tinyML® EMEA

Enabling Ultra-low Power Machine Learning at the Edge

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sensing SW

Monitoring of Vital Signs using Embedded AI in wearable devices

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(an ams OSRAM company)

Agenda

- Introduction to ams OSRAM and 7 Sensing Software
- ams OSRAM AS7050 medical and health sensor
- Respiratory Rate Monitoring using PPG signals
- Power of tiny Machine Learning (ML)
- Conclusions

Introduction to ams OSRAM and 7 Sensing Software

Cor

7 Sensing Software and ams OSRAM

7 sensing SW (an ams OSRAM company)

Mix of AI,
Computer Vision and
Embedded Software experts

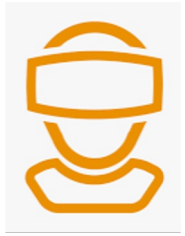
Building AI solutions optimized for processing on Edge Platforms

ams OSRAM

Top 3 global optical semiconductor player

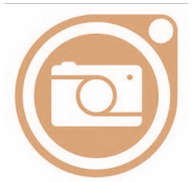
Market leader in light emitters, sensors, optical modules, sensor interface ICs and algorithms

7 Sensing Software: application areas



AR/VR

- Depth-map densification
- Eye-tracking



Imaging

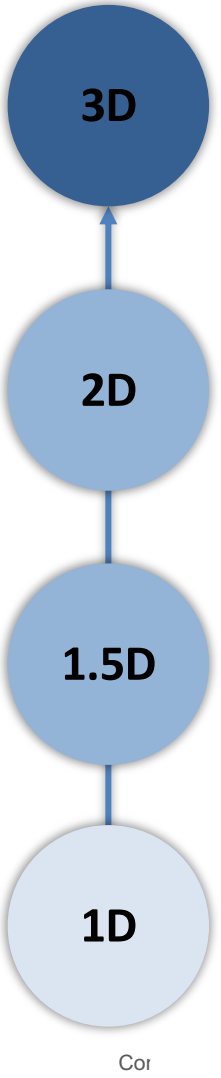
- Auto White Balance
- AI-accelerated image sensing

Human Machine Interface

- Human presence detection
- Gesture recognition
- Head and body pose estimation

Vital Signs

- Blood Pressure monitoring
- Respiratory Rate monitoring



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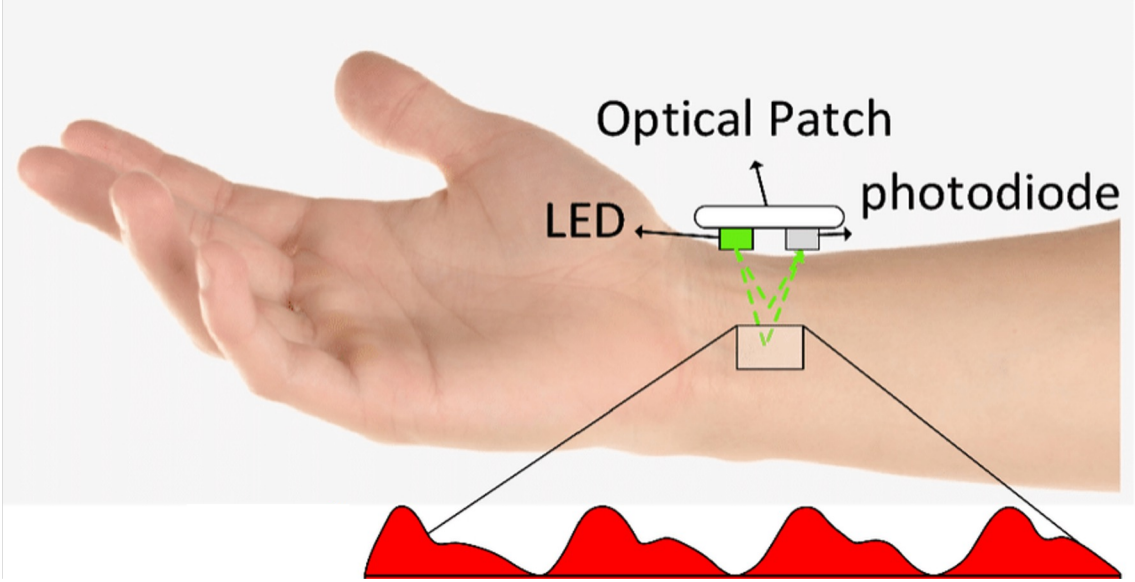
ams OSRAM AS7050 medical and health sensor

Vitals signs and PPG signals

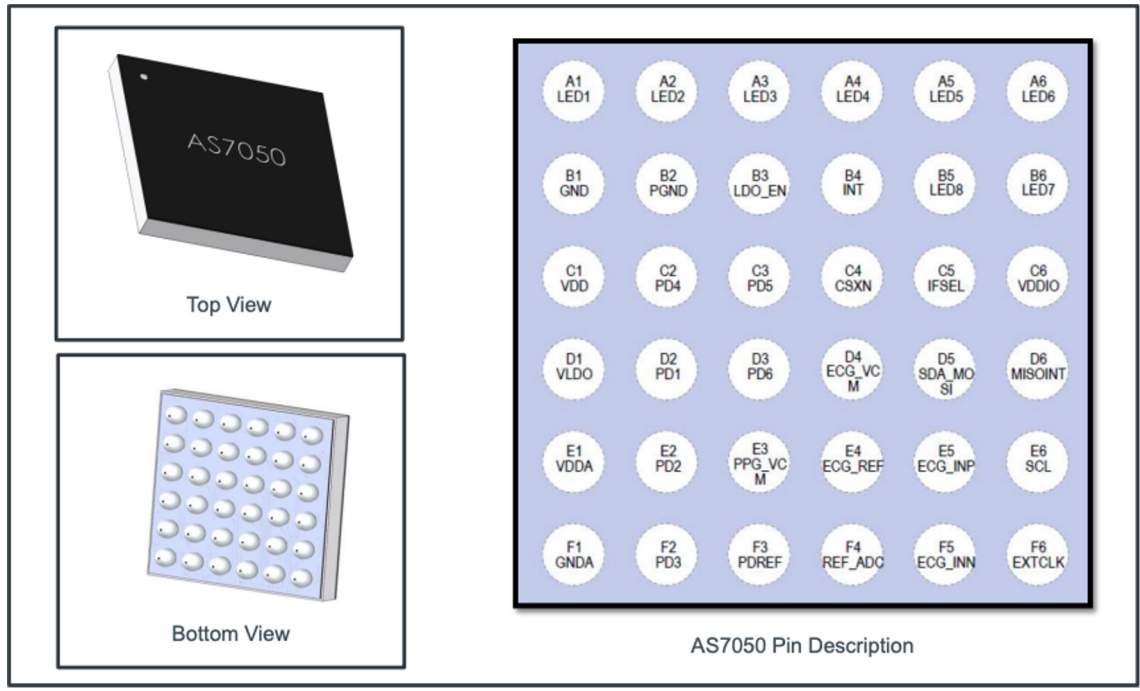
- **Vital signs**: measurements of the body's basic functions.
- **Respiratory Rate (RR):** number of breaths per minute (bpm). Elevated RR (>27 bpm) is predictive of cardiopulmonary arrest.
- **Photoplethysmography (PPG)**: optical technique used to detect volumetric changes in blood in peripheral circulation.



Source: PPG for accurate measurement of the bio-signs

ams OSRAM AS7050 sensor

- **Features**
  - Up to 8 LEDs and 6 Photodiodes
  - Synchronized PPG and ECG channels
  - ECG and PPG channels separated and simultaneous useable
- **Benefits:**
  - Highly flexible LED/PD configuration
  - Allows smallest application size
  - Acquiring several bio-signals in parallel
  - Good Heart Rate measurement quality



Reference: ams OSRAM AS7050 sensor

Respiratory Rate monitoring using PPG signals

Respiratory Rate monitoring using PPG signals: overview

- **Deep Learning** (DL) based algorithm measuring Respiratory Rate from a 20-second PPG signal.
- **Real-world data** acquisition with the wristband using AS7050 sensor.
- **Innovative data augmentation** methods to increase volume of real data and improve algorithm robustness.
- DL model integrated on Cortex-M4 MCU and executed with a **custom AI framework**
  - Required to support 16-bits signal dynamic
  - Low Memory footprint and CPU bandwidth

AS7050 optical sensor

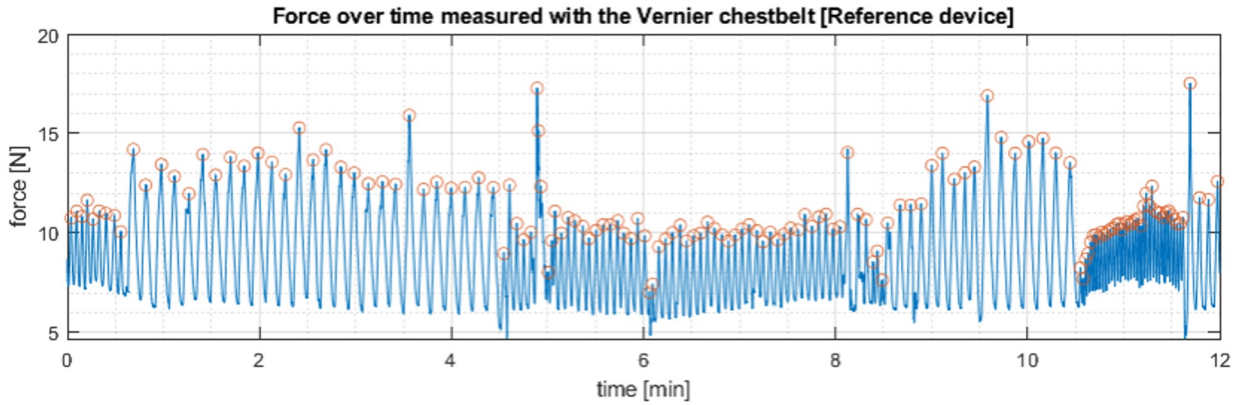
Real-world data acquisition

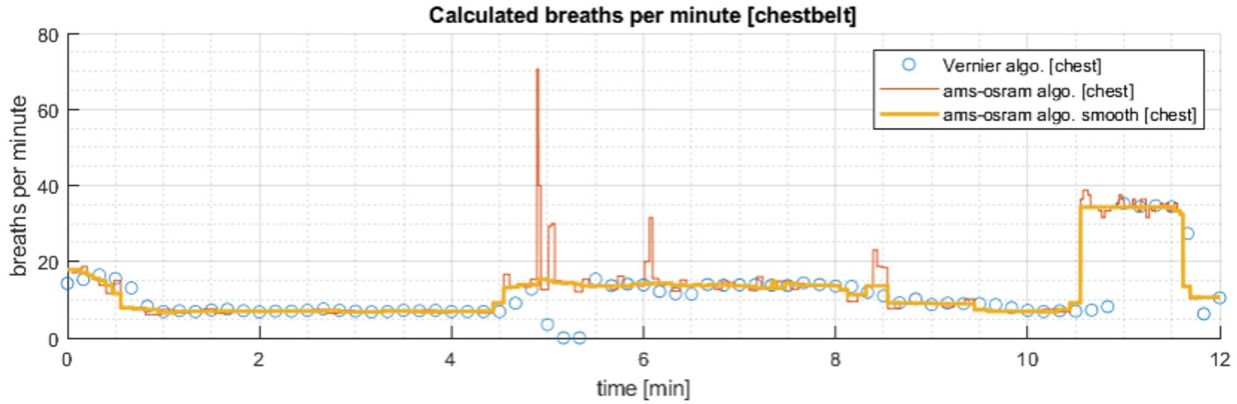
Acquired and calculated signals:

- PPG signal acquired with the **AS7050 wristband**

- Ground-truth Respiratory Rate acquired with the **Vernier chest belt**

- Privacy concern and subject diversity: **40 subjects** of different genders, ages and skin colors.





Reference force signal (upper plot) and derived Ground-truth Respiratory Rate values (lower plot)

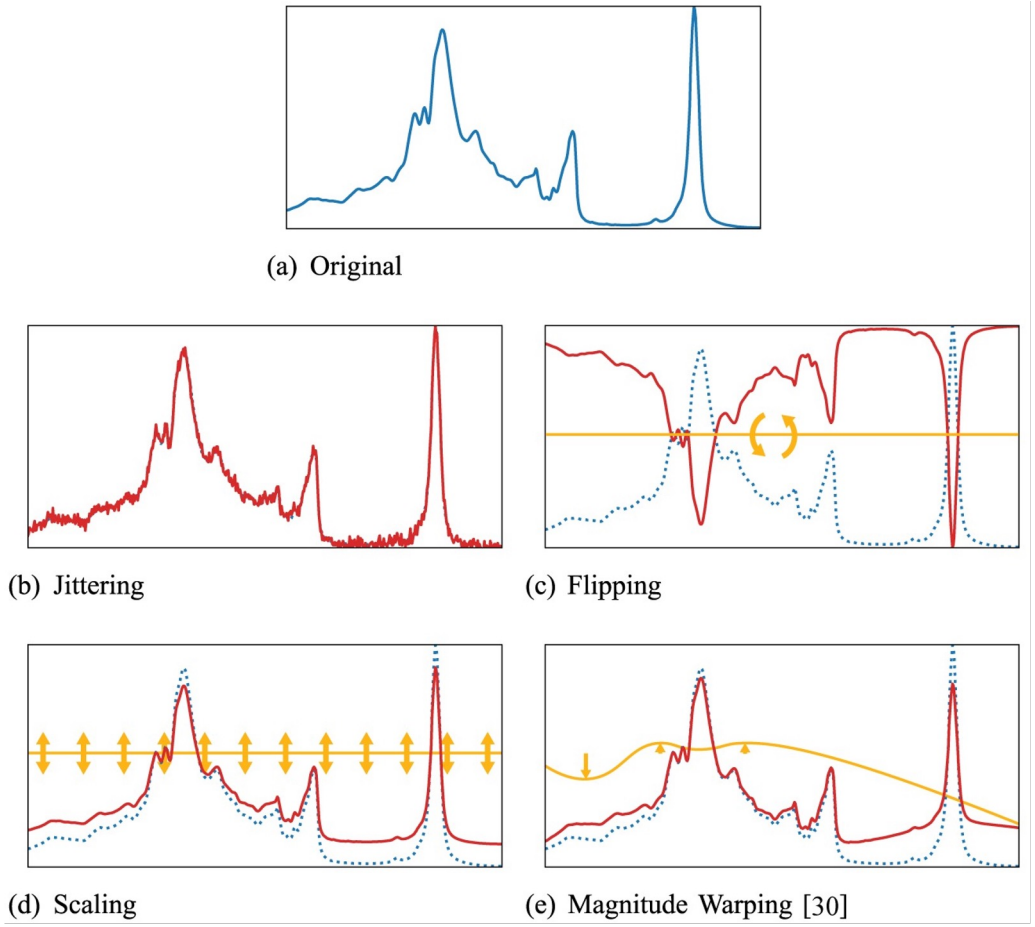
Data augmentation for time series

Deep learning = 80% data + 20% model

Data shortage is a common issue in the field of vital signs monitoring.

Challenges of data augmentation for time series come from their structural patterns and dependence on element order.

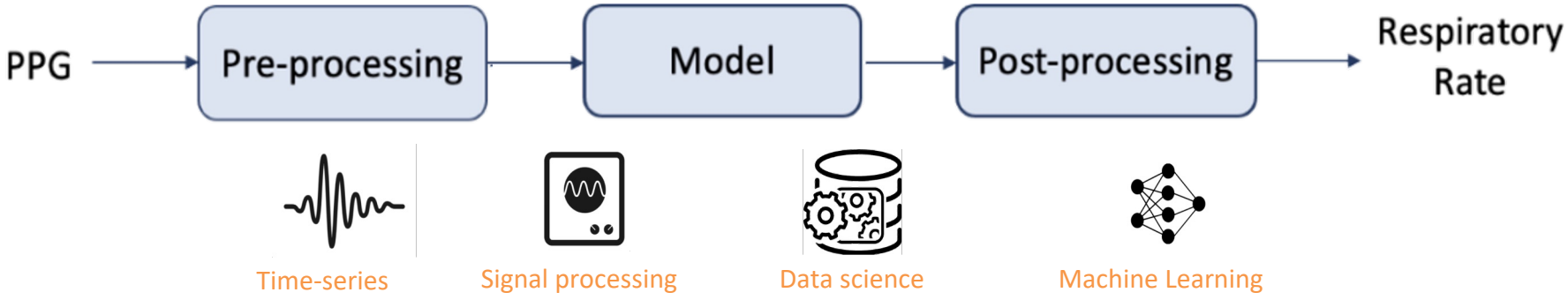
Innovative ways to increase the number of real and synthetic PPG signals were developed to re-balance the training dataset and improve prediction precision.



Source: An empirical survey of data augmentation for time series classification with neural networks

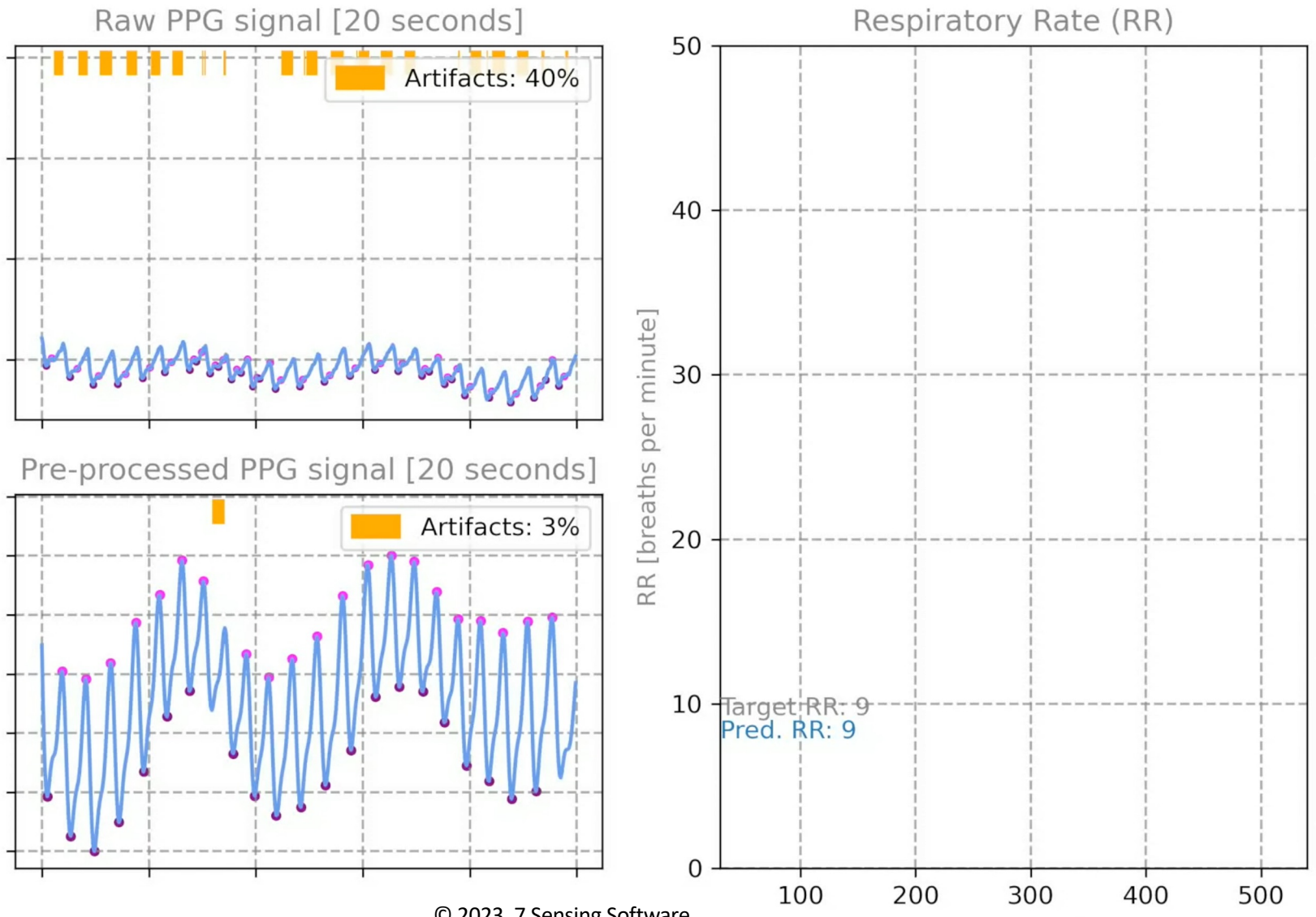
Tiny Machine Learning-based solution

- **Classical algorithms** require ideally shaped PPG signals, and the performances are unsatisfactory.
- **Tiny ML** solution:
  - Extract Respiratory Rate related information from PPG signals by learning from **real-world data** with a Deep Neural Network (DNN) model.
  - Easy to update core algorithm by only updating DNN weights (**35k** parameters).
- The proposed solution achieved performance comparable to **medical-grade** devices.



Respiratory Rate monitoring using PPG signals

Results on instructed breathing



Power of tiny ML

Challenges and solutions

Embedding proposed solution into microcontrollers

- **Challenges:**
  - PPG signal is of large dynamic: **19 bits.**
  - Available AI framework on the market only support float 32 or int 8 weight and data format, while **16 bits** were needed.
- **Solutions:**
  - In-house modified AI framework to support post-training quantization in **16-bits** to avoid signal quality loss and accuracy drop.
  - Converted and optimized DNN to be compatible with the **low-end MCU**: Cortex M4 at 64 MHz with 8.5% computing capacity.

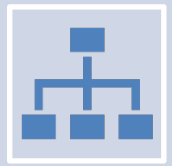
MCU
(Cortex-M4)

Converted and optimized Deep Neural Network to be compatible with the low-end MCU

AS7050 wristband

Custom Deep Learning Integration Framework

Convert DL model (ONNX) to **C code**
DL Inference Engine specifically for **MCU** (C-based engine) and only use static memory allocation

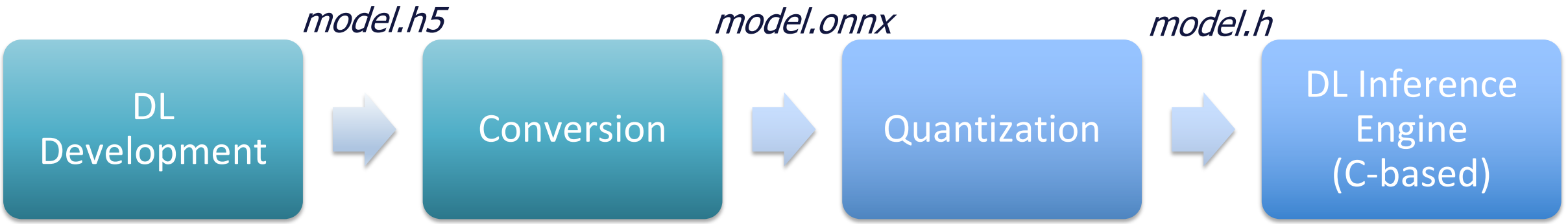


Support common DL **operators**: CNN, RNN, BatchNorm…
Support common DL **architectures**: ResNet, DenseNet...

Support 8-bit, **16-bit and 8/16-bit hybrid** quantization,
Optimize footprint/latency while preserving accuracy

Custom Deep Learning Integration Framework

Workflow for deployment on the edge



- Python libraries (Keras, Tensorflow, Pytorch…)
- 32-bit float

- Convert DL model to ONNX

- 8-bit
- 16-bit
- 8/16-bit hybrid

- Run on all MCU platforms
- Low latency / memory footprint

Standard operation

In-house operation

Conclusions

Conclusions

- Tiny ML-based algorithm to handle **real-world** and **complex** PPG signals.
- Different use cases: **natural and instructed breathing** which significantly impact PPG signal's morphology.
- High Respiratory Rate prediction accuracy: performance comparable to **medical-grade** devices.
- **Solution-agnostic**: no accuracy degradation while evaluating on a different PPG sensor.

Conclusions

- **In-house** and **complete** DL integration framework to port DL models on **MCU:** 16 bits and 8/16-bit quantization and porting flow generalizes to other 1D problems.
- **Power efficient**: 8.5% CPU load on Cortex M4, portable in low-power devices like wearables.

Resources

More about us

ams OSRAM:

https://ams-osram.com

7 Sensing Software:

https://7sensingsoftware.com

ams OSRAM AS7050 sensor:

https://ams.com/en/as7050

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