Brain-Computer-Interface for Software Control in Medical Interventions

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Abstract:

Intra-operative interaction with computer systems is a challenge because of spatial constraints and also because of the need for sterility. Therefore touchless interfaces are interesting alternatives to classical interaction devices. A device that can read and convert brain signals into control and communication commands is called brain-computer-interface (BCI). In this short report we present a study on the performance of a commercial, low-cost BCI (Emotiv EPOC) for software control in surgery and intervention and examine the influence of the already existing cognitive load caused by the medical procedure itself.

Keywords: interaction, brain-computer-interface

1 Introduction and Goals

A device that can read and convert brain signals into control and communication commands is called brain-computer-interface (BCI). BCIs can be useful for people with disabilities or in circumstances, in which normal interactions with a computer are either impossible or dangerous [1]. These circumstances or conditions cause some sort of temporal, so-called induced disability. A physician whose hands are busy during surgery or medical intervention has an induced disability for software control. Hence, more often than not, a second physician operates the software on behalf. Besides the need for assistance, communication errors may be induced. While gestural interaction and voice control have been studied in these conditions, the use of BCI has not. BCI control would be direct, silent, and touchless. In this short report we present a study of the performance of a commercial, low-cost BCI (Emotiv EPOC) for software control in interventions and examine the influence of the already existing cognitive load caused by the medical procedure itself.

Literature and our own initial tests indicated a relatively low bandwidth for communication using BCI [2]. Depending on the number of sensors (14 channels for EPOC) and the classification algorithms, only very few commands can be executed reliably. This might not pose an issue as long as otherwise difficult to communicate actions can be controlled. Based on our initial observation of surgeons in liver-surgery or electrophysiologists performing ablations on the human heart, we chose to support the brain-controlled spacial rotation of a virtual 3D model. Finding the perfect view onto such a model is best accomplished by the one looking for a specific view. Hence for our experiments, we constrained the view control to left and right rotations about a fix axis.

2 Materials and Methods

Instead of real intervention rooms, we conducted our research in a laboratory setting through controlled experiments. With our BCI test system the users can perform two actions: moving an object on the screen to the left and right. It employs the Emotiv EPOC BCI for reading and classifying the brain signals, as well as a software which has been specifically designed and implemented for this study. 12 subjects, four female and eight male participated in the experiments in four groups with different experimental order and within-subjects design.

While the first objective of our study is the determination of the accuracy of this BCI system itself, we ultimately wanted to learn about its suitability for use in an operation or intervention room. Of all distracting elements in such an environment, we *measure the effects* of the coordinated *movements of the users hands* on the BCI performance. This element is of particular interest because it is the primary reason for not being able to employ traditional hand operated input devices. Simply put: the hands (and often feet as well) are already busy during the medical procedure. For a simulation of the challenging manual task, we employed the *Hot Wire* game in which users have to hold and pass a wired handle through the contours of a wired human body without contact (see Fig. 1).

Two groups of mental tasks have been used in this study to induce and investigate brain patterns that can be detected by the BCI [3]. The first group consists of direct *motor cognitive tasks*—the imagination of left and right hand movements (such as opening and closing of a hand). The second group consists of *non-motor cognitive tasks*—the solving of mathematical equations and mental rotation tasks (both of which will be performed in different brain hemispheres). We assess and compare the system accuracy in performing each group of these mental tasks to select the best performing method for BCI control. In addition, we also determined demographics data and the user experience of the subjects with a guided interview.

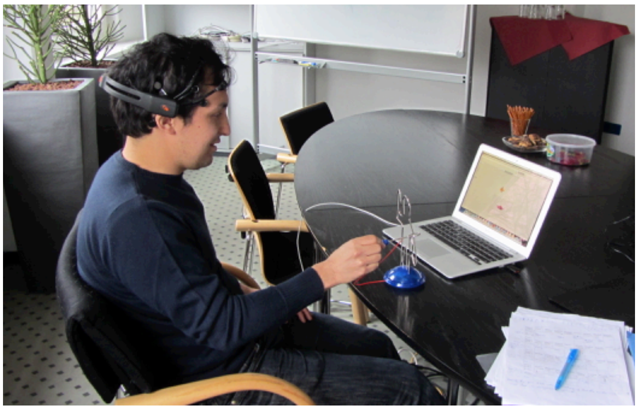

Fig. 1: The setup for the experiments. Here, the subject wears the Emotiv EPOC device on his head and steers the handle of the Hot Wire game while the software asks him to perform a specific mental task. The resulting movement of a virtual 3d object to the left or right hand side is displayed on the computer in real time.

3 Results

Due to page limitations, we will report only the most important findings. The performance results generally show a low detection rate of the BCI system and most of the times, the system had been unable to detect any action during the period the user performed the mental task. However, using non-motor cognitive tasks in both conditions—with and without the challenging manual task—significantly improves the performance. The challenging manual task on the other hand does not make any significant difference in the performance results. The collected data from the questionnaire and observation indicate a good user experience within the experiment. The subjects found the headset as comfortable to wear.

4 Discussion

The system has been detecting non-motor cognitive tasks much better than motor cognitive tasks. This may be due to the math and rotation tasks being more challenging to users thus producing better detectable signals. Another reason could be the sensor locations. There are sensors directly at the brain regions for non-motor cognitive tasks, but there are no electrodes over the areas responsible for hand motor imagery. Working with a low-cost BCI package such as Emotiv EPOC introduces some inevitable limitations to the study. The fixed positions of electrodes are not necessarily ideal for BCI research.

5 Conclusions

Although the performance of the Emotive EPOC in its current form is not reliably enough for medical software control, there are some evidences that suggest it can get improved. For instance, the position of the electrodes needs to be adjustable to the evaluated brain regions. Also the employed classification algorithms for the signals are not documented and cannot be adapted, e.g. by chaining the weight of certain brain regions.

However, the low influence of the manual task on the execution of an additional mental task suggests at least a general suitability of BCI for software control during surgery or interventions.

6 References

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