HAW HAMBURG

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Wirtschaft und Technik

MACHINE LEARNING FOR EDGE BASED ANOMALY DETECTION IN ROBOTIC APPLICATIONS

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FOR A SMARTER WORLD

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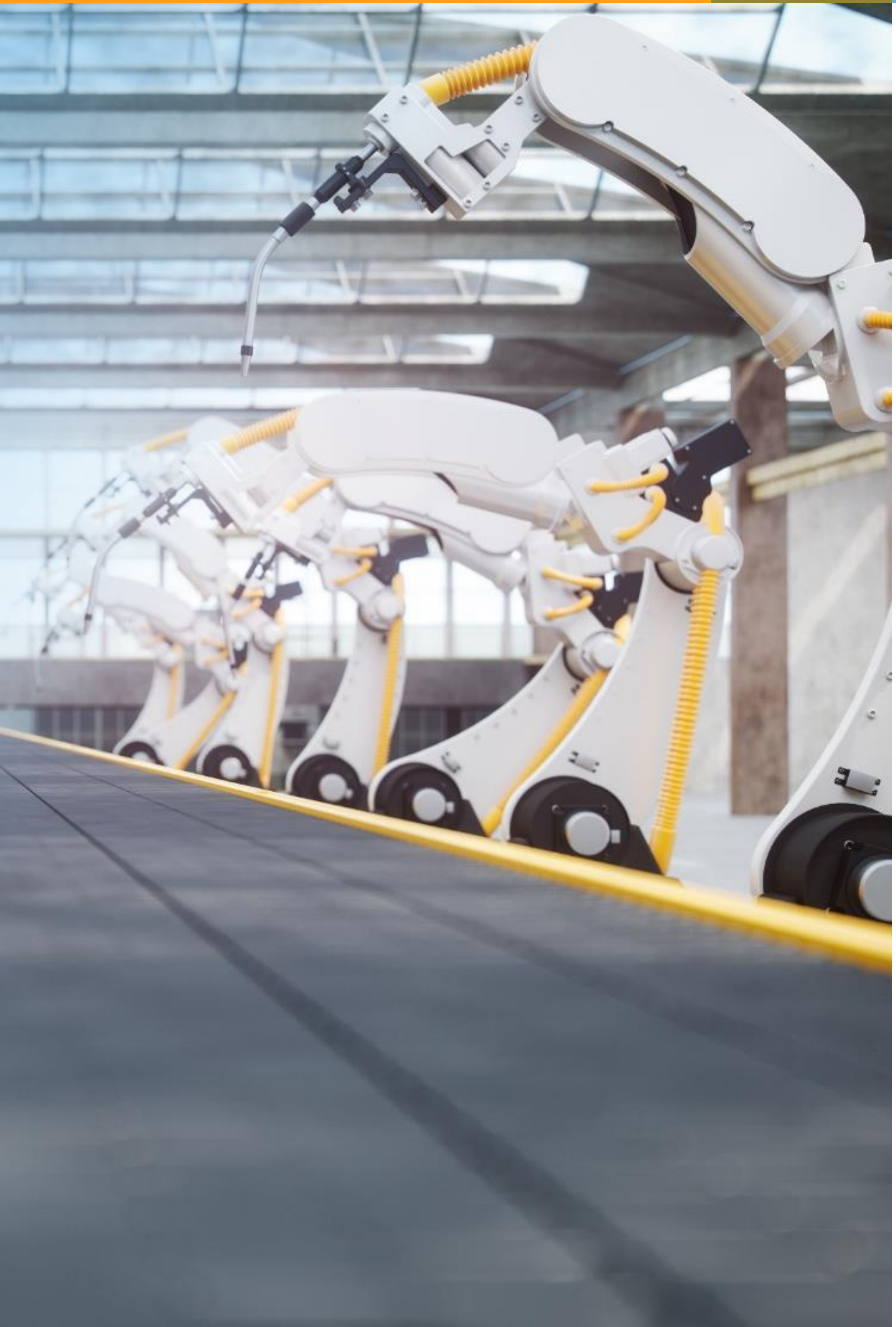

Agenda

Introduction

Algorithms

System Overview

Use Case Evaluation

Summary

Introduction

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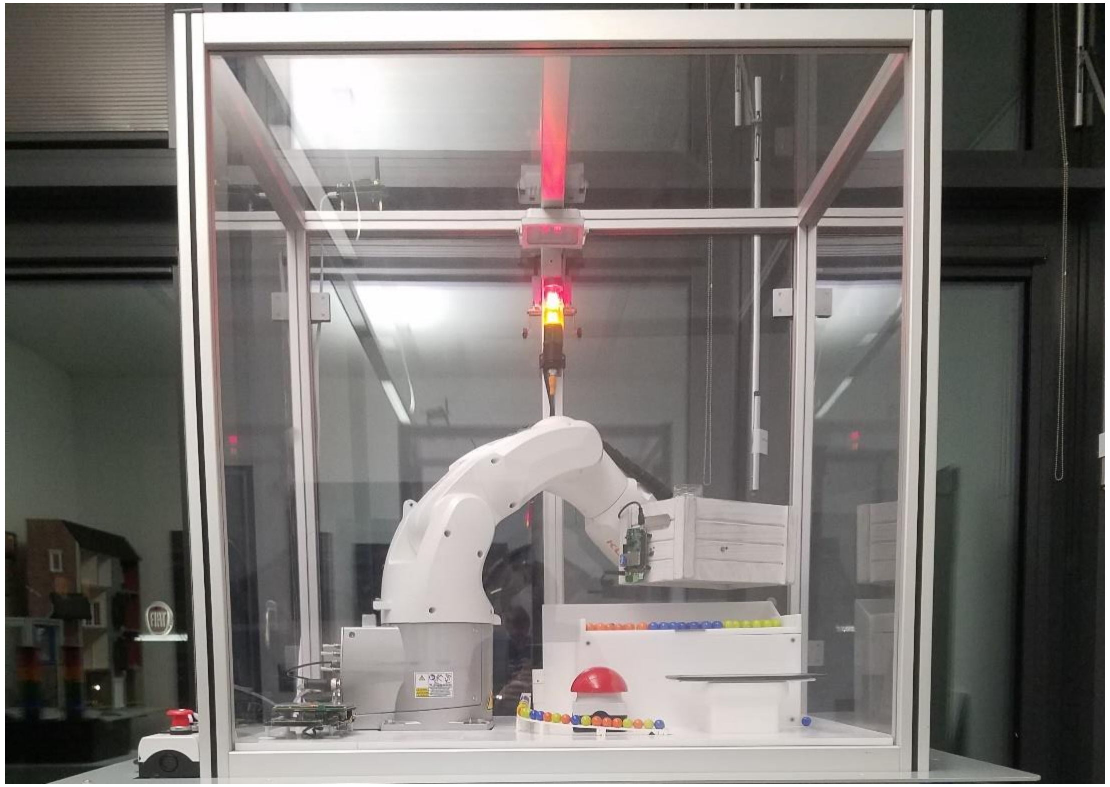
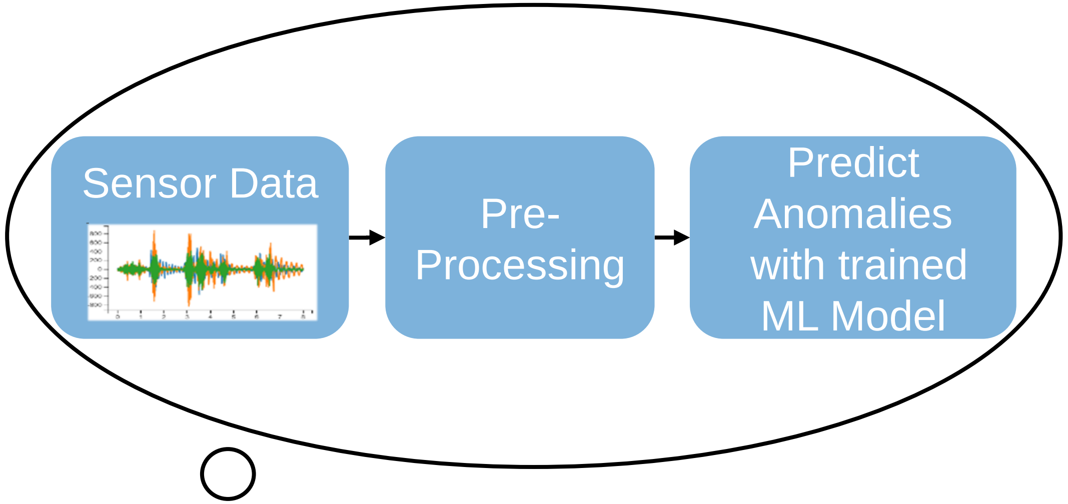
WHAT IF ROBOT CELLS COULD AUTOMATICALLY DETECT PROCESS ANOMALIES DURING OPERATION?

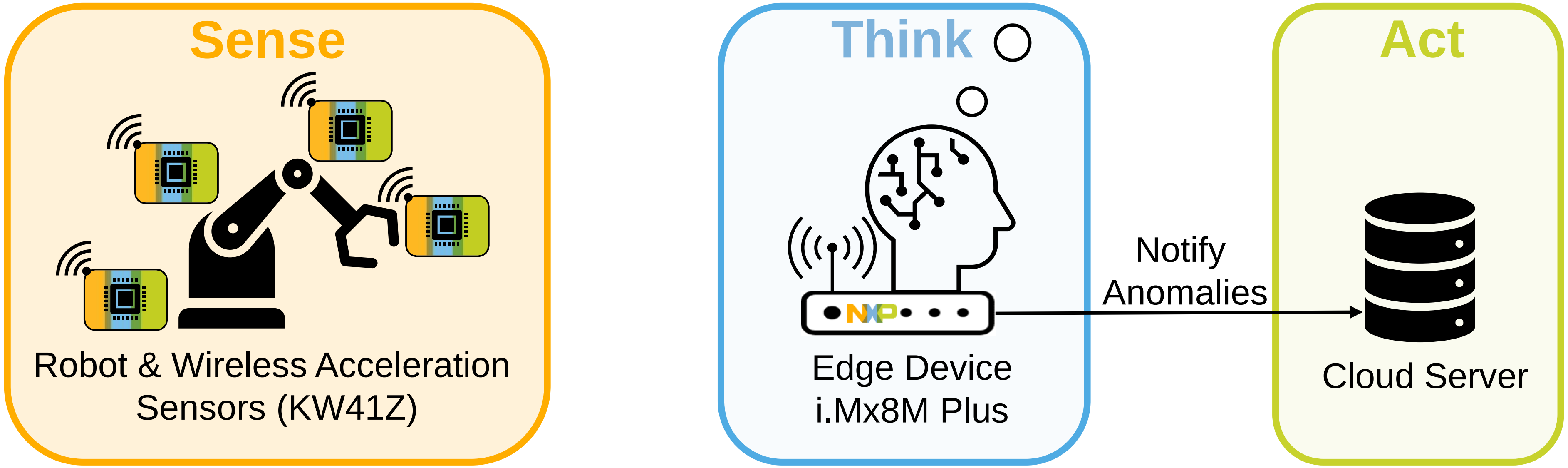
- Production Quality Improvement
- Safety Improvement
- Process Downtime Reduction
- Maintenance Cost Reduction



Edge Computing & Wireless Sensors

- Fast System Response Times
- High Reliability
- High Data Security & Privacy
- High Flexibility





Algorithms

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Basic Concept

- Binary classifier
- Creates hyperplane that separates the data classes with maximum margin

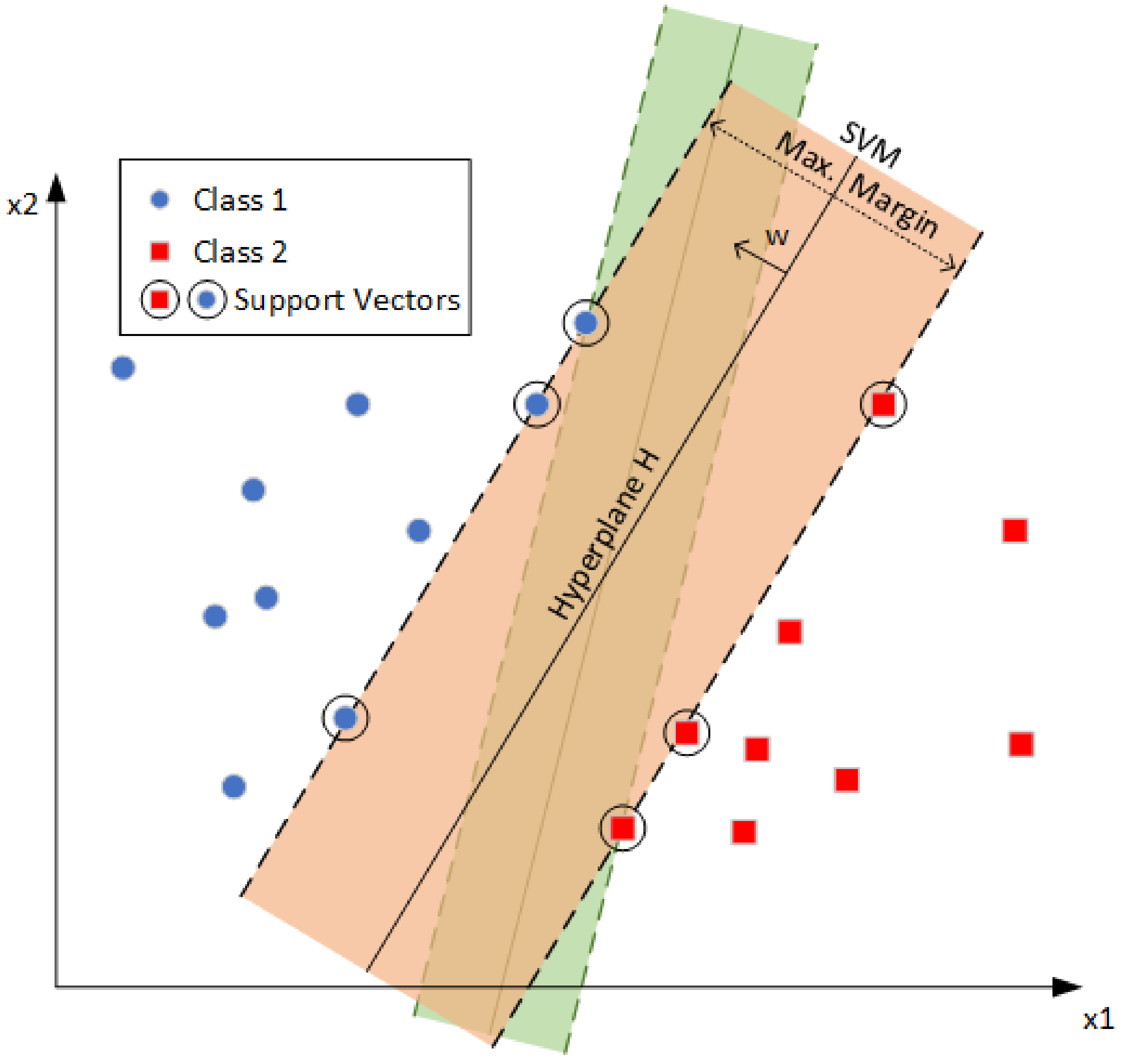
$$H = \mathbf{w}\mathbf{x} + b = 0$$

Optimization Problem

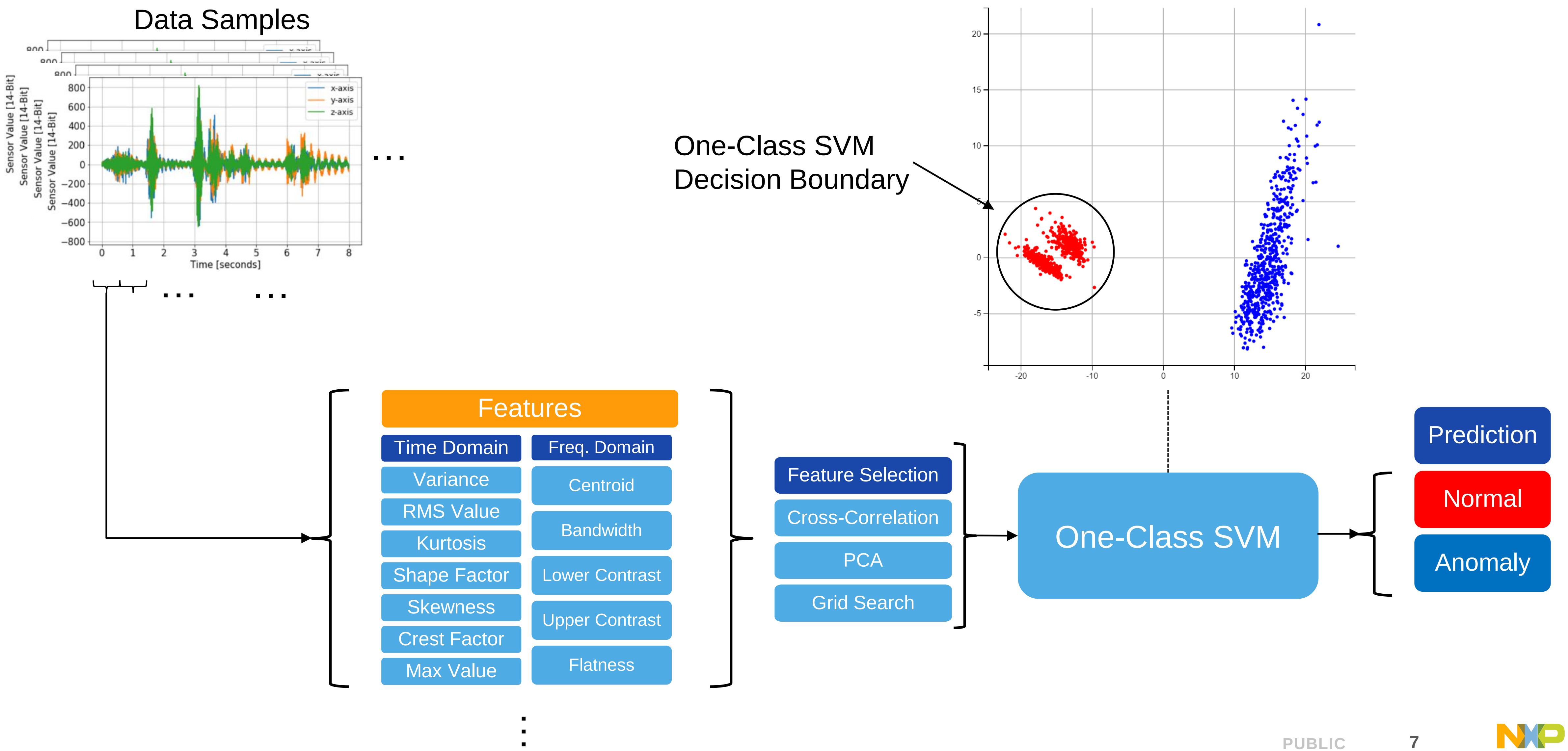
$$\min_{\mathbf{w},b} \quad \frac{1}{2}||\mathbf{w}||^2$$

subject to: $y_i(\mathbf{w}\mathbf{x}_i + b) \geq 1 \ , \ i = 1 \ldots m$

- Convex and quadratic
- Simple to find optimal solution (global minimum)



HOW DOES THE ANOMALY DETECTION WORK? [OCSVM]



Training Objective

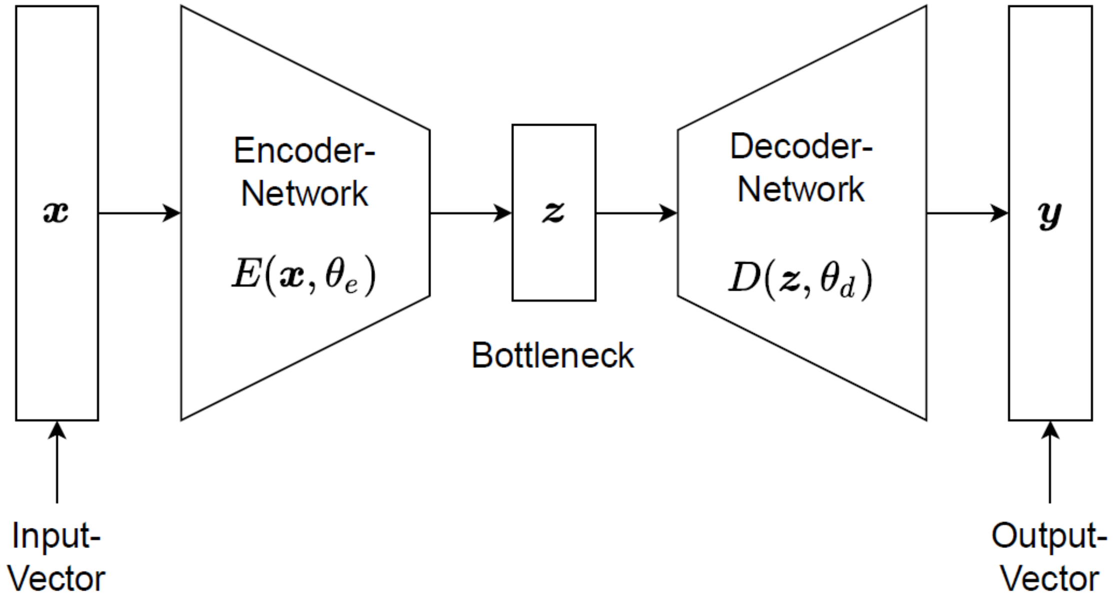
- Learn a lowdimensional representation of normal Data
- Best Reconstruction on Training Data
  - ➢ Minimizing Reconstruction Error

Components

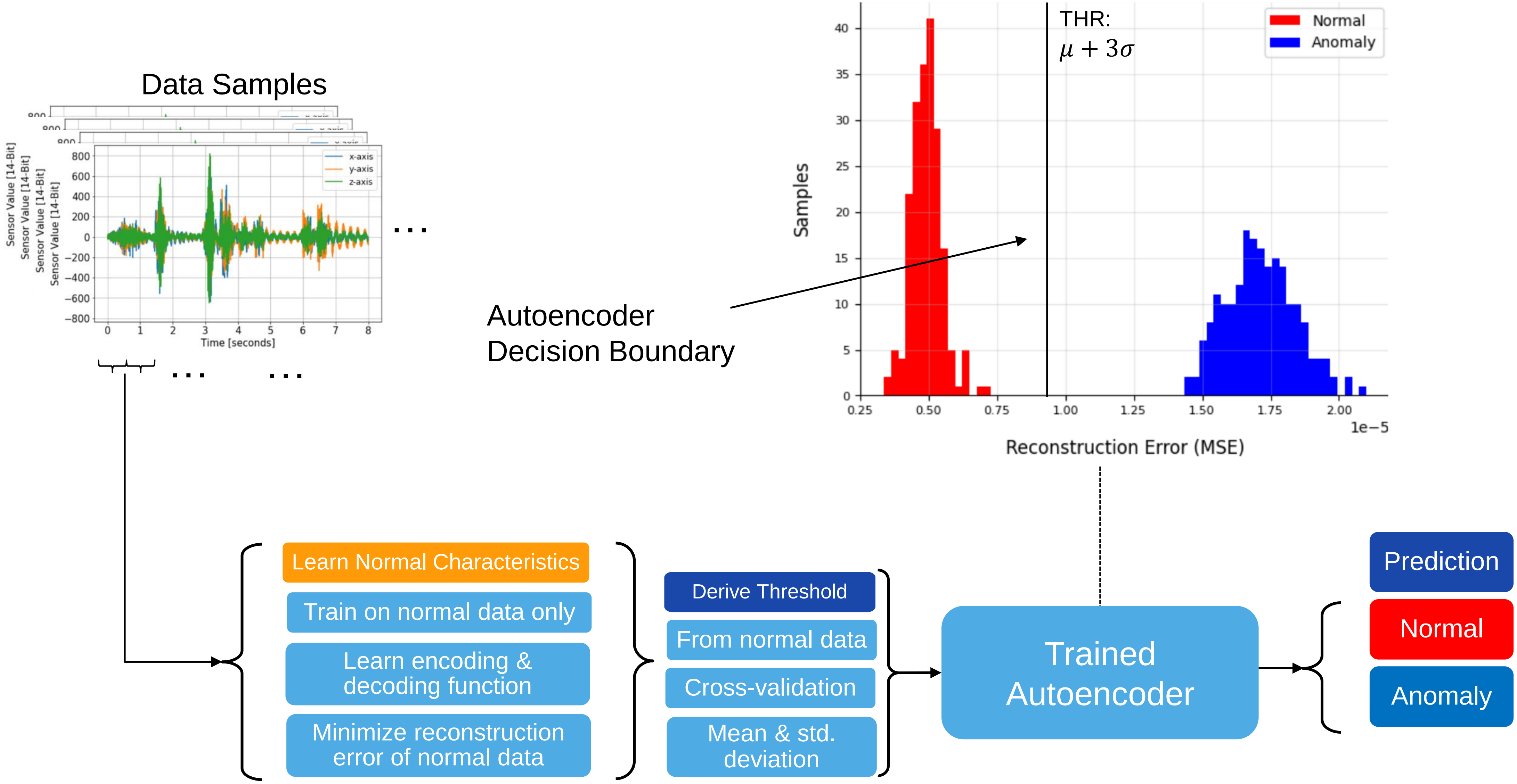
- Encoder: Dimension reduction
- Bottleneck (latent space)
- Decoder: Dimension expansion

Training Approach

- Unsupervised Learning
- Semi-Supervised Learning



AUTOENCODER



System Overview

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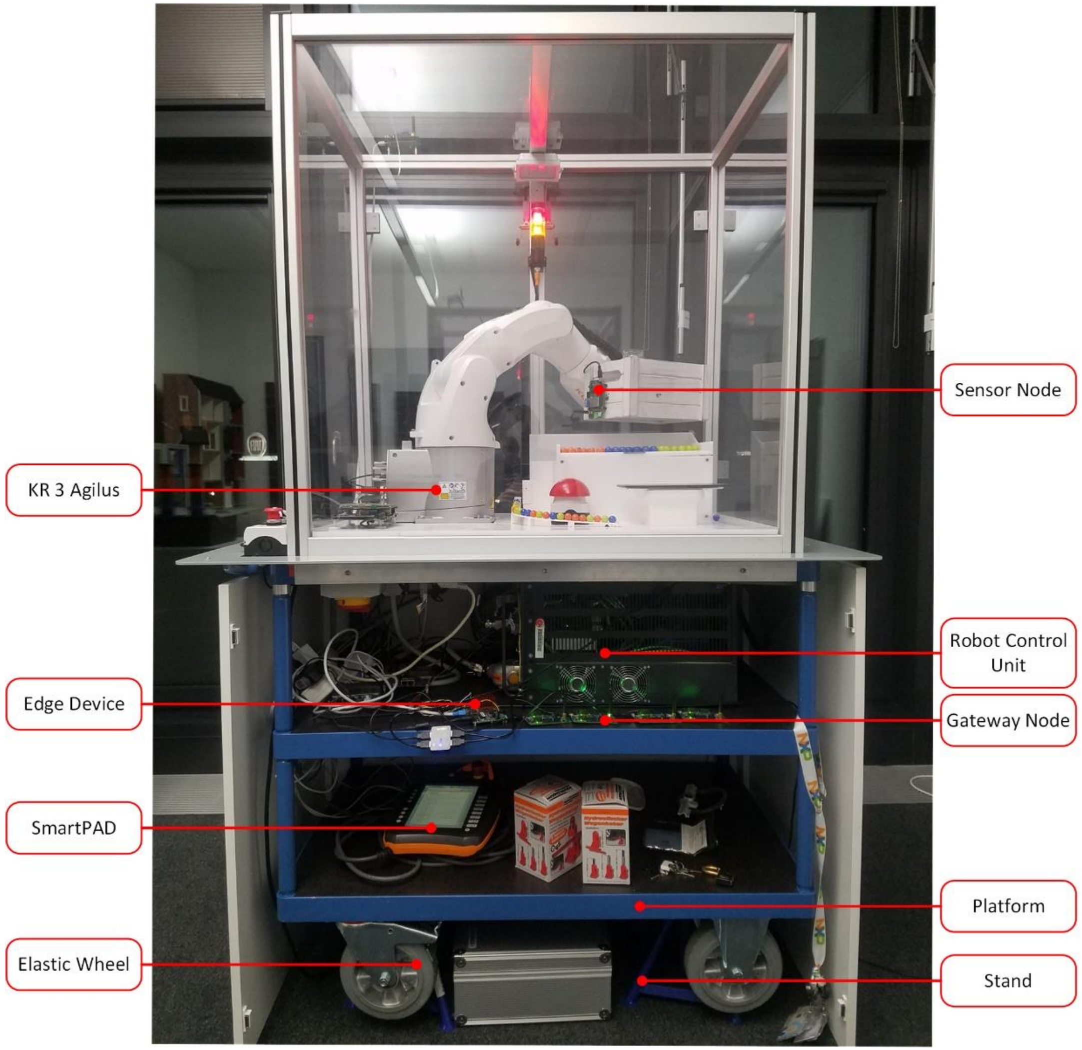
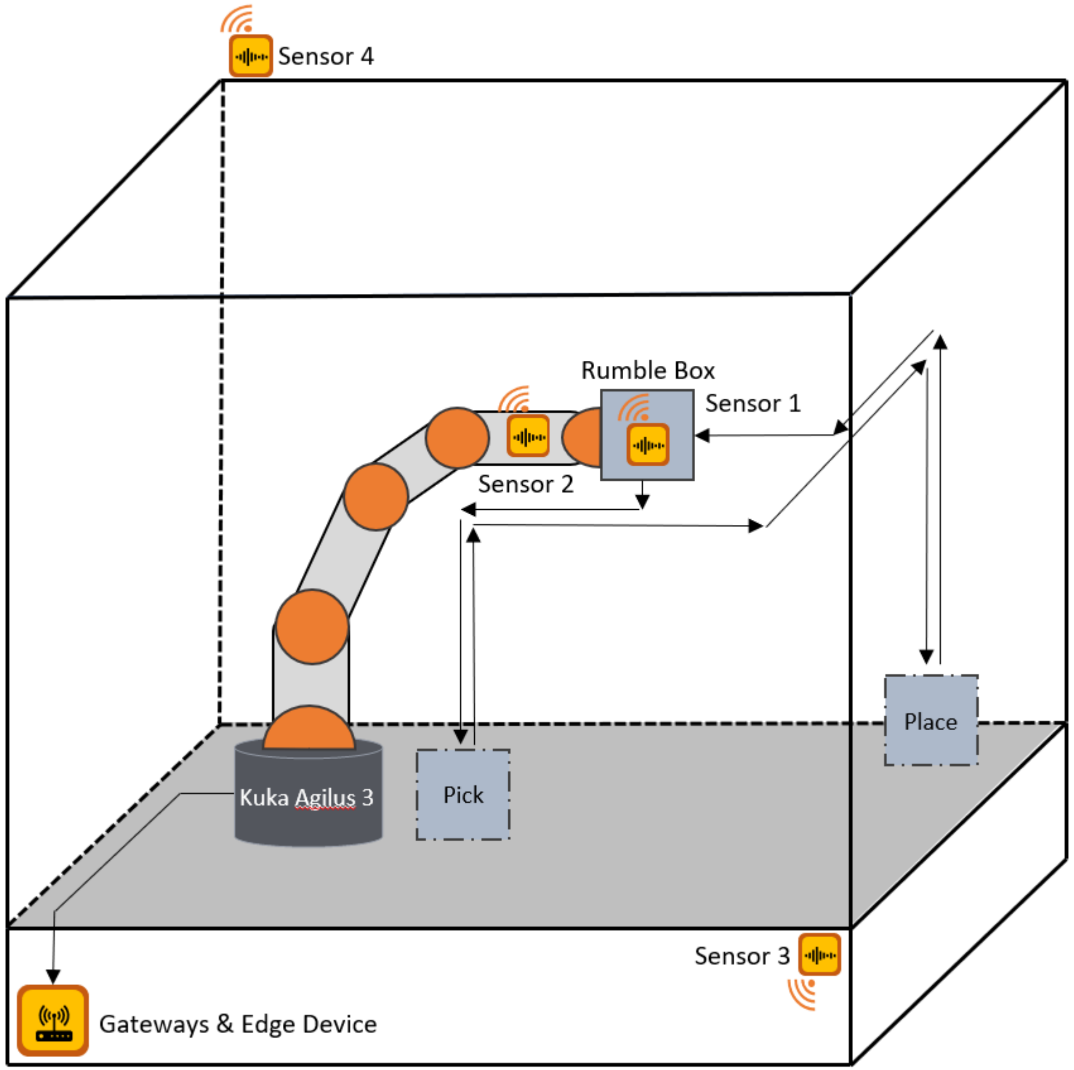
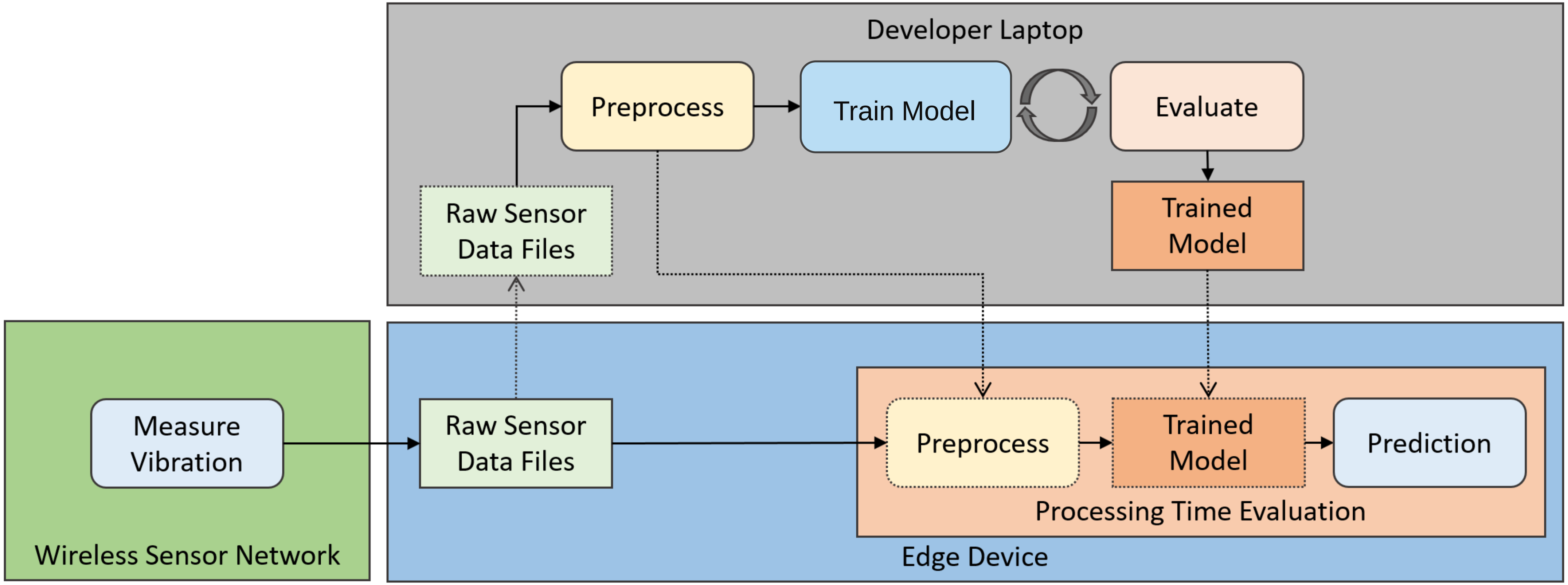
SYSTEM SETUP





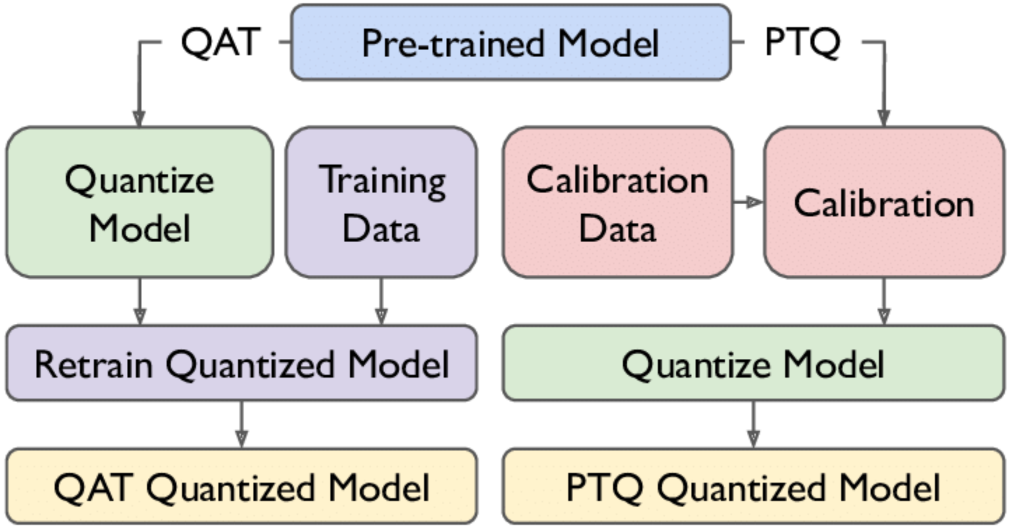

Developer Laptop
Preprocess
Train Model
Evaluate
Raw Sensor Data Files
Trained Model
Measure Vibration
Raw Sensor Data Files
Preprocess
Trained Model
Prediction
Processing Time Evaluation
Wireless Sensor Network
Edge Device

Quantization Characteristics

- Quantization reduces model size and increases inference speed
- Neural Processing Unit (NPU) on i.MX8M Plus only supports 8-Bit quantized models
- 8-Bit quantization can reduce model accuracy significantly

Quantization Schemes

- Post training quantization (PTQ)
  - Lower accuracy but faster training
- Quantization aware training (QAT)
  - Higher accuracy but slower training
- Mixed precision quantization
  - Only quantize specific layers inside the model



[1] Amir Gholami, Sehoon Kim, Zhen Dong, Zhewei Yao, Michael W. Mahoney, and Kurt Keutzer. 2021. A Survey of Quantization Methods for Efficient Neural Network Inference. arXiv:2103.13630 [cs] (June 2021). http://arxiv.org/abs/2103.13630 arXiv: 2103.13630

Use Case Evaluation

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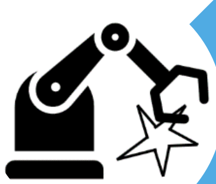
Operator Faults

- Velocity Variation

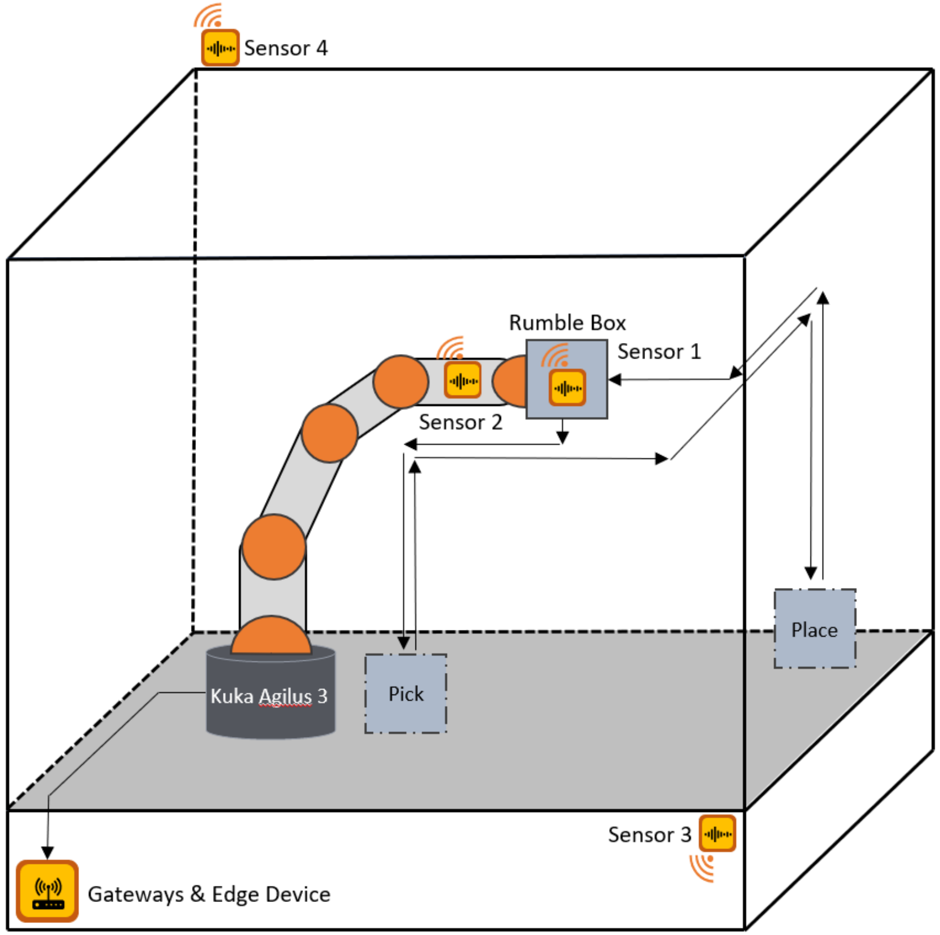
Loose or Broken Robot Parts

- Loose Robot Platform



Collisions

- Loose Mass inside a Box

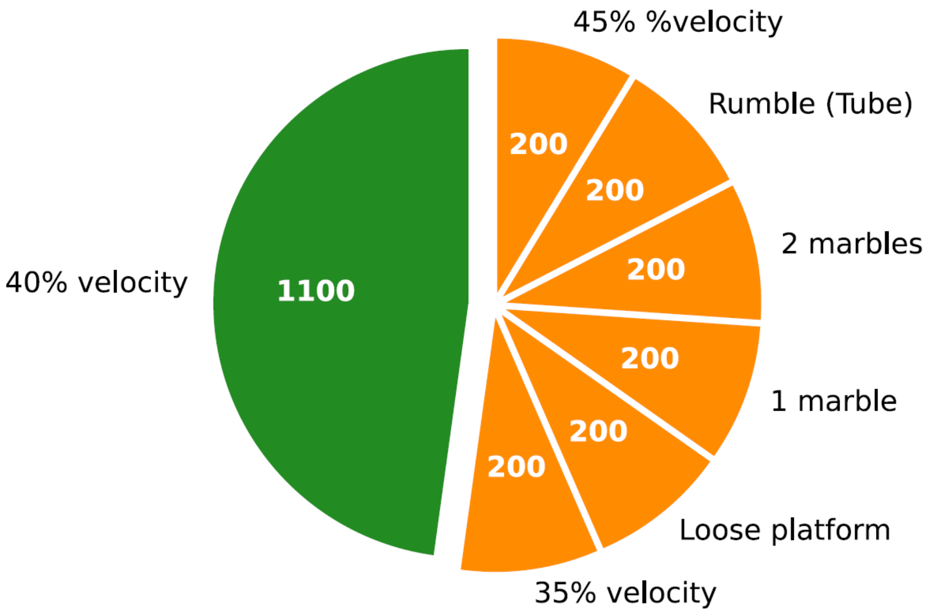


Characteristics

- 4 sensors with 3 axis and 14-Bit resolution
- Sequence length: 8 seconds (windows of 250ms)
- Sampling rate: 800Hz

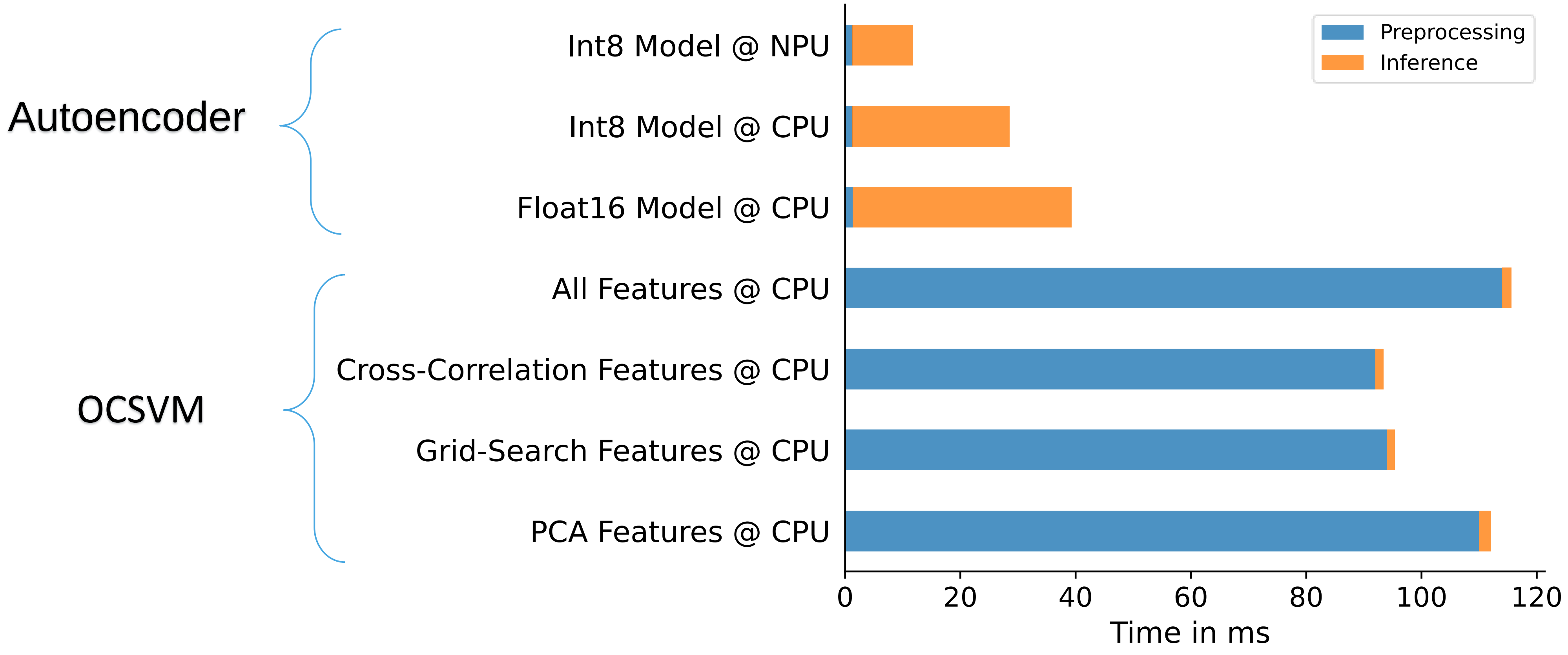
Dataset

- 1100 Normal sequences
- 200 Anomalous sequences for each anomaly case



	-5% Vel.	Loose Platform	1 Marble	2 Marbles	Tube	+5% Vel.	Total Acc.
OCSVM	50.0%	100.0%	98.5%	99.0%	100.0%	100.0%	**91.3%**
Autoencoder FP16	90.8%	90.8%	90.8%	90.8%	90.8%	90.8%	**90,8%**
Autoencoder Int8	66.0%	66.0%	66.0%	66.0%	66.0%	66.0%	**66.0%**

EDGE PROCESSING TIME EVALUATION



Processing times correspond to a window length of 250ms ≙ 2400 raw data samples

Summary

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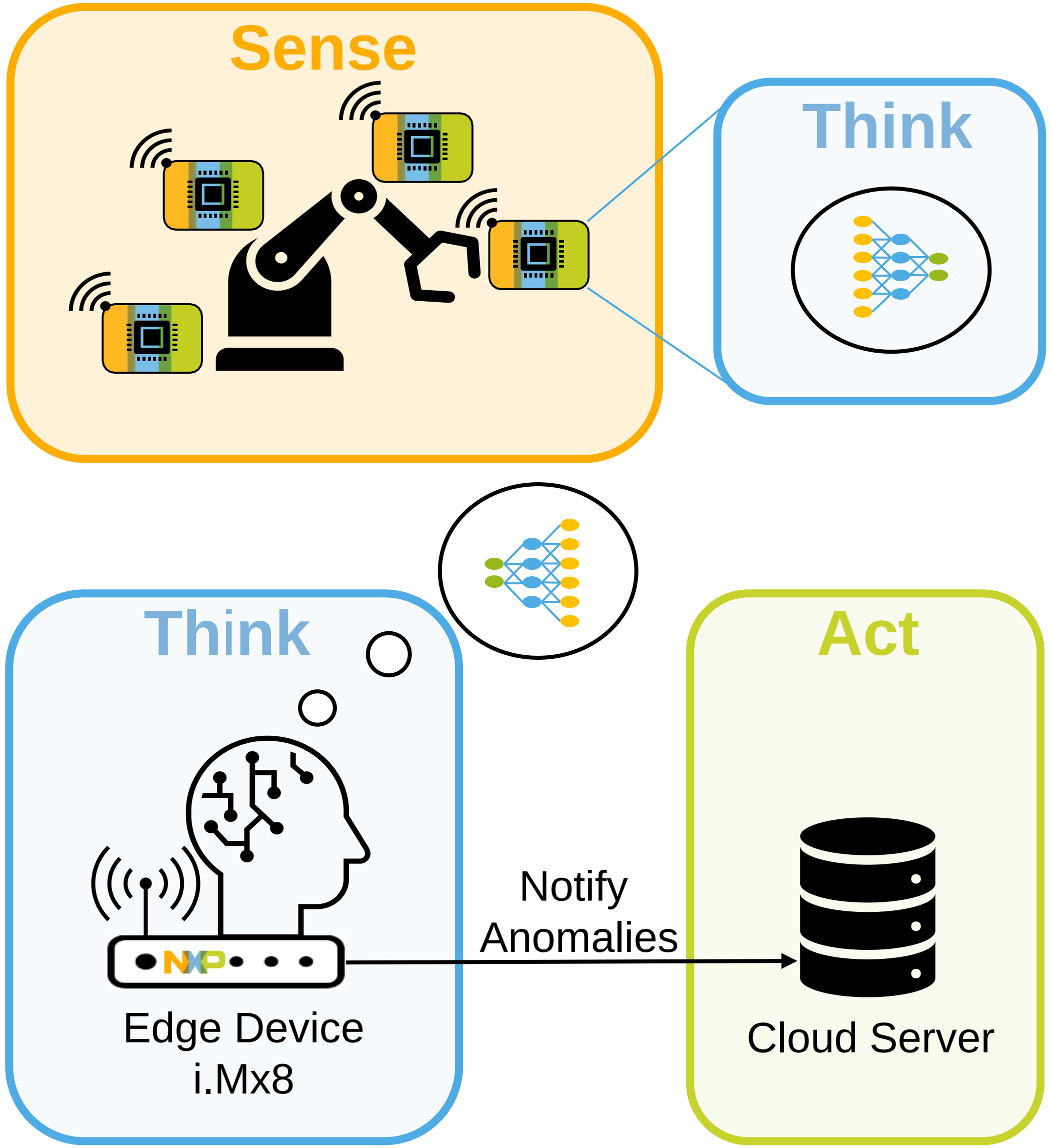
Edge based anomaly detection

- Model quantization can have huge impact on the detection accuracy
- Autoencoder is advantageous in inference processing time
- Autoencoder eliminates the effort of feature extraction

Improvements

- Train autoencoder with QAT
- Use mixed precision quantization
- Move autoencoder encoder to sensor -> Reduction of wireless communication and even fast inference times



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