Deep NN in acoustic emission classification and hysteresis analysis

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Experiment 1

- 4 sensors
- Continuous acoustic emission
- 5 levels of sharpness
- 5 separate holes
- Shorter sections of signal sampled

Figure: *Drilling setup.*

Experiment 1

- Dimensions of final dataset: (12500, 4, 6000)
- Train:Validation:Test split ratio = 7:2:1

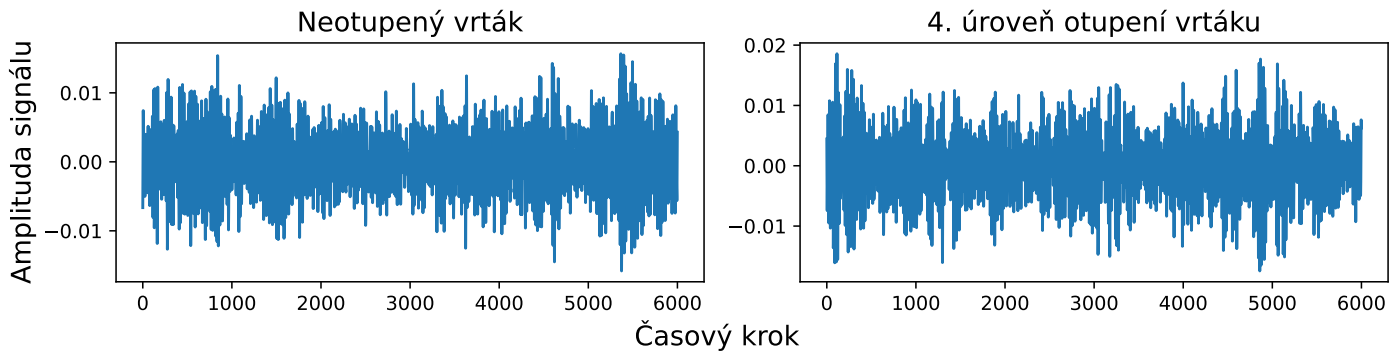


Figure: *Example of AE signal for new and very blunt drill.*

Experiment 2

- 4 sensors
- Continuous AE
- 8 load weight levels
- Constant spinning speed
- Shorter samples
- Dataset of size (16000,4,5000)

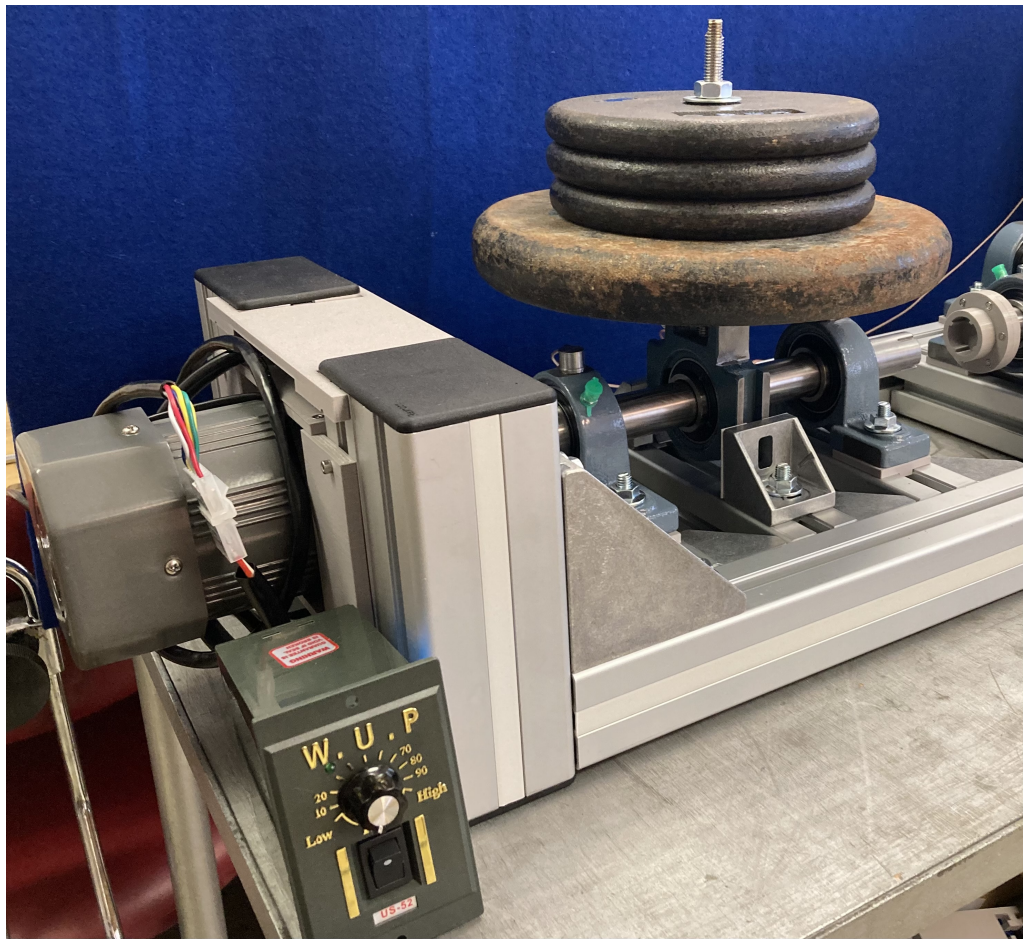
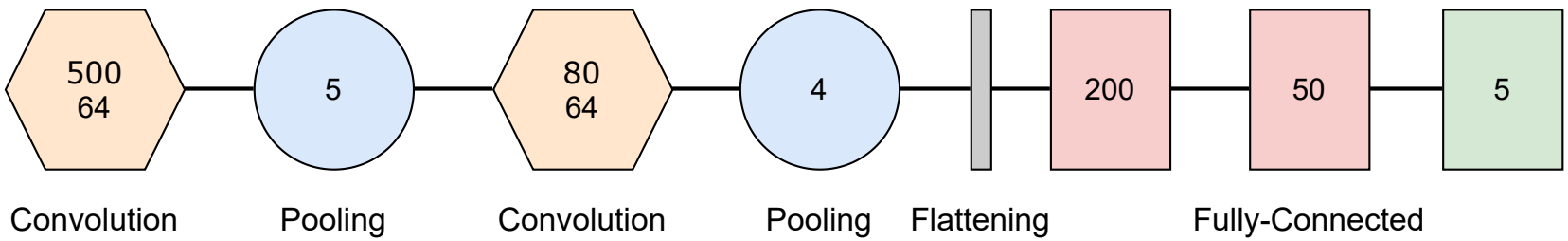


Figure: *Ball bearing loading setup.*

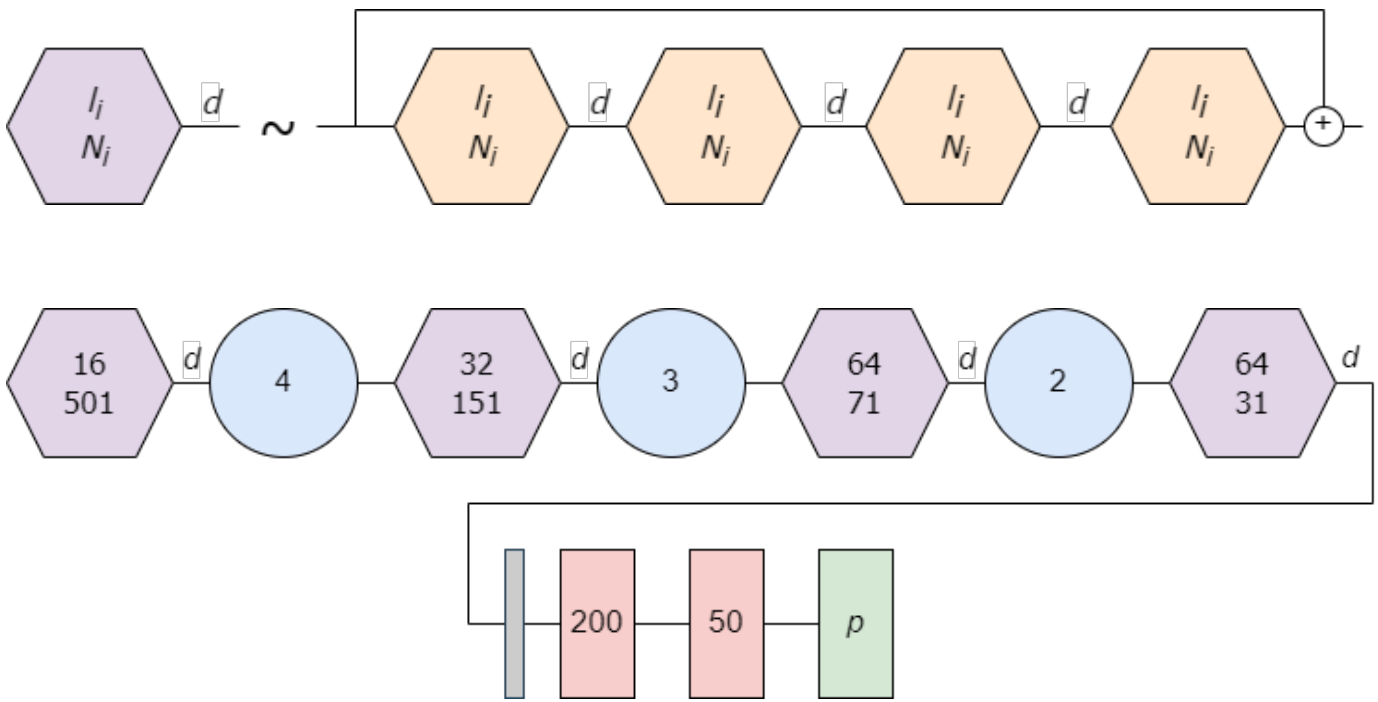
NN architectures - 1. Conv2Net

- Based on LeNet-5
- 2 convolutional layers with filters of size 501 a 81
- ReLU activation
- Use of max-pooling



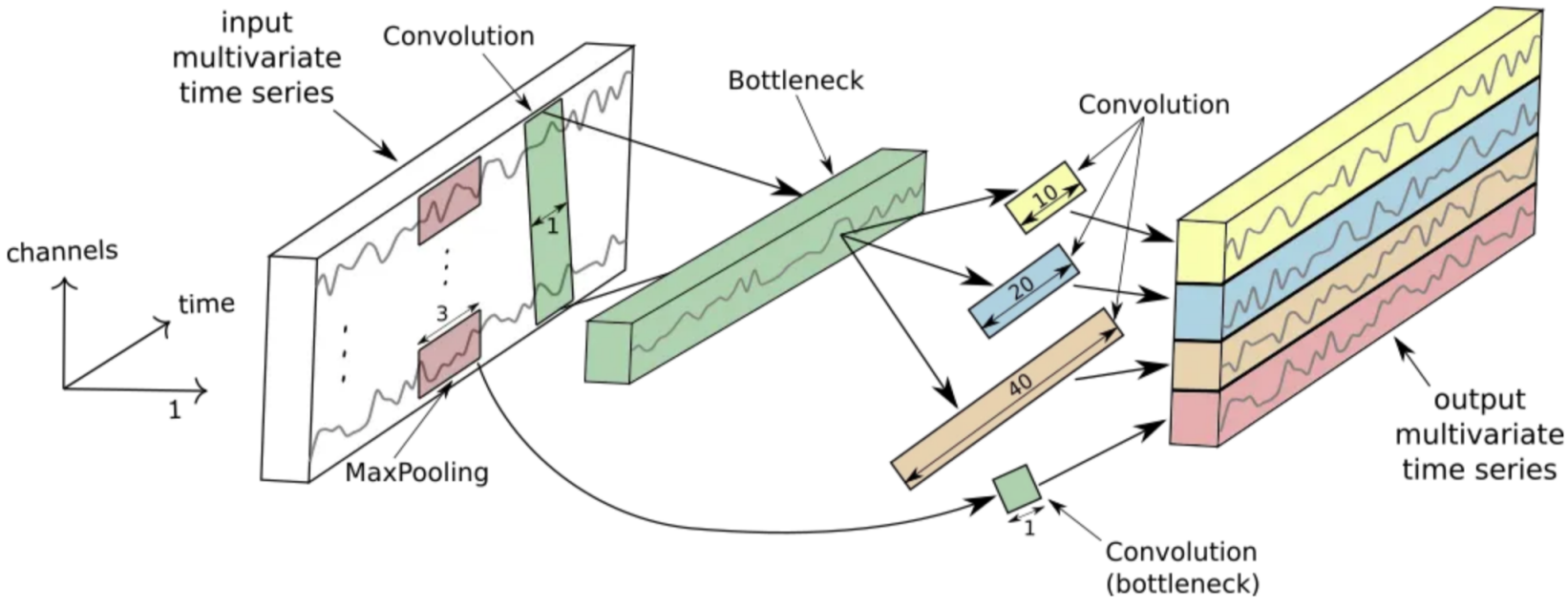
NN architectures - 2. ResNet-16

- Based on ResNets (2015)
- 4 residual blocks
- Each block contains 4 convolutional layers
- BatchNorm a ReLU activation
- max-pooling between blocks



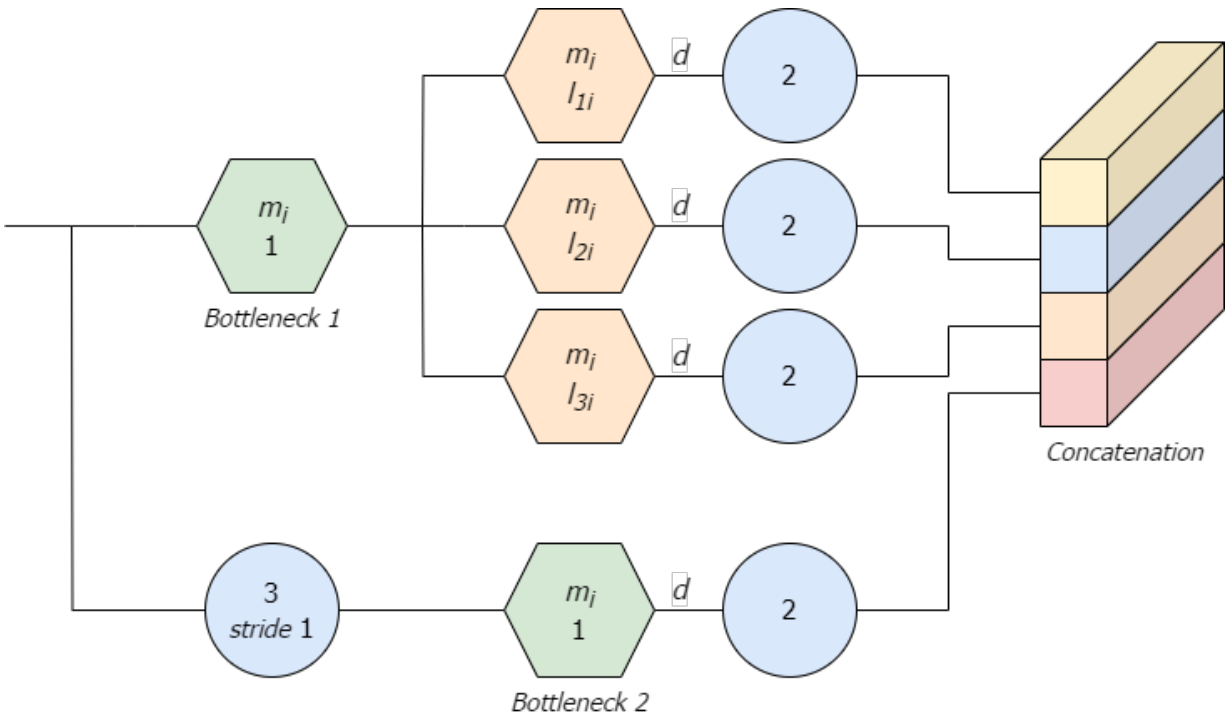
NN architectures - 3. InceptionTime

- 3 IncTime blocks with a residual connection
- Adjusted filter lengths - 41, 101, 301
- Flattening using avg-pooling
- 9 IncTime blocks in total



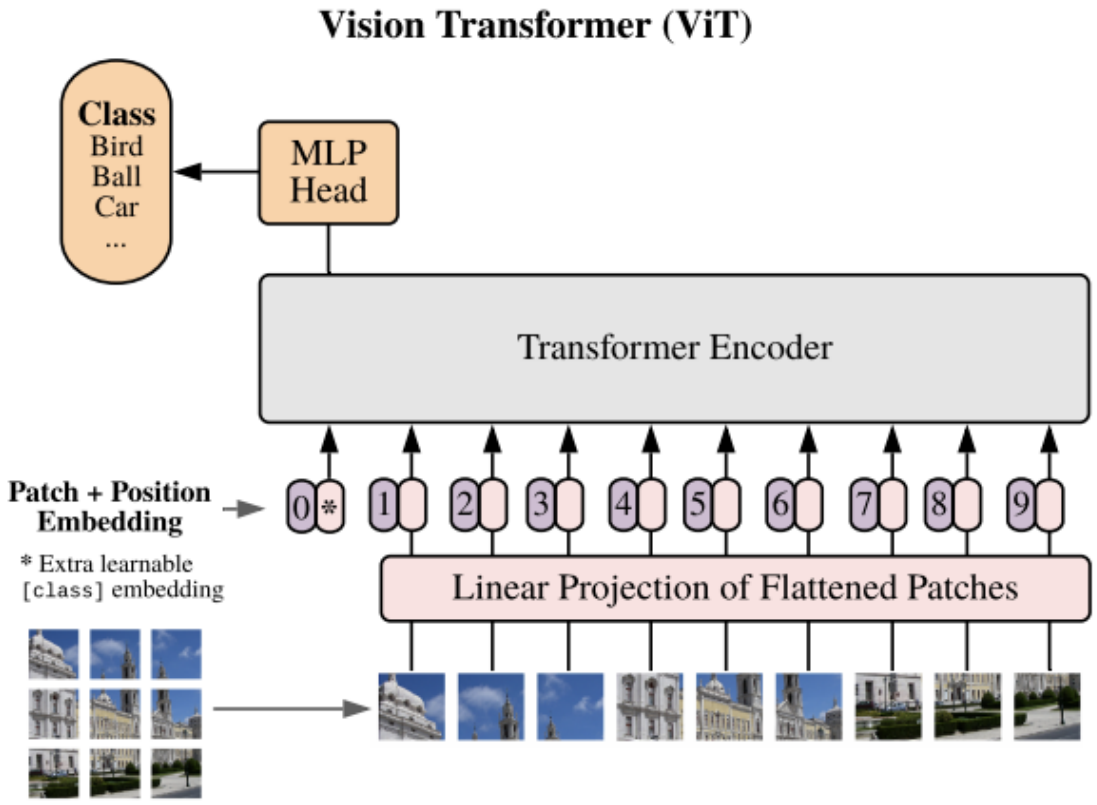
NN architectures - 4. Pooled InceptionTime

- Adjustment of IncTime block: avg-pooling to lower the length of processed signals
- Increasing number of channels, decreasing length of filters



NN architectures - 5. TSiT

- Transformer based on ViT (tsai)
- Signal divided into 1D patches (4x1x40)
- Classification head only on `[class]` token



Results AE - Experiment 1

Table: Classification accuracy on data from 1. experiment (Drill)

	Network type				
	Conv2Net	ResNet-16	InceptionTime	Pooled IncT	TSiT
Mean accuracy	80,4%	81,5%	83,2%	86,4%	56,2%
Std dev	1,96	1,57	4,73	2,15	1,11

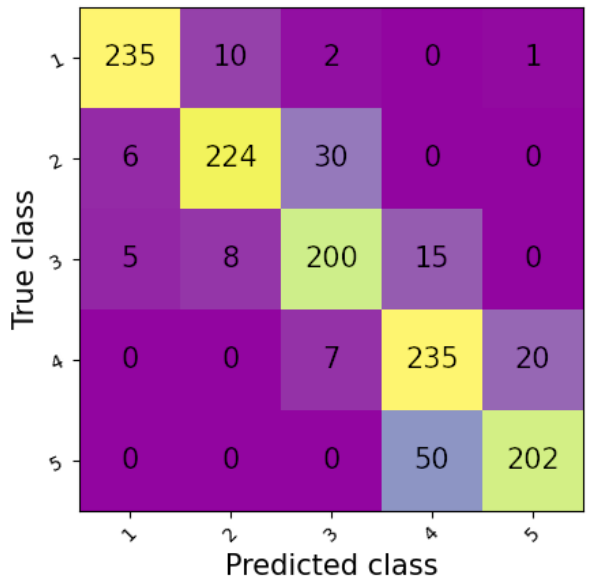


Figure: *Confusion matrix - Pooled Inception Time.*

Results AE - Experiment 2

Table: Classification accuracy on data from 2. experiment (Bearings).

	Network type				
	Conv2Net	ResNet-16	InceptionTime	Pooled IncT	TSiT
Mean accuracy	57%	63,9%	78,1%	84,8%	49,8%
Std dev	4,46	7,68	1,41	0,57	0,44

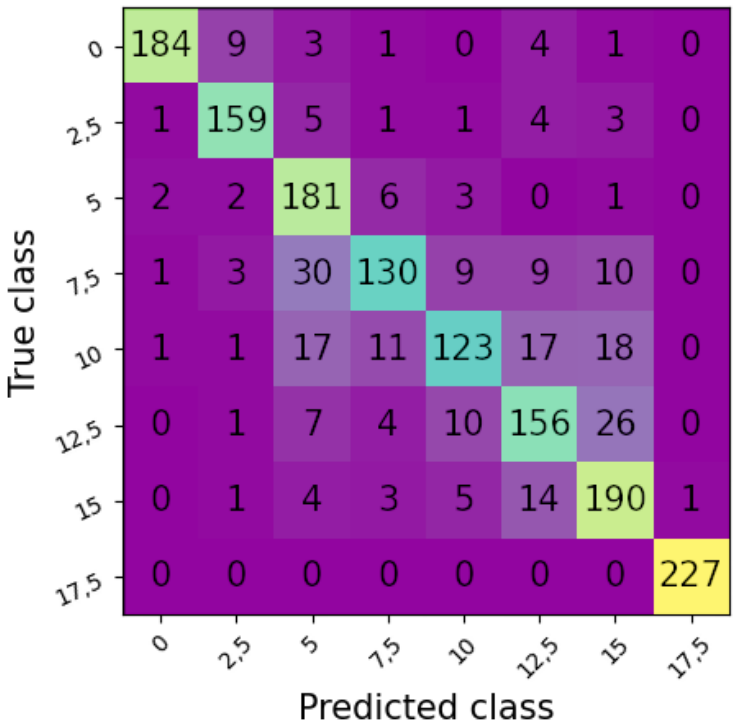


Figure: *Confusion matrix - Pooled Inception Time.*

Results AE - Experiment 2, regression approach

- Pooled Inception Time network adjusted for continuous prediction of load weight (MAE = 1,05kg)

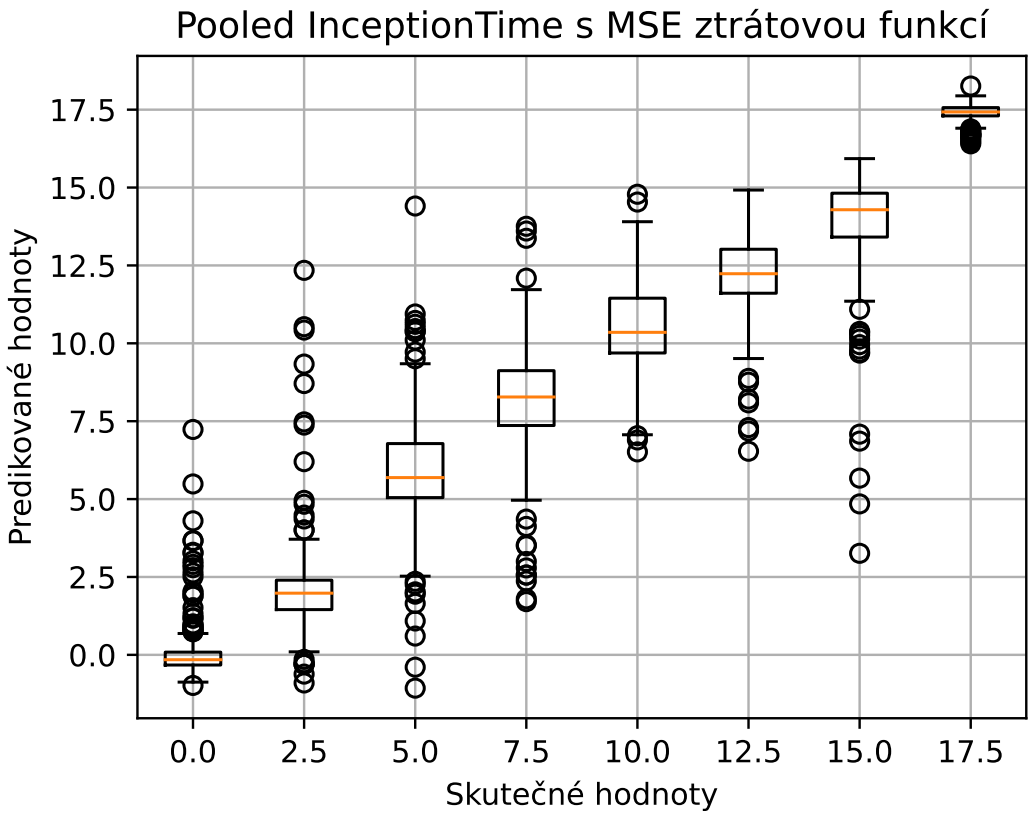


Figure: *Boxplots of load weight predictions.*

Results AE - Length of sampled signals

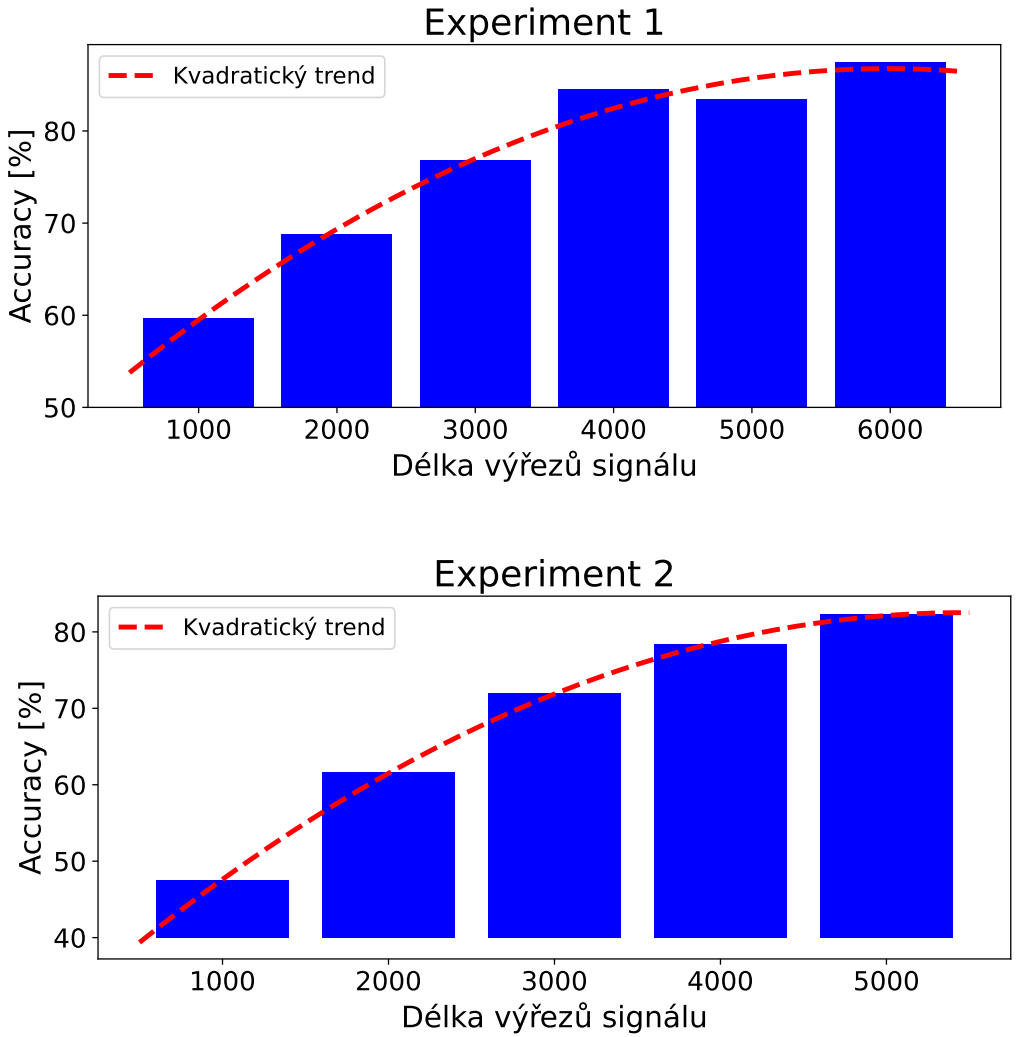


Figure: *Classification accuracy using Pooled Inception Time depending on the length of cut-out signals.*

Hysteresis data analysis

- Hysteresis - memory efect in a dynamic system
- Modeled using Preisach-Mayergoyzova model
- We assume a mixture distribution on PM space

$$p(\boldsymbol{x}|\Theta) = \sum_{i-1}^{M} \lambda_i p_i(\boldsymbol{x}|\theta_i)$$

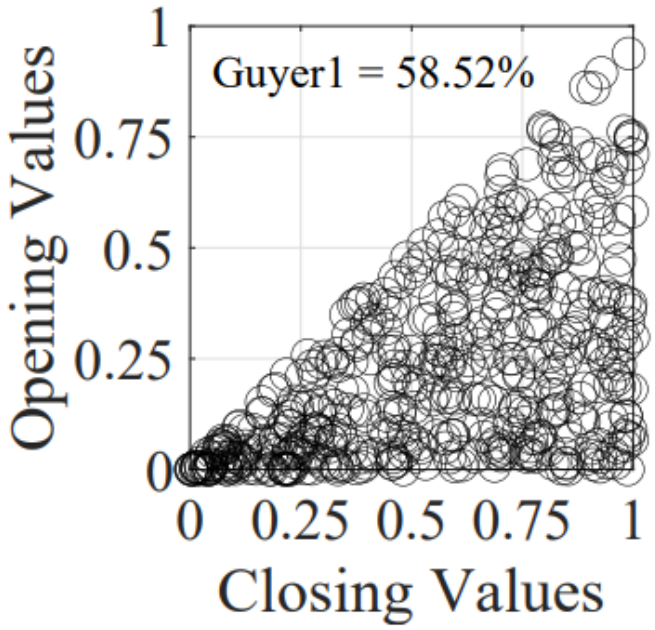


Figure: *Synthetic PM space with Guyer1 dominant distribution.*

Hysteresis data analysis

- Synthetic dataset - 8 types of distributions
- PM space + fixed load profile $\rightarrow$ hysteresis curve
- Goals:
  - Classification of hyst. curves by dominant distribution
  - Prediction of mixing parameters λ_i

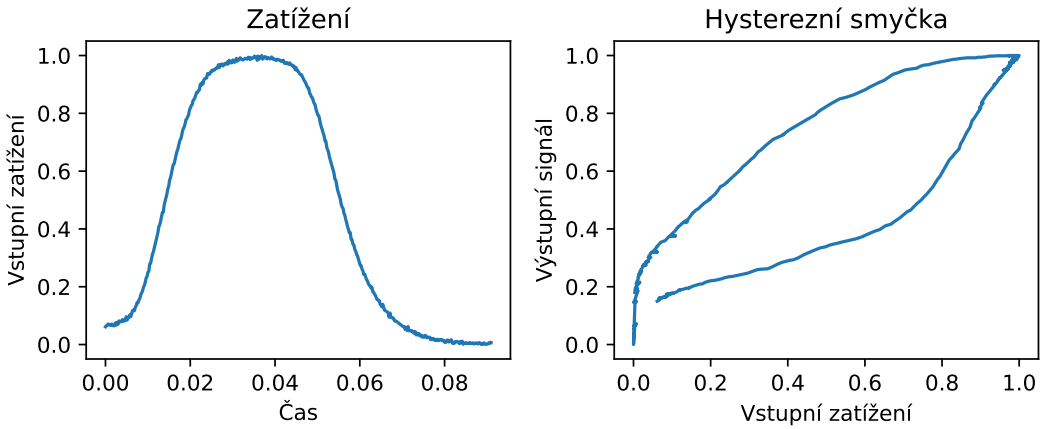


Figure: *Normed load profile and its corresponding hysteresis curve originating in PM space with dominant Laplace distribution.*

Hysteresis data analysis

- Inception Time with filters of length $\{10, 20, 40\}$
- Accuracy of classification by dominant distribution: 69,3%
- In regression setting, predicting $\boldsymbol{\lambda}$: MAE $= 0{,}075$

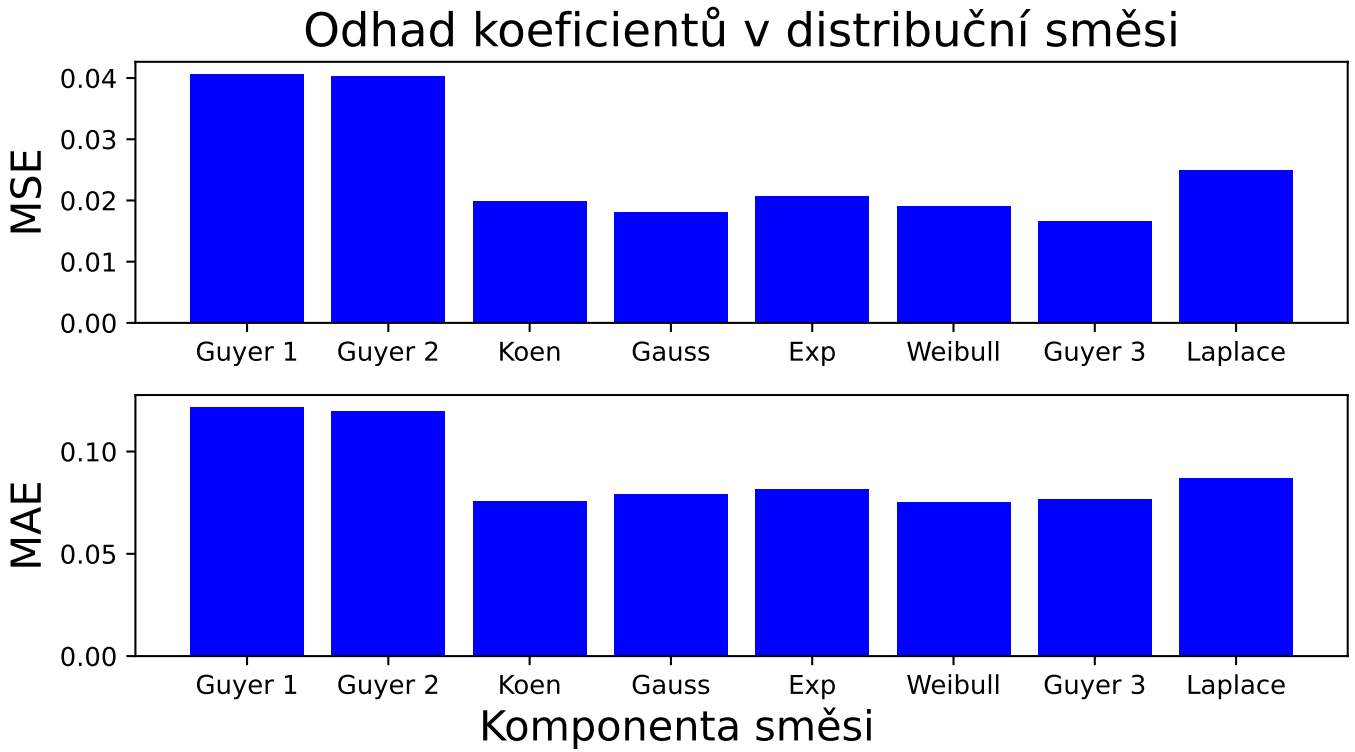


Figure: *Final MSE and MAE for individual predicted coefficients.*

Hysteresis data analysis

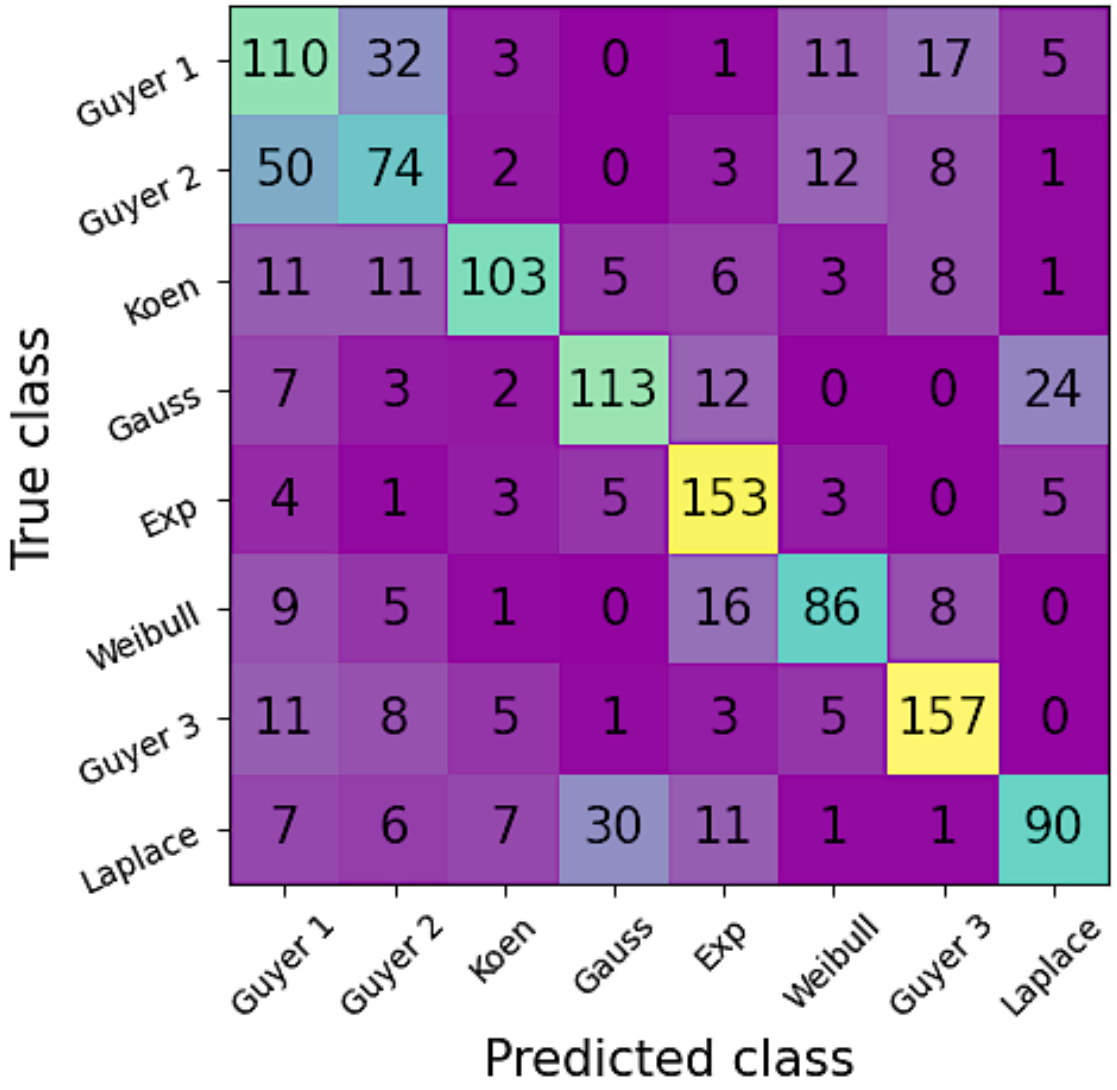


Figure: *Confusion matrix - classification using Inception Time.*

Thanks for attention