

Fusion of Manual Control and BCI Using Long Term and Short Term Quality Measures

Alex Kreilinger^a, Vera Kaiser^a, Christian Breitwieser^a, Christa Neuper^{ab},
Gernot R. Müller-Putz^a

^aInstitute for Knowledge Discovery, Graz University of Technology, Graz, Austria

^bDepartment of Psychology, University of Graz, Graz, Austria

Correspondence: A Kreilinger, Institute for Knowledge Discovery, Graz University of Technology, Graz, Austria.

E-mail: alex.kreilinger@tugraz.at, phone +43 316 873 5302

Abstract. This work presents a hybrid BCI approach where two different input signals (joystick and BCI) are monitored and only one of them is chosen as a control signal at a time. A game-like feedback was used as an application where users could move a car to collect coins and avoid obstacles via either joystick or BCI control. For both types four different quality measures were constantly applied to evaluate the quality of the signal. As soon as the quality dropped below a certain threshold the system would switch to the other control mode and vice versa.

Keywords: Electroencephalogram; Brain-Computer Interface; Fusion; Hybrid; Motor Imagery; Assistive Device

1. Introduction

An important topic these days is the implementation of a hybrid BCI [Breitwieser et al., 2010; Pfurtscheller et al., 2010] system where different input signals (biosignals, manual control signals, and sensor signals) are constantly monitored and fused to achieve a solution with long functionality for the user. This fusion is accomplished by an evaluation and weighting of inputs, which can result in a switching between input modes or in a weighted combination of inputs that generate certain control signals. This work introduces a hybrid BCI where a game can be controlled manually with a joystick or mentally with a BCI based on motor imagery (MI) [Neuper et al., 2006]. The joystick represents any assistive device that would stop working after a long usage due to fatigue. BCI on the other hand is prone to noise, distraction, and fatigue as well. Therefore, both input modalities have their drawbacks and switching between them might be desirable for the user. The switching can be carried out whenever the quality of one signal is considerably worse than the other's. This idea is demonstrated in an experiment, allowing healthy users to control a car game. The insights found here can later be applied for the use with patients.

2. Material and Methods

To simulate the system on healthy subjects instead of patients (e.g., patients with a severed spine at C4/C5 which causes loss of hand control and limited shoulder function) the joystick signal was deteriorated with artificial noise. This noise consisted of artificially generated weakness, tremors, and spasms. Tremors and spasms occurred randomly, weakness however was increased continuously to simulate muscle fatigue. For each control signal four quality measures evaluated a signal whenever it was currently used to control the feedback. The measures were customized to check specifically for indicators of a bad quality. The joystick quality score depended on following factors: shaking (tremors), low range of movement (weakness), invariability (lack of movement or hardware defect), and bias (preference of one side). The measures of the BCI channel were: noise (noisy EEG), instability (unreliable classification), invariability (hardware or software error), and also bias. The measures had a differently strong impact on the quality: noise and shaking would decrease the quality by 10 %/s, low amplitude and instability by 2 %/s, invariability by 1 %/s, whereas the bias was proportional to the bias itself which generally resulted in a rather weak contribution. All those measures were able to recover whenever they were not currently detected (shaking and noise by 3 %/s, all the others by 4 %/s).

Ten subjects took part in the study, all of them had experience in BCI. For the EEG recordings 6 electrodes were placed over C3, Cz, and C4. The data was recorded with a sample rate of 512 Hz and filtered between 0.5 and 30 Hz.

Before running the fusion experiment, subjects had to perform standard BCI training to set up a classifier for MI [Pfurtscheller and Neuper, 2001]. An LDA classifier was used to distinguish between two different tasks: imagination of right hand movement versus foot movement. The following online experiment consisted of 6 runs with 40 trials each. Participants were asked to collect coins and to avoid obstacles with a moving car. Coins appeared in a cue-based way, always 6 in a row with 6 barriers on the opposite side of a street. The car was either controlled directly with the joystick or with the BCI by performing the previously trained MI tasks. The runs always started with active manual control. The signal however deteriorated continuously (mainly the weakness), in order to force a switch to BCI. This switch could only happen when the active quality was below 20 % and the other one above 50 %. To allow switching back after some time, the inactive signal's quality could recover by 1 %/s. Subjects were asked to avoid switching as long as possible, i.e., to reduce quality reducing factors. The measures that affected the quality were called long term measures. Additionally, so-called short term measures were used to inhibit control during times of severe noise impairment by moving the car to the middle and giving a visual alert. In BCI mode this could have happened during a detection of noise, in joystick mode the inhibition was caused by a detection of strong shaking.

3. Results

The fusion worked as expected in a way that low quality signals were discarded soon in favor of the other signal. The fusion system allowed collection of coins after the joystick signal was too weak to allow further points with manual control alone, which is shown in Figure 1. The maximum number of points per run was 240 (6 coins in 40 trials). The BCI accuracy correlated with the active time in BCI mode, meaning that subjects with good BCI performance were able to use BCI mode for a longer time.

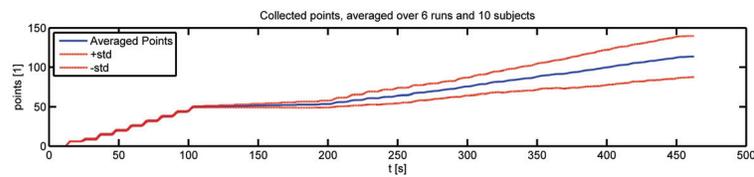


Figure 1. The figure shows the averaged collection of points during 6 averaged runs from 10 subjects over all 40 trials. The first points were always collected with the joystick which was weakened up to a point when no more collection was possible. After this flat line, the fusion was activated and allowed the subjects to use both joystick and BCI, whichever was the better choice at the moment.

4. Discussion

The fusion approach proved to be feasible to be used in patients in future experiments where fatigue and other deteriorating factors concerning assistive devices are highly anticipated and the possibility to use BCI can improve the performance significantly. The setup can also be expanded to be able to deal with more signals, apply more complex rules for weighting, and to permit also a combination of input signals rather than just a switching between them.

Acknowledgements

This work is supported by the European ICT Programme Project FP7-224631.

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