P300-based Brain Computer Interface - a Controller for Internet Browsing

Ashima Dadhwal
B. Tech Student
Dept. of CSE
HMRITM, New Delhi, INDIA

Prerna Dhingra
B. Tech Student
Dept. of CSE
HMRITM, New Delhi, INDIA

Dayanand
Assistant Professor
Dept. of CSE
HMRITM, New Delhi, INDIA

***Abstract*—A Brain-Computer interface (BCI) is a communication system that enables the generation of a control signal from brain signals such as sensorymotor rhythms and evoked potentials; therefore, it constitutes a novel communication option for people with severe motor disabilities (such as Amyotrophic Lateral Sclerosis patients). This paper presents the development of a P300-based BCI. An electroencephalographic (EEG) brain-computer interface (BCI) internet browser was designed and evaluated with 10 healthy volunteers and three individuals with advanced amyotrophic lateral sclerosis (ALS), all of whom were given tasks to execute on the internet using the browser. Participants with ALS achieved an average accuracy of 73% and a subsequent information transfer rate (ITR) of 8.6 bits/min and healthy participants with no prior BCI experience over 90% accuracy and an ITR of 14.4 bits/min. We define additional criteria for unrestricted internet access for evaluation of the presented and future internet browsers, and we provide a review of the existing browsers in the literature. The P300-based browser provides unrestricted access and enables free web surfing for individuals with paralysis.**

Keywords - Brain computer interface (BCI); electroencephalographic (EEG); P300-based BCI; information transfer rate (ITR)

I. INTRODUCTION:

Brain-computer interface (BCI) systems allow users to communicate without movement and provide a direct electronic interface to convey messages and commands from the brain to a computer. A BCI system monitors conscious electrical brain activity via electroencephalogram (EEG) signals and detects patterns that are generated by the user. After the EEG is digitized, it is processed via digital signal processing algorithms to convert the EEG into a real-time control signal . By establishing a communication link between a subject and a computer, BCI can enable physically disabled people to perform many activities, which improve their quality of life and productivity, allowing them more independence.

Figure 1 BCI APPRATUS

BCIs are named according to the type of brain activity used for control. Among several categories of EEG-based BCIs, including P300, steady state visual evoked potential (SSVEP) , event related desynchronization (ERD) , and slow cortical potential based , in this paper, only the P300-based BCI is reviewed. This type of BCI has recently been the focus of many studies, is relatively easy to use for a control signal, and has shown great potential to be used in several different applications such as internet browsing which will be discussed in this paper.

Criteria for Assessment of BCI Internet Browser In 2002, Mankoff and colleagues [15] described the requirements of a system that would “allow true web access”:

- The currently selected link is visible.
- The user can read and navigate text even when it contains no link.
- The user can traverse the history list forward and backward.
- The user can access [his or] her bookmarks and add to them.
- The user can go quickly to a point of interest with a minimal number of [command] signals.
- The user is given alternatives for entering text and dealing with form elements.
- The user is given enough information about link targets to make informed decisions about whether to follow them. Although these are suitable guidelines, these criteria are insufficient and lack specifications for free surfing of the internet, which we consider a part of “true web access”. The primary basis for a “web browser” is that a user can browse any internet site at will. We therefore presently define “free surfing” as the

ability to navigate to any page on the internet that could be accessible by a standard browser, yielding unrestricted internet access, and we add this criterion to our evaluation of existing BCI browsers. The incorporation of physical address entry into an address bar satisfies this criterion.

These additional criteria to allow "for true web access" can be summarized as:

- The user is able to navigate to any page on the internet that could be accessible by a standard browser.
- The user can achieve ≥ 70% navigational (or browsing) accuracy
- The time to execute a navigation decision for any link on a page is not considered excessive by the user. These new criteria provide both a quantitative and qualitative assessment of web access, which can be evaluated via experimental trials and user questionnaires

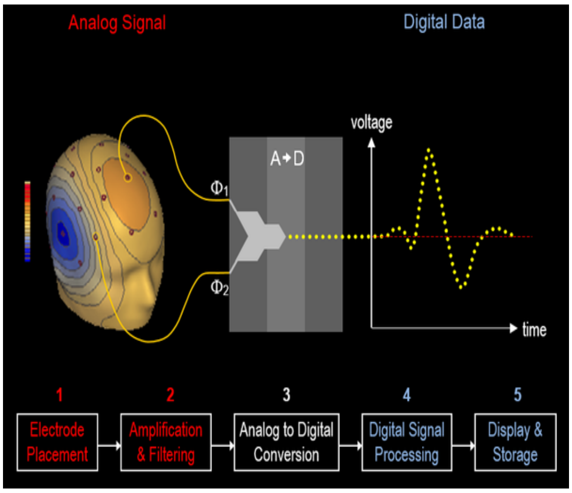

Figure 2 analog to digital

BCI Traditional Definition:

"the goal of BCI technology is to give severely paralyzed people another way to communicate, a way that does not depend on muscle control."(Wadsworth center)

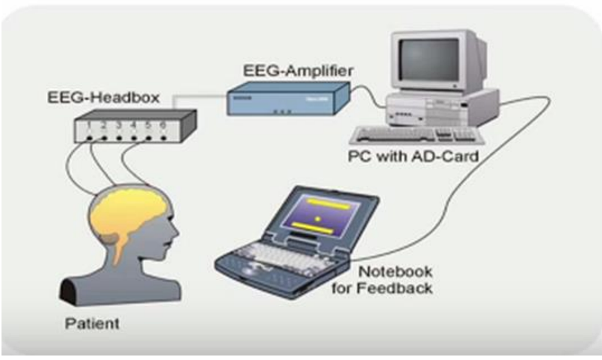

Figure 3BCI Traditional Definition:

BCI Definition: "A system which takes a bio signal measured from a person and predicts(in real time / on a single-trial basis) some abstract aspect of the person's cognitive state.**"**

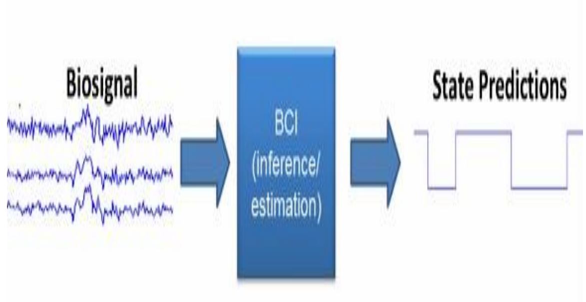

Figure 4 BCI Block dig.

II. WORKING

The browser was designed using the open-source technology of Mozilla's Firefox (Version 2.0), which allows for supplementary "add-on" code to be implemented. The preexisting add-ons that comprise the browser include "Hit-aHint", which enables the links on a page to be selected with simple keystrokes, and GreaseMonkey script "Send-Keys", which simulates typical browser commands by reassigning standard shortcuts. Hit-a-Hint assigns all links on a page a tag with a numeric or alphabetic code, from top to bottom and left to right. Any link displayed in the browser window can then be selected by entering of the corresponding code. By combining these pre-existing elements in Firefox, the browser can be controlled with commands sent from the P3Speller paradigm (via BCI2000 and BCIKeyboard, a tool of BCI2000). Browser functions that can be executed with the P300 Browser are: navigation (forward, back, reload, and home), data form entry, address bar entry, and scroll up and scroll down. These functional options are all presented as icons in an expanded 8-by-8 form of the traditional 6-by-6 P3Speller matrix in BCI2000 (Figure 1). By employing alphabetic code for link tags, each link on the page can be executed by entering either a one- or two-letter command. For example, the twoletter link tag BA can be executed by first selecting a command with an asterisk ("B*") and then the following letter ("A"). Therefore, for sites with over 26 links on a page (up to 338 links on a page), any link can be selected by execution of at most two commands, far less than the amount of commands necessary if the link selection method were binary. Characters in the matrix can not only be used to select links in the browser window, but they can also be used in typographical fashion to write emails or fill out form elements (after the user selects the form element's tag). Visual feedback of the selected command is displayed to the user after every selection. Web browsing is an asynchronous process; the user controls the pace of the activity. However, the P3Speller is a synchronous process, reliant on specific timing to detect a decision made by the user. Because of the difference between asynchronous and synchronous processes, timing between the two monitors was coordinated so the users were not overloaded with information . To allow for variable loading time for each web page (more page content can lead to longer loading times) and also to allow the user to fully assess the page before deciding on a navigational action, pauses of modifiable length are inserted before presentation of link tags (default: 5 seconds after page load) and onset of P3speller sequences (default: 16 seconds after previous command execution). The time duration needed for selection of a P3Speller command depends on the amount of sequences needed to determine the user's target character

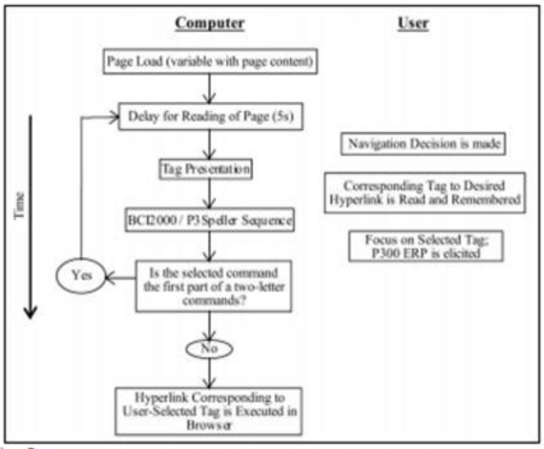

Figure 5 Overview of P300

III. OTHER P300 APPLICATIONS

There has been progress in developing BCI applications to accomplish new tasks or goals .

A. *Brain painting*

An even more novel direction involves utilization of BCIs for creative expression and entertainment. One of the drawbacks to the majority of today's BCI systems has been their emphasis on function instead of usability, resulting in BCI software which lacks the appeal and user experience we have grown accustomed to from commercial products (Allison, 2009). Hence, BCIs might work, but are often confusing, counter intuitive, or boring for the user. When designing novel BCI systems, developers should consider signal acquisition methods, innovative paradigms, and also engaging interaction for the user. New interaction aspects have generally received less attention in BCI research.

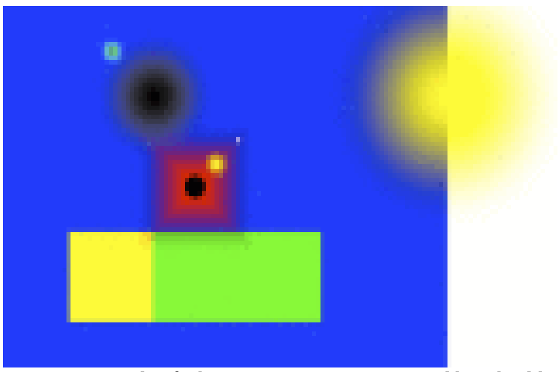

Figure 6 Example of a brain painting picture painted by a healthy volunteer.

B. *Virtual reality*

To operate a BCI to control a virtual environment, several demands must be met: (1) biosignal amplifiers must be functional while the subject is moving; (2) the recordings should ideally be done with a rather small portable device to avoid collisions and irritations within the environment; (3) the BCI system must be coupled with the virtual reality (VR) system for real-time experiments and (4) a special BCI communication interface must be developed to have enough degrees of freedom available to control the VR system. Figure Figure44 illustrates the necessary components in detail. A 3D projector is located next to a projection wall for back projections. The subject can be positioned in front the projection wall to avoid shadows and is equipped with position tracker to capture movements, shutter glasses for 3D effects and the biosignal amplifier including electrodes for EEG recordings. The XVR (eXtreme VR, VRmedia, Pisa, Italy) PC controls the projector, the position tracker, and the shutter glass. The biosignal amplifier is transmitting the EEG data to the SSVEP—P300 BCI system which is connected to the XVR PC via UDP connection to exchange control commands.

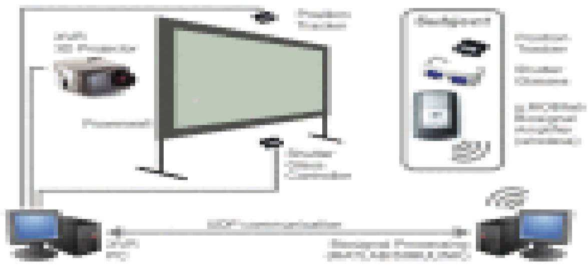

Figure 7 VR media

C. *The first commercial BCI system*

The Intendix BCI system was designed to be operated by caregivers or the patient's family at home. It consists of active EEG electrodes to avoid abrasion of the skin, a portable biosignal amplifier and a laptop or netbook running the software under Windows. The electrodes are integrated into the cap to allow a fast and easy equipment mounting. The system allows viewing the raw EEG to inspect data quality, but automatically informs inexperienced users about the data quality on a specific channel.

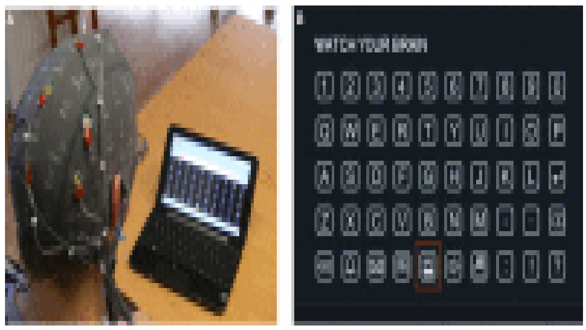

Figure 8The intendix BCI running on the laptop and user wearing the active electrodes. User interface with 50 characters and computer keyboard like layout.
Figure 9 Commercial BCI system

IV. CHALLENGES AND SOLUTIONS

These results show that P300 BCI systems can provide effective communication.

- P300 BCIs, like any BCI, require significant support. An expert is needed to identify and assemble the components, customize parameters to each user, and address acute problems. Severely disabled users also need help to don the electrode cap before each session, and need someone to wash their hair and the cap afterward. Improved software and dry electrodes could help considerably
- Many P300 BCIs may be less effective in persons who cannot control gaze, such as severely disabled users . This problem may be alleviated through different visual stimuli that do not require gaze shifting or using a non-visual modality . However, these solutions might reduce information transfer rate
- P300 BCIs require a monitor or other external stimulation device to generate the flashes, tones, or other events that elicit P300s. Although subjects generally report that these events are not distracting or annoying, this could become a greater problem with long term use or different display parameters. On the other hand, research could focus further on displays that do not produce negative side effects. Also, even BCIs that do not rely on stimuli to generate events may still rely on stimuli for other aspects of system operation, such as an avatar's location in a virtual environment or feedback.
- P300 BCIs are well suited to some tasks, and not others. P300 BCIs have been validated for tasks like spelling, smart home control, or internet browsing, which all entail direct selection. P300 BCIs may be less effective for other tasks. This problem might be reduced with new paradigms and tasks, or hybridizing with another BCI.

V. CONCLUSION

In conclusion, the P300 Browser has been demonstrated to be a useful tool for freely surfing the web with healthy volunteers and people with ALS alike. Although people with ALS reported high expectations for the browser, when asked what they thought about the program, they were largely positive, confirming the results from the experiment and validating the P300 Browser as a useful brain-computer interface application and browser. A version of the P300 Browser updated to work with FF3.0 is available at http://nessi.mozdev.org/.

VI. REFERENCES

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