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Abstract. Brain-Computer Interfaces (BCI) based on the detection of Steady-State Visual Evoked Potentials have proven to be highly efficient. Compared to other BCI paradigm, they usually provide the best information transfer rate. However, this type of BCI requires visual stimuli. These stimuli can be on LEDs or on a computer screen. LEDs can allow flickering lights of high frequencies while flickering lights on an LCD screen can be an integrated as a part of the user interface. We propose a new method for enabling reliable visual stimuli over 20Hz on a classical LCD screen.

Keywords: Brain-Computer Interface, SSVEP, LCD screen, Graphical User Interface

1. Introduction

The reliability of the visual stimuli is an important parameters for BCI based on external stimuli like P300 or SSVEP-BCI. While the required precision of the flashing time is not so crucial for the detection of the P300, the detection of an SSVEP response requires reliable stimuli [Cecotti, 2010]. In fact, if it is not possible to detect a Dirac delta function at a frequency f and its harmonics on the visual stimuli, then it will become harder to detect a Dirac delta function for f and its harmonics in the EEG signal. Therefore, the visual stimuli presented to the user has a direct impact on the efficiency of an SSVEP-BCI. Although it is possible to use old CRT monitors or to change to some extend the frequency of some LCD screens in relation to the resolution of the screen, the usual refresh rate of LCD screens in the mass market is limited to 60Hz. Due to the actual limit of the vertical refresh rate in current LCD screens, it is not possible to chose any frequency for flickering lights. Indeed, the choice of the frequencies for an SSVEP-BCI using an LCD screen is quite limited. It can represent a drawback for commercial and clinical SSVEP-BCI applications. One advantage of LEDs is to enable flickering lights with high frequencies (>20). With LCD screens, we are limited to a maximum of 30Hz due to the Shannon theorem. In this paper, we propose to create visual stimuli on an LCD screen with frequencies between 20 and 30Hz.

2. Methods

To enable a flickering box at 20Hz on a screen with a refresh rate of 60Hz, we consider 3 images that represent the repetitive pattern on the screen. Such pattern can be '110', where 1 and 0 denote a black and white box respectively. For a box flickering at 30Hz, the pattern is '10'. We propose to extend and to evaluate the detection of other repetitive visual structures by combining simple patterns, *i.e.*, pattern containing one change between 1 and 0. For instance, we can enable a frequency of 24Hz by considering the pattern '11010'. We note Np and Sp, the number of undecomposable patterns and the size of the combined pattern P. Thus, the repetitive pattern P will have a peak at the frequency $60*Np/Sp$ Hz and harmonics of $60/Sp$ Hz. With this strategy for displaying visual stimuli, we consider the following frequencies: 30.00, 25.72, 24.00, 22.50 and 20.00Hz. Their corresponding repetitive patterns are '01', '01.01.011', '01.011', '011.011.01' and '011', respectively. For the estimation of the frequency power of SSVEP responses, we first consider spatial filters that are obtained by maximizing the Signal to Noise Ratio (SNR) through the generalized Rayleigh quotient. For more derails, similar techniques are used in [Friman et. al, 2007; Garcia et. al, 2010]. Finally, the detection of a response is simply achieved by selecting the frequency with the highest power.

3. Experimental protocol

The goal of the experiment is to find out if the proposed method allows the detection of SSVEP frequencies. The EEG signal was recorded with 8 sensors (O_1,O_2,P_3,P_4,P_7,P_8,Pz,Fcz). The amplifier was a FirstAmp (Brain Products GmbH) with a sampling frequency of 2kHz. The signal was first bandpassed filtered (4-45Hz). Three healthy adult subjects were asked to look at the five different flickering lights on the screen during 20s. The detection method was applied every 250ms with a time segment of 2s.

4. Results

The average accuracy (in %) of the SSVEP detection is presented in Table 1.

	30.00Hz	25.72Hz	24.00Hz	22.50Hz	20.00Hz
S1	100.00	93.15	85.56	91.78	100.00
S2	100.00	73.97	89.04	68.49	86.30
S3	89.04	76.71	90.41	90.41	100.00
Mean	96.35	81.28	88.34	83.56	95.43

Table 1*. Accuracy (in %) of the SSVEP response detection*.

Although the frequencies obtained with the proposed method are harder to detect, as the size of repetitive pattern is longer, we have shown that it is possible to detect efficiently frequencies above 20Hz on a classical LCD screen. This solution was simply achieved by combining repetitive patterns from 20 and 30Hz. This strategy could also be used for other frequencies in order to obtain a larger number of commands in a BCI.

5. Conclusion

While the choice of LEDs can be judicious for displaying visual stimuli, the graphical user interface will be separated from the visual stimuli [Cecotti, 2010]. Enabling efficient visual stimuli in high frequencies on an LCD screen can be an advantage for spelling applications, video games,... In addition to different frequencies, the phase can be added to extend the number of commands in a BCI [Jia et. al ,2010 ; Zhu et. al, 2010]. Further works will consider and extend the proposed method with new materials, which are initially dedicated for nvidia 3D vision, *i.e.*, a screen with a vertical refresh rate of 120Hz and an nvida graphic card.

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References

Cecotti H, Volosyak I, Gräser A, Reliable visual stimuli on LCD screens for SSVEP based BCI, European Signal Processing Conference (EUSIPCO), Aalborg, 5p, 2010.

Friman O,Volosyak I, Gräser A, Multiple channel detection of steady-state visual evoked potentials for brain-computer interfaces. *IEEE Trans.Biomed. Eng.*, 54(4):742–750, 2007.

Garcia-Molina G, Mihajlovic V, Spatial filters to detect Steady State Visual Evoked Potentials elicited by high frequency stimulation: BCI application. Journal of Biomedizinische Technik / Biomedical Engineering, In press, 2010.

Cecotti H, A self-paced and calibration-less SSVEP based brain-computer interface speller. IEEE Trans.on Neural Systems and Rehab. Eng., 18:127–133, 2010.

Jia C, Gao X, Hong B, Gao S, Frequency and Phase Mixed Coding in SSVEP-based Brain-computer Interface.IEEE Trans Biomed Eng. 2010

Zhu D, Garcia-Molina G, Mihajlovic V, Abtahi S, Aarts RM, Multichannel Phase Synchrony Analysis in SSVEP-based BCI. In 1st Workshop on Tools for Brain-Computer Interaction (TOBI), 2010.