

tinyML[®] On Device Learning Forum

Enabling Ultra-low Power Machine Learning at the Edge

“NeuroMem[®], Ultra Low Power hardwired incremental learning and parallel pattern recognition”

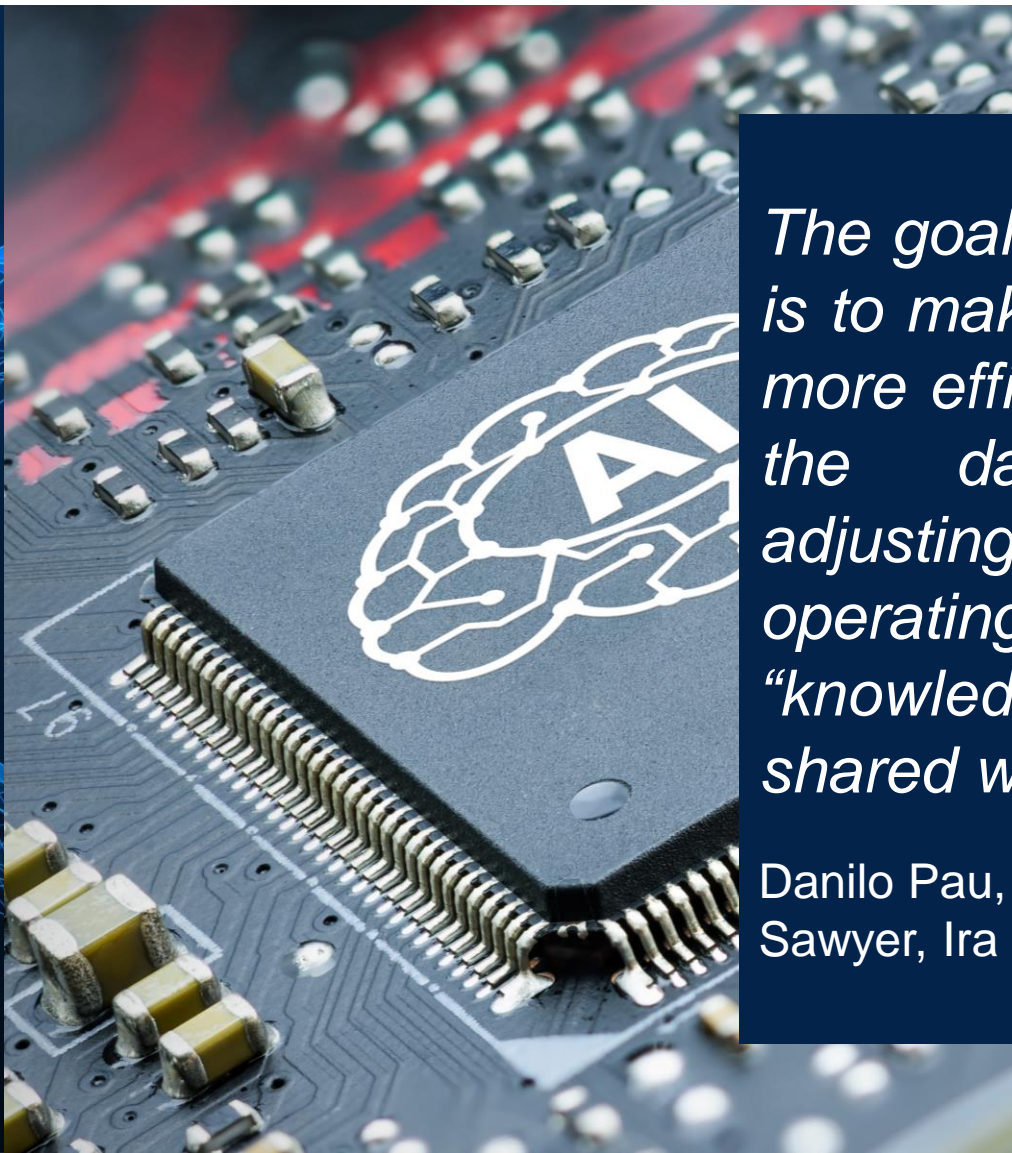
Guy Paillet – Co-founder and Chairman, General Vision Holdings

May 16, 2023



www.tinyML.org

The Dawn of On Device Learning in TinyML



The goal of On Device Learning (ODL) is to make edge devices “smarter” and more efficient by observing changes in the data collected and self-adjusting/reconfiguring the device’s operating model. Optionally the “knowledge” gained by the device is shared with other deployed devices.

Danilo Pau, Elias Fallon, Evgeni Gousev, Davis Sawyer, Ira Feldman, Christopher B. Rogers



tinyML On Device Learning Forum

8/31 – 9/1 , 2022 Online

On device learning Forum

- Academia on 8/31/2022

- [On-Device Learning Under 256KB Memory](#), Song HAN, Assistant Professor, MIT EECS
- [Neural Network ODL for Wireless Sensor Nodes](#), Hiroki MATSUTANI, Professor, Keio University
- [Scalable, Heterogeneity-Aware and Trustworthy Federated Learning](#), Yiran CHEN, Professor, Duke University
- [On-Device Learning For Natural Language Processing with BERT](#), Warren J. GROSS, Professor, McGill University
- [Is on-device learning the next “big thing” in TinyML?](#) Manuel ROVERI, Associate Professor, Politecnico di Milano
- [ODL Professors Panel](#)

- Industry on 9/1/2022

- [TinyML ODL in industrial IoT](#), Haoyu REN, PhD Student, Technical University of Munich/Siemens
- [NeuroMem® wearable, hardwired sub milliwatt real time machine learning with wholly parallel access to “neuron memories” fully explainable](#), Guy PAILLET, Co-founder, General Vision
- [Using Coral Dev Board Micro for ODL innovations](#), Bill LUAN, Senior Program Manager, Google
- [Platform for Next Generation Analog AI Hardware Acceleration](#), Kaoutar EL MAGHRAOUI, Principal Research Scientist, IBM T.J Watson Research Center
- [Enabling on-device learning at scale](#), Joseph SORIAGA, Sr. Director of Technology, Qualcomm
- [Training models on tiny edge devices](#), Valeria TOMASELLI, Senior Engineer, STMicroelectronics

tinyML EMEA Forum - On Device Learning

9/12 , 2022 Cyprus, In person



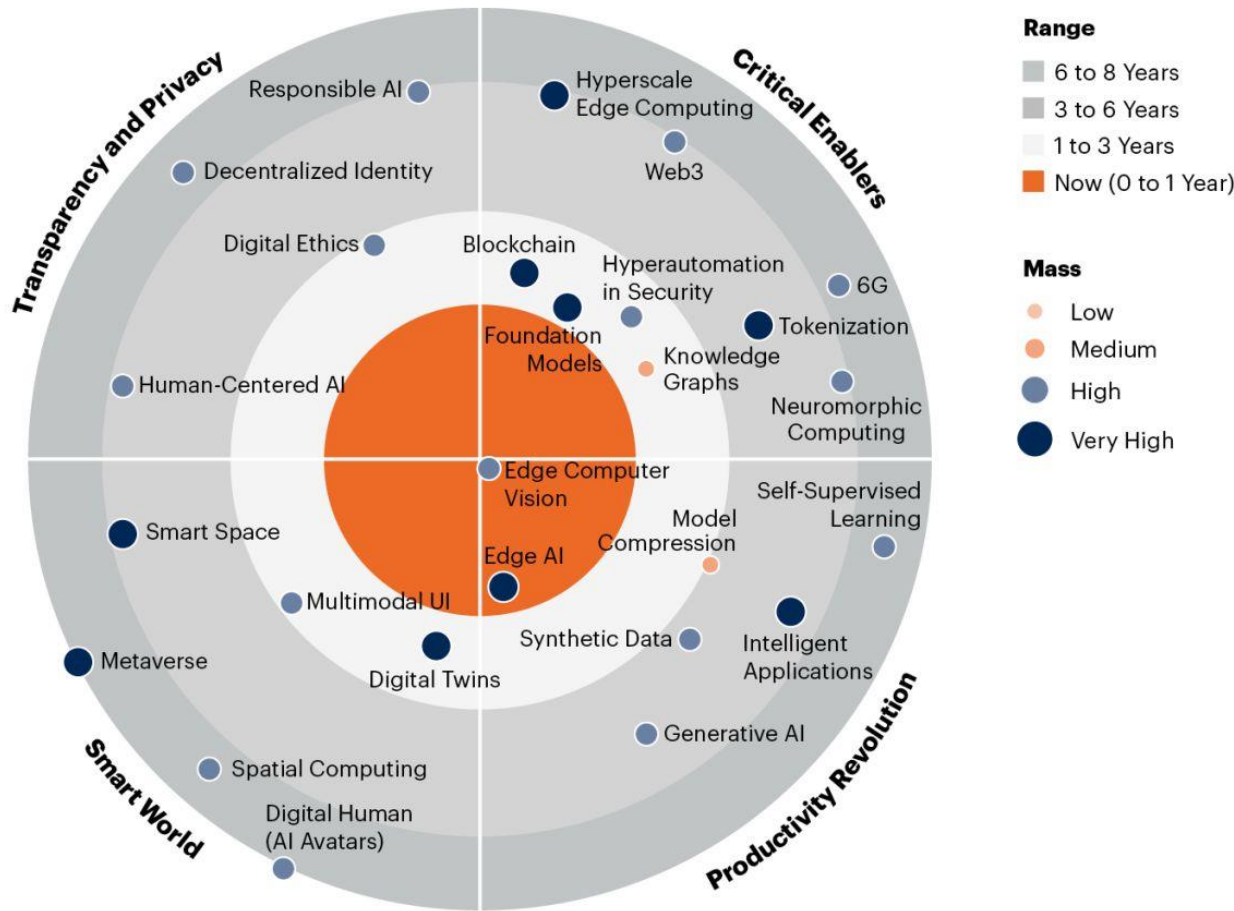
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- [A framework of algorithms and associated tool for on-device tiny learning](#), Danilo PAU, Technical Director, IEEE and ST Fellow, STMicroelectronics
- [In Sensor and On-device Tiny Learning for Next Generation of Smart Sensors](#) Michele MAGNO, Head of the Project-based learning Center, ETH Zurich, D-ITET
- [Continual On-device Learning on Multi- Core RISC-V MicroControllers](#) Manuele RUSCI, Embedded Machine Learning Engineer, Greenwaves
- [On-device continuous event-driven deep learning to avoid model drift](#), Bijan MOHAMMADI, CSO, Bondzai



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2023 Gartner Emerging Technologies and Trends Impact Radar



[gartner.com](https://www.gartner.com)

Note: Range measures number of years it will take the technology/trend to cross over from early adopter to early majority adoption. Mass indicates how substantial the impact of the technology or trend will be on existing products and markets.

Source: Gartner
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On Device Learning Forum 2023, May 16 2023

- 8:00 - 8:10 Opening remarks by **Danilo Pau**
- 8:10 - 8:40 **Charlotte Frenkel** "Merging insights from artificial and biological neural networks for neuromorphic edge intelligence"
- 8:40 - 9:40 **Giorgia Dellaferrera** "Forward Learning with Top-Down Feedback: Solving the Credit Assignment Problem without a Backward Pass"
- 9:40 - 10:10 **Guy Paillet** "NeuroMem®, Ultra Low Power hardwired incremental learning and parallel pattern recognition"
- 10:10 - 10:40 **Aida Todri-Sanial** "On-Chip Learning and Implementation Challenges with Oscillatory Neural Networks"
- 10:40 - 11:10 **Eduardo S. Pereira** "Online Learning TinyML for Anomaly Detection Based on Extreme Values Theory"
- 11:10 - 11:15 Closing remarks by Danilo Pau



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for committing to take tinyML to the next Level, together



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Efficient learning

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through minimal data,
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Perception

Object detection, speech
recognition, contextual fusion



Reasoning

Scene understanding, language
understanding, behavior prediction



Action

Reinforcement learning
for decision making



Edge cloud



Cloud



IoT/IIoT



Automotive



Mobile



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Making Edge AI A Reality

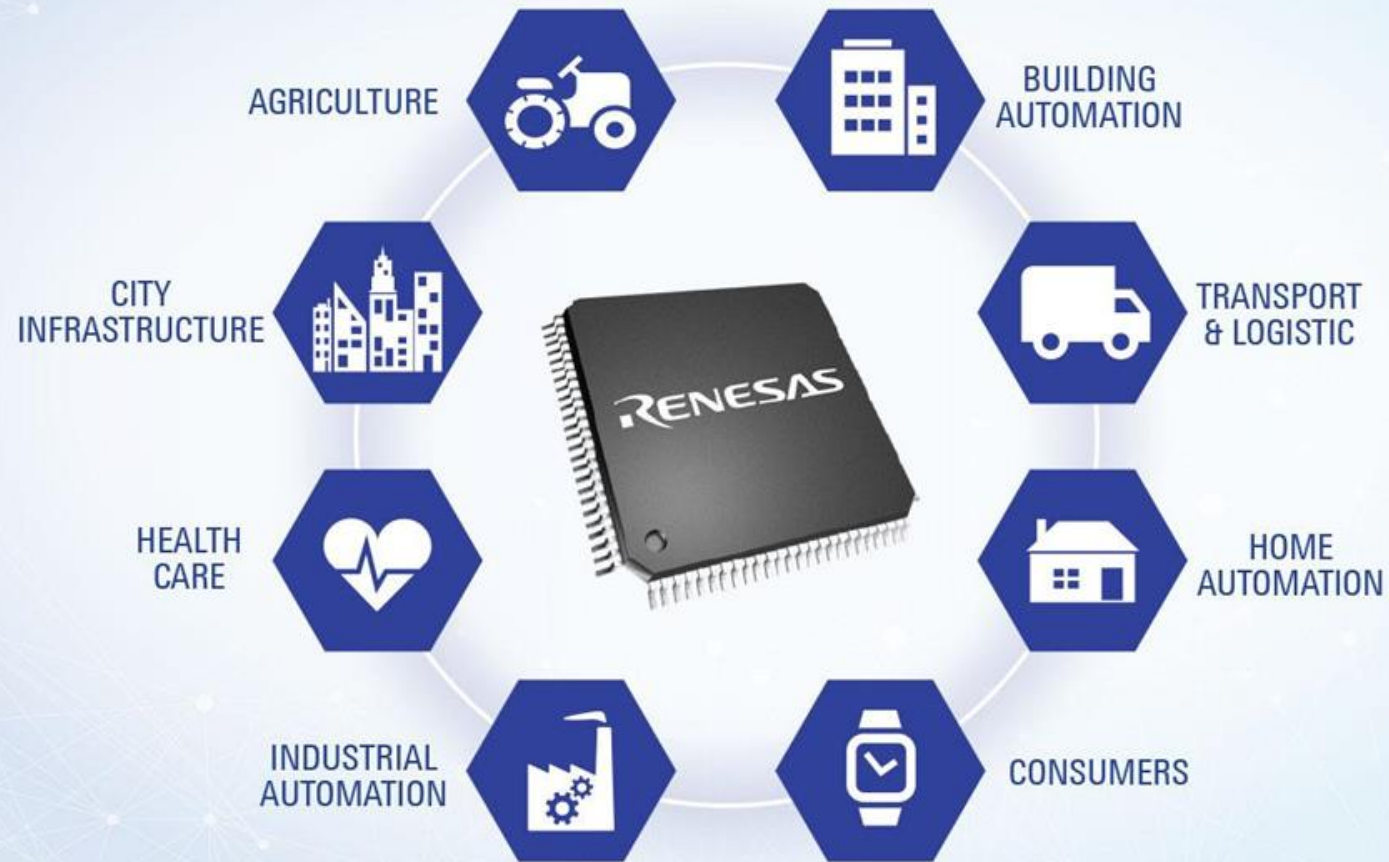
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Where what if
becomes what is.

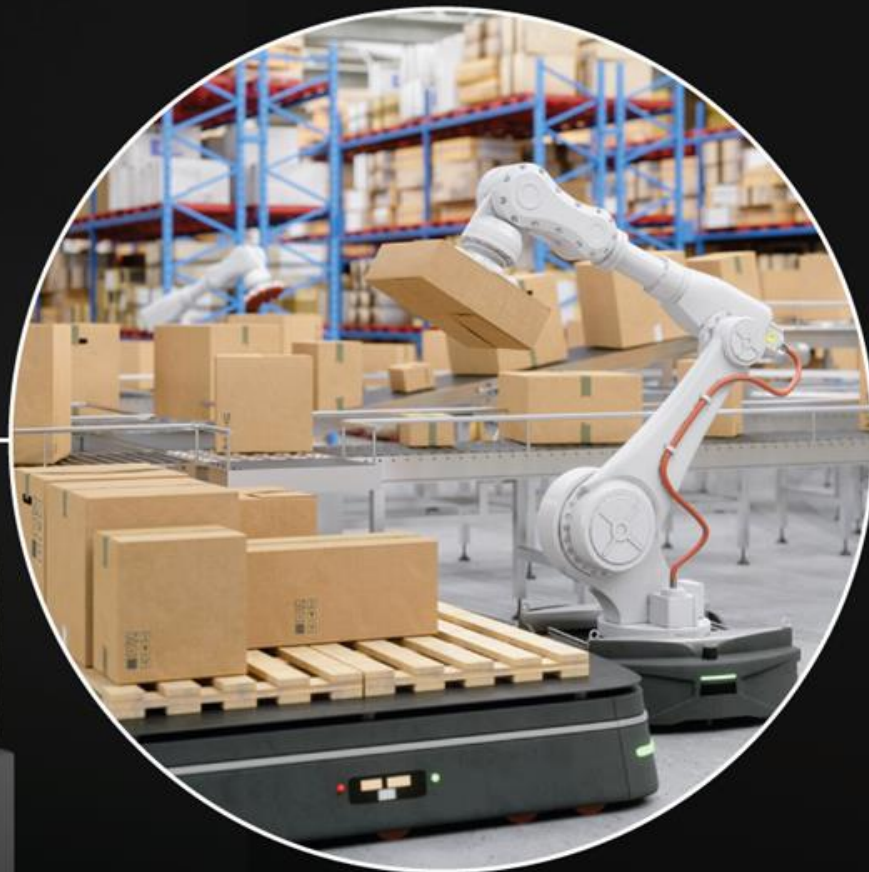
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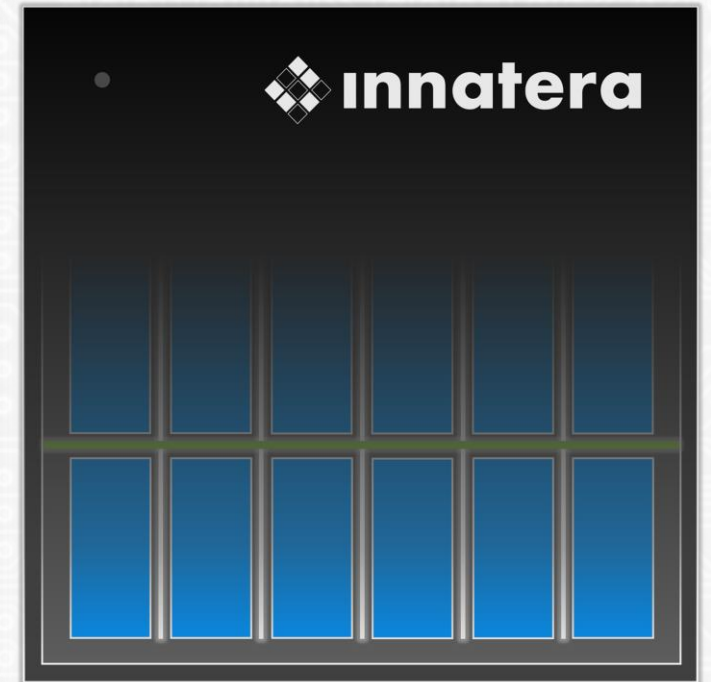
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NEUROMORPHIC INTELLIGENCE FOR THE SENSOR-EDGE

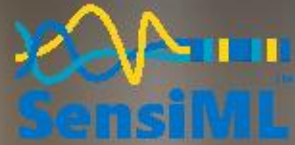


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Microsoft

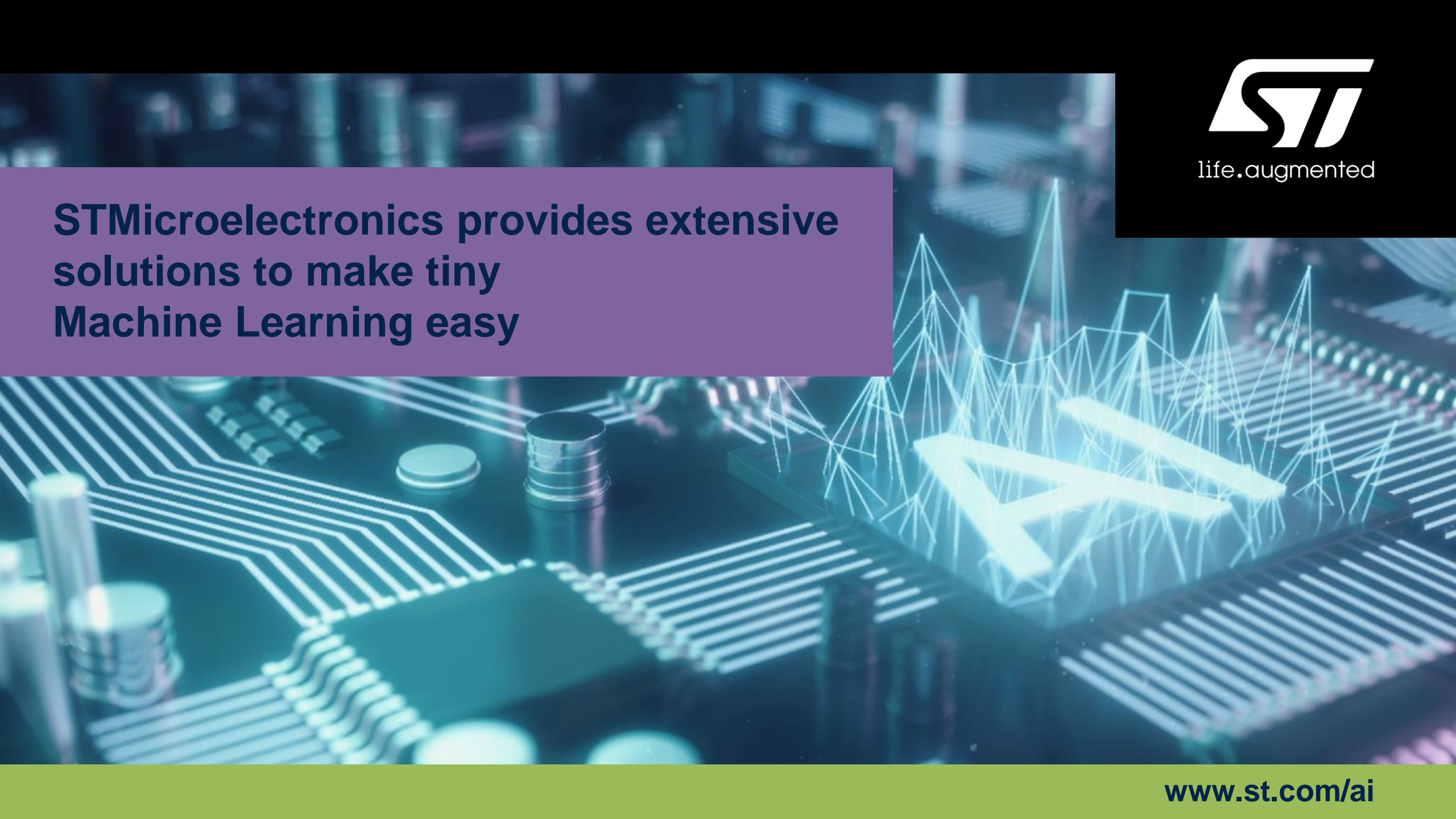
The Right Edge AI Tools Can Make or Break Your Next Smart IoT Product



Analytics Toolkit Suite



sensiml.com/tinyML



STMicroelectronics provides extensive solutions to make tiny Machine Learning easy



life.augmented



ENGINEERING EXCEPTIONAL EXPERIENCES

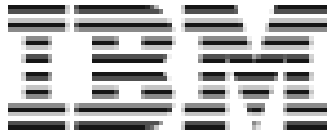
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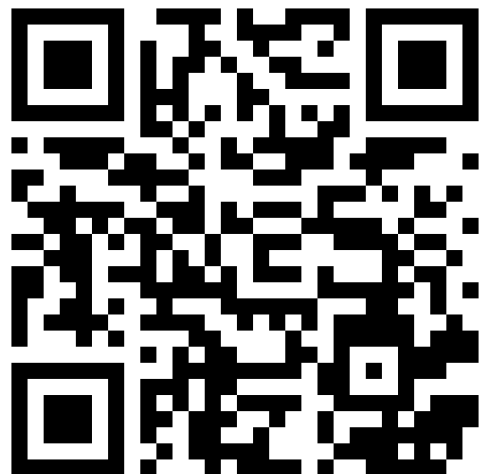
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47 Groups in 39 Countries

tinyML - Enabling ultra-low Power ML at the Edge

<https://www.meetup.com/tinyML-Enabling-ultra-low-Power-ML-at-the-Edge/>



4k members
&
11.6k followers

The tinyML Community

<https://www.linkedin.com/groups/13694488/>





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tinyML EMEA Innovation Forum

June 26 -28, 2023

Amsterdam

EMEA 2023

<https://www.tinyml.org/event/emea-2023>

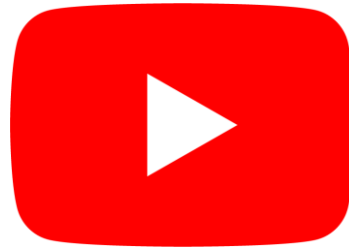
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Reminders

Slides & Videos will be posted
tomorrow



tinyml.org/forums



youtube.com/tinyml



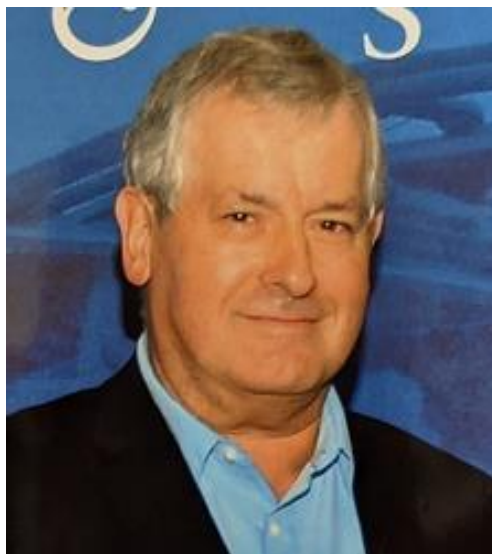
Please use the Q&A window for your
questions



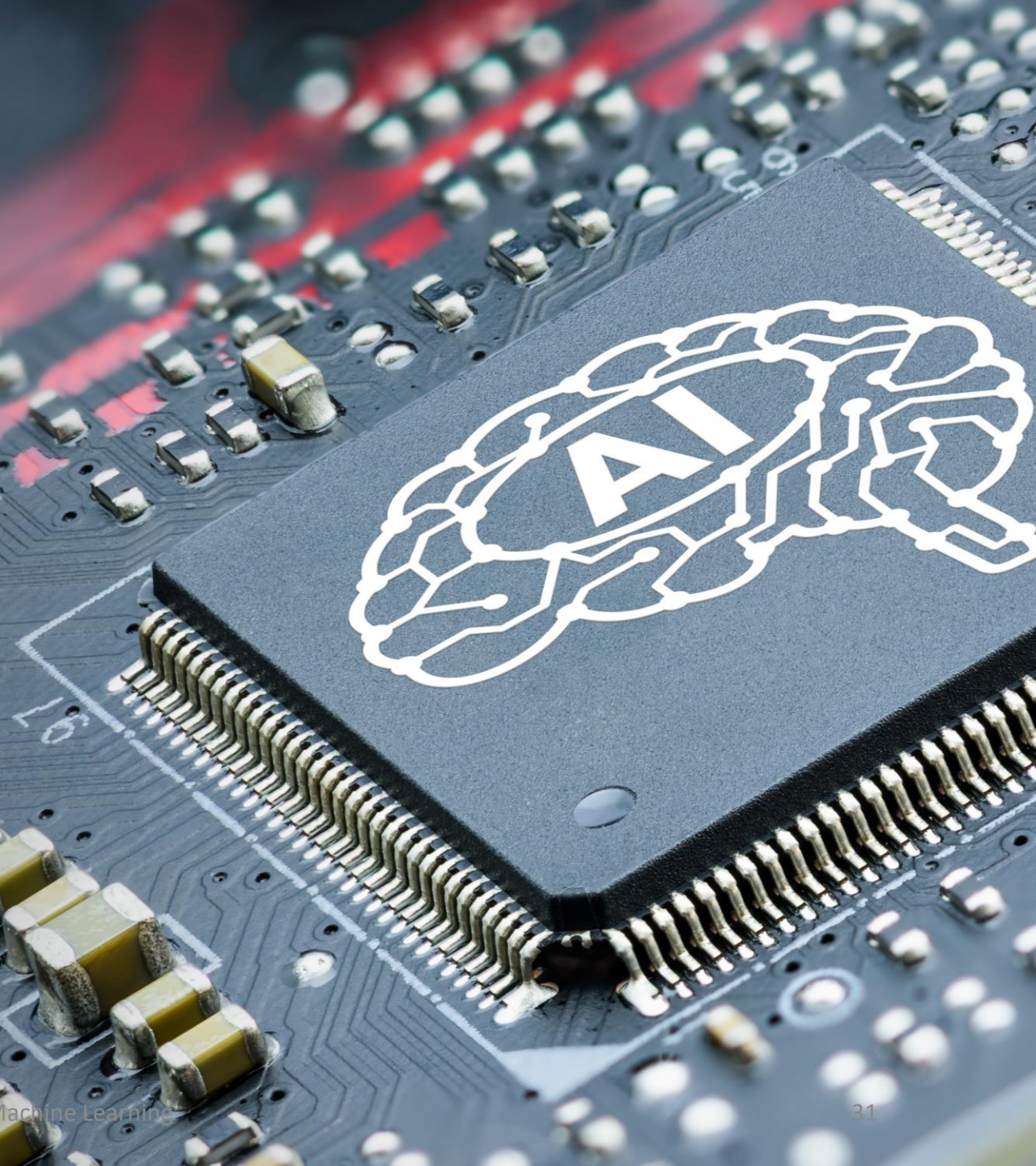


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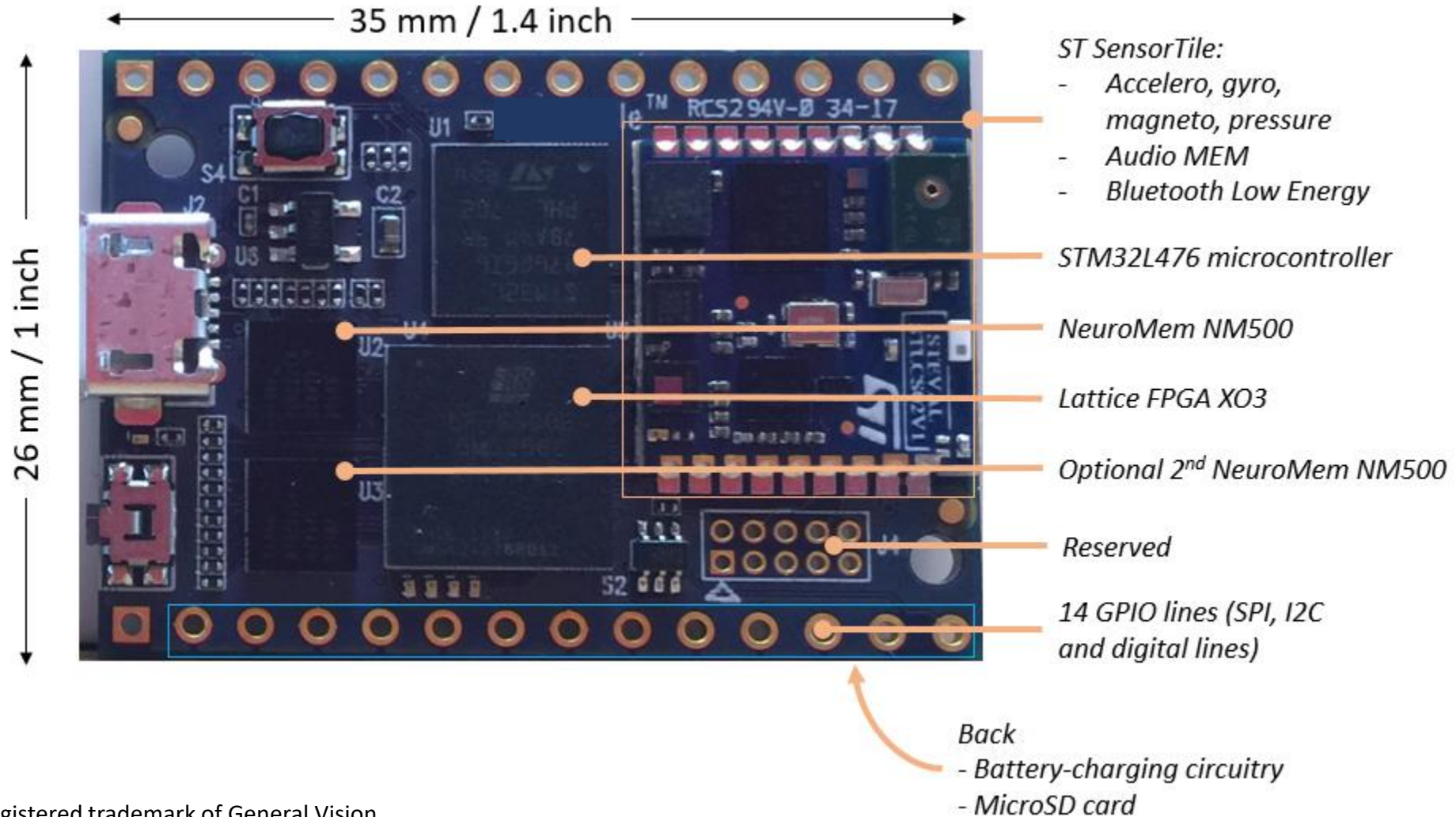
Guy Paillet



Guy's background is hardware design since 1976 starting with Motorola MC6800 as application engineer. He has been innovating on high performance Tiny Machine Learning since 1993 while inventing the ZISC36 with IBM Paris, Guy and family moved from France in 1996 and co-founder General Vision in 2000. Since, General has licensed its NeuroMem ZISC technology giving birth to 4 additional successful Neuromorphic AISC from 2007 to 2022, including the Intel Curie for "NeuroMEMS."



BRAINCARD® the smallest wearable device with on chip learning in the World



BRAINCARD® is a registered trademark of General Vision

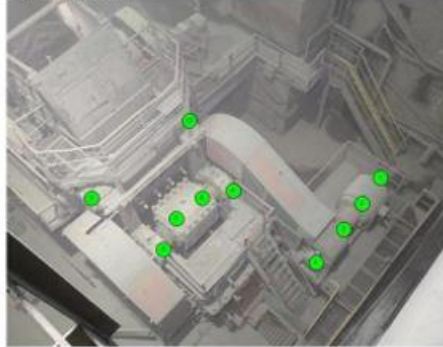


NeuroTechnologijos
UAB

NeuroMem
Smart! by GENERAL VISION

ZYNQ + NM500 industrial application steel factory condition monitoring

Щековая дробилка



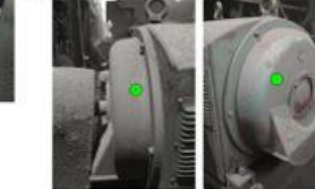
Конусная дробилка



На конусных дробилках есть 2 типа датчиков:
- с радиальным креплением



- с радиальным креплением



Датчик нужно установить
под кожухом



Шнеко-зубчатая дробилка



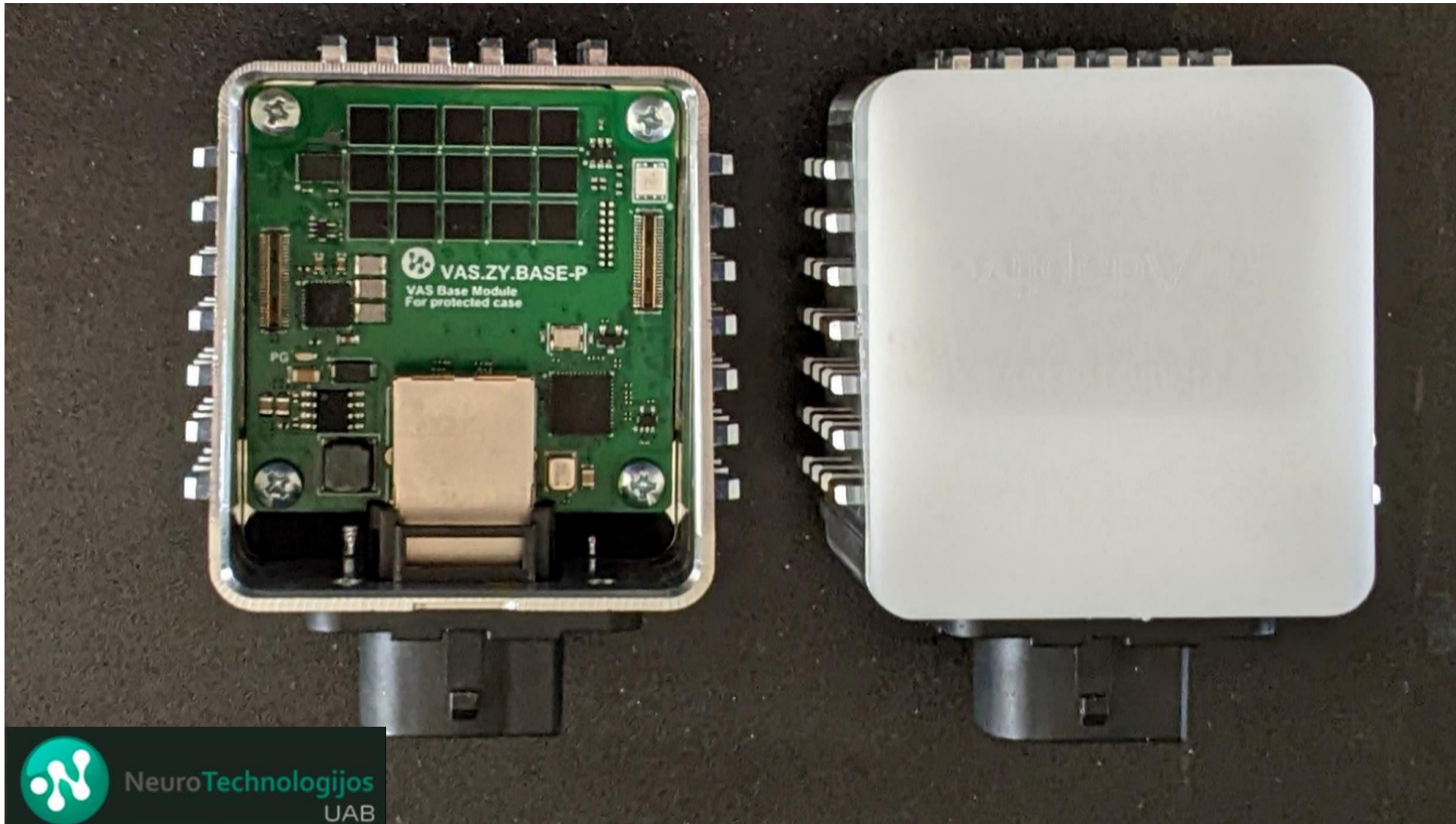
Также, как датчик № 7, 6,
только под кожухом



два варианта крепления
(где будет сподручнее)

Шаровая мельница

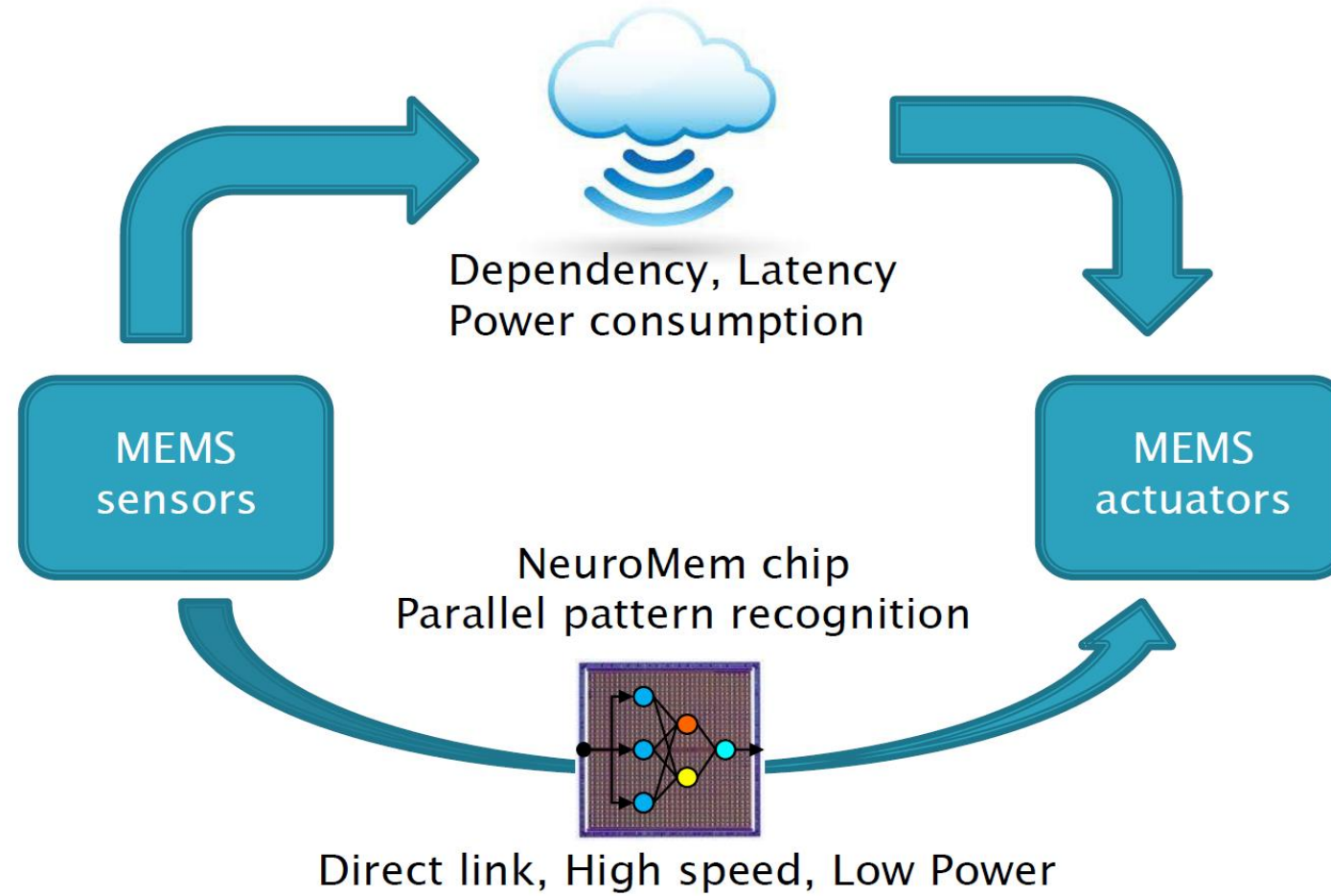






And more at https://general-vision.com/category/post_applications/

The missing brain

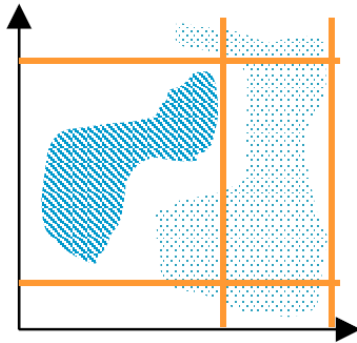


General Vision Inc.

History of classifiers

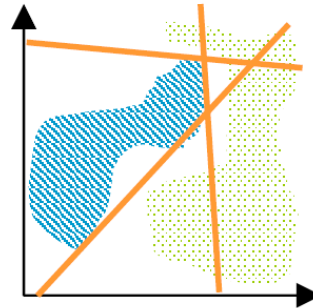
1960: Threshold method

Too simple and not non-linear



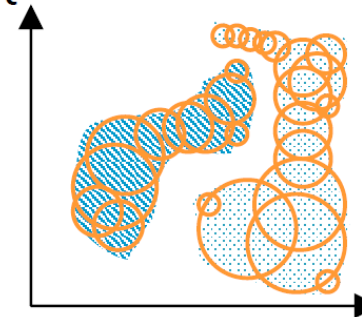
1980: Perceptron method

Too complex,
and time consuming



1990: Radial Basis Function

Map spaces of any shape
with the relevant training
set



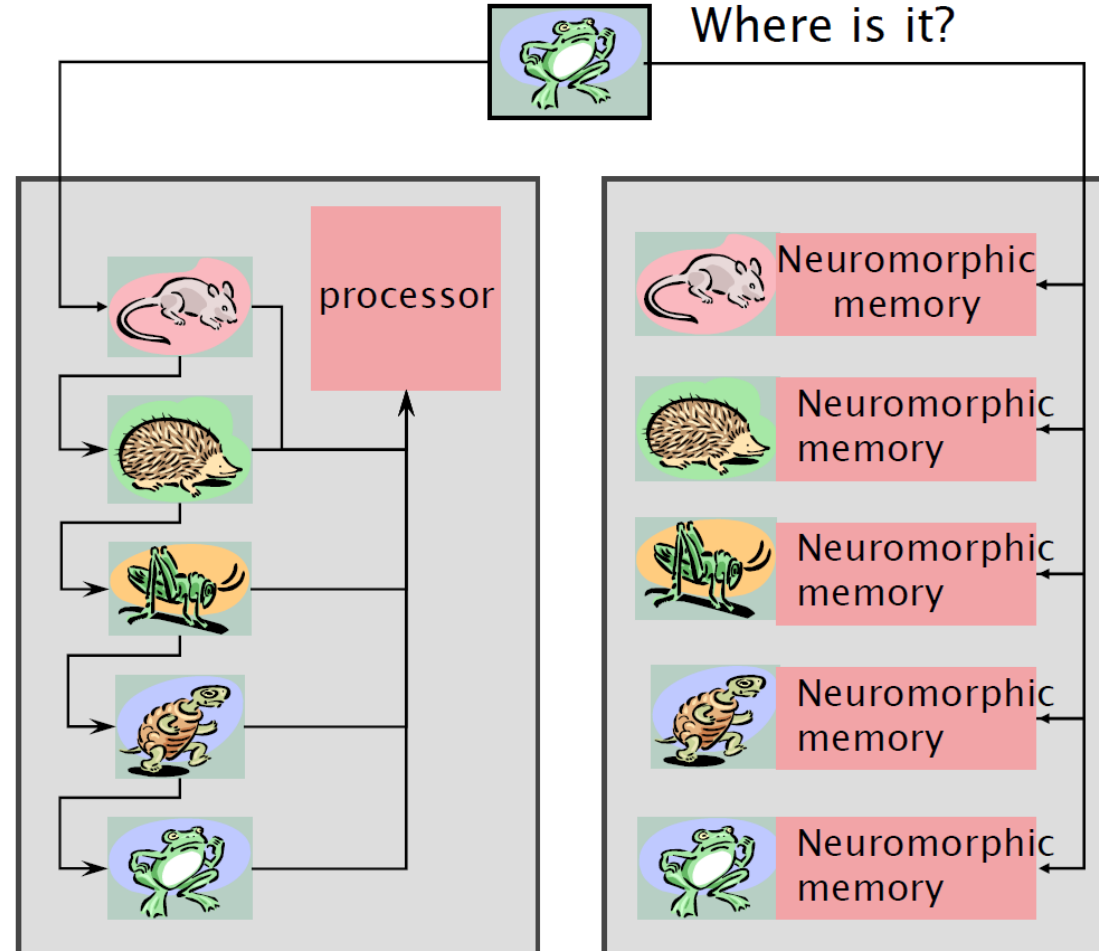
The power of parallelism



CPU/DSP

1 processor for
many memory
entries

Recognition in
N cycles per
entry UNTIL
the right one is
found



NeuroMem

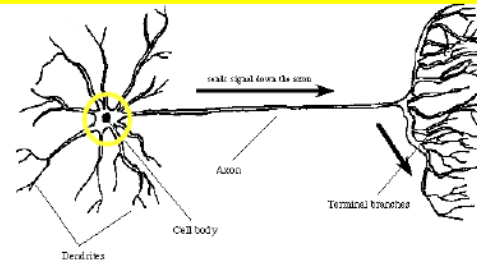
Many memories
with their own
processing unit

Recognition in 16
cycles \forall number
of entries

Biologically inspired...

The brain is a repository of experiences associating **stimuli** to **actuators**

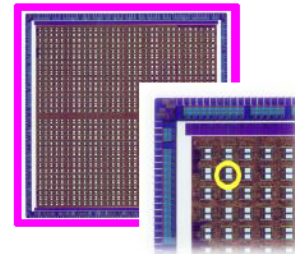
massive parallel wiring!



10 Billions neurons
100 Hz
25 Watts

Patented time domain multiplexing

NeuroMem is a parallel neural network associating **input patterns** to **categories**

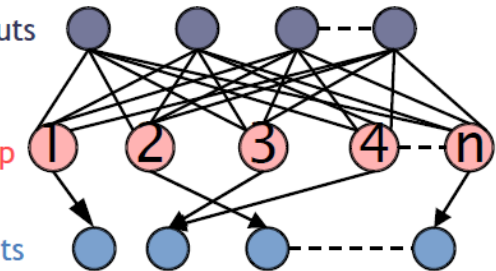


1024 neurons
27 Mhz / 0.5 Watts

256 8-bit inputs

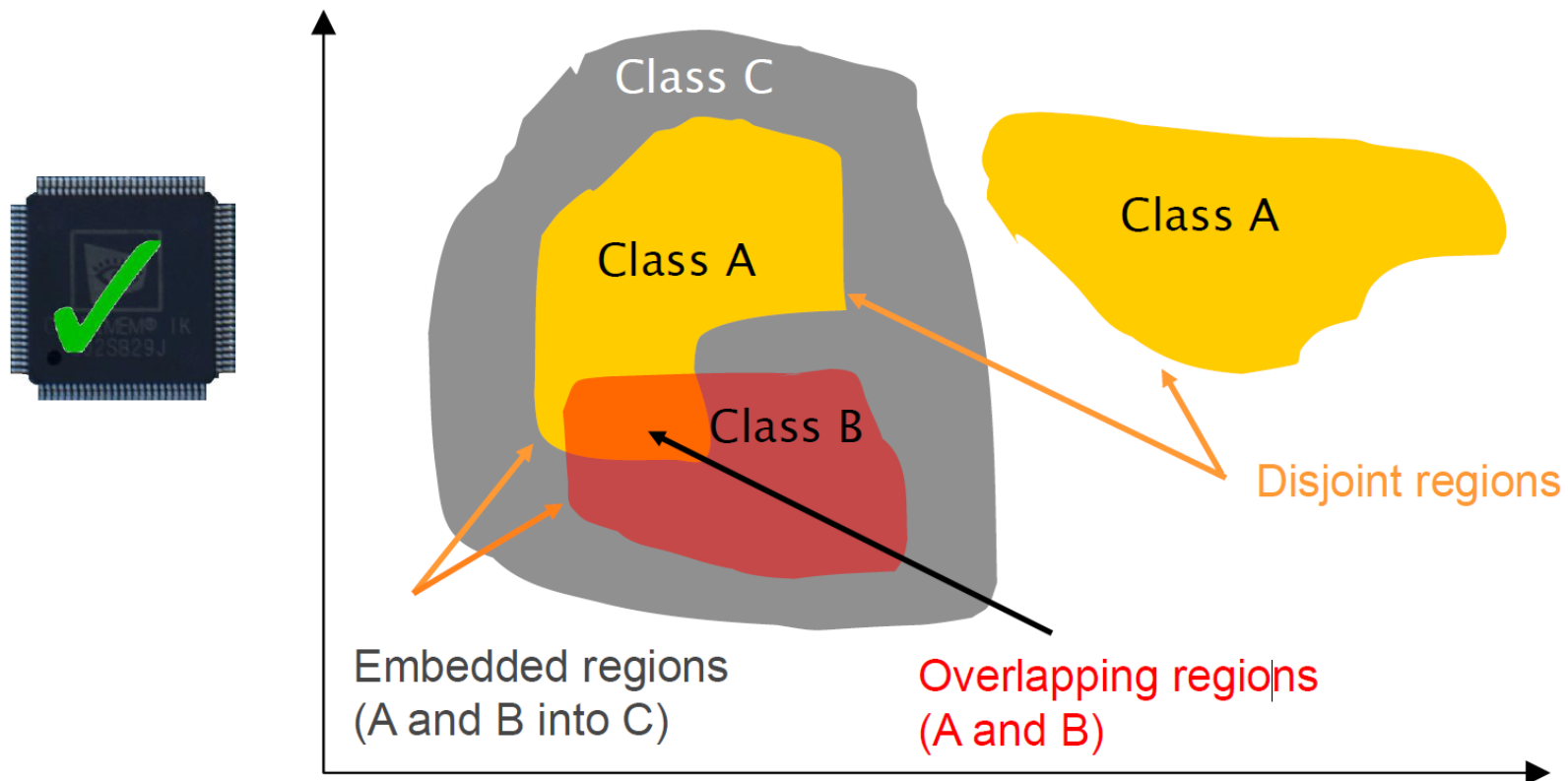
262,144
Synapses/chip
(256 * 1024)

32,766 outputs

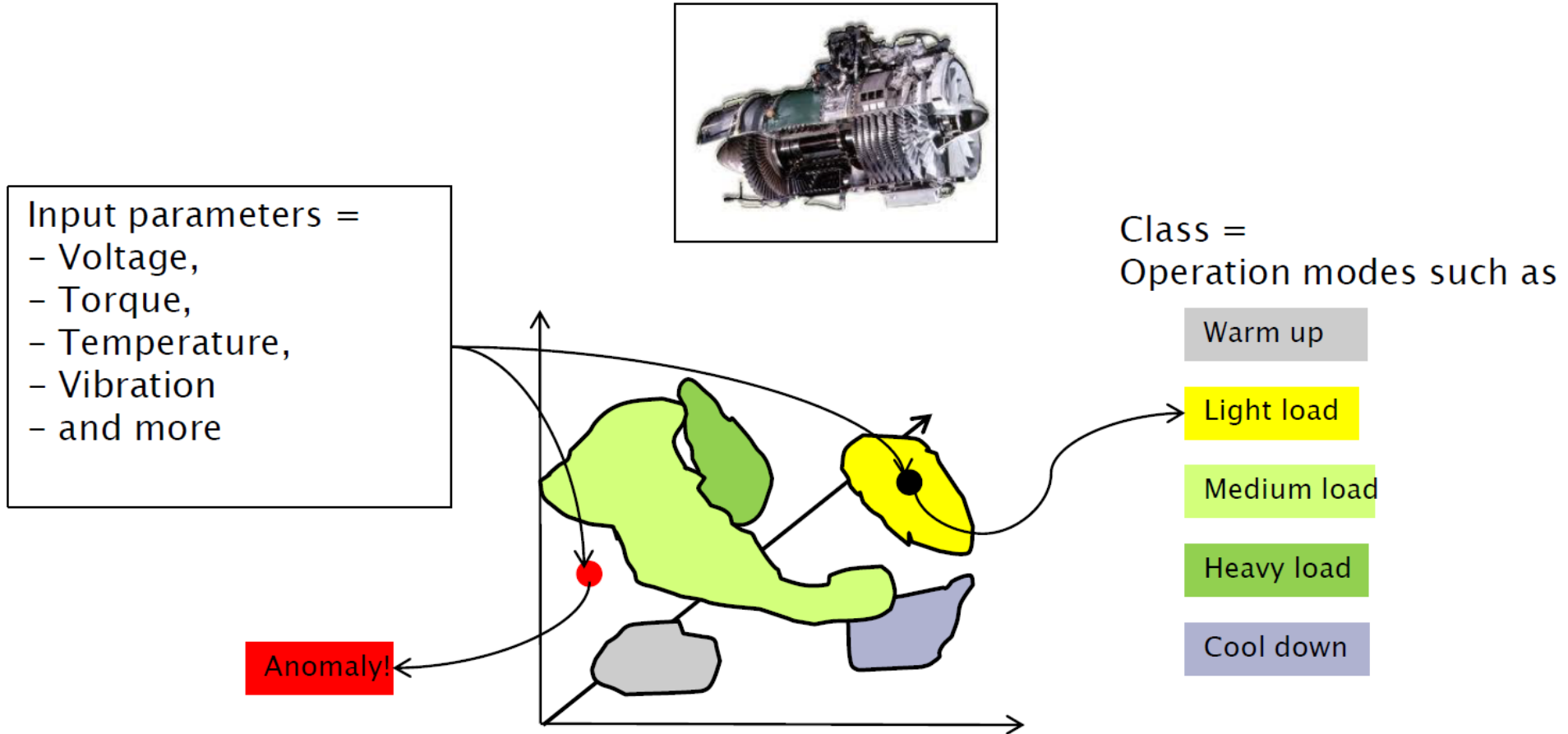


The power of a non-linear classifier

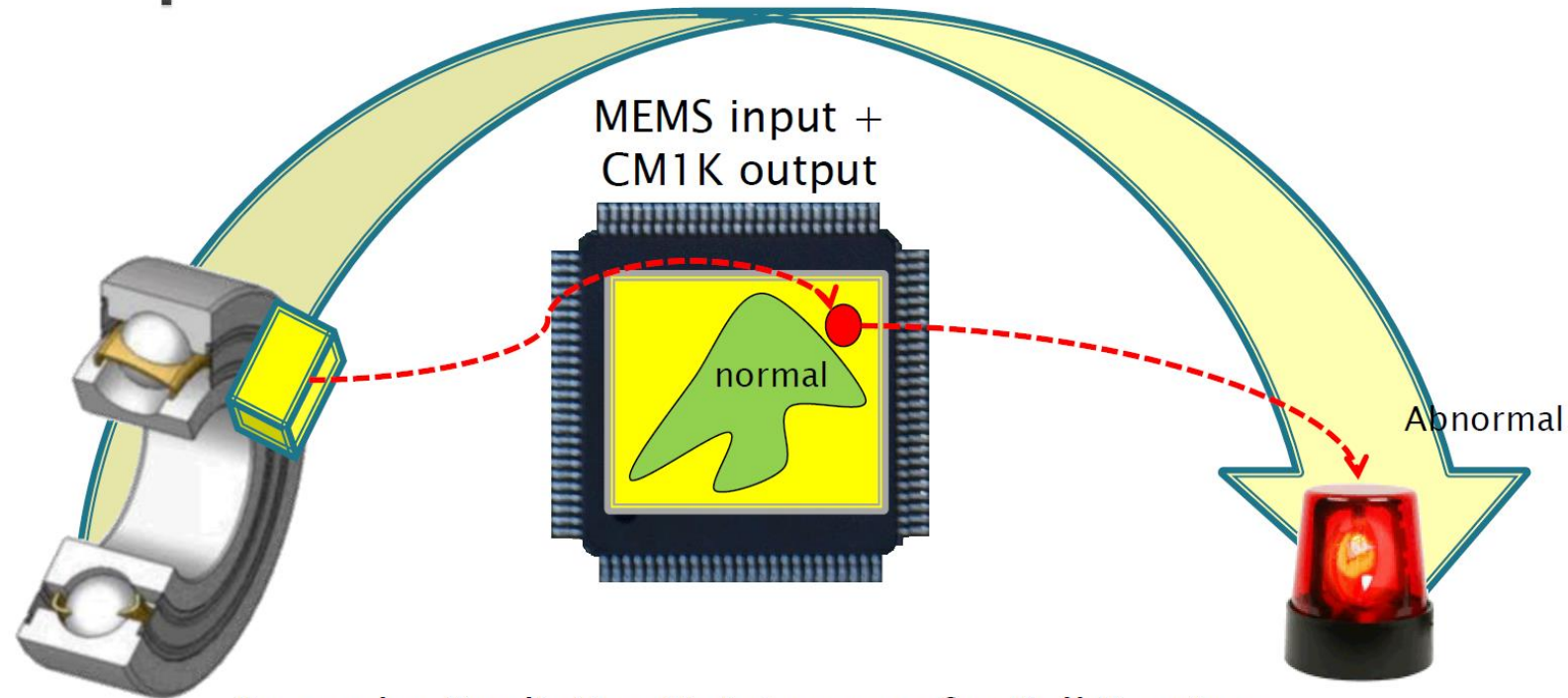
Radial Basis Function to associate and discriminate complex and large datasets



Decision = Non linear classification



The power of small foot print and low power

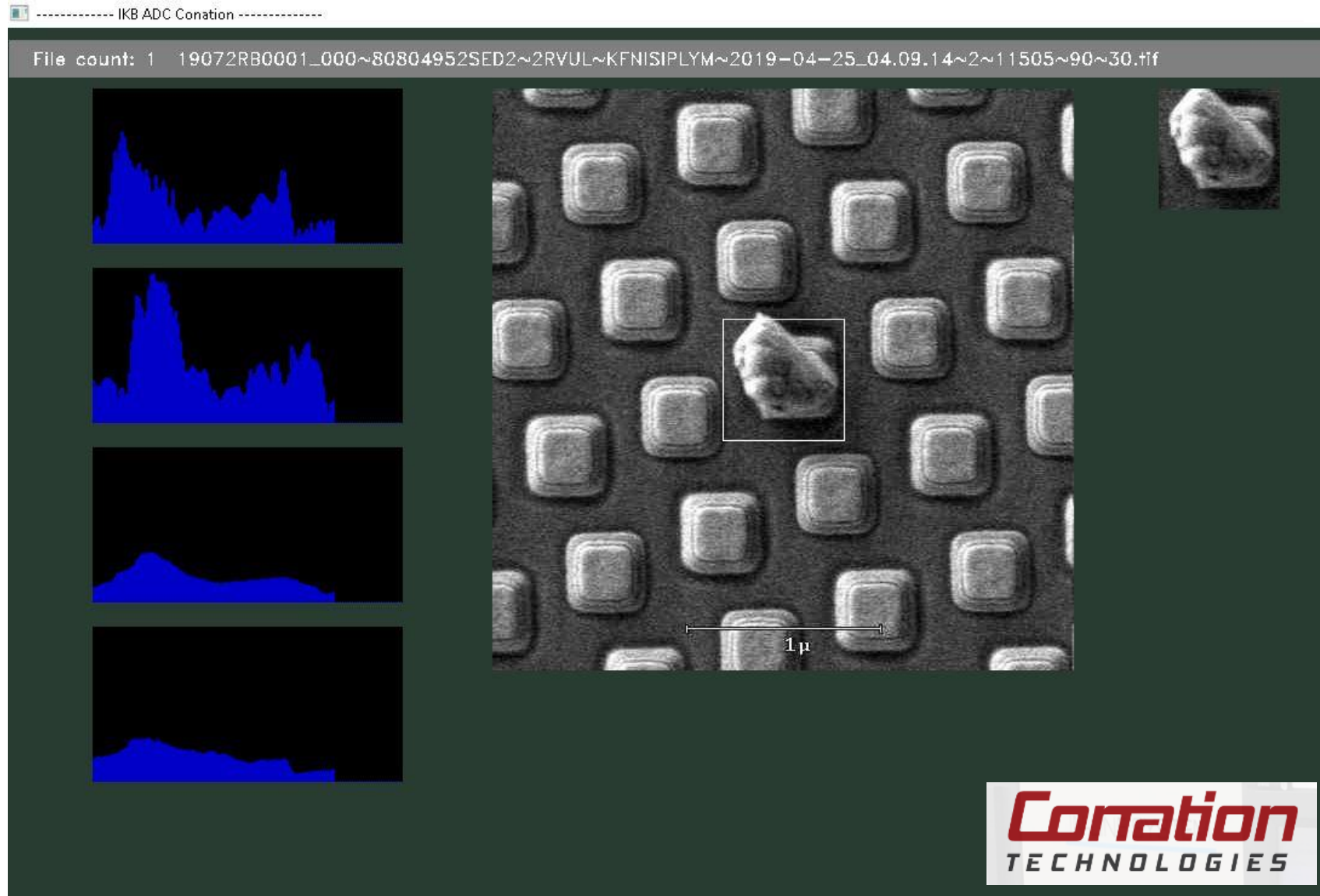


Example: Predictive Maintenance for Ball Bearing

Semi-supervised learning

Logging of abnormal vibrations

Novelties can be reviewed at later time and added to knowledge



Consumer and mobile devices

- ▶ 3D Gesture human machine interface
- ▶ Activity monitoring
- ▶ Blood pressure monitoring
- ▶ Gaze tracking



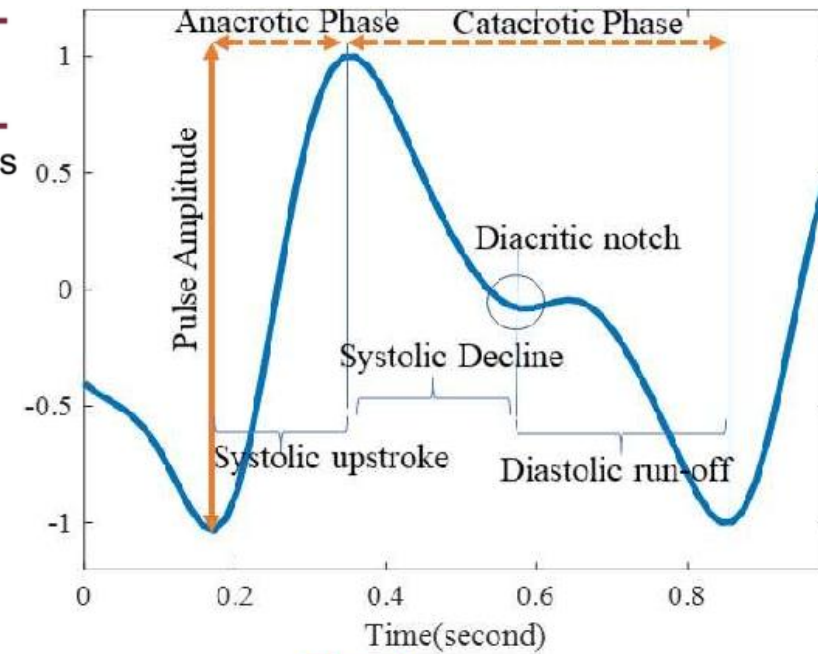
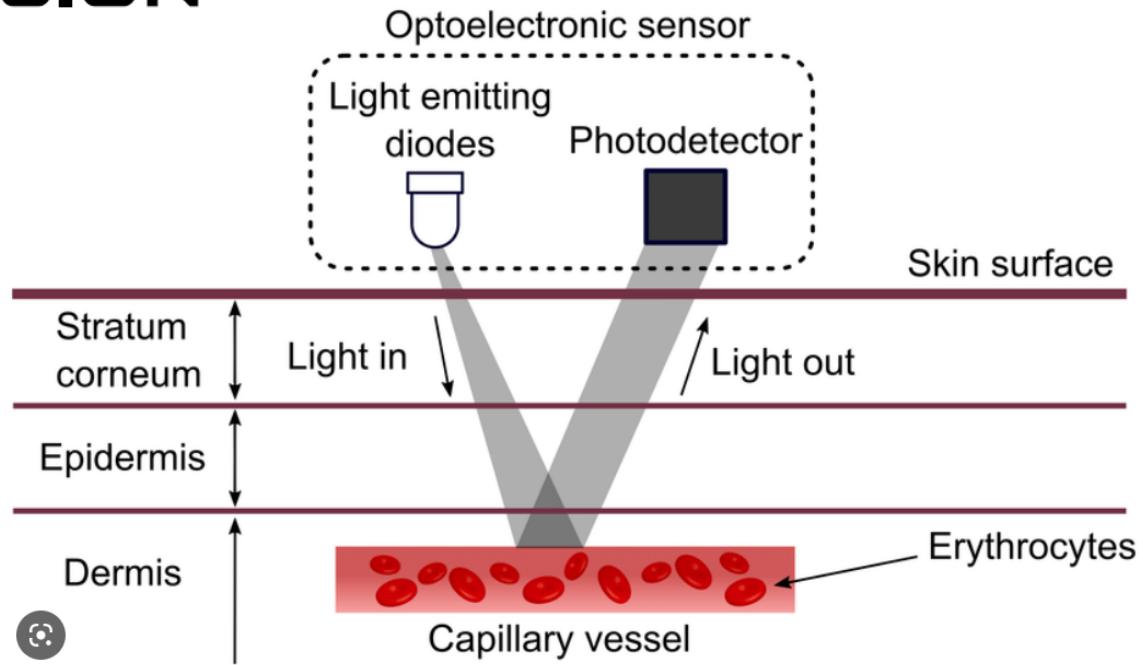
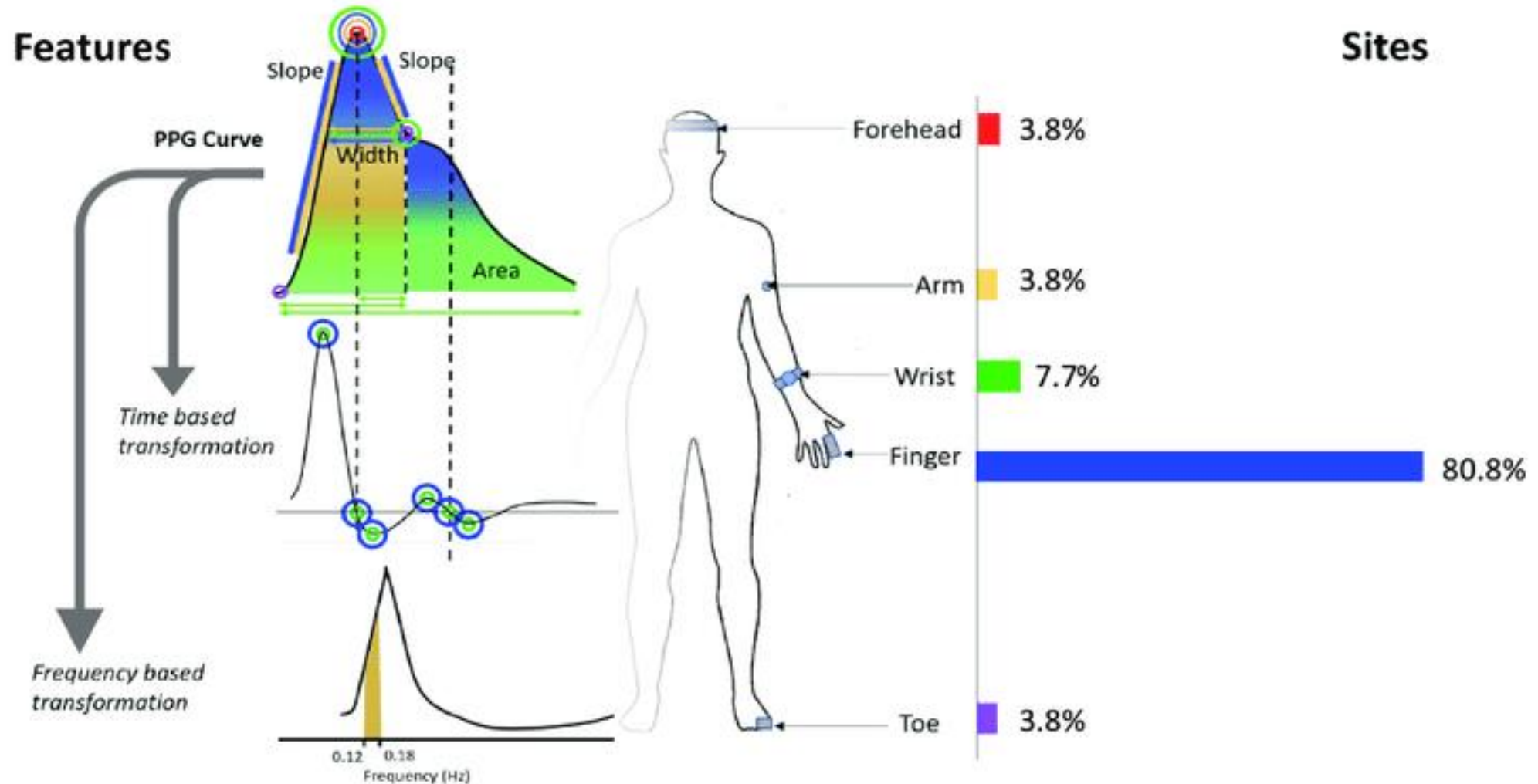
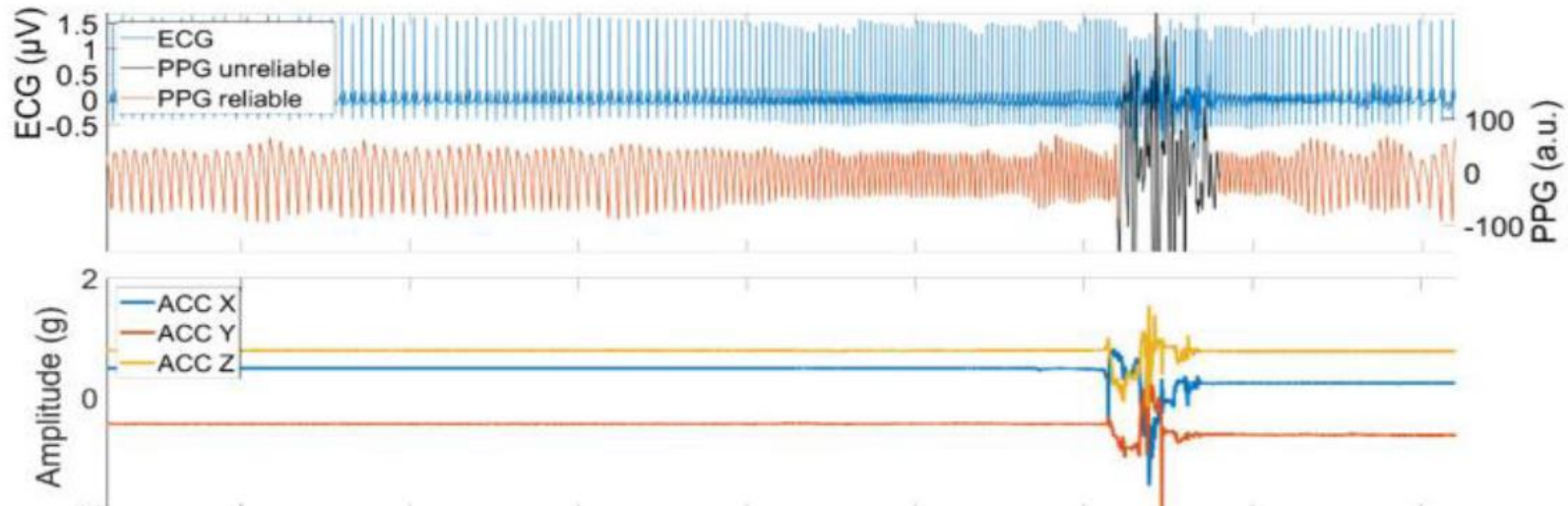
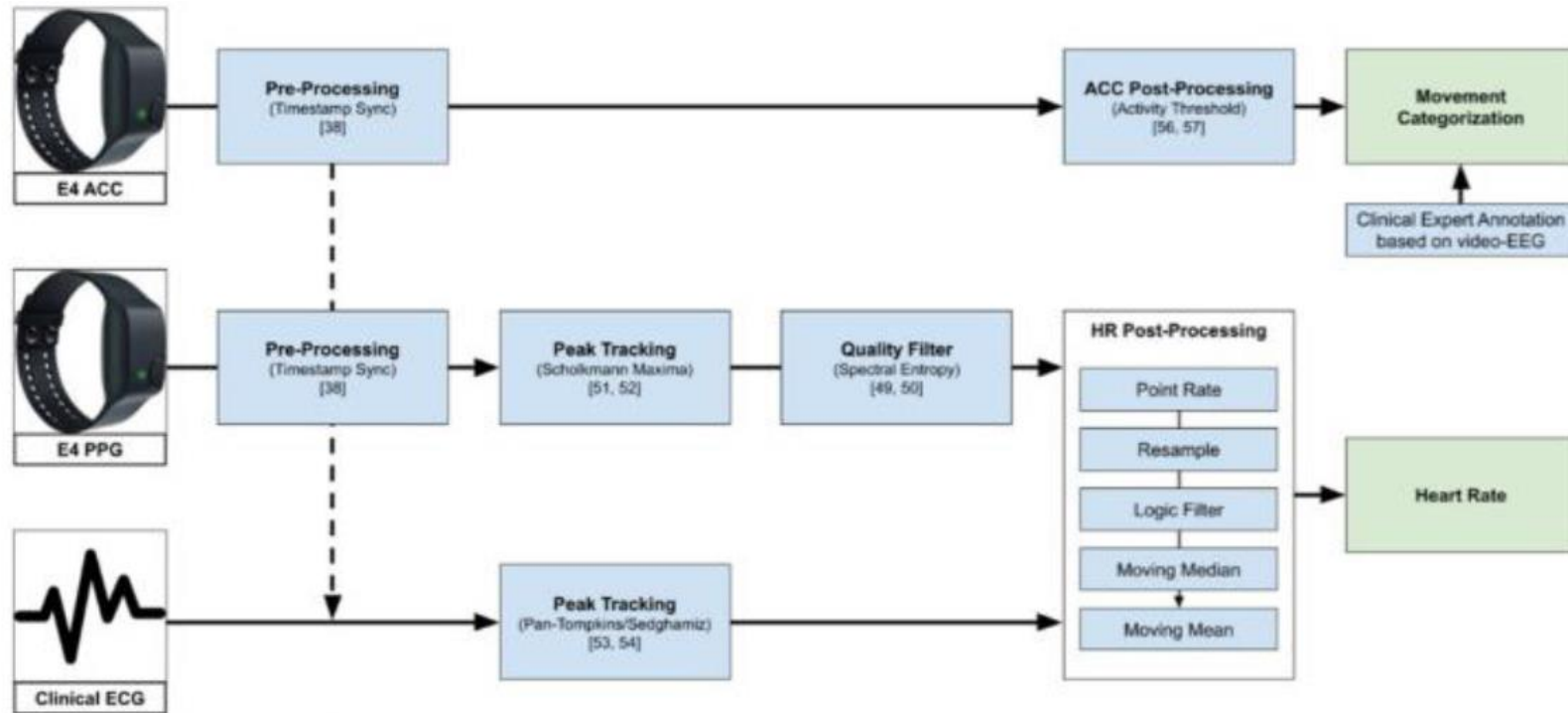


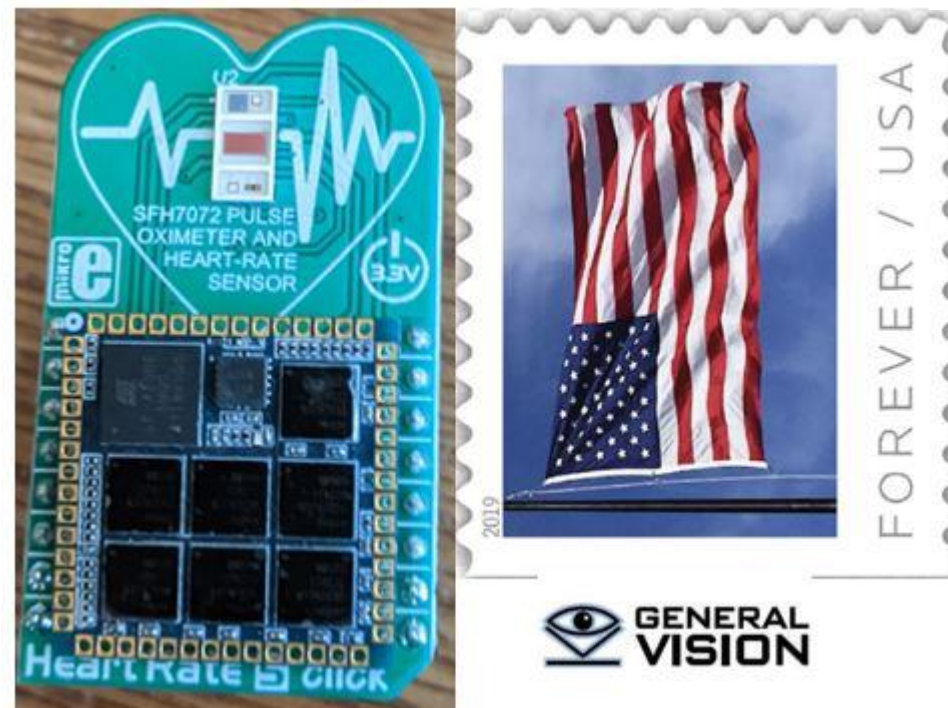
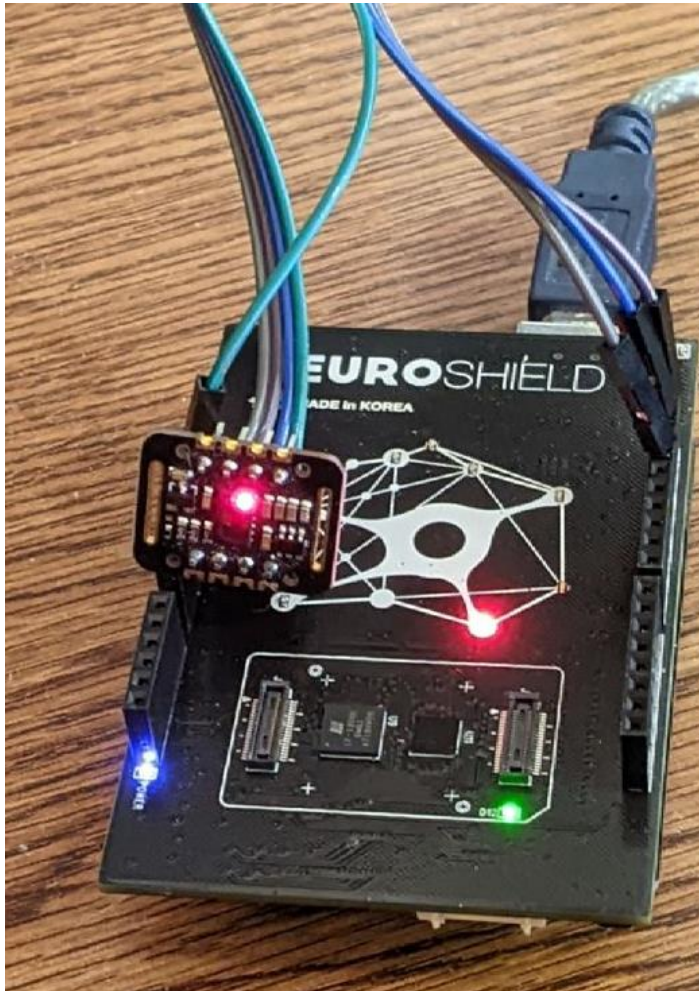
Fig. 1: PPG pulse.

Photoplethysmogram features associated with hypertension

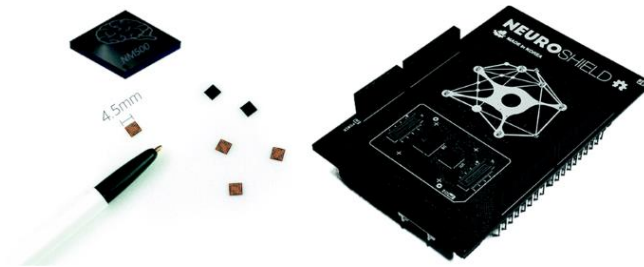
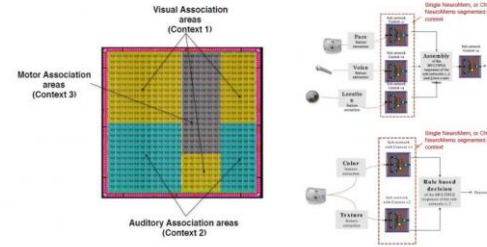
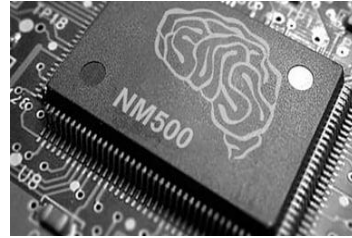
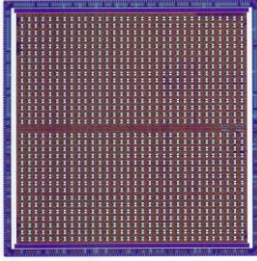
January 2010 - January 2019



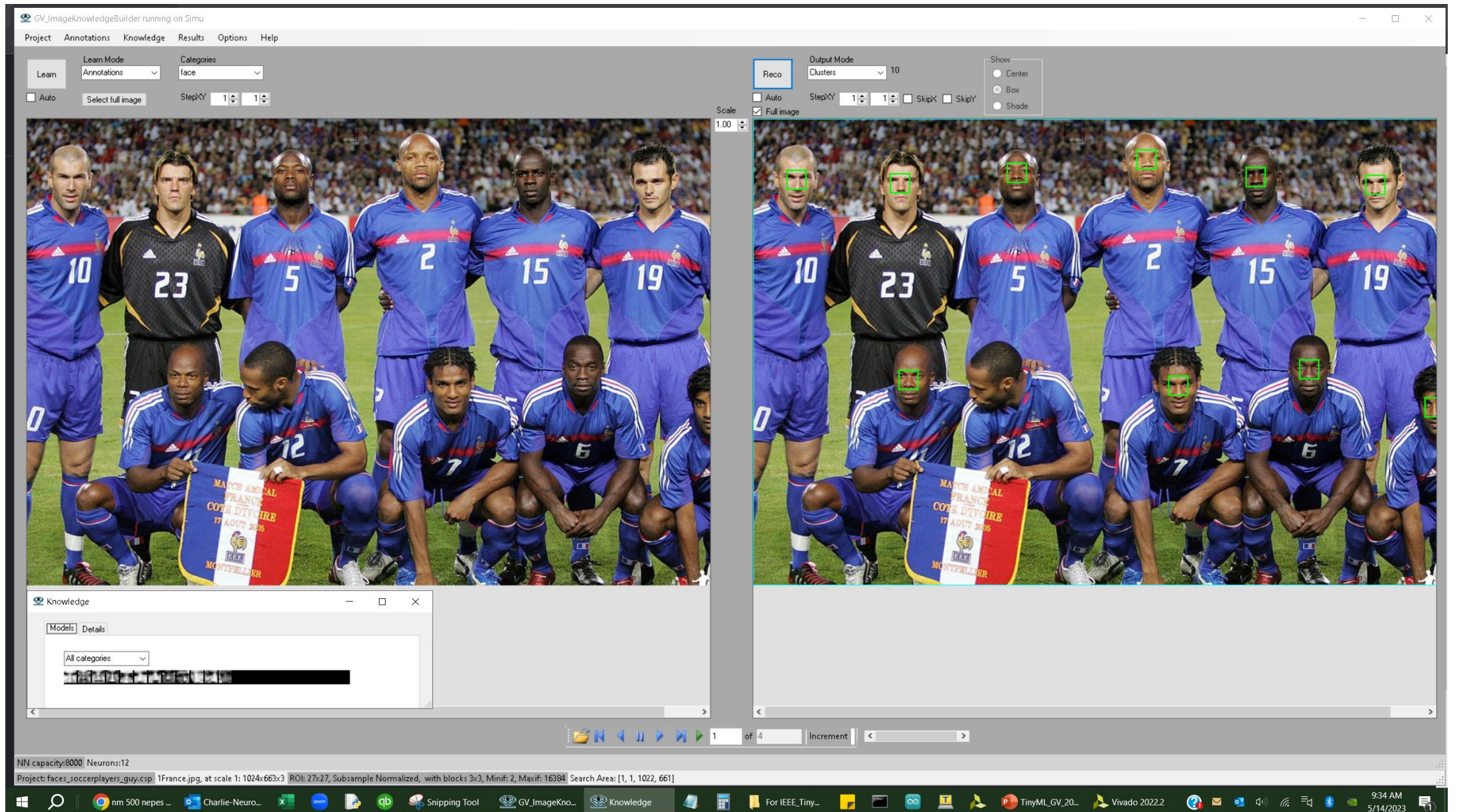


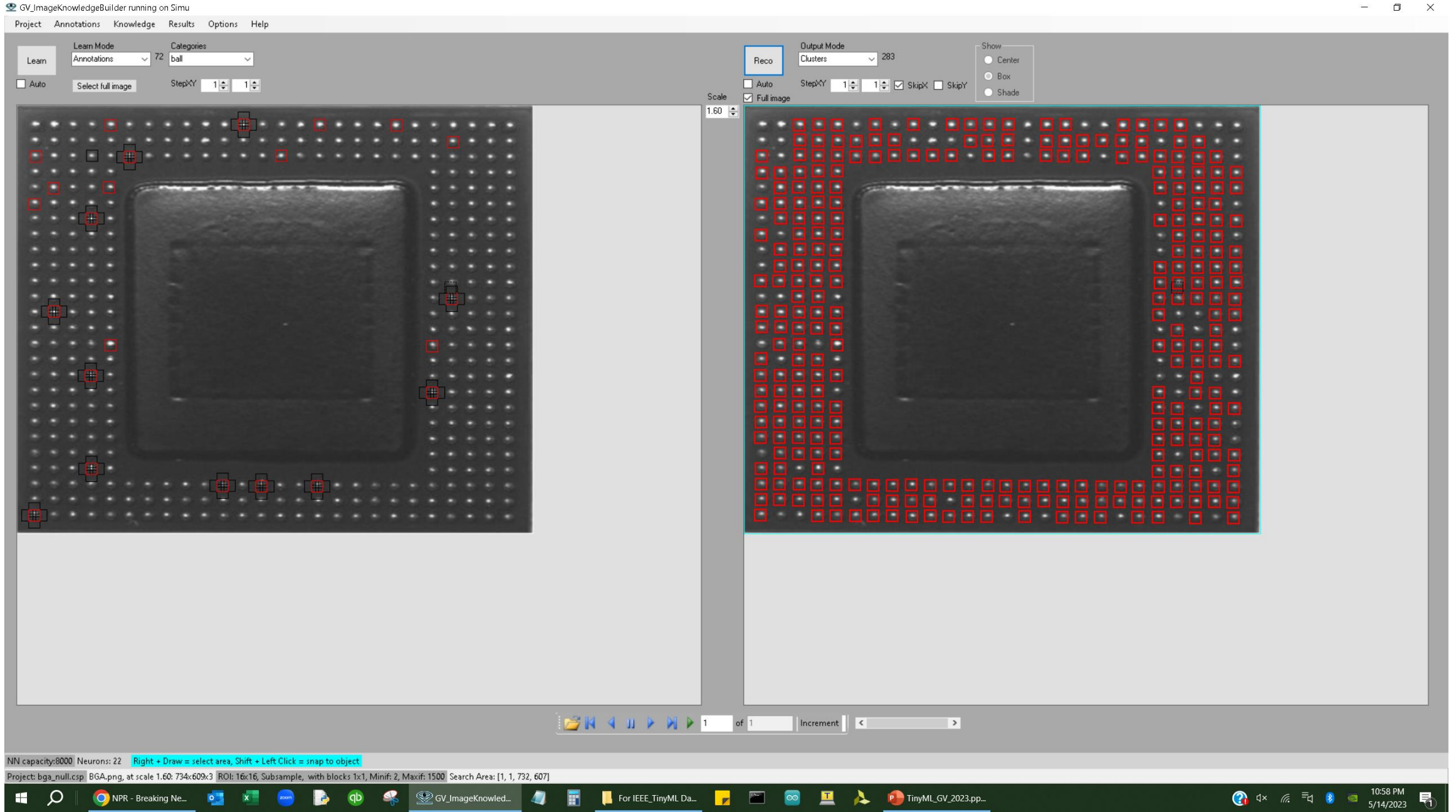


NeuroMem® chips are available TODAY in large volume
 ANM5500 by our licensee Alfaplus (Taiwan)
 NM500 by General Vision (Manufactured by Nepes Korea)



Smallest size chip with
 on chip real time incremental
 Learning capability hardwired
 Rich development tools ecosystem







Silicon Valley / San Francisco!

*After 28 days in the eggs and
five week outside*

*No software, no GPU, minimum energy
They learned real time, incrementally
how to walk, swim, and follow Mom
and Dad by looking at them ...
In a few weeks they will fly miles!!!*

Still a long way to go before
reaching this level of
autonomy with almost no
energy!

Let's be a little realistic about
so called AI achievement!
Thanks to the internet, the
storage and CPU's for the
"hyper-communication"

Courtesy of General Vision





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