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# Fault Diagnosis for Industrial Rotary Machinery based on Edge Computing and Neural Networking

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# About

Presenter:

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PhD student, junior researcher at Petrozavodsk State University.

Field of interest: artificial intelligence and computer science.

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Project: development of the industrial monitoring system.

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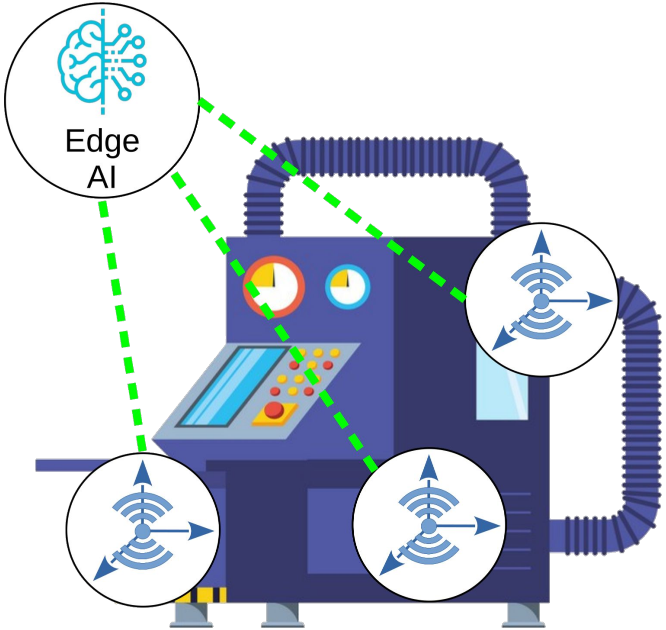
# Problem

Fault diagnosis for industrial rotary machinery: bearing fault detection and classification

1. Convolutional Neural Network (CNN) methods application to fault detection and fault characteristics evaluation.
2. Usage of low-capacity edge IoT devices for real-time data analysis.



# Solution

1. CNN methods application to fault detection and fault characteristics evaluation.
   CNN model:
   a. architecture;
   b. training;
   c. testing.
2. Usage of low-capacity edge IoT devices for real-time data analysis.
   a. concept of an industrial monitoring system based on an edge-centric NN computing device;
   b. performance estimation in a prototype of a monitoring system.

# The CNN model

1-D Convolutional Neural Network (CNN) for vibration signal based bearings fault detection.

Input: vibration signal frame (8192 samples at 64 kHz = 128 ms).

Output: bearing condition:

- healthy,
- outer ring damage,
- inner ring damage.

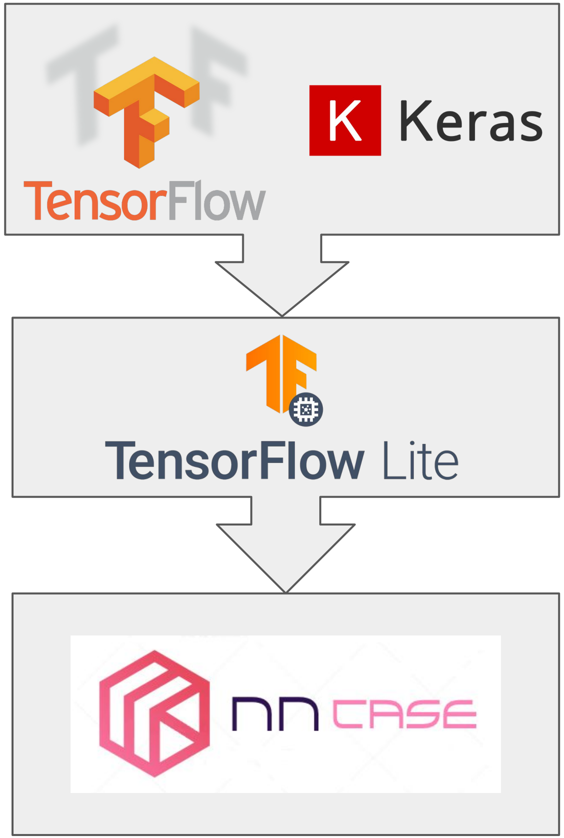
| *Layer* | *Shape* | *Parameters* | |
|---|---|---|---|
| Input | (8192) | | |
| 1D Convolutional Layer | (8192, 2) | Activation | ReLU |
| | | Filters | 2 |
| | | Kernel Size | 64 |
| | | Stride | 1 |
| | | Padding | Same |
| 1D Pooling Layer | (512, 2) | Pool size | 16 |
| 1D Convolutional Layer | (512, 12) | Activation | ReLU |
| | | Filters | 12 |
| | | Kernel Size | 32 |
| | | Stride | 1 |
| | | Padding | Same |
| 1D Pooling Layer | (32, 12) | Pool size | 16 |
| 1D Convolutional Layer | (32, 32) | Activation | ReLU |
| | | Filters | 32 |
| | | Kernel Size | 16 |
| | | Stride | 1 |
| | | Padding | Same |
| 1D Pooling Layer | (2, 32) | Pool size | 16 |
| Fully-connected layer | (150) | Activation | Sigmoid |
| | | Units | 150 |
| Fully-connected layer | (3) | Activation | Softmax |
| | | Units | 3 |

# Tools

Development and training

Deployment:

- platform-specific optimizations;
- enable hardware acceleration.



# The dataset description

Paderborn Bearing Dataset:

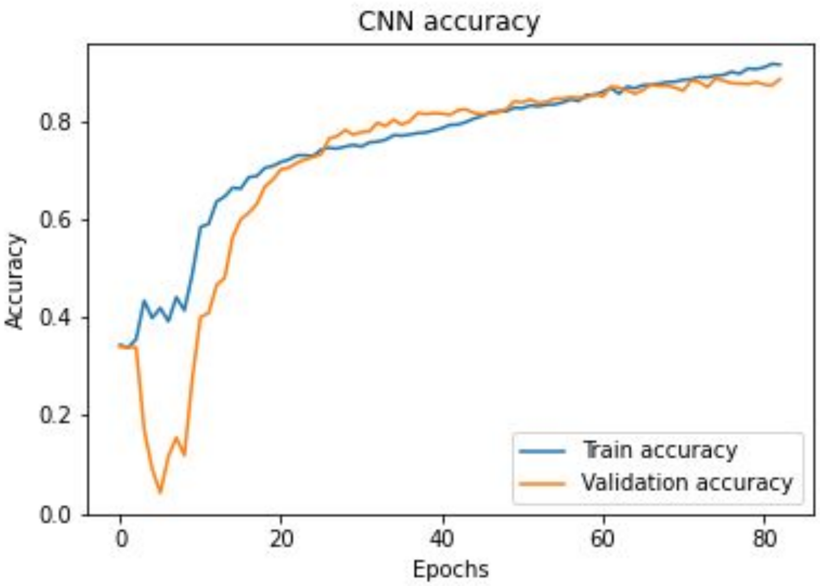
- 32 bearings, with real and artificial damages
- Vibration signal, 4 sec per operating condition, 20 conditions in total, 64kHz, 16-bit

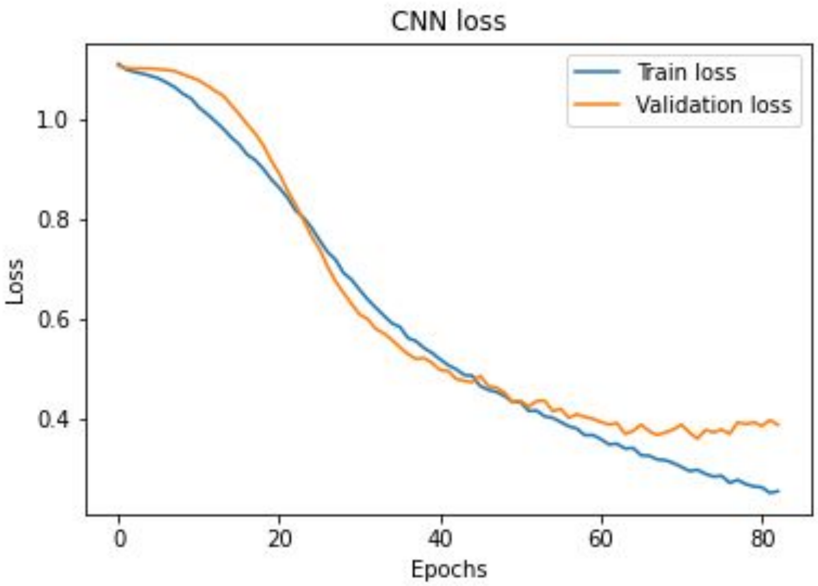
Data selection and preparation:

- 5 bearings for each class (healthy, outer or inner ring damage)
- Validation split ratio 20%
- 8192 samples (128 ms) per frame
- Data normalization

# CNN training

Training and validation accuracy (left) and loss (right) curves of CNN

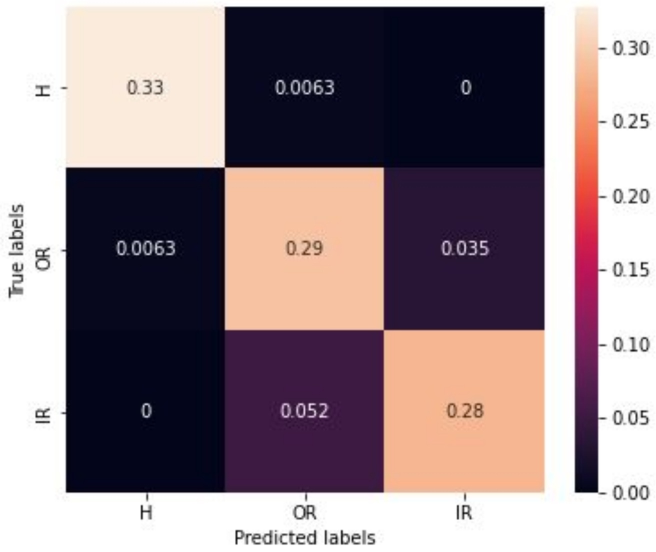


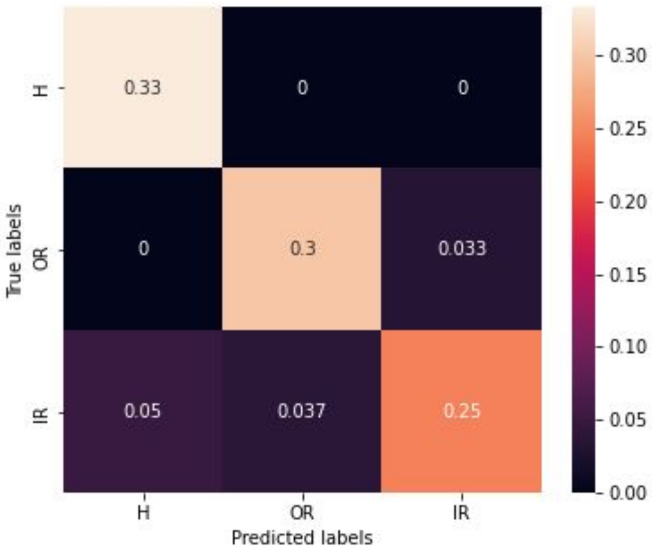




The validation accuracy reach 88%

# CNN testing

Confusion matrix of CNN on training (left) and validation (right) data normalized over all population.




Accuracy: 90% on training and 88% on test dataset.
Applicable both for fault detection and classification.

# Edge-Centric Neural Network Computing Device

## Monitoring system prototype

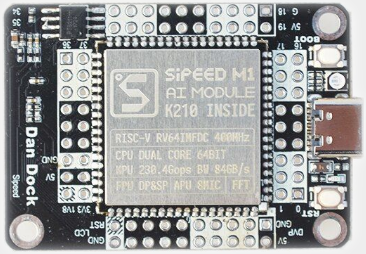
PC

Vibration signal dataset

Data

Result

Edge-Centric NN Computing Device




Kendryte K210

- Dual-core CPU 400 Mhz
- 8 MB SRAM
- CNN hardware accelerator unit

Acceleration could be obtained by leverage hardware acceleration of NN

# CNN performance evaluation on the edge device

1. CNN model storage size 23 Kbytes. Runtime data size 81 Kbytes.

   More than 200 CNNs like this could store simultaneously in SRAM to monitor and diagnose different units.

2. Neural network execution time 212 ms

   Up to 5 units in real-time (check each unit every 1 seconds)

   + Further hardware-specific improvement available (usage of 1×1 or 3×3 convolutions instead of 1×64, 1×32, and 1×16 convolutions)

# Conclusion

1. CNN methods application to fault detection and classification.
    a. lightweight CNN architecture;
    b. high accuracy both for fault detection and classification.
2. Usage of low-capacity edge IoT devices for real-time data analysis.
    a. concept of an industrial monitoring system based on an edge-centric NN computing device;
    b. real-time fault detection and classification possible.

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