Towards a novel control paradigm based on decoding imagined movements from EEG

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Introduction

- First attempt towards the EEG based classification of the movement plane of the right upper-limb during *motor imagination* (MI)
- Possible new 2-class control option for a neuroprosthesis using MIs of the *same* limb
- Classifier is based on the decoding approach presented in [1] and [2]: movement trajectories are extracted in the time-domain from the EEG using frequencies <1 Hz
- 2 movement planes (transverse vs sagittal plane)

Paradigm

- 9 healthy and right-handed subjects
- MI: waving the extended right arm in front of the body in the *transverse* or in the *sagittal* plane (see Figure 1)
- Subjects synchronised movements to the beat of a metronome (2 beats per second)
- Trial sequence is shown in Figure 2 (cue: arrow pointing right or up)
- 8 MI runs, 5 trials per class per run, in total 80 trials per subject
- Subjects had to fixate a cross on the screen to suppress eye movements

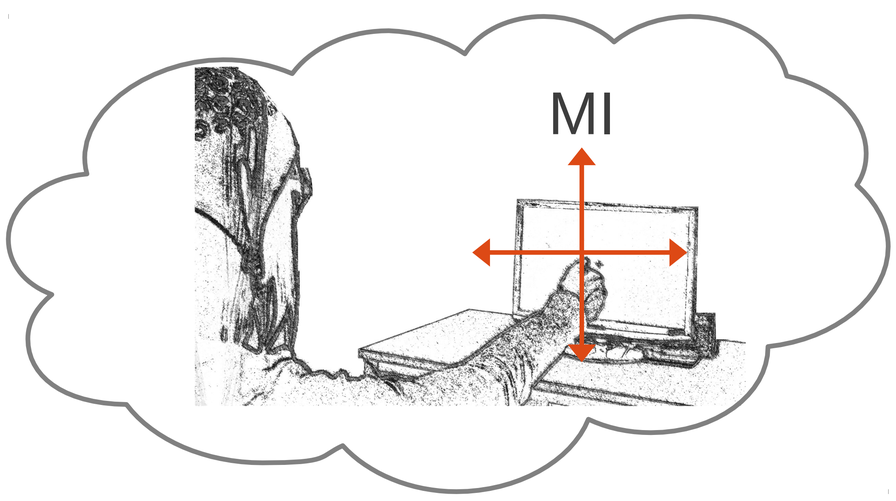

Figure 1: Subjects imagined a movement of the arm in the transverse or sagittal plane.

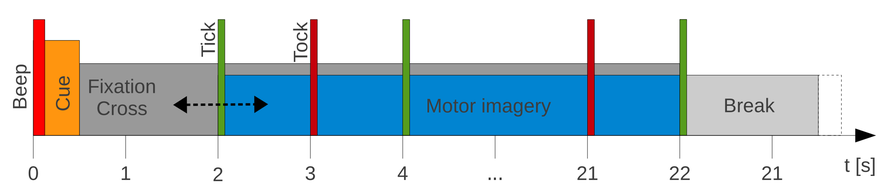

Figure 2: This figure shows the sequence of a trial.

Methods

- 68 EEG electrodes (frontal, sensorimotor and parietal areas) / 3 EOG electrodes
- Removal of eye activity influences with a linear regression method [3]
- Classification (see Figure 3):
  - Band-pass filter with 0.3 Hz and 0.8 Hz cutoff frequencies
  - 2 linear models found with multiple linear regressions (one for each coordinate or movement plane) decoded hand positions from EEG using 3 three time lags in 60 ms intervals
  - Correlation with a sinus of 0.5 Hz over a certain time window (see Figure 4)
  - The linear model with the higher correlation yielded the movement plane or class

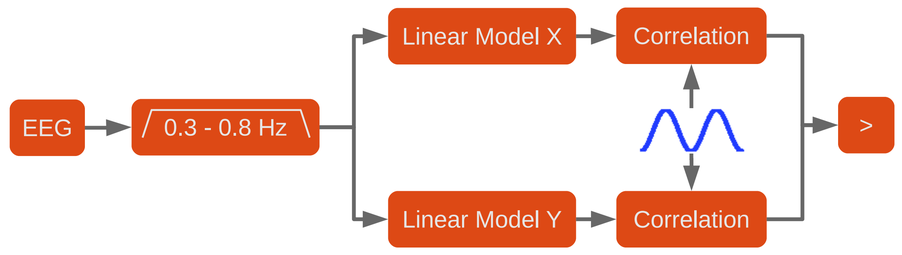

Figure 3: This diagram shows the basic blocks of the classifier.

Results

- EEG based decoding: 8 out of 9 subjects reached significant classification accuracies
- EOG based decoding: 3 out of 9 subjects reached significant classification accuracies
- The mean classification accuracy over subjects with significant EEG based classification accuracies and with non-significant EOG based classification accuracies was 69 %
- Chance level: 59 % ($\alpha = 0.05$)
- Table 1 shows the classification results, Figure 4 shows the classification accuracy in dependence on the length of the correlation window

Table 1: Classification accuracies for all subjects are shown. Significant classification accuracies are written bold. The window length used for correlation was fixed with 17 s.

subject	s1	s2	s3	s4	s5	s6	s6	s8	s9	grand average
mean value [%]	**71**	**67**	55	**82**	**65**	**59**	**70**	**82**	**78**	**70**
std. dev. [%]	17	15	16	13	15	17	15	13	14	10

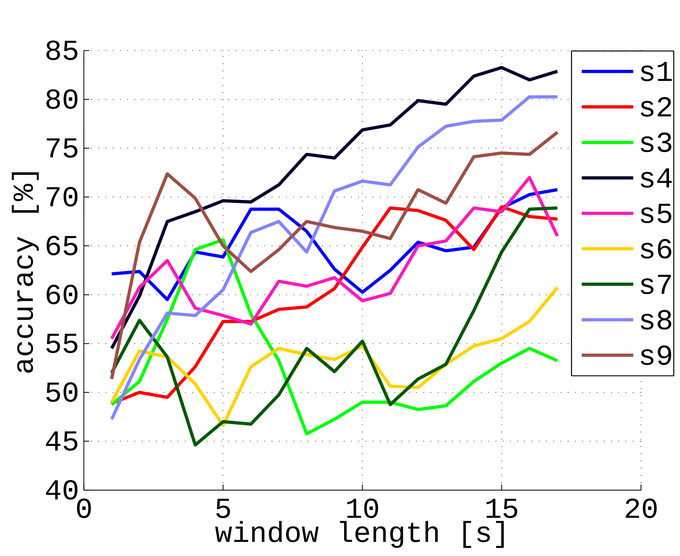

Figure 4: This plot shows the accuracy in dependence of the correlation window length.

Discussion

- Classification of imagined movements in 2 orthogonal planes is possible
- Eye movements-based classification can be excluded in at least 6 subjects
- Classification accuracy dependency on the correlation window: probably due to the decreasing signal-to-noise ratio (SNR) of the correlation coefficient
- For actual applications the correlation window length has to be shortened
- This classifier could add additional classes to e.g. a sensorimotor rhythm-based classifier extending the control possibilities of a neuroprosthesis
- The classification based on the decoding approach indicates that with an improved SNR imagined movement trajectories can be decoded as well

References

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2. P Ofner, and GR Müller-Putz, Decoding of velocities and positions of 3D arm movement from EEG, *Proceedings of the 34th Annual International Conference of the IEEE EMBS*, 6406–6409, 2012
3. A Schlögl, C Keinrath, D Zimmermann, R Scherer, R Leeb, and G Pfurtscheller, A fully automated correction method of EOG artifacts in EEG recordings, *Clinical Neurophysiology*, 118(2007):98–104, 2006