



life.augmented

The background of the slide is a photograph of a suspension bridge and a city skyline at night. The bridge is on the left, and the city skyline is in the center. The sky is dark blue with some clouds, and the water in the foreground is calm. The city lights are reflected in the water.

In-sensor monitoring with intelligent MEMS sensors

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Agenda

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Industrial applications where smart sensors make the difference

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How one IMU can solve many technical challenges

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Demo with ISPU tools

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A customer testimonial experience with an ISPU sensor

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Conclusion & takeaways

Industrial applications where smart sensors make the difference

Vibration and inclination: how to do a better job?

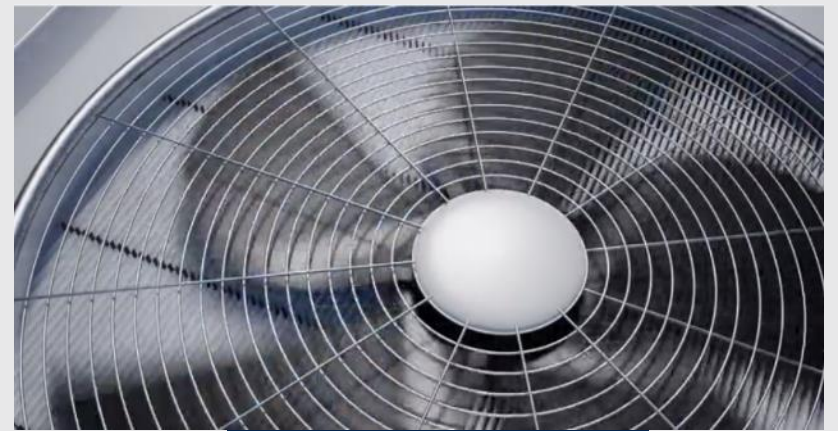
Monitoring is the first step to understand when something is not working properly



Bridges



Buildings



Motors/Fans

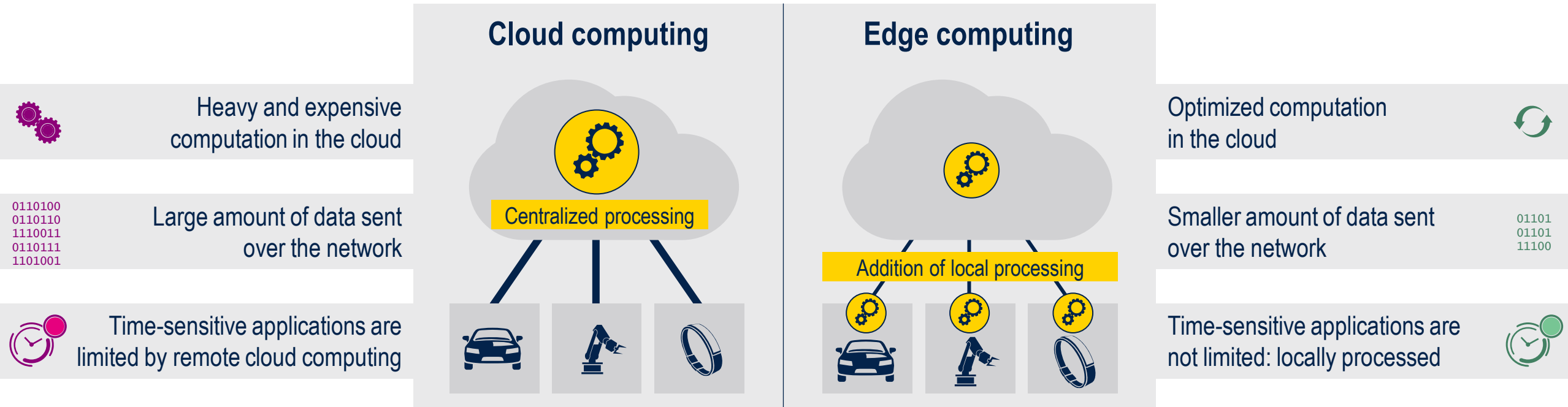
IoT nodes for condition based-monitoring:

34% CAGR ('23-26)*

from 111M in '23 to 279M in '26

A step forward for industrial battery-operated applications

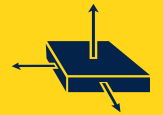
Move from Cloud Computing to Edge Computing now!



Which algorithms for inclination and vibration monitoring?



Self calibration



Sensor Fusion



**Sliding Discrete
Fourier Transform**

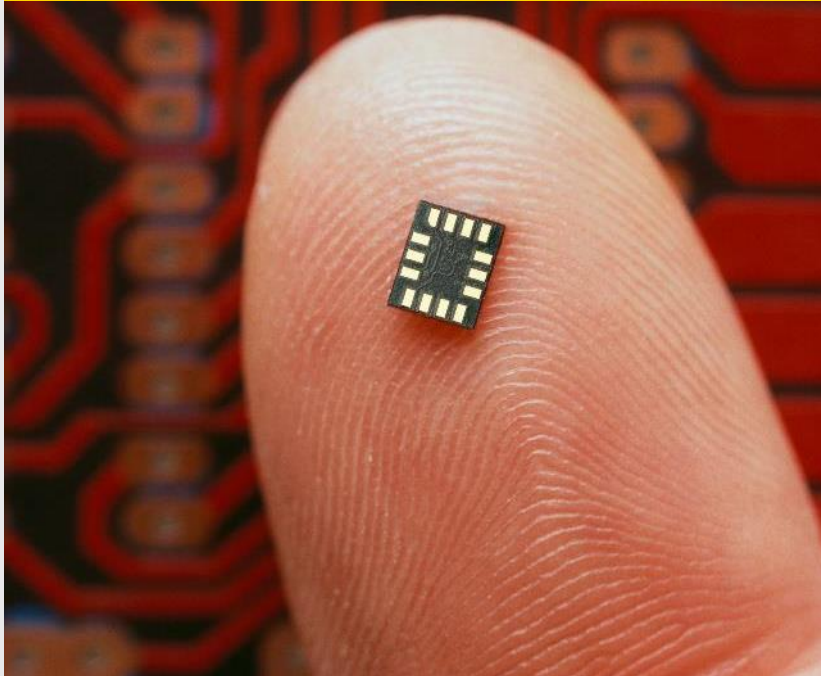


How one IMU can solve many technical challenges

One ST smart sensor for continuous monitoring

A smart sensor for monitoring in industrial applications

Intelligent Sensor Processing Unit



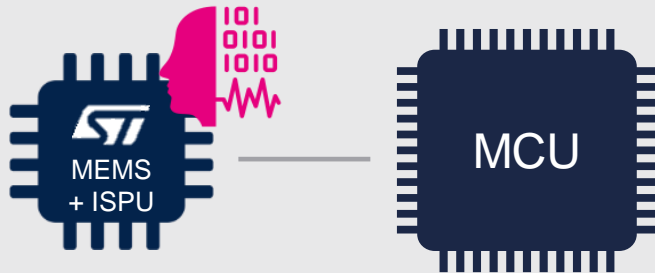


Integrating brains into sensors



ISPU

Intelligent Sensor Processing Unit



ISPU integrated in the sensor ASIC



An **ultra-low power, high-performance programmable core**



Processes data from internal (accelerometer, gyroscope, temperature) **& external sensors**



ISPU toolchain allows developers to program in **C language**



Intelligent Sensor Processing Unit (ISPU)

DSP for real-time processing and Artificial Intelligence

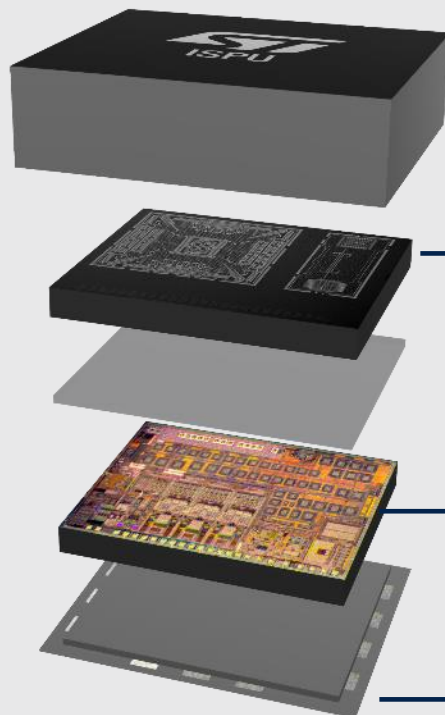
Raw data from MEMS sensor



ISPU locally process
data in a few μ W



Only meaningful
processed data



MEMS Sensor: 3 axis accelerometer &
3 axis gyroscope

Sensor hub to collect data from additional
external sensors (up to 4)

ISPU core

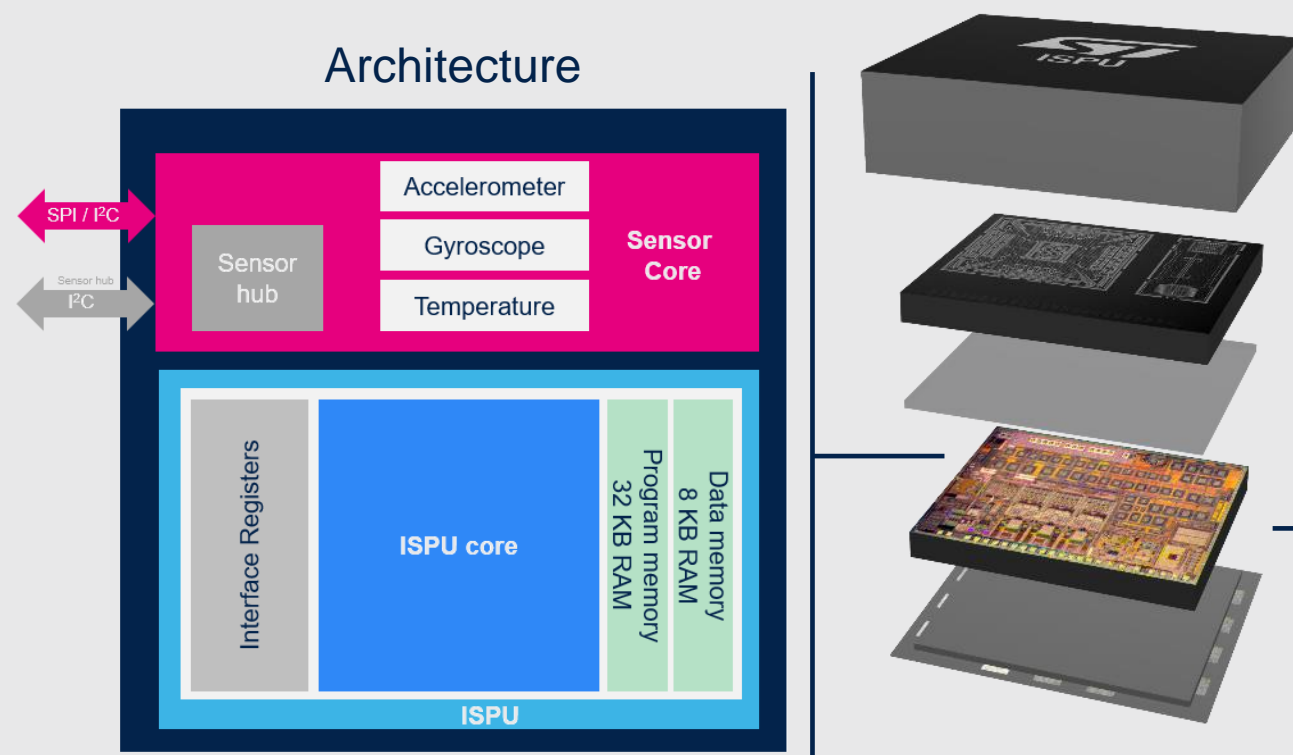
Standard package: 2.5 x 3 mm



Intelligent Sensor Processing Unit (ISPU)

DSP for real-time processing and Artificial Intelligence

Architecture



Small Area: enhanced 32-bit RISC Harvard architecture in 8 kilogates

RAM based: 32 KB program + 8 KB data

Full Precision: Floating Point Unit

Binary Neural Network convolution accelerator: patented by ST

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

Frequency: 5 MHz / 10 MHz

ODR max: 6.66 kHz



A new way to approach the Industry 5.0

AI in the edge with ultralow power 6-axis IMU for industrial market



Higher **detection accuracy**, always on monitoring in **anomaly detection** applications

- Home alarms/Robotics
- Structural monitoring
- Condition monitoring

A **completely new level of capabilities** and **detection accuracy** in **asset tracking** applications



ISPU benefits



Ultra-low power consumption

- Efficiency of the embedded DSP (digital signal processing)
- Very low data exchange with external microcontroller



Ultra Low latency

- Processing / decision taken directly in the sensor



ISPU-toolchain

- Available to implement any C-code algorithm



Data Privacy & security

- Sensor data are locally processed and not provided outside



Integration / Miniaturization

- MEMS mixed-signal state-of-the-art technology node
- No special purpose package

Fully flexible solution

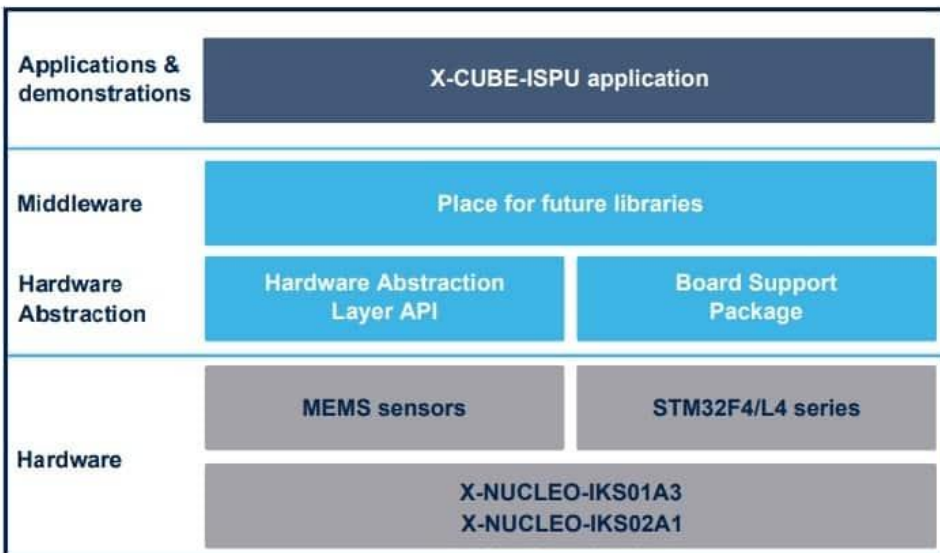
ISPU toolchain (C compiler)



CLI / IDE – AlgoBuilder / Unicleo-GUI

X-CUBE-ISPU

It includes libraries, source code examples and templates



Libraries

Can be used as building blocks for final application

Calibration algorithm
Sensor fusion
Wrist activity detection
Man down
Wrist tilt

Examples

Modify & rebuild examples
See source C code
Review sensor config.

ISPU project folder
output folder:
.ucf, .h, .json

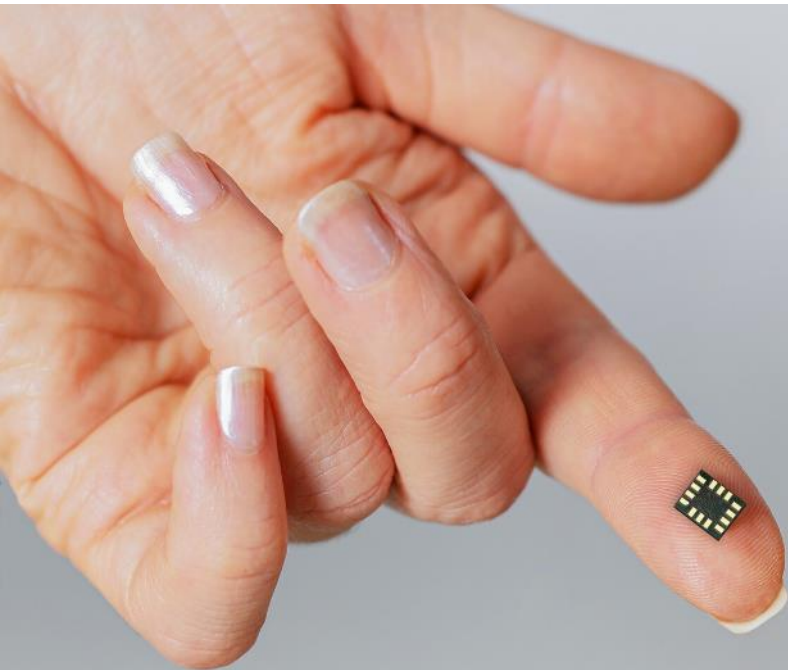
Template

Write your own C code
Configure the sensor
Make the .ucf/.h

.json file can be created from a .json file example

ISPU for inclination and vibration monitoring: the ingredients

Combines in-the-edge processing with ready-to-go- algorithms



ISPU IMU MEMS sensor

- Accelerometer self-calibration
- Sensor fusion
- Sliding discrete Fourier transform (SDFT)

Hardware

- X-NUCLEO-F401RE
- X-NUCLEO-IKS02A1
- STEVAL-MKI230KA

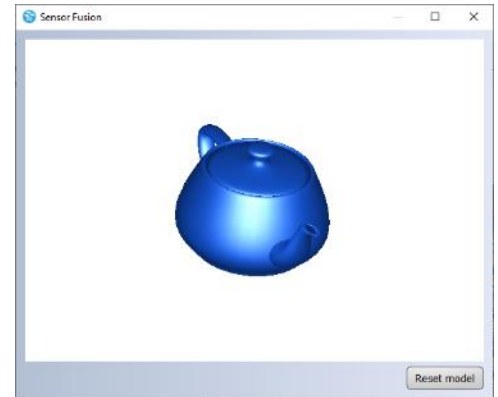
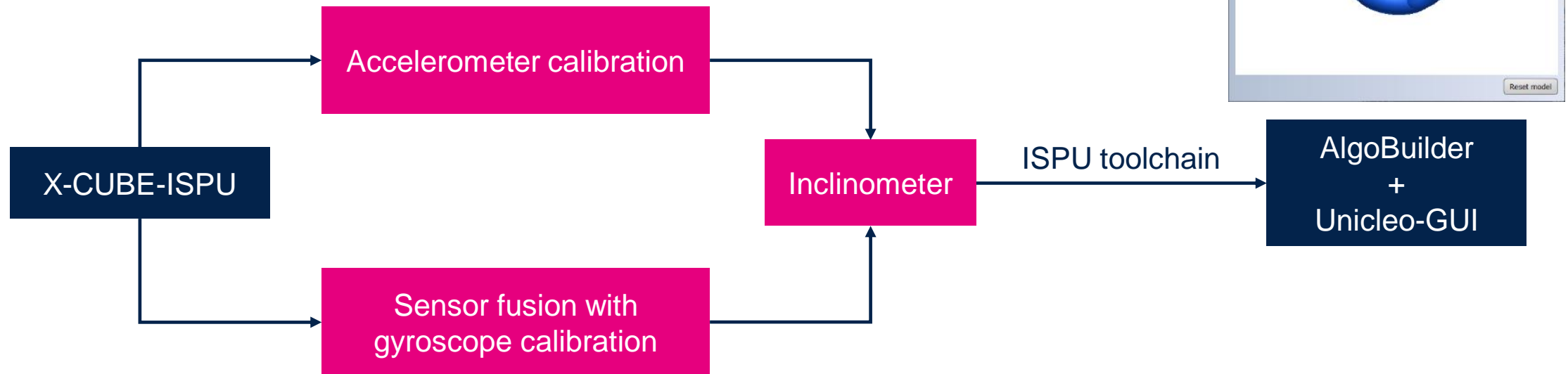
Software

- ISPU GitHub repository
- X-CUBE-ISPU
- STM32CubeIDE with ISPU toolchain
- AlgoBuilder
- Unicleo-GUI

Demo with ISPU tools

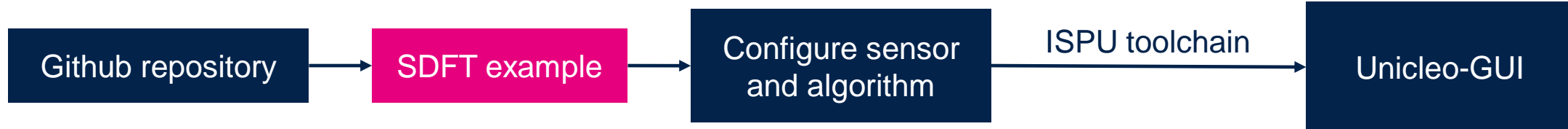
Inclinometer

Detect accurate device tilt for industrial applications



Vibration monitoring

Monitor vibrations in the frequency domain with SDFT



ISPU algorithm	
Elapsed Time [us]	732
ISPU values	
sample	1.00943
DFT_mag[0]	1.00875
DFT_mag[1]	9.59382e-5
DFT_mag[2]	0.000139352
DFT_mag[3]	0.000118667
DFT_mag[4]	0.000264159
DFT_mag[5]	0.000297722
DFT_mag[6]	0.000273753
DFT_mag[7]	0.000120362
DFT_mag[8]	0.000264681
DFT_mag[9]	0.000135759
DFT_mag[10]	3.00524e-5
DFT_mag[11]	0.000194149
DFT_mag[12]	0.000122796
DFT_mag[13]	1.87617e-5

A customer testimonial experience with an ISPU sensor

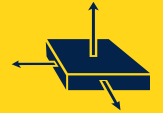
Conclusion & takeaways

Inclination and vibration monitoring in just few μA



$\sim 20\mu\text{A}^*$

Self calibration



$\sim 230\mu\text{A}^{**}$

Sensor Fusion



$\sim 15\mu\text{A}^{***}$

**Sliding Discrete
Fourier Transform**



* @ ODR = 52Hz

** @ ODR = 104Hz

*** @ ODR = 26 Hz with 26 samples window

Takeaways

MEMS sensors with ISPU are a reality

ISPU enables vibration and inclination monitoring

ISPU ecosystem saves effort and reduces time to market

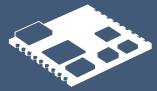
A complete suite to create your condition-based monitoring solution



st.com/ISPU



[X-CUBE-ISPU](#)



Getting started with [Intelligent Sensor Processing Unit](#)



[GitHub](#): enjoy the ready examples



[ST MEMS & Sensors community](#)

Our technology starts with You



Find out more at www.st.com/ispu

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