Artificial Intelligence at the Edge

Moving part of intelligence closer to the data acquisition

- Better user experience
- Realtime, no latency
- Reliable
- Add new functions and services with Embedded AI
- Optimized Cloud usage
- Privacy by design (GDPR compliant)
- Sustainable on energy

Contact us at edge.ai@st.com
Computer Vision for STM32

Give vision to your STM32 product for new features and add-on services

- Food classification
- Person presence detection
- Face recognition
- Multiple object detection

FP-AI-VISION1 v1.0
FP-AI-VISION1 v2.0
FP-AI-FACEREC v1.0

Q2 2021*

*available for alpha customers

Keras
TensorFlow Lite
ONNX

PyTorch

And more

STM32 Cube.AI
STM32 CubeMX

Optimized NN files
STM32.AI lib

Customer application
STM32.Vision lib

run-time
Monitor STM32 equipment health for improved uptime and lower maintenance cost

Get started using dedicated And industrial boards

Condition monitoring for STM32

Vibration monitoring for In-field retrofit of existing systems
Condition monitoring with current for build-in systems

FP-AI-NANOEDG1 v1.0
Q1 2021*

*available for alpha customers
Get the best out of sensors with AI technology

RGB camera
IR camera
Time of Flight
Audio events and voice

Inertial motion sensors
QVAR
Biosignals
TMOS

From sensor data to added-value services
AI tools for STM32
The key steps behind Neural Networks

1. Capture data
2. Train NN Model
3. Clean, label data
   Build NN topology
4. Convert NN into
   optimized code for MCU
5. Process & analyze new
   data using trained NN
ST toolbox for Neural Networks

Capture data

Wide board ecosystem

Clean, label data
Build NN topology

STM32 Cube.AI

Convert NN into optimized code for MCU

Process & analyze new data using trained NN

STM32
Easily implement Neural Networks on STM32

Train Neural Network using any major AI frameworks

- TensorFlow
- ONNX
- PyTorch
- and more...

Convert NN into optimized code

- Select most appropriate MCU
- Review computation and memory consumption per layer

Run on optimized runtime

- Validate code directly on target
- Get accuracy and inference time
- Optimize memory usage
STM32Cube.AI main features

- 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
- Quickly assess model footprint requirements
- Select and configure MCU in STM32CubeMX
- Review model layers in STM32Cube.AI
- Optimize memory allocation
- Fine control of weight mapping
- Split between internal and external memory
- Update model without full FW update

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

And quickly iterate thanks to on-target validation
STM32Cube.AI, an STM32CubeMX expansion

- Power Consumption Calculator
- MCU Selector
- Pinout Configuration
- Code Generation
- Clock Tree Initialization
- Peripherals Configuration
- Middleware Parameters
Collecting data & architecting a NN topology

Services provided by Partners
- Capture Data
- Clean, label data
- Build NN topology

ST tools to support
- ST BLE Sensor mobile phone application
  Collect and label data from the SensorTile.

Selected partners
- Neural Networks engineering services support.
- Data scientists and Neural network architects.
Example form factor hardware to capture and process data

STM32L4

Capture Data

Inference on STM32L476

SensorTile

www.st.com/SensorTile
www.st.com/SensorTile-edu
Fast go to market module to capture data with more accuracy

More advanced, high accuracy and low power sensors
- First Inertial module with Machine Learning capabilities.
- Motion (accelerometer and gyroscope, magnetometer) and slow motion (inclinometer)
- Altitude (pressure), environment (pressure, temperature, humidity, compass) and sound (sound and ultrasound analog microphone)
- Microsoft IoT services ready to make available on a web dashboard the result of the embedded processing

www.st.com/SensorTileBox
Distributed AI: sensor + STM32
Optimize performance and power consumption

Smart Sensor
with Machine Learning Core

- Best ultra-low-power sensing at high performance
  - 550µA (gyroscope and accelerometer)
    → 200µA less than closest competitor
  - 20~40µA (Accelerometer only for HAR)
- Efficient Finite State Machines: 2µA
- Configurable Machine Learning Core: 4~8µA

Smart STM32
Second level of AI processing

- More advanced and complex NNs
- Decisions on multiple sensors
- NN input can be sensor data and/or sensor Machine Learning decisions
- Multiple Neural Networks support
- Actuation & communication

Inertial Sensor
New LSM6DSOX

Deep Learning
Neural Networks
Machine Learning

- Raw Data
- Event Decision
- FSM and MLC Re-configuration

FSM up to 16
MLC up to 8
Form factor hardware

AI IoT node for more connectivity

B-L475E-IOT01A

Capture Data

+ 

Inference on STM32L4

More debug capabilities
- Integrated ST-Link/V2.1
- PMOD extension connector
- Arduino Uno extension connectors

www.st.com/IoTnode
Wireless Industrial node to capture data at industrial grade

STWIN

Capture Data

Industrial-grade sensors
- Industrial scale 9-DoF motion sensors including accelerometer, gyrometer and an ultra wide-bandwidth vibrometer with ultra low noise
- Very high frequency audio and ultrasound microphone
- High precision temperature and environmental monitoring
- Micro SD card for standalone data logging
- BLE5.0 connectivity and WiFi expansion board
- USART

Inference on STM32L4R9

www.st.com/stwin
STM32H7 discovery boards with camera

STM32H747I-DISCO with B-CAMS-OMV

Capture Data

Inference on STM32H747

Computer Vision on microcontroller
- STM32H747 high-performance and DSP with DP-FPU, Arm Cortex-M7 at 480 MHz + Cortex-M4 MCU with 2MB internal Flash, 1MB internal RAM, Chrom-ART Accelerator
- External memory 2x64MB Quad-SPI NOR Flash and 32MB SDRAM
- 4” capacitive touch LCD display module with MIPI® DSI interface
- Camera module adapter board and camera module based on OV5640 5MPx 8b color rolling shutter
- ST-MEMS digital microphones
- Ethernet RJ45 and Wi-Fi / cellular expansion boards
OpenMV integration
Fast machine vision prototyping

Configure Machine Vision in real-time over USB in Python

Run and validate optimized Neural Network

OpenMV CAM
Running MicroPython over STM32

https://github.com/openmv/openmv
### Leader in Arm® Cortex®-M 32-bit General Purpose MCU

<table>
<thead>
<tr>
<th>Arm® Cortex® core</th>
<th>-M0</th>
<th>-M0+</th>
<th>-M3</th>
<th>-M33</th>
<th>-M4</th>
<th>-M7</th>
<th>dual -A7 &amp; -M4</th>
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</thead>
<tbody>
<tr>
<td>STM32MP1</td>
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<td></td>
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<tr>
<td></td>
<td>4158 CoreMark</td>
<td></td>
<td></td>
<td>650 MHz Cortex -A7</td>
<td>209 MHz Cortex -M4</td>
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<tr>
<td>STM32F0</td>
<td>106 CoreMark</td>
<td>48 MHz</td>
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<tr>
<td>STM32G0</td>
<td>142 CoreMark</td>
<td>64 MHz</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>STM32F1</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>STM32F4</td>
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<tr>
<td>STM32H7</td>
<td>3224 CoreMark</td>
<td>240 MHz Cortex -M4</td>
<td>480 MHz Cortex -M7</td>
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<tr>
<td>STM32F7</td>
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<td>216 MHz</td>
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<tr>
<td>STM32L1</td>
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<td>32 MHz</td>
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<tr>
<td>STM32L2</td>
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<tr>
<td>STM32L3</td>
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<td>72 MHz</td>
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<tr>
<td>STM32L4</td>
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<tr>
<td>STM32L5</td>
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<td>STM32L4+</td>
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<td>STM32U5</td>
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<td>160 MHz</td>
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<tr>
<td>STM32U6</td>
<td>1062 CoreMark</td>
<td>180 MHz</td>
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<tr>
<td>STM32U7</td>
<td>1374 CoreMark</td>
<td>240 MHz Cortex -M4</td>
<td>480 MHz Cortex -M7</td>
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<tr>
<td>STM32U8</td>
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<tr>
<td>STM32WB</td>
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<tr>
<td>STM32WE</td>
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<tr>
<td>STM32WF</td>
<td>398 CoreMark</td>
<td>120 MHz</td>
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<tr>
<td>STM32WG</td>
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<td>180 MHz</td>
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<td></td>
</tr>
<tr>
<td>STM32WH</td>
<td>1082 CoreMark</td>
<td>216 MHz</td>
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</tr>
</tbody>
</table>

**Compatible with Machine Learning Partner ecosystems**

**Compatible with Deep Learning STM32Cube.AI ecosystem**

More than 40,000 customers Over 4 Billion STM32 shipped since 2007
Function Packs
AI Solutions on STM32

A full development ecosystem to create your AI application

<table>
<thead>
<tr>
<th>STM32 Cube.AI</th>
<th>AI extension for STM32CubeMX to map pre-trained Neural Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>STM32 Community</td>
<td>with dedicated Neural Networks topic and AI expert partners</td>
</tr>
<tr>
<td>Trainings, hands on, MOOCs and partners videos</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FP-AI-VISION1</th>
<th>Person presence detection</th>
<th>Food classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP-AI-SENSING1</td>
<td>People activity recognition</td>
<td>Audio scene classification</td>
</tr>
<tr>
<td>FP-AI-NANOEDG1</td>
<td>Condition-based monitoring</td>
<td></td>
</tr>
</tbody>
</table>
Audio scene classification (ASC)

- Audio Data capture
- Labelling controlled by smartphone application
- Data stored on the device SD card for future learning
- 3 classes: Indoor, Outdoor, In vehicle labelling
- Embedded audio pre-processing
- Inferences running on the microcontroller
- NN & example dataset provided
- Inference result displayed on mobile app

Demo available
Human activity motion recognition (HAR)

Motion Data Capture
Labelling controlled by smartphone application
Data stored on the device SD card for future learning
Stationary, walking, running, biking, driving labelling

5 classes example

Embedded motion pre-processing
Inferences running on the microcontroller
Inference result displayed on mobile app

Demo available
Enjoy the food classification demo
• Default demo based on 18 classes (224x224 RGB pictures)
• Several camera image output size possible

Full end-to-end optimized software example
• from camera acquisition to image pre-processing before feeding the NN
• Multiple memory mapping possibilities to optimize and test impact on performances
• Retrain this NN with your own dataset
• Quantize your trained network to optimized inference time and memory usage

Embedded image pre-processing (SW) on the STM32H747

Inferences running on the microcontroller

**Demo available**
Person presence detection

One-class image classification demo
- Models from tensorflow.org (L4R and H7) and MobileNet v2 (H7 only)
- QVGA 320x240 color image on the LCD
- Can adapt camera flipping depending on which side camera is placed

Full end-to-end optimized software example
- from camera acquisition to image pre-processing before feeding the NN
- Multiple models fitting STM32L4R to STM32H7 depending on required performance and cost
- Visual wake word for Smart home or cities security cameras
- Reduce false alarms due to object movement detection

Embedded image acquisition and pre-processing (SW)

STM32L4R display accelerations

Inferences running on the microcontroller

Unused 9.4 %
Person 34.8 %
No Person 87.1 %
Embed face recognition in your IoT project

**STM32H7**  
**User-personalized services / features**

- Adjust automatically per user
  - Device **preferred settings** or **ergonomics** per user
  - Customized device **behavior** / action for registered user
  - Customize **alerts**
  - **Prevent child injury** with underage appliance lock
  - Create user-specific **automations**

**Features**

- On-device face enrollment of multiple users
- Real-time face recognition, display enrolled image
- Displays match accuracy and inference speed

Available on-demand as a software library
Contact edge.ai@st.com to get access
Condition monitoring on STWIN

Get straight to proof-of-concept with full anomaly detection system without deep Data Science knowledge

1. Collect dataset from industrial-grade vibration sensor
2. Generate free ML library
3. Integrate and deploy
4. Install on premise
5. Incremental learning on-target
6. Monitor anomalies on-target

Download the dedicated SW package
AI solutions for STM32MP1
STM32MP1 microprocessor
Augmented intelligence

- STM32Cube.AI to convert pre-trained NNs for the Cortex-M4 core
- TensorFlow Lite STM32MP1 support up streamed for native NN inferences support on the dual Cortex-A side
X-LINUX-AI Package for STM32MP1 AI Applications

Application examples in C/C++ and Python
- Image classification: 1000 objects classified
- Multiple object detection: 90 classes

Includes code for camera acquisition and image pre-processing

USB camera or built-in camera module

Inferences running on the microprocessor in 80ms for image classification

Displayed on STM32MP157-DK2, STM32MP157-EV1 and Avenger96 board

► 2x demos available
ST co-development and partnerships
Leverage the power of Edge AI

ST AI Expert team
AI co-development partnerships
Contact us at edge.ai@st.com

Multiple object detection with thermal imager

Meet our expert AIS partners
Visit st.com/stm32cubeai

Predictive maintenance of reflow oven

www.st.com/STM32CubeAI
Contact us at edge.ai@st.com
Releasing your creativity

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@ST_World
community.st.com
www.st.com/STM32CubeAI
Thank you