Finally, what is the best filter for P300 detection?

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Abstract

According to recent literature, the most appropriate preprocessing to improve P300 detection is still unknown or at least there is no consensus about it. Research papers refer to different low-pass filters, high-pass filters, baseline, subsampling or feature selection. In this paper, using a database with 23 healthy subjects we compare the effect on the letter accuracy (single-trial detection) provided by a linear support vector machine of a high-pass filter with cutoff frequencies from 0.1 to 1 Hz and a low-pass filter with cutoff frequencies from 8 to 60 Hz. According to this study, the best combination is for a band-pass filter of 0.1 to 15 Hz.

Introduction

The P300 oddball paradigm such as used in the speller by Farwell and Donchin [Farwell and Donchin, 1988] is the most frequent paradigm used in Brain-Computer Interfaces (BCI) especially for people with severe disabilities. But the signal-to-noise ratio is so low that it is necessary to apply preprocessing techniques to improve the detection of the P300 even when averaging responses to increase the amplitude of the P300 and reduce the EEG background activity. This need is well known and these preprocessings are mostly important but practices still diverge since Farwell and Donchin proposed to use a band-pass filter of 0.02 to 35 Hz. This study shows the impact on letter accuracy of a systematic experimentation of filter cutoff frequencies.

Cutoff frequencies commonly used

Recently, 27 articles on P300 detection were published in the proceedings of the BCI conference held in Graz in September 2011. These studies present a set of cutoff frequencies (see Figure 1). On one side, we observe that no specific value is clearly used for a high-pass filter but 30

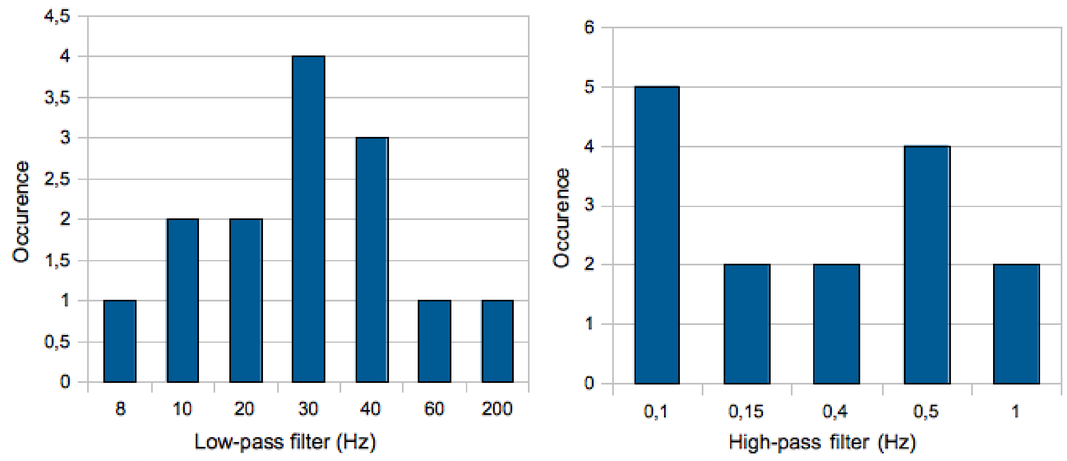

Figure 1. These histograms show the distribution of the cutoff frequency, when mentionned, used for the high-pass filter (left side) and the low-pass filter (right side) among the 27 articles about P300 detection of the BCI conference held in Graz in September 2011.

Methods

To better know the real impact of the high-pass and low-pass filter values, we computed the letter accuracy using the classical 6x6 P300 speller using a combination of cutoff frequencies. The accuracy corresponds to the average accuracy obtained using 23 healthy subjects recorded by the Neuroimaging Laboratory of Universidad Autnoma Metropolitana (Mexico) [Ledesma-Ramirez et al., 2010]. Ten channels (Fz, C3, Cz, C4, P3, Pz, P4, PO7, PO8, Oz) have been recorded at 256 Hz using the g.tec gUSBamp EEG amplifier, a right ear reference and a right mastoid ground. An 8th order bandpass filter, 0.1-60 Hz and a 60 Hz notch have been used at the recording time. The stimulus is highlighted for 62.5 ms with an inter-stimuli interval of 125 ms. A complete description of the parameters used for the speller and the data are available in BCI2000 and Matlab formats on the database website: http://akimpech.izt.uam.mx/p300db. For the experiments, we used sessions 1 (copy spelling session) and 3 (free spelling session) of the database respectively for training and testing a linear support vector machine (SVM). We assessed the influence of different cutoff frequencies on the letter accuracy (single-trial detection). The datasets contain 5520 realizations for training and 5895 for testing with a time segment of 1s.

Results

We used several band-pass filters obtained by combining order 2 Butterworth low- and high-pass filters. The low cutoff frequencies are 0.1, 0.5 and 1 Hz and the high cutoff frequencies are 8, 10, 15, 20, 30, 40 and 60 Hz. According to Table 1, a [0.1, 15] Hz band-pass filter increases the performances. Our experiments have also shown a reduction of the standard deviation over the 23 subjects for this band-pass.

Table 1: Results for letter accuracies on single-trial detection for the testing set using a linear SVM for several band-pass filters. There are 5895 realizations and 36 classes thus, according to 10 000 random simulations, two accuracies are significantly different ($p<0.05$) if their difference is greater than 0.41.

		High cutoff frequencies						
		8Hz	10Hz	15Hz	20Hz	30Hz	40Hz	60Hz
Low cutoff frequencies	without	51.97	52.56	53.62	53.62	52.12	50.41	48.25
	0.1Hz	51.72	52.36	**53.71**	53.29	51.96	50.52	48.37
	0.5Hz	52.14	52.87	53.19	52.94	51.36	50.13	47.72
	1Hz	52.28	53.05	53.05	52.29	50.67	49.12	46.42

Discussion

This paper analyses the effect on letter accuracy (single-trial detection) of high- and low-pass cutoff frequencies of the preprocessing filters. According to our systematic experimentation on 23 healthy subjects, we conclude that a [0.1, 15] Hz band-pass filter offers a good compromise between removing noise and preserving information for a P300 speller. Further works will also present the effect of a downsampling step, as well as of the baseline removal. Furthermore, a comparison between classical linear filtering and non-linear filtering techniques such as wavelet denoising will be presented.

References

[1] C. Ledesma-Ramirez, E. Bojorges-Valdez, O. Yanez-suarez, C. Saavedra, L. Bougrain, G. G. Gentilleti. An Open-Access P300 Speller Database, BCI workshop, Monterrey, 2010 http://akimpech.izt.uam.mx/dokuwiki

[2] Farwell, L.A. and Donchin, E. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials, Electroencephalography and clinical Neurophysiology, vol. 70, no. 6, pp. 510?523, 1988