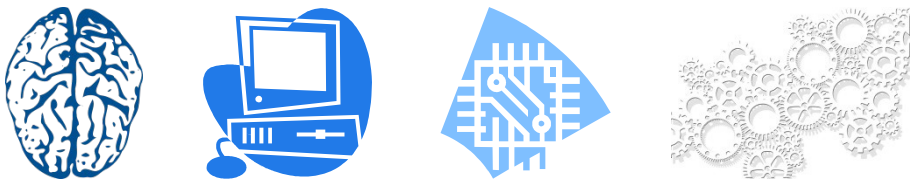
Westsächsische Hochschule Zwickau
University of Applied Sciences



Spinal cord injury

Evaluation of analysis methods for electroencephalography signals

Dominik Wetzel

Universitätsklinikum Leipzig
Anstalt öffentlichen Rechts

Fraunhofer IWU

Europa fördert Sachsen.
ESF
Europäischer Sozialfonds

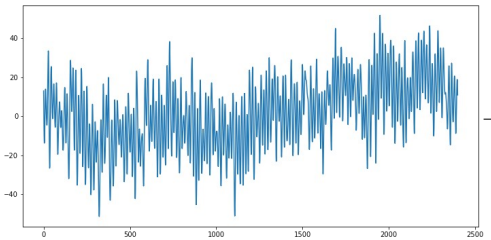
Contents

- Overview
- Preparation
- Features
- Evaluation
- Results
- Conclusion

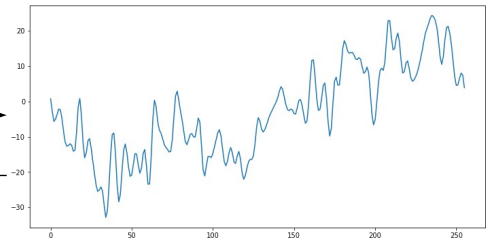
[1]

Overview

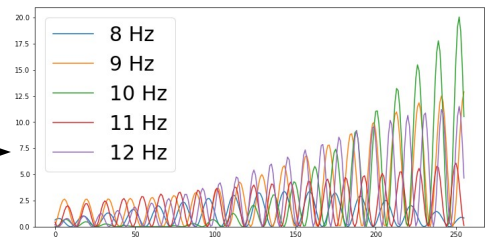
EEG-Signal



Resample (256 Hz)



Preparation

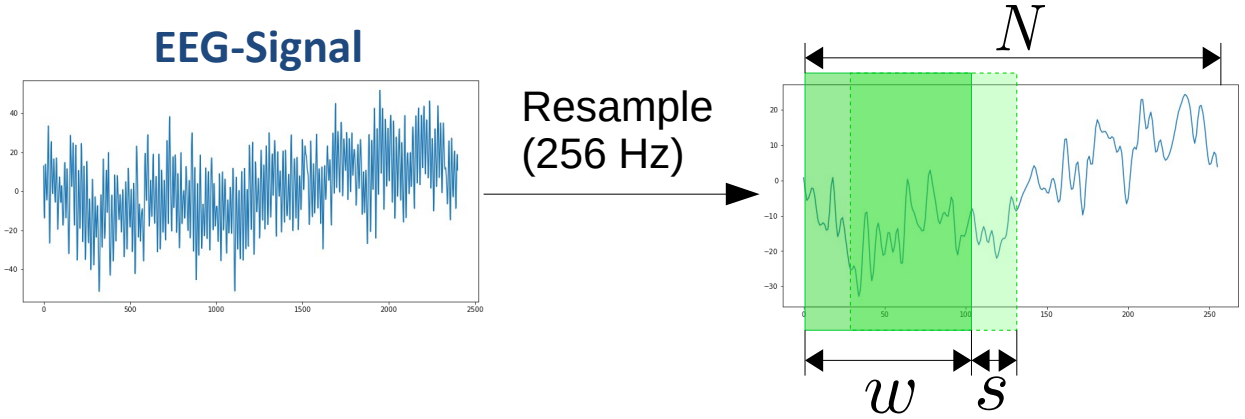


- Bandpower
- CWT
- SSA

Features

- Statistical measures
- Fractal dimension
- Common Spatial Pattern
- Diskrete Wavelet Transform
- Running variation coefficient

Overview



Preparation and feature extraction per window and electrode
→ approx. 60,000 features

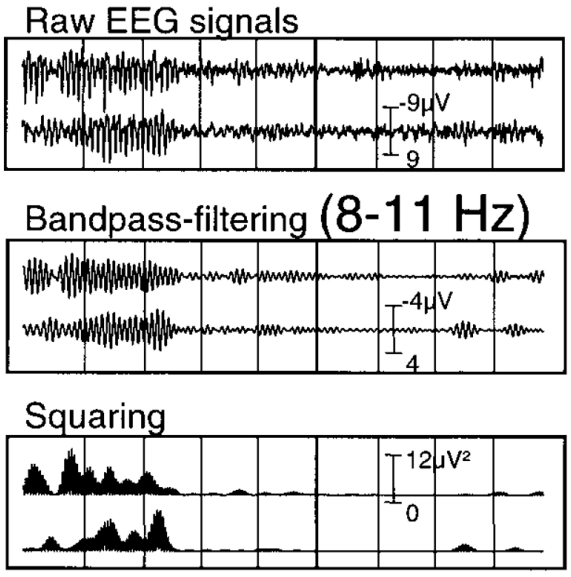
$$w = \text{windowsize (e.g. 85 samples)}$$
$$s = \text{shift (e.g. 15 samples)}$$
$$N = \text{signallength (e.g. 125.531 samples)}$$

$$\#windows = \frac{N - w}{s} \approx 8363$$

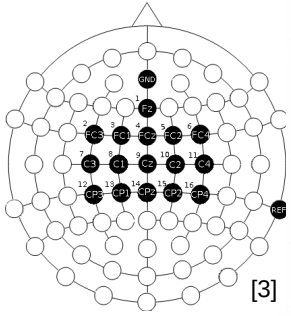
$$win = \#electrodes(16) \times w$$

Preparation

- Bandpower



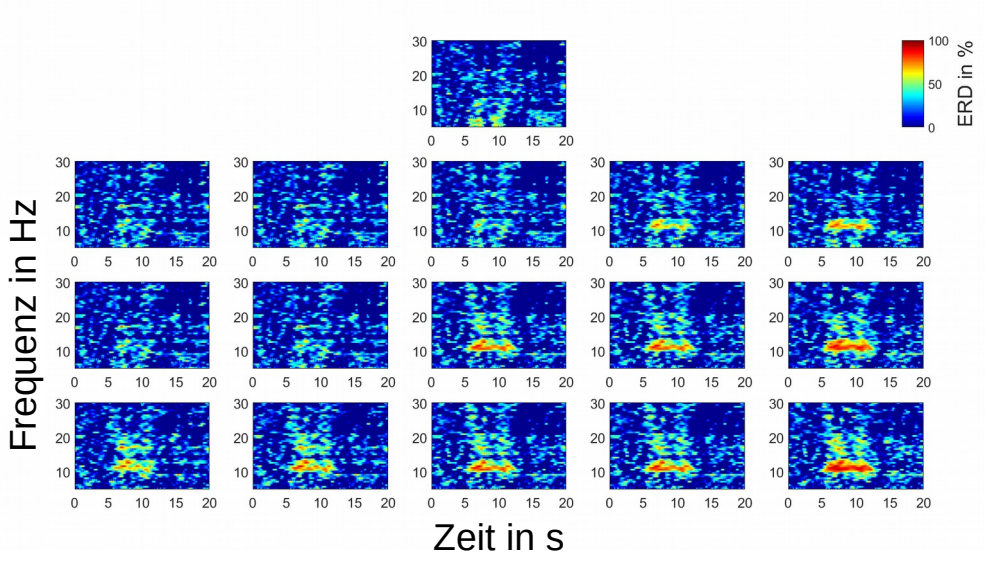
[2]



[3]

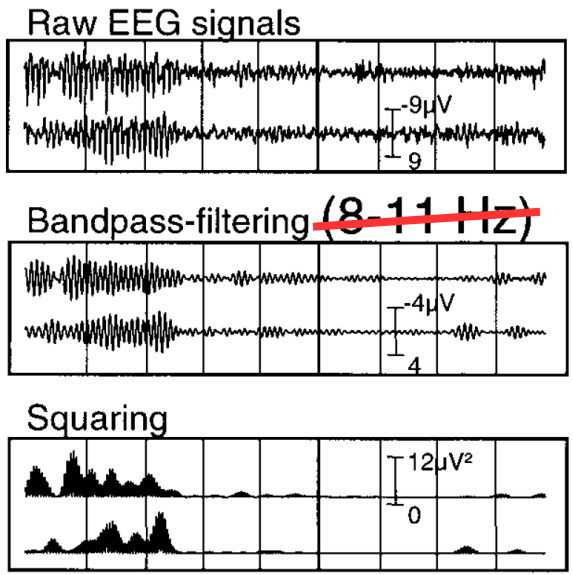
motivated by Event-Related-Desynchronisation (ERD):

$$ERD(f,t) = \frac{Bandpower_{ref}(f) - Bandpower(f,t)}{Bandpower_{ref}(f)}$$



Preparation

- Bandpower

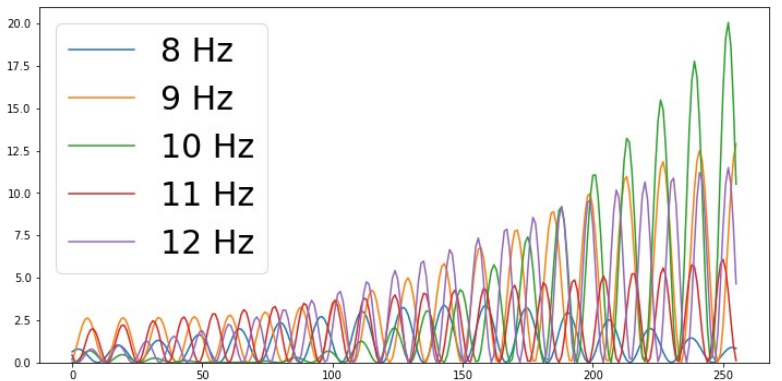


[5]

Singlefrequencies:

- 8, 8.5,…,11.5 Hz Δ 1 Hz
- 39, 40, …, 46 Hz Δ 1 Hz
- 70, 75, …, 85 Hz Δ 10 Hz

IIR bandpass filter (Butterworth)



Preparation

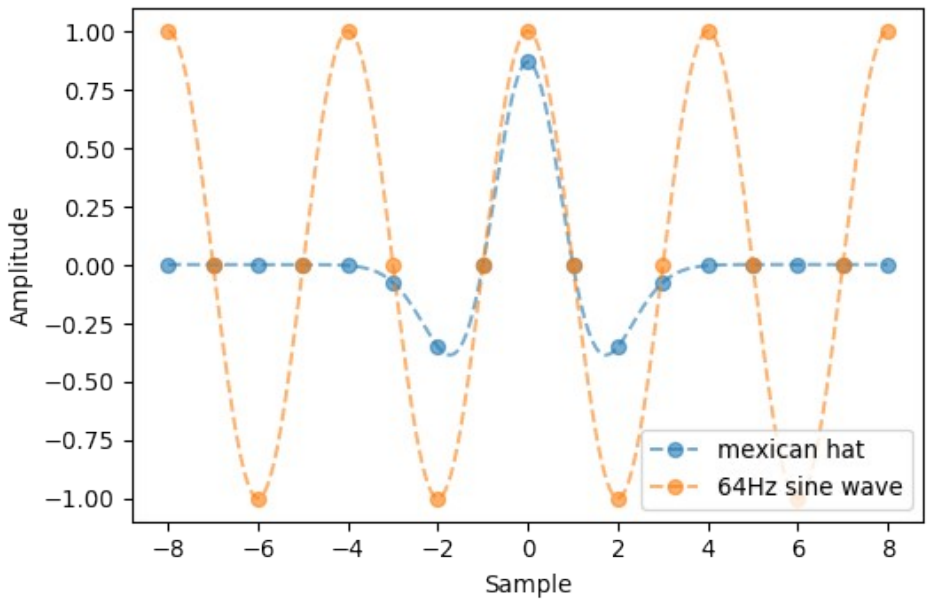
- Continous Wavelet Transformation (CWT)
  - Wavelet = small wave, local, non-periodic
  - Scales of wavelet

Used wavelet: Mexican hat

$$\psi(t) = \frac{2}{\sqrt{3}\sqrt[4]{\pi}}(1-t^2)e^{-\frac{t^2}{2}}$$

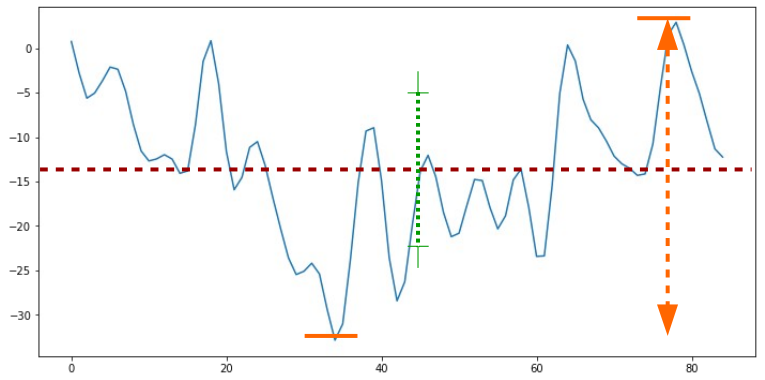
Used scales:

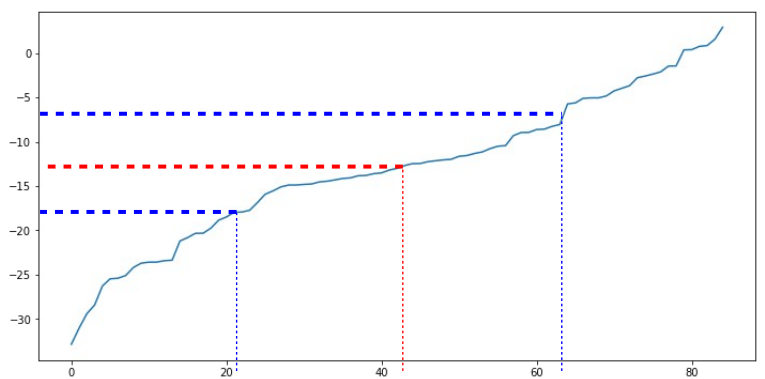
- 0.7, 0.75, …, 0.85 $\approx$ 90 – 70 Hz
- 1.35, 1.55, …, 2.15 $\approx$ 47 – 30 Hz
- 5, 6, …, 9 $\approx$ 13 – 8 Hz



Features: Statistical measures

- Min / Max / Range — G1
- Mean
- Standarddeviation
- Variance — G2
- Median
- 25-Percentil and 75-Percentil — G3





Features: Fractal dimension

- Measures complexity of a signal[4]

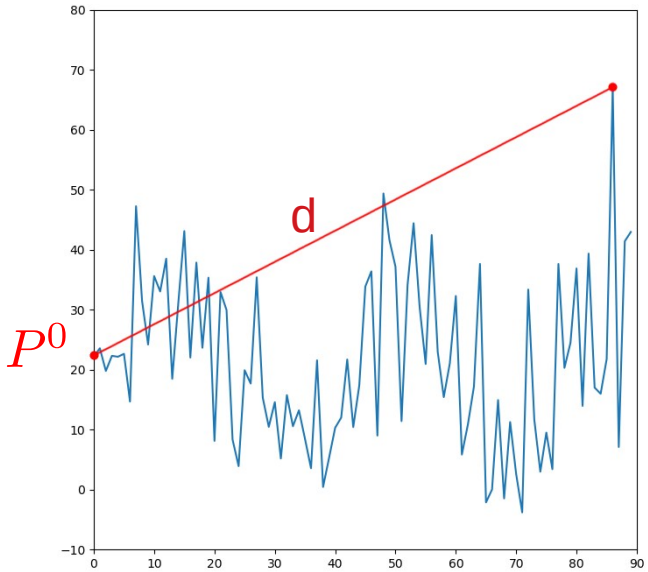
$$FD = \frac{\ln(L)}{\ln(d)}$$

$$P_x^i = \text{x-value of point } i$$

$$P_y^i = \text{y-value of point } i$$

$$L = \sum_{i=0}^{w-1} \sqrt{(P_y^i - P_y^{i+1})^2 + 1}$$

$$d = \max_{i=1\ldots w} \sqrt{(P_x^0 - P_x^i)^2 + (P_y^0 - P_y^i)^2}$$



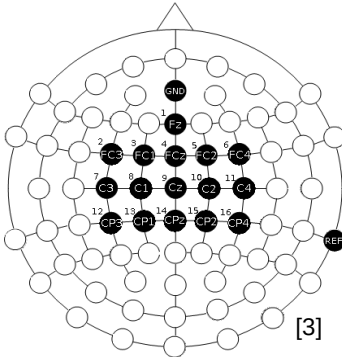
Features: Common Spatial Pattern[5]

- Difference between electrodes in each class
- Calculation of W-Matrix through SVD
- Calculation of the features:

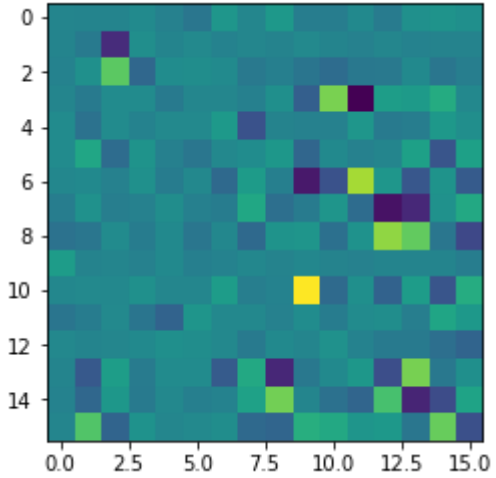
$$Z = W \cdot E \qquad E := (win \times win^T)$$

$$\text{Zm} = \text{first } m \text{ rows and last } m \text{ rows of } Z$$

$$CSP_j = \log\left(\frac{var(Zm_j)}{\sum_{i=1}^{m} var(Zm_i)}\right)$$



[3]



W-Matrix

Evaluation of the features

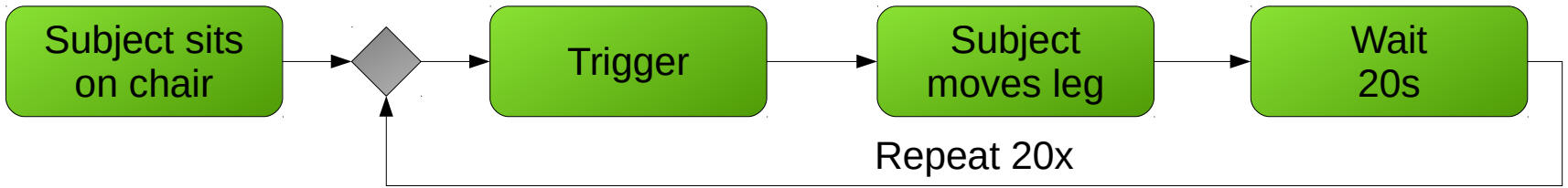
- Not all features → just useful ones
- Classificationmodel with ranking (e.g. RandomForest)
- Measure:

$$f_n(x) = \begin{cases} 1: & \text{Feature } x \text{ belongs to } n \text{ best ranked} \\ 0: & \text{otherwise} \end{cases} \qquad n = 42$$

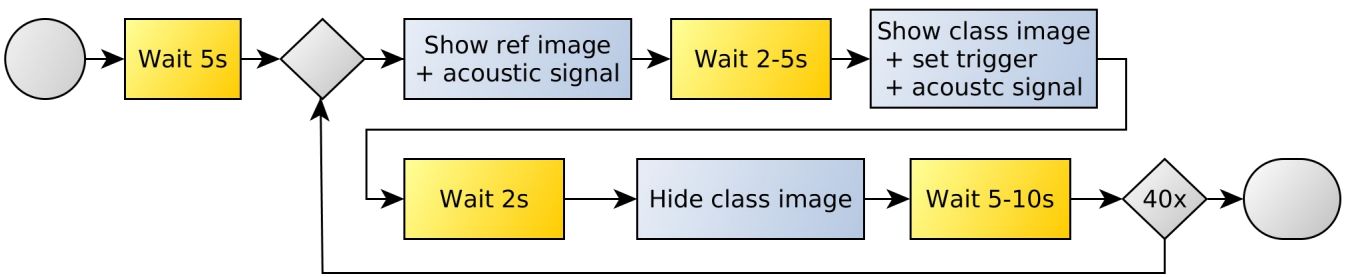
- Allows feature selection
- Why? → Specific and performant models

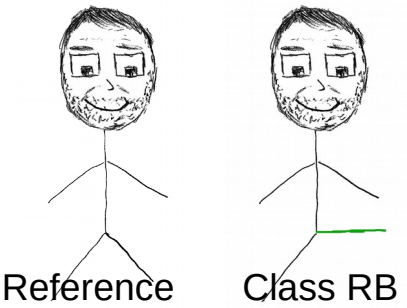
Test environment

- Parameters: fs = 256 Hz, Notch-Filter (48-52 Hz)
- Preliminary test: 2 classes – movement/no movement

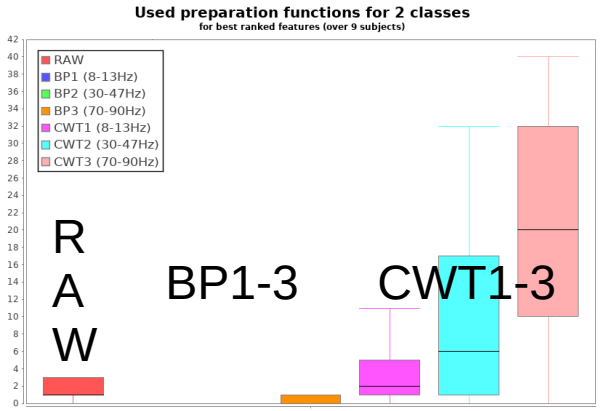


- Extension: 5 classes – (left/right)+(arm/leg) / None

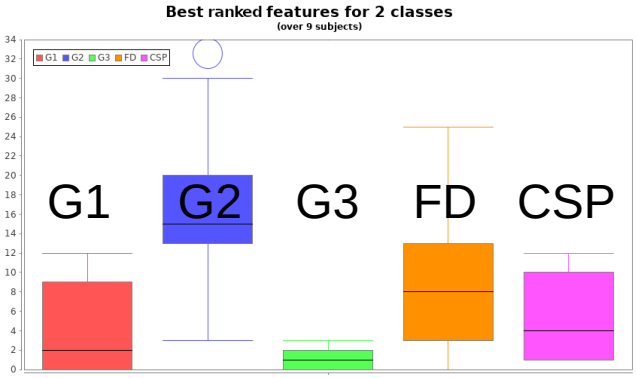




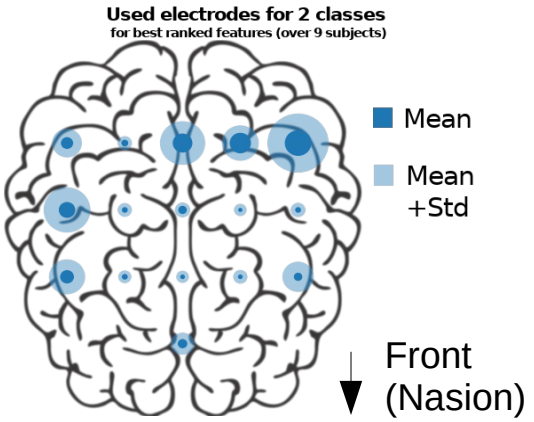
Preliminary results



- CWT outperforms Bandpower
- Higher frequency bands seem more important



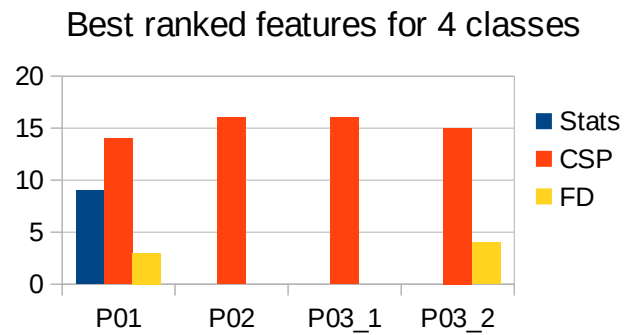
- Almost every feature seems useful (besides percentiles)
- Fractal dimension and Std most useful

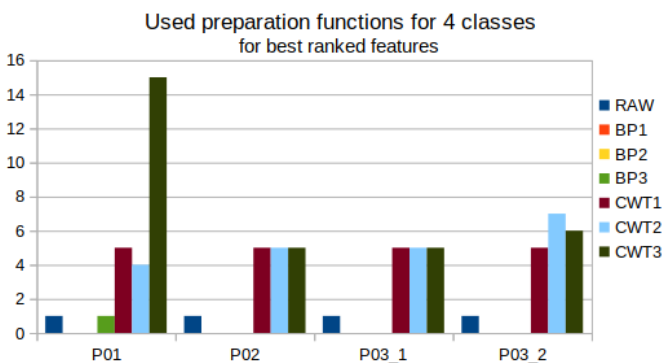


- Left and upper right electrodes seem more important
- Useful for spatial features (CSP)

Adjustments for next test

- Adjusted CSP algorithm for MultiClass
  - → CSP much more important than other features
- Lesser electrodes (3 left, 3 right)
- Lesser preparation steps
- Test different feature selection algorithms





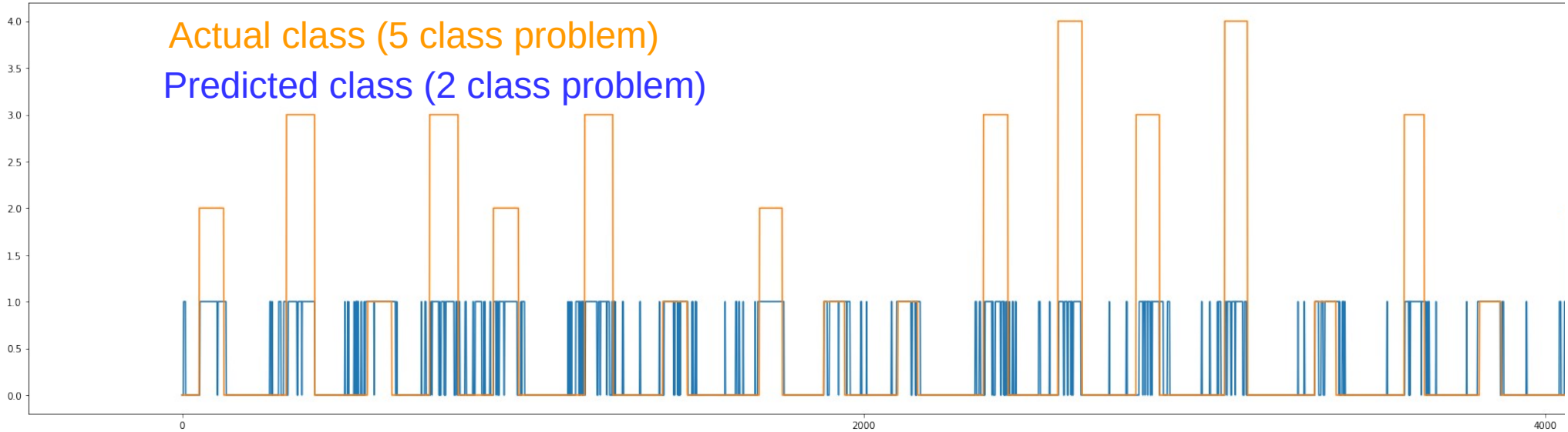
Conclusion

- Higher frequency bands > 30Hz contain information
- CWT seems good preparation step
- CSP and fractal dimension seem good features
- Bandpower can be omitted
- Feature evaluation measure to simple
- Findings allow creation of performant and specific models

Recent results

- Use features with SVM (2 classes – movement / no movement):

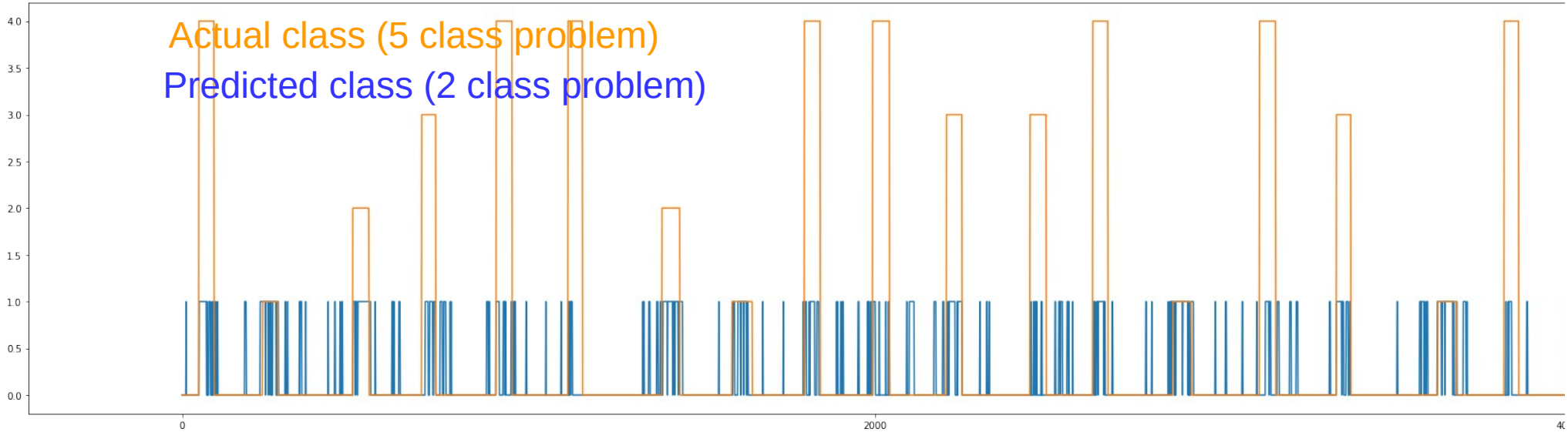
  Prediction on training data:



Recent results

- Use features with SVM (2 classes – movement / no movement):

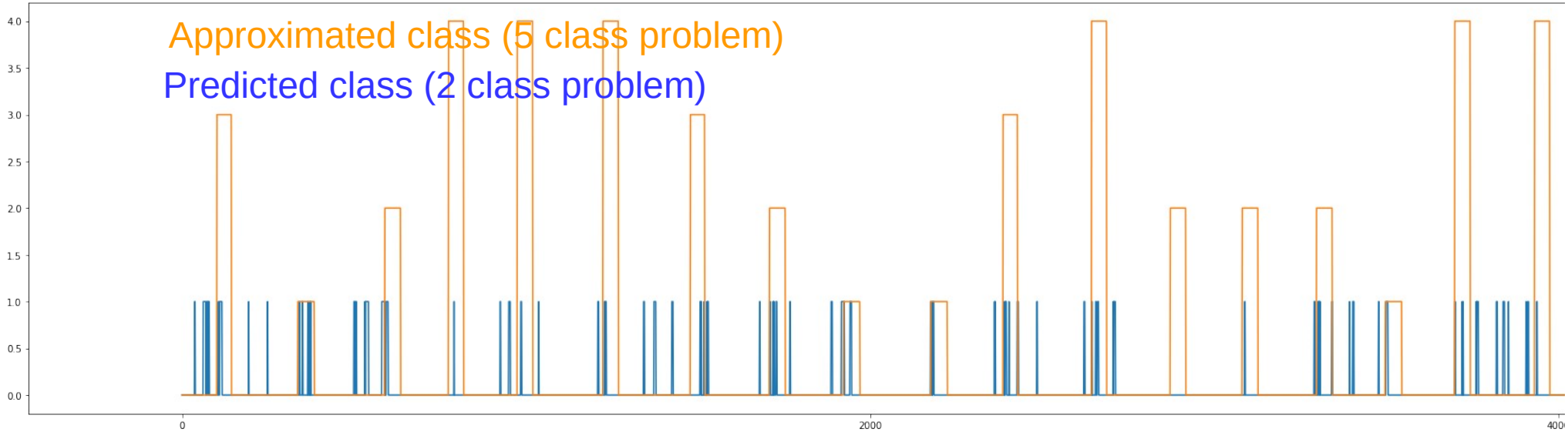
  Prediction on other data:



Recent results

- Use features with SVM (2 classes – movement / no movement):

  Prediction on imagined data:



Questions?

Thank you for your attention!

References

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