“Practical TinyML for industrial safety and personnel performance monitoring”

Oleg Puzanov - Leantegra

December 20, 2021
tinyML Talks Strategic Partners

Additional Sponsorships available – contact Olga@tinyML.org for info
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

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

AI Ecosystem Partners

Stay Connected

@ArmSoftwareDevelopers

@ArmSoftwareDev

Resources: developer.arm.com/solutions/machine-learning-on-arm

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WE USE AI TO MAKE OTHER AI FASTER, SMALLER AND MORE POWER EFFICIENT

Automatically compress SOTA models like MobileNet to <200KB with little to no drop in accuracy for inference on resource-limited MCUs.

Reduce model optimization trial & error from weeks to days using Deeplite's design space exploration.

Deploy more models to your device without sacrificing performance or battery life with our easy-to-use software.

BECOME BETA USER bit.ly/testdeeplite
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

Test

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
Enabling the next generation of Sensor and Hearable products to process rich data with energy efficiency.
Groovety Inc.

SOFTWARE DEVELOPMENT SERVICES FOR TINYML SOLUTIONS

1 Development tools
   SDK, IDE, compilers, leveraging on TVM, uTVM & LLVM

2 Firmware
   Drivers, BSP, protocols, etc.

arm AI PARTNER
HOTG is building the **distributed infrastructure** to pave the way for **AI enabled edge applications**.
LatentAI

Adaptive AI for the Intelligent Edge

Latentai.com
Maxim Integrated: Enabling Edge Intelligence

**Advanced AI Acceleration IC**

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/MAX78000](http://www.maximintegrated.com/MAX78000)

**Low Power Cortex M4 Micros**

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/microcontrollers](http://www.maximintegrated.com/microcontrollers)

**Sensors and Signal Conditioning**

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/sensors](http://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**

**For more information, visit:** [www.qeexo.com](http://www.qeexo.com)

**Target Markets/Applications**

- Industrial Predictive Maintenance
- Automotive
- Smart Home
- Mobile
- Wearables
- IoT
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.
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
# BROAD AND SCALABLE EDGE COMPUTING PORTFOLIO

## Microcontrollers & Microprocessors

<table>
<thead>
<tr>
<th>Arm® Core</th>
<th>Renesas Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm® Cortex®-M 32-bit MCUs</td>
<td>Ultra-low Energy 8 &amp; 16-bit MCUs</td>
</tr>
<tr>
<td>Arm® ecosystem, Advanced security, Intelligent IoT</td>
<td>Bluetooth® Low Energy, SubGHz, LoRa®-based Solutions</td>
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<tr>
<td>Arm®-based High-end 32 &amp; 64-bit MPUs</td>
<td>High Power Efficiently 32-bit MCUs</td>
</tr>
<tr>
<td>High-resolution HMI, Industrial network &amp; real-time control</td>
<td>Motor control, Capacitive touch, Functional safety, GUI</td>
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<tr>
<td>Arm® Cortex®-M0+ Ultra-low Power 32-bit MCUs</td>
<td>40nm/28nm process Automotive 32-bit MCUs</td>
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<tr>
<td>Innovative process tech (SOTB), Energy harvesting</td>
<td>Rich functional safety and embedded security features</td>
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</tbody>
</table>

**Renesas Synergy™**
- Arm®-based 32-bit MCUs for Qualified Platform
- Qualified software and tools

## Core technologies

### AI
A broad set of high-power and energy-efficient embedded processors

### Security & Safety
Comprehensive technology and support that meet the industry’s stringent standards

### Digital & Analog & Power Solution
Winning Combinations that combine our complementary product portfolios

### Cloud Native
Cross-platforms working with partners in different verticals and organizations
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.

sensiml.com
**SynSense** builds sensing and inference hardware for ultra-low-power (sub-mW) embedded, mobile and edge devices. We design systems for real-time always-on smart sensing, for audio, vision, IMUs, bio-signals and more.

https://SynSense.ai
SYNTIANT

Neural Decision Processors
- At-Memory Compute
- Sustained High MAC Utilization
- Native Neural Network Processing

ML Training Pipeline
- Enables Production Quality Deep Learning Deployments

Data Platform
- Reduces Data Collection Time and Cost
- Increases Model Performance

End-to-End Deep Learning Solutions for TinyML & Edge AI

partners@syntiant.com
www.syntiant.com
tinyML Summit 2022
Miniature dreams can come true...
March 28-30, 2022
Hyatt Regency San Francisco Airport
https://www.tinyml.org/event/summit-2022/

Registration will be open on December 15, 2021.
Deadline for poster submission is December 17.
The Best Product of the Year and the Best Innovation of the Year awards are open for nominations between November 15 and February 28.

tinyML Research Symposium 2022
March 28, 2022
https://www.tinyml.org/event/research-symposium-2022
Call for papers – Submission deadline is December 17, 2021.

More sponsorships are available: sponsorships@tinyML.org
Next tinyML Talks

<table>
<thead>
<tr>
<th>Date</th>
<th>Presenter</th>
<th>Topic / Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuesday, January 4</td>
<td>Cedric Nugteren, software engineer, Plumerai</td>
<td>Demoing the world’s fastest inference engine for Arm Cortex-M</td>
</tr>
</tbody>
</table>

Webcast start time is 8:00 am Pacific time

Please contact talks@tinyml.org if you are interested in presenting
20+ years of experience in IT. Worked in world-famous companies Motorola/Freescale, AMD, LG Electronics, Ring/Amazon etc. He has experience in building IT delivery organizations from scratch to several hundred people.

In 2016-2017 he worked on a solution unique to the automotive industry with 3D Augmented Navigation, which includes components used for Autonomous Driving, which is available in Audi cars starting 2021.

In 2017-2019 he worked as General Manager at Ring Ukraine, which was sold to Amazon for over 1 billion USD, where together with the company’s COO he was able to scale the company from a few dozen to 1000+ highly skilled specialists in 3 years, as well as helped to deliver a large number of new flagship products.

In his recent roles of COO and R&D director, he executed strategic startup transformations and implemented processes for rapid growth of technology business.

Before that, he had a 16 years track record of engineering leadership, working on embedded software for Sequans, AMD, LG Electronics, Nordic Semiconductor and others.

Sergii holds an MBA degree from London Business School and MSc degree in Computer Science from National Aerospace University.
Reminders

Slides & Videos will be posted tomorrow

tinyml.orgforums  youtube.com/tinyml

Please use the Q&A window for your questions
Speaker: Oleg Puzanov

★ CEO and Co-Founder at Leantegra: www.leantegra.com
★ Since 2003 in commercial IT projects and companies
★ Embedded systems and IoT projects from year 2004
★ Serious about sports: 6 x Ironman, 10 x Half Ironman, multiple ultra marathons
Leantegra: Our Focus

Industrial RTLS and safety

- BLE
- UWB
- Wi-Fi
- LTE (NB-IoT)
- TETRA
- 5G - development in progress

MINES
FACTORIES
WAREHOUSES
OIL&GAS
Case Study: DTEK Underground Mine

Successfully launched and completed the project for DTEK - the largest energy company in Ukraine.

2,100 BLE beacons and 1700 Smart Lamp devices deployed in Yubileynaya mine, together with a customized Leantegra CVO Portal.

Reverse BLE RTLS as the main technology for positioning and industrial Wi-Fi as the backhaul network.

Main features: BLE RTLS, messaging, methane-CO telemetry, alarms, rich multi-layered mapping, advanced data reporting.
Customers and Partners

- IT Integrator
- mineARC
- RAMJACK Technology Solutions
- Инпромтех
- D.TEK
- METINVEST
- Сільпо
- Dundee Precious Metals
- Auchan
- Нова Поста
- DOSTYK PLAZA
- Lifestylepanel
- TCD
- Globberry
- BORYS PIL
Leantegra Hardware

- UWB-BLE RTLS tags
- IP67 RTLS anchors
- Mining BLE-LTE Locators
- ATEX BLE Beacons
- IP67 BLE Beacons
- Mining BLE-WiFi Locators
Example #1: Smart Cap Lamp

Reverse LTE-BLE locator based on Cat-M1 and NB-IoT protocols, embedded into cap lamps. Developed for Dundee Precious Metals mine in Bulgaria.
Example #2: Smart Cap Lamp

BLE-WiFi locator and Smart Lamps for DTEK underground mine in Ukraine.
Supports the reverse RTLS and telemetry for methane, CO and temperature.

Developed in partnership with InPromtex company.
Our Algorithms: Wireless UWB TDoA

Fully wireless and asynchronous TDoA algorithm, which doesn’t require clock synchronizations among RTLS anchors.

The algorithm had been researched and developed by Leantegra - patent pending.

- Up to 100x times less power consumption than UWB TWR.
- Up to 500 trackables in one zone (one room) - good scalability.
- Normally TDoA systems require clock syncing over Ethernet cables, which limits choices for the network equipment. No such limitation here.
Our Algorithms: Reverse BLE RTLS

Special type of 1D-2D BLE RTLS developed for tunnels - for example: underground mines

→ BLE beacons are mounted inside tunnels, RTLS anchors (locators) are embedded into cap lamps.
→ The main advantage - RTLS installation **without cables**.
→ Case study: 2100 BLE beacons and 1750 locations for the DTEK mine in Ukraine.
Some Theory: IMU

**Accelerometer**
- Linear acceleration measured in m/s² or g
- Includes the gravity component, which must be subtracted
- Zero-G offset - deviation at rest from [0;0;1] gravity vector

**Gyroscope**
- Angular velocity in deg/sec or rad/sec
- Bias affected by temperature
- Orientation = integration of angular velocity

**Magnetometer**
- Magnetic field strength on each axis, measure in Gauss

**Barometer**
- Barometric pressure sensor, used for altitude measurement

- **3DOF**
  - accel

- **6DOF**
  - accel, gyro

- **7DOF**
  - accel, gyro, barom

- **9DOF**
  - accel, gyro, magn

- **10DOF**
  - accel, gyro, magn, barom
IMU: What We Use

STMicroelectronics LIS2DH12
3-axis accelerometer, used in older WiBeat BLE beacons and UT-100 UWB tags.

Bosch BMP390
High precision barometer, used in all newer UWB anchors and tags.

Bosch BMI270
IMU with 3-axis accelerometer and 3-axis gyroscope, used in all newer UWB tags.

Bosch BMI160
IMU with 3-axis accelerometer and 3-axis gyroscope, used in some customer devices.
Our Usage Scenarios for IMU

Adaptive Transmission
- Power saving mode with dynamic adjustments of TX rate for RTLS tags, based on active-inactive state.

Kalman Filtering for RTLS
- Accelerometer is used as a second data source for Kalman filter in the RTLS engine. Smoother trajectories on a map.

Motion Recognition
- Previously custom code for ML and now TensorFlow Lite with Edge Impulse SaaS for on-device ML scenarios.
On-device ML Advantages

**Power savings** - for the case of UWB RTLS devices up to 5-10 times (!!):
- Smaller UWB frames
- Smaller TX rate

**Latency** - enabling sub-10ms scenarios for feedbacks:
- Haptic feedback
- Emergency braking for collision avoidance

**Offline mode** - devices keep working without network coverage:
- Important for life-critical systems
- Partial network coverage is possible = less IT infrastructure expenses
Back in early 2019 implemented the custom code for ML algorithms running on Leantegra WiBeat 2.0 BLE beacons: Nordic nRF52832, LIS2DH12 accelerometer

- No gyroscope - no rotation matrix and no linear acceleration vector in the formula.
- Scalar formula instead of vectors:
  \[ ACC = \sqrt{AX^2 + AY^2 + AZ^2} - GS \]
- Comments:
  - ACC - resulting acceleration
  - AX, AY, AZ - raw acceleration data
  - GS - gravity scalar with zero-G offset
- Must be trained and later used in one specific position - for example: mounted on hard hats.
- Not flexible to other mounting options - as wearable or carried inside pockets.
Motion Recognition v0.1: Result
New Framework: TagML

Time-critical detection and machine learning scenarios, which run entirely on Leantegra UWB-BLE devices or industrial PPE appliance.

Integrated and customized TensorFlow Lite libraries and Edge Impulse SaaS for Leantegra UWB-BLE devices to enable on-device machine learning scenarios.
TagML: E2E Deployment Process

Data labeling via BLE GATT and on-device collection
TagML: E2E Deployment Process

MQTT data collection and saving into CSV files
TagML: E2E Deployment Process

The pipeline in Edge Impulse
TagML: E2E Deployment Process

Generating features and testing the NN model in Edge Impulse
Generating C++ library for Nordic nRF52840, compiling the device firmware
MQTT data from the RTLS devices is delivered to Leantegra RTLS server and CVO Portal for visualizations
Thank You

Our contact e-mail
contact@leantegra.com
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