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MILEA – An Approach for Small Scale Applications

Kathrin Gerhard and Eduard Moser

Robert-Bosch GmbH, Germany

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An Approach for Small Scale Applications
Introduction

MILEA

- **Who are we?**
  - Team within Bosch, who answers the question:

    *"How can we bring a ML algorithm **simple** and **efficient** on an embedded device?"*
  - Therefore, we developed a library called **MILEA**:
    - **MILEA** = **M**achine **I**ntelligence **L**ibrary for **E**mbedded **A**pplications

- **What is presented?**
  1. Environment
  2. Motivation
  3. Implementation
  4. Algorithms and Runtime
  5. Key Facts

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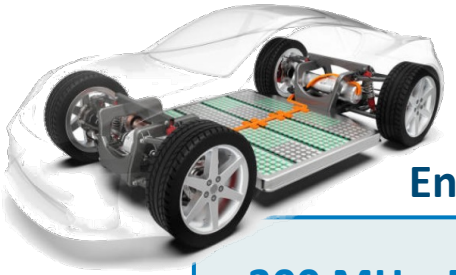
1. Environment

- **Different Controllers**:
  - Example: IFX - 32-bit AURIX™ TriCore™ TC27xx, supporting **safety requirements**
    - TriCore specification: 300 MHz, FLASH 8MB, RAM 1MB (see: www.infineon.com)
  - also, similar ARM cores or big-endian architectures are supported
- **Real-time** operation to control engine feature
- A **small part** of the processes **uses ML-features**:
  - Neural Net: currently about 5
  - Gaussian Process: about 3
  - SVM: about 2
  - Binary Decision Tree, Random Forest: about 3
  - furthermore, in-house data-based algorithms: about 20

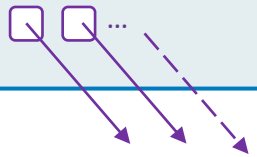


Engine Control Device

300 MHz, FLASH 8MB, RAM 1MB

more than 2700 processes

ML applications



each ML process uses a small part of the resources:
e.g., **< 1ms, FLASH 80 KB, RAM 2KB**

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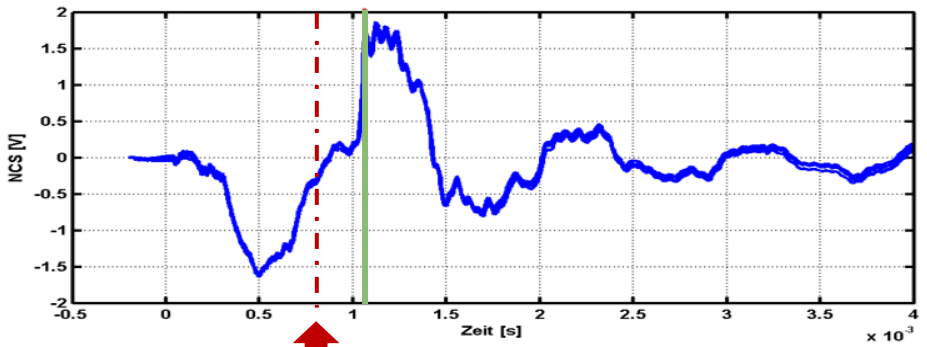
2. Motivation (1)

- **Example**: **Virtual Pressure Sensor** (within vehicles)

  → Goal: Detection of the fast-rising pressure signal

Detecting the right criteria with AI model ☑



Sensor signal of Bosch component

Preventing wrong detection by physical model ☒

Why do we need ML on a microcontroller?

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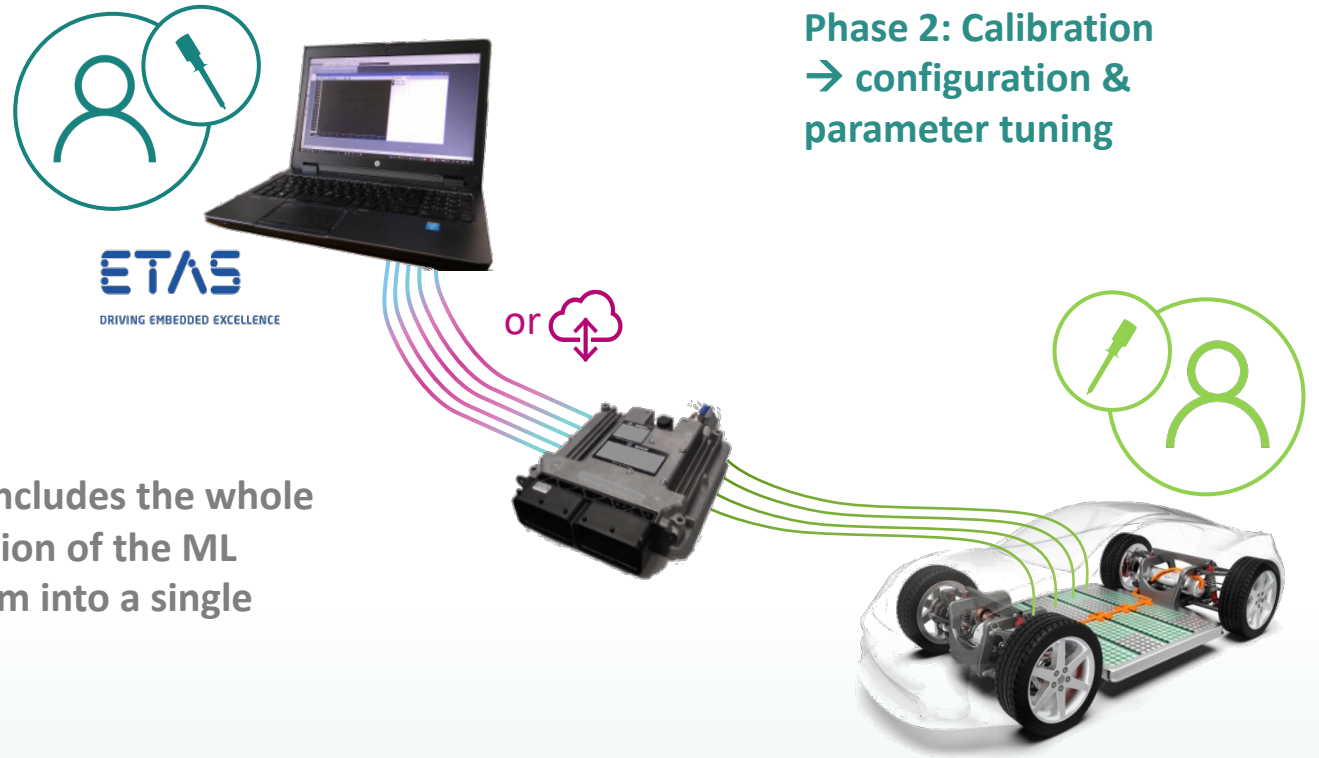
3. Implementation (1): Two-Phase Deployment Process

1. **Software development:**
   coding and updates shall be finished during the first part of the product development

2. **Calibration:**
   the second flexible way of deployment is performed via calibration:
   → configuration
   → tuning



Phase 2: Calibration
→ configuration & parameter tuning

MILEA includes the whole description of the ML algorithm into a single "screw"

MILEA especially uses the second phase to allow **flexible** and **easy** changes on the software.

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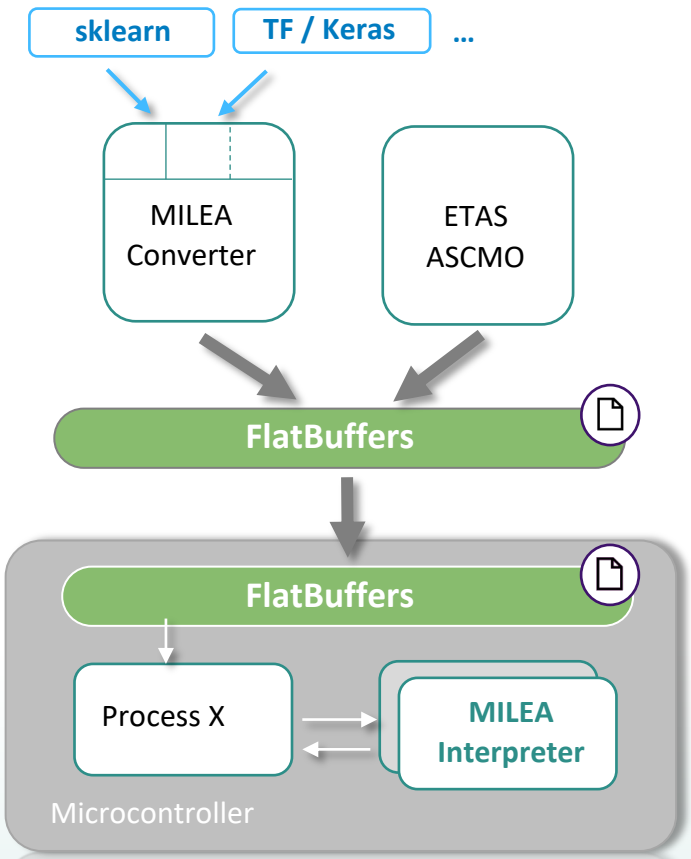
3. Implementation (2)

1. Single “screw”: The description of a ML algorithm is stored in a **configuration file** (in FlatBuffers format) and configures the ML model
   - individual FlatBuffers schemes per algorithm
2. Each ML algorithm is an **interpreter*** (<10KB)
3. The user provides the **configuration file** and **call** respective **interpreter** in a **real-time** process
4. Two-phase **validation**
   - Interpreter: validation performed on a wide range of configurations as well as requirement based
   - Model: Use-case validation as part of the product development

*currently, all algorithms are based on floating-point implementation



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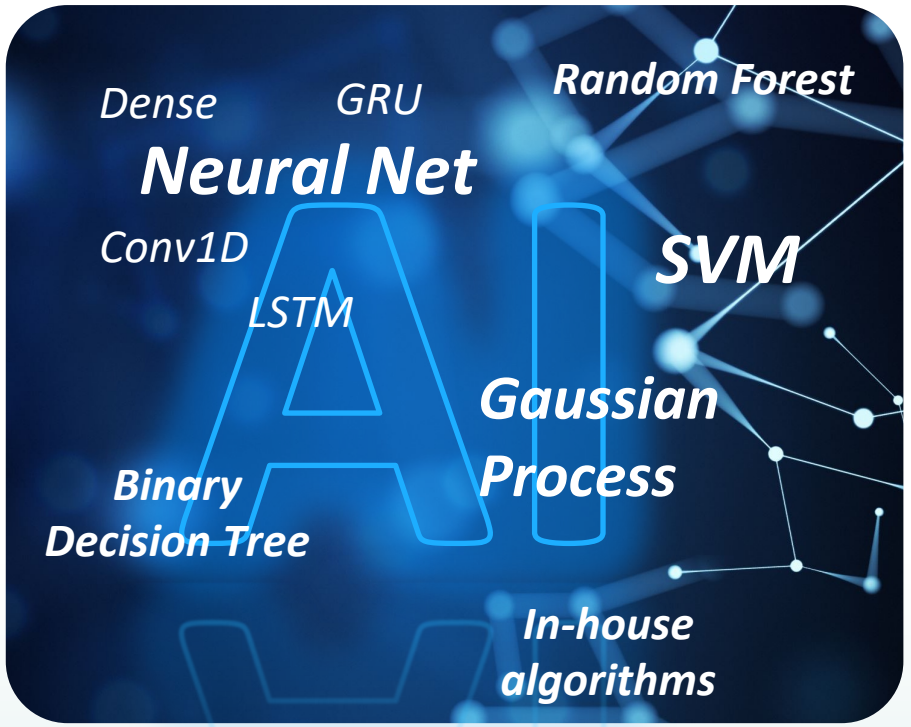
4. Algorithms and Runtime (1)

- Supported Algorithms:*



*Further algorithms on request

- **Example:** *Sensor Plausibility Check*
  - detects if data has been manipulated
  - Neural Net:
    - 10 inputs
    - 3 LSTM layers (30, 20, 10 units)
    - 5 dense layers

Model	Runtime
First LSTM Layer	180 µs
Total	403 µs

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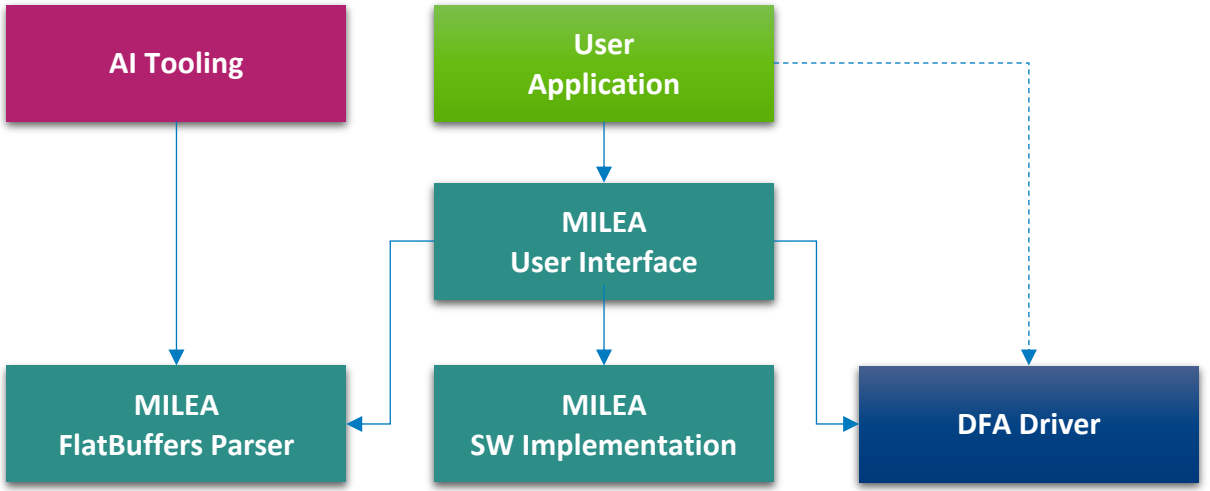
4. Algorithms and Runtime (2)

- **Support for Hardware Accelerator: DFA**
  - DFA = **D**ata**F**low **A**rchitecture
  - MILEA compatible to DFA driver
  - Internally, identical parameters
- DFA **speeds up** MILEA **performance**
  - FlatBuffers flag: SW execution vs. HW acceleration
  - HW up to ~50x faster, same result



Model	SW	HW (DFA)
Dense Layer: - 40 inputs, 192 neurons - activation function: ReLU	266 µs	7 µs

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Key Facts

- Only a **small part** of the processes **uses ML-features**
- **Two-phase** deployment process:
  - initial ML model deployed via FlatBuffers
  - FlatBuffers can be updated in calibration phase and allows **flexible** and **easy** changes of the network topology without new software build
- MILEA SW is **ready for series** and already used in several functions
- MILEA enables easy **access to AI methods** from external machine learning frameworks **for embedded use**
- MILEA has **no HW and SW dependencies**
- Extension with additional AI algorithms possible

MILEA is small, efficient, flexible, and easy to use.

Contact:

Kathrin Gerhard

E-Mail: kathrin.gerhard@de.bosch.com

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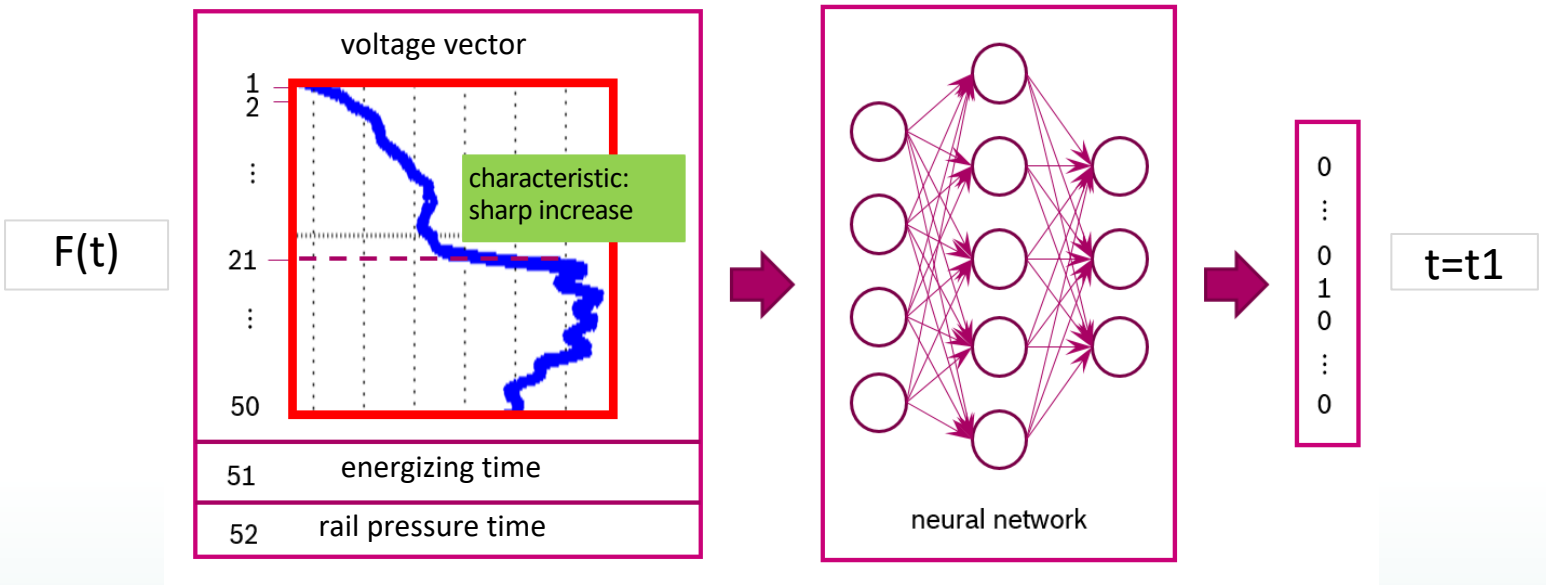
2. Motivation (2)

- **Example**: **Virtual Pressure Sensor** (within vehicles)

  → Solution: AI is the key!



Neural Network:

- 52 inputs
- 2 hidden dense layers
- 50 outputs

How can we deploy the neural net on the embedded device?

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