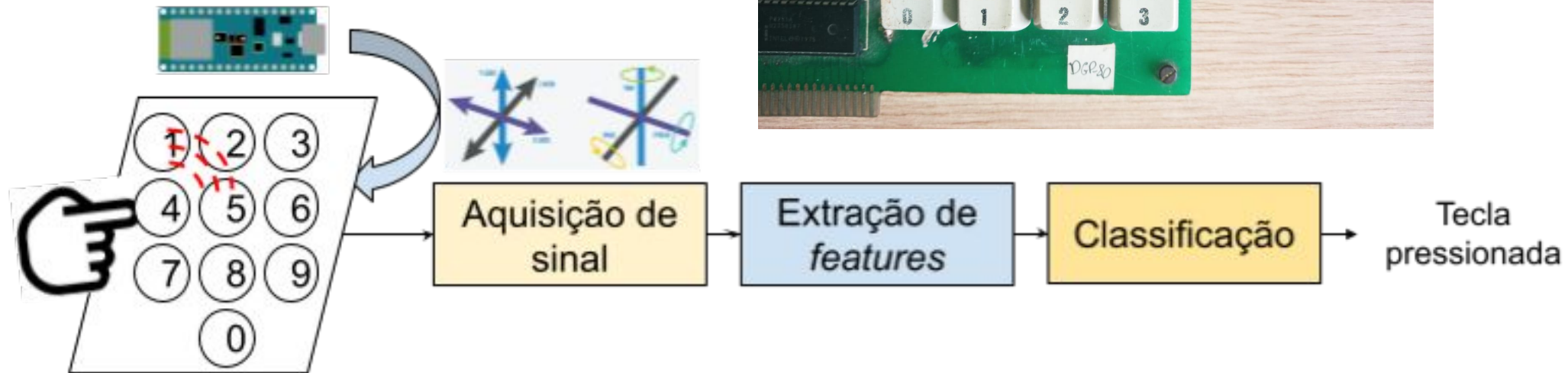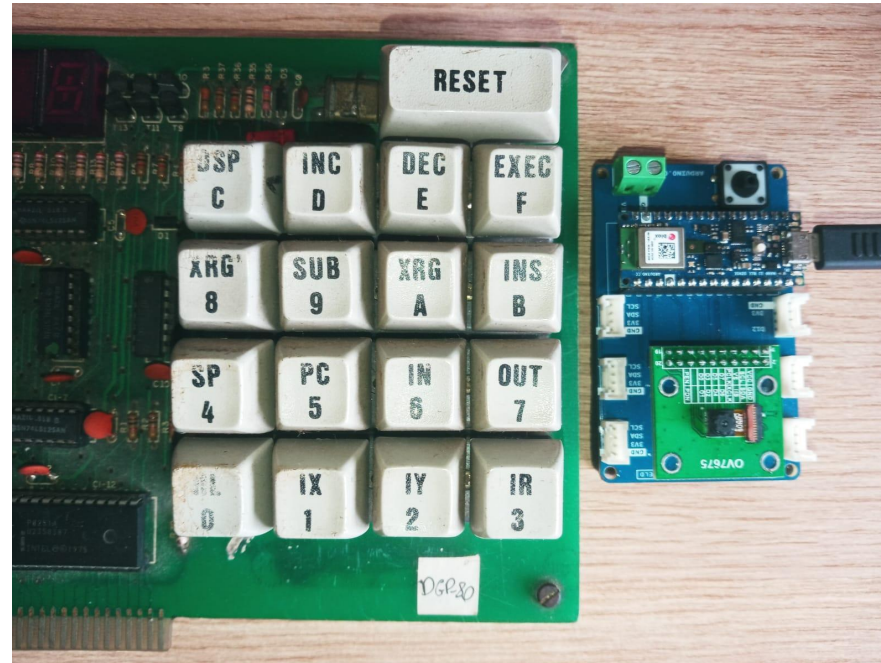
aedes_aegypti sample - Frequency Components

aedes_aegypti sample - Spectogram

https://github.com/Mjrovai/wingbeat-mosquito-tinyml

Key Stroke Detection

Renam Castro
Professor IFESP

Aquisição de sinal → Extração de *features* → Classificação → Tecla pressionada

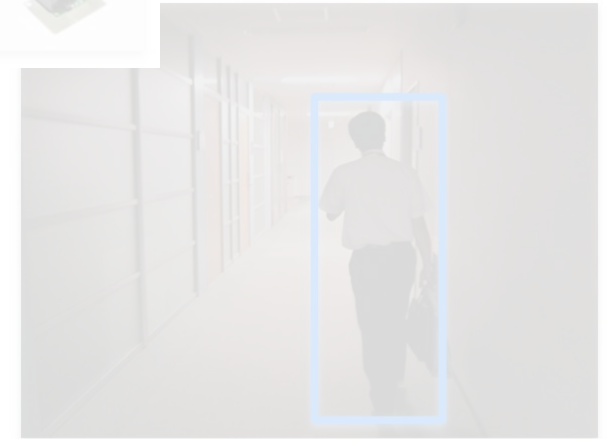IESTI01 2021.2 – Final Group Project Key Stroke Detection

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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
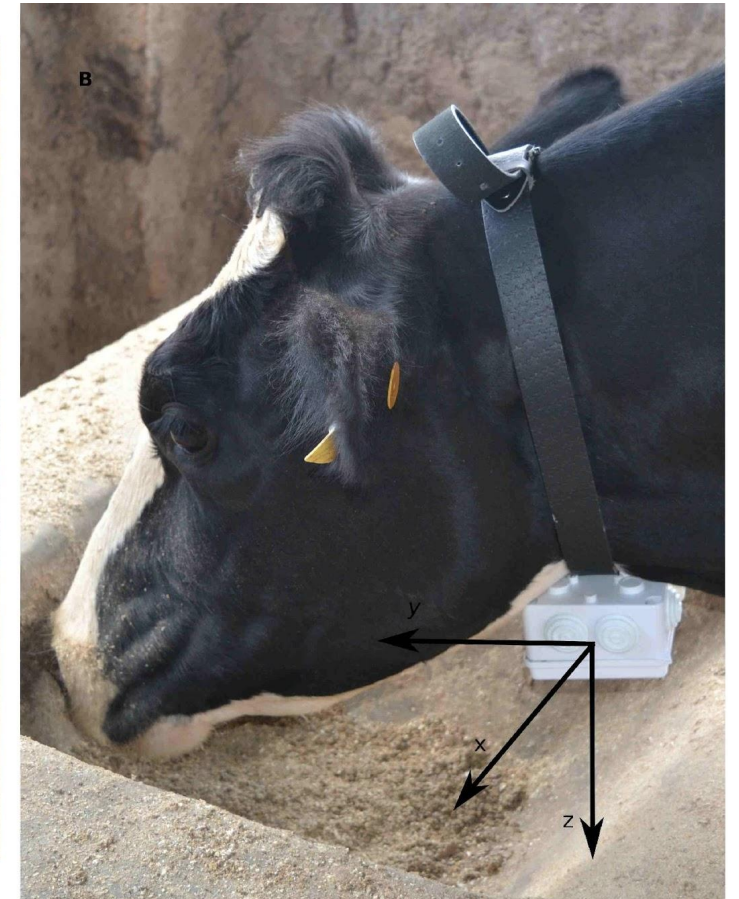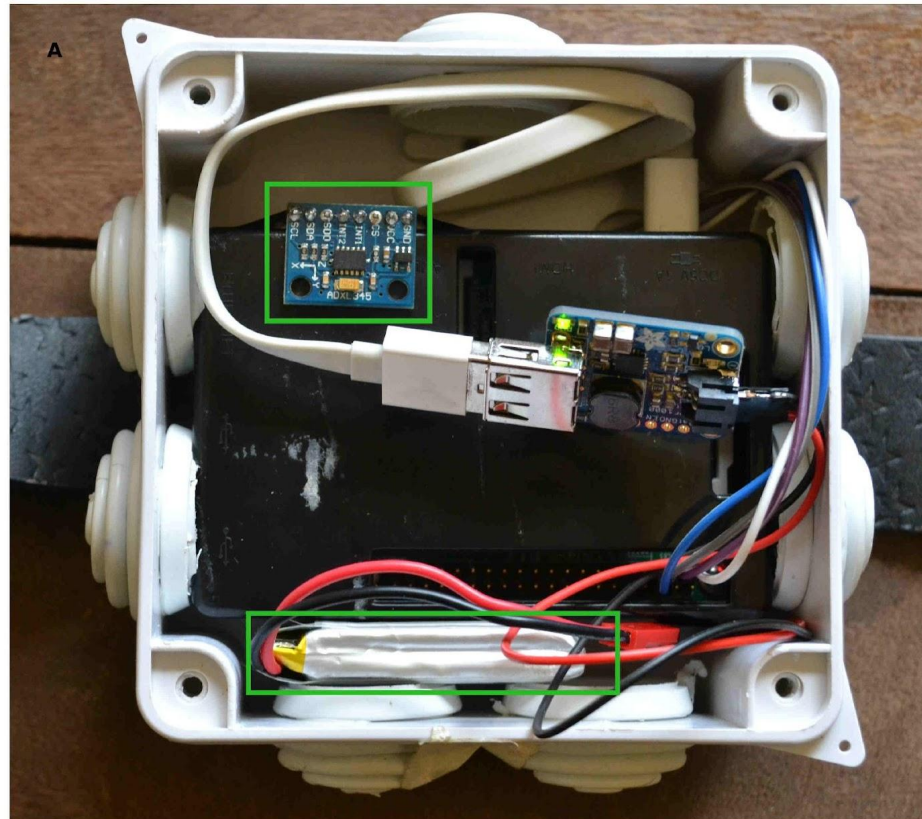
Predict and classify common Elephant behavior
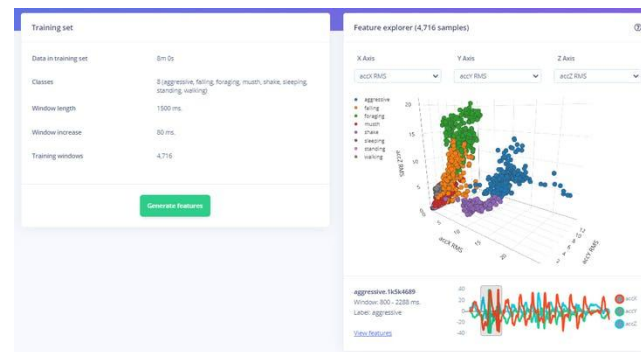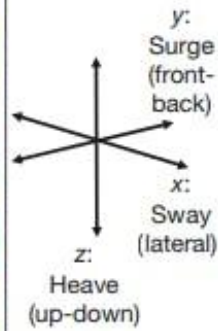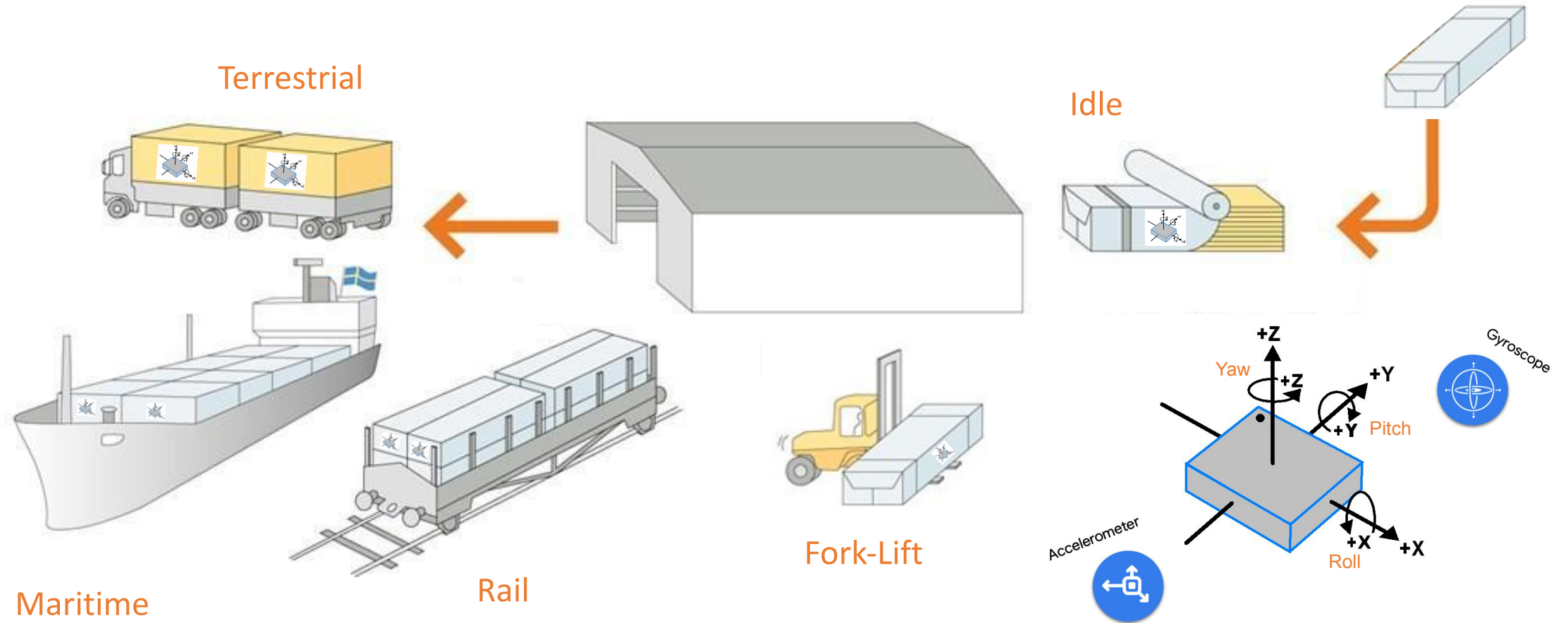

Aggressive

Standing

Sleeping

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

Mechanical Stresses in Transport

Terrestrial

Idle

Maritime

Rail

Fork-Lift

+Z

Yaw

+Z

+Y

+Y

Pitch

Gyroscope

Accelerometer

+X

+X

Roll

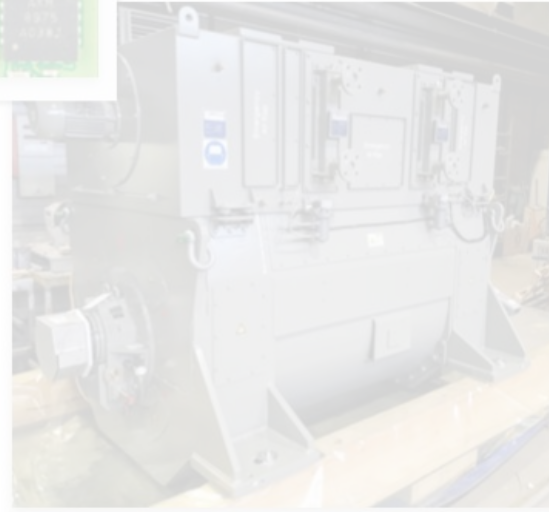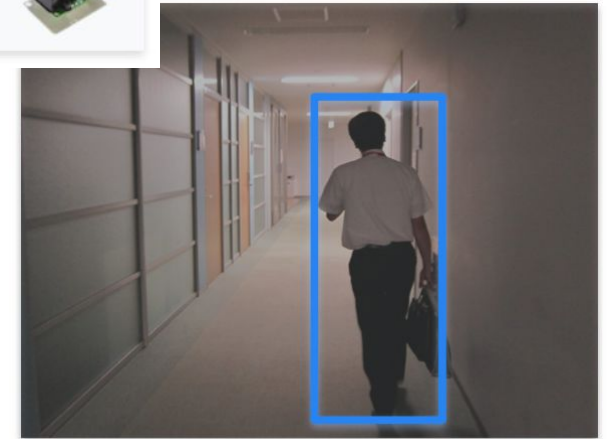# **Application:** Factory machinery

Ball Bearings

Accelerometer

Sound

Vibration

Vision

Forest Fire Detection

TinyML Aerial Forest Fire Detection

IESTI01 - Forest Fire Detection – Proof of Concept

Detecting Diseases in the Bean plants

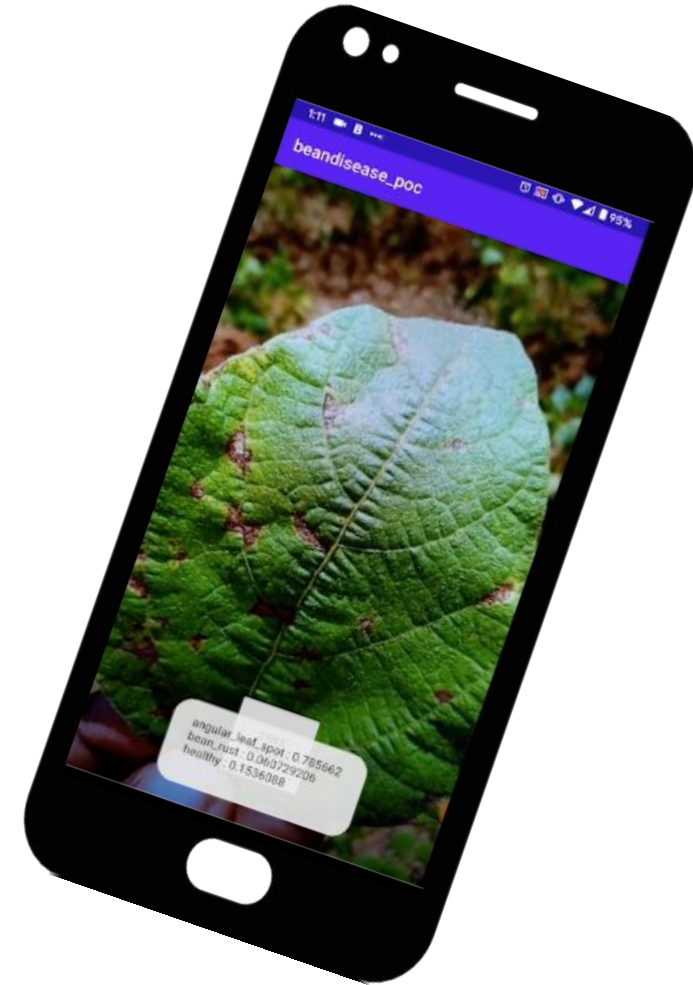

AIR Lab Makerere University
UGANDA

Angular Leaf Spot   Bean Rust   Healthy
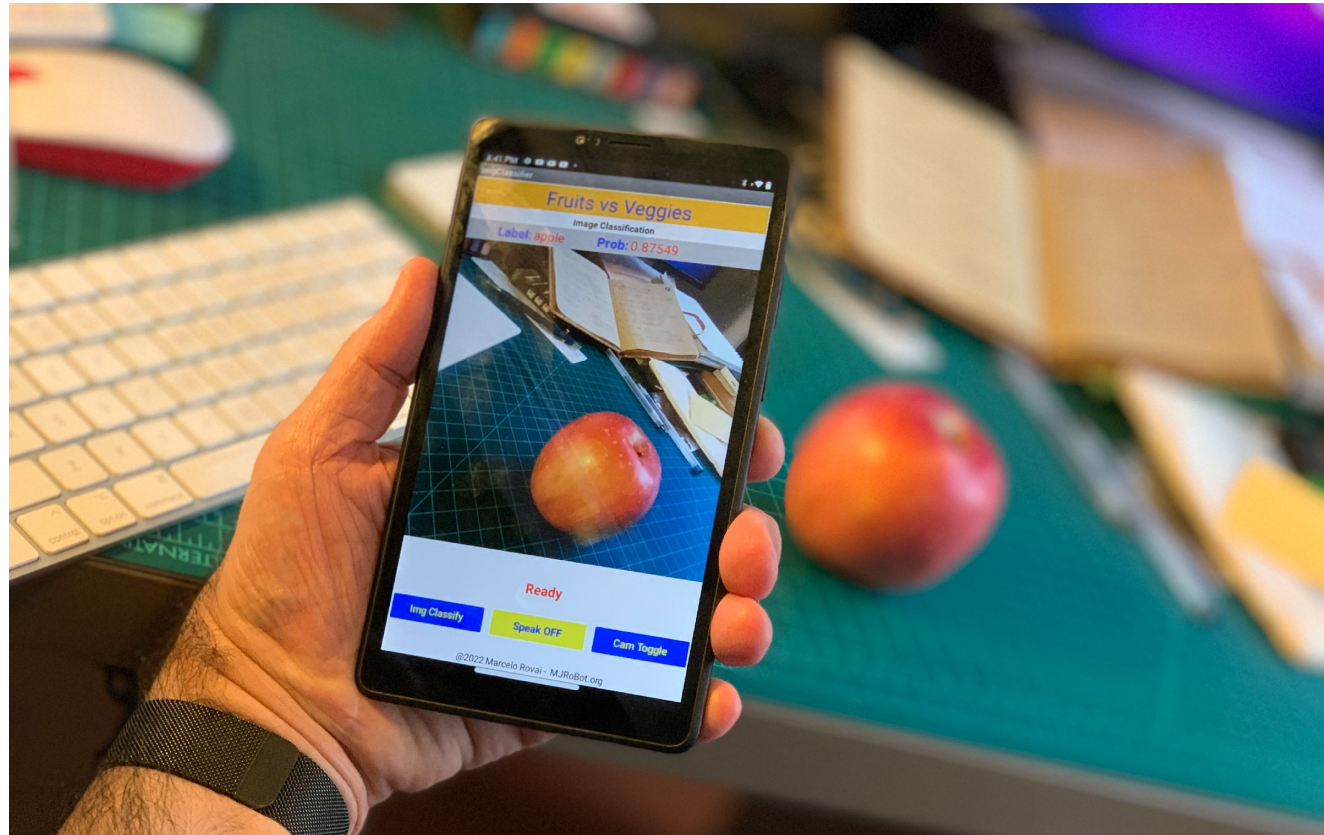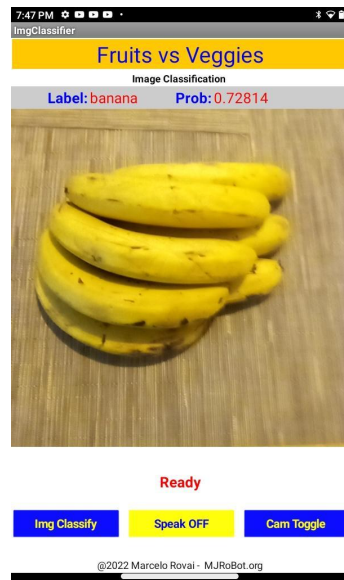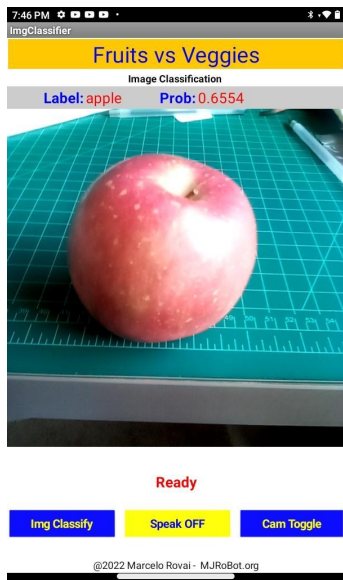
Dataset: https://github.com/AI-Lab-Makerere/ibean/

Learn the steps to build an app that detects crop diseases
(Android Studio)

Classifying Images using Smartphones

https://www.hackster.io/mjrobot/app-inventor-edgeml-image-classification-fruit-vs-veggies-b671da

Coffee Disease Classification

João Vitor Yukio Bordin Yamashita
Graduando em Engenharia Eletrônica pela UNIFEI

https://www.hackster.io/Yukio/coffee-disease-classification-with-ml-b0a3fc

Other TinyML / MCUs Project Examples

Vision

- Image Classification with ESP32-CAM [Doc]
- Image Classification with Portenta H7 [Doc]

Sound

- Listening Temperature with Nano 33 [Doc]

Vibration

- Motion Recognition with RPi Pico [Doc]
- Gesture Recognition with Wio Terminal [Doc]

To learn more about Edge AI

- UNIFEI - IESTI01 TinyML - Machine Learning for Embedding Devices
- 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
- "Deep Learning with Python" book by François Chollet
- "TinyML" book by Pete Warden, Daniel Situnayake
- "TinyML Cookbook" by Gian Marco Iodice
- "AI at the Edge" book by Daniel Situnayake, Jenny Plunkett

Thanks
And stay safe!