BCI Competition 2008 – Graz data set B

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Experimental paradigm

This data set consists of EEG data from 9 subjects of a study published in [1]. The subjects were right-handed, had normal or corrected-to-normal vision and were paid for participating in the experiments. All volunteers were sitting in an armchair, watching a flat screen monitor placed approximately 1 m away at eye level. For each subject 5 sessions are provided, whereby the first two sessions contain training data without feedback (screening), and the last three sessions were recorded with feedback.

Each session consists of several runs, illustrated in Figure 1. At the beginning of each session, a recording of approximately 5 minutes was performed to estimate the EOG influence. The recording was divided into 3 blocks: (1) two minutes with eyes open (looking at a fixation cross on the screen), (2) one minute with eyes closed, and (3) one minute with eye movements. The artifact block was divided into four sections (15 seconds artifacts with 5 seconds resting in between) and the subjects were instructed with a text on the monitor to perform either eye blinking, rolling, up-down or left-right movements. At the beginning and at the end of each task a low and high warning tone were presented, respectively. Note that due to technical problems no EOG block is available in session B0102T and B0504E, (see Table 1 for a list of all subjects)

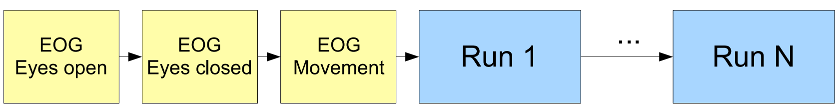

Figure 1: Timing scheme of one session (for screening and feedback sessions).

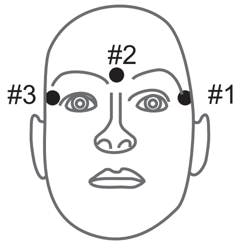

Figure 2: Electrode montage of the three monopolar EOG channels.

Data recording

Three bipolar recordings (C3, Cz, and C4) were recorded with a sampling frequency of 250 Hz. The recordings had a dynamic range of ±100 µV for the screening and ±50 µV for the feedback sessions. They were bandpass-filtered between 0.5 Hz and 100 Hz, and a notch filter at 50 Hz was enabled. The placement of the three bipolar recordings (large or small distances, more anterior or posterior) were slightly different for each subject (for more details see [1]). The electrode position Fz served as EEG ground.

In addition to the EEG channels, the electrooculogram (EOG) was recorded with three monopolar electrodes (see Figure 2, left mastoid serving as reference) using the same amplifier settings, but with a dynamic range of ±1 mV. The EOG channels are provided for the subsequent application of artifact processing methods [2] and must not be used for classification.

The cue-based screening paradigm (see Figure 3a) consisted of two classes, namely the motor imagery (MI) of left hand (class 1) and right hand (class 2). Each subject participated in two screening sessions without feedback recorded on two different days within two weeks. Each session consisted of six runs with ten trials each and two classes of imagery. This resulted in 20 trials per run and 120 trials per session. Data of 120 repetitions of each MI class were available for each person in total. Prior to the first motor imagery training the subject executed and imagined different movements for each body part and selected the one which they could imagine best (e. g., squeezing a ball or pulling a brake).

Each trial started with a fixation cross and an additional short acoustic warning tone (1 kHz, 70 ms). Some seconds later a visual cue (an arrow pointing either to the left or right, according to the requested class) was presented for 1.25 seconds. Afterwards the subjects had to imagine the corresponding hand movement over a period of 4 seconds. Each trial was followed by a short break of at least 1.5 seconds. A randomized time of up to 1 second was added to the break to avoid adaptation.

For the three online feedback sessions four runs with smiley feedback were recorded (see Figure 3b), whereby each run consisted of twenty trials for each type of motor imagery. At the beginning of each trial (second 0) the

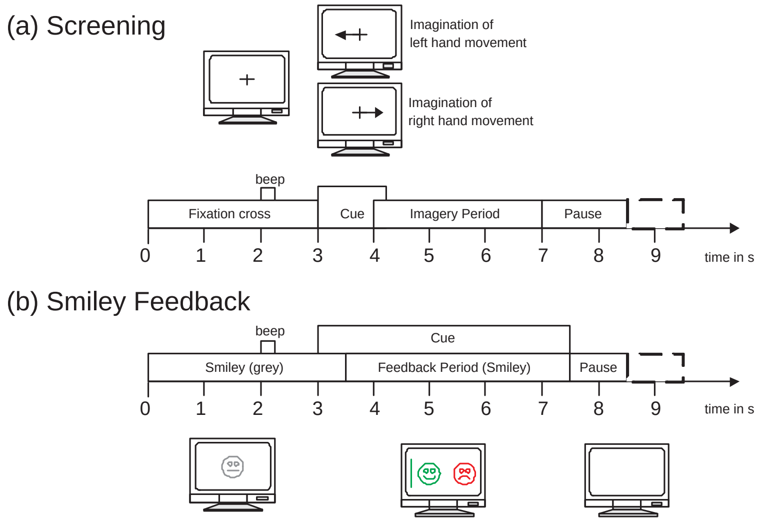

Figure 3: Timing scheme of the paradigm. (a) The first two sessions (01T, 02T) contain training data without feedback, and (b) the last three sessions (03T, 04E, 05E) with smiley feedback.

feedback (a gray smiley) was centered on the screen. At second 2, a short warning beep (1 kHz, 70 ms) was given. The cue was presented from second 3 to 7.5. Depending on the cue, the subjects were required to move the smiley towards the left or right side by imagining left or right hand movements, respectively. During the feedback period the smiley changed to green when moved in the correct direction, otherwise it became red. The distance of the smiley from the origin was set according to the integrated classification output over the past two seconds (more details see [1]). Furthermore, the classifier output was also mapped to the curvature of the mouth causing the smiley to be happy (corners of the mouth upwards) or sad (corners of the mouth downwards). At second 7.5 the screen went blank and a random interval between 1.0 and 2.0 seconds was added to the trial. The subject was instructed to keep the smiley on the correct side for as long as possible and therefore to perform the MI as long as possible.

Data file description

All data sets are stored in the General Data Format for biomedical signals (GDF), one file per subject and session. However, only the first three sessions contain the class labels for all trials, whereas the remaining two sessions are used to test the classifier and hence to evaluate the performance. All files are listed in Table 1. The GDF files can be loaded using the open-source toolbox BioSig, available for free at http://biosig.sourceforge.net/. There are

ID	Training	Evaluation
1	B0101T, B0102T, B0103T	B0104E, B0105E
2	B0201T, B0202T, B0203T	~~B0204E~~, ~~B0205E~~
3	B0301T, B0302T, B0303T	~~B0304E~~, ~~B0305E~~
4	B0401T, B0402T, B0403T	~~B0404E~~, ~~B0405E~~
5	B0501T, B0502T, B0503T	~~B0504E~~, ~~B0505E~~
6	B0601T, B0602T, B0603T	~~B0604E~~, ~~B0605E~~
7	B0701T, B0702T, B0703T	~~B0704E~~, ~~B0705E~~
8	B0801T, B0802T, B0803T	~~B0804E~~, ~~B0805E~~
9	B0901T, B0902T, B0903T	~~B0904E~~, ~~B0905E~~

Table 1: List of all files contained in the data set, the striked out evaluation data sets will be provided after the deadline of the competition. The first two sessions (`...01T`, `...02T`) contain training data without feedback, and the last three sessions (`...03T`, `...04E`, `...05E`) with smiley feedback. Note: Due to technical problems no recording for EOG estimation (eyes open, closed, eye movements) exists in session `B0102T` and `B0504E`.

versions for Octave[1]/MATLAB[2] as well as a library for C/C++.

A GDF file can be loaded with the BioSig toolbox with the following command in Octave/MATLAB (for C/C++, the corresponding function `HDRTYPE* sopen` and `size_t sread` must be called):

```
[s, h] = sload('B0101T.gdf');
```

Note that the runs are separated by 100 missing values, which are encoded as not-a-numbers (NaN) by default. Alternatively, this behavior can be turned off and the missing values will be encoded as the negative maximum values as stored in the file with:

```
[s, h] = sload('A01T.gdf', 0, 'OVERFLOWDETECTION:OFF');
```

The workspace will then contain two variables, namely the signals `s` and a header structure `h`. The signal variable contains 6 channels (the first 3 are EEG and the last 3 are EOG signals). The header structure contains event information that describes the structure of the data over time. The following fields provide important information for the evaluation of this data set:

```
h.EVENT.TYP
h.EVENT.POS
h.EVENT.DUR
```

[1] http://www.gnu.org/software/octave/

[2] The MathWorks, Inc., Natick, MA, USA

Event type		Description
276	0x0114	Idling EEG (eyes open)
277	0x0115	Idling EEG (eyes closed)
768	0x0300	Start of a trial
769	0x0301	Cue onset left (class 1)
770	0x0302	Cue onset right (class 2)
781	0x030D	BCI feedback (continuous)
783	0x030F	Cue unknown
1023	0x03FF	Rejected trial
1077	0x0435	Horizontal eye movement
1078	0x0436	Vertical eye movement
1079	0x0437	Eye rotation
1081	0x0439	Eye blinks
32766	0x7FFE	Start of a new run

Table 2: List of event types (the first column contains decimal values and the second hexadecimal values).

The position of an event in samples is contained in `h.EVENT.POS`. The corresponding type can be found in `h.EVENT.TYP`, and the duration of that particular event is stored in `h.EVENT.DUR`. The types used in this data set are described in Table 2 (hexadecimal values, decimal notation in parentheses). Note that the class labels (i. e., 1 and 2, corresponding to event types 769 and 770) are only provided for the training data and not for the testing data.

The trials containing artifacts as scored by experts are marked as events with the type 1023. In addition, `h.ArtifactSelection` contains a list of all trials, with `0` corresponding to a clean trial and `1` corresponding to a trial containing an artifact.

In order to view the GDF files, the viewing and scoring application SigViewer v0.2 or higher (part of BioSig) can be used.

Evaluation

Participants should provide a continuous classification output for each sample in the form of classlabels (1, 2), including labeled trials and trials marked as artifact. A confusion matrix will then be built from all artifact-free trials for each time point. From these confusion matrices, the time course of the accuracy as well as the kappa coefficient will be obtained [3]. The algorithm used for this evaluation will be provided in BioSig. The winner is the algorithm with the largest kappa value `X.KAP00`.

Due to the fact that the evaluation data sets will not be distributed until the end of the competition, the submissions must be programs that accept

EEG data (the structure of this data must be the same as used in all training sets[3]) as input and produce the aforementioned class label vector.

Since three EOG channels are provided, it is required to remove EOG artifacts before the subsequent data processing using artifact removal techniques such as highpass filtering or linear regression [4]. In order to enable the application of other correction methods, we have opted for a maximum transparency approach and provided the EOG channels; at the same time we request that artifacts do not influence the classification result.

All algorithms must be causal, meaning that the classification output at time k may only depend on the current and past samples $x_k, x_{k-1}, \ldots, x_0$. In order to check whether the causality criterion and the artifact processing requirements are fulfilled, all submissions must be open source, including all additional libraries, compilers, programming languages, and so on (for example, Octave/FreeMat, C++, Python, . . .). Note that submissions can also be written in the closed-source development environment MATLAB as long as the code is executable in Octave. Similarily, C++ programs can be written and compiled with a Microsoft or Intel compiler, but the code must also compile with g++.

References

[1] R. Leeb, F. Lee, C. Keinrath, R. Scherer, H. Bischof, G. Pfurtscheller. Brain-computer communication: motivation, aim, and impact of exploring a virtual apartment. IEEE Transactions on Neural Systems and Rehabilitation Engineering 15, 473–482, 2007.

[2] M. Fatourechi, A. Bashashati, R. K. Ward, G. E. Birch. EMG and EOG artifacts in brain computer interface systems: a survey. Clinical Neurophysiology 118, 480–494, 2007.

[3] A. Schlögl, J. Kronegg, J. E. Huggins, S. G. Mason. Evaluation criteria in BCI research. In: G. Dornhege, J. d. R. Millán, T. Hinterberger, D. J. McFarland, K.-R. Müller (Eds.). Toward brain-computer interfacing, MIT Press, 327–342, 2007.

[4] A. Schlögl, C. Keinrath, D. Zimmermann, R. Scherer, R. Leeb, G. Pfurtscheller. A fully automated correction method of EOG artifacts in EEG recordings. Clin.Neurophys. 2007 Jan;118(1):98-104.

[3] One evaluation data set is distributed from the beginning of the competition to enable participants to test their program and to ensure that it produces the desired output.