KASETSART UNIVERSITY

# Machine Learning and Signal Processing in MATLAB

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# Acoustic-based predictive maintenance

- Prediction of impending faults of machinery based on recorded audio
- Results could be remaining useful life (RUL), machine health status, or anomalies

- Real-time end-to-end processing pipeline:
  - Audio recording and buffering
  - Framing/segmentation
  - Feature extraction
  - Prediction
  - Reporting

- These processes are constantly running

# Deployment vs training

- We use machine learning for fault prediction because fault patterns are generally too complicated to detect algorithmically or heuristically

- A deployed model will be part of the full pipeline:
  - Audio recording and buffering
  - Framing/segmentation
  - Feature extraction
  - Prediction
  - Reporting

- During model training, we'll work with offline recorded audio
  - **Framing/segmentation** could be done once offline
  - We would then work on refining and hyperparameter tuning the **feature extraction** and **prediction model**

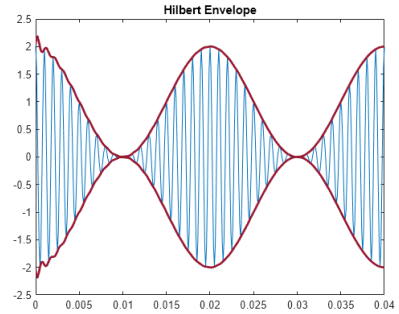
# Machinery sounds

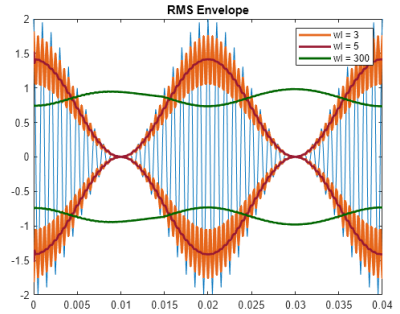
- Noisy environment with multiple machines running at the same time
- Sounds of rotations, movements, clashing, pumping, punching, etc.

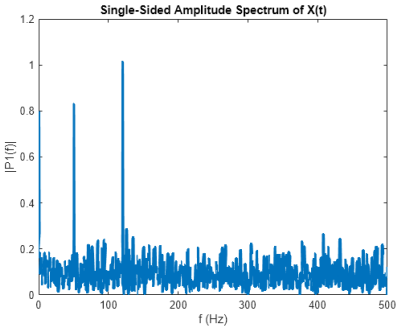
- Signs of faulty equipment
  - Humming/whining
  - Rattling, continuous clicking/tapping
  - Hissing
  - Grinding/scraping
  - Thumping/banging
  - Intermittent knocking
  - Chirping/squealing
  - Etc.

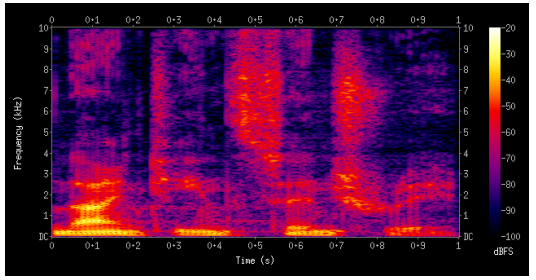
# Audio feature extraction

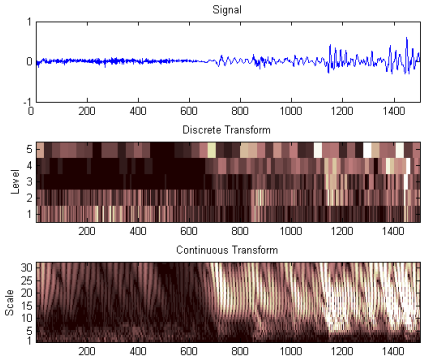
- Using Signal Processing Toolbox
- Time-domain features
  - Level (linear/decibel)
  - Amplitude envelopes
  - Moving average/RMS
- Frequency-domain features
  - FFT (spectrum)
- Time-frequency features
  - STFT (spectrogram)
  - Wavelet transform
  - MFCC
- Dimensionality reduction

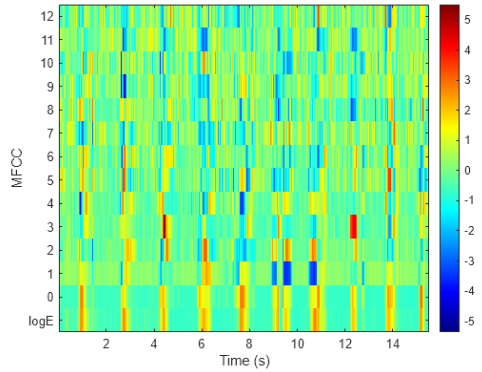


# Noise reduction

- Might be done as a preprocessing step before feature extraction (or even before framing/segmentation)
- Need to be careful to not also remove useful features from the audio

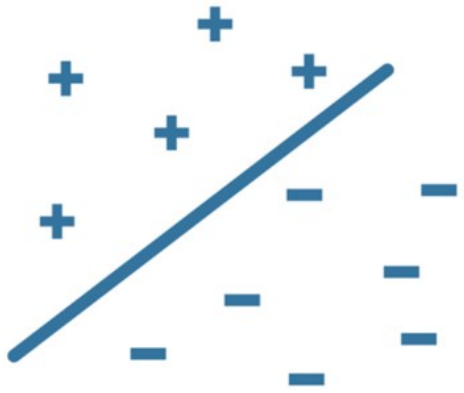
- Techniques
  - Frequency selective filtering
  - Spectral subtraction
  - Spectral gating
  - Wiener filtering
  - Wavelet denoising
  - Adaptive filtering
  - ML-based noise reduction

# Machine learning models

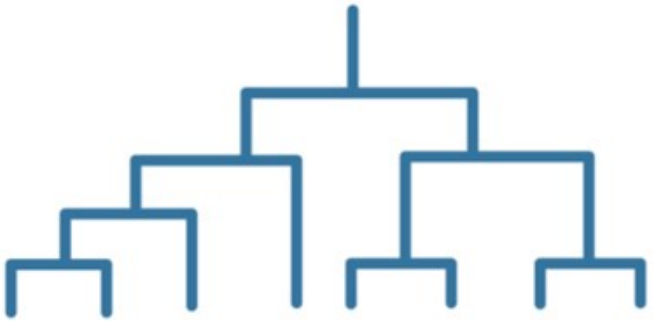
- With our limited hardware, complex deep learning models are generally not feasible
- Regression models could be used for RUL prediction
- But we'll focus on classification models
  - Health status
  - Anomalies
  - Failure modes

# Classification models

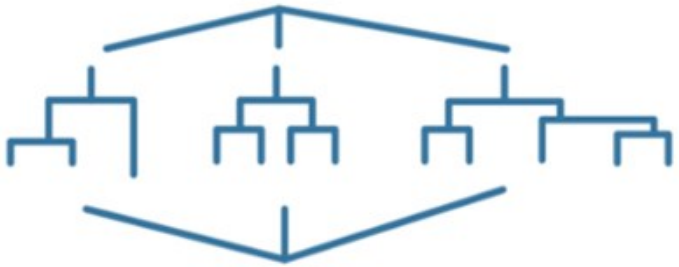
Support vector machine (SVM)



Decision tree



Ensemble method

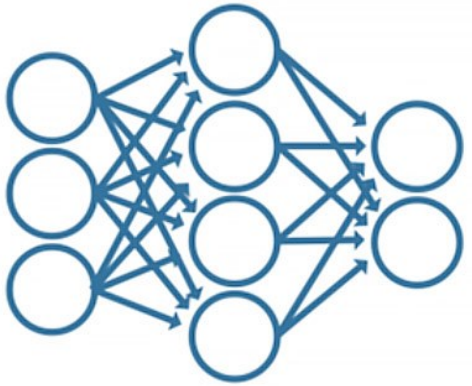


# Classification models

Naïve Bayes

k-nearest neighbor (kNN)

Neural network



# MATLAB Toolboxes

- Signal Processing Toolbox
- DSP System Toolbox
- Audio Toolbox
- Wavelet Toolbox
- Statistics and Machine Learning Toolbox
- Deep Learning Toolbox
- MATLAB Coder/Simulink Coder