



life.augmented



How to use ST's intelligent sensors in

MEMS
Studio



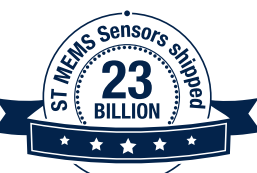
Steven Bakker

Product Marketing Engineer

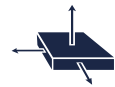


Jeffrey Edrington

Field Application Engineer

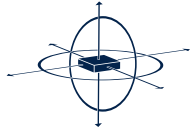


ST MEMS and Sensors



Accelerometers Inclinometers

LIS2DH12
LIS2DW12 / LIS2DTW12
LIS2DU12
LIS2DUX12 / LIS2DUXS12
H3LIS331DL
ST1VAFE3BX
IIS2DH
IIS2DLPC
IIS2DULPX
IIS2ICLX
IIS3DWB
AIS2DW12
AIS2IH



6-axis IMUs

LSM6DSO / LSM6DSOX LSM6DSO32 / LSM6DSO32X
LSM6DSR / LSM6DSRX
LSM6DSV / LSM6DSV16X LSM6DSV16BX / LSM6DSV32X
LSM6DSO16IS
LSM6DSV256X/320X
ISM330DHCX
ISM330BX
ISM330IS
ASM330LHH / ASM330LHHX ASM330LHHXG1
ASM330LHB/ASM330LHBG1



Magnetometers

LIS2MDL	IIS2MDC
LSM303AGR	ISM303DAC



Absolute Pressure

LPS22DF	ILPS22QS
LPS28DFW	ILPS28QSW



Temperature

STLM20 / STTS751
STTS22H



IR Presence

STHS34PF80



Microphones

MP23ABS1	IMP23ABSU
MP34DT06J	IMP34DT05
MP23DB01HP	



Proximity and Ranging

VL53L4ED
VL53L4CX
VL53L4CD
VL53L7CX
VL53L7CH
VL53L8CX
VL53L8CH

Ambient Light Sensor

VD6283TX



Consumer

Industrial



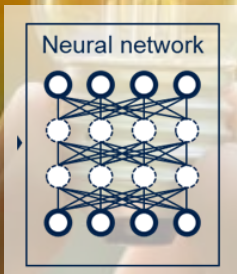
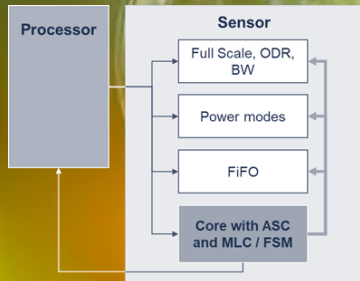
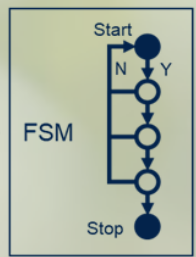
Automotive



AEC-Q100

Bringing intelligence and integration in the edge

Smart Sensors



MLC & FSM

Machine learning core and **finite state machine** for in-the-edge processing

Sensor Fusion

Embedded in the sensor to be fast, accurate, and low power

ASC

Adaptive self-configuration. Smart sensors reconfigure themselves

ISPU

Intelligent sensor processing unit. Standard and AI programming in sensors!

Vertical AFE

Vertical analog front end with motion detection for specific applications (verticals)

ENG

ECG

IR sensor

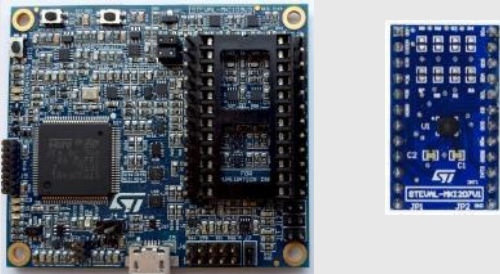
Infrared Sensor based on Thermal MOS technology. Innovative sensing of biometrics and presence detection



Sensors evaluation and development platforms

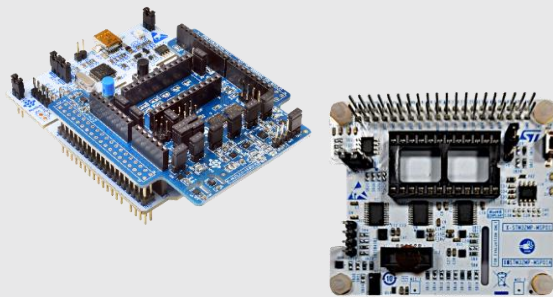
Professional MEMS tool **STEVAL-MKI109V3**

ST MEMS adapters motherboard based on the STM32F401VE and compatible with all **ST MEMS adapters**



Expansion Boards **X-NUCLEO-IKS02A1, X-NUCLEO-IKS4A1, X-STM32MP-MSP01**

MEMS and sensor expansion board for STM32 Nucleo and STM32MPU Disco



Small Form Factor **SensorTile.box PRO STWIN.box**

Motion MEMS and environmental sensors in a compact package for quick prototyping



IoT Discovery Board **B-U585I-IOT02A**

Sensors IoT Node with cloud connectivity to major cloud providers



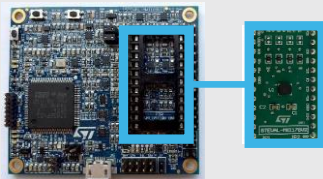


Sensors evaluation and development SW packages

MEMS-Studio

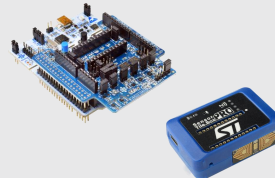
Unico-GUI

MEMS evaluation kit
software package for Linux,
Mac OSX and Windows



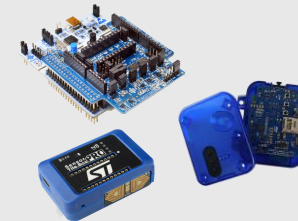
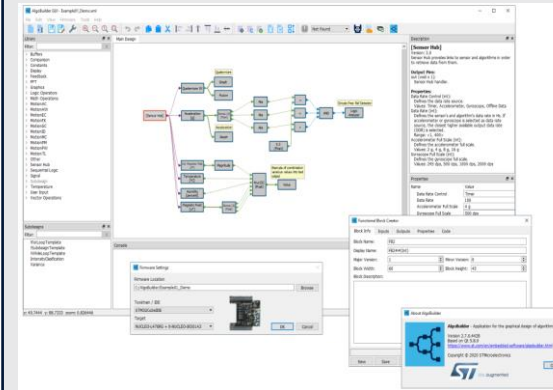
Unicleo-GUI

Graphical user interface
to configure and display
sensors data



AlgoBuilder

Application for the graphical
design and testing of
algorithms



Function Packs

FP-SNS-STBOX1
FP-ATR-BLE1
FP-IND-PREDMNT1
FP-SNS-DATALOG2

SW packages

X-CUBE-MEMS1
X-CUBE-MEMSMIC1
X-CUBE-ALGOBUILD
X-CUBE-ISPU

ISPU-TOOLCHAIN

Mobile Apps

ST BLE Sensor
ST Asset Tracking

Cloud Apps


DSH-PREDMNT
DSH-ASSETTRACKING

What's MEMS Studio?

One desktop software solution for a 360° experience of ST's entire MEMS sensor portfolio



Experience a versatile **development environment**, enabling the **evaluation and programming** of all MEMS sensors



Develop embedded **AI features**, evaluate embedded **libraries**, **analyze data**, and design **no-code algorithms**



Discover the **all-in-one solution** that includes Unico-GUI, Unicleo-GUI and AlgoBuilder

All-in-one software solution

From 3 different tools



To a single unified tool



All the functionalities of Unico-GUI, Unicleo-GUI & AlgoBuilder

Other additional features

Why MEMS Studio?

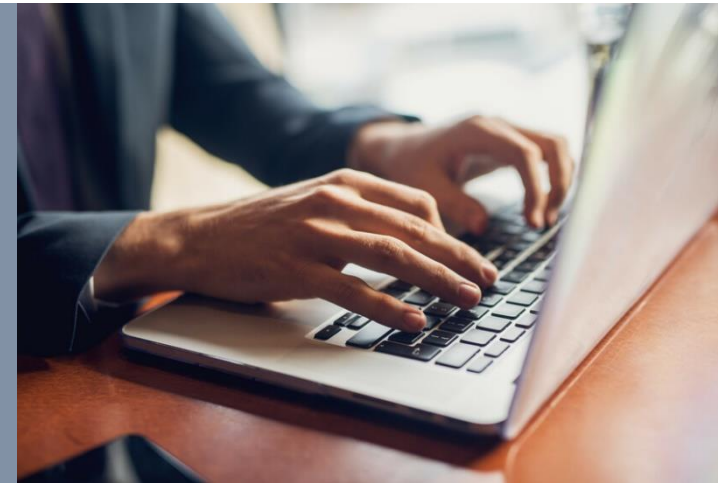


Reduced effort

Single software download
Seamless experience from
evaluation to programming
Single GUI

Scalable

Covers sensor programming,
evaluation,
and firmware generation



Improved functionalities

Runtime and offline data analysis

Wide support

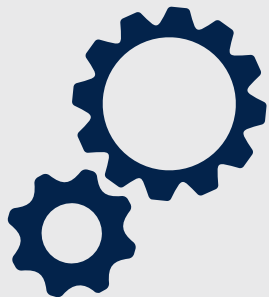
Multiplatform operating systems
(Windows, macOS, and Linux)



MEMS Studio journey

1

Sensor configuration



- Access to the full sensor register map
- Interrupt status monitoring

2

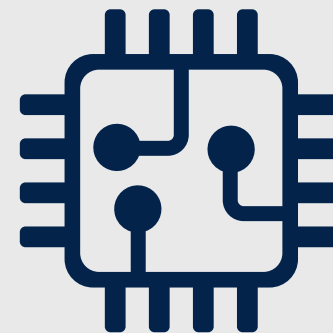
Sensor data analysis



- Visualization charts of runtime sensor data (line charts, bar graphs, 3D plots)
- Data logging
- Time & frequency domain offline data visualization, data labeling, and editing
- Fast Fourier transform (FFT) analysis
- Spectrogram analysis

3

Application development

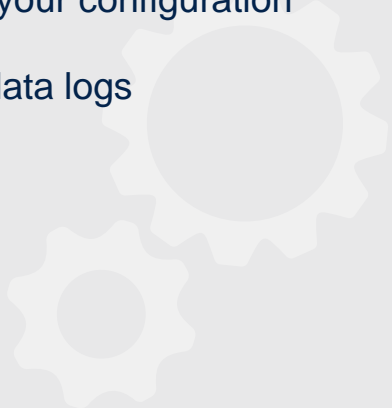


- Testing of advanced embedded features (FIFO, pedometer, free fall, ...)
- In-sensor AI & ML algorithm design and programming
- Visualization and data logging of the output of the embedded libraries
- Development of no-code algorithms for data processing in STM32 MCUs

How to get start quickly with MEMS Studio

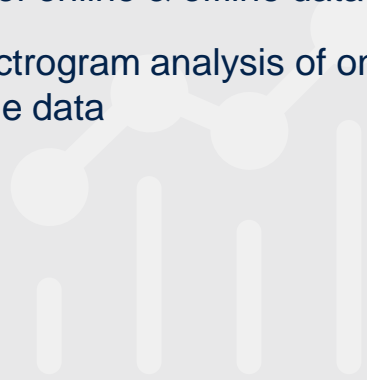
1

Sensor configuration

- ☐ **Connect** your board
 - ☐ **Configure** the sensors
 - ☐ **Access** the advanced sensor features
 - ☐ **Evaluate** your configuration
 - ☐ **Acquire** data logs
- 

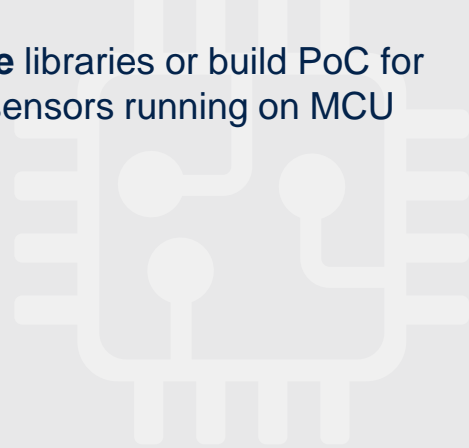
2

Sensor data analysis

- ☐ **Export** sensor data log to a .csv file
 - ☐ **Analyze the** data: visualization, labeling, preprocessing, and editing
 - ☐ **Run** fast Fourier transform (FFT) analysis of online & offline data
 - ☐ **Run** spectrogram analysis of online and offline data
- 

3

Application development

- ☐ **Generate** firmware code for your board through a graphical tool
 - ☐ **Build** the generated code and program on a target board
 - ☐ **Visualize** data on the GUI
 - ☐ **Evaluate** libraries or build PoC for MEMS sensors running on MCU
- 

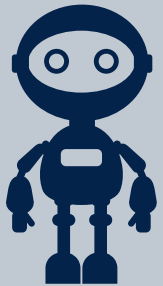
Intelligent Sensors

What is AI?

AI Development Timeline and Some Definitions

Artificial Intelligence

Early Artificial Intelligence stirs excitement



Machine Learning

Machine Learning begins to flourish



Deep Learning

Deep Learning breakthroughs drive AI boom



Any technique that enables computer to mimic **human behavior**

Subset of AI. Algorithms and methodologies that improve over time through **learning from data**

Subset of ML. Learning algorithms that derive meaning out of data, by using a hierarchy of multiple layers that **mimic the neural networks of the human brain**

1950'

1960'

1970'

1980'

1990'

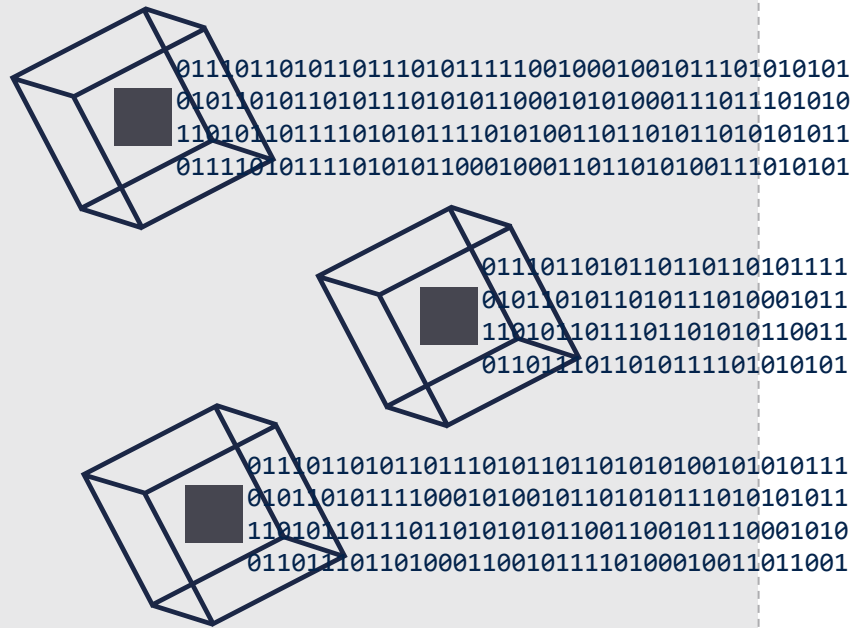
2000'

2010'

2020'



More data = more power consumption



IoT nodes with
standard sensors

Sensors embedded in more and more IoT nodes



Data to process are increasing exponentially



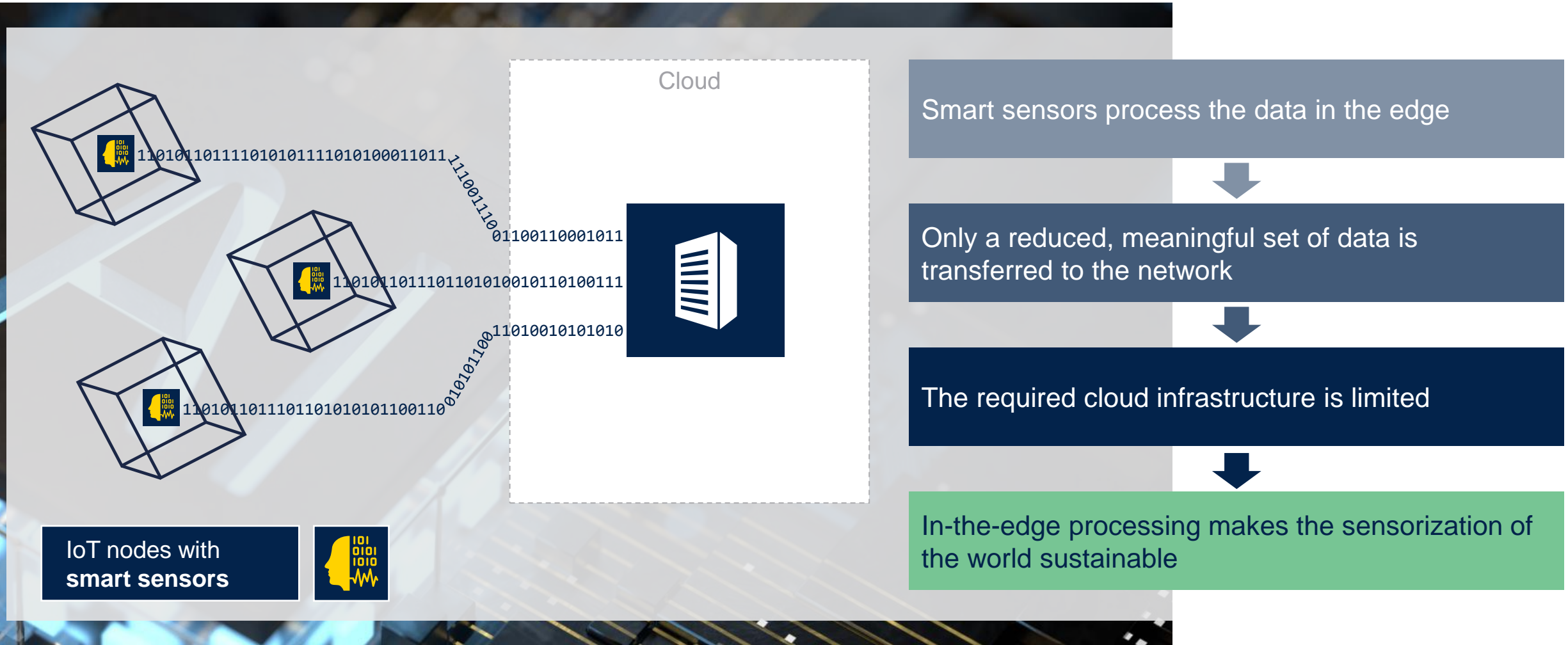
With a centralized processing approach, the
required cloud infrastructure is huge



Associated power consumption is not sustainable



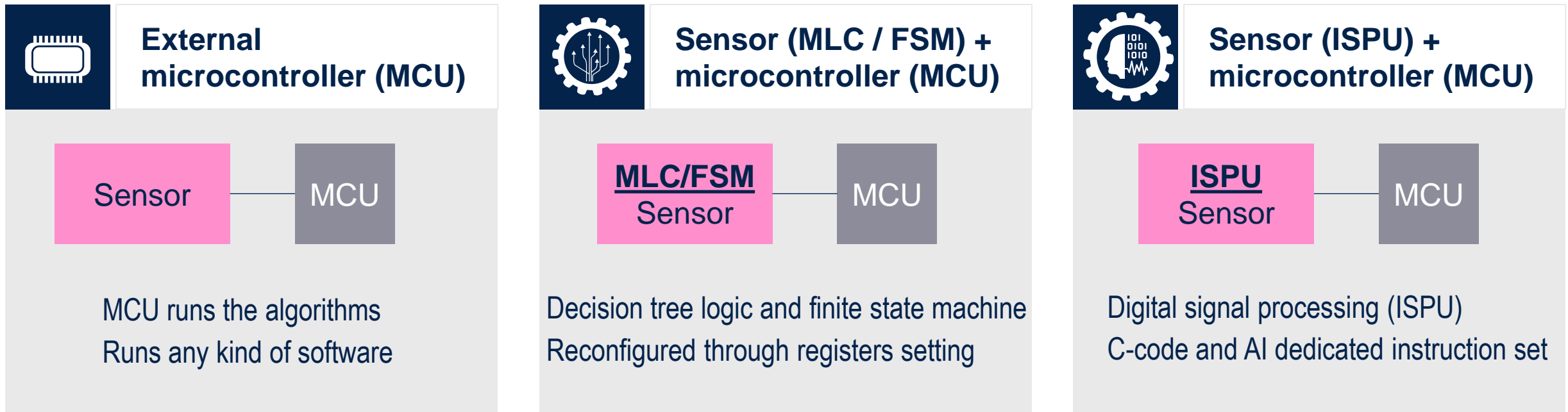
Adding intelligence to make sensorization sustainable



In-sensor processing

Optimize current consumption and latency

FSM = Finite State Machine
MLC = Machine Learning Core
ISPU = Intelligent Sensor Processing Unit
AI = Artificial Intelligence



Must consider the full system consumption, not just the single device

Why MLC and FSM?

Machine Learning Core

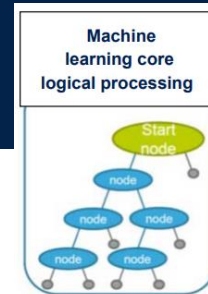
Activity Tracking



Data acquisition campaign

Engine identifies data pattern matching with user defined classes

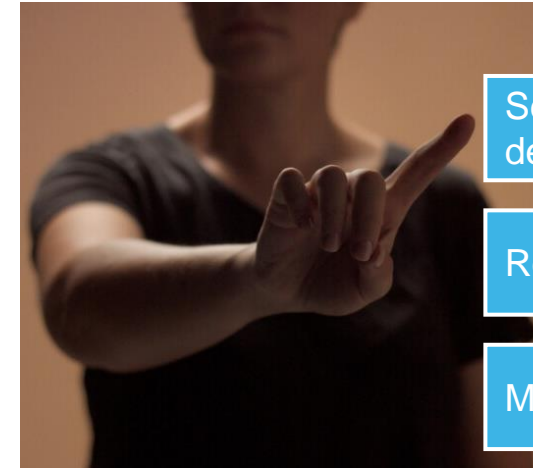
Understand scenarios based on training data



- Labeled Sensor data with features
- Machine Learning based logic
- Pattern classification using a Decision Tree*

Finite State Machine

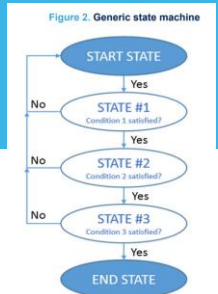
Gesture Recognition



Series of state parameters with defined transitions

Recognize gestures

Multiple FSM programs in parallel

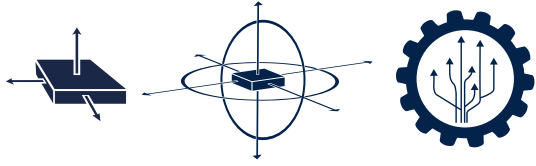


INPUT

LOGIC

OUTPUT

- Sensor Samples data
- Events/Triggers based logic using thresholds / timers
- Event detection using commands and conditions



Sensors with Machine Learning Core (and Finite State Machine)

FSM = Finite State Machine
MLC = Machine Learning Core

	Consumer	Industrial	Automotive ^{AEC-Q100}
MLC 1.0 & FSM 1.0	6-axis IMU * LSM6DSOX / LSM6DSO32X	2-axis inclinometer * IIS2ICLX	6-axis IMU * ASM330LHHX
	6-axis IMU * LSM6DSR / LSM6DSRX	6-axis IMU * ISM330DHCX	6-axis IMU * ASM330LHB
<hr/>			
MLC 2.0 & FSM 2.0	3-axis accelerometer LIS2DUX12 / LIS2DUXS12	<u>MLC 2.0 and FSM 2.0 improvements</u> <ul style="list-style-type: none">• MLC data rate increase (spike detection)• Processing of high-resolution sensors (i.e pressure sensor)• AI data directly stored in FIFO and exportable• Recursive sliding windows (short time events capture)• Adaptive Self Configuration (ASC)	
	6-axis IMU * LSM6DSV16X / LSM6DSV16BX		

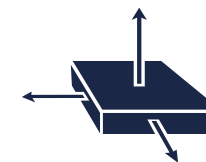
*sensor hub (connect ext. sensors)



LSM6DSV16X inertial sensor

Gym activity recognition

Machine learning core (MLC) for gym activity recognition
Wearable device (smartwatch / wristband)



accelerometer
data



No activity



Bicep curls



Lateral raises



Squats

GitHub repository



[LINK](#)

GitHub

MLC

accelerometer

Ultra low current consumption

6 μ A

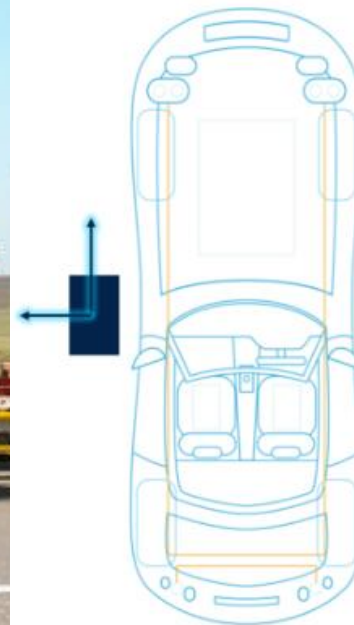
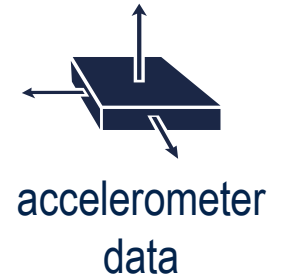
10.5 μ A
(@30Hz)



ASM330LHHX inertial sensor

Vehicle monitoring

Machine learning core (MLC) for tow detection
Sensor placed on the vehicle



**Forward/backward
lift with flatbed**

**Front/back
wheel lift**

MLC

accelerometer

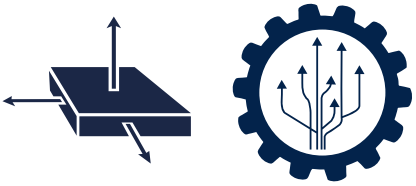
GitHub repository



STEVAL-MK1109V3
ProfiMEMS motherboard
+
DIL24 adapter w/ASM330LHHX

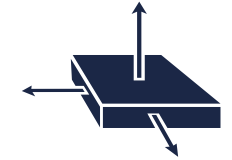


Unico
Graphical User Interface



LIS2DUXS12 inertial sensor Asset tracking

**Combined Machine Learning Core (MLC) and
Finite State Machine (FSM) capabilities**



accelerometer
data

Detect and track the various
states of a package

- **In motion**
- **Shaken**
- **Stationary - Upright**
- **Stationary - Not upright**

Detect events

- **Impact**
- **Free-fall**

GitHub repository



MLC + FSM

accelerometer

Ultra low current consumption

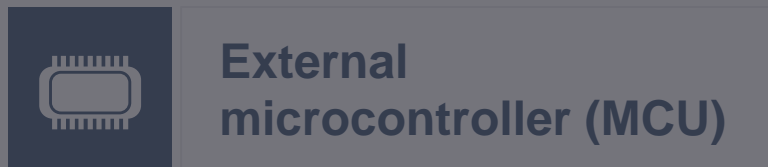
14.5 μ A

**5.4 μ A
(@25Hz)**

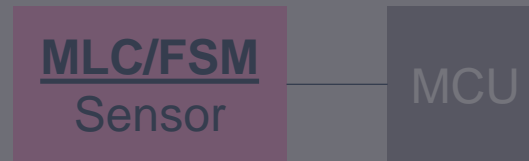
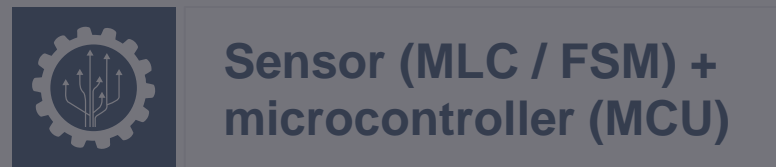
In-sensor processing with ISPU

Optimize current consumption and latency

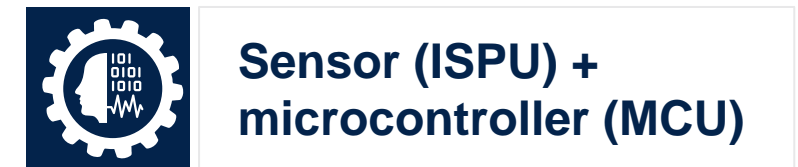
FSM = Finite State Machine
MLC = Machine Learning Core
ISPU = Intelligent Sensor Processing Unit
AI = Artificial Intelligence



MCU runs the algorithms
Runs any kind of software

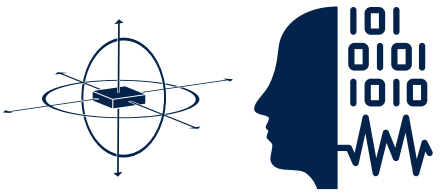


Decision tree logic and finite state machine
Reconfigured through registers setting



Digital signal processing (ISPU)
C-code and AI dedicated instruction set

Must consider the full system consumption, not just the single device

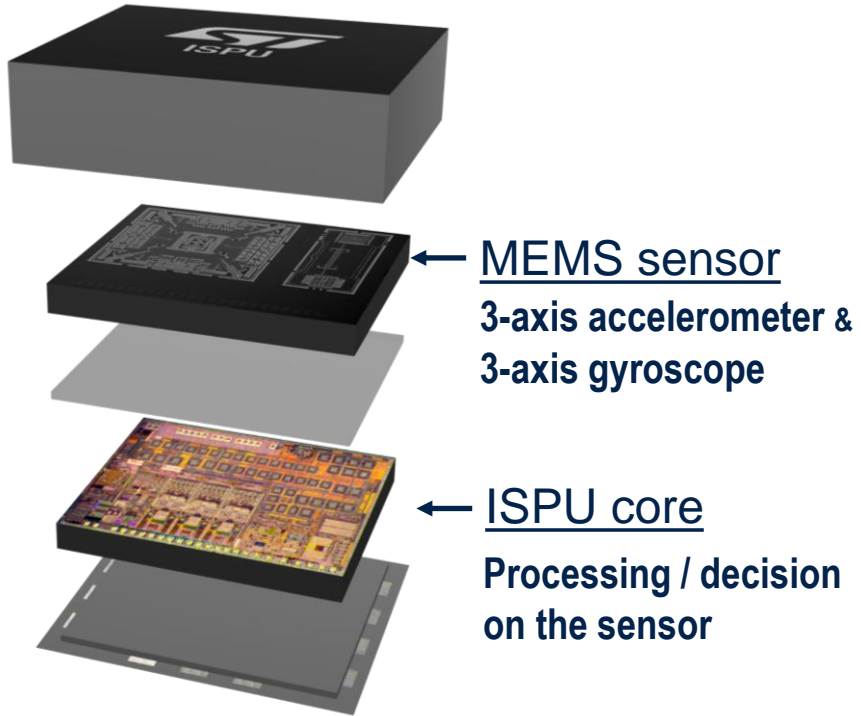


What's inside the ISPU

Sensors with intelligent sensor processing unit (ISPU)



2.5 x 3.0 x 0.83 mm
14 pin LGA package



Ultra-low current consumption



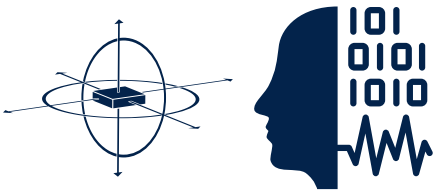
Low latency



Easily programmable

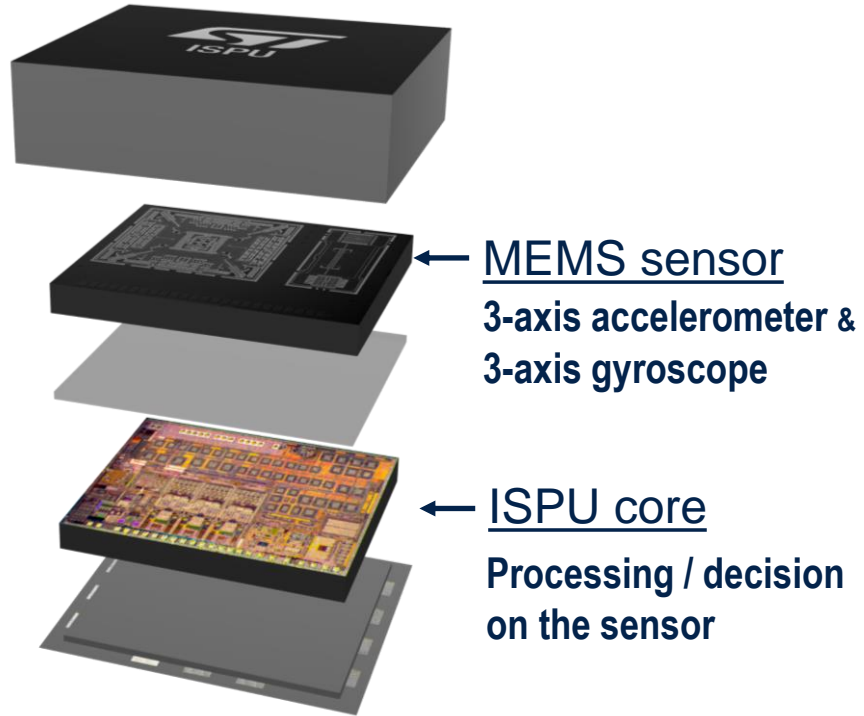
- commercial AI tools
- open-source models
- C language

NANOEDGE AI
STUDIO 



What's inside the ISPU

Sensors with intelligent sensor processing unit (ISPU)



2.5 x 3.0 x 0.83 mm
14 pin LGA package

Small Area: enhanced 32-bit RISC Harvard architecture

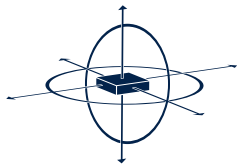
Full Precision: Floating Point Unit

Fast interrupt response: 4 cycles vs 15 (Cortex®)

RAM based: 40 kB (program + execution)

Binary Neural Network convolution accelerator: patented by ST

Frequency / Output data rate: 5MHz / 3.33kHz – 10 MHz / 6.66kHz



Sensors with Intelligent Sensor Processing Unit

Consumer

6-axis IMU *
LSM6DSO16IS

Industrial

6-axis IMU *
ISM330IS



Sensor (ISPU) +
microcontroller (MCU)

ISPU
Sensor

MCU

Benefits



Optimized for
inertial data



Integrated computing
cell, MCU in standby
with sensor wakeup



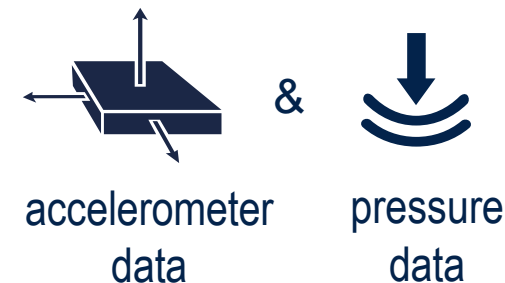
Local ISPU sends
pre-processed data



LSM6DSO16IS inertial sensor

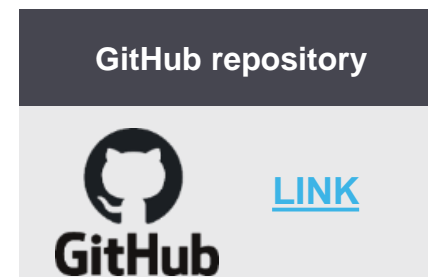
Man-down detection

Intelligent sensor processing unit (ISPU)
Embedded DSP (digital signal processing) with sensor fusion



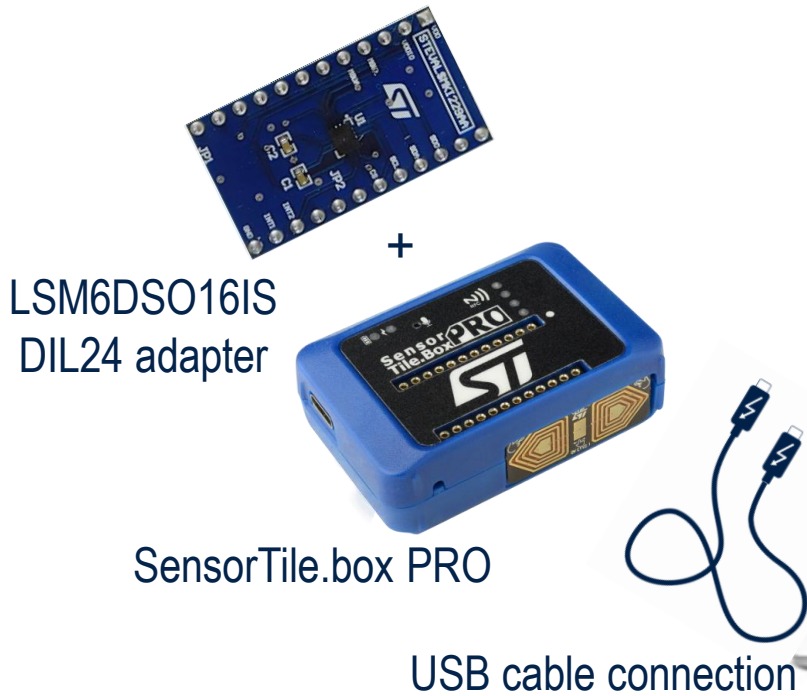
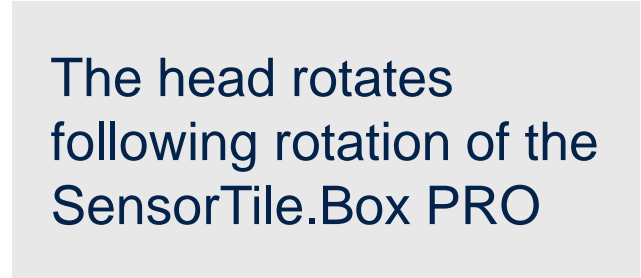
Man-down

ISPU





Sensors with intelligent sensor processing unit (ISPU)



ISPU fusion

Ultra low current consumption

226μA

180μA
(@104Hz)

490μA
(@104Hz)

accelerometer

gyroscope

Complete Ecosystem

All building blocks
for devices

Lower barriers for
developers getting started

Lower barriers from
prototyping to first product

Enable product & service
commercialization

Microcontrollers



Secure solutions



Sensors & actuators



Connectivity solutions



Power management



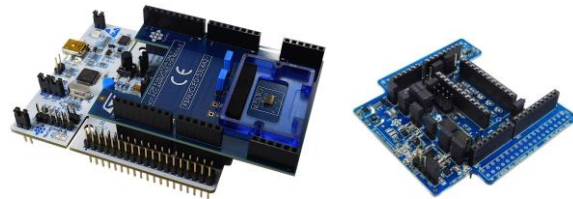
Motor control



Analog components



Stackable boards
& modular SW



STM32 Nucleo Development
& Expansion Boards

Form-factor boards



Pre-integrated software
for vertical applications



Smart Things



Smart Home
& City



Smart Industry

Development ecosystem



Code generators



Prototyping
software



Development
environments



Artificial
Intelligence
toolbox



Debug
solutions

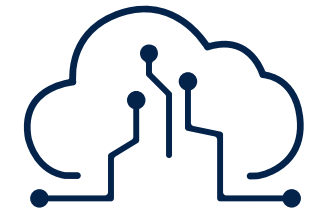


Simulation
and analysis tools



On-line
design tools

Native Integration with Cloud



Partner Program and ST community



ST has sensors and tools to help you add intelligence to the edge



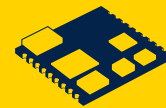
Smart Sensors for edge processing



Ultra low power consumption



Advanced features – MLC, FSM, sensor fusion



Small form factor

Machine Learning solutions in sensors: Ecosystem

A complete suite to create ML applications in sensors



Programming with **ST Tools** and **ST Partners**



Getting start with **ST development kit**



st.com/mlc



Examples for motion recognition and context recognition

GitHub



Videos, training material, in products campaign available



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



Resources for MEMS Studio

One user-friendly tool for all sensors and ST ecosystem boards



Get the **tool** now!

Download



Discover the [databrief](#)



Read our [user manual](#)



[ST Edge AI Suite](#) - set of tools for integrating AI features in embedded systems

Our technology starts with You



Find out more at www.st.com/MEMS-Studio

© STMicroelectronics - All rights reserved.

ST logo is a trademark or a registered trademark of STMicroelectronics International NV or its affiliates in the EU and/or other countries.

For additional information about ST trademarks, please refer to www.st.com/trademarks.

All other product or service names are the property of their respective owners.



life.augmented