

# TINYML EDUCATOR SERIES

Hello..

## Let's talk about TinyML

Intelligence on Microcontrollers

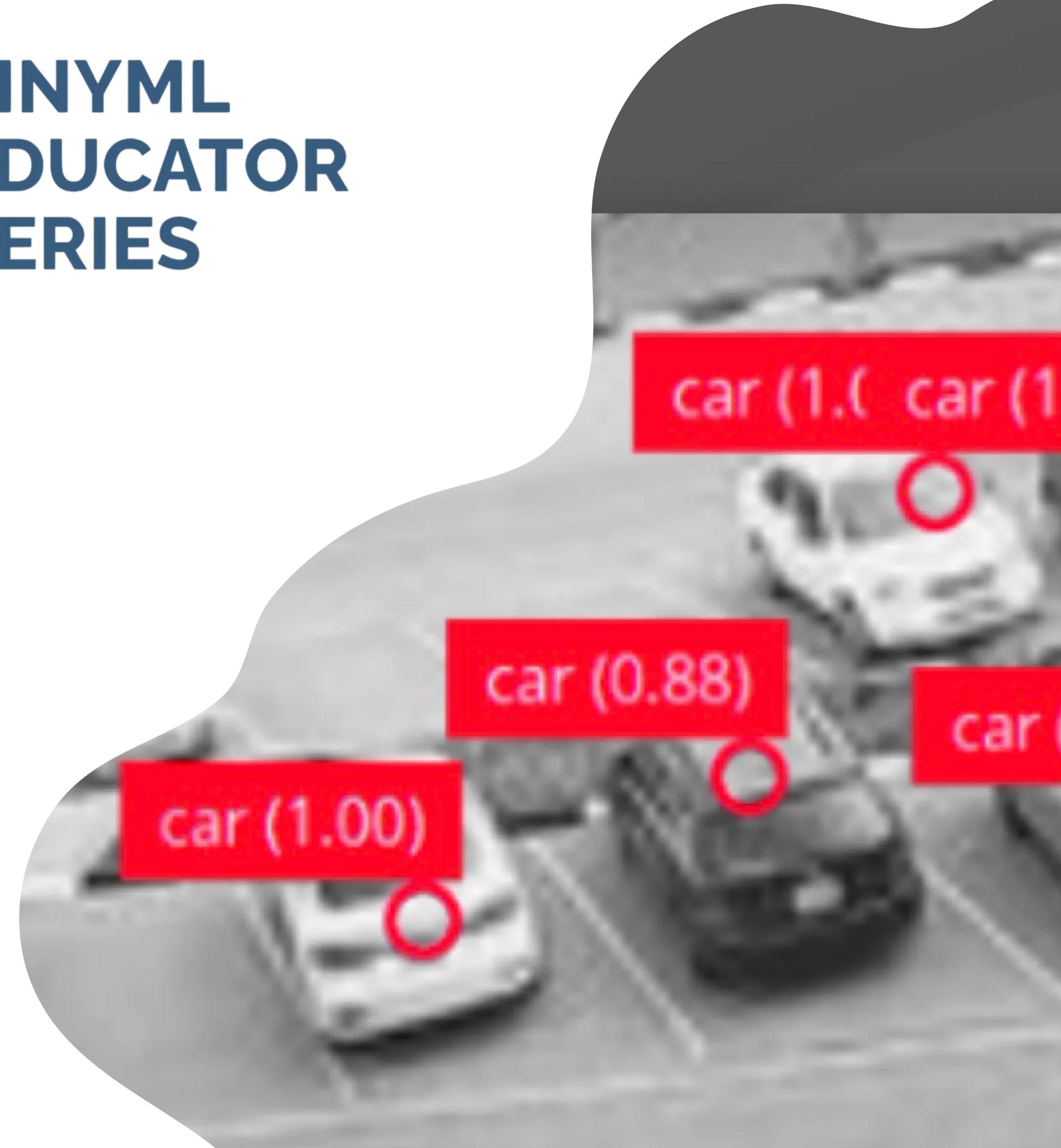


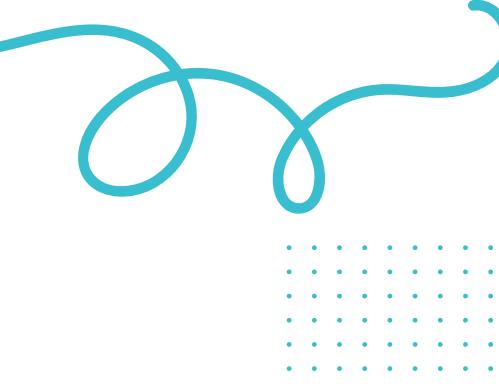
**Solomon Muhunyo Githu**

Researcher Waziup e.V.

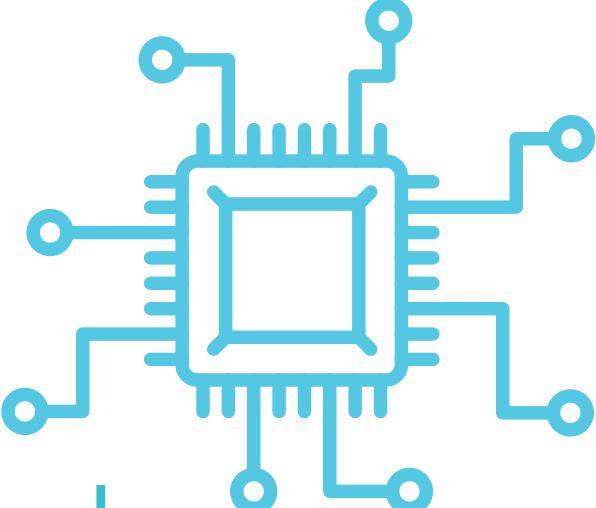
Contributor, Edge Impulse Expert Network

August 2023.

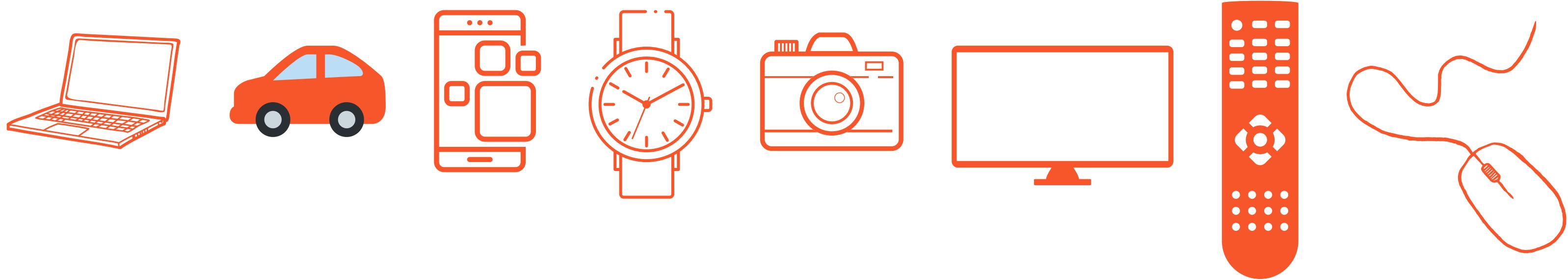




# Introduction to embedded systems



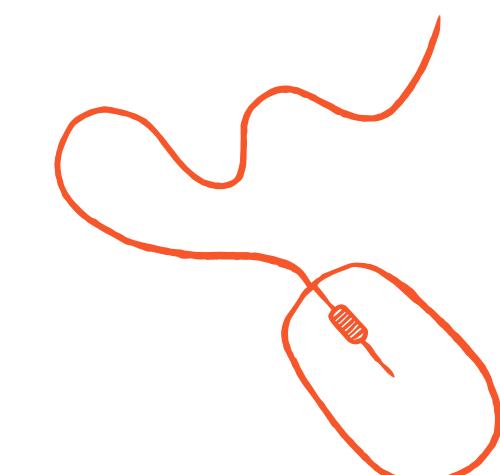
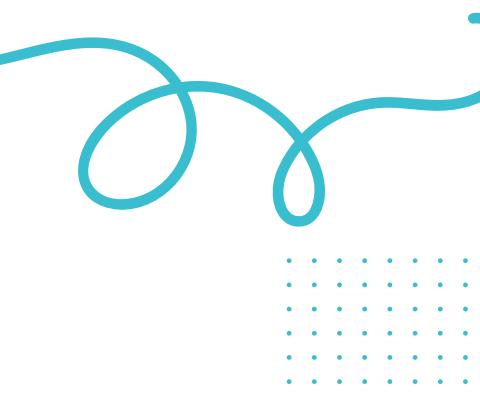
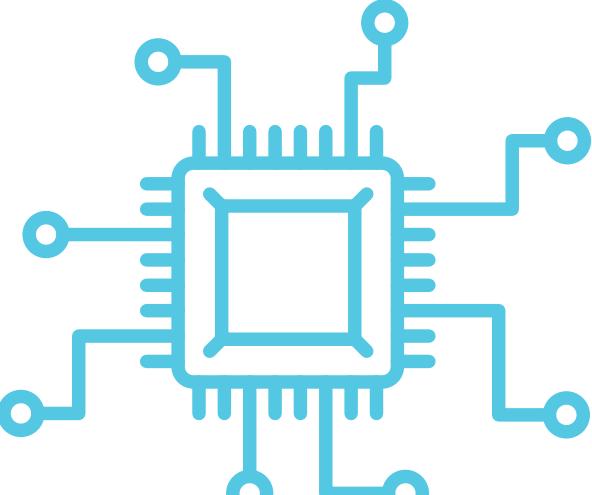
An embedded system is a computer system (hardware and software) that has a dedicated function within an electronic or mechanical system.



Microcontrollers are computers designed to control features of systems say vehicle, smartphone, laptop, robot, airplane, ATM machine, parking systems, drones, rockets; among others

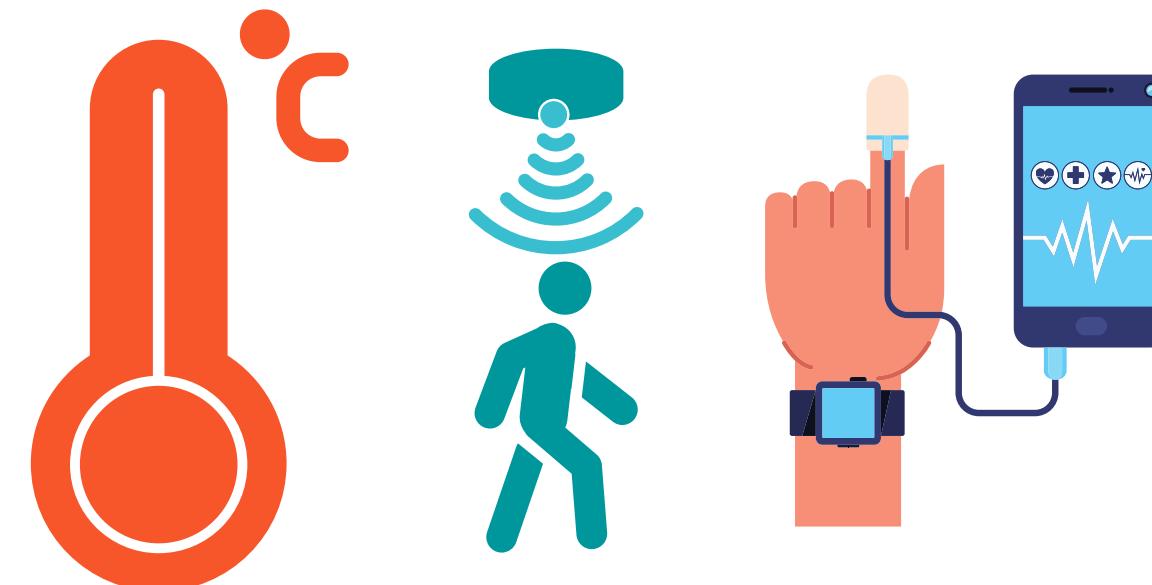
# Introduction to embedded systems..

Your keyboard uses a microcontroller to detect when keys are pressed, your mouse uses it to detect movements, your computer monitor uses it to turn and display, pictures are captured from a camera using a microcontroller and sent to the CPU.



# Introduction to sensors

Sensors gather data from the environment (temperature, humidity, motion, etc.) and produce a signal.

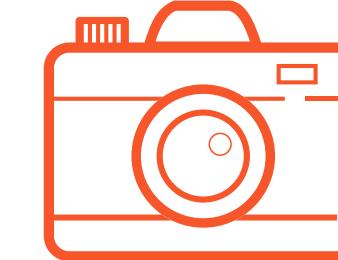


They enable contextual awareness for TinyML applications  
(describe what something means as it relates to a place or something)

# Sensor Types for Embedded Systems

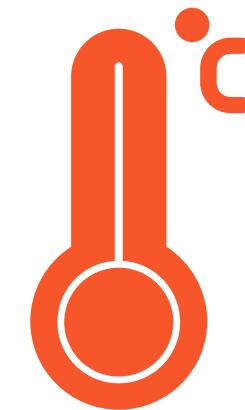
- **Image Sensors:**

- Camera modules for visual data.
- Object detection, image classification.



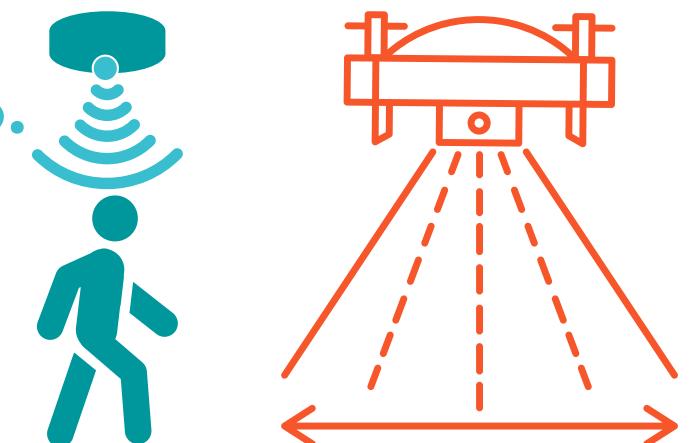
- **Environmental Sensors:**

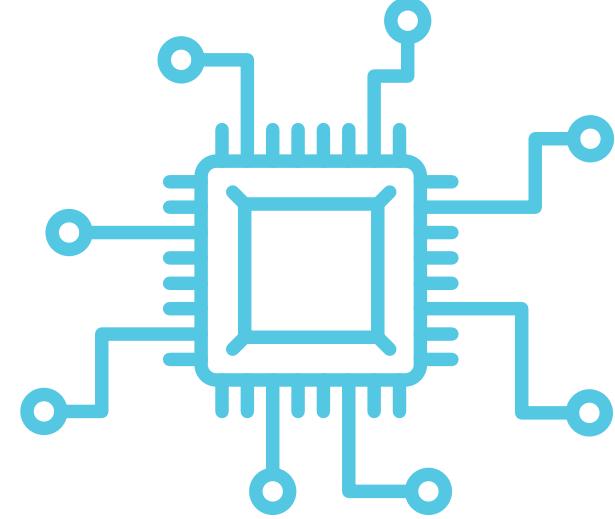
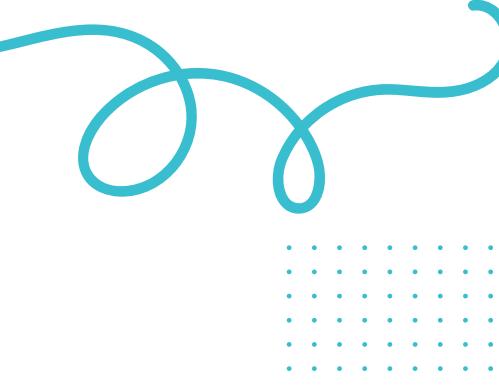
- Measure temperature, humidity, air quality, etc.
- Useful in agriculture, HVAC systems, and more.



- **Motion Sensors:**

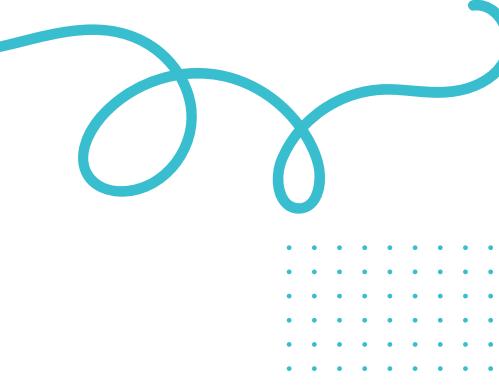
- Accelerometers, gyroscopes, magnetometers.
- Gesture recognition, activity tracking.





# Types of embedded hardware

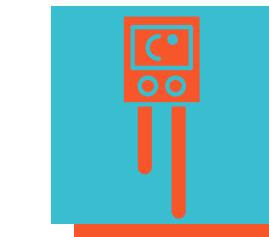
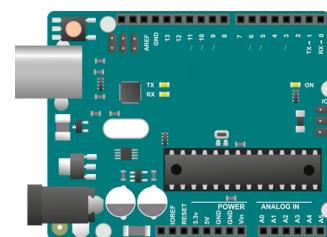
- **Microcontrollers (MCUs):**
  - Power-efficient, suitable for battery-powered devices.
  - Limited computational resources.
  - Examples: Atmega microcontrollers, STM32 microcontrollers, RP2040.
- **System-on-Chip (SoC):**
  - Integrates CPU, memory, GPU, I/O ports, and other components in one circuit.
  - Offers a balance between power and performance.
- **Field-Programmable Gate Arrays (FPGAs):**
  - Customizable hardware for specific tasks.
  - High-performance computing for complex applications.
- **Neural Processing Units (NPUs):** AI accelerators designed specifically for neural network computations.
  - Offer higher performance and energy efficiency compared to general-purpose processors.
  - Ideal for running TinyML models on edge devices.
  - Examples: Google Edge TPU, Syntiant's NDP120 Neural Decision Processor



# IoT architecture



Simply, IoT is connecting devices to the internet so their data can be seen from anywhere in the world. These devices can also be controlled from anywhere through the internet.



Devices



Cloud



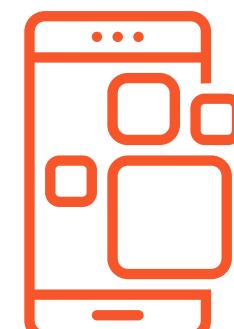
Users



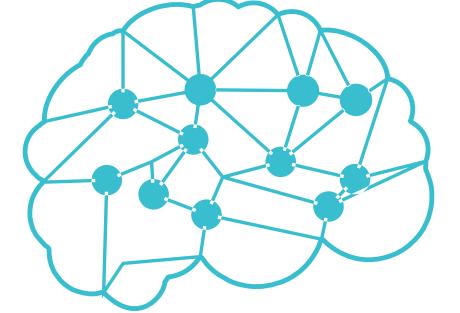
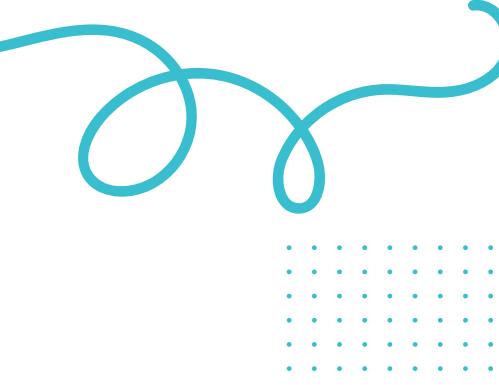
Car and elephant have been detected



Process data and classify if a car or elephant is detected



Car and elephant have been detected



## Solving IoT challenges

By running ML models on the embedded devices we can get benefits such as:



### Latency

Data does not need to be transferred to the cloud



### Reduced bandwidth

Little or no internet connection may be required



### Energy saving

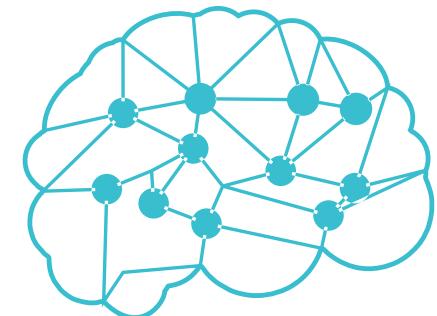
Microcontrollers require less power to perform



### Privacy

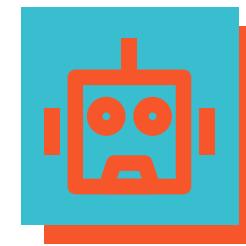
Data is not transferred or stored on the cloud



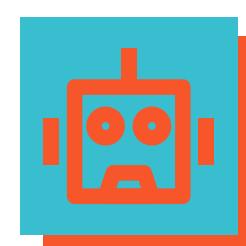


## TinyML, What is it?

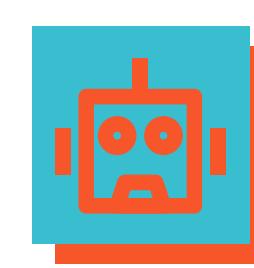
TinyML is a branch of machine learning and embedded systems research that looks into the types of models that can be run on small, low-power devices like microcontrollers



**Small devices**

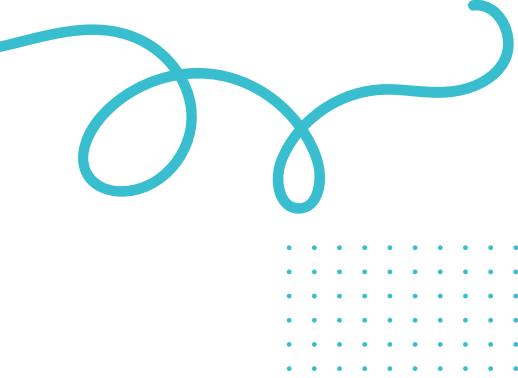


**Low-power devices**

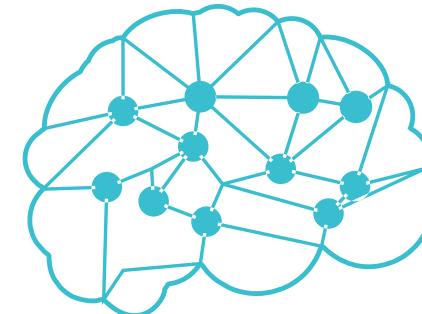


**Resource constrained devices**





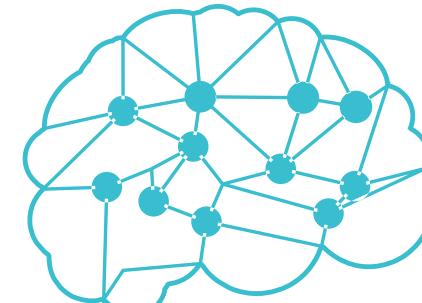
# TinyML, requirements



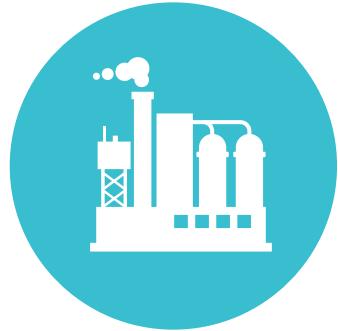
- **Hardware:**
    - Resource-constrained devices like microcontrollers.
    - Specialized hardware accelerators (e.g., FPGAs, TPUs) for efficiency.
  - **Software:**
    - Lightweight machine learning formats(e.g. TensorFlow Lite).
    - Optimized model architectures for efficient execution.
    - Embedded development tools and IDEs.
- 



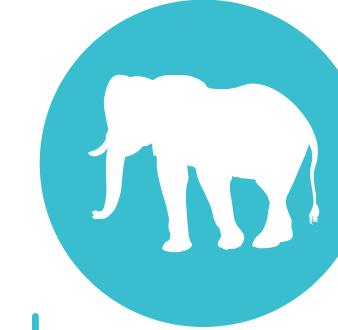
# Applications of TinyML



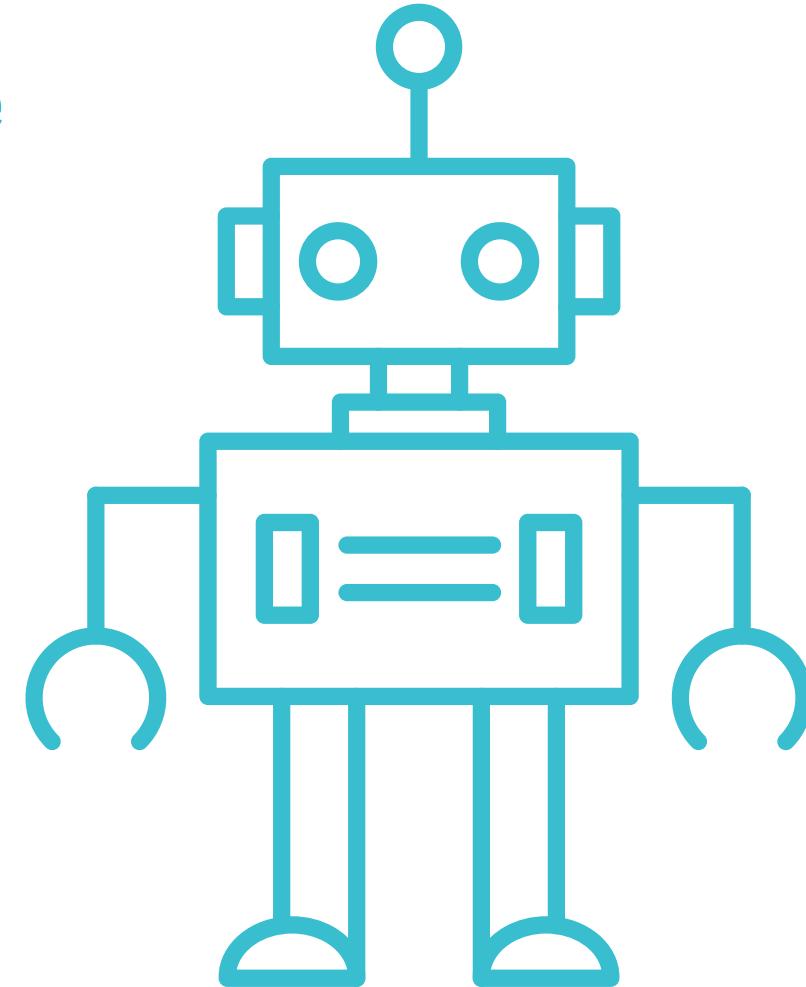
**Personal assistant like  
Siri**



**Industrial predictive  
maintenance**



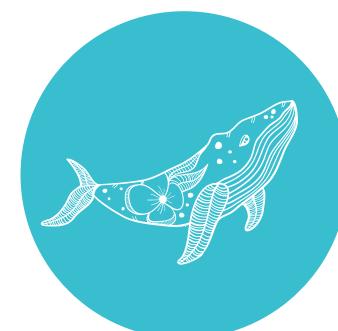
**Wildlife tracking**



**Detecting crop  
diseases**

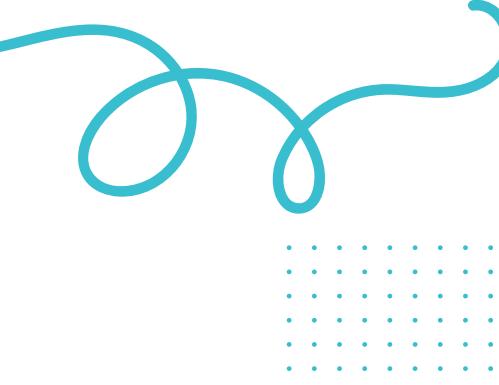


**Healthcare**



**Ocean life  
conservation**

**The Future of ML is tiny and bright**



## Some cool TinyML MCUs

**Arduino Nano 33 BLE Sense**

**Arduino Nicla Vision**

**Arduino Nicla Sense ME**

**Arduino Portenta H7 + Vision Shield**

**Arduino Uno R4**

**Espressif ESP32**

**Espressif ESP-EYE**

**Himax WE-I Plus**

**Open MV Cam H7 Plus**

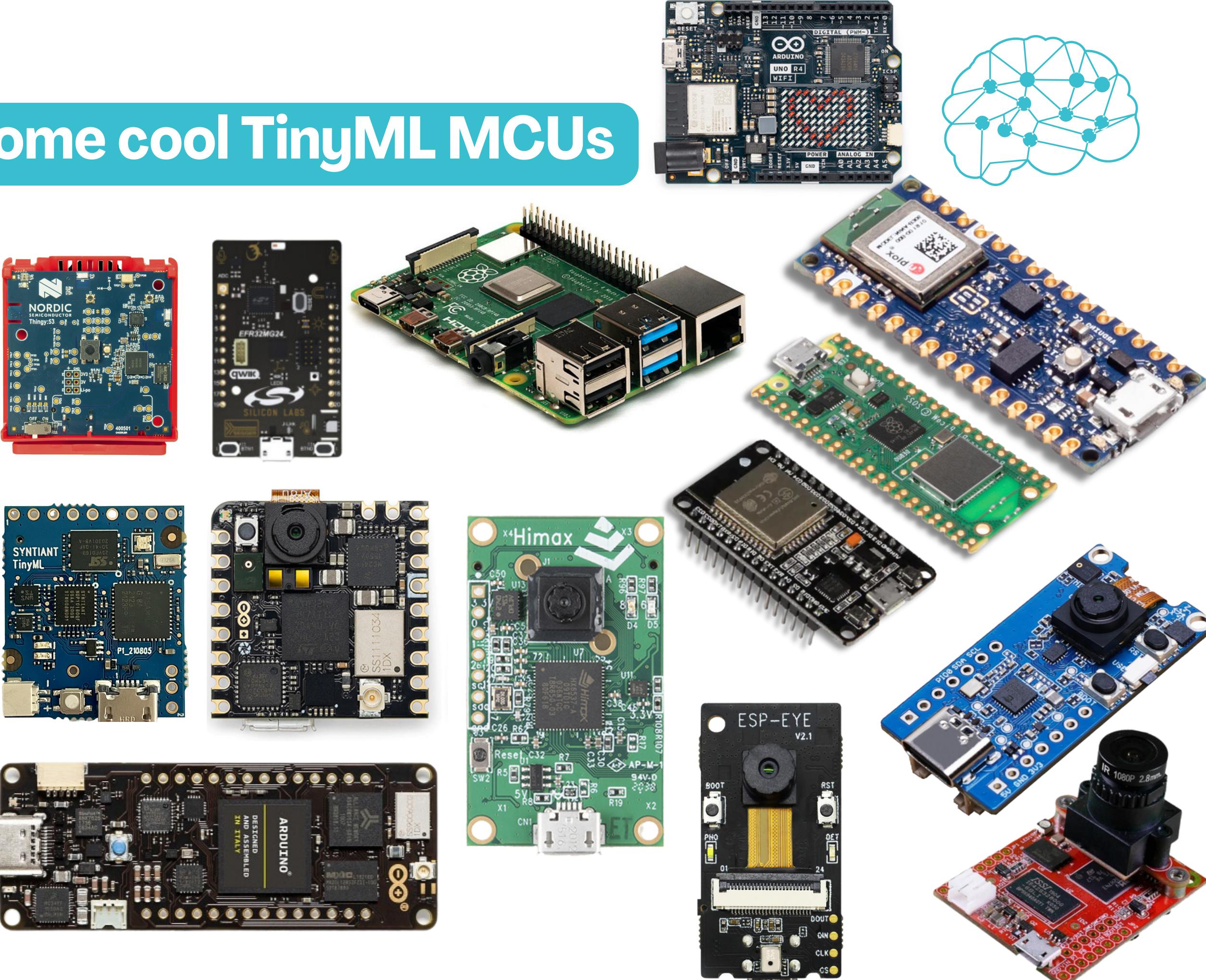
**SiLabs xG24 Dev Kit**

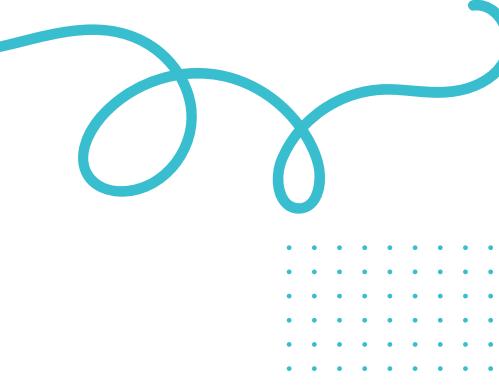
**Seeed Grove - Vision AI Module**

**Sony's Spresense**

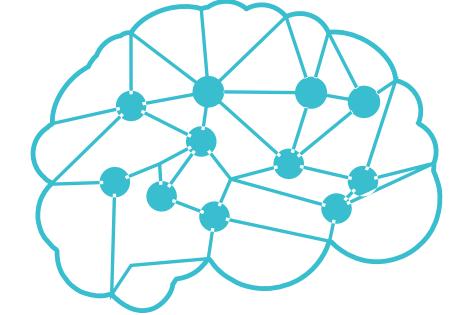
**Syntiant Tiny ML Board**

**Raspberry Pi Pico**





So tiny, how?



**TF Lite for Microcontrollers is a modified version of the TensorFlow Lite framework that is meant to run on embedded devices with only a few tens of kilobytes of memory.**

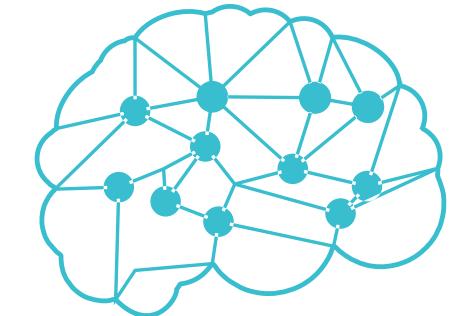
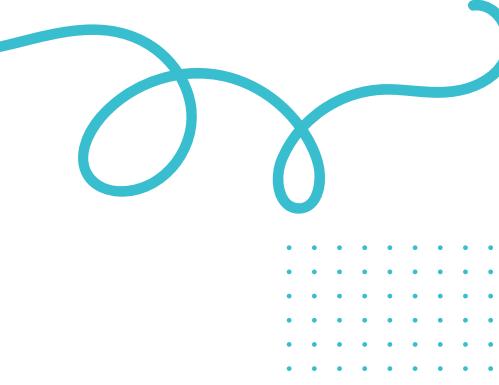
**It supports Android, IOS, Arduino etc..**

**Not only Python you can use C, C++ and JAVA**

**Pretrained models**



TensorFlow is an open source framework developed by Google researchers to run machine learning, deep learning and other statistical and predictive analytics workloads.



# Machine Learning tasks

01

**Classification** –  
what's happening right  
now?

02

**Anomaly detection** –  
is this behavior out of  
the ordinary?

03

**Forecasting** – what  
will happen in the  
future?

Right algorithm ✓

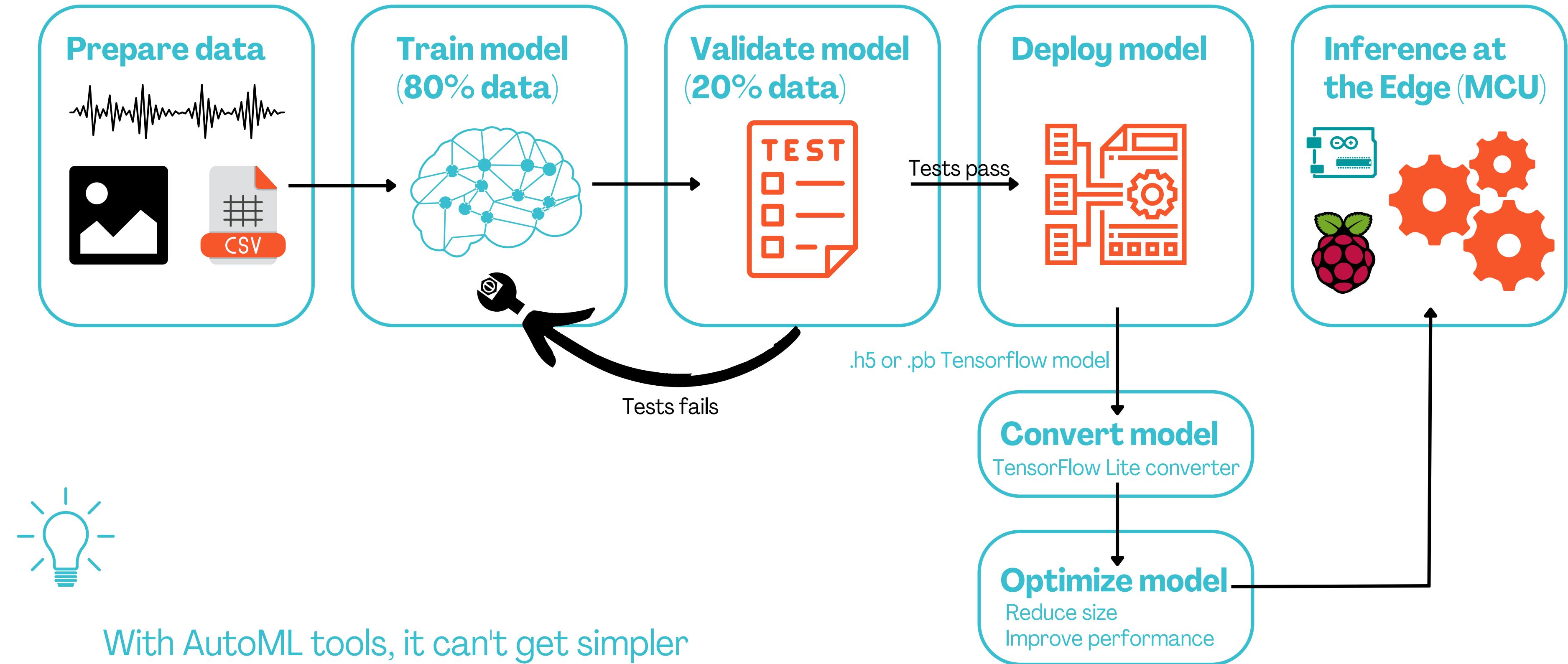
Neural network – algorithm mimicking human  
brain

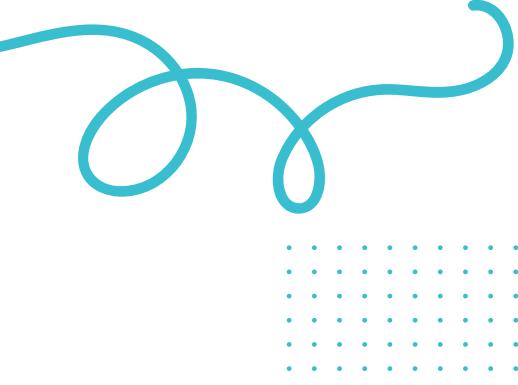
K means clustering – tries to group similar kinds  
of items in form of clusters

Regression – statistical technique that relates a  
dependent variable to one or more independent  
variables

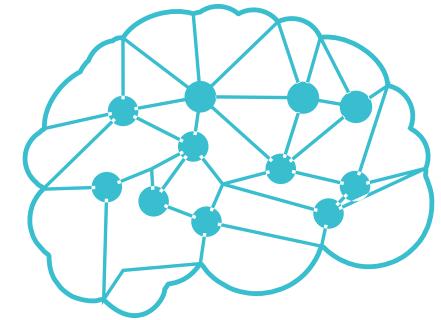


# TinyML project flow





## Next steps



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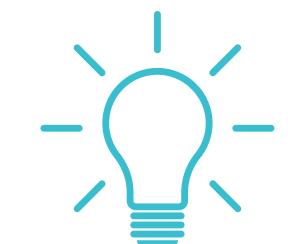
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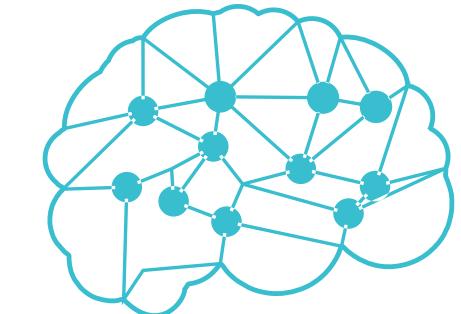
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