



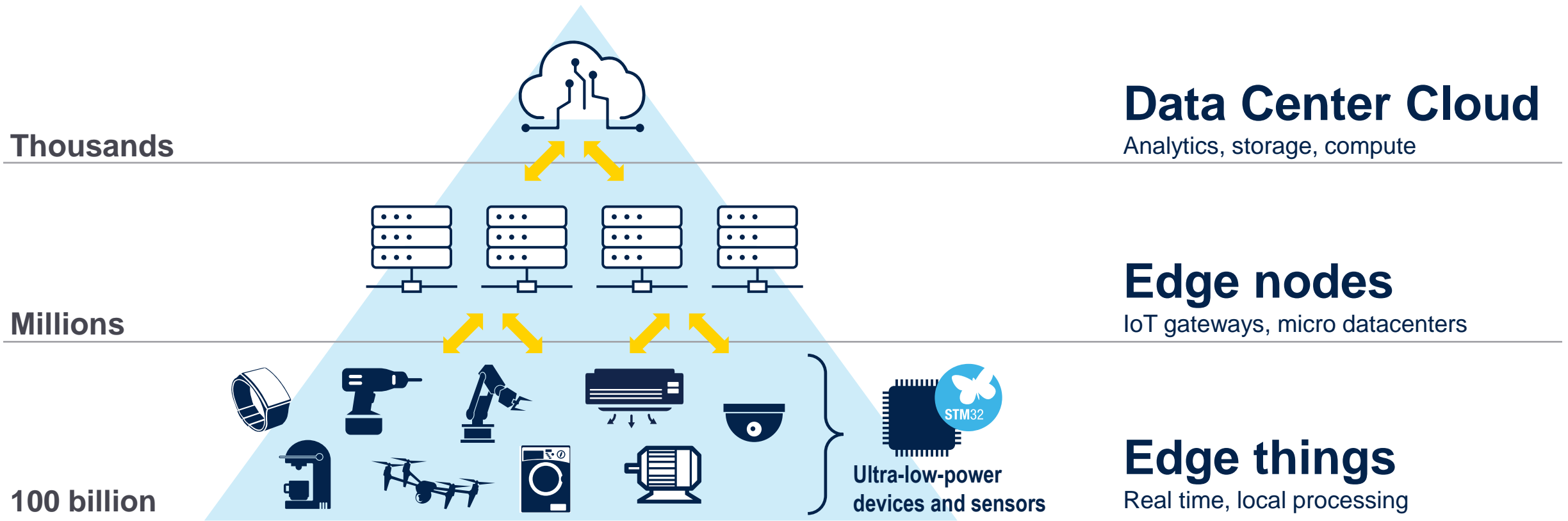
# Artificial intelligence solutions running on STM32

Lisa DING

ST Edge AI Marketing

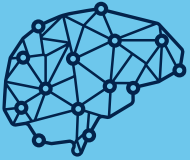
# Distributed artificial intelligence approach

Leverage billions of devices at the edge!



# Embedded AI to be mainstream

## Hype Cycle for Artificial Intelligence, 2021



Global Shipments of Deep Edge AI Devices to Reach 2.5 Billion by 2030

Source: [ABI Research](#)



**realistic value** and **business outcome** for Companies



AI products will be a standard on the market in 2 to 5 years (Gartner)

# The rise of Edge AI



**Ultra-low latency**  
Real-time applications

**01** **Reduced data transmission**  
**10** Generate meaningful information



**Enhanced privacy and security**  
No data sharing in the cloud



**Power efficiency**  
Low-data / Low-power



**Improved accuracy**  
analyze data from a wide range  
of sensors and sources

**Edge AI benefits many application domains:**

## **Industrial maintenance**

Condition monitoring  
Predictive maintenance



## **Control systems**

From home heating systems  
to industrial machines



## **Internet of Things (IoT)**

Smart cities, smart buildings,  
connected homes, and  
industrial automation



# Overview



# Use Case



INDUSTRIAL | DEMO

## Fan anomaly detection based on vibrations

Learn to detect abnormal behavior at the edge on a vibrating machine.



INDUSTRIAL | CUSTOMER

## AI solution for industrial predictive maintenance with NKE Watteco

Predictive maintenance solution for industrial equipment.



TRANSPORTATION | CUSTOMER

## AI solution for monitoring automatic doors with Crouzet

Predictive maintenance on motors for automatic door motors.



INDUSTRIAL | DEMO

## Anomaly detection in an electric motor

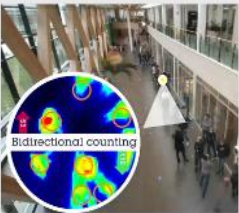
Current sensing to detect abnormal behaviors in motors.



INDUSTRIAL | CUSTOMER

## AI solution for industrial predictive maintenance with Oxytronic

Predictive maintenance solution for industrial equipment.



SMART OFFICE | CUSTOMER

## People flow counting Sensor with Schneider Electric

An innovative approach to measure people flows using an in-house thermal sensor.



SMART CITY | DEMO

## Acoustic scene classification

Identify different environments (indoor, outdoor, in-car) using a simple microphone.



WEARABLES | DEMO

## Human Activity Recognition

Easily identify 5 different activities with a 3D accelerometer.



INDUSTRIAL | DEMO

## People presence detection (visual wake word)

Human detection on high-performance MCU.



INDUSTRIAL | DEMO

## Aftermarket wireless digit reader

Equip meters with aftermarket wireless & low-power readers.

# NKE WATTECO



## CHALLENGE

Easily and quickly deploy predictive maintenance 4.0 solutions without the usual constraints of deploying an AI-based solution, which are to:

- Collect huge amounts of data to train static models
- Work with data scientists to develop complex algorithms

## SOLUTION

The “Shazam of vibrations” right out of the box. With embedded AI based on NanoEdge AI Studio, snap Bob assistant to the machines in your factory and Bob will carefully learn and analyze the vibrations and warn you before a problem impacts the production line.

## BENEFITS

With just a few contextual inputs, anyone can generate optimized and effective machine learning algorithms with NanoEdge AI Studio. The ability to learn algorithms on the device allows the user to tailor anomaly detection to a specific equipment or environment to reduce false positives and false negatives.



## Application of NanoEdge AI Studio



Microcontroller	M3 @ 80Mhz
Library Type	Anomaly detection
Signals used	Vibrations
RAM / FLASH	6K / 28K

# IRMA

## Intelligent Resource for Maintenance Application



### CHALLENGE

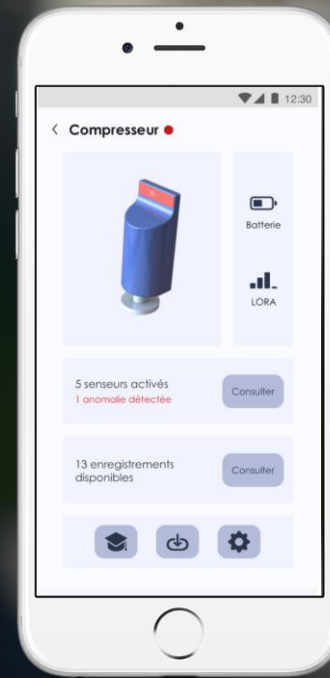
Being able to predict issues in machinery is a considerable advantage in many respects. Yet, it is often complicated to understand precisely the nominal operating state of an equipment to deduce a malfunction.

### SOLUTION

IRMA can predict failures thanks to its multiple sensors and its embedded AI at the edge. First, IRMA collects data (vibration, temperature, pressure, humidity, acoustics and gas) then compares them via the embedded AI algorithms with a database that is constantly enriched. IRMA warns you at the slightest anomaly.

### BENEFITS

*"Without data science experts on the team and within a very short development time, we managed to create a unique solution on the market combining embedded intelligence and 6 sensors. IRMA has already been recognized as a major innovation by several industrial awards and is already installed in production by prestigious customers"*



LoRaWAN® + BLE + Zigbee, IP67, ATEX Zone 0

Application of NanoEdge AI Studio

NANOEDGE AI  
STUDIO 

Microcontroller	STM32L4
Library Type	Anomaly detection and classification
Signals used	Humidity, acoustic, vibration (1 and 3 axes), temperature, gas, pressure
RAM / FLASH	9Kb / 17Kb

# Predictive maintenance for electrical solutions

## CHALLENGE

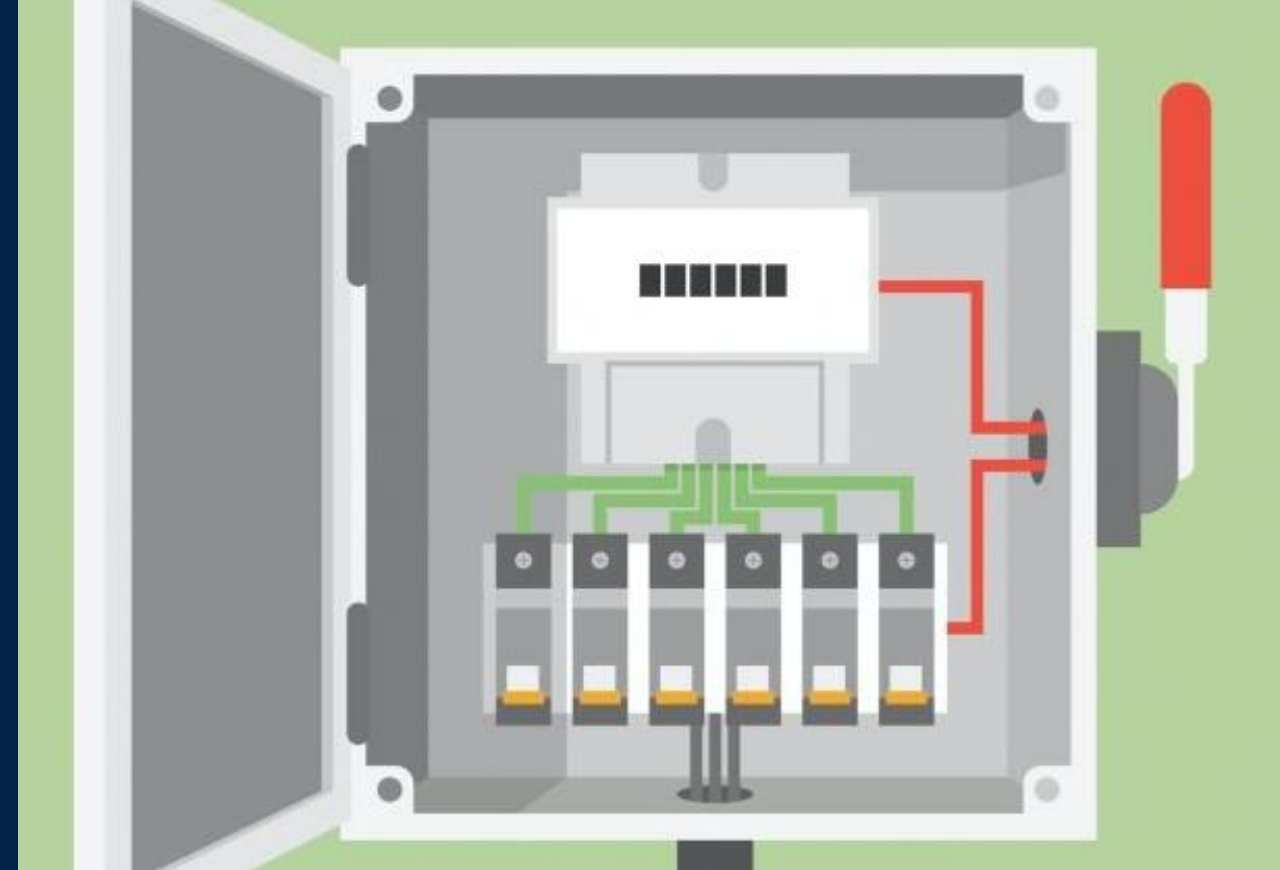
The mechanical ageing of circuit breakers is virtually impossible to anticipate, leading to untimely power outages and costly production downtimes.

## SOLUTION

NanoEdge AI solution has been successfully implemented inside circuit breakers to learn the normal switching patterns and help plan predictive maintenance activities.

## BENEFITS

*“Using Machine Learning libraries developed with NanoEdge AI Studio, we were able to anticipate behaviors that were previously difficult to detect. An AI that is simple to implement and directly integrated into the heart of our equipment is an important added value in future developments.”*



## Application of NanoEdge AI Studio

NANOEDGE AI  
STUDIO 

Microcontroller	STM32G4
Library Type	Anomaly detection and classification
Signals used	Current & Vibrations
RAM / FLASH	12Kb / 20Kb

# People presence detection & counting

## CHALLENGE

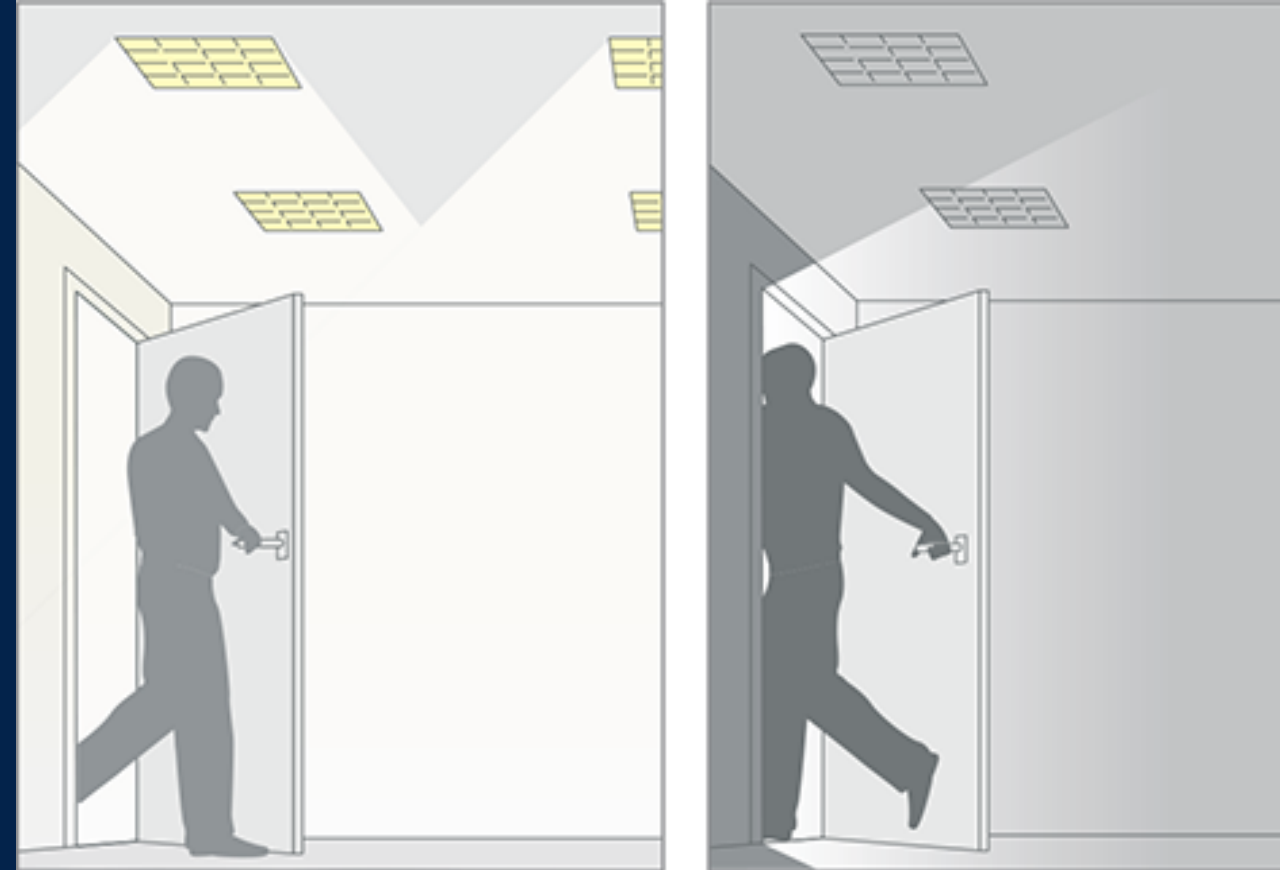
Being able to detect when people are in a corridor or in a room even if they are standing still, without implementing camera-based solutions for smart light and smart heating/air conditioning systems in smart buildings.

## SOLUTION

NanoEdge AI Studio can classify any time series data, such as waves, particle movements, electrical field changes and more. This allows users to develop advanced and tailored solutions.

## BENEFITS

*“Using environmental change to detect presence allows to create computer-vision-like solutions without the disadvantage of having a camera. It enables low-power solutions, safeguarding privacy and security while remaining accurate. NanoEdge AI Studio has helped us develop such a solution in record time thanks to its ease of use and high performance.”*



## Application of NanoEdge AI Studio

NANOEDGE AI  
STUDIO 

Microcontroller	STM32U5
Library Type	Classification
Signals used	Wave or particle
RAM / FLASH	21Kb / 45Kb

# Electrical Arc detection

## CHALLENGE

Solar panels are often damaged by electric arcs caused by impurities or physical damage. This can lead to electric fire causing damage or endanger nearby people

## SOLUTION



Arc have been characterized in literature from current/voltage measurement. Building large database helps to efficiently learn more arc features

Arc abnormal event can be identified by classifying arc fault features using ML or Neural Networks

## BENEFITS

Local arc detection greatly increases reactivity to shut down the system, making panel safer and decreasing amount of damage



## Application of NanoEdge AI Studio



Microcontroller	STM32H7/G4
Library Type	Anomaly detection
Signals used	Voltage & current



# STM32 product portfolio



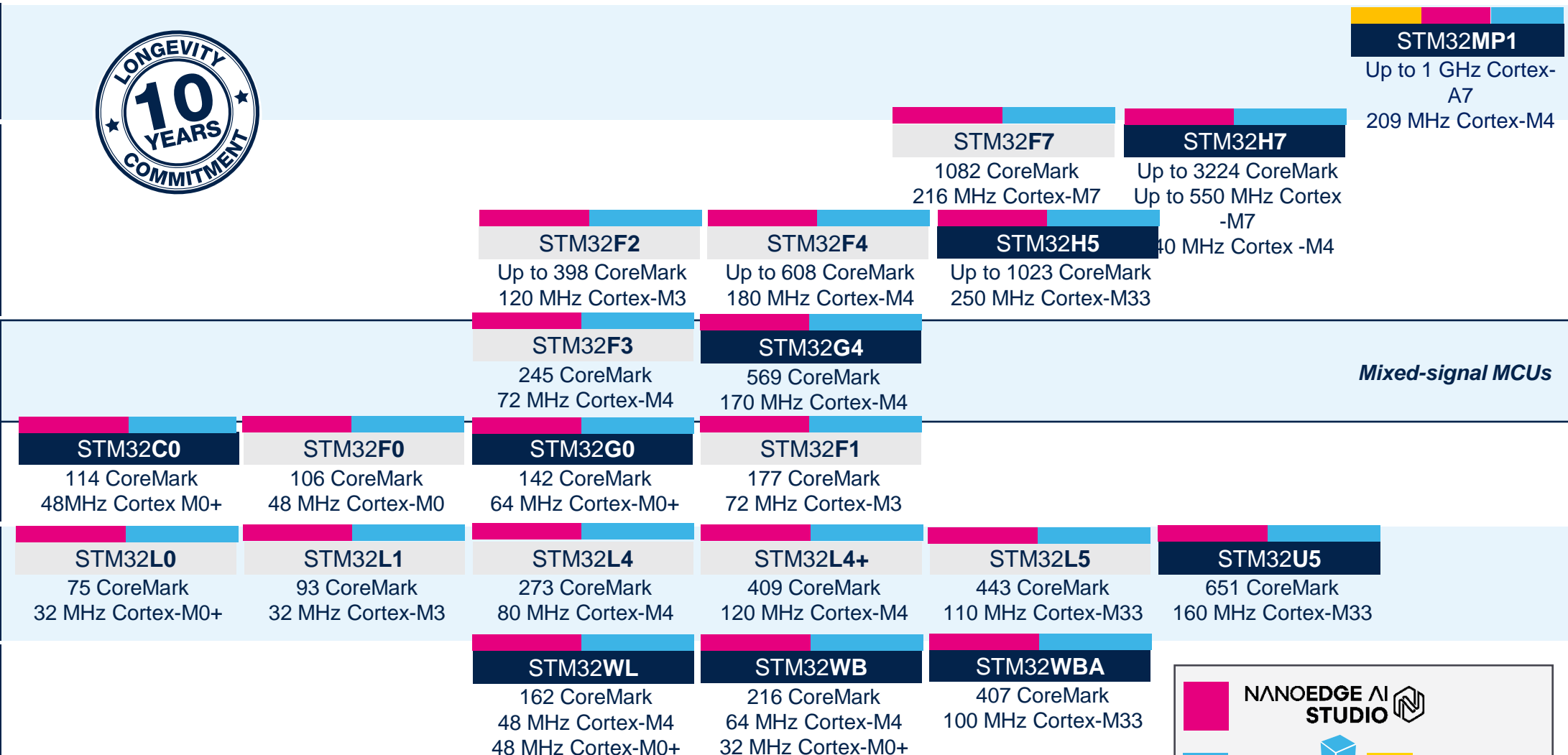
**MPU**

**High Performance MCUs**

**Mainstream MCUs**

**Ultra Low power MCUs**

**Wireless MCUs**



Latest Product



**NANOEDGE AI STUDIO**

**STM32 Cube.AI**

**X-LINUX-AI**

# For teams with AI expertise

STM32Cube.AI helps you accelerate your embedded development



Easily evaluate, convert, and deploy machine learning and deep neural networks on STM32

An AI extension integrated with the STM32Cube MCU development environment to **optimize** and **tune** models, directly on target.

- Develop and train your model with major AI frameworks



- Best ML performance on STM32 (MLPerf™ Tiny benchmarks)
- Validate performance directly on target
- Small footprint, runs on any STM32

# AI development workflow – ST software offering

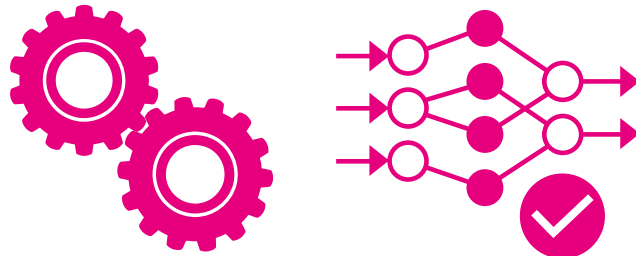
## 1 Data preparation



Data acquisition

Data processing

## 2 Data science



Model selection and training

Model validation

## 3 Model implementation



Creation of model library

Model inference

NANOEDGE AI STUDIO 

Automated Edge AI software

STM32   
Cube.AI

Edge AI toolkit




All STM32  
MCUs

# ST ecosystem eases your AI implementation to reach production level




	Edge AI toolkit for model optimization on STM32	Automated ML software for end-to-end Edge AI solution designs on STM32
Key benefits	<ul style="list-style-type: none"> <li>✓ Get optimized C-code from your trained model</li> <li>✓ Desktop and online versions</li> <li>✓ Benchmark service on remote hardware (online version)</li> <li>✓ On-device performance validation</li> </ul>	<ul style="list-style-type: none"> <li>✓ The easiest way to integrate AI into your system</li> <li>✓ Save resources and development cost</li> <li>✓ Reach the highest performance with the automated model finder embedded in the tool</li> </ul>
Application domain	All	Time series (except voice and speech)
Business model	Free of charge	Free for prototyping on STM32 dev boards Production requires right of use

# STM32Cube.AI overview



**STM32Cube.AI**  
The original desktop front end AI optimizer for STM32

**NEW**



**STM32Cube.AI Developer Cloud**  
The brand-new online AI services front end for STM32




**X-CUBE-AI for STM32Cube.MX**



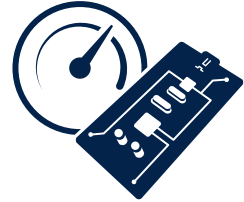
**X-CUBE-AI Command Line Interface**




**ST model zoo**



**Web GUI + REST API**



**Board farm**

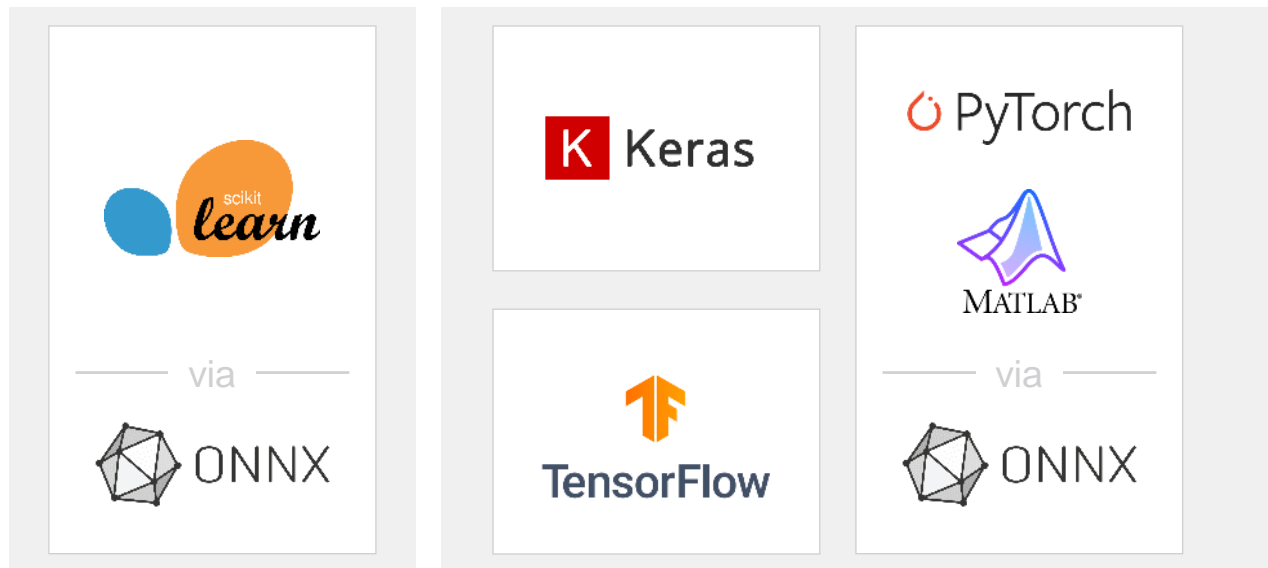


**STM32Cube.AI** Core engine technology

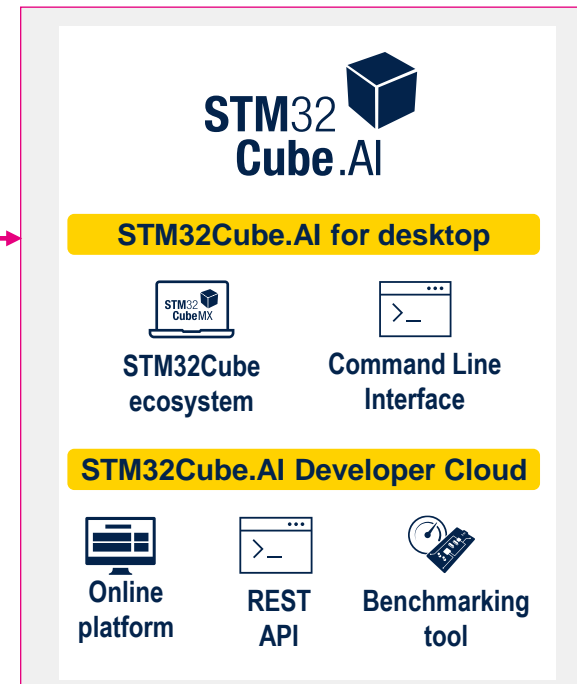
# One tool – two versions to deploy AI on STM32

Load your trained neural network model

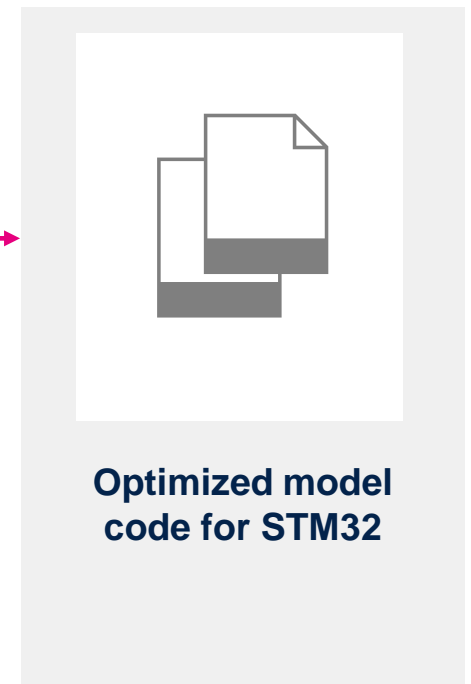
or pick one from STM32 model zoo



Optimize and validate your NN model



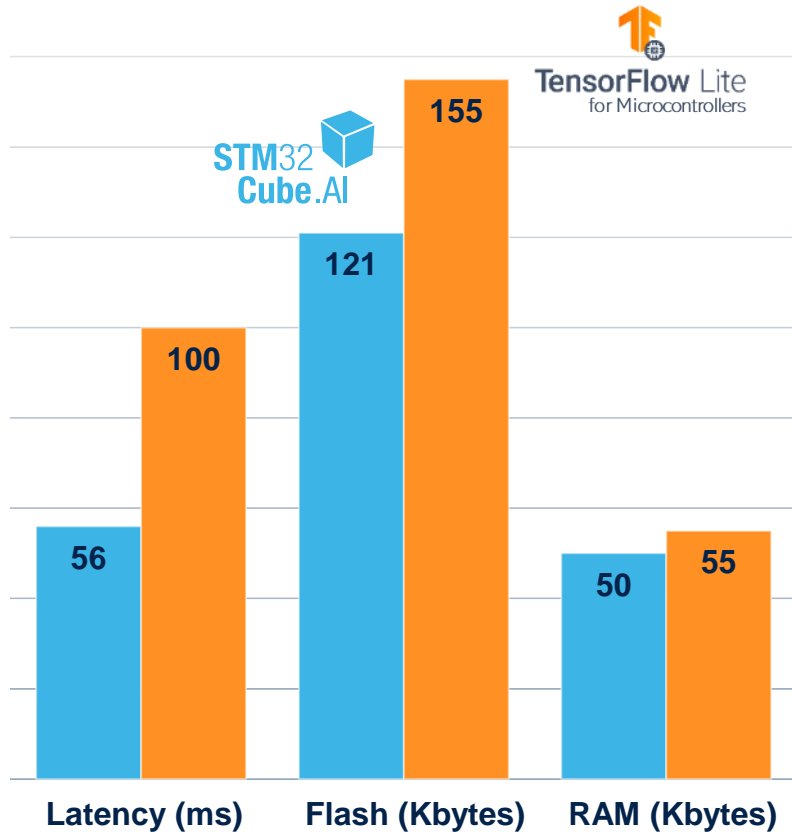
Generate optimized code for STM32



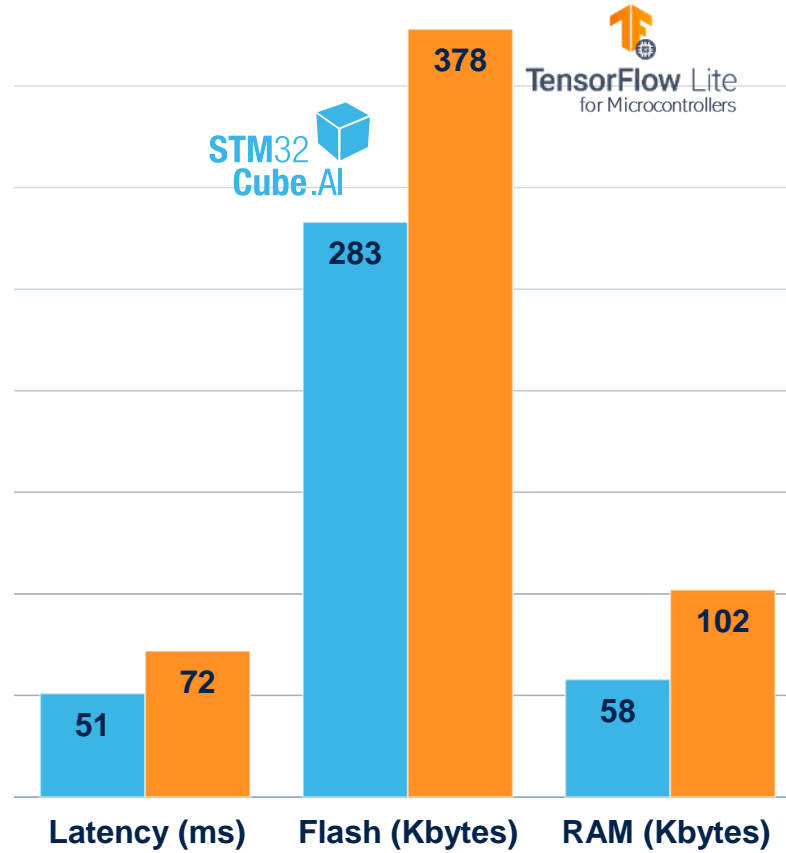
# STM32Cube.AI

## Get the best AI performance on STM32

### Image Classif v1.0 MLPerf Tiny



### Visual Wake Word v1.0 MLPerf Tiny



UP TO  
**60 %**  
faster inference time\*

UP TO  
**20 %**  
space freed up in  
flash and RAM\*



**HW Target:** STM32H7A3  
**Flash:** 2 Mbytes  
**RAM:** 1.4 Kbytes  
**Freq:** 280 MHz

**SW Version:**  
X-Cube.AI v 7.3.0  
TFLm v2.10.0

\* versus TensorFlow Lite for microcontroller

# For embedded developers

## NanoEdge AI Studio, an automated ML design solution



### A unique solution thought from scratch

#### HOW DID WE DO IT?

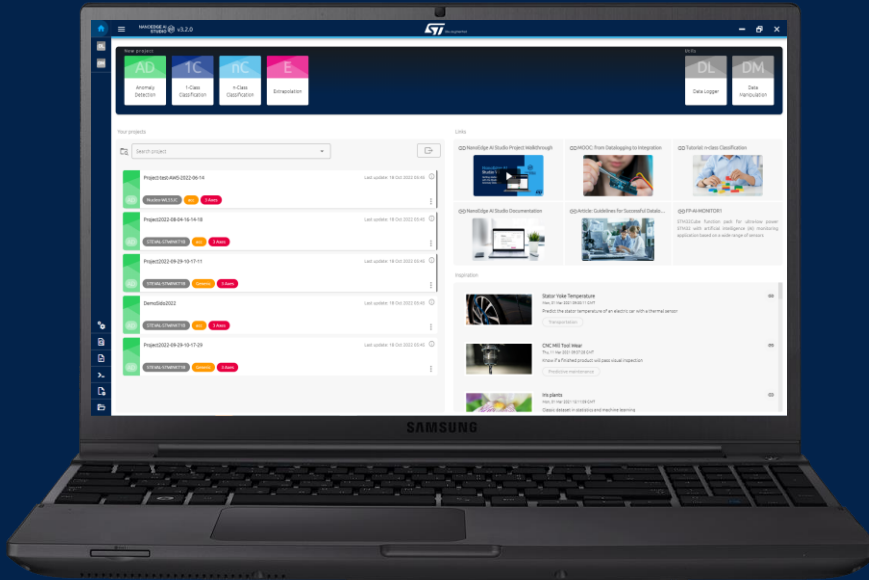
We rewrote the algorithms, from the algebra, ML, and signal processing algorithms, so that they can LEARN and INFER inside an MCU.

- Patented technology
- Designed for embedded developers
- Ultra memory efficient (Flash and RAM)
- Unsupervised learning in the device
- Superior security
- Small footprint, runs on any STM32
- Close to 100% accuracy and confidence

# NanoEdge AI Studio enabling on-device learning

## ON THE PC

1 Create the library, ONCE.

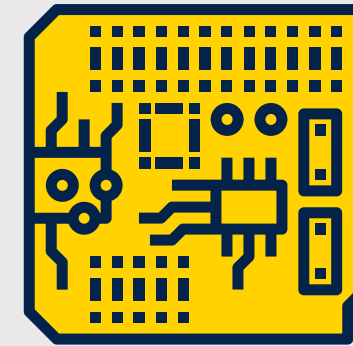


Standalone PC (Win/Linux) solution

## ON THE MCU

2 Use the library, MANY TIMES.

Create and embed  
a self learning engine



For anomaly detection, the model is  
self-trained at the Edge.

# NanoEdge AI Studio in the AI development workflow

1

## Data preparation

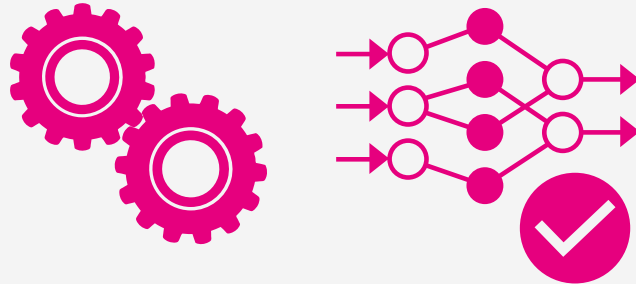


Data acquisition

Data processing

2

## Model development

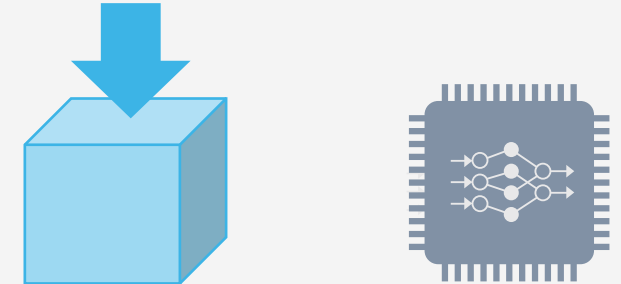


Model selection and training

Model testing

3

## Model implementation



Model library creation

Model inference

Automated Edge AI Software

Data logging tools

NANOEDGE AI STUDIO 



# All the tools needed for data preparation



DL  
Data Logger

“

I want the tools to easily create my dataset”




# All the tools needed for data preparation



DM  
Data  
Manipulation

“

I want to quickly and efficiently clean my data”

NANOEDGE AI STUDIO v3.2.0  life.augmented

File Action Result

Log\_ISPU\_Spacer\_2022-06-13-163838.log

Ignore first header line

182 Lines 768 Columns

Delimiter: Space

File preview

1	2	3	4	5	6	7	8
-453	-1523	15386	517	-154	16106	1068	729
659	95	16368	1006	388	16779	313	-164
722	1012	15909	552	1007	17633	-461	-510
272	269	17697	-851	-911	17448	-836	-1172
45	-463	17629	-727	-1399	16834	-349	-1244

Rows per page: 5 1-5 of 100

Action

Extract lines

1 182

Extract 182 lines

RUN

1.234	1.234	1.234
1.234	1.234	1.234
1.234	1.234	1.234
1.234	1.234	1.234
1.234	1.234	1.234

Remove column(s)

Change columns number

Shuffle

(Log\_ISPU\_Spacer\_2022-06-13-163838.log)  
Log\_ISPU\_Spacer\_2022\_132ce\_0\_extract\_lines\_0

182 Lines 768 Columns

RUN NEW ACTION SAVE AS

Add file(s)

Drop files or click to import

# State-of-the-art machine learning for ever smarter products



AD  
Anomaly  
Detection

1C  
1-Class  
Classification

nC  
n-Class  
Classification

E  
Extrapolation

“

I want them to autonomously adapt to their target environment and detect anomalies by themselves”

“

I want to detect any outliers”

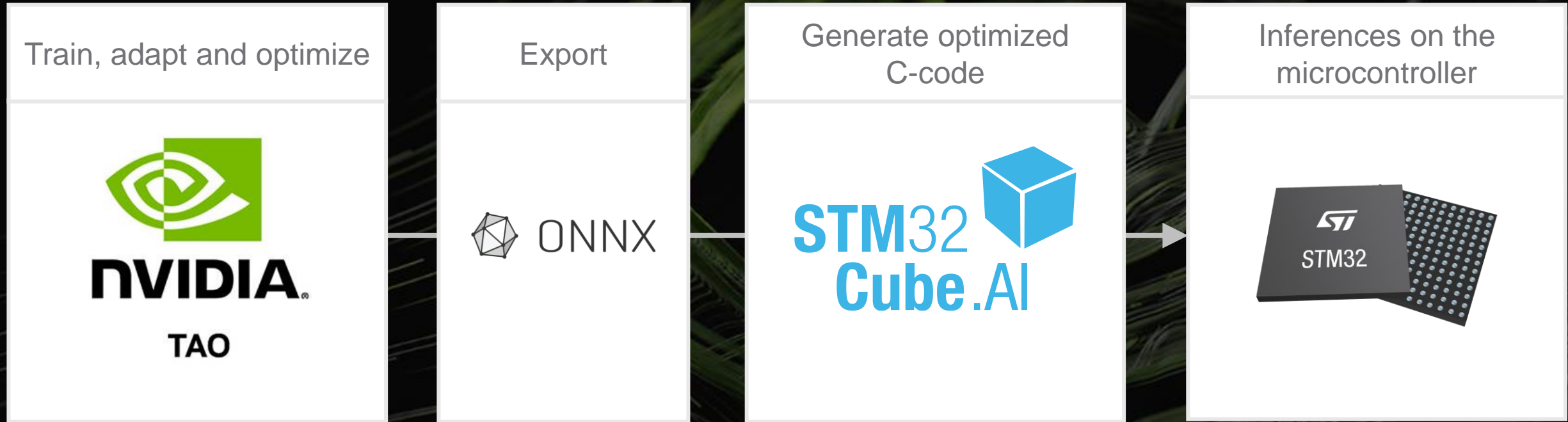
“

I want to know by name what problems are occurring”

“

I want to anticipate the vibration level so that I have time for corrective actions”

# A complete AI training and optimizing ecosystem





# Mobilenet v2 0.5 - people presence detection

## Trained model



Accuracy: **86.7 top 1**



Memory footprint

**2710 KB of Flash**  
**820 KB of RAM**



**1.3 FPS**

running on STM32H747



**NVIDIA**

TAO

+

**STM32**   
**Cube.AI**

## Pruned quantized model



Accuracy: **86.2 top 1**



Memory footprint

**240 KB of Flash**  
**242 KB of RAM**

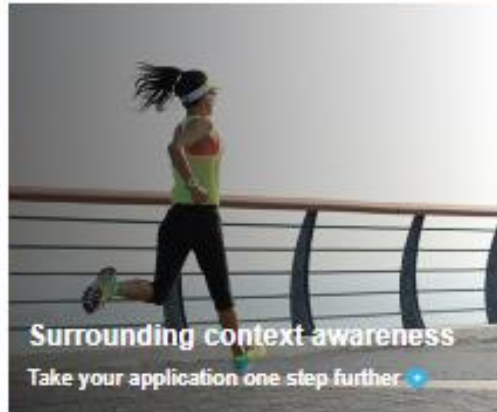


**9 FPS**

running on STM32H747



<https://stm32ai.st.com/zh>



- NEAI download: [link](#)
- NEAI use case: [link](#)
- AI resource: [link](#)

# Release your creativity



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[community.st.com](#)



[stm32ai.st.com/zh](#)



[wiki.st.com/stm32](#)



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[Videos](#)



[STM32Cube.AI blog articles](#)



# Our technology starts with You



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