BCI-SSVEP: preliminary analysis of feature extractors and classifiers

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Introduction: Brain-Computer Interface (BCI) allows converting brain signals into control commands. A usual approach of BCI is based on Steady State Visually Evoked Potentials (SSVEP), which explores the increase in brain activity that emerges in the visual cortex of a subject exposed to a scintillating visual stimulus at a specific frequency. In this study, we compare the performance of a BCI-SSVEP in four scenarios, combining two feature extractors –Welch's Method and Fast Fourier Transform (FFT) – and two classifiers – a linear classifier based on least squares and a feedforward artificial neural network (ANN).

Materials and Methods: In this study, we have used the brain signals acquired of two healthy volunteers [1]. The brain activity was registered at 256 Hz, by electroencephalography, using 16 dry electrodes. The visual stimuli blinked on a monitor at four frequencies: 6, 10, 12 and 15 Hz. The database used was composed of 8 instances of 12 s for each frequency, totaling 32 trials per volunteer. The signal processing was performed in three stages: preprocessing, feature extraction and classification. In the preprocessing, the signal of 12 s was windowed in 3 s and filtered by the Common Average Reference technique, in order to eliminate noises and artifacts. In sequence, the feature extraction was operated by two techniques: (1) FFT: the features were considered the FFT magnitude of signal at the evoked frequencies, (2) Welch: the features were the power spectral density (PSD) of signal estimated around 0.1 Hz of evoked frequencies – the values were normalized by the sum of the PSD of the four bands. In the last stage, the classifiers (linear and the ANN) were trained with 78% of the samples, randomly selected, and validated with the remaining 22%, this process was repeated 20 times for each scenario.

Results: Table 1 presents the average accuracy obtained for each scenario.

			Average Accuracy (%)				
Volunteer	**Classifier**	**Extractor**	**6 Hz**	**10 Hz**	**12 Hz**	**15 Hz**	**average ± standard deviation**
1	**Linear**	**FFT**	77.14	69.29	77.86	79.29	75.90 ± 4.49
		Welch	75.71	85.71	79.29	83.57	81.07 ± 4.46
	ANN	**FFT**	80.00	75.00	76.42	81.42	78.21 ± 3.00
		Welch	80.71	97.14	77.14	97.14	88.03 ± 10.62
2	**Linear**	**FFT**	73.57	73.57	72.14	66.42	71.43 ± 3.40
		Welch	73.57	87.14	83.57	87.14	82.86 ± 6.41
	ANN	**FFT**	83.57	75.71	72.14	75.00	76.61 ± 4.89
		Welch	78.57	96.43	77.86	95.00	86.97 ± 10.12

Table 1 – Comparison of performance of BCI-SSVEP applying different classifiers and feature extractors.

Discussion: The results show that the feature extraction by the Welch's method provides better attributes than by FFT, with difference of accuracy of about 10%. The ANN has slightly higher results than those obtained by the linear classifier; however, this difference remained within the margin of the standard deviation. The performance among the frequencies was closed, not revealing a clear polarity for either of the two volunteers. Nonetheless, the accuracy for 10 and 15 Hz were slightly better using Welch.

Conclusion: All scenarios evaluated are adequate for the implementation of a BCI-SSVEP, presenting a hit rate higher than 70% to discriminate four classes. For both volunteers, the best performance was obtained with the combination of Welch's method and ANN. However, the simplicity of implementation and the low computational cost of the linear classifier may justify its use, since it provides practically the same accuracy.

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Reference: [1] Leite, H. M. A. (2018). Design de interação para interfaces cérebro-computador baseadas em potenciais visualmente evocados.