Gaze and BCIs as Gaming Inputs: Opportunities and Open Challenges

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Abstract
Despite the advances in technology, the way we interact with video games has remained essentially unchanged, relying mostly on keyboards, mice and gamepads. In the last few years, however, alternative user input modalities such as eye-gaze tracking (EGT) and brain-computer interfaces (BCIs) have attracted the attention of the gaming industry and developers because they can improve gamers' experience. As such, the aim of this paper is three-fold. First, we will explore the use of EGT and BCI as alternative gaming inputs, highlighting their advantages and disadvantages. Second, we will discuss the opportunities that arise from such a multimodal approach, with applications ranging from multi-genre gaming to serious games for education and health. Lastly, we will highlight the existing challenges with EGT and BCI and describe how they may affect the gaming industry.

Author Keywords
Eye-gaze; Eye-tracking; Brain-computer interface; Games; User Experience

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces – Input devices and strategies; K.8.0 [General]: Games.

Introduction

Video games have been part of our daily life for nearly 40 years with the apparition of the first arcade games and home consoles. While game mechanics and graphics have evolved dramatically (mainly due to advance in hardware capabilities), input devices remain fundamentally the same where user-game interaction is handled by joysticks and buttons (in different layouts and shapes). The gaming industry is always searching for new technologies to improve the gamer's interaction, engagement and experience. In the incorporation of new input interfaces, there are successful examples such as the use of accelerometers and gyroscopes in controllers (e.g. Wii Remote by Nintendo), as well as voice and gesture control (e.g. Kinect by Microsoft) [12].

With the objective of providing a user-customized and natural interface, physiological signals (such as galvanic skin response and heart rate) have been utilized as game inputs thanks to the biofeedback phenomenon. Biofeedback consists of a real-time feedback loop between the game and the user, where the user reacts to a certain action produced by the game, and the game can adjust that action based on the user reaction (and so forth); this approach has been used principally in relaxation games [4]. Noteworthy, physiological inputs based on biofeedback do not convey user voluntary commands i.e. the user reacts to a given game stimulus, (indirect-control inputs). In contrast, with a voluntary (or direct-controlled) input the user is able to send a command to the game at any moment [10].

Two important inputs which can be used as voluntary commands and with biofeedback are: eye-gaze tracking (EGT) and brain-computer interfacing (BCI), both described below, followed by their combination.

Eye-gaze tracking input

Eye-gaze tracking (EGT) devices estimate user's gaze direction and map it into coordinates on a screen or video. These devices have been used for research in different fields such as ophthalmology, neurology, psychology and marketing. EGT not only provides information about the user's focus of attention but also provides clues about the her cognitive state. Gaze has been studied as an input in human-computer interaction (HCI) since three decades ago [2], and more recently in gaming [6]. When used as direct control, ETG input provides an intuitive navigation/cursor tool; on the other hand, when used as indirect input, EGT analysis provides information about the user's cognitive state.

Brain-computer interface input

A brain-computer interface (BCI) is a system that allows conscious flow of information (commands) from brain to a computer without the intervention of any muscular activity, i.e., a BCI measures brain activity, processes it and produces an answer according to the user's intention. In its origins, BCIs were designed to serve as communication tools for people with a severe loss of motor function caused by disease or accident. Advances in signal processing methods and computational power together with the appearance of consumer-grade EEG headsets (such as MindSet[1], Epoch[2] and Muse[3]) have positively impacted the use of BCIs to other applications as HCI [11] and gaming [9]. While in its definition a BCI sends conscious commands (direct control), a variant type is the so called passive BCI, where the application adapts itself according with the user's cognitive state to enrich the HCI [13].

[1] http://neurosky.com
[2] http://www.emotiv.com/epoc.php
[3] http://www.choosemuse.com/

Multimodal approach

The integration of EGT and BCI inputs has as goal to overcome the disadvantages of each modality. An example of this combination is presented in [13], where the BCI input deals with the lack of selection method in a pure EGT interface whereas the EGT input provides a higher information transfer rate than the one obtained with a BCI system. As result, an improvement in the usability and reliability of a search-and-select task was obtained. The utilization of this multimodal approach in games has been seldom explored. Given that EGT and BCIs can serve as direct and indirect inputs, there are 4 configurations for the EGT-BCI integration that are described below together with its possible implementation in different game genres [1].

I. EGT direct and BCI direct

In this configuration, EGT input is used as cursor while the BCI input serves as voluntary selection method. Games that base its user interaction on point-and-click tasks exploit this configuration at its best, providing a touchless interface which is well suitable in healthy and disabled gamers [5]. A Puzzle game implementation is presented in [7].

II. EGT direct and BCI indirect

EGT provides direct control over a cursor or camera while the BCI input provides context (cognitive [3] and affective [8]) awareness to the game. Context information can be used in Action games to change graphics details (e.g limited or blurry vision in First Person Shooter games), or it can be used in Strategy and Puzzle games to modify its difficulty (e.g Chess and Tetris respectively). In this scenario an alternative input modality is needed for selection.

III. EGT indirect and BCI direct

Game adaptation is derived from the context information obtained from the natural-gaze analysis (e.g user's intention [2]), while BCI performs as direct-controlled input. This configuration can be applied to the existing BCI games ([9]) to incorporate context awareness.

IV. EGT indirect and BCI indirect

In this scenario, both inputs are dedicated to providing complementary context information to the game. This information can be used for biofeedback, but also can be provided to the adversary (human or machine) in Strategy games to foresight user's intentions and evade them. In Puzzle games, context can be utilized to give clues when the user is stuck. Lastly, in Action games, context can adapt the game to demand more attention from the user.

Serious games

Serious games are those which primary purpose is other than entertainment. Two fields where serious games with the utilization of EGT-BCI inputs will have huge importance are:

Education: With the EGT analysis it is possible to detect where the student is looking and identify distractors, while the BCI input assess the student state of mind during gaming (learning). Additionally, providing instructor's gaze data to the student can improve his attention and understanding on the material. This can be utilized not only for educational but also for military purposes.

Health: EGT-BCI context complementarity can lead to games that evaluate the cognitive processes during gaming and help identify clues of e.g. attention deficit hyperactivity disorder. Games which objective is to reinforce certain mind states or behaviours can be used in the treatment of disorders (e.g. autism, Alzheimer's disease and depression).

Open Challenges

The EGT-BCI multimodal input presents a way to augment game interaction and user experience, nevertheless in order to be adopted by the gaming industry five main issues need to be addressed. *(1) BCI accuracy:* which is related to the quality of the recorded neural signals and to the processing. *(2) Calibration:* none or fast calibration process (preferentially hidden in the game). *(3) Quick hardware setup:* improvement in dry-electrode and use of remote EGT. *(4) Remote EGT technology:* resistance to illumination changes and larger tracking area. *(5) Movement robustness (for EGT and BCI):* necessary for exercising games and sport training.

Lastly, the implementation of the combined EGT-BCI input goes farther than applying it to existing games; exploration in innovative game mechanics that fully exploit the data provided by the multimodal input is necessary in order to pave the way to natural and touchless user interfaces with the objective of increasing game enjoyment.

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