Acoustic Features and Autoencoders for Fault Detection in Rotating Machines: A Case Study

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November 18, 2024

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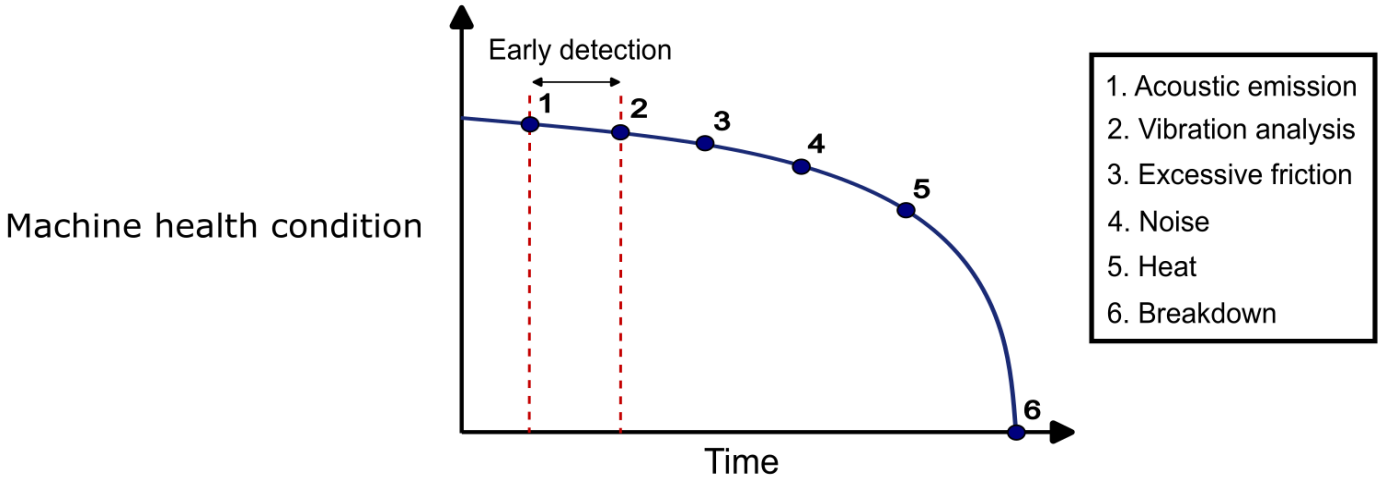
Outline

- Motivation
- Case Study: MaFaulDa
- Autoencoder Based Approah
- Results and Discussion
- Final Remarks

Motivation

- Electric motors are ubiquotous in industrial processes
- Machinery faults might result in human and economic harm



- Preventive maintanance and early fault detection

Figure adapted from: Saufi, S.R. et al.: Challenges and Opportunities of Deep Learning Models for Machinery Fault Detec- tion and Diagnosis: A Review. IEEE Access 7, 122644–122662 (2019).

Motivation

- Obtaining labeled data is challenging
  - Determination of every possible failure type
  - Different operational environments
- Autoencoders for Machine Fault Detection (MFD)
  - Unsupervised (only normal operation data required)
  - Only acoustic data is considered (early detection)

Case Study

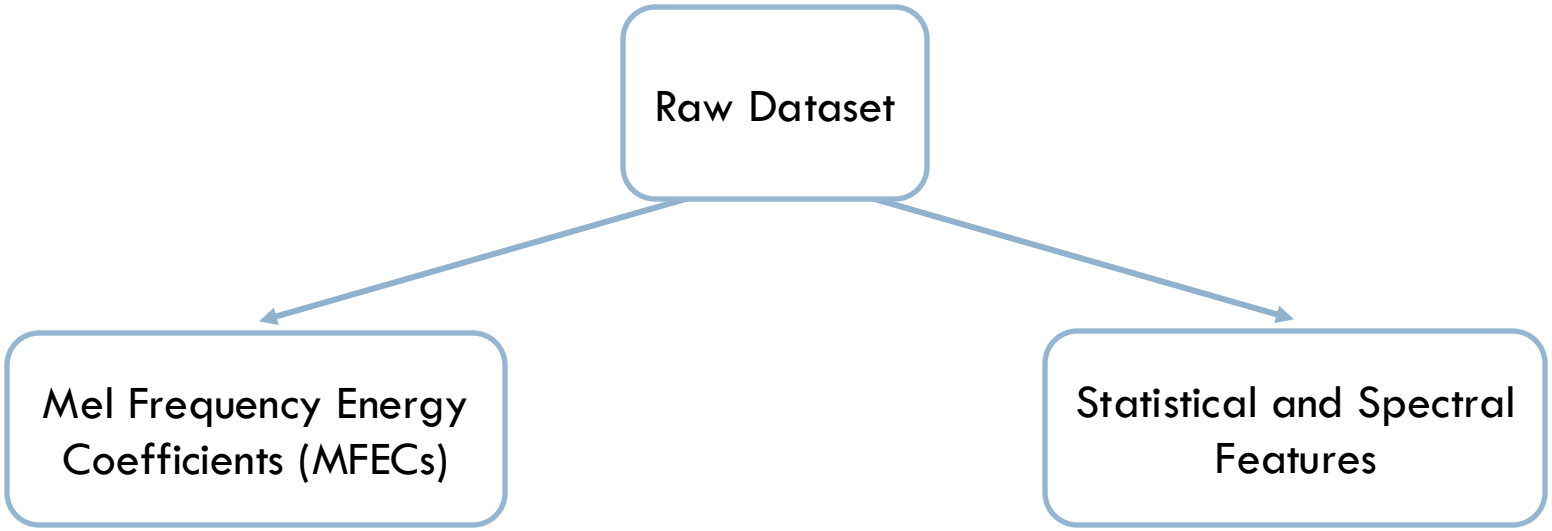
MaFaulDa

MaFaulDa: Machinery Fault Database

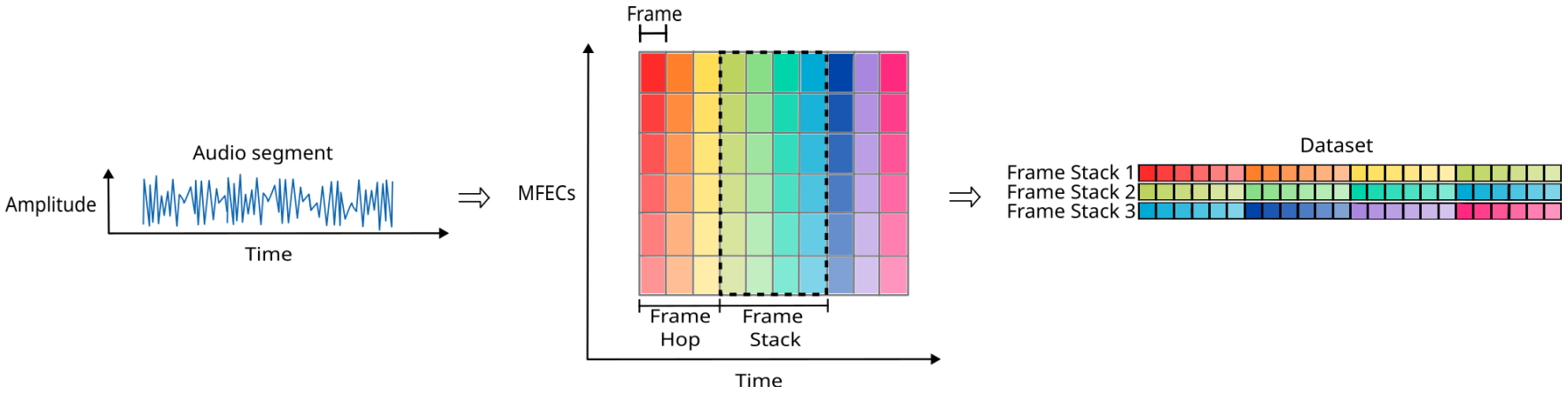
- 1,951 multivariate time-series (50KHz)
  - 49 under normal operation condition
  - 1,902 faulty scenarios (5 different types – merged as fault)
- Eight different sensors (time-series)
  - Six acceleromenters
  - A tachometer
  - A microphone
- We consider classes "normal" and "fault" (merged)

Mafaulda: Machinery fault database (2016), https://www02.smt.ufrj.br/~offshore/mfs/

Feature Extraction



Mel Frequency Energy Coefficients (MFECs)



- In brief, application o FFT to windowed segments
- Window frames are stacked into resulting objects
- We also down-sampled the audio signal (3 subsamples)
- Final dataset with ~410k objects / 1,600 features
  - ~10k normal *vs* ~400k abnormal

Statistical and Spectral Features

- The "traditional" approach for feature extraction
- A total of 13 features are extracted for each series

root mean square; square root of the signal's amplitude; kurtosis value; kurtosis factor; skewness value; peak-to-peak value; crest factor; impulse factor; margin factor; shape factor; frequency center; root variance frequency and; rms frequency

- Previous work on MaFaulDa relied on these features

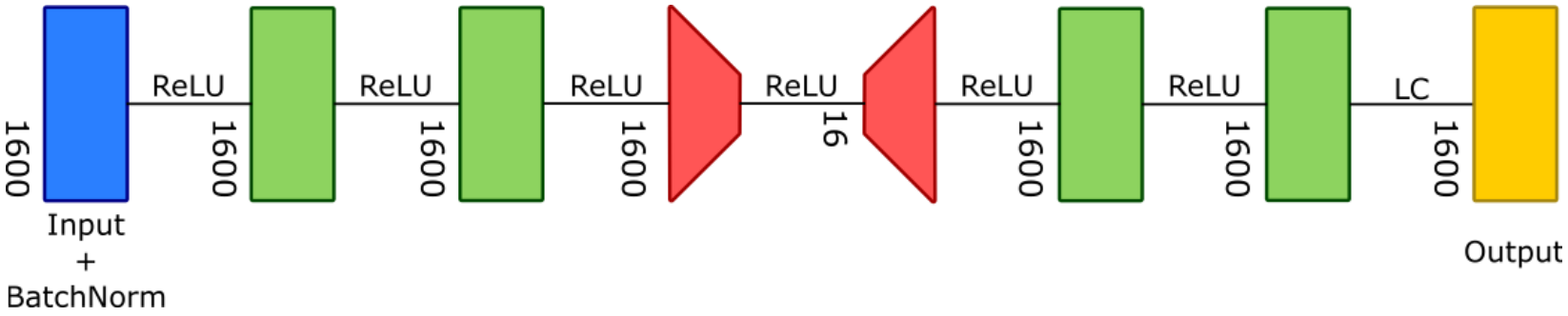
Statistical and Spectral Features

- Two baseline feature sets from this extraction procedure
- Acoustic data sensor only – a single time-series (**B13**)
  - Final feature set with cardinality 13
- All data sensors – a total of eight time series (**B104**)
  - Final feature set with cardinality 104

Autoencoder Based Approach

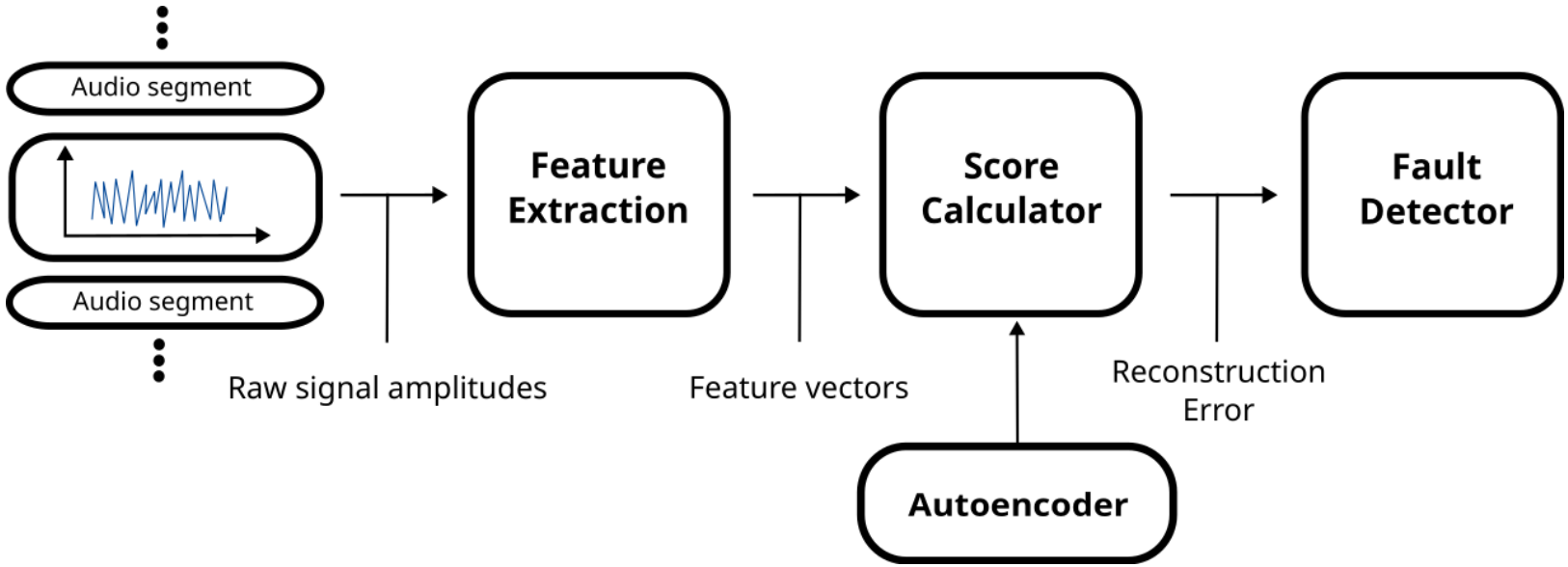
Autoencoder Based Approach

- After grid search on different parameters
  - Six internal layers
  - ReLu activation Function + Adam optimizer



Autoencoder Based Approach

- Fault indicated if reconstruction error is *high enough*
  - Employed a validation set and resorted to Youden Index
  - Four values considered for threshold
    - Min, Max, Mean, Median (as observed in validation set)



Results and Discussion

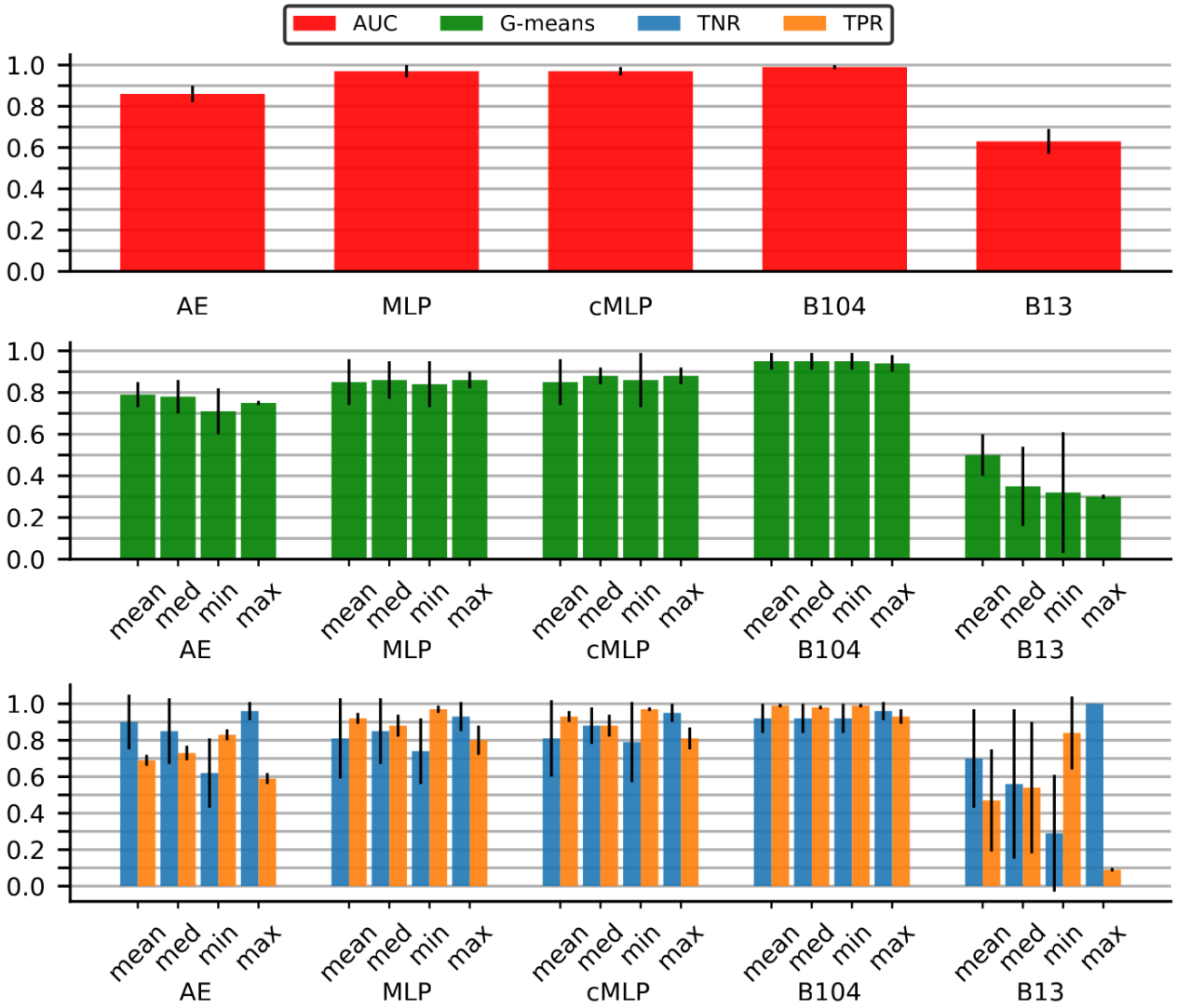
Results and Discussion

- We considered four baselines, all MLPs

B104	B13	MLP	cMLP
[104-Input]	[13-Input]	[1600-Input]	[1600-Input]
[BatchNorm]	[BatchNorm]	[BatchNorm]	[BatchNorm]
[104, 104, ReLU]	[13, 13, ReLU]	[1600, 1600, ReLU]	[1600, 16, ReLU]
[104, 104, ReLU]	[13, 13, ReLU]	[1600, 1600, ReLU]	[16, 1600, ReLU]
[104, 1, Sigmoiid]	[13, 1, Sigmoid]	[1600, 1, Sigmoid]	[1600, 1, Sigmoid]

- Evaluations were performed considering
  - AUC, G-means, TPR and, TNR

Results and Discussion



Final Remarks

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- Autoencoders provide promising results
  - No need for labeled data
- MLPs based on full feature set and MFECs
  - Good overall results, but need labeled data
- Statistical and Spectral Features
  - Poor results based only on acoustic features

Final Remarks

- Fault detection based on Autoencoders
  - Viable considering only acoustic data
- We plan to explore different flavors
  - Convolutional and Variational Autoencoders
- Explore models on open-set scenarios

Thanks for the attention

Questions?

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