tinyML® EMEA

Enabling Ultra-low Power Machine Learning at the Edge

tinyML EMEA Technical Forum 2021 Proceedings

June 7 – 10, 2021

Virtual Event

www.tinyML.org

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How to implement Distributed Deep Edge AI with STMicroelectronics?

STMicroelectronics

Agenda

1. ST strategy for TinyML
2. The Context Awareness use case & function pack
3. Human Activity Recognition in Smart Sensor LSM6DSOX
4. Acoustic Scene Classification on STM32L4R9ZIJ6 MCU
5. Context Awareness Demo

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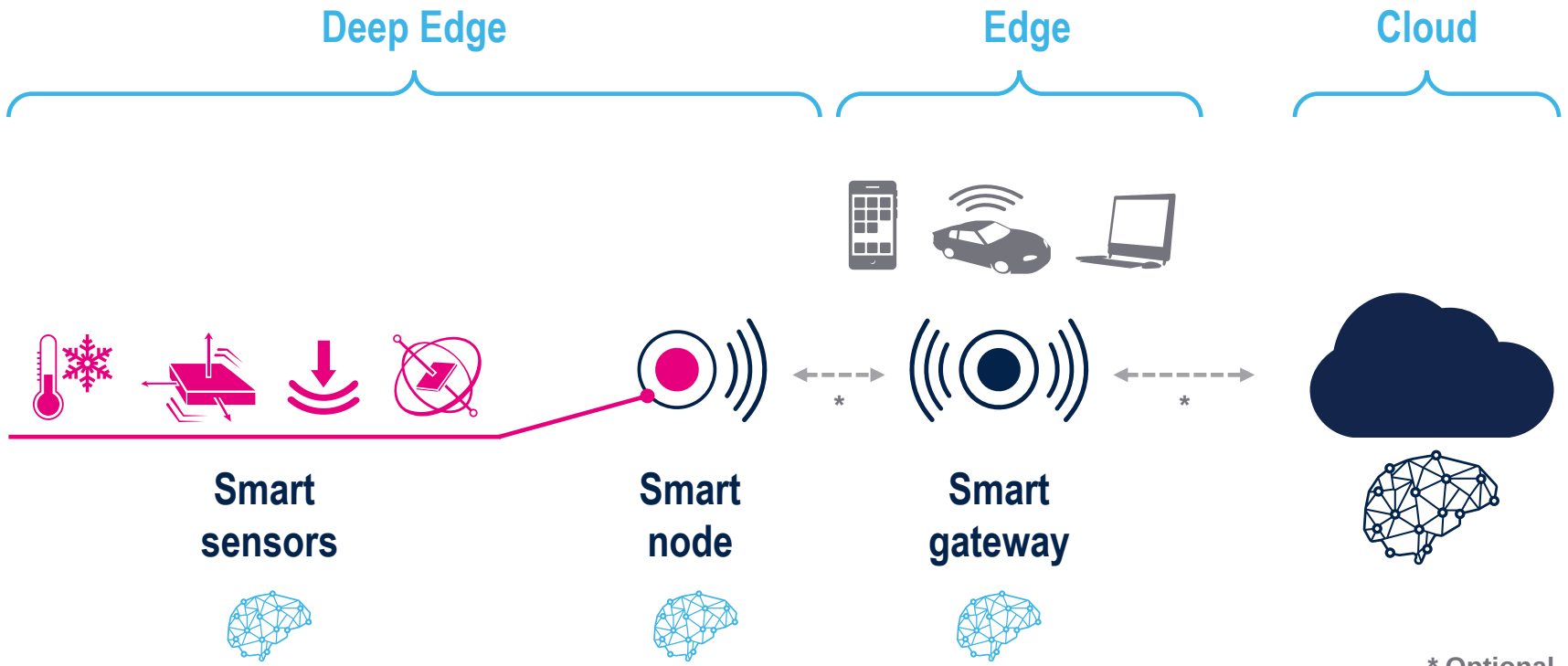
ST strategy for TinyML

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
use case & function pack

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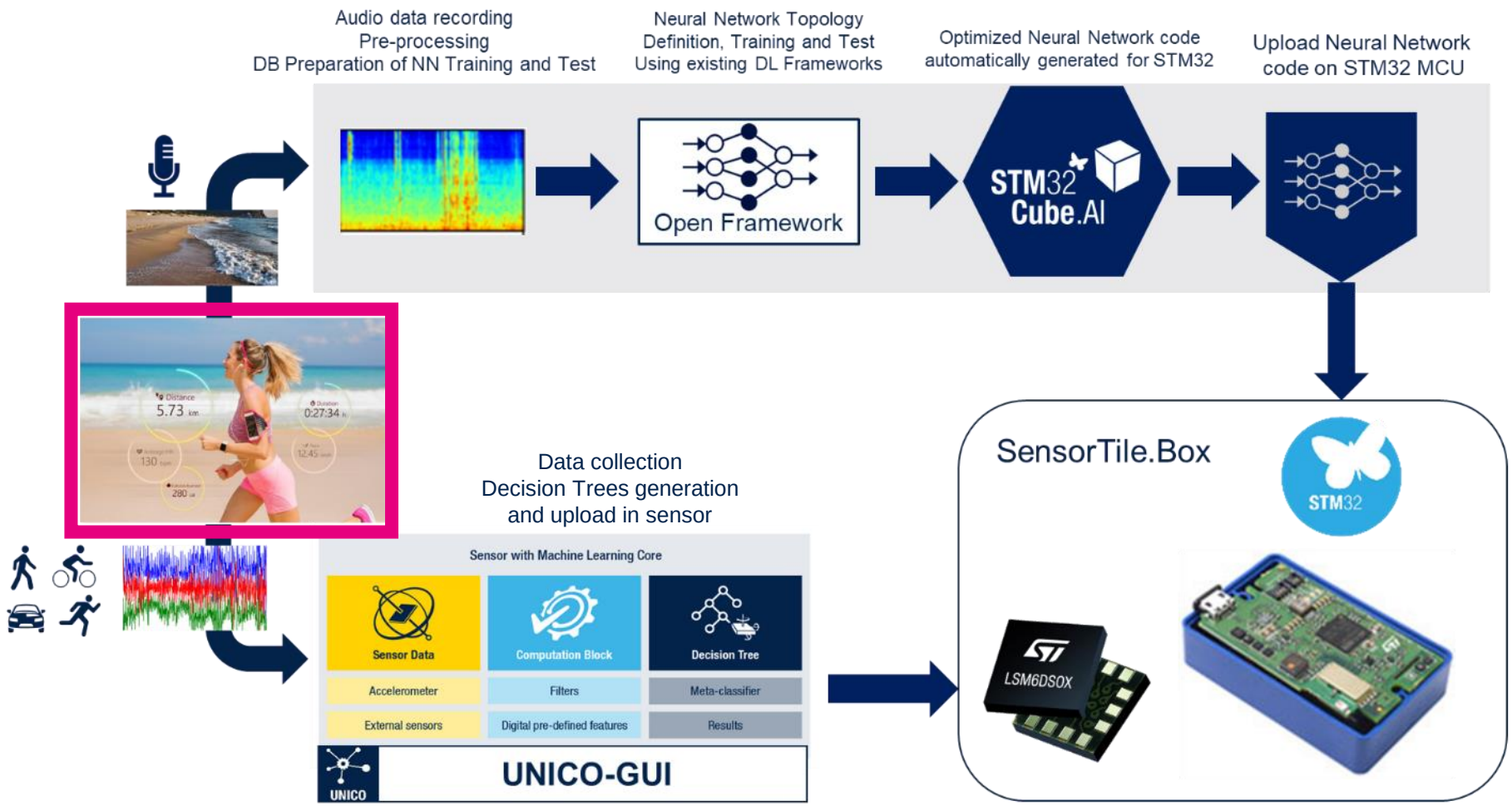
Context awareness: where are we? what are we doing?

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

MCU
Audio Scene Classification

Sensor
Human Activity Recognition



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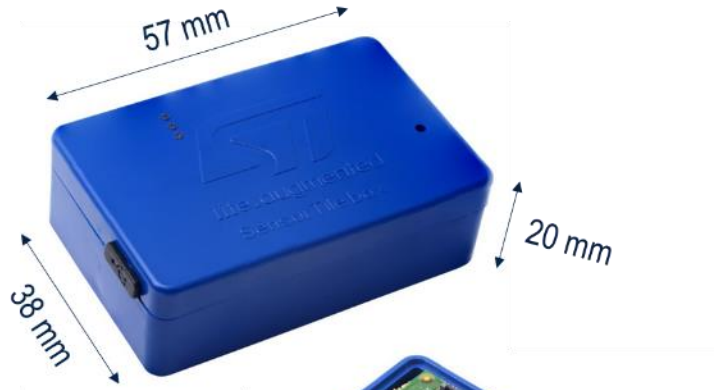
Context awareness activity recognition: What do you need?

STEVAL-MKSBOX1V1 evaluation board

Multi-sensor kit with portable sensor box and smart sensor app

- Compact casing, IP54-compliant
  57 x 38 x 20 mm (L x l x h)
  Additional cases (with flanges or hinges) available
- 500 mA-h Li-Po battery
- 8 GB µSD card as mass memory
  extendable to 64 GB
- Compatible with “ST BLE Sensor” app
  Available on Google Play and App Store



STEVAL-MKSBOX1V1 STBLEsensor App

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Where can you find the SensorTile.box (STEVAL-MKSBOX1V1)?

Evaluation kit available in ST eStore and Distributors:
https://estore.st.com/en/steval-mksbox1v1-cpn.html

STEVAL-MKSBOX1V1 ACTIVE

SensorTile.box wireless multi sensor development kit with user friendly app for IoT and wearable sensor applications

Learn More about STEVAL-MKSBOX1V1

Quantity	$ per Unit	Savings
1 - 4	$42.88	0%
5 - 500	$42.87	0%
500 +	Contact Sales	

Contents:

- STEVAL-MKSBOX1V1 with 2 different cases
- SD-Card and rechargeable battery
- JTAG20 to STDC14 adapter
- STDC14 cable

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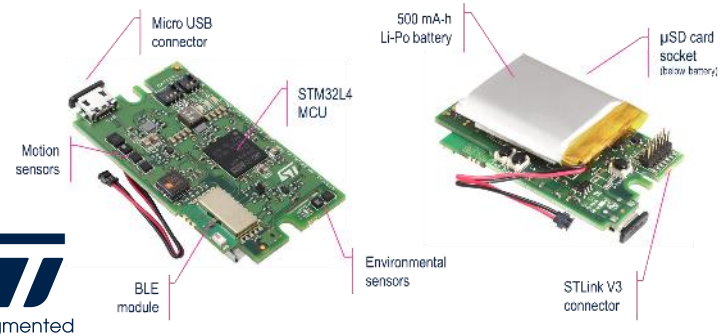
What's inside the SensorTile.box (STEVAL-MKSBOX1V1)?

Motion Sensors

Low-power 6-axis IMU, embedding Machine Learning
LSM6DSOX

High-performance and low power accelerometers
LIS3DHH & LIS2DW12

Magnetometer
LIS2MDL



Environmental Sensors

Altimeter / Pressure sensor
LPS22HH

Accurate temperature sensor
STTS751

Humidity sensor
HTS221

Analog wide-band microphone
MP23ABS1

Processing

STM32L4 low-power MCU
STM32L4R9ZIJ6

Connectivity

Bluetooth Low Energy Module
SPBTLE-1S

Power management

Battery charger
STBC02

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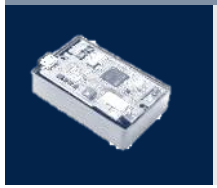
Pre-integrated application example

The SensorTile.box is supported by several STM32Cube function packs

FP-SNS-STBOX1



For building custom applications using the the Pro Mode

FP-ATR-BLE1

For asset tracking using BLE connectivity

FP-SNS-ALLMEMS

Ultra-low power IoT node with BLE connectivity, digital microphone, environmental and motion sensors

FP-AI-SENSING1

Ultra-low power IoT node with artificial intelligence (AI) application based on audio and motion sensing

FP-AI-CXTAWARE1

Ultra-low power context awareness with distributed artificial intelligence (AI): acoustic analysis with NN on MCU and motion analysis with ML on IMU

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What's inside the FP-AI-CTXAWARE1?

Complete firmware

Context awareness node with BLE connectivity, digital microphone, environmental and motion sensors, and perform real-time monitoring of sensors and audio data

Middleware library

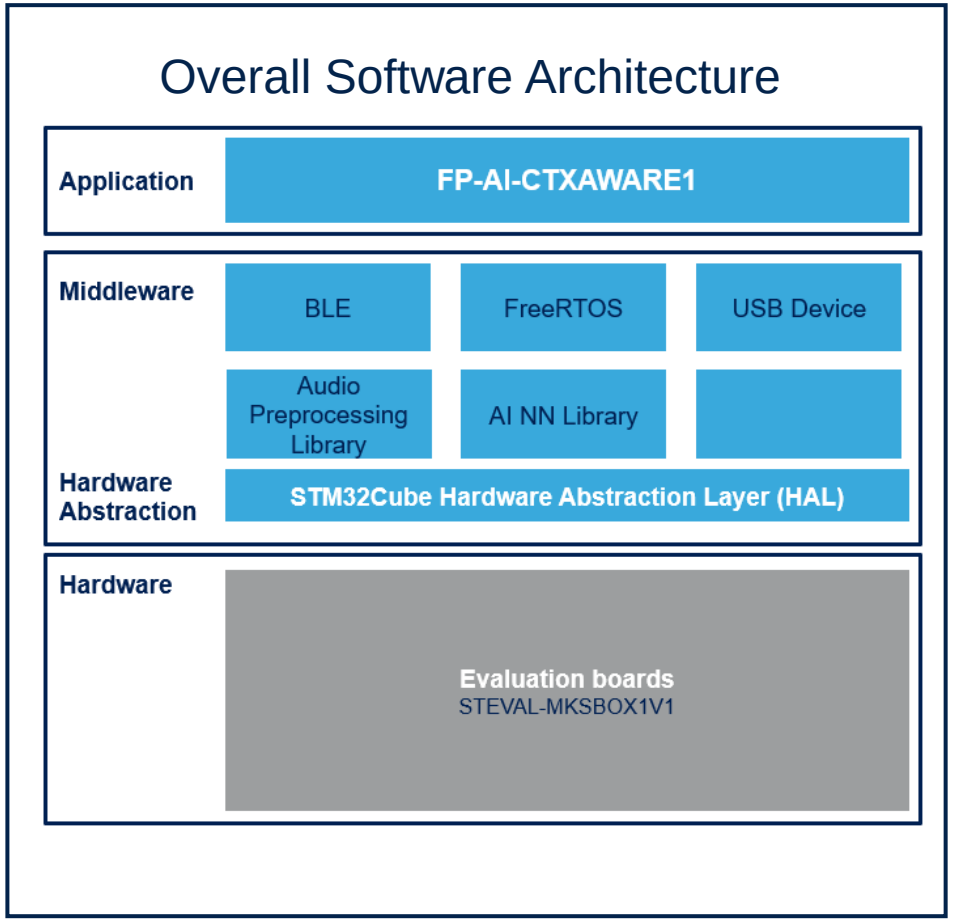
generated thanks to STM32CubeMX extension X-CUBE-AI, featuring example implementation of neural networks for real time acoustic scene classification (ASC) application

Concurrent execution ML & NN

with concurrent execution of the MLC for HAR and neural network for ASC

Features

Ultra-low power implementation based on the use of an RTOS
Compatible with ST BLE Sensor application for Android/iOS
Free, user-friendly license terms



Latest info available at www.st.com

FP-AI-CTXAWARE1

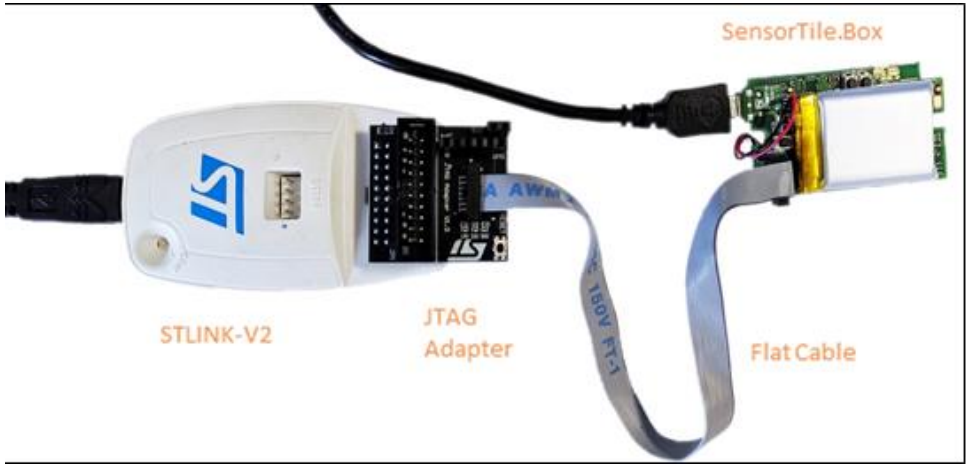
Setup & application examples
Hardware prerequisites

- 1x STEVAL-MKSBOX1V1 evaluation board
- Laptop/PC with Windows 7, 8 or 10
- 1 x microUSB cable
- 1x USB type A to Mini-B USB cable
- ST-Link/V2 in-circuit debugger/programmer for STM8 and STM32

MicroUSB Cable

Mini USB

ST-Link/V2



STEVAL-MKSBOX1V1

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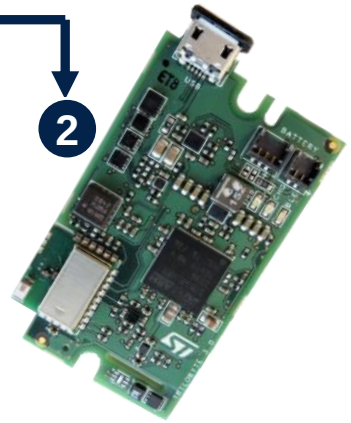
Setup & application examples
Software and other prerequisites

- **STM32 ST-Link Utility**
  - Download and install STSW-LINK004 from www.st.com
- **FP-AI-CTXAWARE1**
  Copy the .zip file content into a folder on your PC. The package will contain source code example (Keil, IAR, STM32Cube IDE) based on **STEVAL-MKSBOX1V1**.
- **ST BLE Sensor Application** for Android or iOS, to download from Google Store / iTunes
- **Serial line monitor,** e.g. TeraTerm (https://ttssh2.osdn.jp/)

FP-AI-CTXAWARE1 setup overview

1 www.st.com/stm32ode-fp



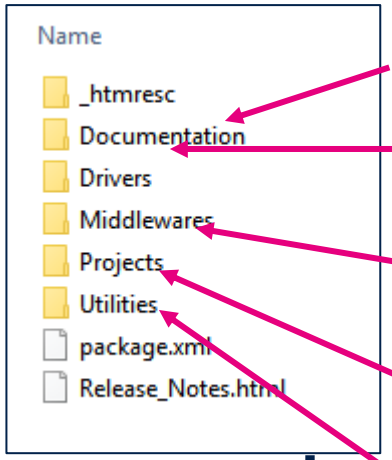
2

3

Download & unpack

Select Function Pack: FP-AI-CTXAWARE1

FP-AI-CTXAWARE1 package structure



Docs

BSP, HAL drivers

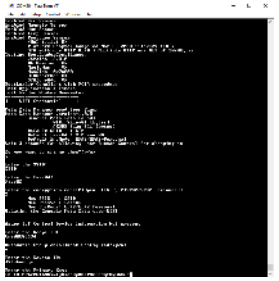
BlueNRG-1, FreeRToS, AI-Library

Applications

MLC programs

4

Android™/iOS™ smartphone and ST BLE Sensor application or Serial Line Monitor



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Projects\STM32L4R9ZI-SensorTile.box\Applications\BLELowPower\EWARM
Projects\STM32L4R9ZI-SensorTile.box\Applications\CLAi\EWARM

KEIL™ Tools by ARM | IAR SYSTEMS | STM32 CubeIDE

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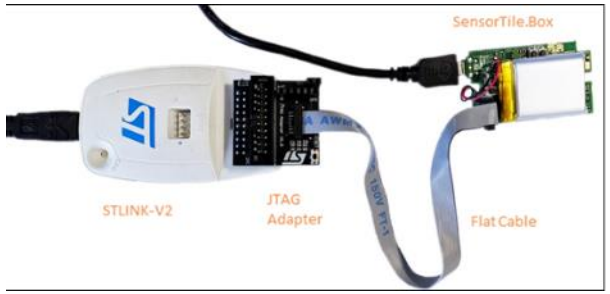

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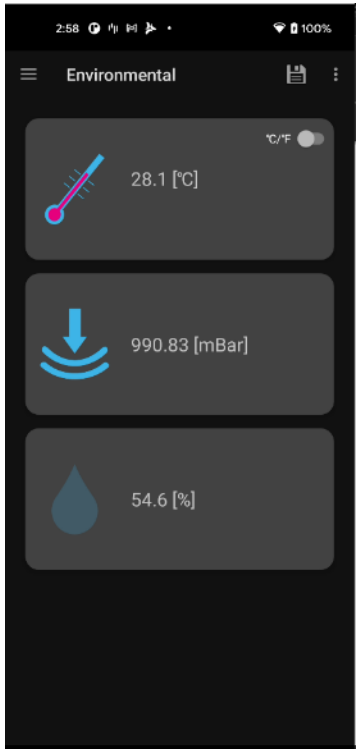
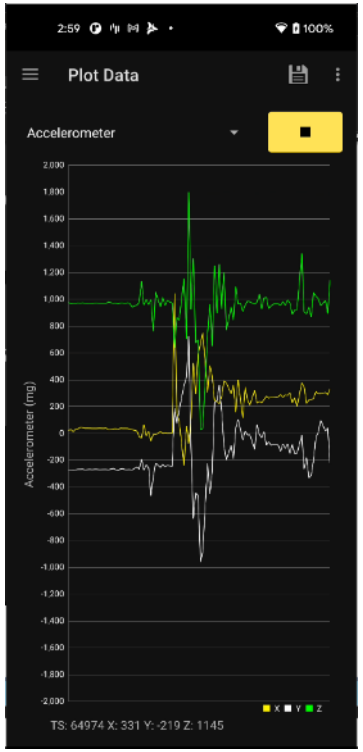
BLELowPower (FP-AI-CTXAWARE1) BLE version

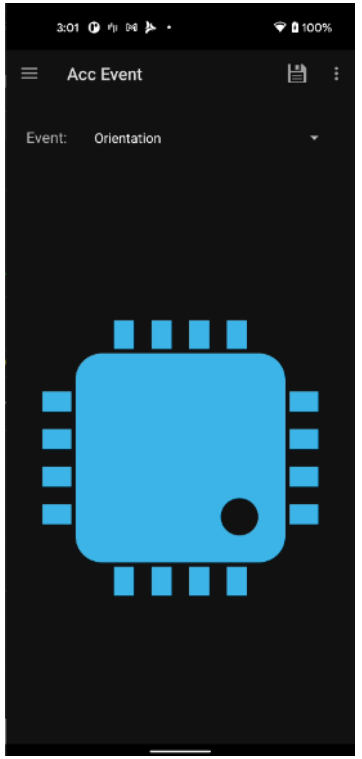
Environmental



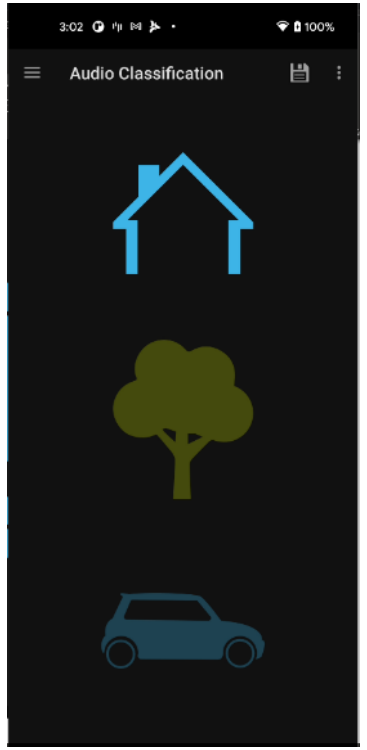
Plot



HW features



Audio scene classification



Activity recognition

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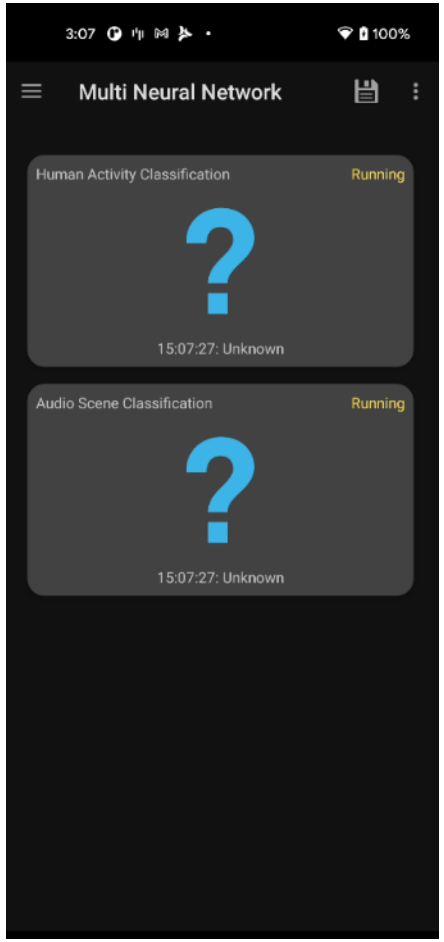
BLELowPower (FP-AI-CTXAWARE1) BLE version

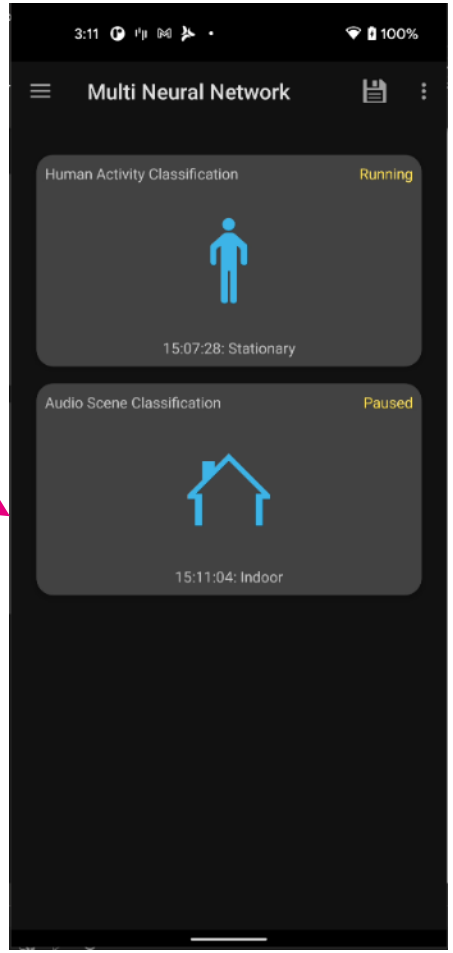
Human Activity Recognition (HAR) running on MLC provides indication about activity status (“Stationary”, “Walking”, “Jogging”, “Biking”) while Acoustic Scene Classification (ASC) is used for context awareness (“Indoor”, “Outdoor”, “In Vehicle”)



The Human Activity Recognition (HAR) is always running on MLC (LSM6DSOX) without consuming power on STM32

The Acoustic Scene Classification (ASC) runs periodically for controlling the context, and changing the program on MLC if it is necessary

Indoor/ Outdoor	In Vehicle
Stationary	Stationary
Walking	Walking
Jogging	Driving
Biking	



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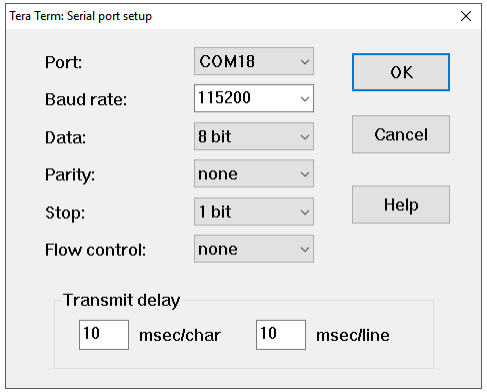
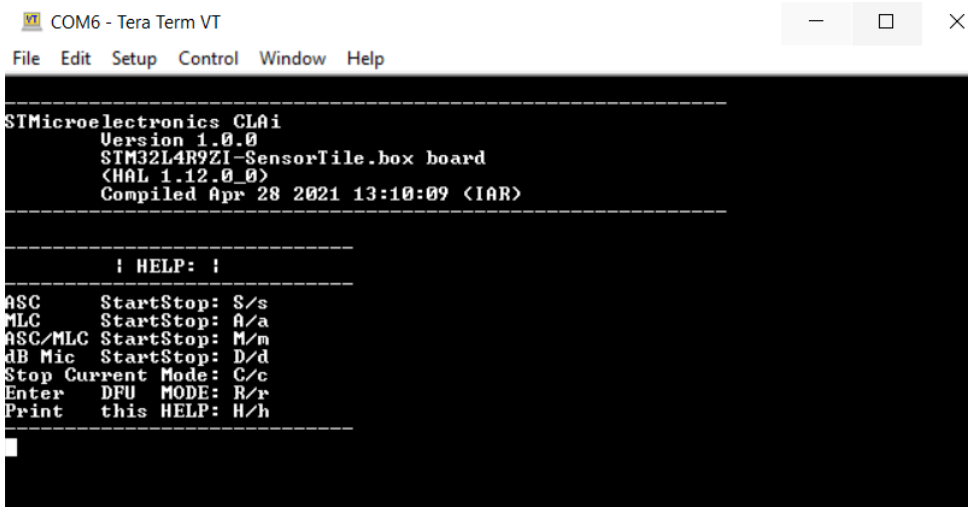
Command Line AI Application (CLAi) (FP-AI-CTXAWARE1) Command Line version

Same functionalities as the Bluetooth version

Serial Line Monitor Configuration

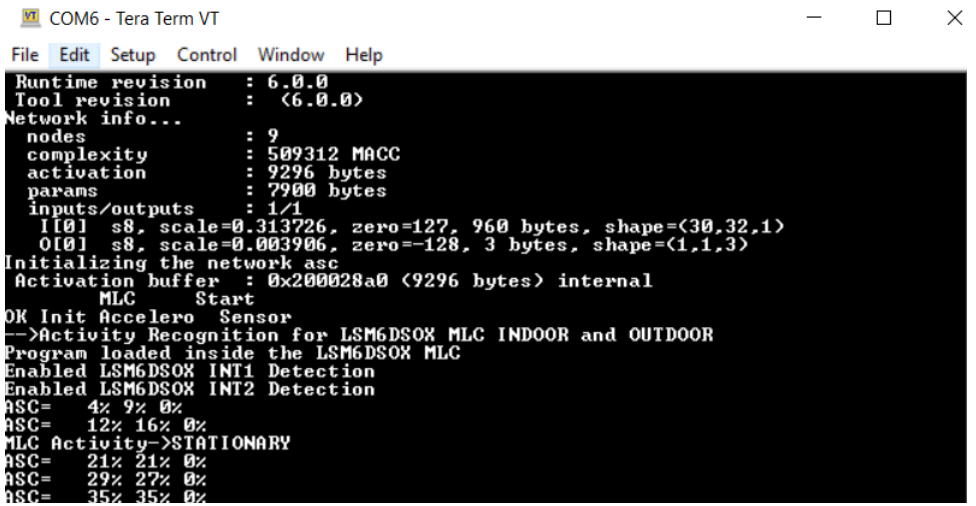


At the beginning the Board will print out the usage:



Using the Command Line interface, it's possible to:

- Run the Audio Scene Classification
- Run the Activity Recognition
- Run the Activity Recognition and the Audio Scene Classification in a combined mode
- Print out the dB measured by microphone



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Documents & related resources

All documents are available in the Design tab of the related products webpage

FP-AI-CTXAWARE1

- **DB4483:** STM32Cube function pack for ultra-low power context awareness with distributed artificial intelligence (AI): acoustic analysis with NN on MCU and motion analysis with ML on IMU – **databrief**
- **UM2870:** Getting started with the STM32Cube function pack for ultra-low power context awareness node with artificial intelligence (AI) application based on audio and motion sensing – **user manual**
- **Software setup file**

STEVAL-MKSBOX1V1

Gerber files, BOM, Schematic

DB3903: SensorTile.box wireless multi sensor development kit with user friendly app for IoT and wearable sensor applications – **databrief**

UM2580: How to use the wireless multi sensor development kit with customizable app for IoT and wearable sensor applications – **user manual**

Consult www.st.com for the complete list

Human activity recognition in smart sensor LSM6DSOX

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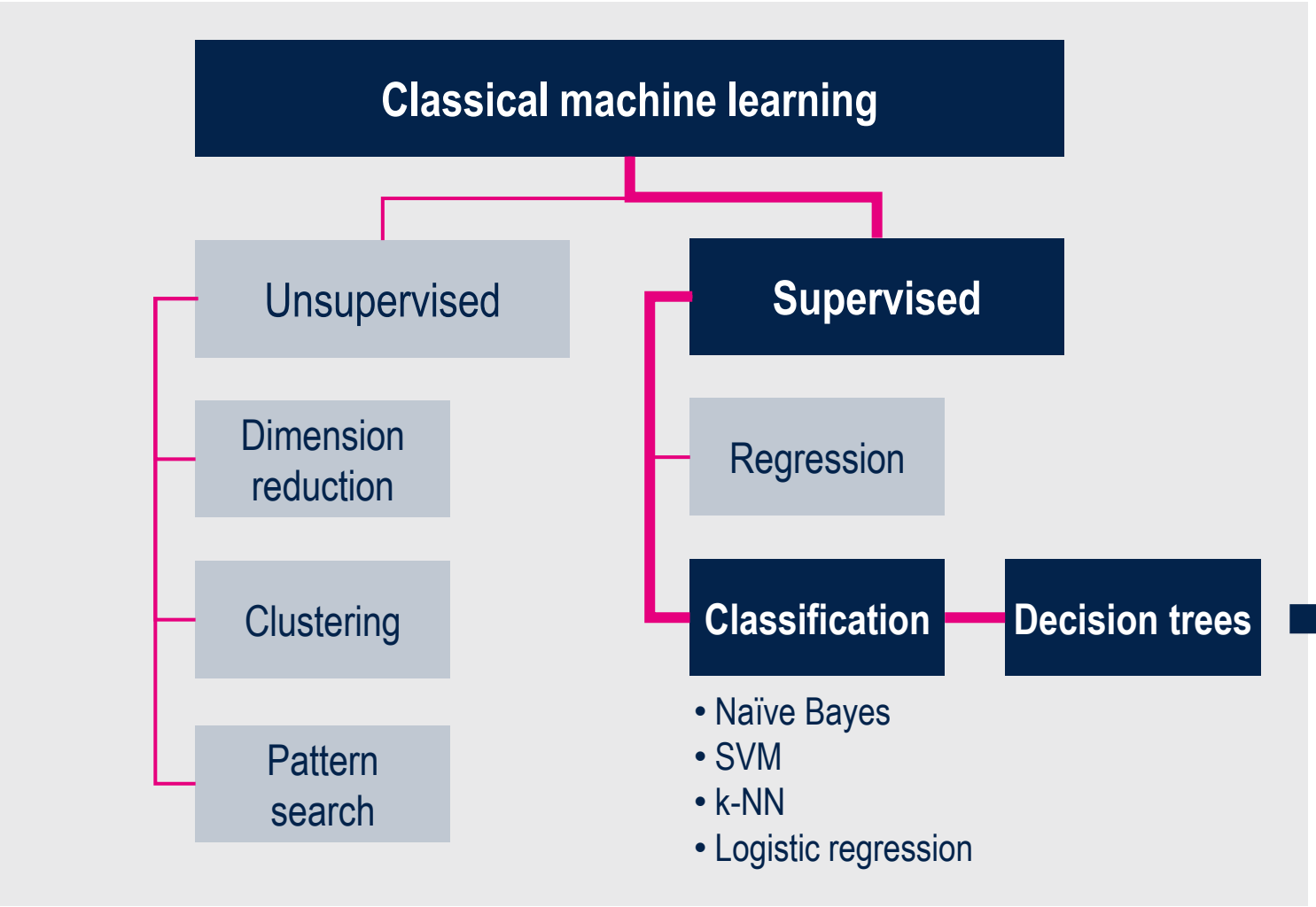
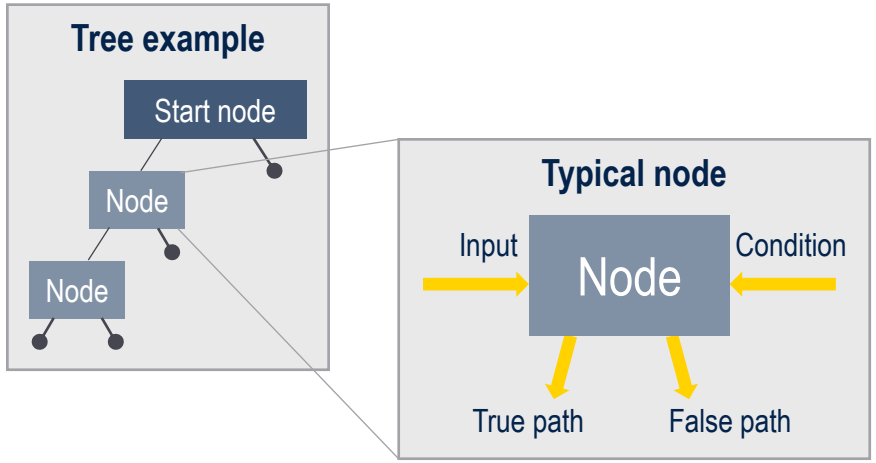
Machine learning embedded in ST sensors



New products with engine embedded:

- 6x IMUs with sensor hub
- Inclinometer



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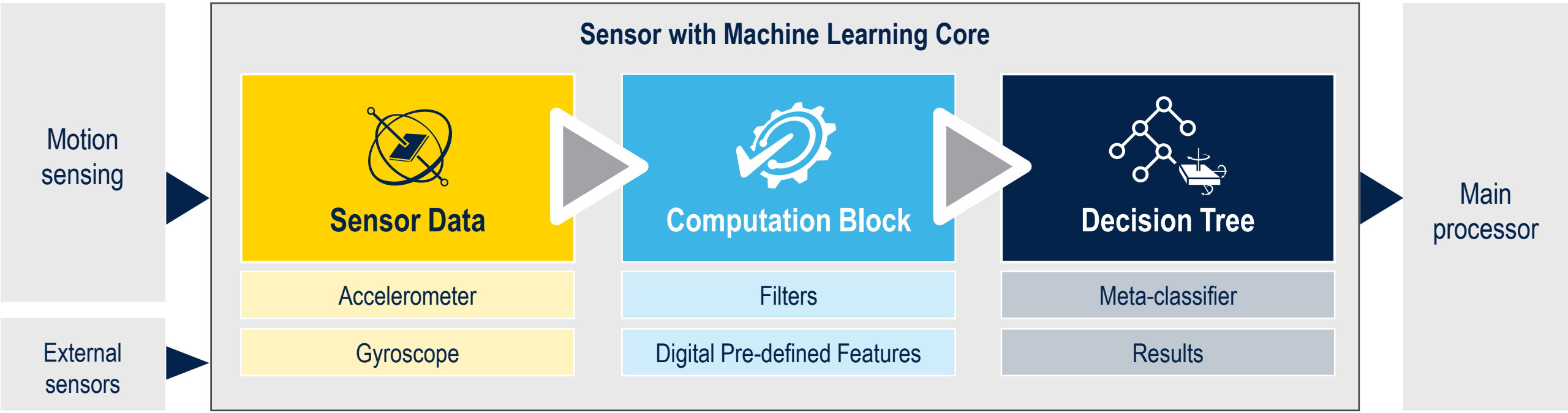
What is a Machine Learning Core (MLC)?

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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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: 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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HAR in UNICO-GUI demo

Machine Learning solutions in sensors: ecosystem

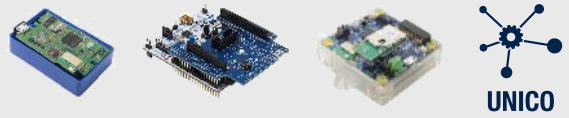
A complete suite to create ML applications in sensors

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 STM32L4R9ZIJ6 MCU

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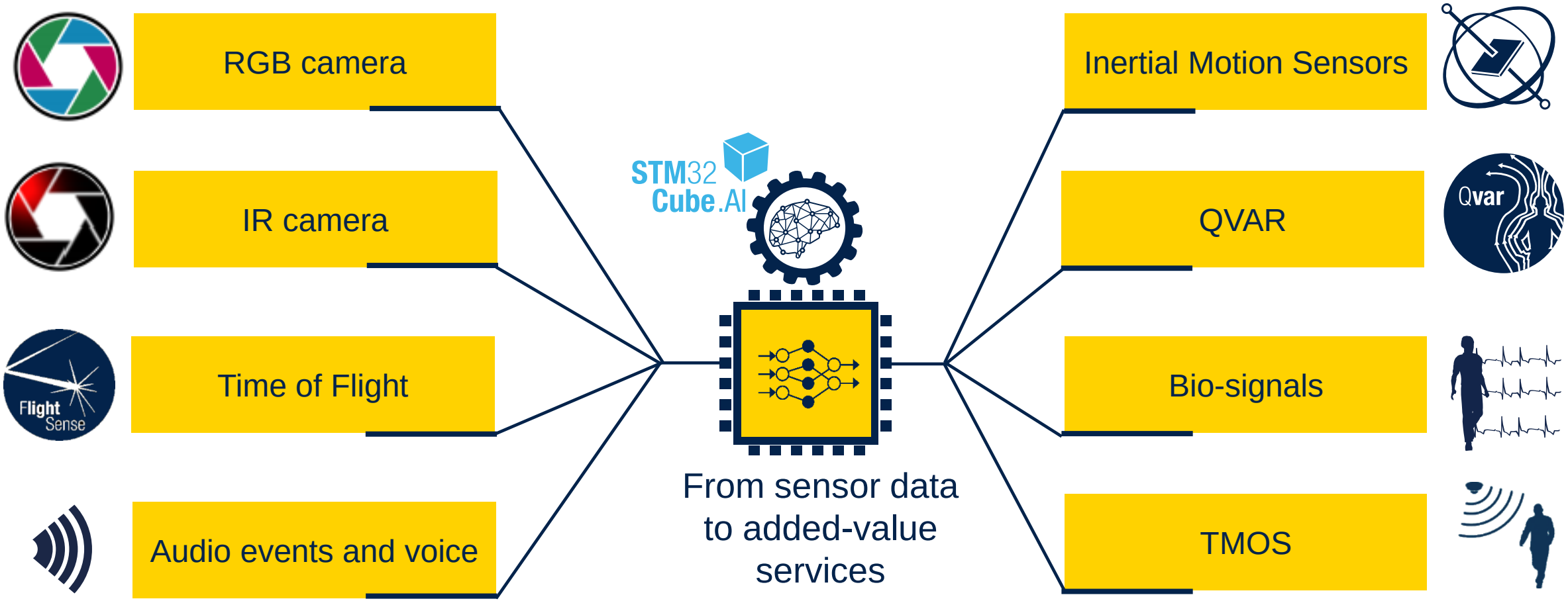
Enhance sensor technologies with AI on MCU



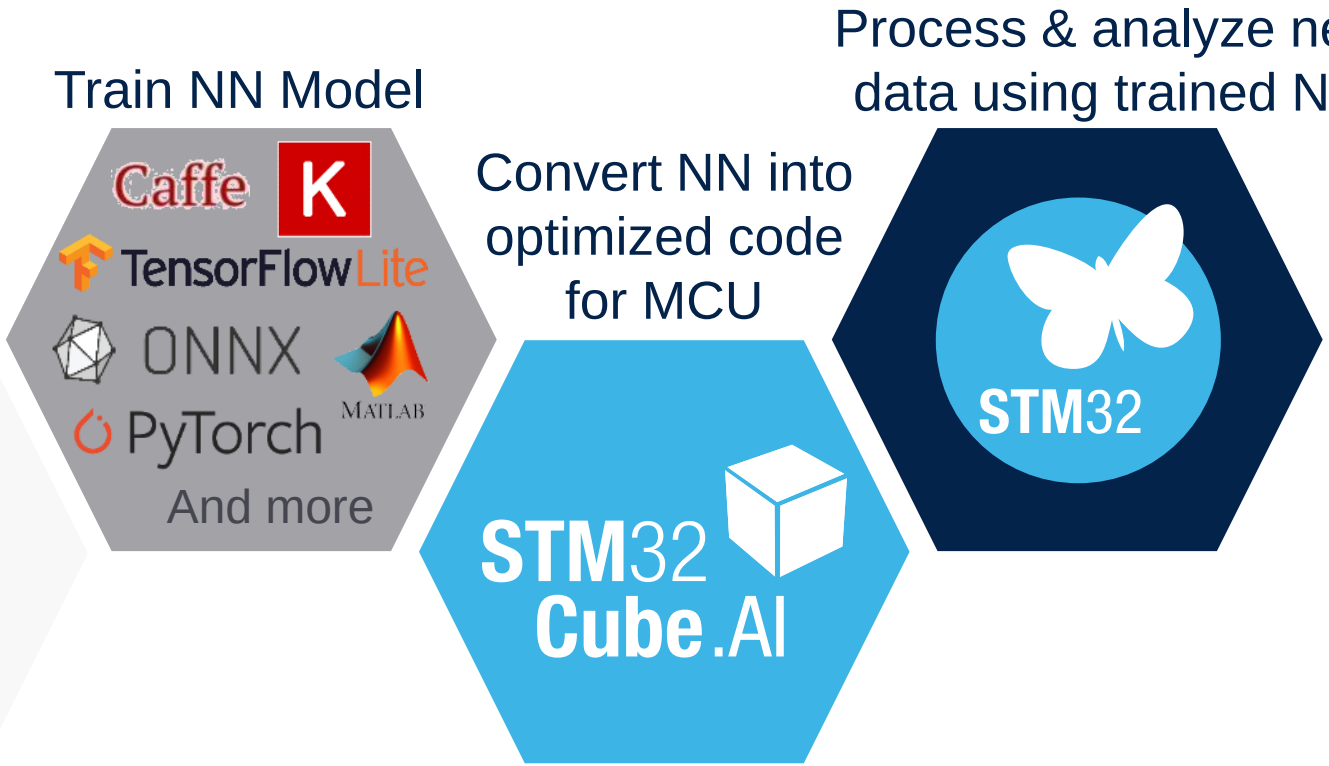
Convert models from any AI framework

Input your framework-dependent, pre-trained Neural Network into the **STM32Cube**.AI conversion tool

Automatic and fast generation of an STM32-optimized library

STM32Cube.AI offers interoperability with state-of-the-art Deep Learning design frameworks

Any framework that can export models in **ONNX** open format can be imported



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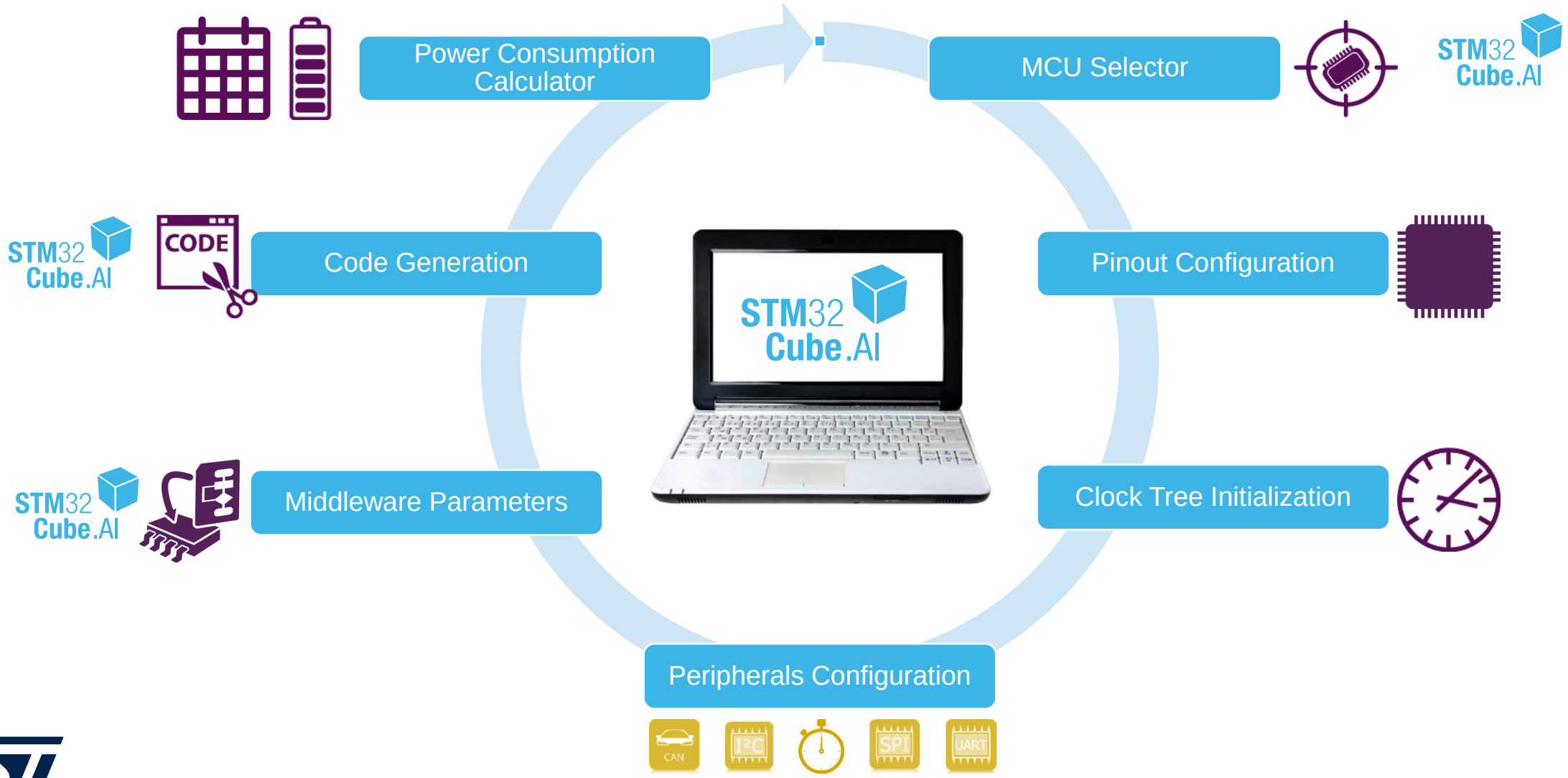
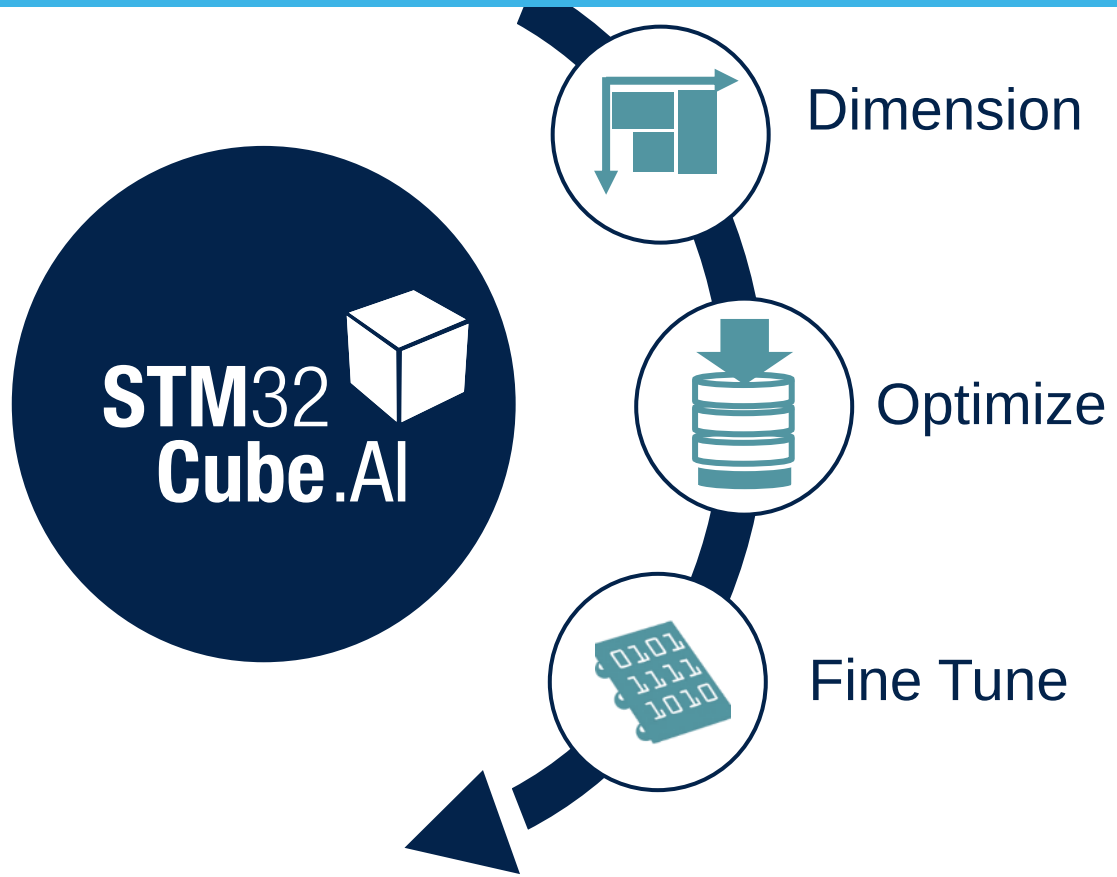
STM32Cube.AI, an STM32CubeMX expansion pack



STM32Cube.AI main features

STM32Cube.AI is available both as a graphical and command line interface



- ✓ Quickly assess model footprint requirements
- ✓ Select and configure MCU in STM32CubeMX
- ✓ Review model layers in STM32Cube.AI

- ✓ Generate C-code for pre-trained model
- ✓ Support quantized models to reduce RAM, flash and latency with minimal loss of accuracy
- ✓ Use light run-time libraries
- ✓ Optimize for performance

- ✓ Optimize memory allocation
- ✓ Fine control of weight mapping
- ✓ Split between internal and external memory
- ✓ Update model without full FW update

And quickly iterate thanks to on-target validation

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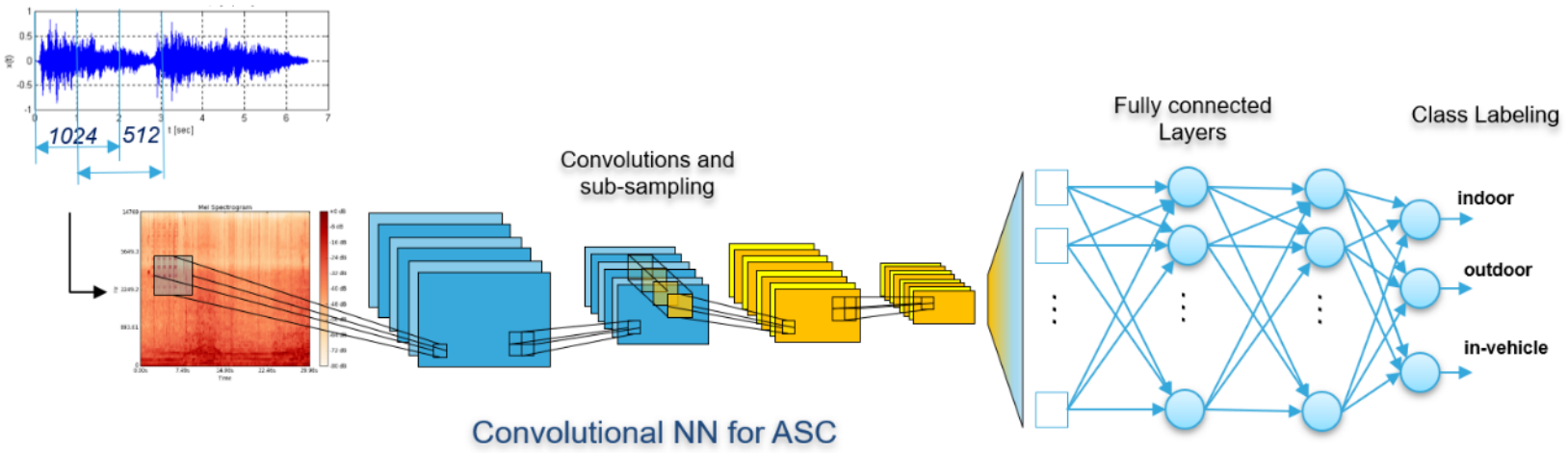
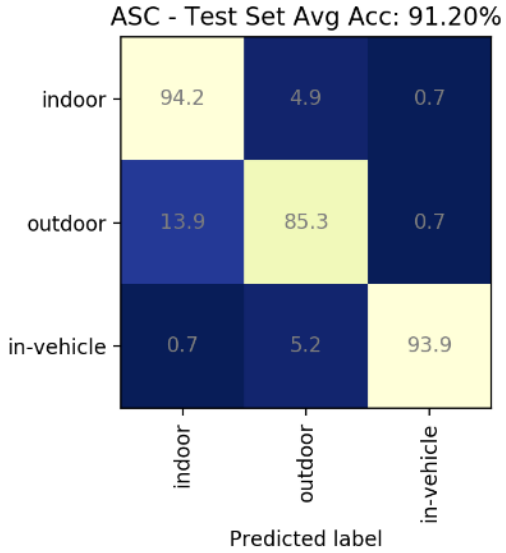
Audio scene classification using STM32Cube.AI



Convolutional NN for ASC



Model Accuracy (f32)

Class	Training Set	Validation Set	Test Set
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

Dataset Composition

Model	Avg. Acc. (%)	NVM (KB)	RAM (KB)	Inference Time (ms)
ASC CNN int8	89.17	7.71	10.02	30.631

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

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Context awareness demo

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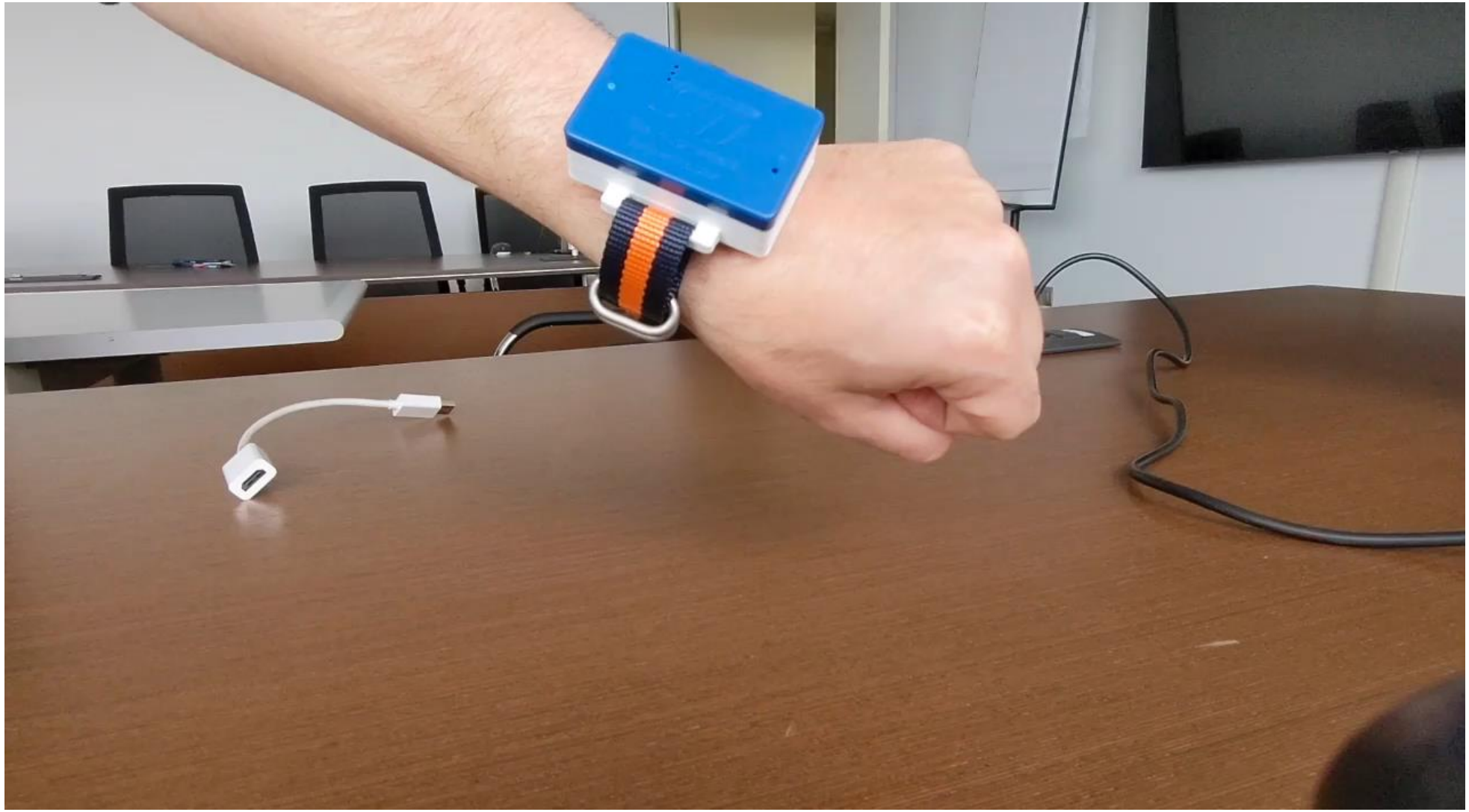
Demo video



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www.st.com/ai

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Our technology starts with You

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Intelligent Agent
Neuton

Automated TinyML

Zero-code SaaS solution

Create tiny models, ready for embedding, in just a few clicks!

Compare the benchmarks of our compact models to those of TensorFlow and other leading neural network frameworks.

Build Fast. Build Once. Never Compromise.

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Virtual
JUNE 7-10,2021

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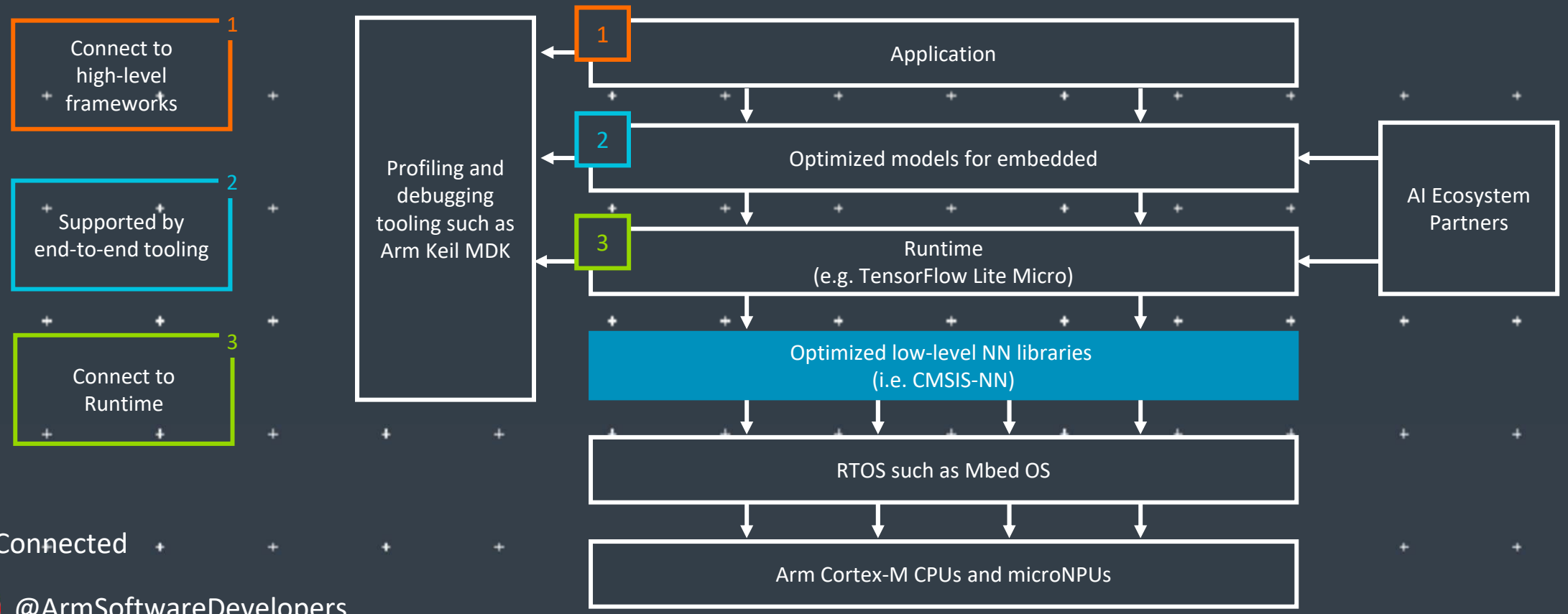
Arm: The Software and Hardware Foundation for tinyML



Stay Connected

@ArmSoftwareDevelopers

@ArmSoftwareDev

Resources: developer.arm.com/solutions/machine-learning-on-arm

arm

TinyML for all developers

C++ library

Arduino library

WebAssembly

Dataset

Acquire valuable training data securely

Enrich data and train ML algorithms

Edge Device

Real sensors in real time

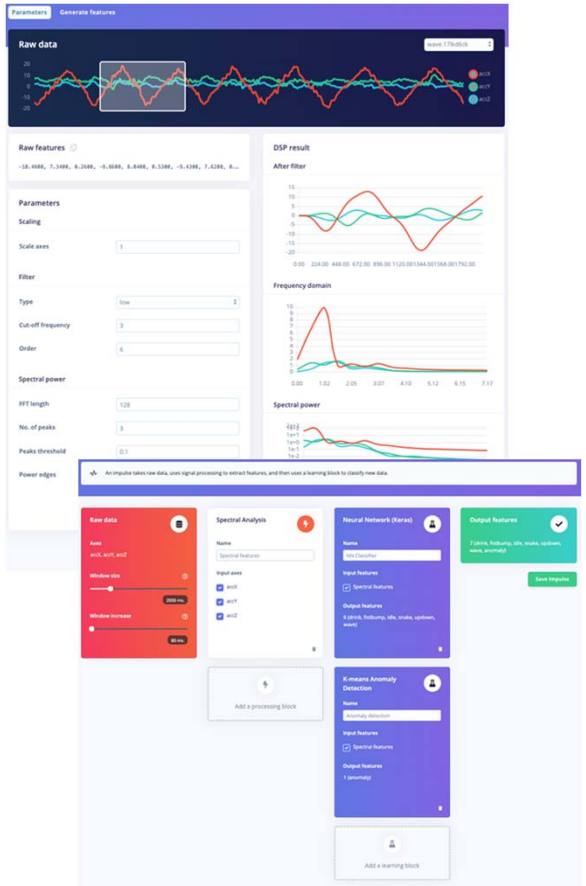
Open source SDK

Impulse

Embedded and edge compute deployment options

Test impulse with real-time device data flows

Test



www.edgeimpulse.com

Qualcomm
AI research

Advancing AI research to make efficient AI ubiquitous

Power efficiency

Model design, compression, quantization, algorithms, efficient hardware, software tool

Personalization

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Reasoning

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Action

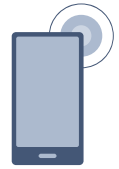
Reinforcement learning for decision making

Edge cloud

Cloud

IoT/IIoT

Automotive



Mobile

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Founded in 2017 and headquartered in Irvine, California, the company is backed by Amazon, Applied Materials, Atlantic Bridge Capital, Bosch, Intel Capital, Microsoft, Motorola, and others. Syntiant was recently named a CES® 2021 Best of Innovation Awards Honoree, shipped over 10M units worldwide, and unveiled the NDP120 part of the NDP10x family of inference engines for low-power applications.

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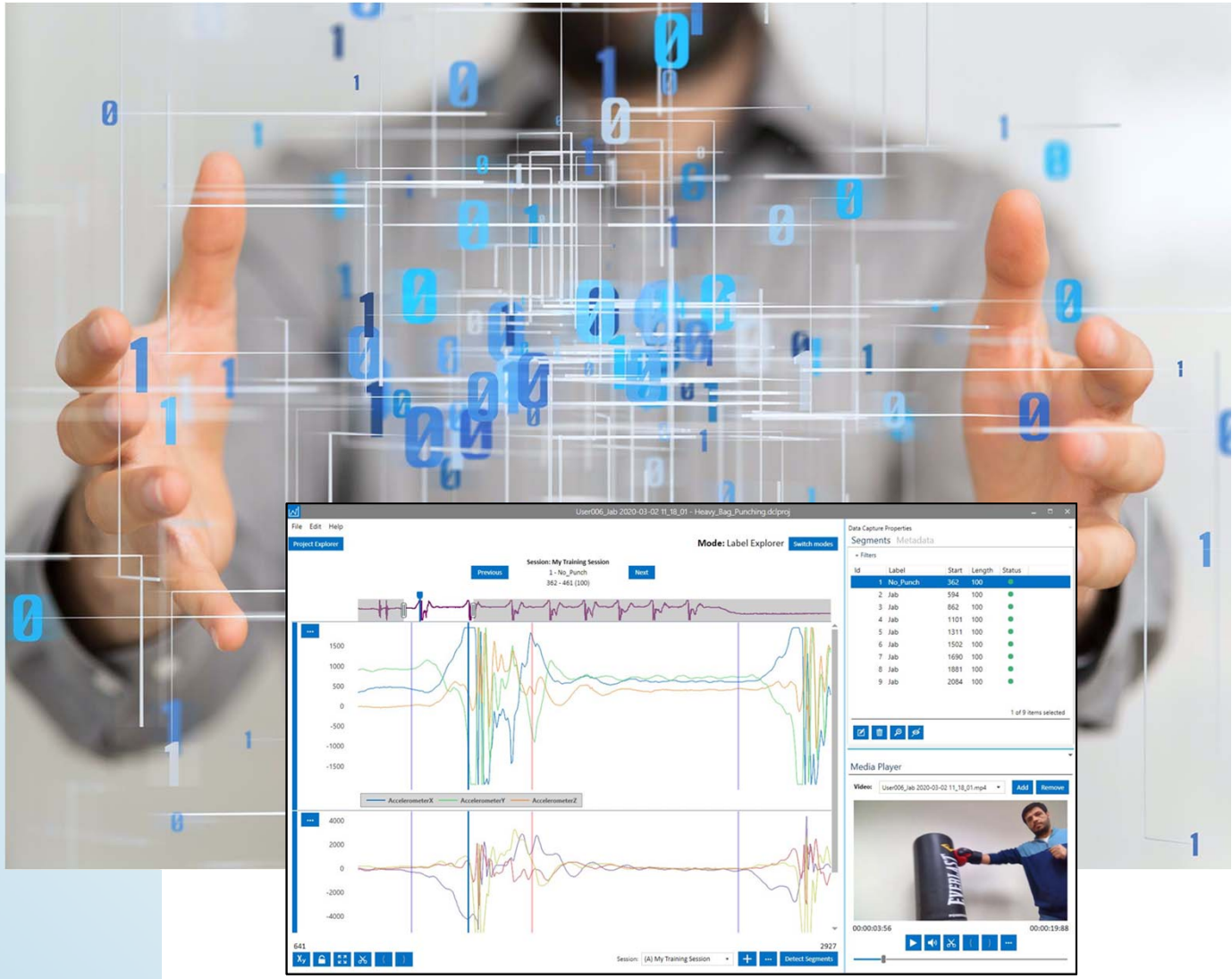

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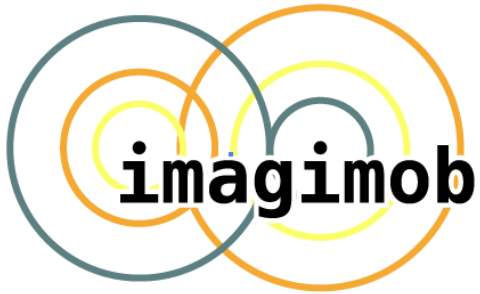

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