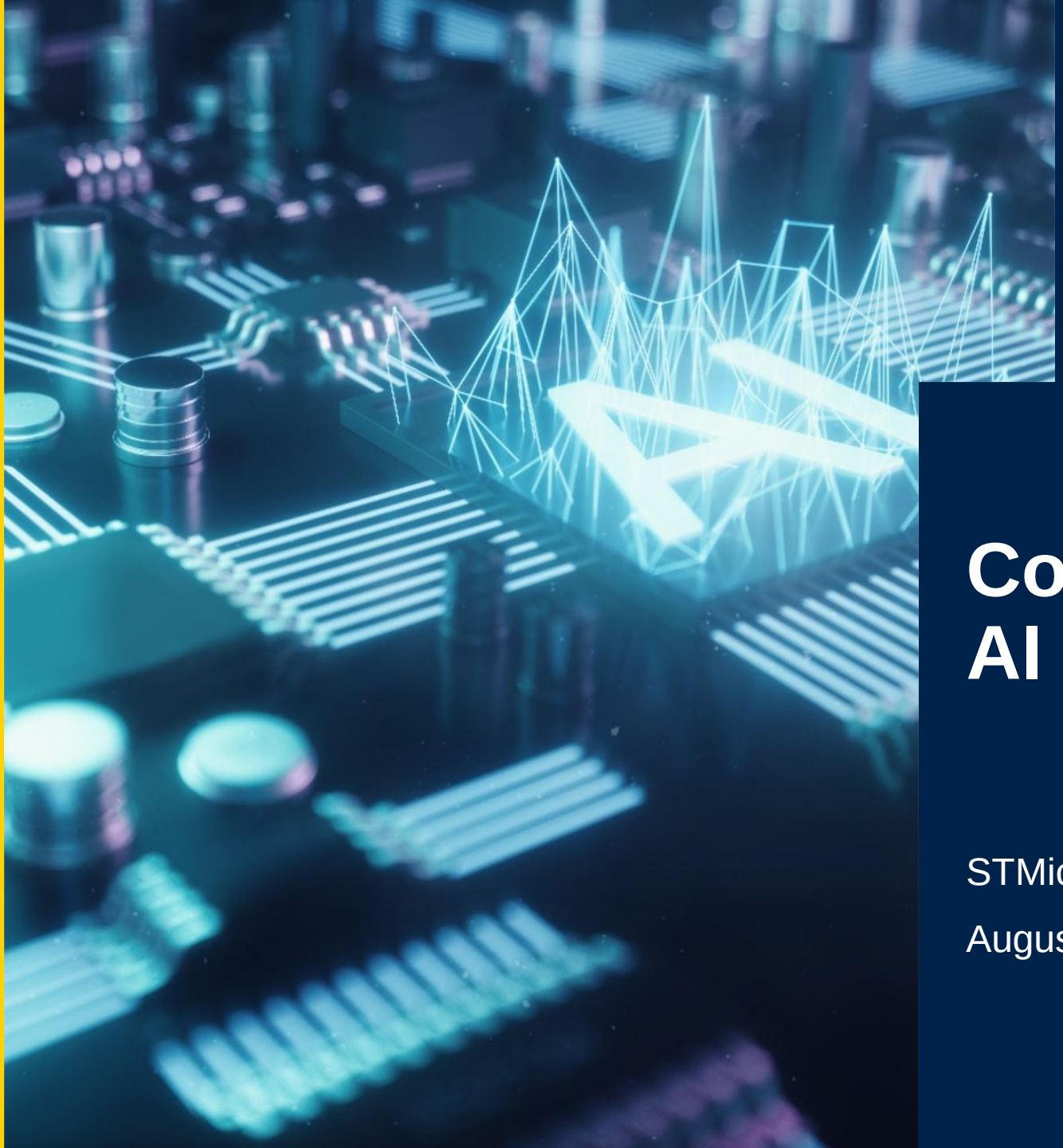

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Context Awareness using AI @ Deep Edge

STMicroelectronics

August 2021

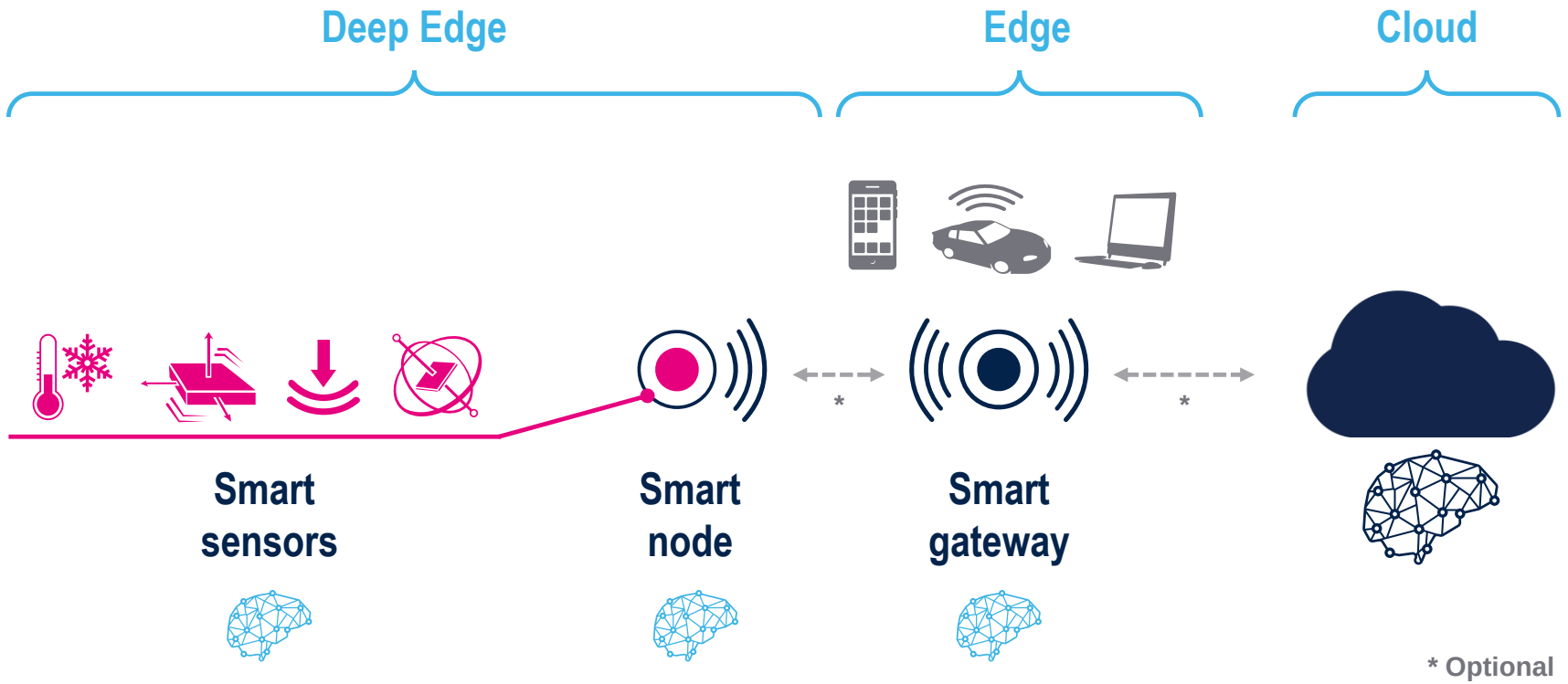
Introduction

Moving closer to data source

Pros
- Responsiveness (fast)
- Bandwidth (low)
- Improved privacy (data stored locally)
- Energy saving

Cons
- Distribute the processing over multiple devices

Deep Edge AI
Data are processed in the smart sensors, smart nodes and smart gateways



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AI in endpoints and gateways

AI complexity

Edge gateway

Sensor nodes Endpoints

Smart sensors

Solutions

STM32 32-bit Microprocessors with ARM® Cortex® A+M cores, embedded memory and peripherals

STM32 32-bit Microcontrollers with ARM Cortex-M cores, embedded memory and peripherals

Advanced sensors that can be used alone or in combination with an MCU/MPU to further improve power savings

Tools

TensorFlowLite & X-Linux-AI + STM32Cube.AI

STM32Cube.AI tool to automatically optimize **Artificial Neural Networks** for **STM32 MCUs** and **MPUs**

Current generation of **Smart Sensors** with **MLC** and **FSM** to **enabling ML processing**

Context awareness: where are we? what are we doing?

FP-AI-CXTAWARE1: the best power system saving solution

MCU
Audio Scene Classification

FP-AI-SENSING1

STM32 Cube.AI

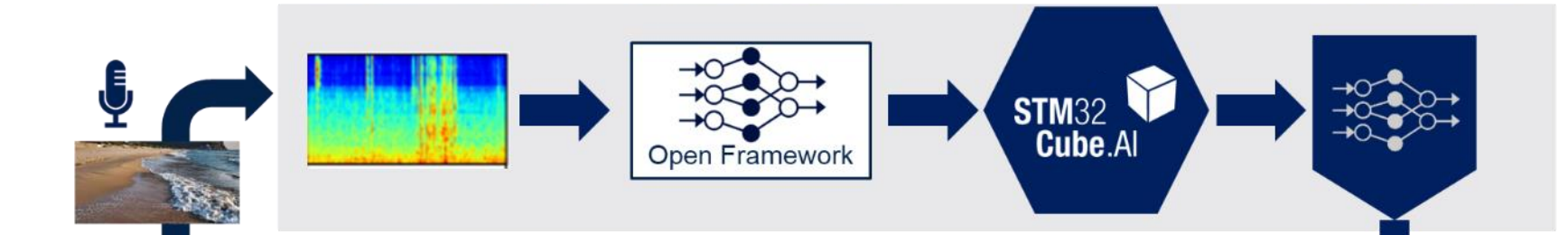
Sensor
Human Activity Recognition

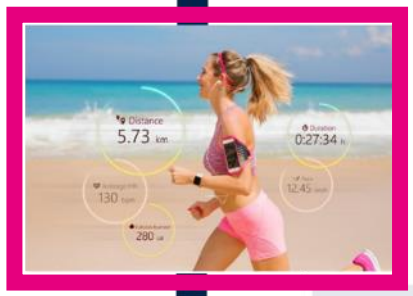
Audio data recording
Pre-processing
DB Preparation of NN Training and Test

Neural Network Topology
Definition, Training and Test
Using existing DL Frameworks

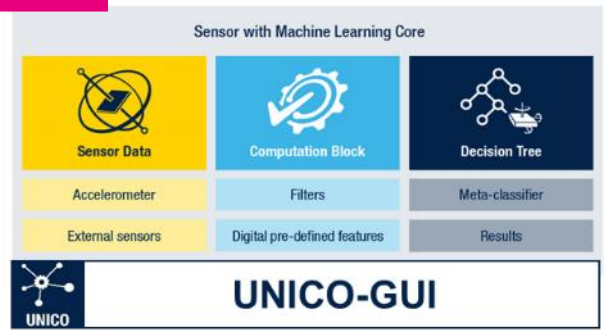
Optimized Neural Network code
automatically generated for STM32

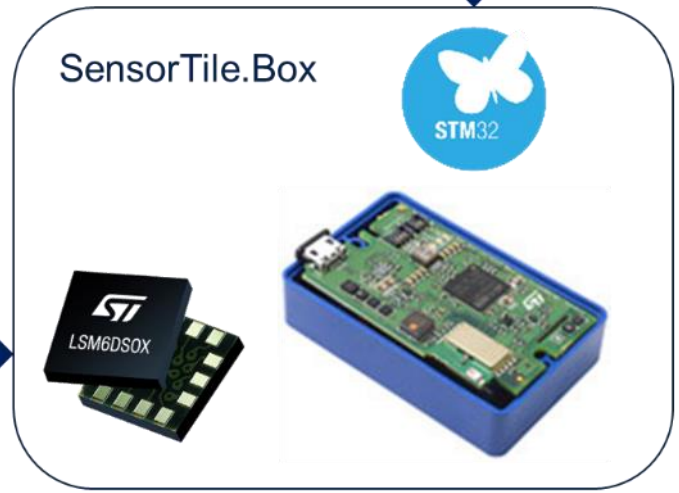
Upload Neural Network
code on STM32 MCU





Data collection
Decision Trees generation
and upload in sensor





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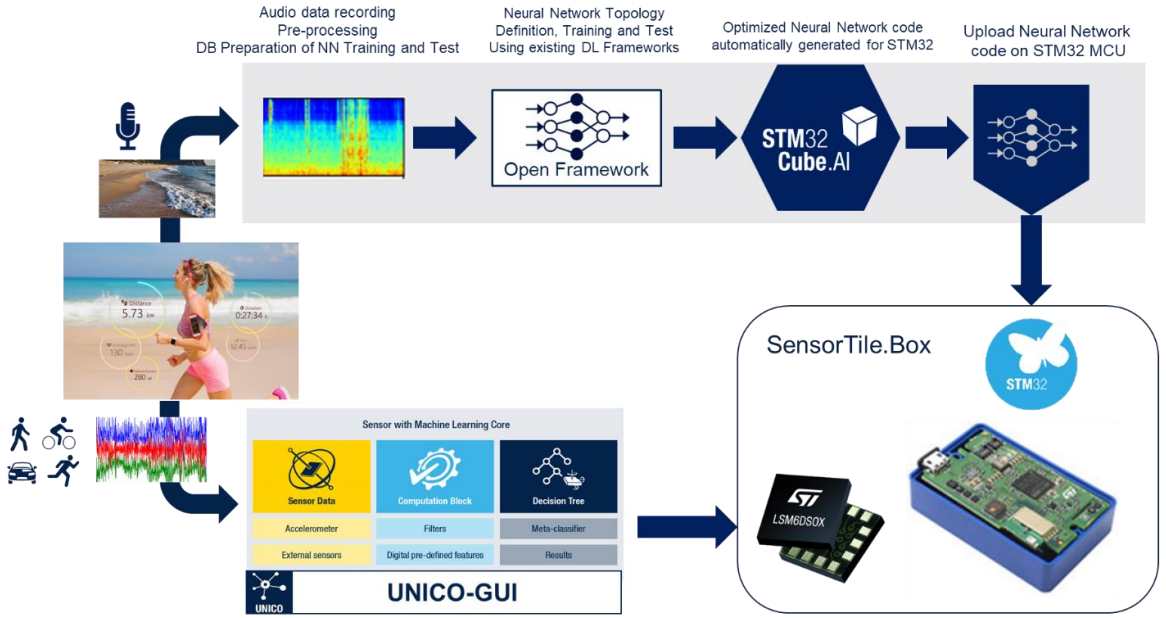
New Function Pack: **FP-AI-CTXAWARE1**

- Short Description
  - STM32Cube function pack for ultra-low power context awareness with distributed artificial intelligence (AI): acoustic analysis with DNN on MCU and motion analysis with ML on IMU
- Description
  - Machine Learning Core (MLC) featuring real-time human activity recognition (HAR) generated thanks to Unico-GUI and running on LSM6DSOX
  - Middleware library generated thanks to STM32Cube.AI, an STM32CubeMX expansion pack), featuring example implementation of neural networks for acoustic scene classification (ASC) application
  - Multi-network support: concurrent execution of the MLC for HAR and the neural network for ASC
- Core Products
  - LSM6DSOX
  - STM32L4R9ZIJ6



STEVAL-MKSBOX1V1

ST BLE sensor App

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Human activity recognition in smart sensor LSM6DSOX

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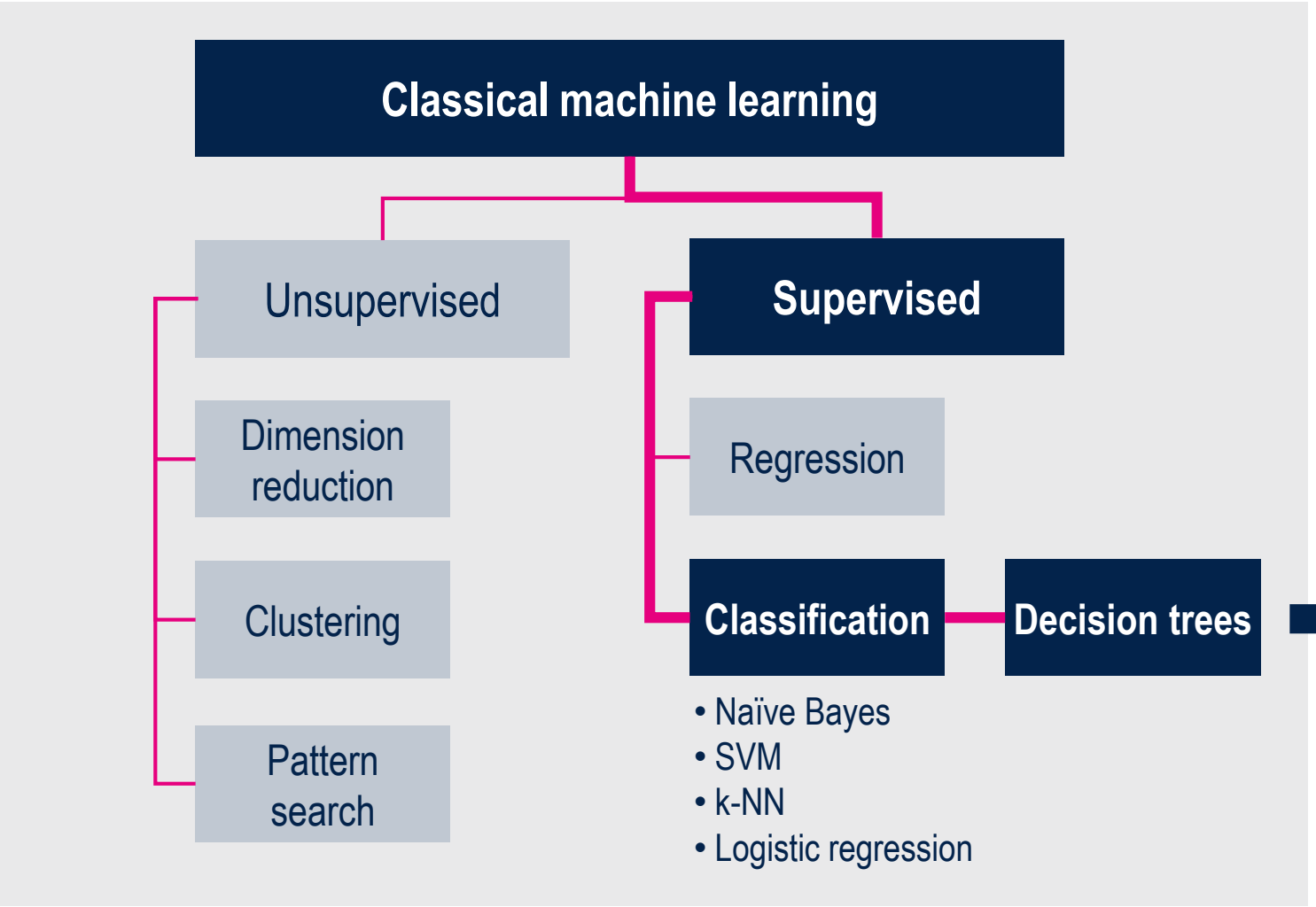
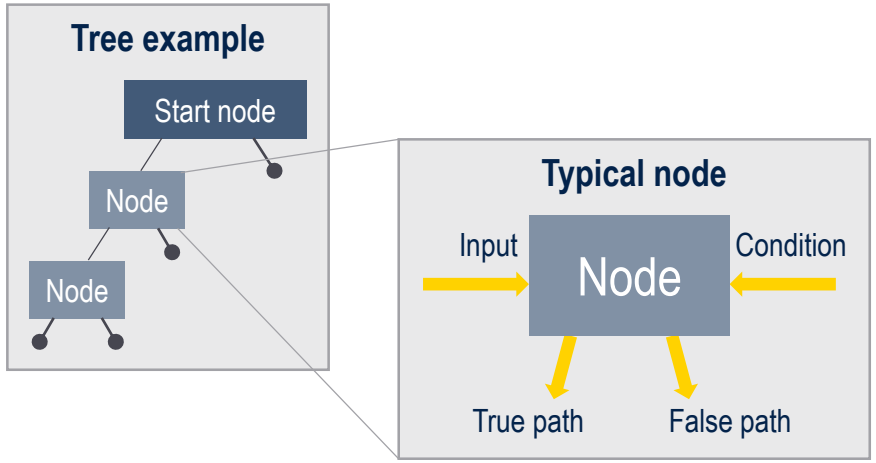
Machine learning embedded in ST sensors



New products with engine embedded:

- 6x IMUs with sensor hub
- Inclinometer



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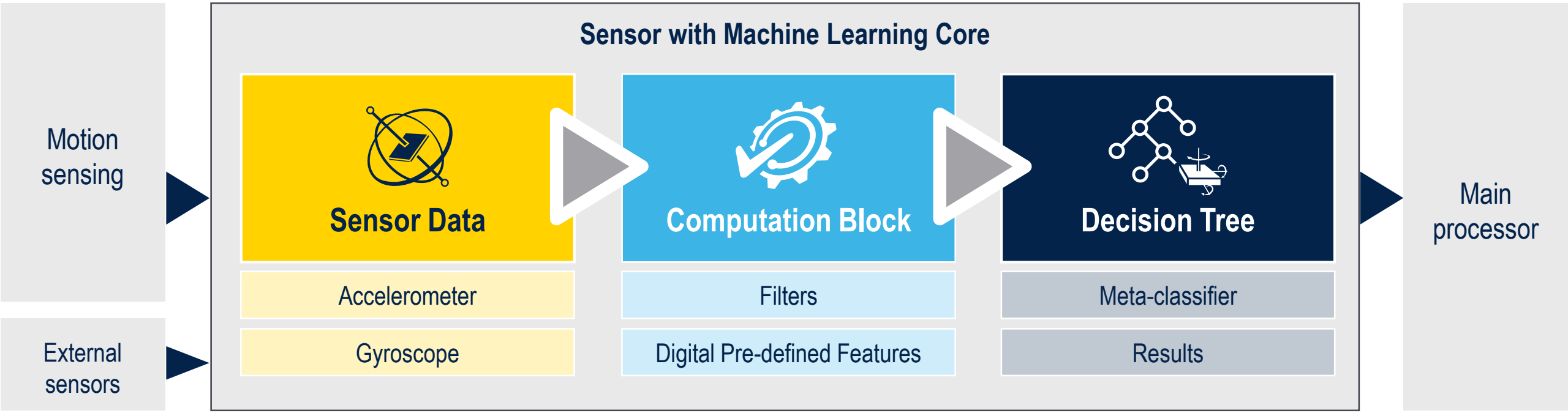
What is a Machine Learning Core (MLC)?

MLC is an in-sensor classification engine based on Decision Tree logic



MLC is able to **increase accuracy** with a **better context detectability**, **offloading the main processor** while the built-in sensors identify motion data

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Machine Learning solutions in sensors: new developer model approach

Shorter development time and better accuracy with Machine Learning techniques (Decision Trees)

How it works in 5 simple steps and with an intuitive use case:

User defines **Classes** to be recognized

Label data and select **filters and features**

Build the decision tree based on a wide range of SW tools.

Program the decision tree into the MLC enabled Sensor

Run the MLC model and process incoming data in real time

Capture data → Label data → Build decision tree → Embed decision tree → Process new data

HOW

UNICO-GUI

UNICO

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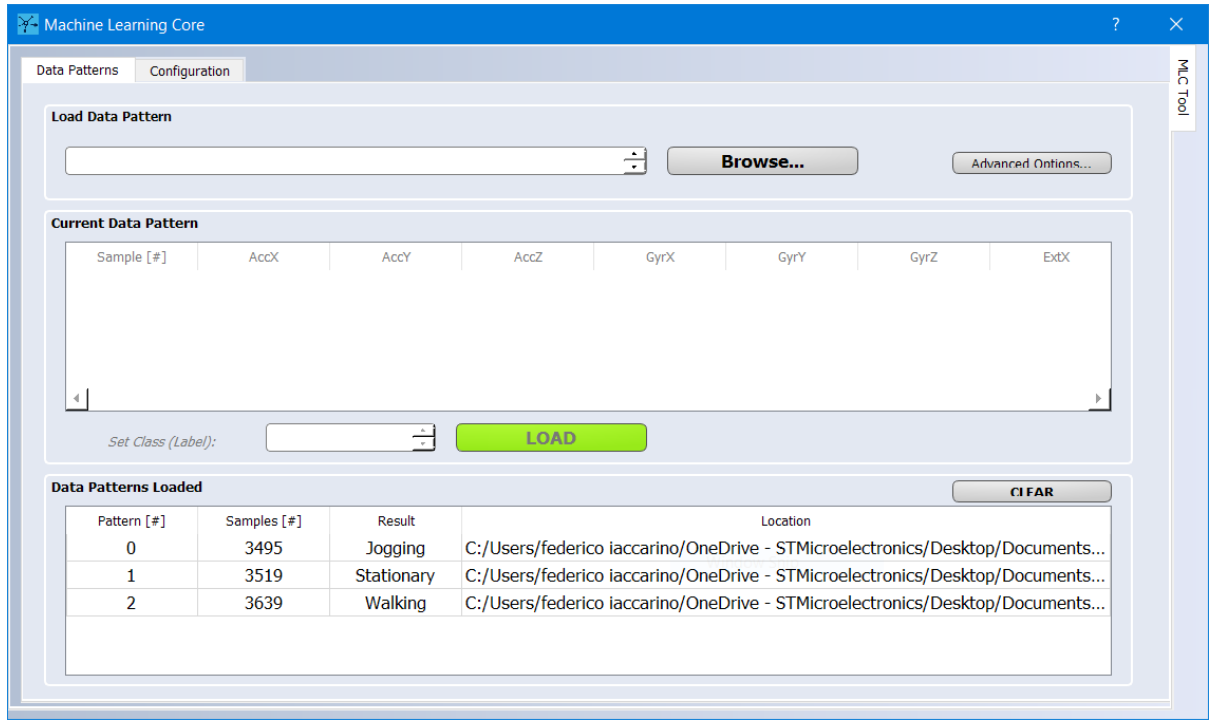
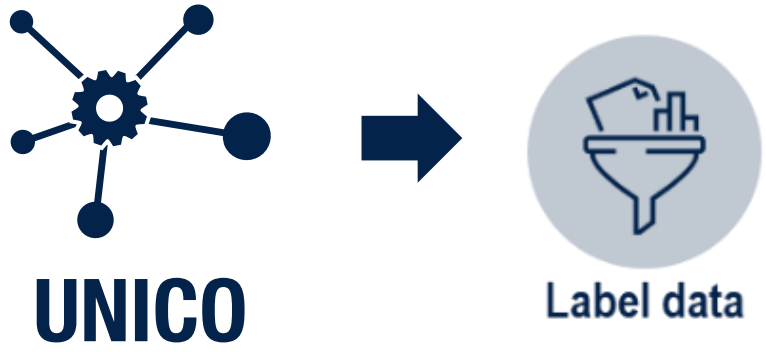
Developing a decision tree based on a dataset with UNICO-GUI (1)

UNICO-GUI: import and label the data



- Starting from an acquired dataset, it is possible to use **UNICO-GUI to import the data and label** the classes that have been acquired.
- More logs relative to the same class can be uploaded
- Labelling the data is a crucial step in the process of generating the decision tree.



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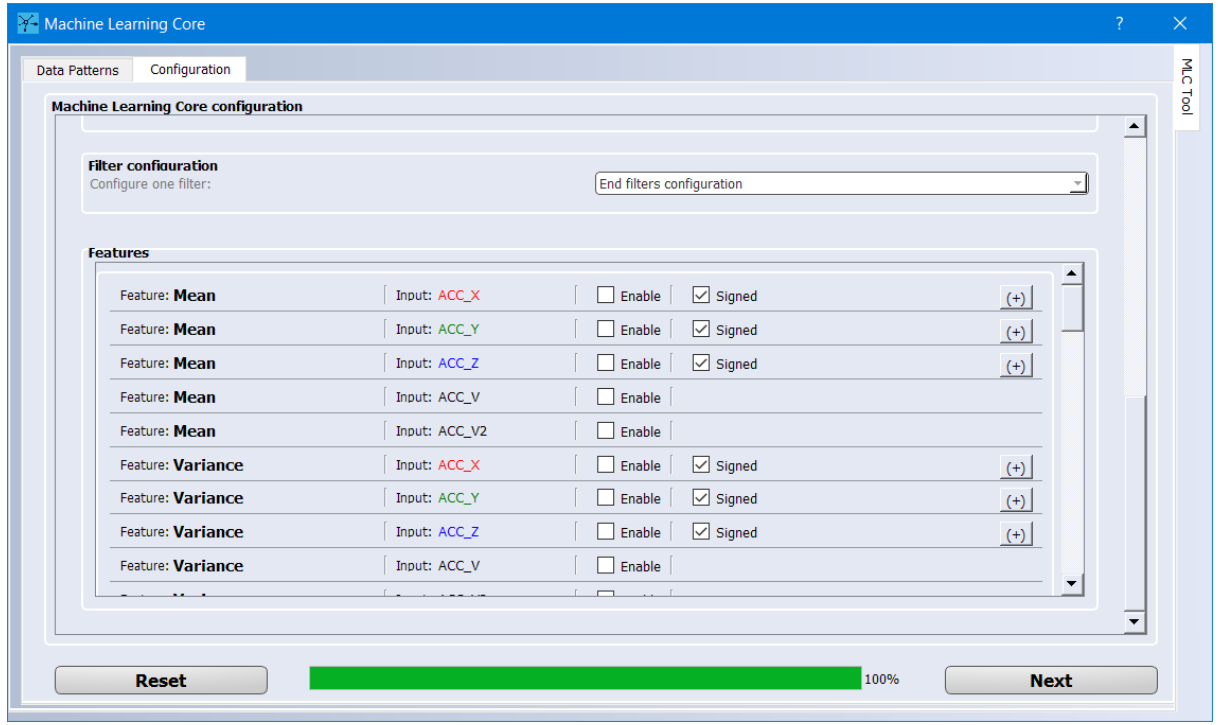
Developing a decision tree based on a dataset with UNICO-GUI (2)

UNICO-GUI: select the features



- To generate the decision tree, it is necessary using **UNICO-GUI to select the features** that will be used to discriminate the several classes that needs to be identified.
- UNICO-GUI also supports multiple decision tree generations (LSM6DSOX can run up to 8 decision trees in parallel).

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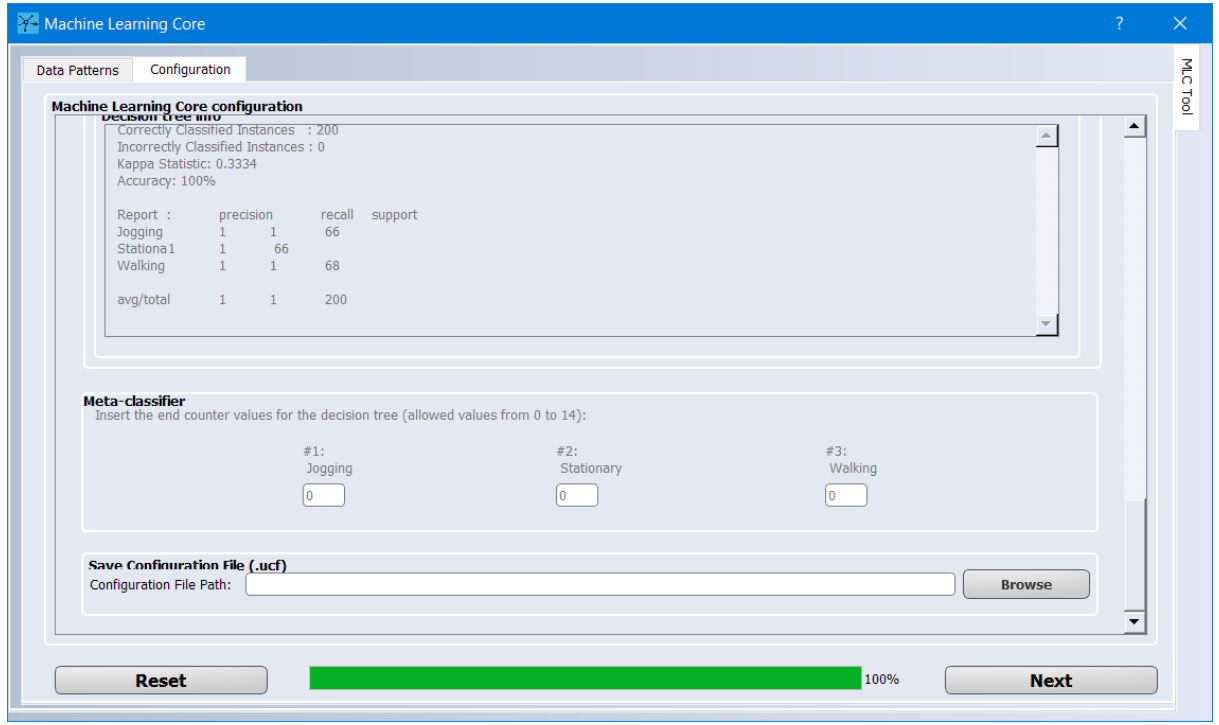
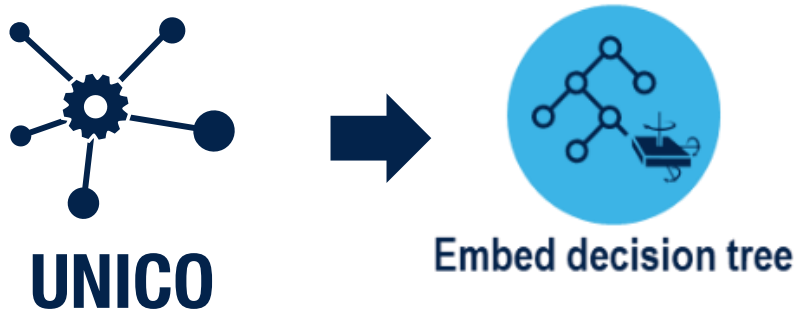
Developing a decision tree based on a dataset with UNICO-GUI (3)

UNICO-GUI: build the decision tree and generate the sensor configuration



- Once the decision tree(s) is evaluated, **UNICO-GUI can generate a configuration file (UCF)** that is easily uploaded in the sensor to implement it.
- The UCF file contains all that is needed to properly configure the sensor (ODR, FS, MLC, etc...) to behave in the way it has been programmed in UNICO-GUI.



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ML solutions in accelerometers and gyroscopes

Personal Electronics

LSM6DSOX

LSM6DSO32X

- Activity recognition
- Gym activity recognition
- Airplane mode detection

LSM6DSRX

- Virtual Reality
- Sensor Fusion
- Vehicle stationary detection

Industrial IoT

ISM330DHCX

IIS2ICLX

- Smart antennas
- Industrial IoT
- Dynamic inclinometers

- Structural health monitoring
- Leveling instruments
- Equipment installation and monitoring

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Machine Learning solutions in sensors: ecosystem

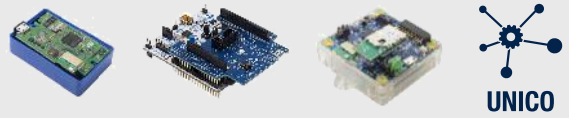
A complete suite to create ML applications in sensors

st.com/mlc

Function packs for quick prototyping

FP-AI-CXTAWARE1

Getting start with **ST development kit and GUI**



Examples for motion recognition and context recognition

GitHub

Videos, training material, in products campaign available

MEMS & Sensor community: **MEMS Machine Learning & AI**

Acoustic scene classification on STM32 MCU

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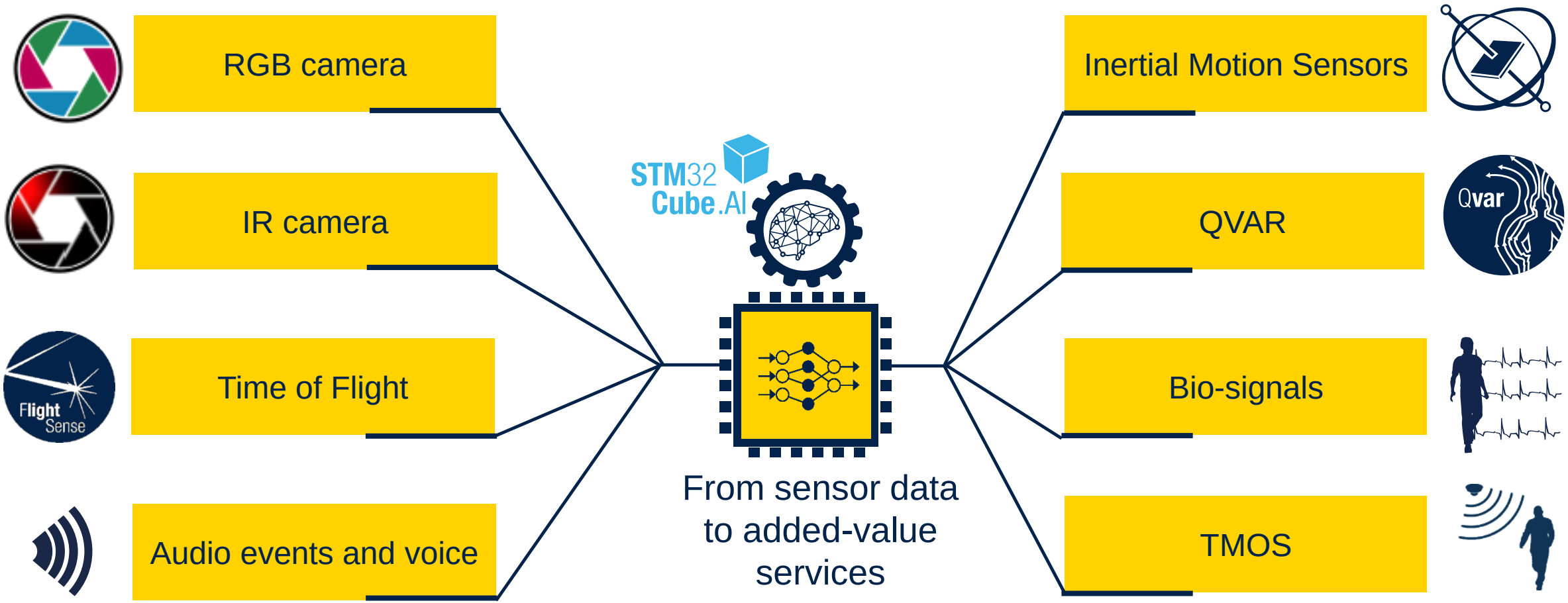
Enhance sensor technologies with AI on MCU



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Convert models from any AI framework

Train Neural Network using any major AI frameworks

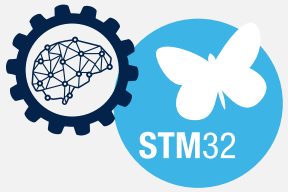
And more

Convert NN into optimized code

STM32 Cube.AI

Select most appropriate MCU
Review computation and memory consumption per layer

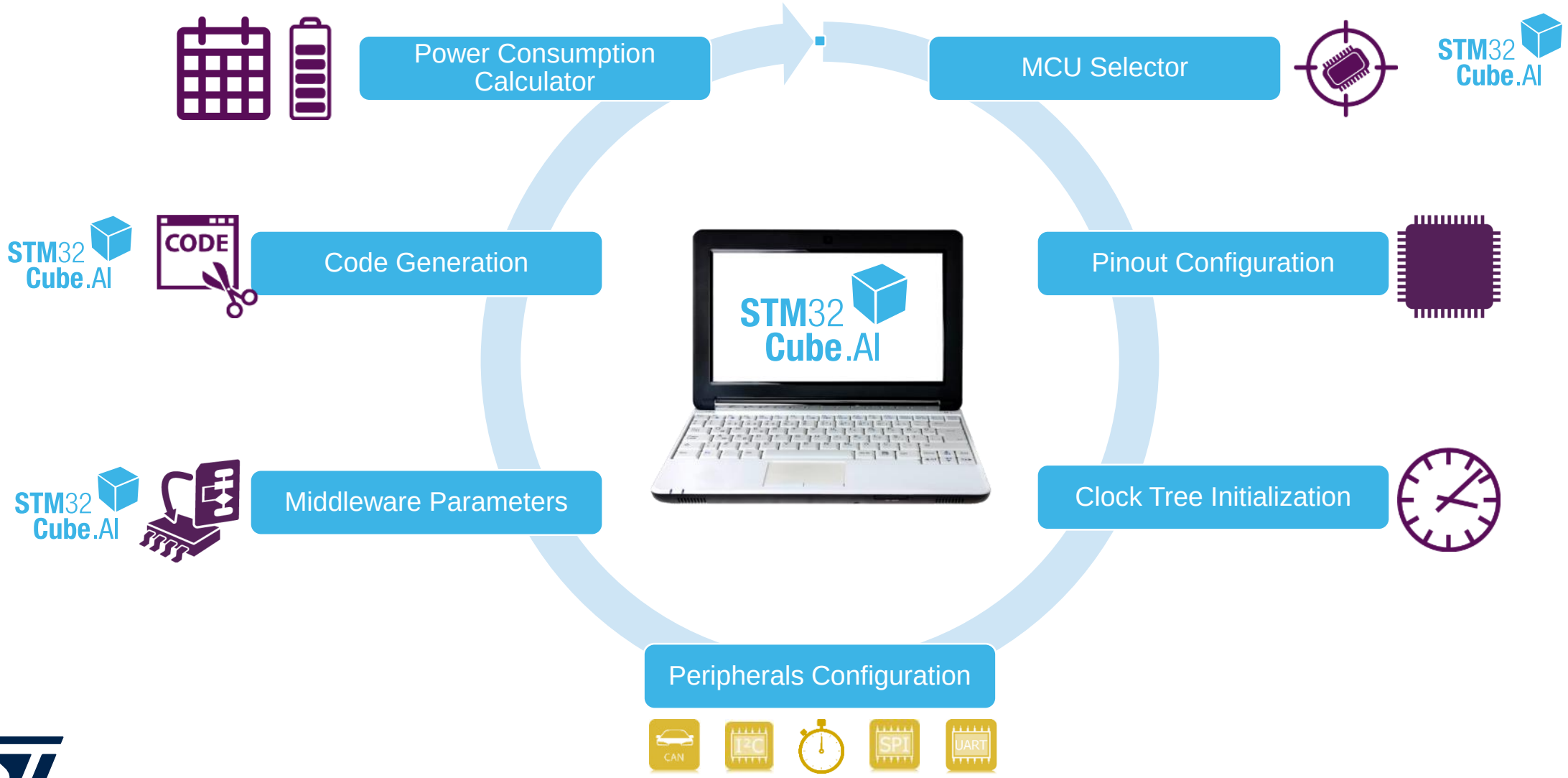
Run on optimized runtime



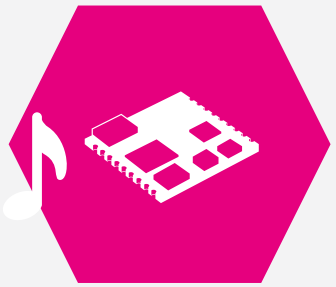
run-time

Validate code directly on target
Get accuracy and inference time
Optimize memory usage

STM32Cube.AI, an STM32CubeMX expansion pack



Audio scene classification (ASC)



3 classes

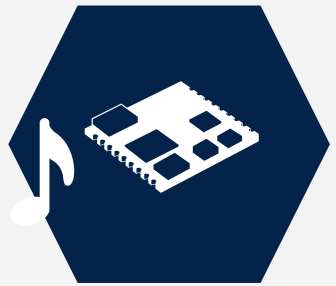
Indoor, Outdoor, In vehicle

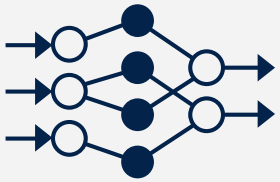
labelling

Audio **Data capture**

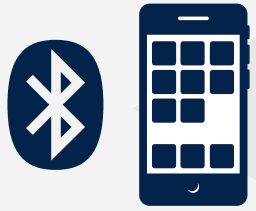
Labelling controlled
by smartphone application

Data stored on the device
SD card for future **learning**





NN & example
dataset provided

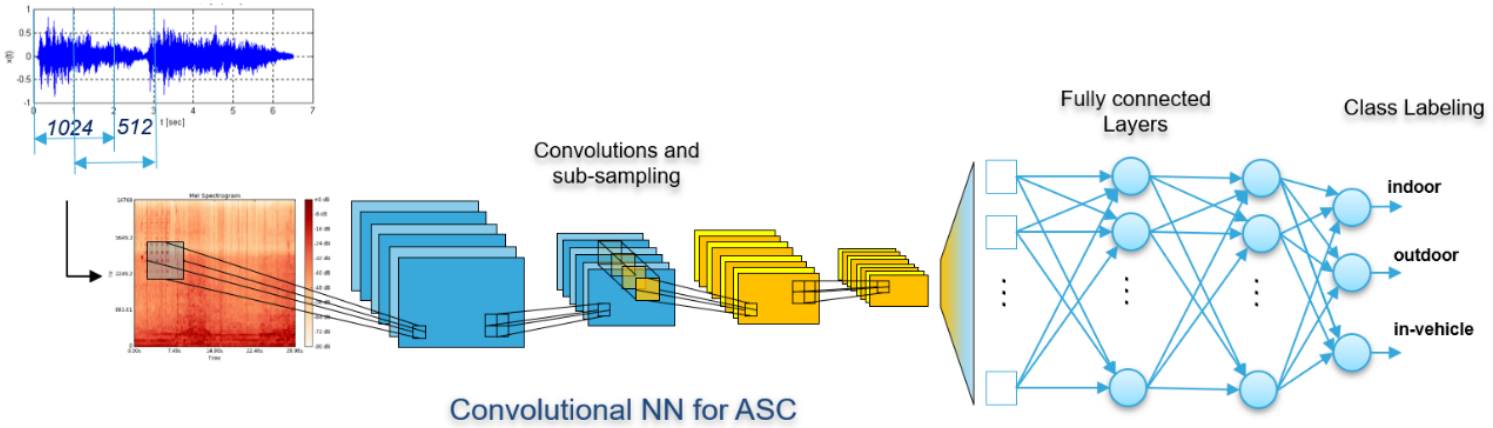


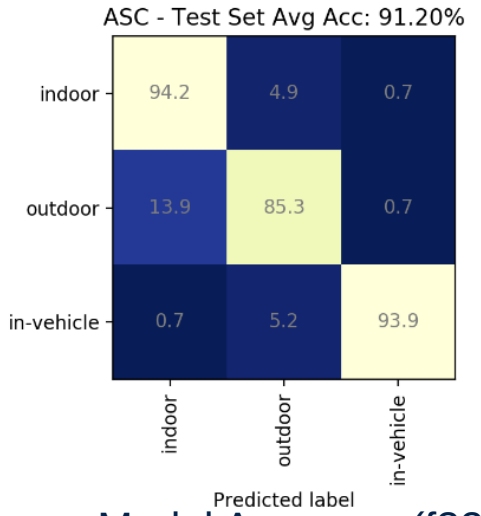
Embedded **audio**
pre-processing

Inferences running
on the microcontroller

Inference result
displayed on mobile app

Audio scene classification model
converted with STM32Cube.AI





Model Accuracy (f32)

Class	Training Set *(hh:mm:ss)*	Validation Set *(hh:mm:ss)*	Test Set *(hh:mm:ss)*
Indoor	6:02:50	1:21:12	7:19:49
Outdoor	6:03:22	1:19:28	1:46:53
In-vehicle	6:03:29	1:20:51	3:58:13
Total	18:09:41	4:01:31	13:04:55

ASC Dataset

STM32 Cube.AI

Model	Avg. Accuracy	NVM	RAM	Inference Time
ASC CNN int8	89.17%	7.71 kB	10.02 kB	30.631 ms

- Quantized ASC int8 model optimized with STM32Cube.AI
- Performance on STM32L476 @ 80MHz

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AI Solutions on STM32

A full development ecosystem to create your AI application

STM32Cube.AI

AI extension for STM32CubeMX to **map pre-trained Neural Networks**

NANOEDGE AI STUDIO

Studio for ML library generation capable of **on-device learning** on STM32 MCU

STM32 **Community** with dedicated Neural Networks topic and **AI expert partners**

Trainings, hands on, MOOCs and partners **videos**

FP-AI-VISION1

Computer Vision applications

FP-AI-SENSING1

Audio and Sensing applications

FP-AI-NANOEDG1

Condition-based equipment monitoring

FP-AI-MONITOR1

Time series-based monitoring

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Context awareness demo

Want to see a demo?

Demo Video Context Awareness

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Want to learn more?

www.st.com/ai

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Our technology starts with You

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