

Track 7



Inteligencia Artificial Aplicada

10. Embedded ML (TinyML) Intro & Applications

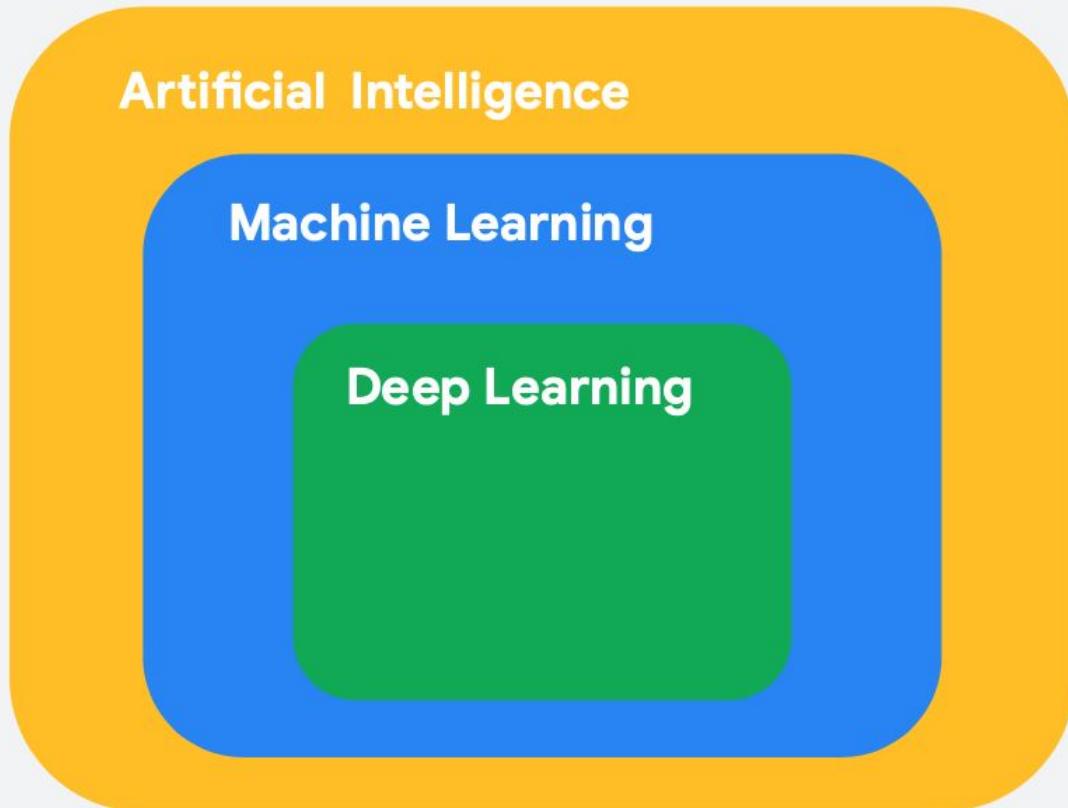
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UNIFEI - Universidade Federal de Itajubá, Brazil



Embedded ML (TinyML)

Introduction



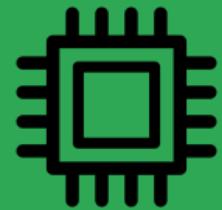
AI: Any technique that enables computers to mimic human behavior

ML: Ability to learn without explicitly programming

DL: Extract patterns from data using neural networks

EdgeAI/ML

TinyML



EdgeAI (or EdgeML) is the processing of Artificial Intelligence algorithms on **the network 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 generate data at ultra-low power consumption (battery operated), so that they can operate continuously ("**always on devices**")

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

TinyML



Fastest-growing field of **ML**



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

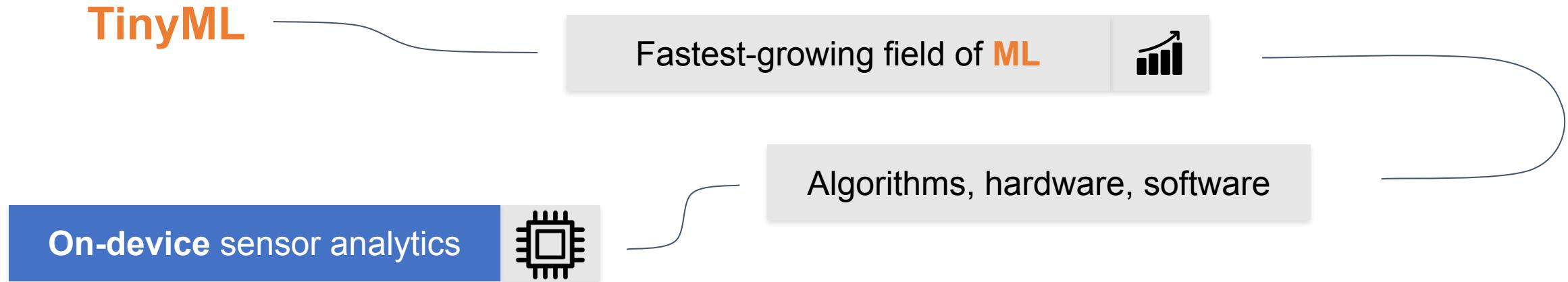
TinyML

Fastest-growing field of **ML**

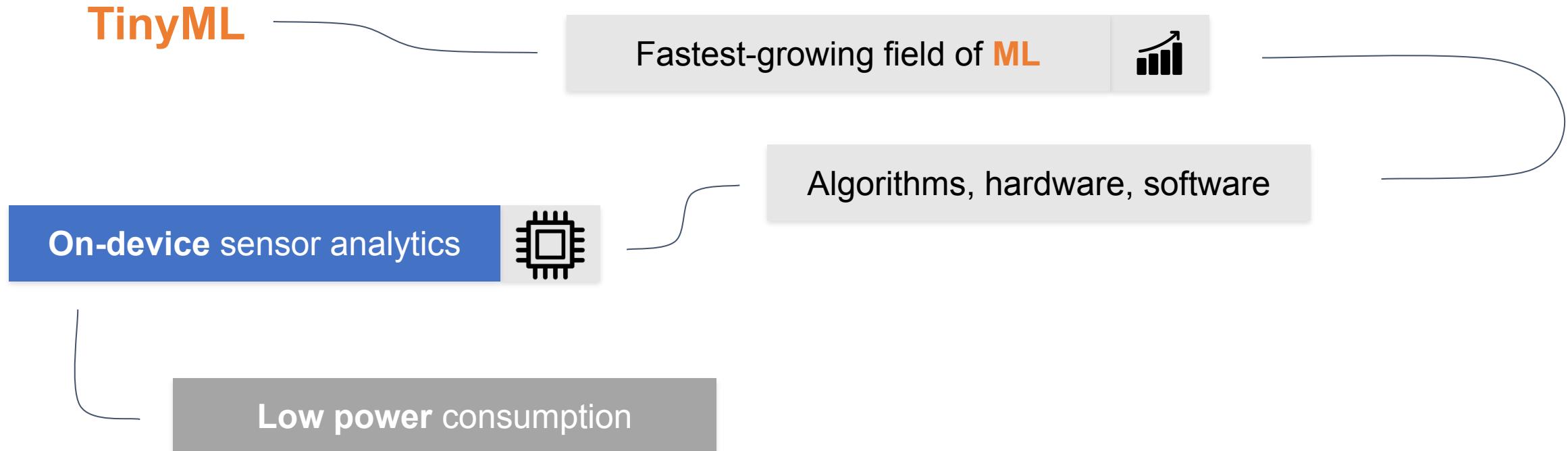


Algorithms, hardware, software

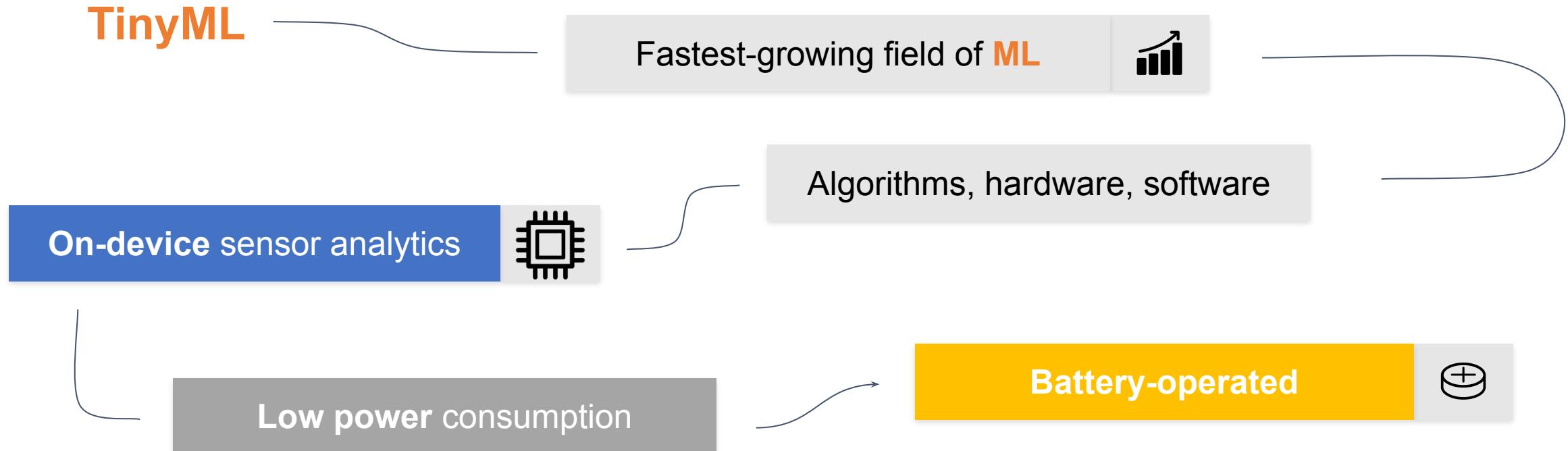
What is Tiny Machine Learning (**TinyML**)?



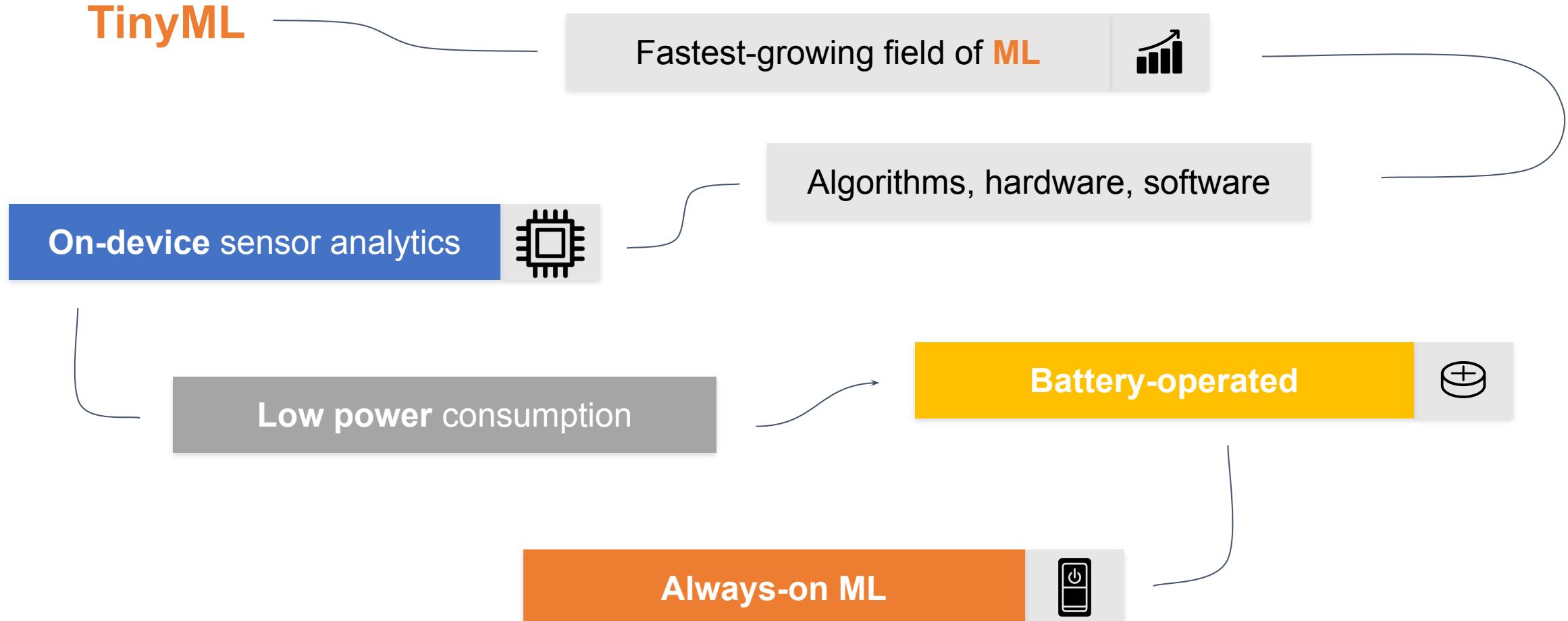
What is Tiny Machine Learning (**TinyML**)?



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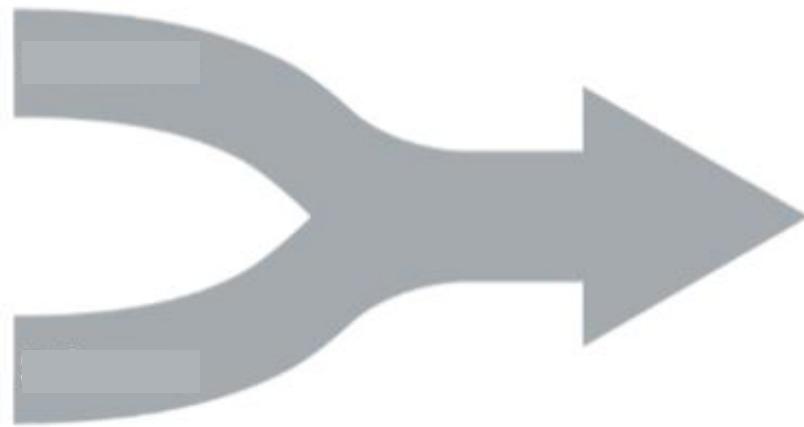
What is Tiny Machine Learning (**TinyML**)?



What Makes **TinyML** ?

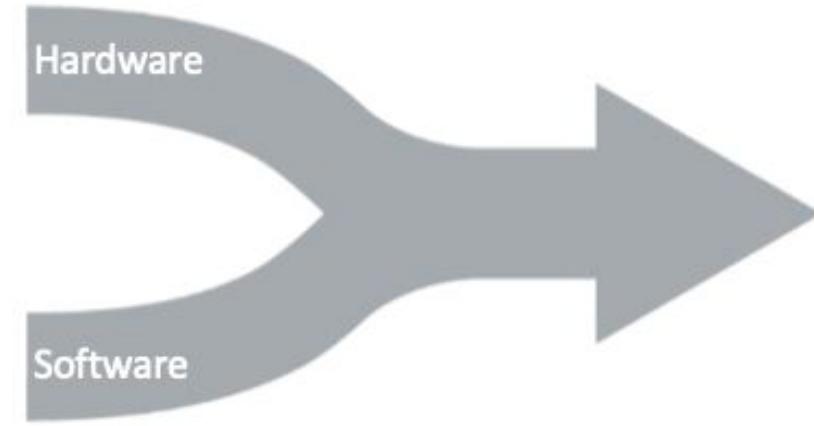
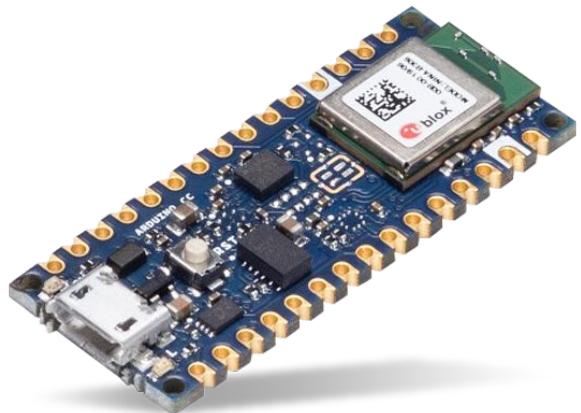
Embedded
Systems

Machine
Learning



TinyML

What Makes **TinyML** ?

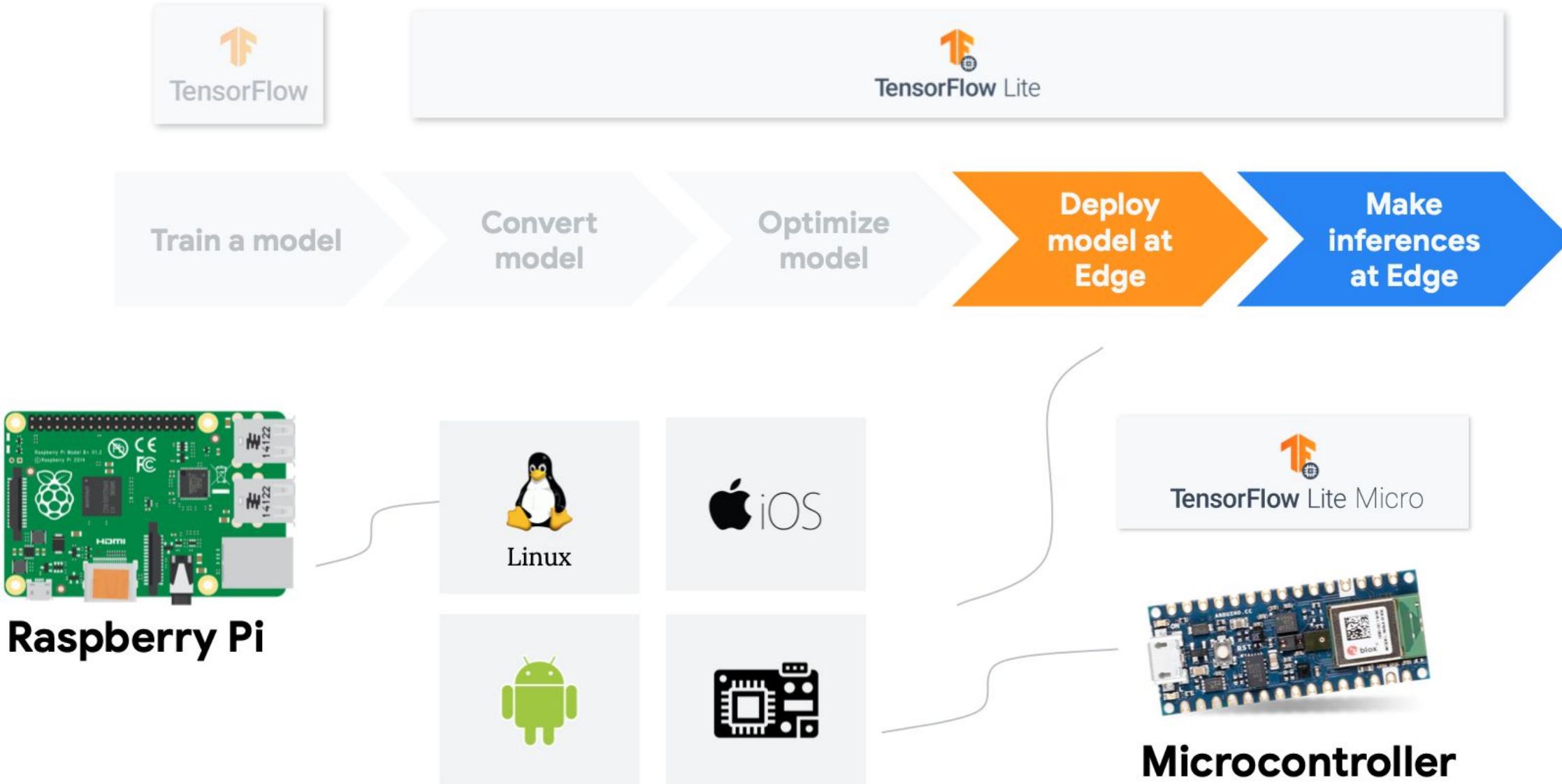


TinyML

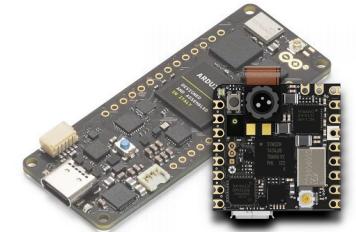


TensorFlow Lite

Software



Hardware



Raspberry Pico (W)

Arduino Nano
Sense

ESP 32

Seeed XIAO BLE
Sense

Arduino Pro

32Bits CPU

Dual-core Arm
Cortex-M0+

Arm Cortex-M4F

Xtensa LX6 Dual
Core

Arm Cortex-M4F

Dual Core Arm Cortex
M7/M4

CLOCK

133MHz

64MHz

240MHz

64MHz

480/240MHz

RAM

264KB

256KB

520KB

256KB

1MB

ROM

2MB

1MB

2MB

2MB

2MB

Radio

(Yes for W)

BLE

BLE/WiFi

BLE

BLE/WiFi

Sensors

No

Yes

No

Yes

No (Portenta)
Yes (Nicla)

Price

\$

\$\$\$

\$\$

\$\$

\$\$\$\$

Application Complexity vs. HW

Power



EdgeML

TinyML



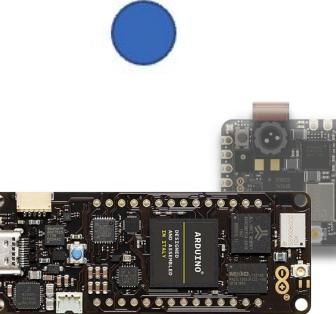
Anomaly Detection
Sensor Classification
20 KB



Rpi-Pico
(Cortex-M0+)



KeyWord Spotting
Audio Classification
50 KB



Arduino Pro
(Cortex-M7)

Image
Classification
250 KB+



TinyML

Object Detection
Complex Voice
Processing
1 MB+



RaspberryPi
SmartPhone
(Cortex-A)



Jetson Nano
(Cortex-A + GPU)

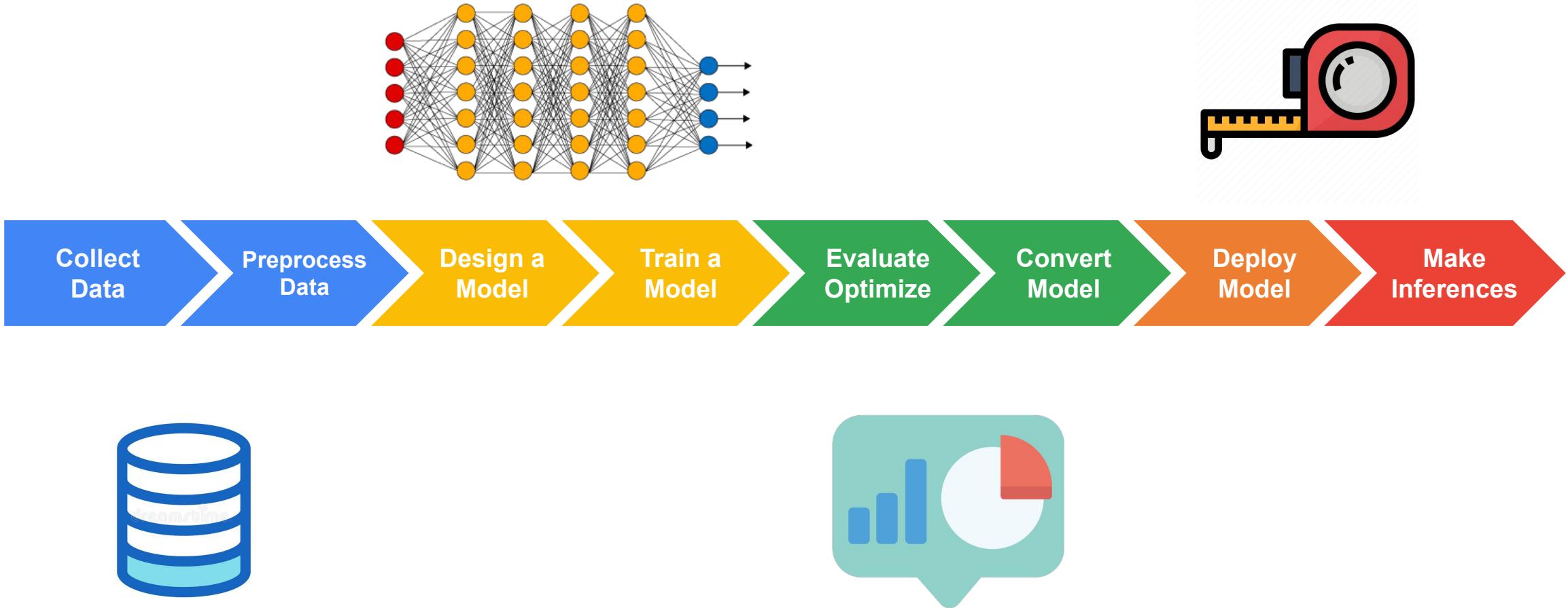
Application Complexity ↑

CPU Power / Memory →

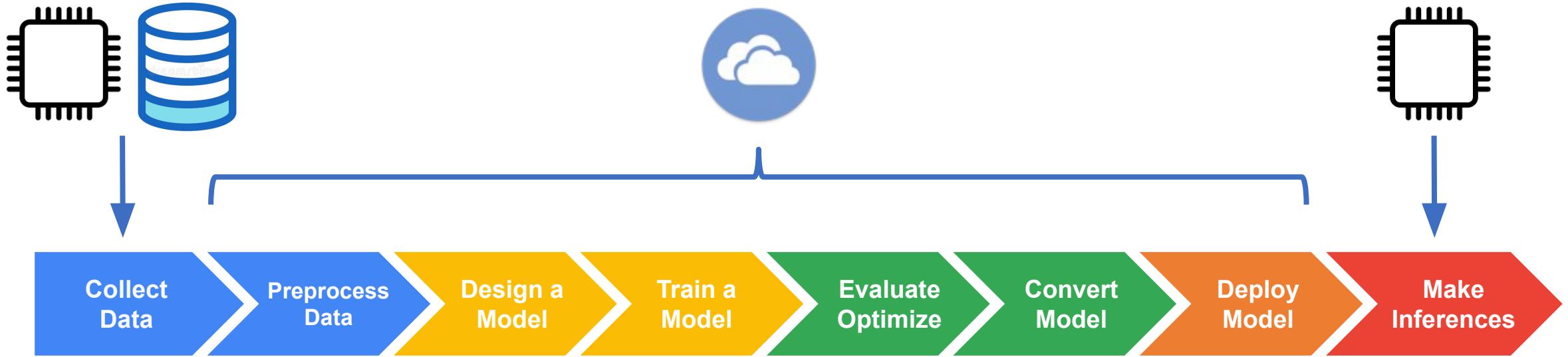
Video
Classification
2 MB+

How to Train a ML Model?

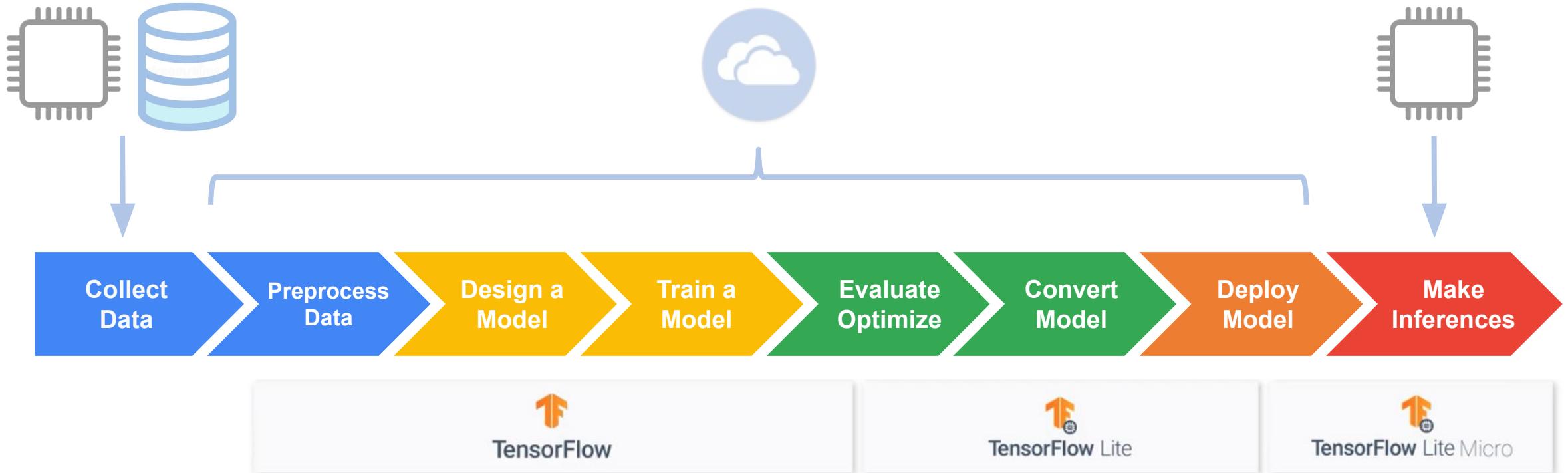
Machine Learning Workflow (“What”)



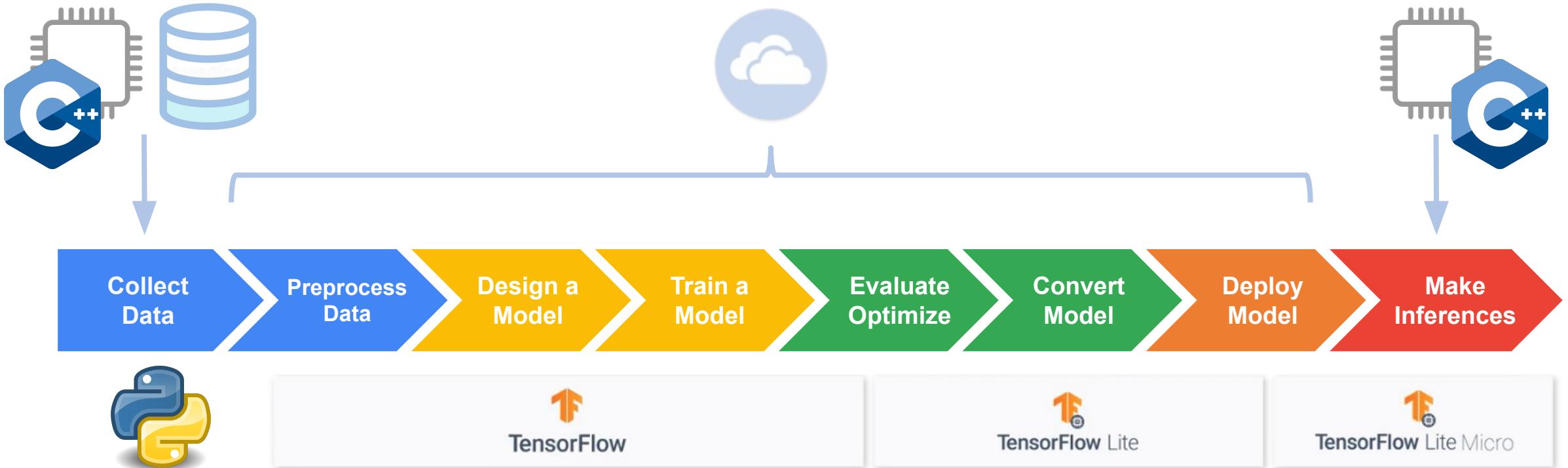
Machine Learning Workflow (“Where”)



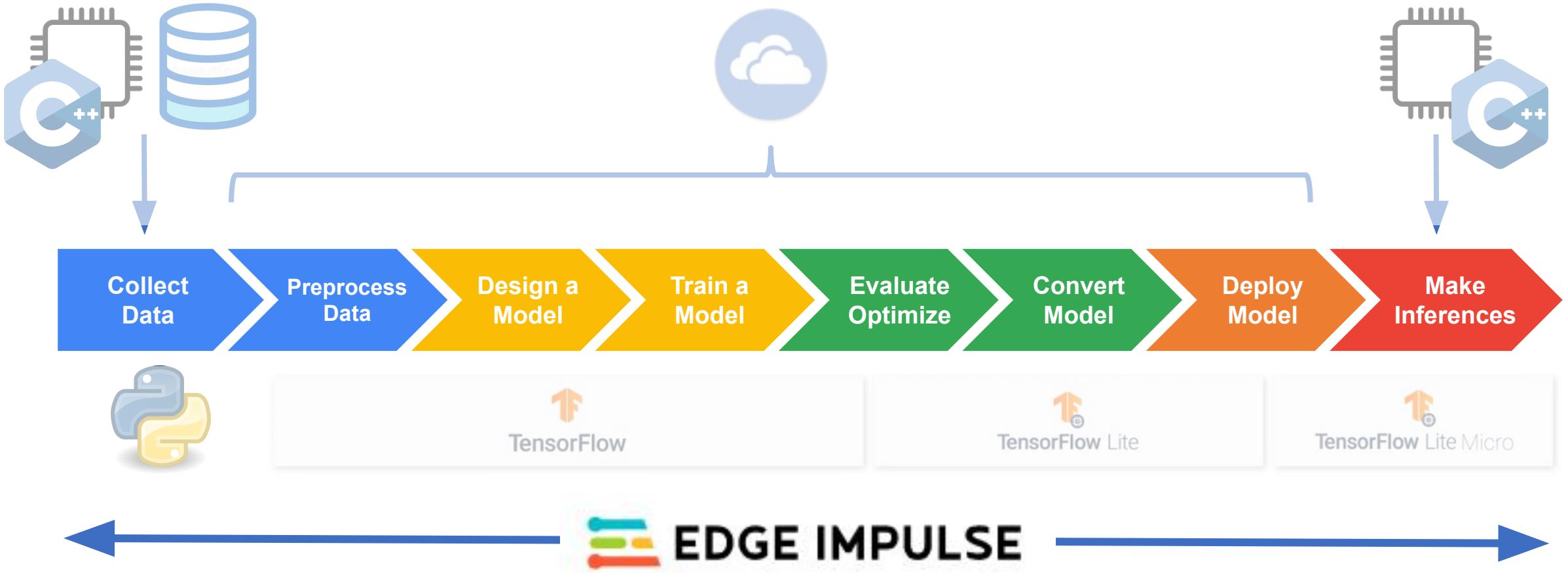
Machine Learning Workflow (“How”)



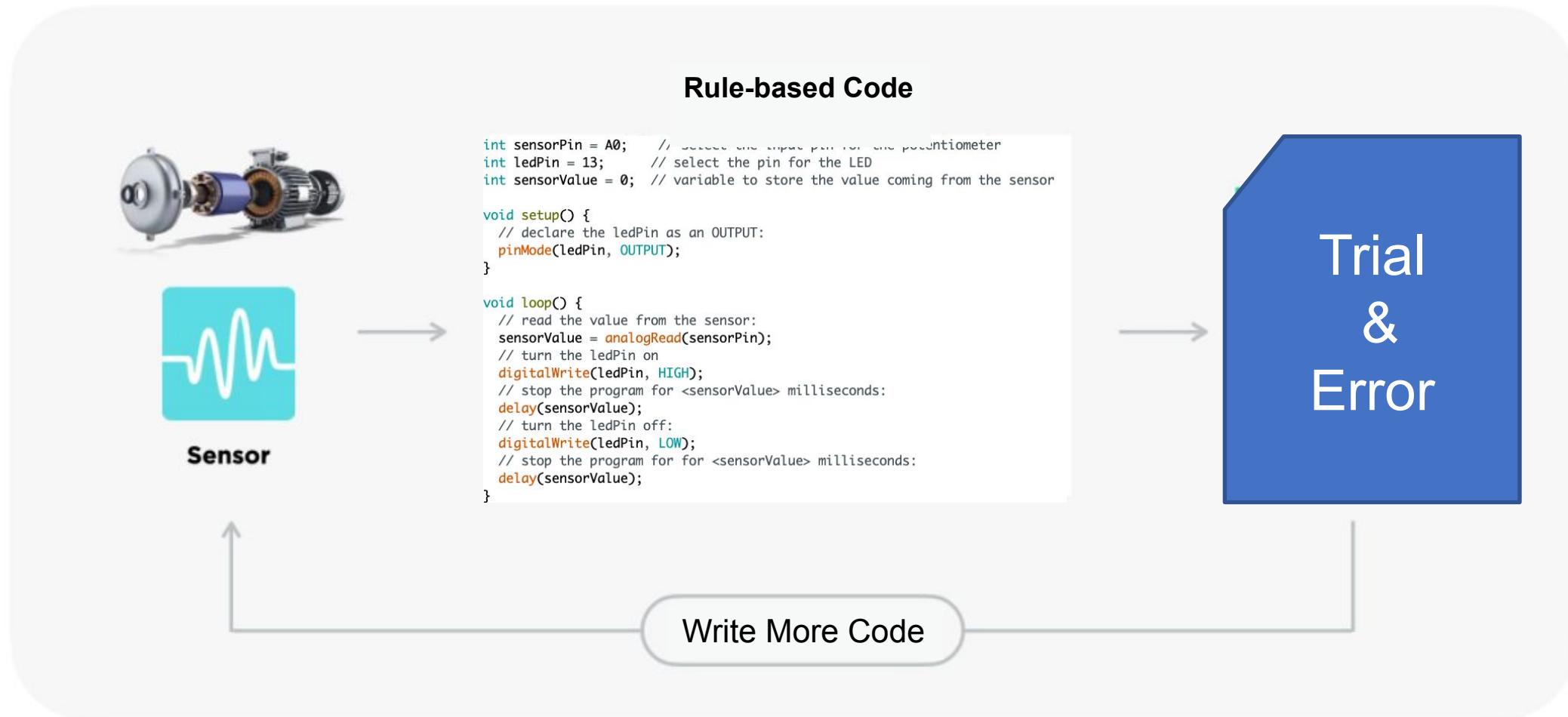
Machine Learning Workflow (“How”)



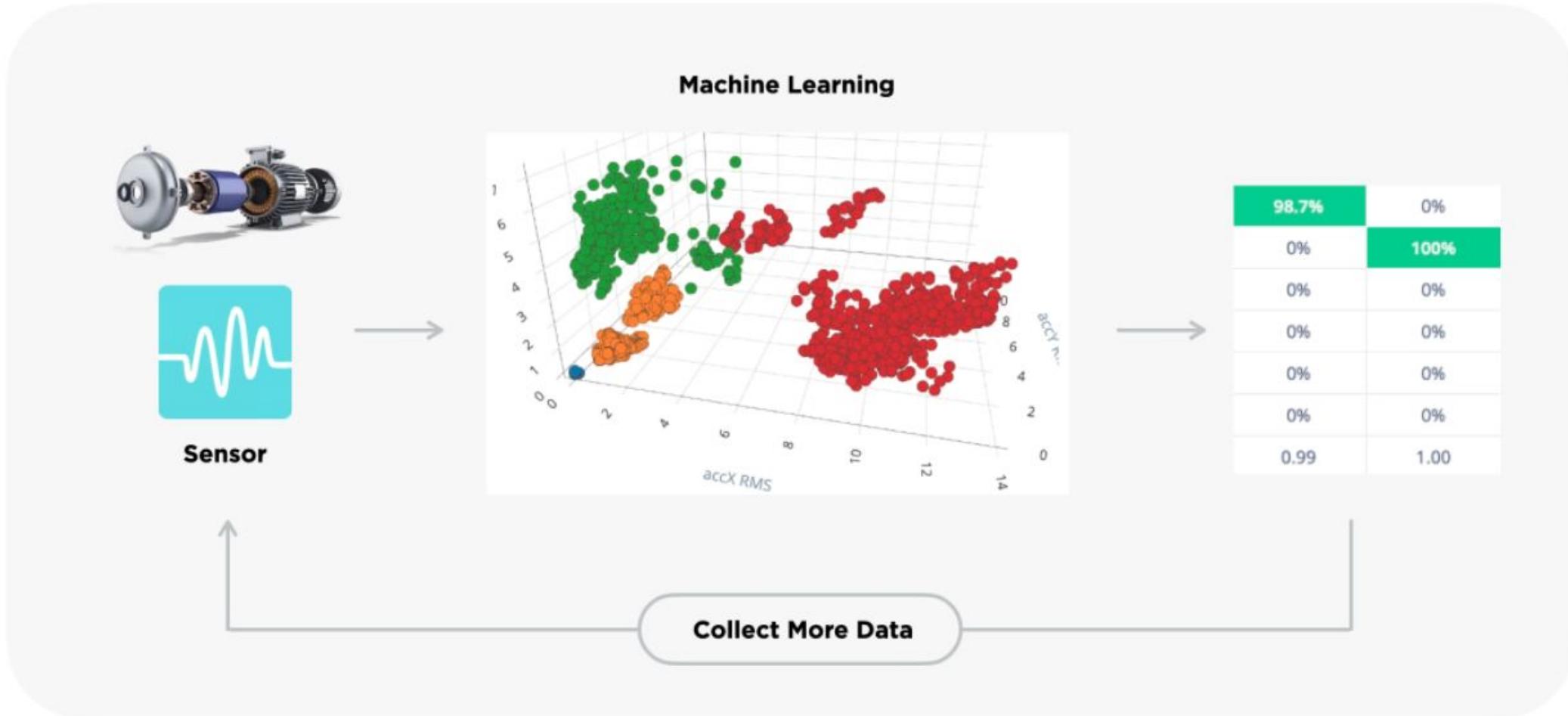
Machine Learning Workflow (“How”)



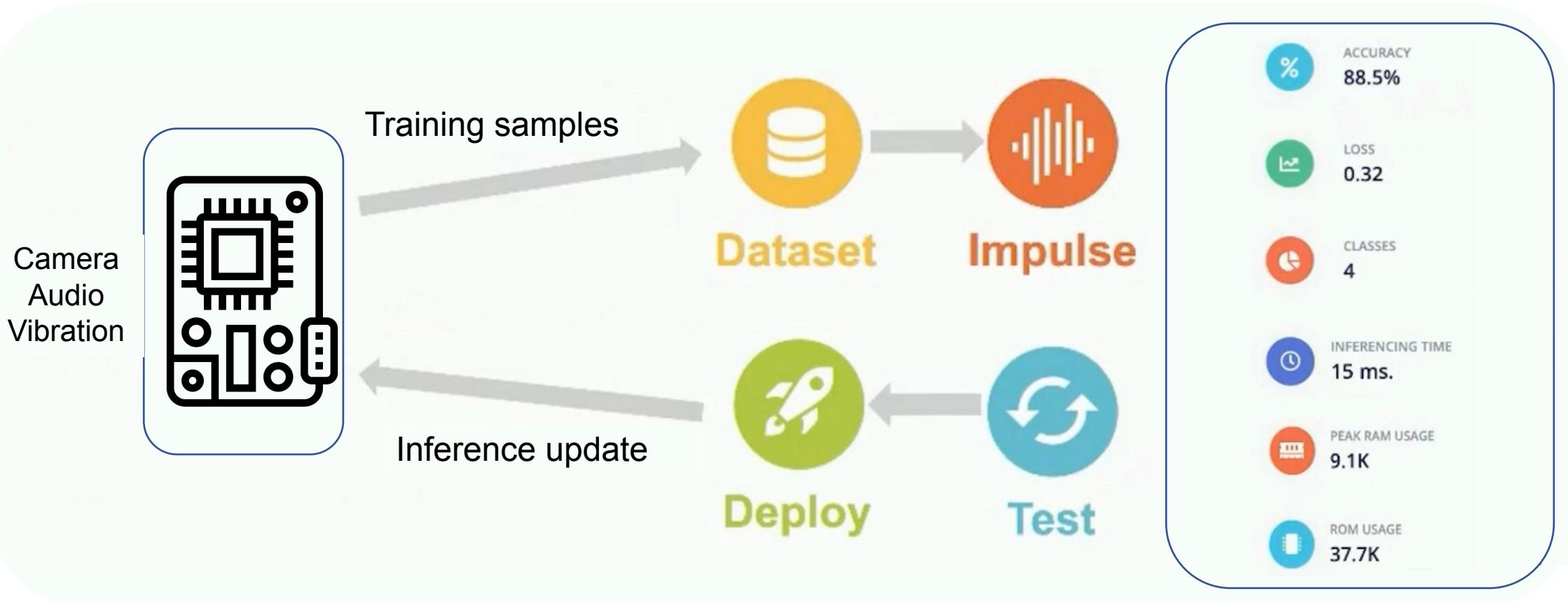
From rule-based engineering to...

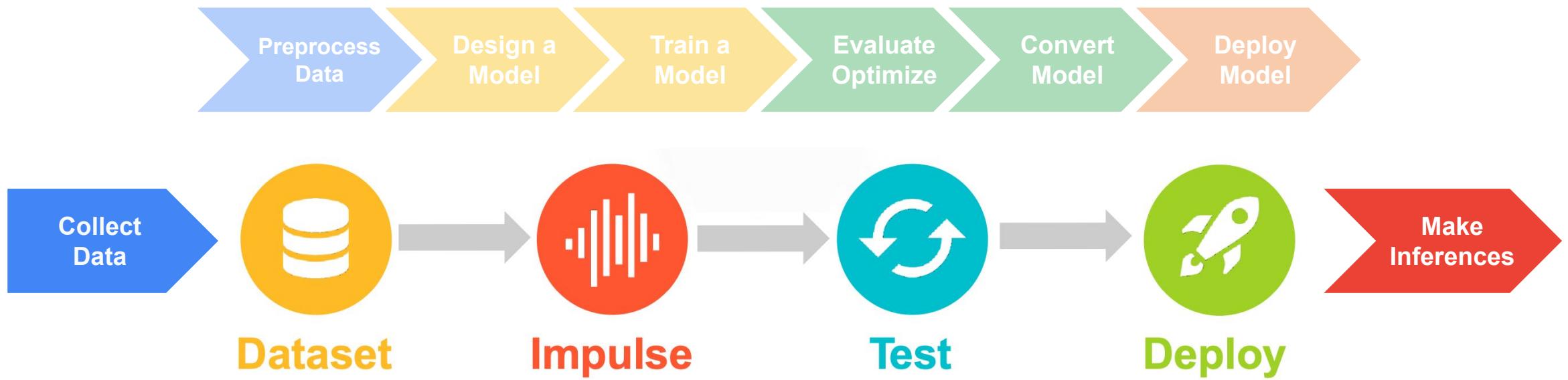


Data-driven engineering

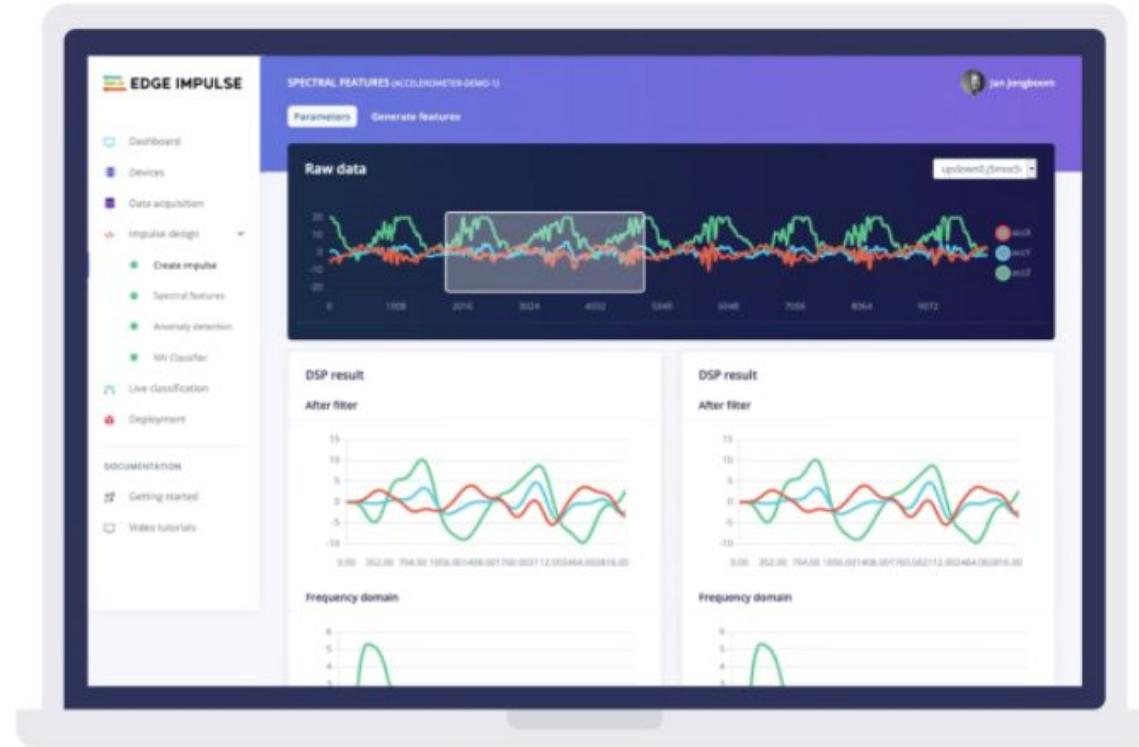
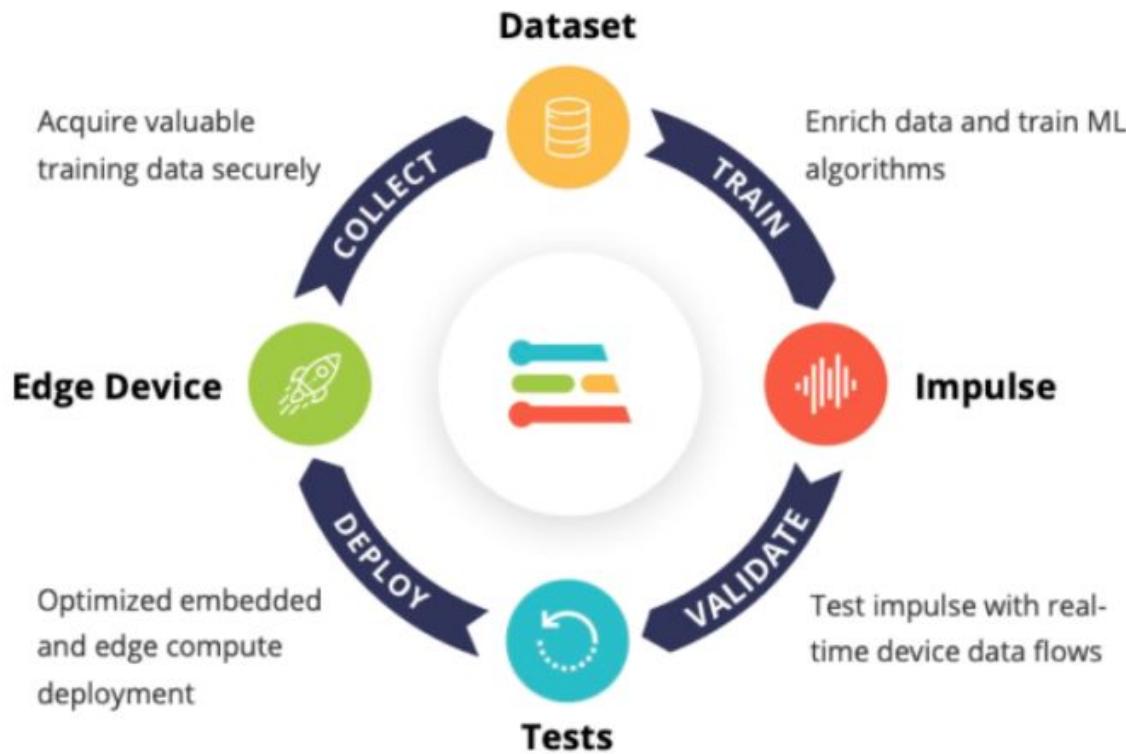


Data-driven engineering





EI Studio - Embedded ML platform (“AutoML”)



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

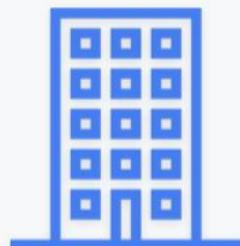


TinyML Application Examples

TinyML Application Areas



Home

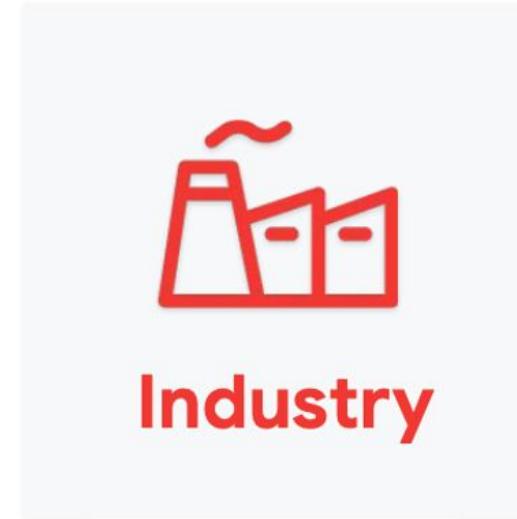
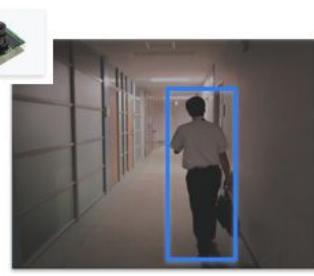


Office



Industry

TinyML Application Areas



Endpoints Have Sensors, Tons of Sensors

Motion Sensors

Gyroscope, Radar,
Accelerometer

Acoustic Sensors

Ultrasonic, Microphones,
Geophones, Vibrometers

Environmental Sensors

Temperature, Humidity,
Pressure, IR, etc.

Touchscreen Sensors

Capacitive, IR

Image Sensors

Thermal, Image

Biometric Sensors

Fingerprint, Heart rate, etc.

Force Sensors

Pressure, Strain

Rotation Sensors

Encoders

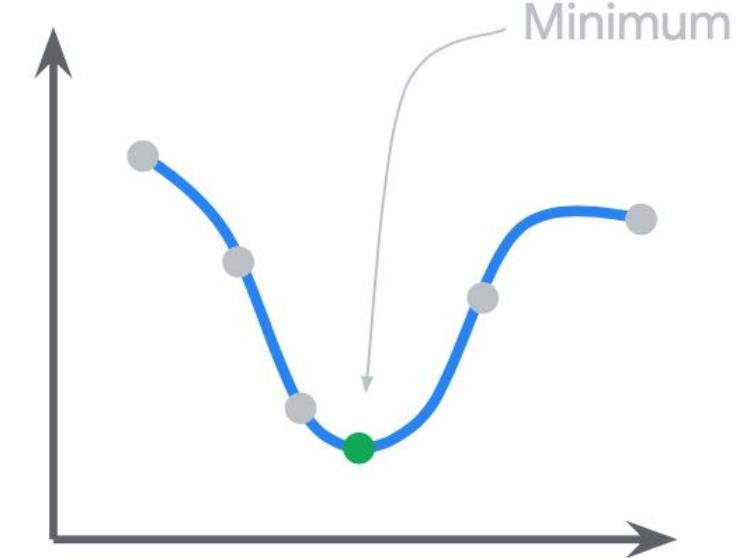
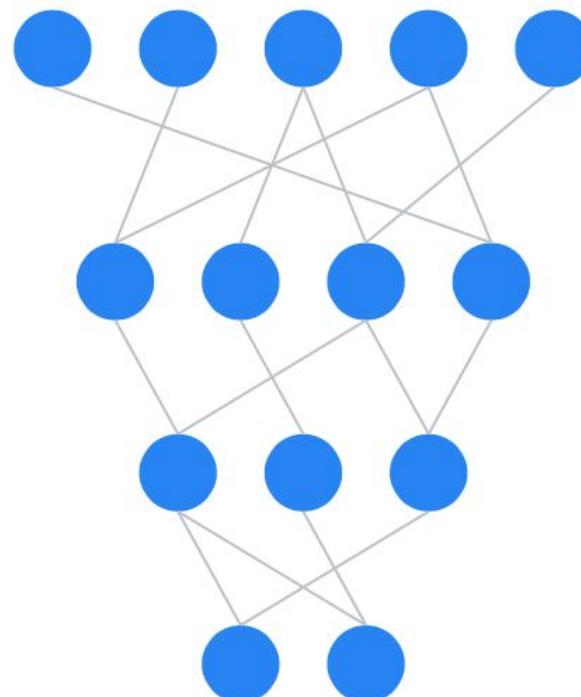
Sensors Metrics

Acoustic Sensors
Ultrasonic, Microphones,
Geophones, Vibrometers

Image Sensors
Thermal, Image

Motion Sensors
Gyroscope, Radar,
Accelerometer

Models



End-to-end **TinyML** application design

Datasets Preprocessing

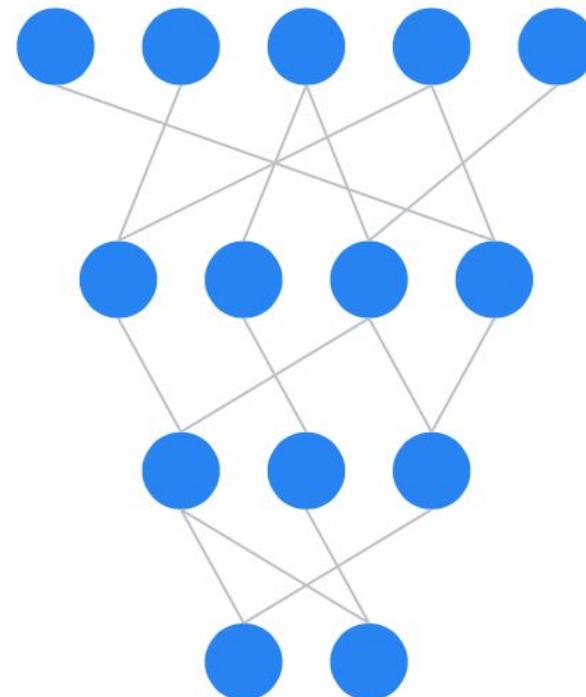
Quantization Pruning

Resource constraints

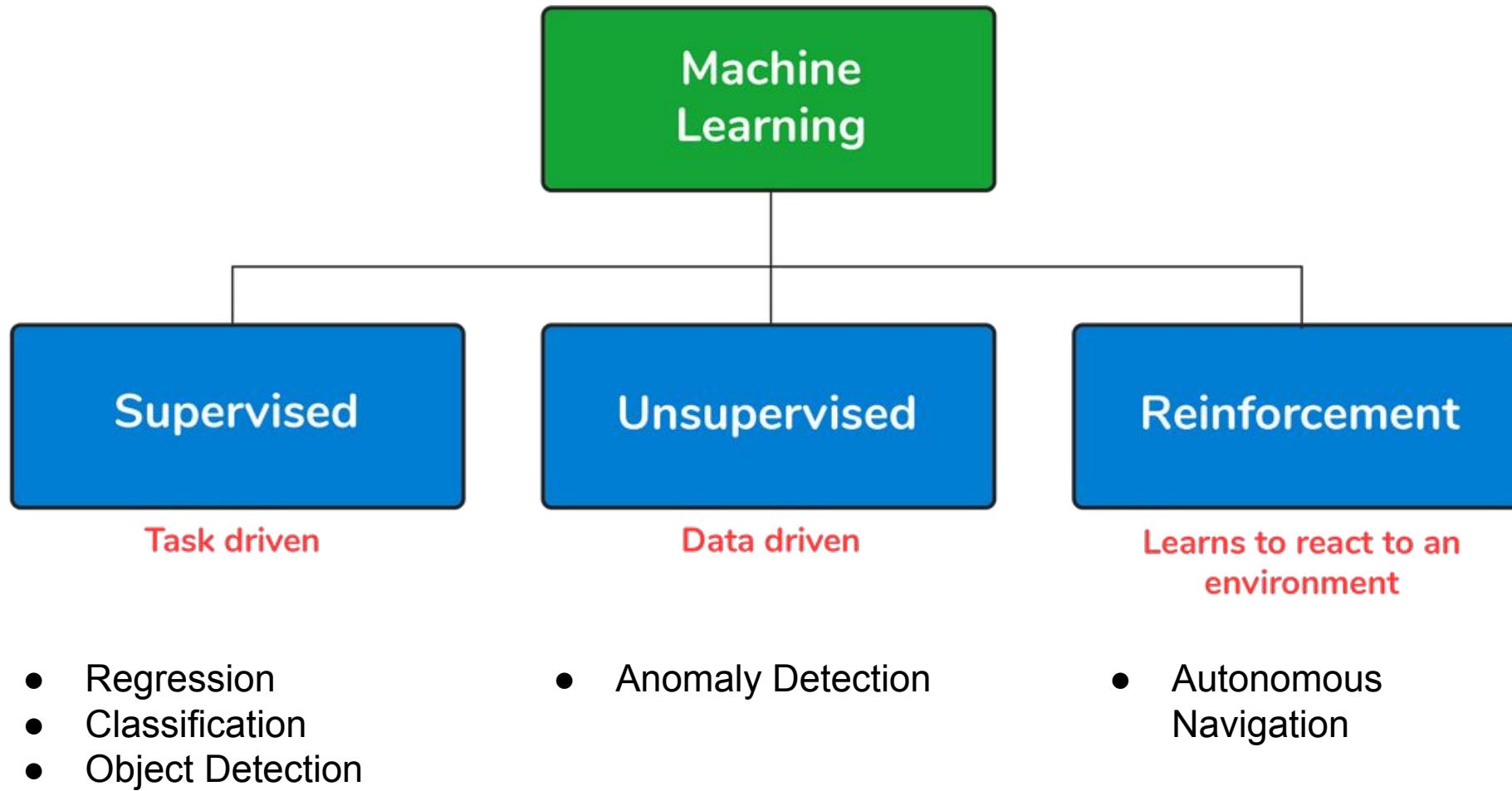
Sound

Vision

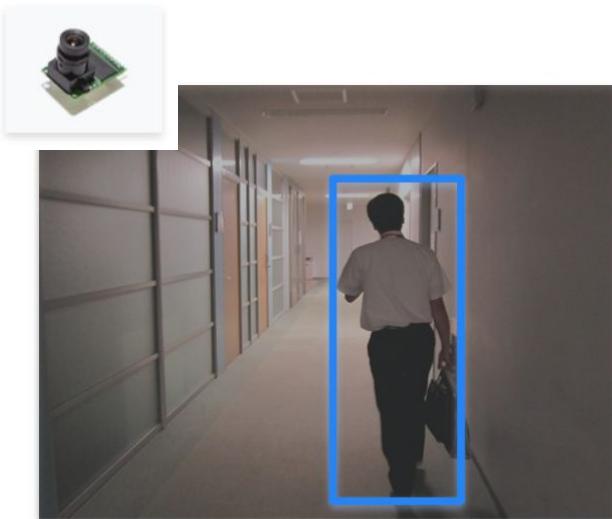
Vibration



End-to-end **TinyML** application design



Vision



Sound



Vibration



Thanks



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