Brain-Computer Interface for Navigating in Virtual Environments

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Introduction

In recent years, the appealing idea of a direct interface between the human brain and an artificial system – called *Brain Computer Interface* (BCI) – has motivated a growing community of researchers [1-3]. The conceptual approach is to model the brain activity variations and map them into some kind of actuation or command over a target output (*e.g.*, a computer interface or a robotic system). Continuing advances in a number of fields have supported the idea that the concept is viable, although a significant research and development effort has to be conducted before these technologies enter routine use.

Nowadays, the principal reason for the BCI research is the potential benefits to those with severe motor disabilities (*e.g.*, amyotrophic lateral sclerosis, brainstem stroke or severe cerebral palsy). The first demonstrations have already been performed: tetraplegic patients control hand prostheses; completely paralyzed persons write letters and they do it all with the power of their thoughts [3]. From another viewpoint, BCIs can also be seen as a new and exciting means of communication in the field of multimedia and human-computer interaction.

Independently of the application, feedback is a very important component in the training phase of a BCI. In contrast with simple visual presentations, virtual reality is a powerful tool to generate three dimensional feedback with arbitrary adjustable complexity (from very simple pictures till highly complex scenes with textures and animated objects). In this line of thought, virtual reality opens up new possibilities to improve BCI-feedback and create new paradigms, with the intention to obtain a better control of the prototype system.

Objectives

This PhD proposal focuses on the design and development of an EEG-based BCI to exploit the benefits of advanced human-machine interfaces. Specifically, we intend to investigate how the electric activity of the brain can be used in the context of the navigation in virtual environments when using a Head Mounted Display (HMD). The aim is to develop a multidisciplinary research by combining insights of cognitive neuroscience, signal processing, machine learning and virtual reality. The main objectives of the work are:

- To departure from current assumptions to develop non-invasive EEG-based BCIs; EEG conveys information about intents (mental commands) and cognitive states (errors, alarms, attention, frustration, confusion, etc) that are crucial for a purposeful interaction.
- To improve the signal-processing algorithms to better extract every bit of information from the collected signals. The problem in EEG analysis is that finding optimized electrode positions and frequency bands is the most important part. Instead of band power, other features are to be extracted from the EEG using adaptive autoregressive models (AAR), common spatial patterns (CSP) or hidden markov models (HMM).

- To apply different mapping methods like principal component analysis (PCA) or independent component analysis (ICA) and different classifiers such as neural networks.
- To develop an asynchronous BCI-prototype system that continuously analysis the recorded signal to decide when an intended mental state takes place. The major concern will be directed towards designing a generalized framework that supports rapid prototyping of various experimental strategies and operating modes.
- To study the several reasons for using a BCI in VR: rehearsal of scenarios that are too dangerous in the real world (*e.g.*, controlling a wheelchair); prototyping devices (*e.g.*, robotic hand); prototyping new control methods; studying the effects of watching virtual body part actions (*e.g.*, applied for stroke rehabilitation) and increasing motivation and/or mental effort in BCI feedback experiments.
- To investigate whether VR feedback stimulates the subject to achieve a better performance or to decrease the training effort. One characteristic component for virtual reality is immersion, which is the ability to focused attention to the environment. Further investigations are necessary to find suitable mental control strategies which allow the subject to really navigate (left-right, forward-backward, up-down) through the environment and to understand the advantages of using a Head Mounted Display (HMD).

References

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