# Automated Failure Detection of Air Conditioners Based on Sensor Signal Classification

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# Outline

1. Motivation
2. Problem
3. Components of the developed solution
4. Results
5. Future work

# Motivation

- Increasing competition in the industrial sector.
- Essentialness of optimization of operational cost.
- High service availability and continuity expectations.
- Failures of technical and business processes should be handled ASAP.

# Automated failure detection of air conditioners

- Motion and temperature sensors attached to air conditioners.
- Signal data collection via wireless connections.
- Our task is to develop a method which is capable to
  1. detect machinery failure,
  2. classify the type of malfunction, and
  3. continually adapt the received data.

# Categories of failure

- V-belt problems (torn, loose).
- Bearing problems.
- Air transportation problems (air shutters closed, half closed).
- Fastening problems.
- Imbalance problems.

# Setup of the monitoring system

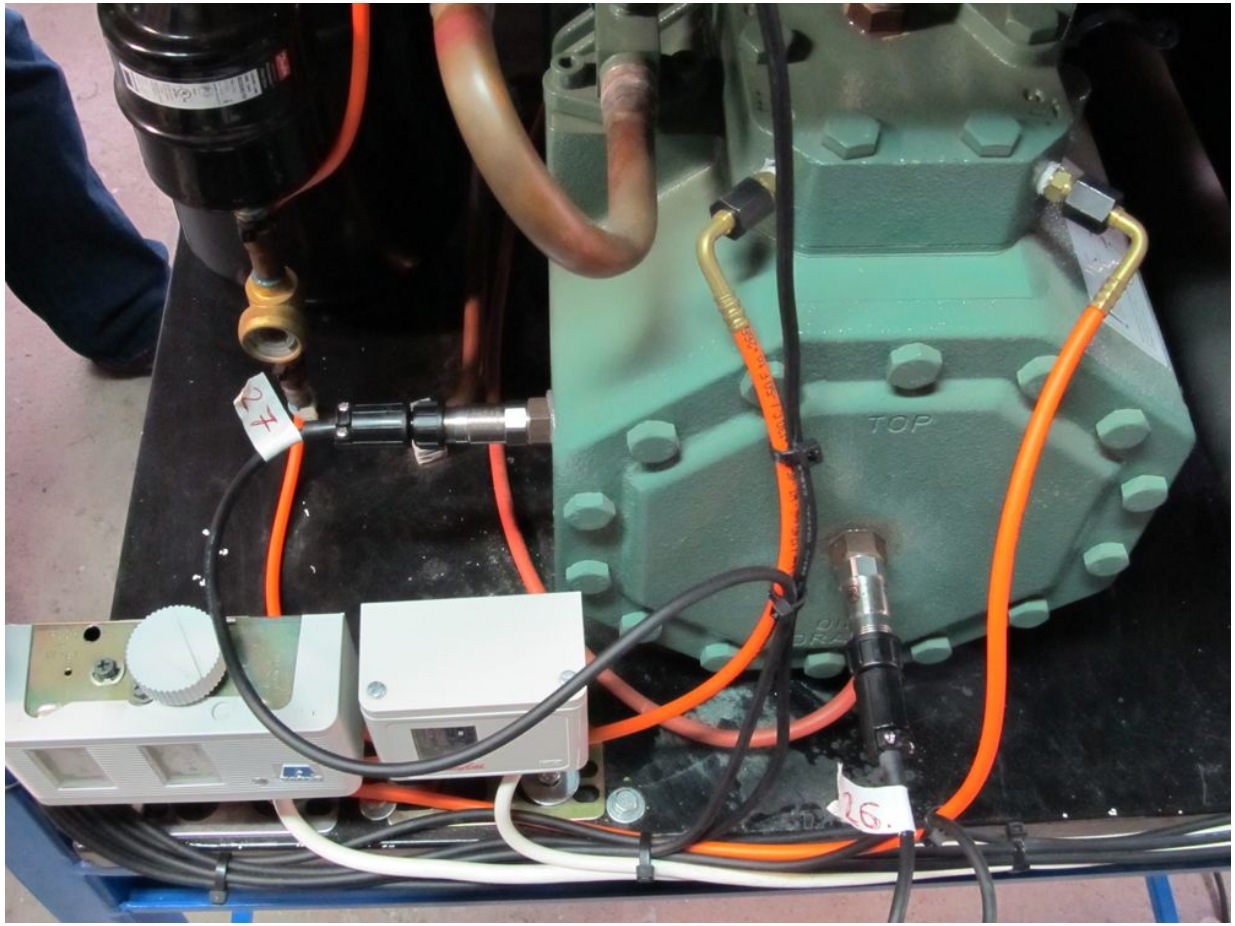



Figure: Sensors attached to an air conditioner.

# Structure of the developed technique

- Feature extraction.
  - Preprocessing of the given signal.
  - Calculation of the DFT.
  - Post-processing of the DFT.
  - Create a sample vector based on configuration files.
- Sample classification
  - Training of a neural network
  - Signal classification

# Feature extraction

- Preprocessing.
  - Resampling.
  - Usage of Hanning window.
- Frequency analysis by Fourier transformation.
- Post-processing.
  - Smoothing.
  - Normalization.

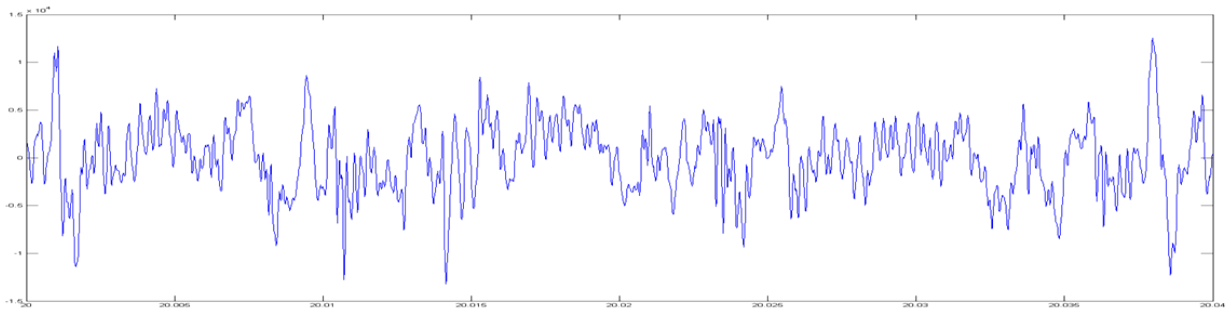
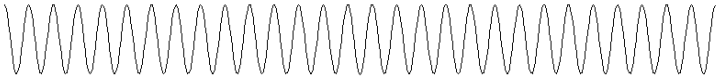


Figure: Raw data.

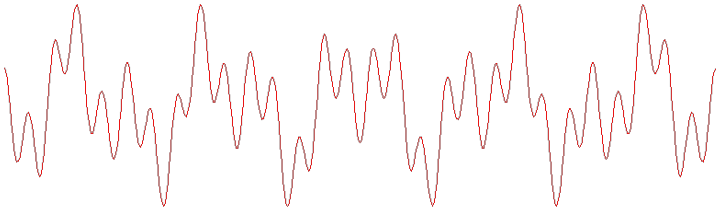
# Fourier analysis

Signal A

Signal B



Signal C



Signal A + B + C

# Fourier analysis

- Extracted features.
  - Dominant frequency's place.
  - Dominant frequency's value.

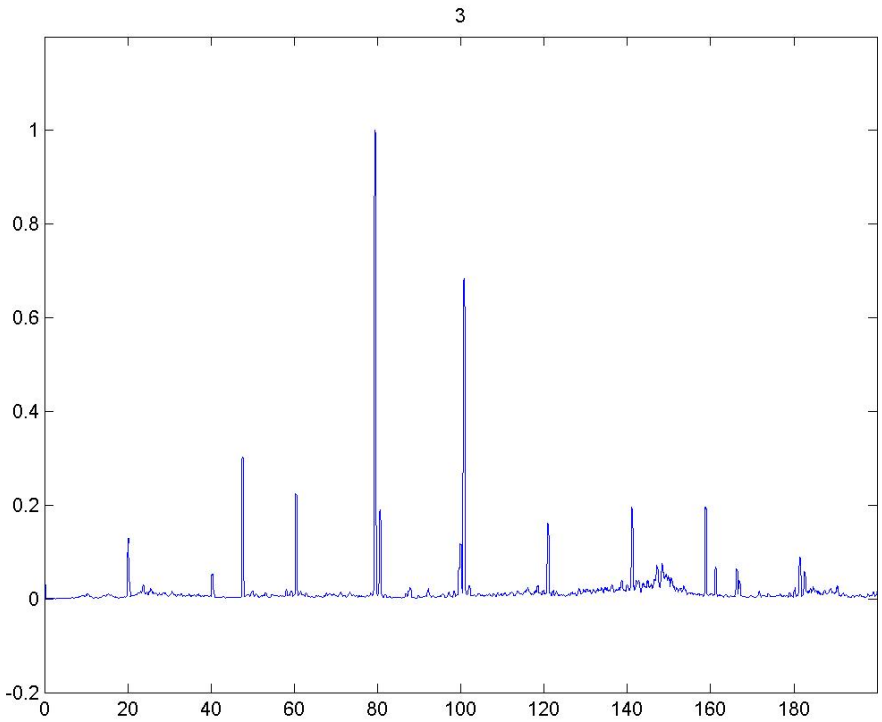



Figure: Example of a Fourier transformed sensor signal.

# Why do we use neural networks?

- Reasons of using Neural networks.
  - We have to enhance the classification in the future.
  - We do not know which feature could be relevant.

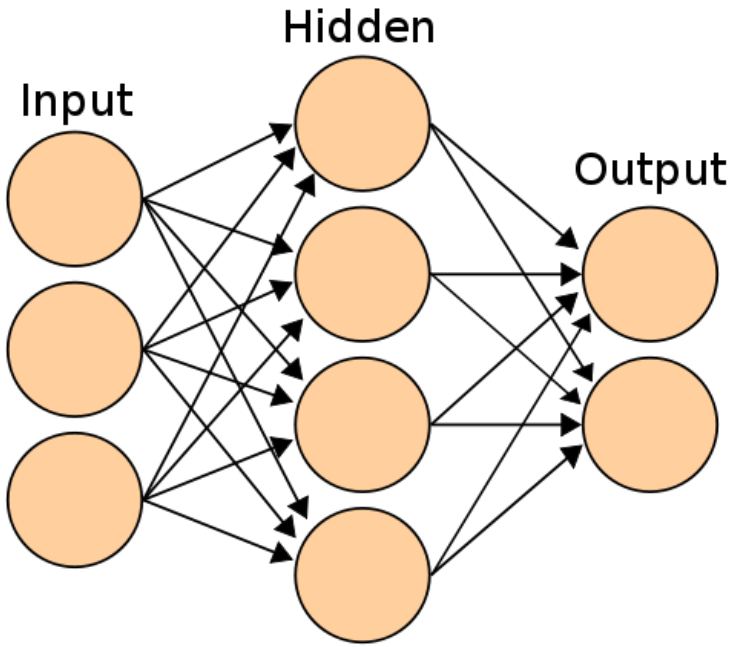



Figure: Neural network Exmaple.

# Concept of artificial neuron

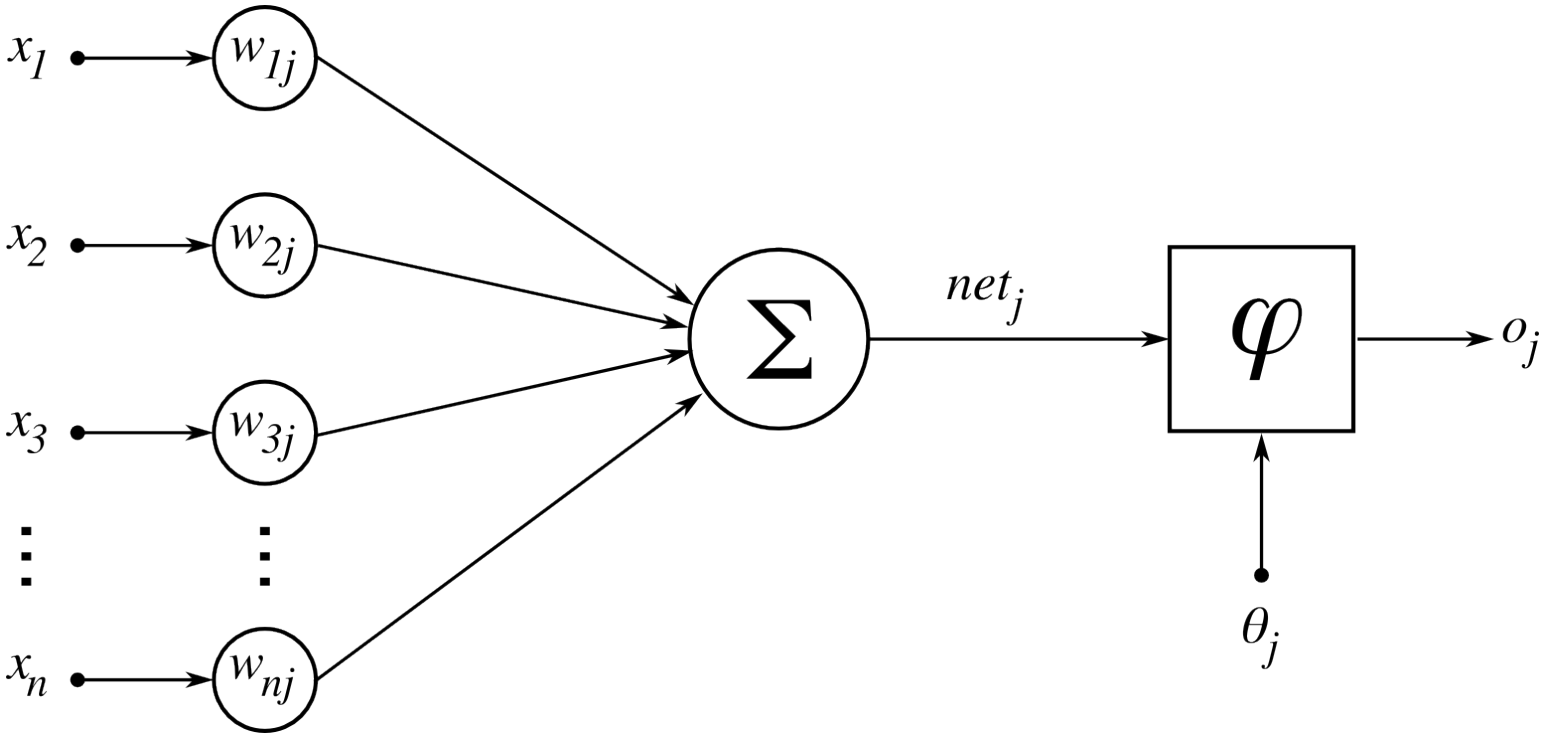



Figure: General artificial neuron.

# Classification with neural networks

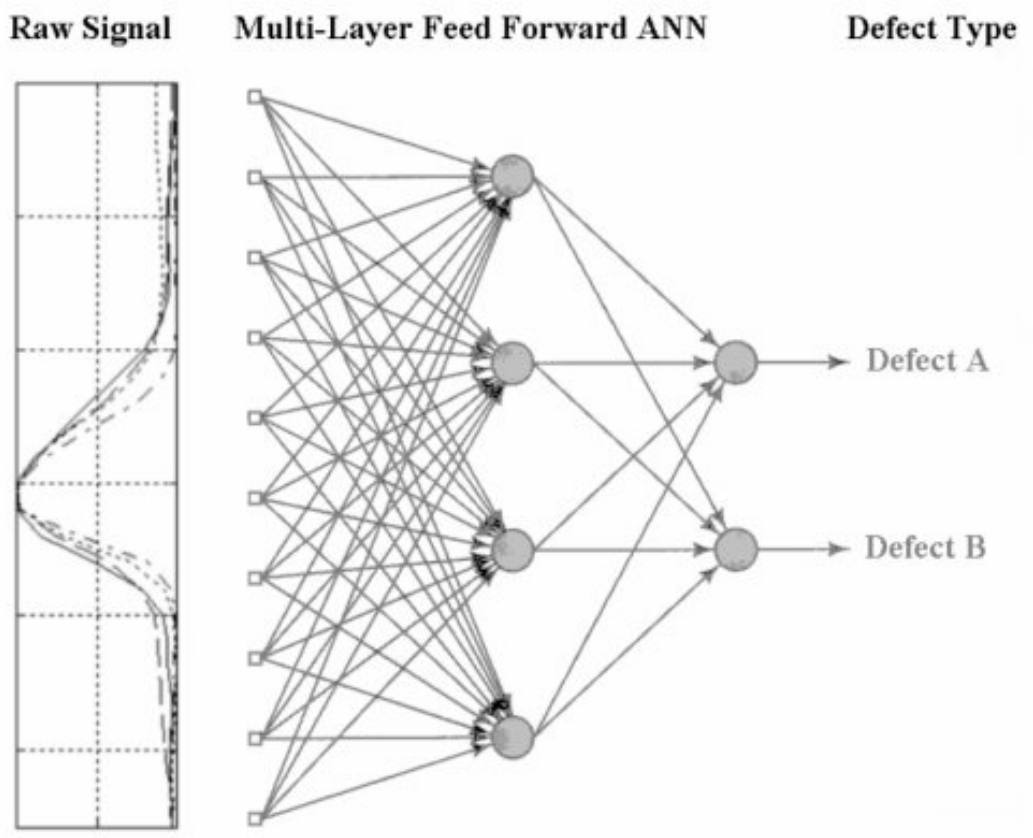



Figure: Multi-layer neural network for classification.

# Parameters of classification

- Feature vectors' size varies from 10 to 200.
- Back propagation for training.
  - Nguyen-Widrow algorithm for bias and weight initialization.
  - Gradient for training.
  - Mean squared error for performance evaluation.
  - On the average, 100 epochs in each training.

# Proposed system

1. Sensors monitor air conditioner operation.
2. Sensor data is collected to a central station.
3. Features extracted from raw signals.
4. Feature vectors are classified by a neural network.
5. State of air conditioners are updated.
6. Service teams are detached if it is necessary.

# Classification rate of success with a single sensor.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 60 | 56 | 100 | 40 | 49 | 69 | 42 | 84 | 59 |
| 2 | 84 | 75 | 64 | 84 | 74 | 60 | 76 | 62 | 70 | 52 |
| 3 | 80 | 73 | 74 | 82 | 82 | 51 | 79 | 46 | 38 | 79 |
| 4 | 68 | 85 | 98 | 98 | 50 | 60 | 57 | 78 | 80 | 54 |
| 5 | 46 | 74 | 78 | 100 | 86 | 62 | 71 | 50 | 98 | 58 |
| 6 | 100 | 68 | 14 | 100 | 88 | 67 | 67 | 72 | 84 | 65 |
| 7 | 72 | 75 | 74 | 100 | 84 | 67 | 65 | 64 | 94 | 64 |
| 8 | 76 | 74 | 58 | 100 | 72 | 75 | 66 | 58 | 90 | 45 |
| 9 | 62 | 66 | 66 | 100 | 62 | 64 | 77 | 60 | 86 | 57 |
| 10 | 60 | 76 | 66 | 100 | 48 | 64 | 79 | 82 | 74 | 65 |

Table: Columns are types of failure, rows are sensor id-s.

# Classification rate of success with multiple sensors.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1, 2, 3 | 82 | 69 | 88 | 100 | 94 | 60 | 88 | 76 | 92 | 74 |
| 4, 5, 6 | 88 | 89 | 94 | 98 | 100 | 82 | 79 | 96 | 98 | 73 |
| 7, 8 | 96 | 72 | 84 | 94 | 100 | 82 | 85 | 84 | 94 | 51 |
| 9, 10 | 56 | 81 | 88 | 0 | 92 | 70 | 77 | 76 | 96 | 57 |
| 1-10 | 100 | 85 | 98 | 100 | 100 | 91 | 85 | 100 | 100 | 96 |

Table: Columns are types of failure, rows are sensor configurations.

# Future work

- Find better parameter settings for feature extraction.
  - Number of frequency intervals.
  - Number and type of features.
  - Size of time interval from which the DFT is calculated.
- Refine classification.
  - Number of neurons in the hidden layers.
  - Sensor set.

Thank you for your attention!