BrainGain: BCI for HCI and Games

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Abstract. In this position paper we describe part of the Dutch BrainGain research project on Brain Computer Interfacing (BCI) and our planned research in this project. We focus on BCI research for healthy users. In the BrainGain project our task is to look at Human Factors aspects of BCI applications, to look at multimodal interactions that include BCI interactions, and to design games, game environments and game interfaces that allow BCI interactions. Recently we see game companies taking an interest in BCI, among others leading to some games where movements of the 'healthy' user help to intensify brain patterns that control a virtual environment. One line of research we hope to exploit is the use of BCI in exertion interfaces.

1 INTRODUCTION

BCI (Brain-Computer Interfacing) has become a research topic in computer science and, in particular, human-computer interaction. In 2007 a large scale BCI project was approved in the Netherlands. This BrainGain project (http://www.nici.ru.nl/braingain/) started in September 2007 and is funded by the Dutch government with 14 million Euro. Part of this funding is assigned to BCI research for the 'healthy user'. That is, research that does not necessarily aim at results and applications for users with special needs. In the project description it is mentioned that:

- The psychiatric and neurological professionals in the consortium also want to investigate the use of modern methods of analysis of brain signals for specifically developed therapies. These developments could also be applied to the needs of healthy users, in terms of health, performance, or quality of life. For example, the costs of stress to the society are high, and learning to relax, concentrate or meditate could provide a useful application of BCI for healthy users.

And there is an economical perspective too:

- In order to also create an economical impulse, the consortium will develop a broad range of applications, which will allow healthy users to also benefit from the newly developed technologies. Possible applications include entertainment, such as computer games driven by brain signals. Or, in more professional surroundings, to present information on a computer screen only when visual attention is detected, such as might be useful for air traffic controllers or customs officials checking scanned luggage.

From [1]: "Also, the elderly in general and the 100 million baby boomers in specific –in control of the largest concentration of funds than any other demographic group– will demand longer life, personalised health care, intelligence and memory support, and improvement of their senses and mobility." Future interfaces will allow us to communicate at an emotional and intentional level. Sensors and actuators will be integrated everywhere in our environment. They will capture verbal, nonverbal, physiological, and brain information and this information will be processed and interpreted in order to support the users in their daily activities.

Obviously, also in professional environments captured information can help the environment to support a user in performing his tasks. BCI can play a role in solving the threat of sensory and cognitive overload for, for example, pilots and crisis team members, but also for everyday life activities such as driving, controlling devices and gaming. Especially in the latter applications the hardware must be designed for use in everyday life, i.e. unobtrusive, lightweight and wearable, preferably wireless, and with low power consumption. Often there is not a single task to be performed, as is mostly the case for severely disabled persons. Moreover there is information to be captured and fused from various input modalities and brain activity displayed in various brain regions with not always distinguishable functions.

2 BCI FOR HEALTHY USERS: TOPICS

In the part of the BrainGain project that is devoted to BCI for healthy users we have chosen the following topics to research [1]:

- **Attention Monitoring and Adaptation**: To stay highly alert for extended periods of time is critical for flight controllers, truck drivers and security personnel scanning luggage or checking many video monitors. To detect visual alertness is an important prerequisite to warrant user performance. Experiments have shown that ongoing brain activity (in particular posterior alpha activity) is a better detector of visual alertness than behavioural measures. These new findings could be used to create a BCI that determines the user's visual alertness and for example adjust the visual load in the interface or even advise the user to take a break. Such systems can be installed at airport traffic controllers, security inspectors etc. The combination with other physiological measures used in HCI is an important multi-dimensional challenge.
- **Classifying Images**: The brain outperforms software tools when it comes to classifying images or the semantic understanding of images. In many areas, enormous amounts of images are available but very hard to access because they are not labelled. Automatic analysis of image contents is very difficult and despite the huge efforts put into machine algorithms, limited progress is made, while the brain does these kinds of tasks very easily. Using a BCI may give us access to these very powerful brain mechanisms to interpret

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images. E.g., specific event related potentials may occur when a primed object is present in an image, even when many images are shown in rapid serial presentation. By using this effect, observers may be able to reliably classify images at very high speeds.

- **Motion Control for Virtual or Remote Worlds:** The general question here is "to what extent can brain signals be used for navigation in (relatively) fast in-the-loop applications for gaming, simulation, and remote control applications". In these areas, using our locomotion system as input device (e.g., walking on a treadmill) is cumbersome, complicated and expensive. Usually, motion control is accomplished by keyboard or joystick, sometimes in combination with a head tracker to allow for a natural way of looking around. The drawback of these motion control devices is that they are unnatural, possibly disturbing the user's feeling of presence, and that they occupy the hands. The latter is undesirable when the hands are required to interact with the remote or virtual world. In this research hands-free (self-) motion control interfaces based on brain signals will be investigated.
- **Multimodal Measures of the User Experience:** In this research we investigate the following topics. (1) Brainsignals and user experience: In the case of intelligent, adaptive interfaces the system tries to adapt itself to the way the user experiences the interaction. The brain signals contain information about this experience. In a series of controlled experiments it will be determined what brainsignals can tell us about the user experience. (2) Correlations between brainsignals and other information from the body: Measures of biosignals such as heart rate, respiration, perspiration, body temperature and muscle tension can point to factors of the user experience as well. In experiments brainsignals will be traced together with other physiological measures and information from voice, face and head. (3) Expressivity and reliability: For each modality and each combination of modalities it has to be determined what they can express and how reliably they express this. Combination of modalities reduces noise and can dissolve ambiguities. It is important to have a good indication of the reliability of the various measures. (4) Interface: The inferences about the cognitive and affective state of the user that can be made on the basis of the information from the various measures will be used in the development of adaptive interfaces for games.
- **Employing BCI in game environments:** Currently there is a development from traditional videogames using keyboard, mouse or joystick, to games that use all kinds of sensors and algorithms that know about speech characteristics, about facial expressions, gestures, location and identity of the gamer and even physiological processes that can be used to adapt or control the game [2]. The next step in game development is input obtained from the measurement of brain activity [3,4]. 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. Relaxation games have been designed and also games that adapt to the affective state of the user. For the design of game and training environments we need the integration of theoretical research on multimodal interaction, intention detection, affective state and visual attention monitoring, and on-line motion control. It also requires the design of several prototypes of games. Some of these games will be elaborated into events for the general audience (as dissemination projects). Next to games for amusement we will explore (serious) games for educational, training and simulation purposes. Selection and design of BCI methods feasible for commercial computer games is still difficult. Here price, ease of fitting, required data rate, etc. put strict constraints on the technology. However, the computer game industry is ready to embrace these applications and can even drive some of the developments.

It should be mentioned that the development of (serious) brain games fits in many initiatives in the Netherlands to develop company-based game technology, such as the Benelux Game Initiative (BGIn) in which Dutch game development companies are the founding fathers and the GATE research project (started in 2006) in which many Dutch game development companies are involved. The entertainment games market in the Netherlands was estimated (AGS) 200MEuro in 2005 and is growing, with impact on education, care, sports and digital lifestyle. For serious gaming the market was estimated to be over 350MEuro, with areas of interest that include care, safety and defense. Initiatives to stimulate economic activity in these areas are taken by governmental organizations (Ministry of Economic Affairs, and others).

3 BCI FOR GAMES

3.1 BCI for Games: Commercial Explorations

Presently, the majority of BCI users are patients that do not have control, or full control, of their muscles and that have to learn to control a prosthetic device, a communication device, or a mobility device (e.g., a wheelchair) by thought. Nevertheless, there are various reasons to look at the use of BCI technology in the context of exertion interfaces [5] for healthy users. Exertion interfaces are interfaces that deliberately require physical effort. These interfaces can play a role in sports, health (fitness), and entertainment. Often they are accompanied with a large screen where opponents are displayed and where computer vision and other sensors are used to capture the bodily activity of players. There are good reasons to investigate the role of BCI for such interfaces. BCI allows:

- Finding out about the user's mental state and trying to adapt the interface and the interaction modalities to this mental state. Obviously, there are other modalities that can be considered too, for example, physiological information or information obtained from nonverbal cues (pose, facial expression, prosody). In exertion interfaces monitoring this information can help to adapt the required or desired exertion efforts to the user's physical and mental state [2]. Existing exertion interfaces only have limited knowledge about the user. For example, in a mediated football game [5] the interface knows about who kicked the ball that hits a wall, where the wall is hit, and how hard the wall is hit. More direct information about the player is, however, not available. Adding knowledge about brain activity to knowledge obtained from other measured input modalities helps to adapt the interface to the user.

- Making exertion interfaces more interesting and engaging by adding a new modality to the already available and more 'traditional' input modalities for exertion interfaces. Again, existing exertion interfaces have not only poor knowledge about their users; they also make poor use of modalities that are available for the user to control the exertion interface. Obviously, it should be mentioned, that depending on the interaction that is required, there is not always a need to take into account all possible input modalities for an exertion interface. Nevertheless, BCI provides an extra input modality. That is, BCI allows the adding of an extra input modality to the ones that have already been made available for a long time. This input modality consists of voluntarily and consciously produced or externally evoked brain activity that can be recognized and translated into commands to the interface.

Measuring brain activity for gamers can be used so that the game environment (1) knows what a subject experiences and can adapt game and interface in order to keep the gamer 'in the flow' of the game, and (2) allows the gamer to add brain control commands to the already available control commands for the game. The general assumption is that the added value of BCI commands or the adaptation of the game to a mental state of a gamer that can be measured from brain activity, may lead to a commercial 'killer application'. For example, a game that can be played by enormous numbers of gamers, but a top level in the game can only be reached when the gamer is able to master a certain BCI command that adds to the already available multimodal commands of the game or that can be used to modify a more traditional game control command. The willingness of gamers to spend large amounts of time to games they are interested in makes it possible to integrate BCI learning requirements in a natural way in game situations. Another issue that need to be dealt with when we want to move forward in attracting the game audience to BCI is the hardware that has to be used, in particular the use of EEG caps. This 'hardware' is improving. Some game companies provide rather fancy caps (Figure 1) that rather than being considered obtrusive provide more status to the gamer. It is expected that wireless technology will allow a gamer to move around freely in an environment, rather than being connected through cables to a computer.

Figure 1. Left: A traditional EEG cap. Right: A helmet used in commercial applications.

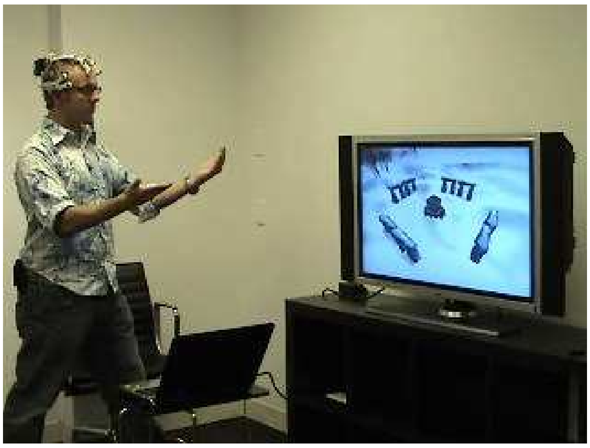

Figure 2. Lifting a heavy stone in a Stonehenge game designed by Emotive Systems.

3.2 BCI for Games: Motor Imagery Applications

As is well-known, an interesting class of brain activity for game playing is related to motor imagery. That is, the user imagines a certain movement. For example imagining a left foot movement can be distinguished from imaging a right foot movement. This kind of mental simulation of movement can be measured and distinguished. Not only for feet, but also for arms or hand, the tip of the tongue, et cetera. Intending to move, imagine a movement, planning a movement, they all activate similar cortical areas.

This explains the succes that BCI has for patients who are not able to use hands or feet, or patients who suffer the locked in syndrome (ALS) and are not able to move or to speak. In various applications it has been shown that they can learn to move a cursor on a screen, to navigate in a virtual world and to control a wheelchair. Much of the current BCI research concentrates on improving such medical applications and also at looking at other ways to improve the quality of life of those patients.

However, although not really of interest for ALS patients and other disabled patients, these imagined movements activate the brain areas that are also activated by the execution of the same movements. Hence, for healthy users it becomes possible to activate brain patterns by consciously produced movements and have these brain patterns measured and translated into commands for a computer, in order to navigate in a virtual world, to move or lift (heavy) virtual objects (Figure 2 [6]) or to control a robotic device. Moreover, it allows us to design games, game environments, and exertion interfaces that are also controlled by body movements but where the capturing of the body movement is not done by sensors or cameras, but by measuring associated brain activity.

3.3 BCI for Games: The Braingain Project

Investigating the possibilities of BCI for HCI and game applications, including exertion interfaces, is one of our tasks in the Dutch national BrainGain project. Apart from fundamental research on distinguishing various types of brain activity when the user (or gamer) is involved in various tasks, using different modalities to perform this task, we will also introduce BCI versions of games and exertion interfaces we have introduced previously [7]. One example is the 'Jump and Run' exertion interface where the gamer controls the movements of an avatar, who moves at high speed in a virtual world and has to avoid obstacles (Figure 3). A camera observes the movements of the human player and our aim is to play a similar game (similar, i.e., not necessarily requiring imagined movements resembling the physical movements in the original game) by measuring brain activity associated with imaginary and/or real movements in such a way that no cameras are needed anymore: "Look Ma, No Cameras!"

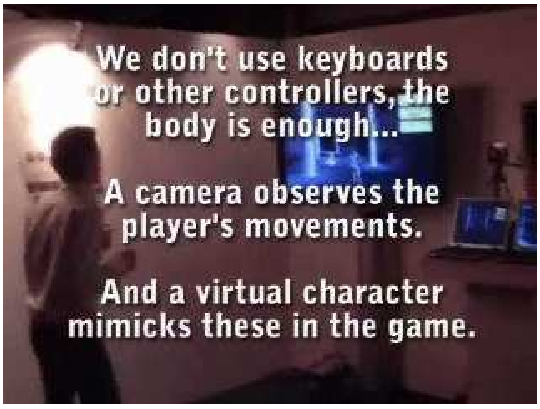

Figure 3. The 'Jump and Run' exertion interface

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