



Static and dynamic inclinometers for Industrial IoT applications

Inclinometer Working Principle



Static Inclinometer: IIS2ICLX



Dynamic Inclinometer: ISM330DHCX



Machine Learning Core





Tilt measurement with an accelerometer

- Tilt measurement with an accelerometer is based on **projection of the Gravity vector** on its sensing axes
- An accelerometer does **not** measure **only the gravitational acceleration**, but any acceleration caused for example by:
 - Constant acceleration of the device
 - Centripetal acceleration due to a rotation of the device
 - Vibrations, for example due to a running machine or engine nearby
- Such accelerations **cannot be easily differentiated** from gravitational acceleration and can introduce measurement errors
- Therefore, accurate results require **static or quasi-static conditions**

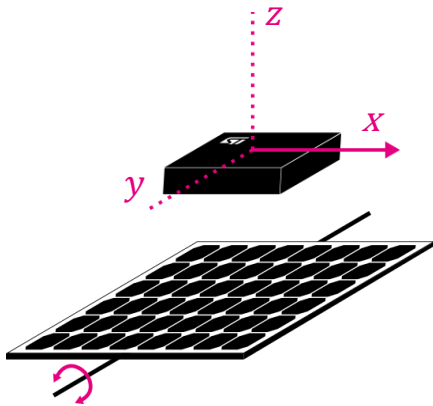




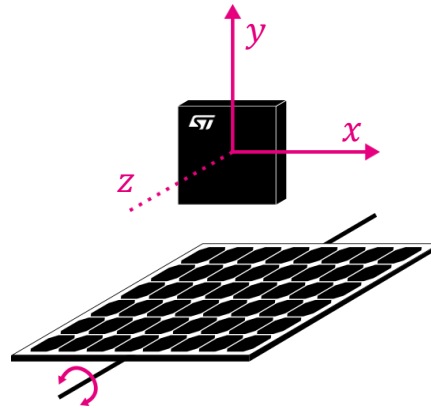
Industrial application examples

Inclinometer application examples with possible sensor placements:

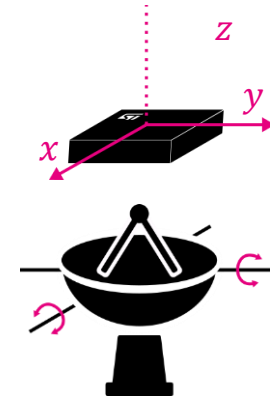
1. Tilt sensing of a solar panel that is rotated around a single axis
2. Dual-axis tilt sensing of an antenna



1-axis inclinometer



2-axis inclinometer
vertical placement



2-axis inclinometer
horizontal placement



Static inclinometers in industrial applications

Antenna Leveling



Antenna pointing,
platform leveling
and stabilization

Robotics and IIoT



Robotics and
Industrial
automation

Inclinometers for industrial vehicles



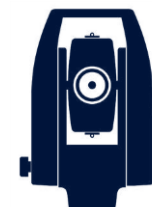
High accuracy
inclinometers for
industrial vehicles,
forklift,
construction
machines

Equipment Installation & monitoring



Installation and
monitoring of
equipment, tracker
for solar panels

Leveling Instruments



Precise leveling
instruments

Structural Health Monitoring



Building and
infrastructure
condition
monitoring
(inclination and low
frequency
vibration)





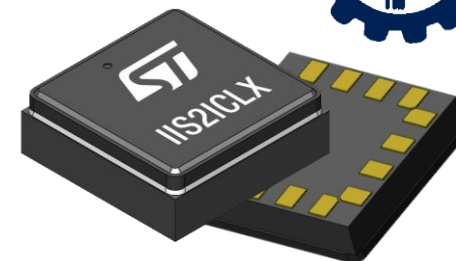
IIS2ICLX

High-accuracy 2-axis digital inclinometer

High-accuracy, high-resolution, low-power, 2-axis digital inclinometer with embedded Machine Learning Core



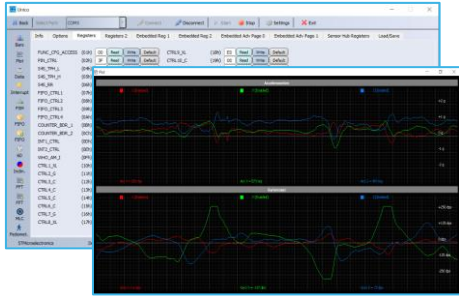
- **2-axis**, digital inclinometer, low power
- Top notch performance: **resolution, accuracy, stability** over temperature and time
 - Accuracy better than 0.5° over full temp. range and over time
- **Programmable Bandwidth** (-3dB) up to 260Hz
- **Ultra-low noise** (15 $\mu\text{g}/\sqrt{\text{Hz}}$)
- **Offset** change vs Temp <0.075 mg/°C
- Programmable **Machine Learning Core & Finite State Machine** to integrate AI algorithms and reduce power consumption at system level
- Extended operating temperature range: from **-40 to +105 °C**
- No Calibration required – ST is testing and calibrating at Final Test
- **ST Advantage: Accuracy, Resolution, High Stability & Repeatability**



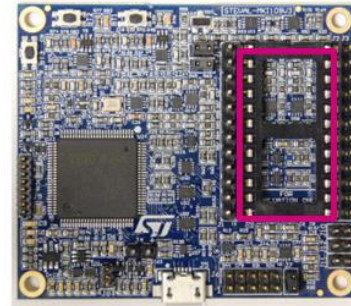
Ceramic Cavity
LGA 5x5x1.7 16L



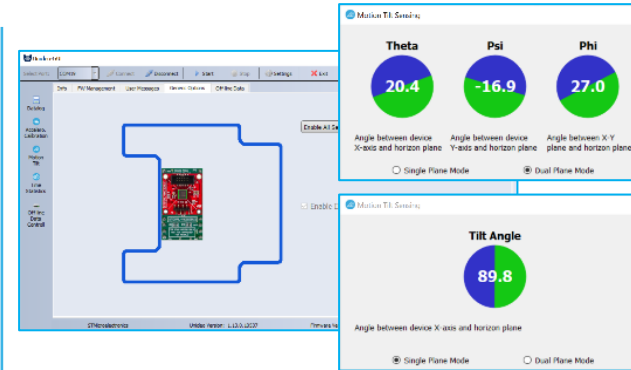
Development tools for the IIS2ICLX



PC Application
Unico-GUI



**Professional MEMS
motherboard**
STEVAL-MKI109V3



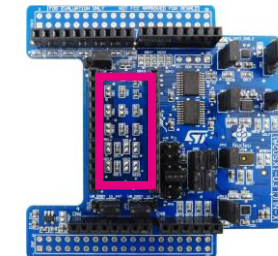
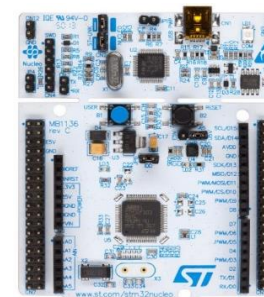
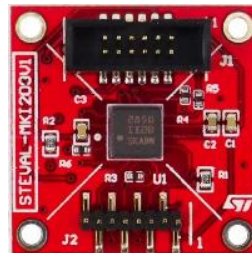
**PC Application and
Software package**
Unicleo-GUI
X-CUBE-MEMS1



DIL24 adapter board
STEVAL-MKI209V1K (IIS2ICLX)



DIL24 adapter board
STEVAL-MKI209V1K (IIS2ICLX)

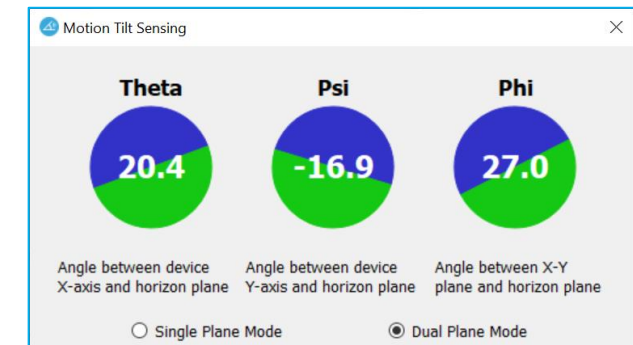
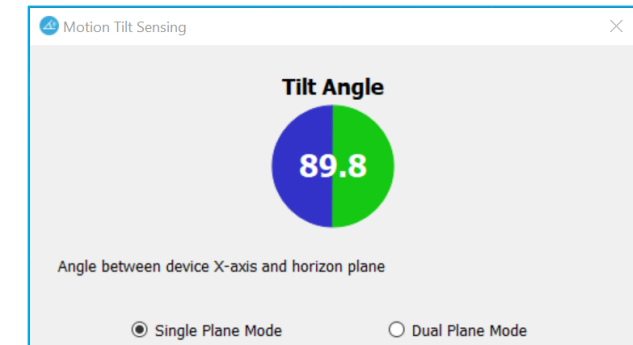
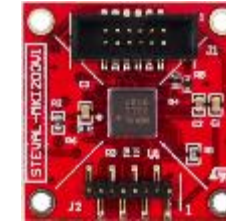


**STM32 NUCLEO &
Industrial Sensor
expansion board**
e.g., NUCLE-F401RE
X-NUCLEO-IKS02A1



Tilt Measurement Library for IIS2ICLX MotionTL2

- **MotionTL2** is a dedicated library for 2-axis accelerometers that provides real-time information about tilt angles of the user device in single or dual plane mode
- The MotionTL2 sensor fusion library features:
 - Calculation of angles according to the desired mode
 - Configuration of knobs to mitigate vibration noise
- The MotionTL2 library is part of the **X-CUBE-MEMS1** software package
 - Sample implementation is available for the STEVAL-MKI209V1K (DIL24 adapter board with the IIS2ICLX)
 - The implementation utilizes also MotionAC2 for calibration
- Available for ARM Cortex-M0+, M3, M4 and M7 architectures
- User Manual: UM2775



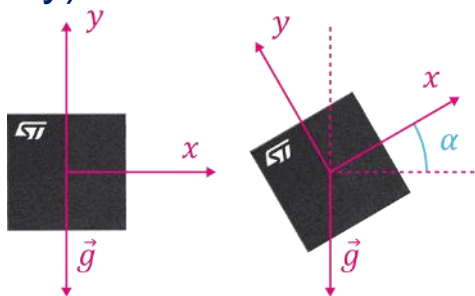


Tilt Measurement Library for 2-axis AXLs

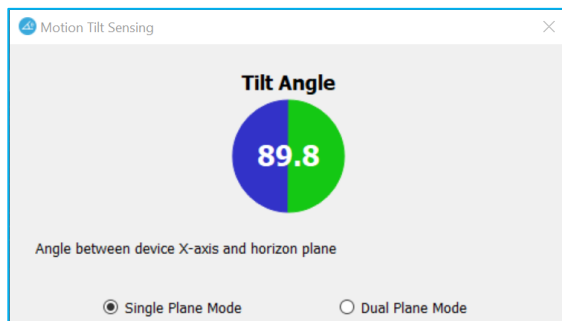
Measurement modes

Single plane mode

- Single plane mode provides the angle of X axis with respect the horizontal plane
- The reference position is when the **X axis is in horizontal plane and Y axis is pointing up** (towards the sky)

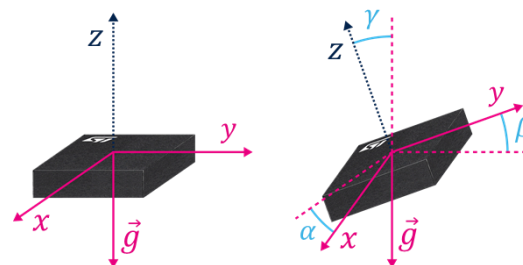


Range:
[-180°, +180°]

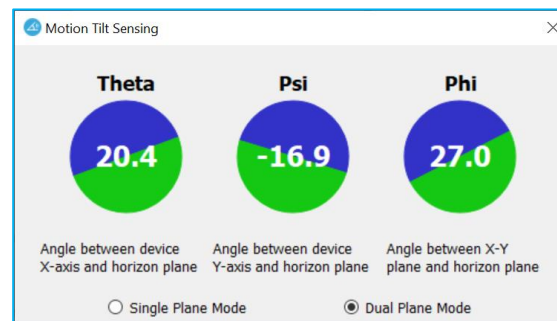


Dual plane mode

- This mode provides angles between the horizontal plane, X-axis (α) and Y-axis (β), and angle between vertical axis and gravity vector (γ)
- The reference position is when the **X and Y axis are in the horizontal plane**



Range:
[-90°, +90°]





Dynamic inclinometers in industrial applications

Industrial Vehicles



Inclinometers for
industrial vehicles.
Mining, cranes

Robotics



Robotics

Autonomous Vehicles



Inclinometers for
autonomous
vehicles

Equipment Installation & monitoring



Antenna pointing
and stabilization,
platform leveling
and stabilization





ISM330DHCX

6-axis IMU with Machine Learning Core

Best-in-class accuracy 6-axis IMU with Machine Learning Core



High Accuracy, Stability and linearity over temperature and time

- Gyro Offset vs T ± 0.005 dps/°C (typ)
- Gyro Bias Instability 3°/hr (typ)
- Rate Noise Density 5 mdps/ $\sqrt{\text{Hz}}$ (typ)
- Axel Noise Density 60 $\mu\text{g}/\sqrt{\text{Hz}}$ (typ) – ODR up to 6.6kHz

Programmability & digital features

- Programmable Machine Learning Core & Finite State Machines to integrate AI algorithms
- 9 kB Embedded FIFO
- Sensor Hub

Configurability

- Angular rate range: from ± 125 dps up to ± 4000 dps
- Axel Full Scale: from ± 2 g up to ± 16 g
- Low power and high performance modes

Extended operating temperature range from -40 to +105 °C

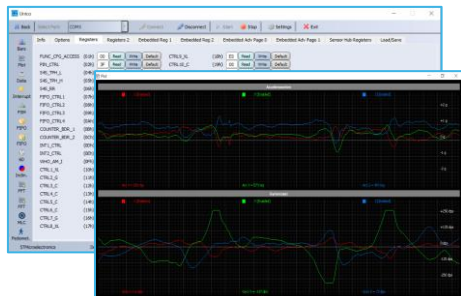


LGA 14L
2.5x3x0.86 mm

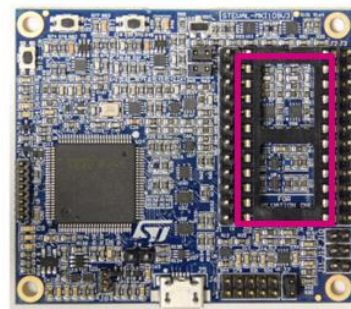




Development tools for the ISM330DHCX



PC Application
Unico-GUI



**Professional MEMS
motherboard**
STEVAL-MKI109V3

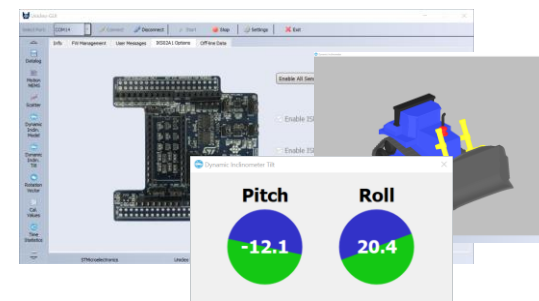
ISM330DHCX's DIL24 adapter boards



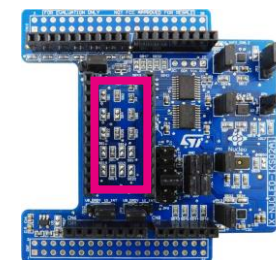
STEVAL-MKI207V1



STEVAL-MKI210V1K



**PC Application and
Software package**
Unicleo-GUI
X-CUBE-MEMS1



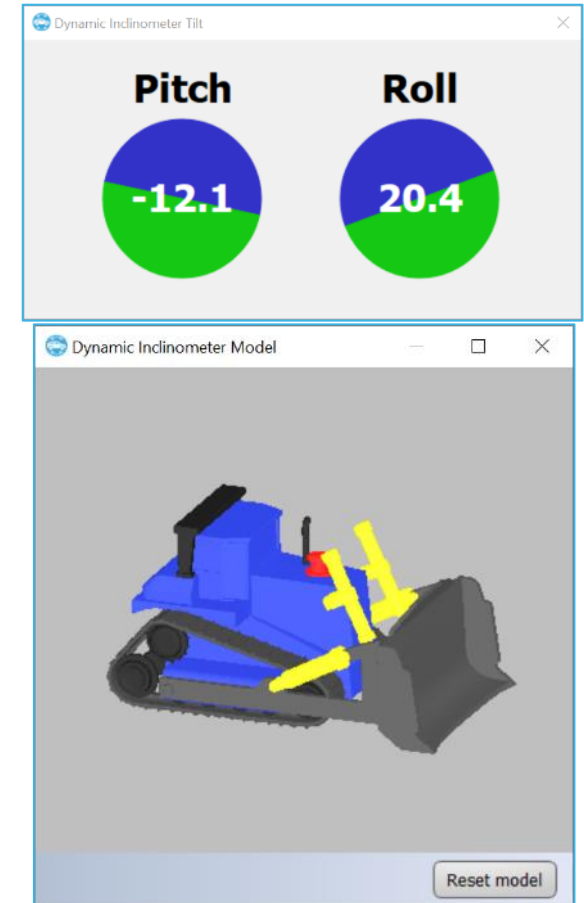
**STM32 NUCLEO &
Industrial Sensor
expansion board**
e.g., NUCLEO-F401RE
X-NUCLEO-IKS02A1



Dynamic Inclinometer Library for ISM330DHCX MotionDI

- **MotionDI** is a library that provides real-time motion **sensor fusion and tilt information** - accurate estimation of **device orientation even in presence of vibrations and motion** using Kalman filtering
- The **MotionDI** sensor fusion library features:
 - Real-time 6-axis motion-sensor **data fusion** (accelerometer, gyroscope)
 - Computation of **rotation vector, quaternions, gravity and linear acceleration data**
 - **Accelerometer and Gyroscope calibration**
- Available for ARM Cortex-M3, M4 and M7 architectures
- Requires 6-axis IMU (ISM330DHCX)
- The **MotionDI** library is part of the [X-CUBE-MEMS1](#) software package
 - An example implementation is available for following Nucleo boards:

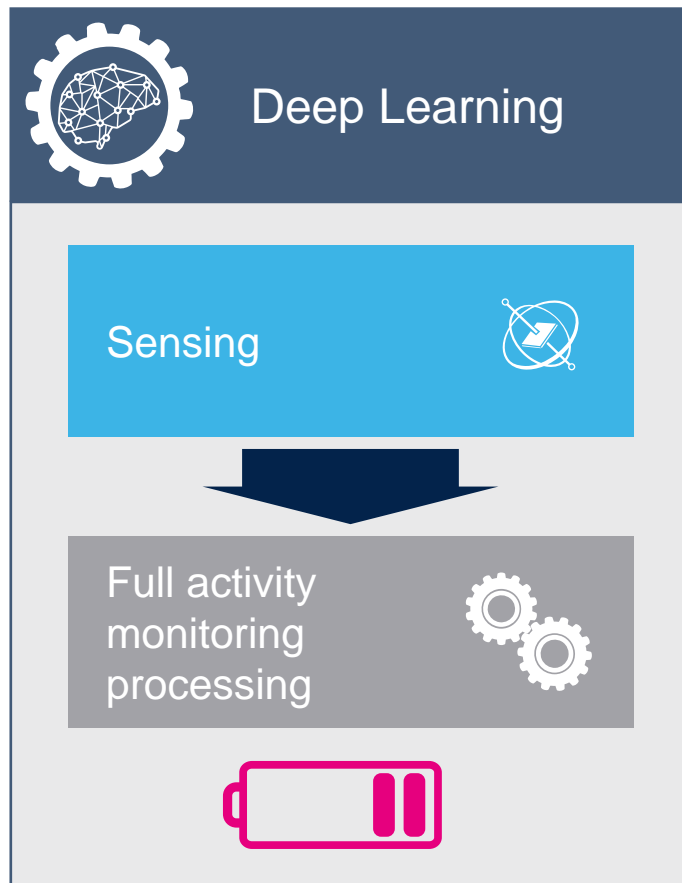
STM32 development board	MEMS & Sensors expansion board
NUCLEO-F401RE	X-NUCLEO-IKS01A2
NUCLEO-L476RG	X-NUCLEO-IKS01A3
NUCLEO-L152RE	X-NUCLEO-IKS02A1



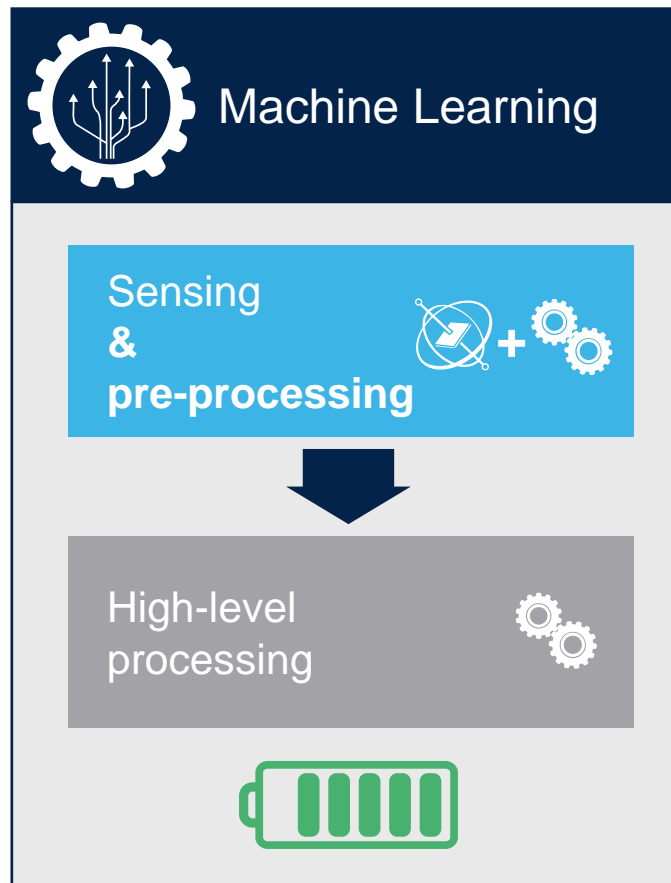


From low power sensor to low power system

Machine Learning Core (MLC) for real edge computing enables high system flexibility

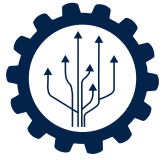


Power
optimization at
system level



- Higher computation power
- Lower power consumption
- Cost optimized solution

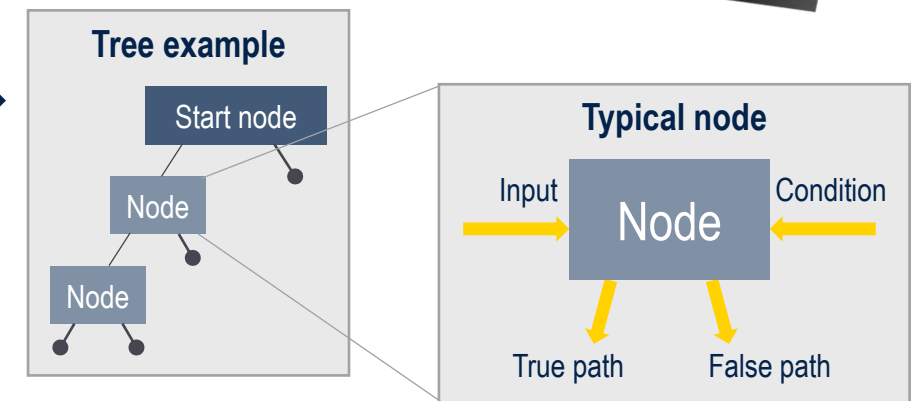
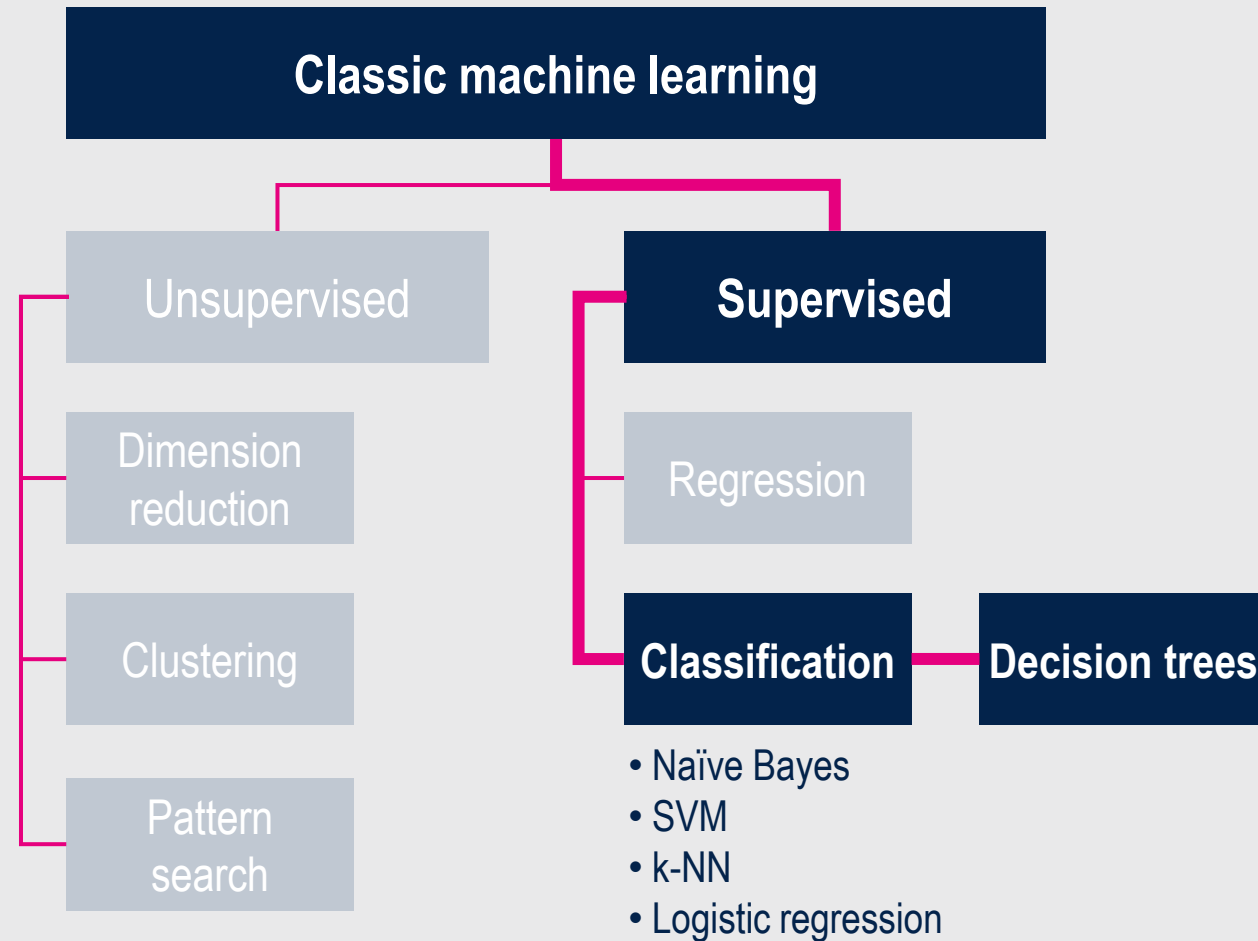
This is the added value!

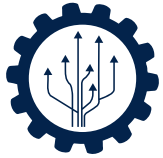


Machine Learning embedded in ST sensors

MLC is an in-sensor engine embedded in the latest products:

- 6x IMUs
- Inclinometer





Explore MLC resources and examples

- Machine Learning Core landing page is the reference product resources and ML introduction to users:



<https://www.st.com/MLC>



- Decision tree examples are available online at the dedicated **GitHub project for Machine Learning Core**



https://github.com/STMicroelectronics/STMems_Machine_Learning_Core

