eyeReader: SSVEP-based BCI*

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Abstract— **The eyeReader is a brain computer interface that allows subjects to read an electronic book (eBook), using affordable, commercially available components. Concentrating on a blinking light induces SSVEP (steady-state visually evoked potentials) signals in the brain's occipital lobe at the same frequency as the stimulus. EEG signals from the occipital lobe are acquired with the Emotiv EPOC™ headset, while the subject concentrates on a blinking box on the computer screen. Features of the EEG signals in the frequency domain are used to detect the presence and frequency of an SSVEP signal. The SSVEP signal is used as a control signal to turn eBook pages.**

I. Introduction

In the US, motor neuron diseases (MNDs) such as multiple sclerosis and Lou Gehrig's disease affect 7 out of every 100,000 people [1]. These individuals may experience decreased quality of life due to limited ability to interact with the environment or act independently. We propose an assistive technology, the eyeReader, a completely hands-free eBook reader that the user controls via a noninvasive EEG interface. On a computer screen, an eBook page is flanked by two rectangles that blink at controlled rates (blinkers). When the user wants to turn the page forward or backward, he can concentrate on a blinker, and the SSVEPs at the corresponding frequency elicited at the corresponding frequency that can be detected by EEG. We chose the Emotiv-EPOG EEG headset, an inexpensive (299 USD), easy-to-use, and commercially available EEG headset. We hope to enable people affected by severe loss of voluntary motion due to MNDs by providing an easy-to-use and inexpensive eBook interface controlled by brain signals.

II. METHODS

The eyeReader allows users to read an eBook via an EEG headset and a laptop or tablet (Fig.1). SSVEP signals are acquired from O1 and O2 electrodes on the Emotiv EPOC ™ EEG headset with a 128Hz sampling rate and analyzed in real-time in C++.

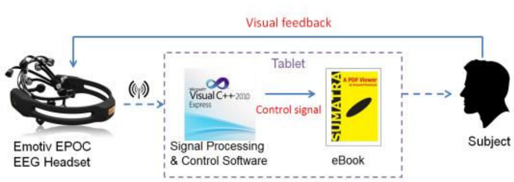

Figure 1 – Bock diagram of signal flow through the eyeReader system. Video: http://www.youtube.com/watch?v=lwLlkm59UpE

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Fig. 2 shows the signal averaging and frequency-based feature selection that was used to generate the control signal to flip eBook pages. As described by Middendorf [2], the two criteria for identifying the subject looking at a peak were determined with the FFT magnitude (Mag):

$$\mathrm{Mag}[f] > k_1. \quad (1)$$

$$\mathrm{Mag}[f] \,/\, (\mathrm{Mag}[f_{left}] + \mathrm{Mag}[f_{right}]) > k_2. \quad (2)$$

We chose k_1 and k_2 that yielded maximum information gain from a training data set, where the user was randomly prompted to look at a blinker or nothing for several seconds over the course of ten minutes.

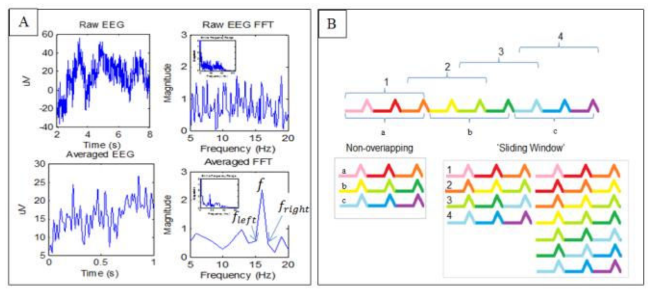

Figure 2 – Signal averaging (A) using the sliding window method (B) and inputs used for the decision tree.

III. Conclusion

The eyeReader was tested on two healthy subjects to validate our detection method. JD was tested once, and JL was tested once without practice and once after 3 months of practice over 2-3 two-hour sessions a week with an SSVEP-detection system that provided positive feedback. The detection accuracies (Table 1) range from 80% and 99% and average to 86.2%. At least one control signal can be detected every 10 seconds (an approximately 5.2 bits/minute information transfer rate), which is acceptable for navigating an eBook interface for patients with severe loss of voluntary control.

***Table 1** - Summary of data collected*

Subject		**Trials**	**Accuracy (*Freq.*)**	**Accuracy (*Freq.*)**	**Time for Command**
JD		25	91 (10Hz)	82 (8Hz)	7 s
JL	*Before training*	48	85 (16Hz)	80 (12.8Hz)	4.375 s
	After training	28	99 (16Hz)	80 (12.8Hz)	4.375 s

References

[1] MNDA, *About MND.* 2013. From http://www.mndassociation.org/what-is-mnd/Brief+guide+to+MND

[2] M. Middendorf, G. McMillan, G. Calhoun, and K.S. Jones, "Brain-computer interfaces based on the steady-state visual-evoked response." *IEEE Transactions on Rehabilitation Engineering*, 8(2), pp. 211-214, 2000