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Jochumsen, Mads Rovsing; Waris, Asim; Niazi, Imran Khan

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Detection of Attempted Stroke Hand Motions from Surface EMG

Mads Jochumsen, Asim Waris, and Imran K. Niazi

***Abstract*—Brain-Computer Interfaces have been proposed for stroke rehabilitation, but a potential problem with this technology is the dependence of high-quality brain signals. The aim of this study was to investigate if attempted hand open motions can be detected from the muscle activity instead. Ten stroke patients performed 63±7 attempted movements while three channels of EMG were recorded. Hudgins time-domain features and linear discriminant analysis were used, and 92±3% of the movement activity was correctly classified. The Spearman correlation between the upper limb Fugl-Meyer score and the classification accuracies was 0.58 (P=0.08). In conclusion, attempted movements from stroke patients can be detected using EMG.**

I. Introduction

Brain-Computer Interfaces have been proposed as a means for stroke rehabilitation. Several studies have reported clinical improvements and induction of neural plasticity after training with a Brain-Computer Interface (BCI) [1] where movement-related brain activity has been detected and used for triggering electrical stimulation or rehabilitation robots. To be able to drive the external devices, the movement-related brain activity such as movement-related cortical potentials or event-related desynchronization must be detected from single-trial EEG. Movement detection through EEG in stroke patients has been reported to be in the range of roughly 70-80% [2]. It is a challenging task to detect attempted movements from single-trial EEG due to several factors such as non-stationarity of the signals, artifacts and shifts in attention. Moreover, the signal quality must be good, which require that the EEG cap is mounted correctly, and the impedance of the electrodes is low. This will often require the help of an extra person (therapists or relatives) to mount the cap and prepare the electrodes [3]. Thus, it would be ideal if another control signal than EEG could be used, which would be more accessible such as surface EMG. It has been shown that there was no difference between the induction of neural plasticity using EEG- and EMG-triggered electrical stimulation [4]. Moreover, many stroke patients have or quickly regain residual EMG activity that may be used to drive an external rehabilitation device. Several studies have reported that EMG of different arm motions can be decoded in stroke patients with various levels of impairment [5-8]. The aim of this study is to detect attempted hand open motions of the affected hand in stroke patients using a simple electrode setup with three surface bipolar EMG channels. The motions will be detected using simple signal processing techniques. The contribution of the features to the motion classification will be investigated, and it will be tested if the motion classification is correlated with the upper limb Fugl-Meyer score.

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M. Jochumsen is with the Department of Health Science and Technology, Aalborg University, Aalborg, Denmark (mj@hst.aau.dk).

A. Waris is with the Department of Biomedical Engineering & Sciences, School of Mechanical & Manufacturing Engineering, National University of Sciences and Technology (NUST), Islamabad, Pakistan (asim.waris@smme.nust.edu.pk).

I. K. Niazi is with the Centre for Chiropractic Research, New Zealand College of Chiropractic, Auckland, New Zealand (imran.niazi@nzchiro.co.nz).

II. Methods

A. Subjects

Ten chronic stroke subjects participated in this study (see Table I). All subjects provided their informed consent before participation; the local ethical committee (Riphah/RCRS/REC/00651) approved the procedures.

B. Recordings

TABLE I
Patient Information

Subject	Upper limb Fugl-Meyer score (max 66)	Affected Side	Lesion type
1	55	Left	Ischemic
2	36	Right	Ischemic
3	23	Right	Ischemic
4	46	Left	Ischemic
5	26	Left	Ischemic
6	65	Right	Ischemic
7	17	Right	Ischemic
8	59	Left	Ischemic
9	55	Right	Ischemic
10	28	Right	Hemorrhagic

Six surface EMG electrodes were placed on Flexor Carpi Radialis, Extensor Carpi Radialis, and Flexor Carpi Ulnaris forming one bipolar derivation from each muscle. The signals were referenced to a moist wristband. The signals were amplified with a gain of 10000 and sampled with 2048 Hz.

C. Experimental Setup

The subjects were seated in a comfortable chair, and electrodes were placed on the most affected forearm. The signal quality was checked, and the subjects were instructed in how to perform the movements. The movements were hand open, which they had to maintain for six seconds. Between the movements, the subjects were given a break of ~12 seconds (see Fig. 1). The movements were visually cued and synchronized with the amplifier. The EMG onsets were visually inspected before further processing. On average 63±7 movements were performed.

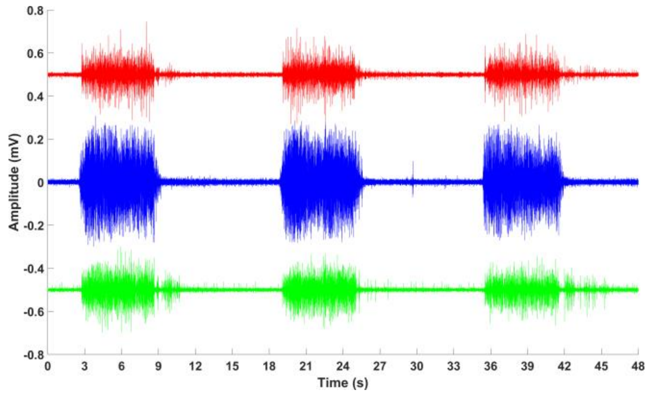

Fig. 1. EMG of three hand open motions (subject 4). Red: Flexor Carpi Radialis. Blue: Extensor Carpi Radialis. Green: Flexor Carpi Ulnaris.

D. *Pre-Processing, Feature Extraction and Classification*

The EMG was bandpass filtered from 20-500 Hz and notch filtered from 48-52 Hz using a 2nd order Butterworth filter. Movement epochs were extracted from the movement onset and two seconds after this point. Idle epochs were extracted during the rest period from one to three seconds prior the movement onset. Four feature types were extracted from 200-millisecond windows in the 2-second epoch without overlap. The features were: 1) mean absolute value (MAV), 2) waveform length (WL), 3) zero crossings (ZC), and 4) slope sign changes (SSC). The features of the movement and idle class were classified using linear discriminant analysis in five different scenarios using all feature types and each feature type individually. The classification was performed using 5-fold cross-validation using all epochs movement and idle epochs.

E. *Statistics*

A Friedman test with "Feature Type" as factor (five levels: All, MAV, WL, ZC, and SSC) was performed on the classification accuracies obtained using the different feature types. This was followed up with posthoc analysis using a Bonferroni correction. The Spearman correlation was calculated between the classification accuracies obtained using all feature types and the upper limb Fugl-Meyer score.

III. Results

The results are summarized in Fig. 2. The following classification accuracies were obtained (mean ± standard): 92±3% (all features), 90±5% (MAV), 89±5% (WL), 87±5% (ZC), and 89±3% (SSC). A significant effect of "Feature Type" ($\chi^2_{(4)}$=20.8; P<0.001) was found. The posthoc analysis revealed higher classification accuracies when using all features compared to WL, ZC, and SSC. The Spearman correlation between the classification accuracies and the upper limb Fugl-Meyer score was 0.58, the correlation between the two variables was not significant (P=0.08).

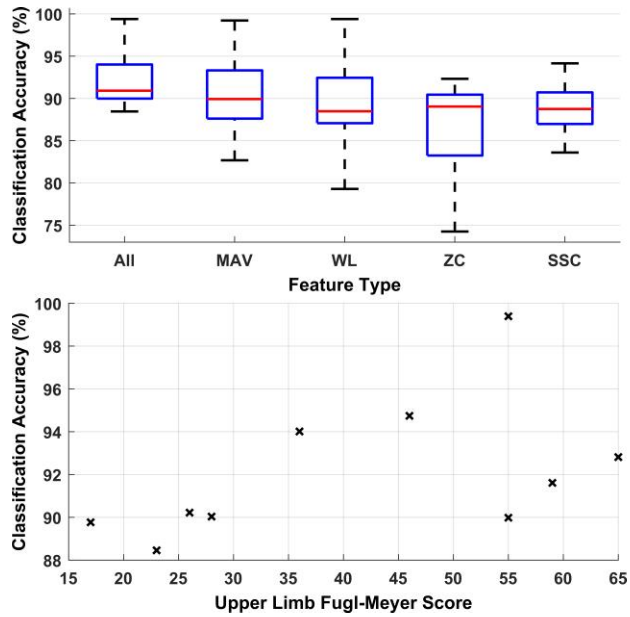

Fig. 2. Top: Boxplot of the classification accuracies across subjects when using the different feature types. Bottom: Scatter plot of the upper limb Fugl-Meyer score and the classification accuracies obtained using all feature types.

IV. Conclusion

It is possible to discriminate between attempted hand open motions and resting EMG using a simple EMG setup and processing methods. Thus, EEG may not be needed for movement detection. This could be important for motor rehabilitation applications of the hand where patients need to activate a rehabilitation device. However, the patients would need to have some residual EMG. The limitation of this work is that only a small sample of stroke patients were included, and stroke is a very heterogeneous condition.

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