EdgeAI
Artificial intelligence at the edge

Bringing intelligence to sensors

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Typical IoT Project

Microcontroller

COMM Error Alarm

Cloud

WAN

Pump Relay & LED

Typical IoT Project
Comm Device

Actuators (Output)

Microcontroller

Sensors (Input)
Typical IoT Project

Cloud Data Storage

COMM Error
Alarm

Pump Relay &
LED

Lamp Relay &
LED

Sensors for data capture

Buttons for
Local Ctrl

Local
Display

Remote Control Page

ArduFarmBot

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

- ✔ Power
- ✔ Connectivity
  - ✔ Bandwidth
  - ✔ Latency
  - ✔ Complex Infra
ArduFarmBot AIoT Project

IoT  EDA  AI (ML)

https://github.com/Mjrovai/Python4DS/tree/master/ArduFarmBot_Data_Analysis
Typical EdgeAI(ML) Project

Cloud

LoRa

32 bit - Microcontroller

Pump Relay
Lamp Relay

Pump and Lamp turned On

Few eventual data to be sent to a cloud, as a Pump and Lamp turned On and data when it occurred log

Low Power

Sensor

Soil Moisture
Local Temp & Hum
Local Luminosity
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

EdgeML

TinyML

Object Detection
Complex Voice Processing
1 MB+

Video Classification
2 MB+

KeyWord Spotting
Audio Classification
250 KB+

Anomaly Detection
Sensor Classification
50 KB

Rpi-Pico (Cortex-M0+)
Arduino Nano (Cortex-M4)
Arduino Pro (Cortex-M7)

Raspberry Pi (Cortex-A)
SmartPhone (Cortex-A)
Jetson Nano (Cortex-A + GPU)

Source: Edge Impulse
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
Industry – Anomaly Detection
Predictive Maintenance

Asset Tracking & Monitoring

Human & Animal Sensing

Motion, current, audio and camera

Motion, temp, humidity, position, audio and camera

Motion, radar, audio, PPG, ECG

→ Industrial
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EDGE IMPULSE

→ Health
→ Consumer
→ Industrial
Agriculture – Smart Farm - Animal Behavior

SMARTernak

BASE STATION
5 km coverage, to connect devices with Platform.
* Leverage LPWA: LoRa or NB-IoT connectivity

PLATFORM
Where the heavy-lifting happens.

BARN STATION
Collection of sensors to monitor environment, sound, and more. Also as Mini Gateway to relay data from wearable device.
*optional

SMART CAMERA
* in development

CARETAKER
One farmer/caretaker can easily handle hundreds of cattle, or vast grazing area

WEARABLE DEVICE
Cattle-wearable device contains plethora of sensors

VIRTUAL FENCE
Contain and move cattle without physical posts and wires.

FARM MANAGER / OWNER / INVESTOR
Monitor the farm and manage operation comfortably from anywhere in the world

https://dycodex.com/smarternak/
On-device Activity Prediction

Predictive Maintenance

- Industrial
- White goods
- Infrastructure
- Automotive

Asset Tracking & Monitoring

- Logistics
- Infrastructure
- Buildings
- Agriculture

Human & Animal Sensing

- Health
- Consumer
- Industrial

Motion, current, audio and camera

Motion, temp, humidity, position, audio and camera

Motion, radar, audio, PPG, ECG
Health - Human Sensing

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

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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 EdgeInsight 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 prevents people from working and supporting themselves and their families, impeding economic development. Countries with intensive mosquito control programs have much lower income levels than those that don’t have them.

Countries affected by malaria turn to control rather than eradication. Vector control means decreasing contact between humans and disease carriers on an area-by-area basis. It is therefore important to be able to detect the presence of mosquitoes in a specific area.

This paper presents an approach based on TinyML and on embedded devices.

https://github.com/Mjrovai/wingbeat-mosquito-tinyml
Key Stroke Detection
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.”

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

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https://sites.google.com/site/cwamainadekut/research
Predict and classify common Elephant behavior

Mechanical Stresses in Transport

Terrestrial

Maritime

Rail

Fork-Lift

Idle

ICTP SciTyiriML 21 - Hands on Embedded ML - Motion/Anomaly Detection and Scientific Applications
Application: Factory machinery
Forest Fire Detection

TinyML Aerial Forest Fire Detection

IESTI01 - Forest Fire Detection – Proof of Concept
Detecting Diseases in the Bean plants

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

Coffee Disease Classification

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

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Other TinyML / MCUs Project Examples

- Image Classification with ESP32-CAM  [Doc]
- Image Classification with Portenta H7  [Doc]
- Listening Temperature with Nano 33  [Doc]
- 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!