tinyML Summit 2021 Proceedings

March 22 – 26, 2021
Virtual Event

www.tinyML.org
Welcome at the 2021 tinyML Summit-Day3!

Evgeni Gousev, Senior Director, Qualcomm AI Research & tinyML Foundation BoD Chair

Marian Verhelst, Summit Chair, Professor KU Leuven/imec & tinyML Foundation BoD

March 25, 2021

www.tinyML.org
tinyML in 2020: Highlights

Focus on building awareness and ecosystem growth

- 4809 meetup members, 1856 LinkedIn, 3320 YouTube channel subscribers
- 49 on-line events globally, 68 speakers, 100+ videos on tinyML YouTube
- 4 days inaugural tinyML Asia 2020, Nov 11-14, 1800 attendees
- tinyML is emerging as a fast growing mainstream
tinyML in 2021: Preview
Focus on interactivity, applications (incl. 4Good) and talent

- **NEW:** tinyML EMEA 2021, June 7-10, on-line but LIVE starting at 8am PDT
- tinyML Asia 2021, October/Nov (TBD) – hopefully in-person in Shanghai
- tinyML Summit 2021, January 22-24, 2022 – most likely in-person in Silicon Valley, CA
- **NEW:** tinyML for Good initiative
  - WG Chaired by Kate Kallot, NVIDIA; Contact: 4Good@tinyML.org
- **NEW:** tinyML Vision Challenge (April 15-August 15): focus on applications
  - Partnership w/ huckster.io; soliciting sponsorships and HW platforms: sponsorships@tinyML.org
- **NEW:** Educational activities
  - WG Chaired by Prof. Vijay Reddy, Harvard Univ; Contact: edu@tinyML.org
- **NEW:** tinyML Application workshops (by verticals) – Fall 2021 (TBD)

Let us know if you/your colleagues are interested in being involved!
tinyML for Good Working Groups

Kate Kallot
Head, Emerging Areas
NVIDIA
kate@tinyML.org

Contact: 4good@tinyML.org
June 7-10, 2021 (virtual, but LIVE)
Deadline for abstracts: May 1

Sponsorships are accepted: sponsorships@tinyML.org
tinyML EMEA-2021 Committee:

**TPC Chair:**
Theocharis Theocharides
Professor, KIOS Center
University of Cyprus

**TPC Co-Chair:**
Peter Debacker
Principal MTS, Group lead
IMEC, Belgium

**General Chair:**
Evgeni Gousev
Senior Director
Qualcomm AI, USA

**Luca Benini**
Professor, ETH Zurich

**Tijmen Blankevoort**
Engineering Manager,
Qualcomm AI Research
Amsterdam

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ARM, Sweden

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Emza V.S., Israel

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University of Cyprus

**Carlo Reita**
Director, Partnerships
CEA-LETI, France

**Andreas Spanias**
Professor, SensSIP Center
ASU, USA

**Marian Velhelst**
Professor, MICAS
KU-Leuven

**Danilo Pao**
ST Microelectronics
Italy
• Venue: Shanghai, China (Plan B – virtual)
• Dates: Oct/Nov 2021 (TBD)
• Targeting 600-800 attendees, if in person
  (inaugural 2020 event was attended by 1800, but on-line)
• Venue: Hyatt (near SFO), Burlingame, Silicon Valley, CA

• Dates: January 22-24, 2022
  • + Tutorials
  • + 2nd tinyML Research Symposium

• Targeting 500-700 attendees (to ensure highest quality and networking value)

• Sponsorships@tinyML.org
THANK YOU Sponsors for the very strong support of the tinyML Summit as a virtual event despite a challenging year.
Executive Sponsors
Arm: The Software and Hardware Foundation for tinyML

1. Connect to high-level frameworks
2. Supported by end-to-end tooling
3. Connect to Runtime

Application

Optimized models for embedded

Runtime (e.g. TensorFlow Lite Micro)

Optimized low-level NN libraries (i.e. CMSIS-NN)

RTOS such as Mbed OS

Arm Cortex-M CPUs and microNPUs

Stay Connected

@ArmSoftwareDevelopers
@ArmSoftwareDev

Resources: developer.arm.com/solutions/machine-learning-on-arm
Advancing AI research to make efficient AI ubiquitous

Power efficiency
- Model design, compression, quantization, algorithms, efficient hardware, software tool

Personalization
- Continuous learning, contextual, always-on, privacy-preserved, distributed learning

Efficient learning
- Robust learning through minimal data, unsupervised learning, on-device learning

Perception
- Object detection, speech recognition, contextual fusion

Reasoning
- Scene understanding, language understanding, behavior prediction

Action
- Reinforcement learning for decision making

A platform to scale AI across the industry

Qualcomm AI Research is an initiative of Qualcomm Technologies, Inc.
NEURAL PROCESSING

- Samsung brings AI in the hands of everyone, with >300M Galaxy phones per year. Fingerprint ID, speech recognition, voice assistant, machine translation, face recognition, AI camera; the application list goes on and on.

- In the heart of AI applications is the NPU, the neural processor that efficiently calculates AI workloads. Samsung NPU is a home grown IP that was employed since 2018 inside Samsung Exynos SoC.

- Samsung NPU is brought by global R&D ecosystem that encompasses US, Korea, Russia, India, and China. In US, we are the fore-runner to guide the future directions of Samsung NPU, by identifying major AI workloads that Samsung’s NPU needs to accelerate in 3-5 years. For this, we collaborate with world-renowned academia research groups in AI and NPU.
Platinum Sponsors
**Eta Compute** creates energy-efficient AI endpoint solutions that enable sensing devices to make autonomous decisions in energy-constrained environments in smart infrastructure and buildings, consumer, medical, retail, and a diverse range of IoT applications.

[www.etacompute.com](http://www.etacompute.com)
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AKIDA™ Neuromorphic Technology: Inspired by the Spiking Nature of the Human Brain

• Supports ultra-low power applications (microwatts to milliwatts)
• Edge capabilities: on-chip training, learning, and inference
• Designed for AI Edge applications: vision, audio, olfactory, and smart transducer applications
• Licensed as IP to be designed into SoC or as silicon
• Sensor inputs are analyzed at the point of acquisition rather than through transmission via the cloud to the data center. Enables real time response for power-efficient systems
• Software Development Platform
BabbleLabs AI speech wizardry in Cisco Webex

AI meets speech - deep experience in speech science, AI/ML, embedded systems

- Massive compute
- Novel deep neural networks
- Massive data corpus
  - 300 TFLOPS per engineer
  - Silicon-optimized software
  - 40K hours of speech
  - 15K hours of music
  - 10K hour of noise
  - 100K room models

Applications:
- Speech enhancement
- Speech recognition
- Conferencing
- Call centers
- Digital Assistants
- Calling
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TinyML for all developers

**Dataset**
- Acquire valuable training data securely
- Enrich data and train ML algorithms

**Edge Device**
- Real sensors in real time
- Open source SDK
- Embedded and edge compute deployment options

**Impulse**
- Test impulse with real-time device data flows

**Test**
- Acquire valuable training data securely
- Enrich data and train ML algorithms
- Test impulse with real-time device data flows

www.edgeimpulse.com
The Eye in IoT

Edge AI Visual Sensors

- Machine Learning algorithm
- <1MB memory footprint
- Microcontrollers computing power
- Trained algorithm
- Processing of low-res images
- Human detection and other classifiers

CMOS Imaging Sensor
- Ultra Low power CMOS imager
- Ai + IR capable

IoT System on Chip
- Machine Learning edge computing silicon
- <1mW always-on power consumption
- Computer Vision hardware accelerators

info@emza-vs.com
GrAI Matter Labs has created an AI Processor for use in edge devices like drones, robots, surveillance cameras, and more that require real-time intelligent response at low power. Inspired by the biological brain, its computing architecture utilizes sparsity to enable a design which scales from tiny to large-scale machine learning applications.

www.graimatterlabs.ai
Enabling the next generation of **Sensor and Hearable products** to process rich data with energy efficiency

- **Visible Image**
- **Sound**
- **IR Image**
- **Radar**
- **Bio-sensor**
- **Gyro/Accel**

**Wearables / Hearables**

**Battery-powered consumer electronics**

**IoT Sensors**
Himax Technologies, Inc. provides semiconductor solutions specialized in computer vision. Himax’s WE-I Plus, an AI accelerator-embedded ASIC platform for ultra-low power applications, is designed to deploy CNN-based machine learning (ML) models on battery-powered AIoT devices. These end-point AI platforms can be always watching, always sensing, and always listening with on-device event recognition.

Imagimob AI SaaS

• End-to-end development of tinyML applications
• Guides and empowers users through the process
• Support for high accuracy applications requiring low power and small memory
• Imagimob AI have been used in 25+ tinyML customer projects
• Gesture control
Adaptive AI for the Intelligent Edge
Health sensors measure PPG and ECG signals critical to understanding vital signs. Signal chain products enable measuring even the most sensitive signals.

Advanced AI Acceleration IC

Low Power Cortex M4 Micros

Sensors and Signal Conditioning
Qeexo AutoML
Automated Machine Learning Platform that builds tinyML solutions for the Edge using sensor data

Key Features

- Supports 17 ML methods:
  - Multi-class algorithms: GBM, XGBoost, Random Forest, Logistic Regression, Gaussian Naive Bayes, Decision Tree, Polynomial SVM, RBF SVM, SVM, CNN, RNN, CRNN, ANN
  - Single-class algorithms: Local Outlier Factor, One Class SVM, One Class Random Forest, Isolation Forest
- Labels, records, validates, and visualizes time-series sensor data
- On-device inference optimized for low latency, low power consumption, and small memory footprint applications
- Supports Arm® Cortex™- M0 to M4 class MCUs

End-to-End Machine Learning Platform

For more information, visit: www.qeexo.com

Target Markets/Applications

- Industrial Predictive Maintenance
- Smart Home
- Wearables
- Automotive
- Mobile
- IoT
Add Advanced Sensing to your Product with Edge AI / TinyML

Pre-built Edge AI sensing modules, plus tools to build your own

Reality AI solutions
- Prebuilt sound recognition models for indoor and outdoor use cases
- Solution for industrial anomaly detection
- Pre-built automotive solution that lets cars “see with sound”

Reality AI Tools® software
- Build prototypes, then turn them into real products
- Explain ML models and relate the function to the physics
- Optimize the hardware, including sensor selection and placement

https://reality.ai  info@reality.ai  @SensorAI  Reality AI
Build Smart IoT Sensor Devices From Data

SensiML pioneered TinyML software tools that auto generate AI code for the intelligent edge.

- End-to-end AI workflow
- Multi-user auto-labeling of time-series data
- Code transparency and customization at each step in the pipeline

We enable the creation of production-grade smart sensor devices.
Silicon Labs (NASDAQ: SLAB) provides silicon, software and solutions for a smarter, more connected world. Our technologies are shaping the future of the Internet of Things, Internet infrastructure, industrial automation, consumer and automotive markets. Our engineering team creates products focused on performance, energy savings, connectivity, and simplicity. silabs.com
Syntiant Corp. is moving artificial intelligence and machine learning from the cloud to edge devices. Syntiant’s chip solutions merge deep learning with semiconductor design to produce ultra-low-power, high performance, deep neural network processors. These network processors enable always-on applications in battery-powered devices, such as smartphones, smart speakers, earbuds, hearing aids, and laptops. Syntiant's Neural Decision Processors™ offer wake word, command word, and event detection in a chip for always-on voice and sensor applications.

Founded in 2017 and headquartered in Irvine, California, the company is backed by Amazon, Applied Materials, Atlantic Bridge Capital, Bosch, Intel Capital, Microsoft, Motorola, and others. Syntiant was recently named a CES® 2021 Best of Innovation Awards Honoree, shipped over 10M units worldwide, and unveiled the NDP120 part of the NDP10x family of inference engines for low-power applications.

www.syntiant.com

@Syntiantcorp
TensorFlow is an end-to-end open source platform for machine learning. Our ecosystem of tools, libraries, and community resources help users push the state-of-the-art in building and deploying ML powered applications.
JOIN OUR SESSIONS DURING THE TINYML SUMMIT

Performing inference on BNNs with xcore.ai
Tuesday, March 23 at 12pm (PST)

TinyML: The power/cost conundrum
Thursday, March 25 at 12pm (PST)

VISIT XMOS.AI TO FIND OUT MORE
Silver Sponsors

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HOTG

SynSense
tinyML Foundation support and organization

Ira Feldman
Managing Director
ira@tinyML.org

Bette Cooper
Event Organizer
bette@tinyML.org

Rosina Haberl
Social Media
rosina@tinyML.org

Olga Goremichina
Meetups and Talks
olga@tinyML.org
Huge THANK YOU to tinyML Summit 2021 Org. Committee
What is tinyML?

tinyML enables machine intelligence **right next** to the physical world

tinyML - most energy efficient
- metadata/privacy by design
- best/fast latency
- no connectivity issues
tinyML enabled **DEVICES ($)** – near-term forecast

- $60B market by 2024 (devices only)
- 41% CAGR growth

Source: Pitchbook, Emerging Tech, IoT, 2H-2020
## tinyML 2021

<table>
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<th>2021 Summit (March 2021)</th>
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<td>Attendees</td>
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<td>Companies</td>
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tinyML Summit 2021 by numbers

- **5** days of tutorials, talks, panels, breakouts, symposium
  - **4** tutorials
  - **6** keynotes & **6** plenary tinyTalks (more in breakouts)
  - **2** panel discussions
  - **5** disruptive news presentations
  - **17** breakout/partner sessions
  - **6** Best Product and Innovation Award Finalists & Presentations

- **69** speakers, **5000+** registered attendees from **99** countries!
Thank you to all tinyML Summit 2021 Speakers and Panelists
### tinyML summit week

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<th>Monday</th>
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<td>tinyML outlook</td>
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<td>VC panel</td>
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# tinyML keynotes

## Tuesday

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<th>Time</th>
<th>Speaker</th>
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<tr>
<td>8.15-9.00am</td>
<td>Keynote: Song Han (MIT)</td>
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<td>9.00am-9.45am</td>
<td>Keynote: Luca Benini (ETHz)</td>
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## Wednesday

- Keynote: Diana Marculescu (UTexas)
- Keynote: Sek Chai (Latent AI)

## Thursday

- Keynote: Vikas Chandra (Facebook Reality Labs)
- Keynote: Mohammad Rastegari (Apple)
# tinyML summit week

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tinyML disruptive news – *Thursday*

a small number of time slots for companies / experts to share the very latest substantial and disruptive developments and upcoming products of significance in the field of tiny machine learning.

**Breaking News on Disruptive Products and Tools**

Sean MCGREGOR, Member of Technical Staff, Syntiant

Ravishankar SIVALINGAM, Sr. Staff Engineer/Manager, Qualcomm

Jan JONGBOOM, CTO, Edge Impulse

Meng LI, Senior AI Research Scientist, Facebook Inc.

Harsha VISWANATH, Principal AI Technical Leader - Azure Edge Device, Platform and Solutions Group, Microsoft
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Inaugural tinyML Research Symposium (March 26)
Edu@tinyML Foundation: Educational initiative and WG

Charter and some activities (under discussion):

- Training Courses
- HW starter kits
- Teaching future teachers
- Publications
- Research Symposium
- Summer schools
- Interactions with NSF and similar (and funding) organizations globally
- K12 and STEM
- Strong synergy with 4good@tinyML.org and tinyML Vision Challenge
- Sharing best educational practices, globally
- Academia to Industry partnership, Jobs-Jobs-Jobs in tinyML

Contact: edu@tinyML.org
Housekeeping: Eventee platform and WebEx meetings

1. Ask your question and vote here:

2. Provide feedback/comments and rating after presentation here:

3. Join parallel breakout meeting-style sessions on Cisco WebEx from Eventee here:
Massive tinyML opportunities in all verticals where machine intelligence meets physical world of billions of sensors.
Join Growing tinyML Communities:

**Meetup**
tinyML - Enabling ultra-low Power ML at the Edge

**LinkedIn**
The tinyML Community
https://www.linkedin.com/groups/13694488/

**YouTube**
The tinyML Channel
https://www.youtube.com/tinyML
We thank the authors for their presentations and everyone who participated in the tinyML Summit 2021.

Along with a special thank you to the sponsors who made this event possible!
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Arm: The Software and Hardware Foundation for tinyML

1. Connect to high-level frameworks
2. Supported by end-to-end tooling
3. Connect to Runtime

- Profiling and debugging tooling such as Arm Keil MDK
- Optimized models for embedded (e.g. TensorFlow Lite Micro)
- Runtime (e.g. Tensorflow Lite Micro)
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Advancing AI research to make efficient AI ubiquitous

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[www.etascompute.com](http://www.etascompute.com)
Lattice Semiconductor (NASDAQ: LSCC) is the low power programmable leader. We solve customer problems across the network, from the Edge to the Cloud, in the growing communications, computing, industrial, automotive and consumer markets. Our technology, relationships, and commitment to support lets our customers unleash their innovation to create a smart, secure and connected world. www.Latticesemi.com.
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Cisco Webex
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IoT System on Chip
- Machine Learning edge computing silicon
- <1mW always-on power consumption
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Computer Vision Algorithms
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- Processing of low-res images
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www.graimatterlabs.ai
Enabling the next generation of **Sensor and Hearable products** to process rich data with energy efficiency

Visible Image

Sound

IR Image

Radar

Bio-sensor

Gyro/Accel

Wearables / Hearables

Battery-powered consumer electronics

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Imagimob AI SaaS

- End-to-end development of tinyML applications
- Guides and empowers users through the process
- Support for high accuracy applications requiring low power and small memory
- Imagimob AI have been used in 25+ tinyML customer projects
- Gesture control
LatentAI

Adaptive AI for the Intelligent Edge

Latentai.com
Health sensors measure PPG and ECG signals critical to understanding vital signs. Signal chain products enable measuring even the most sensitive signals.

www.maximintegrated.com/MAX78000

The new MAX78000 implements AI inferences at low energy levels, enabling complex audio and video inferencing to run on small batteries. Now the edge can see and hear like never before.

www.maximintegrated.com/microcontrollers

Large (3MB flash + 1MB SRAM) and small (256KB flash + 96KB SRAM, 1.6mm x 1.6mm) Cortex M4 microcontrollers enable algorithms and neural networks to run at wearable power levels.

www.maximintegrated.com/sensors
Qeexo AutoML

Automated Machine Learning Platform that builds tinyML solutions for the Edge using sensor data

Key Features

- Supports 17 ML methods:
  - Multi-class algorithms: GBM, XGBoost, Random Forest, Logistic Regression, Gaussian Naive Bayes, Decision Tree, Polynomial SVM, RBF SVM, SVM, CNN, RNN, CRNN, ANN
  - Single-class algorithms: Local Outlier Factor, One Class SVM, One Class Random Forest, Isolation Forest
- Labels, records, validates, and visualizes time-series sensor data
- On-device inference optimized for low latency, low power consumption, and small memory footprint applications
- Supports Arm® Cortex™- M0 to M4 class MCUs

End-to-End Machine Learning Platform

Target Markets/Applications

- Industrial Predictive Maintenance
- Smart Home
- Wearables
- Automotive
- Mobile
- IoT

For more information, visit: www.qeexo.com
Add Advanced Sensing to your Product with Edge AI / TinyML

Pre-built Edge AI sensing modules, plus tools to build your own

Reality AI solutions
- Prebuilt sound recognition models for indoor and outdoor use cases
- Solution for industrial anomaly detection
- Pre-built automotive solution that lets cars "see with sound"

Reality AI Tools® software
- Build prototypes, then turn them into real products
- Explain ML models and relate the function to the physics
- Optimize the hardware, including sensor selection and placement

https://reality.ai  info@reality.ai  @SensorAI  Reality AI
Build Smart IoT Sensor Devices From Data

SensiML pioneered TinyML software tools that auto generate AI code for the intelligent edge.

- End-to-end AI workflow
- Multi-user auto-labeling of time-series data
- Code transparency and customization at each step in the pipeline

We enable the creation of production-grade smart sensor devices.
Silicon Labs (NASDAQ: SLAB) provides silicon, software and solutions for a smarter, more connected world. Our technologies are shaping the future of the Internet of Things, Internet infrastructure, industrial automation, consumer and automotive markets. Our engineering team creates products focused on performance, energy savings, connectivity, and simplicity. silabs.com
Syntiant Corp. is moving artificial intelligence and machine learning from the cloud to edge devices. Syntiant’s chip solutions merge deep learning with semiconductor design to produce ultra-low-power, high performance, deep neural network processors. These network processors enable always-on applications in battery-powered devices, such as smartphones, smart speakers, earbuds, hearing aids, and laptops. Syntiant's Neural Decision Processors™ offer wake word, command word, and event detection in a chip for always-on voice and sensor applications.

Founded in 2017 and headquartered in Irvine, California, the company is backed by Amazon, Applied Materials, Atlantic Bridge Capital, Bosch, Intel Capital, Microsoft, Motorola, and others. Syntiant was recently named a CES® 2021 Best of Innovation Awards Honoree, shipped over 10M units worldwide, and unveiled the NDP120 part of the NDP10x family of inference engines for low-power applications.

www.syntiant.com  @Syntiantcorp
TensorFlow is an end-to-end open source platform for machine learning. Our ecosystem of tools, libraries, and community resources help users push the state-of-the-art in building and deploying ML powered applications.
A DEEP TECH COMPANY AT THE LEADING EDGE OF THE AIOT

JOIN OUR SESSIONS DURING THE TINYML SUMMIT

Performing inference on BNNs with xcore.ai
Tuesday, March 23 at 12pm (PST)

TinyML: The power/cost conundrum
Thursday, March 25 at 12pm (PST)

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