BCI for Games: A ‘State of the Art’ Survey

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Abstract. Brain-Computer Interfacing (BCI) has found applications for disabled users. Progress in BCI research allows looking at applications for ‘abled’ users. For these applications users have other demands, and they will be critical about devices that limit physical movements and that require long periods of training. Prototype BCI applications now appear in the domain of games and entertainment that aim at adapting and controlling a game using brain signals in addition to traditional physical and mental abilities.

1 Introduction

Brain-computer interfacing (BCI) has seen progress in the medical domain, for example for prosthesis control or as biofeedback therapy for the treatment of neurological disorders [1]. Due to this progress we now see attempts to introduce BCI outside the medical domain [2,3,4]. Presently, BCI in human-computer interaction research assumes that devices to measure brain activity patterns can be non-invasive, similar to offering the user a mouse, a keyboard, a camera, a joystick or a Wii-like controller. The most common way to get information from a user’s brain is to use an EEG (Electroencephalography) cap. Such a cap is equipped with sensors (electrodes) that detect activity from different brain regions associated with different brain functions (affect, perception, imaging, movement …). Today’s non-intrusive EEG-based BCI technology allows patients to communicate with the outside world and it allows patients to control prosthetic devices. Moreover, it allows ‘situational disabled’ users, that is, users who are able to use hands, feet, gaze, etc., to add an extra control modality to their abilities. Think of a pilot in a fighter plane, a manager in a crisis situation, or a gamer trying to reach a next level in a game.

2 BCI Developments and Applications

In BCI research and technology for games and entertainment we distinguish developments in the following areas: (1) BCI research that allows us to collect information from brain activity that informs us about the cognitive state of the user. Such information can be used to adapt a game or an interface to the user; (2) BCI research that allows us to develop applications where information derived from brain activity allows us to control an application. In this case brain activity can be evoked ‘externally’ using certain stimuli, or it can be evoked by the gamer in order to address certain challenges offered by the game; (3) Mainstream BCI research that aims at distinguishing and classifying brain activity in different regions of the brain using pattern recognition and machine learning algorithms in order to get knowledge about the cognitive state of the user or to recognize the user’s mental control meant to progress in the game; (4) BCI research that aims at developing hardware and software that allows unobtrusive interfacing with BCI applications; hence, no long periods of training and calibration, and no extensive preparations before a user can start.

We can look at these issues in some detail:

Control by affective state: Measuring cognitive activity allows us to detect what the user is experiencing during specific tasks. Such information allows the interface to decrease or increase task load, or, in the context of games, to increase or lower the difficulty level of the game. There are other ways to infer cognitive processes that provide us information about interest, attention, confusion, frustration, irritation, relaxation, satisfaction, fatigue, boredom, etc. Other behavioral and physiological measures are possible, and in game environments we certainly want and have the possibility to get information from eye gaze, facial expressions, body movements and physiological information other than brain activity (hearth rate, blood pressure, skin conductivity). Dynamically tailoring the game to the affective state of the user allows the application to adjust the information flow and to provide effective and pleasant feedback, keeping the user in the flow of the game [5].

Issueing commands by brain signals: What brain activity can be induced by the gamer in order to control the game? In addition, can the game environment be designed in such a way that at certain game decision moments it evokes brain activity to choose among possible alternatives? Various kinds of brain activity that can be used for game control can be distinguished. We can look at brain activity related to imagining movements, activity that occurs when an anticipated event really happens, activity related to a difficult mental task, or activity that is explicitly and externally evoked in order to guide the user in decision making. For example, imaging a movement of your left foot, imagining a movement of your index finger, or imagining a movement of the tip of your tongue, all these imagery movements lead to distinguishable brain activity in the motor cortex of the brain. Similar activity in similar regions of the motor cortex appears when executing or intending to execute such movements. Hence, there is a natural mapping from imagining movements to having these movements executed in a prosthetic device, a robot or as commands in a game environment. Event-related potentials (ERPs) are evoked by external stimuli to which the brain responses automatically. Other brain activity can be evoked by artificial stimuli such as, for example, flickering lights on a screen. Clearly, games can be designed in such a way that such stimuli are a natural in the game.

Developments in BCI technology: In current BCI research we see the use of EEG caps with 32 until 256 electrodes to measure brain activity. We do not know whether so many electrodes are necessary for useful game aplications. We see also the use of EEG in combination with EMG (electromyogram) techniques. Rather than being happy with additional sources of information, BCI researchers often consider influence of muscle and eye movements as artefacts that have to be discounted. We can not expect that current EEG caps will become part of a gamer’s equipment. In addition to being expensive, it is not necessarily the case that for games we need up to 256 electrodes measuring activity from various parts of the brain. Moreover, setting up a BCI session takes too much time, requiring application of conductive gel, electrode positioning and clean-up after a session. We now see the development of 'dry-cap' technology, allowing a user to use an EEG cap in a similar way as using a mobile phone, an iPod, a Wii, a microphone or teleconferencing equipment. An issue that certainly should be addressed is that in experiments not all users are able to perform at the same level. That is, not all users are able to imagine movements or perform other mental tasks in such a way that a BCI system is able to detect them.

3 BCI for Games and Entertainment

In the previous sections we already made many references to BCI and games. Maybe, in adition, it should be mentioned that BCI game applications are not that different from BCI medical applications or BCI military applications. Gamers, patients and military are handicapped. That is, the circumstances in which they have to perform challenge their abilities to control the environment and these circumstances can ask for control that can not be delivered by available conventional modalities (speech, gaze, keyboard, mouse …). 'Induced disability' or 'situational disability' are words that are used to describe these circumstances. Everybody, handicapped or not, will meet situations where benefits can be obtained from extra communication modalities.

This is particularly true in games, sports and entertainment situations where users have to compete. There are also other reasons that make games, gamers and the game industry interesting. Gamers are early adaptors. They are quite happy to play with technology, to accept that strong efforts have to be made in order to get minimal advantage, and they are used to the fact that games have to be mastered by training, allowing them to go from one level to the next level and to get a higher ranking than their competitors. Moreover, there are enormous numbers of gamers. Having advantage by being the first to introduce a new type of game or a new game element may bring game companies enormous profits. This certainly is an impetus to invest in research and development in brain-computer interfacing.

Nowadays, when we look at BCI games we are asking for theory that allows us to distinguish and employ activity in different regions of the brain (using machine learning algorithms) and that allows us to map each of these activities to commands that are meant to control or adapt a game. These activities can be evoked because:

- the gamer is experiencing the game, the task and the interface, and gets, among others, frustrated, engaged, irritated, bored or stressed;
- there are external stimuli (visual, auditory, ..) consciously generated by the game to force the user to choose among certain possibilities (i.e., make decisions in the game) or that occur in a more natural way because BCI recognizes that a gamer is interested in a particular event that happens during a game;
- the gamer consciously tries to evoke this activity by performing a mental task; e.g., imagining a movement or doing a mental calculation, leading to brain signals that can be recognized and transformed in such a way that the application is controlled by this imaginary movement.

4 Conclusions

There are examples in which researchers 'play' with potential BCI game applications. These attempts are done to develop knowledge about BCI and sometimes there is the explicit aim to contribute to the development of BCI applications and BCI games. Game-like situations have been designed to illustrate research. User-controlled brain activity has been used in games that involve moving a cursor on the screen or guiding the movements of an avatar in a virtual environment by imagining these movements [4]. Relaxation games have been designed [6] and also games that adapt to the affective state of the user [5]. Many variations have been introduced: controlling Google Earth, playing the game of Pong, balancing an avatar on a rope, navigating in Second Life, etc.

There are many challenges unique to BCI applications in HCI. One example is the inevitable presence of artifacts traditionally deemed to be "noise" in traditional BCI explorations. In our applications, we cannot typically control the environment as tightly as in many medical applications nor are we willing to restrict the actions of the user. Hence, we have to devise techniques that either sidestep these issues, or better yet, that leverage the additional information we have availabe to us. A particular point of interest is how to fuse information coming from more traditional input modalities (e.g. touch, speech, gesture, etc.) with information obtained from brain activity.

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