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EEG-triggered dynamic difficulty adjustment for multiplayer games

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ABSTRACT

In online games, gamers may become frustrated when playing against stronger players or get bored when playing against weaker players, thus losing interest in the game. Dynamic Difficulty Adjustment (DDA) has been suggested as an intelligent handicapping mechanism, by reducing the difficulty for the weaker player, or increasing the difficulty for the stronger player. A key question when using DDA, is when to activate the difficulty adjustment.

In this paper we suggest using the Emotiv EPOC EEG headset to monitor the personal excitement level of a player and use this information to trigger DDA when the player's excitement decreases in order to ensure that the player is engaged and enjoying the game. We experiment with an open-source third-person shooter game, in a multiplayer adversarial setting. We conduct experiments, showing that the detected excitement patterns correlate to game events. Experiments designed to evaluate the DDA triggering mechanism confirm that DDA triggered based on EEG increases the players excitement and improves the gaming experience compared to the heuristic triggered DDA and the experience of playing a game without DDA.

1. Introduction

Video games are a popular activity for children and adolescents in the western world today, with almost 97% of the younger US population playing video games for at least one hour per day [20].

While the goal of a gamer in a video game may be to kill enemies, or collect prizes, game creators typically aim to keep players entertained and engaged over a long period of time [42]. It was often observed that playing against the game artificial intelligence (AI) is not as challenging as playing against other players [28,43]. When playing against other humans, however, it is important to play against players of similar levels of expertise, because when a weaker player plays against a much stronger one, often both players feel dissatisfied — the stronger player is bored, while the weaker player is frustrated. When a gamer wishes to play against one of their friends, matching suitable opponents may become even harder.

Dynamic difficulty adjustment (DDA), in which the players' abilities to influence the environment are dynamically modified throughout the game, provides a possible solution to this problem [46,47,55,32,39]. When a weaker player faces a stronger one, the level of difficulty for the weaker player can be reduced, as well as the level of difficulty for the stronger player can be increased. For example, in a first-person shooter game, where the goal of a player is to kill the avatar of his/her opponent, the bullet damage of the weaker player can be increased, and the bullet damage of the stronger player can be decreased. In addition, it may be possible to identify and implement a variety of game-specific adjustments in many games, with the aim of improving the user experience by ensuring that the games difficulty level is optimal for the players. However, one of the most challenging issues associated with DDA is knowing when to trigger such game modes.

Presumably, game modifications should be triggered only when needed, in order to avoid erratic game behavior. In the past, researchers have mainly suggested heuristics based on the game state [3,27,53]. For example, in a game that keeps an ongoing score, a decision can be made to apply DDA when the difference in the players' scores exceeds a certain predefined threshold. This heuristic addresses the situation when one player becomes too strong compared to the other player, based on the assumption that in this situation the stronger player may feel bored, while the weaker player may feel frustrated. The scoring mechanism hence contains clues to the players' state of mind.

In this paper we suggest a different approach — measuring the players excitement and activating the game modes when the excitement level drops below a predefined threshold. This approach attempts to directly address the core problem of degraded game experience, rather than relying on a scoring mechanism or similar heuristics to determine when the players are no longer excited by the game. We implement a passive feedback/affective state regulation method by using the Emotiv EPOC headset to read electroencephalography (EEG) signals and the

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Emotiv Affective Suite[1] to translate the signal into an affective state.[2] Then, based on the affective state, the game mechanism triggers DDA.

We conduct two user studies. The first user study assesses the correlation of the EEG signals to game events, and the results of this study show a good correlation between the Emotiv value for "short term excitement" (STE) and game events. Although, both positive and negative emotions can be utilized to improve gameplay [5], in this paper we attempt to improve the players' experience by maximizing STE. The second study compares our EEG-triggered DDA to a standard heuristic approach based on elapsed time and game status, as well as to a control game in which DDA is not implemented. The primary hypothesis tested here is that EEG-triggered DDA increases the players' excitement and improves the gaming experience compared to the heuristic triggered DDA and the experience of playing a game without DDA.

The contributions of the paper are twofold. First, we present a case study for the design of EEG-triggered DDA technique in a modified version of the open-source third-person shooter game, "Boot Camp".[3] Second, we study the user experience, comparing EEG-triggered DDA to standard heuristics triggering, as well as a game without DDA. Our study confirms that gamers enjoyed the EEG-triggered DDA better than the other two options and that this technique significantly increases the player's level of excitement. Our study further shows that the choice of the triggering strategy is important and significantly impacts the way players experience the game.

The rest of the paper is structured as follows: We begin by providing some background on brain-computer interfaces, EEG, and DDA in Section 2. We review the Boot Camp game that we use in our experiments and discuss additional related work. Then in Section 3 we discuss our EEG-triggered DDA triggering technique, and the modifications that we added to Boot Camp in order to allow DDA. We also explain the heuristic method of triggering DDA which is also evaluated in our experiments. In Section 4 we move to the user study that we conducted, first showing that EEG measurements in this setting correlate well with game events, and then comparing EEG to heuristic triggering of DDA. We discuss the main results of this study in Section 5 and conclude in Section 6 with a summary of this research and an indication of future research directions.

2. Background

In this section we briefly review the rapidly growing field of brain-computer interfaces and assessment of the affective state. We discuss BCI application to games, dynamic difficulty adjustment (DDA) in games, and the "Boot Camp" third-person shooter game.

2.1. Brain-computer interface

A brain-computer interface (BCI), also known as a mind-machine interface (MMI) or a brain-machine interface (BMI), is a direct communication pathway between the brain and a computer. In a BCI, signals from the brain are analyzed to determine the user's state of mind or intentions. By detecting features of the brain activity and creating a feedback loop, users can communicate to a computer without other types of input devices [36].

The applications of BCI are heterogeneous. Initially, BCI research was mainly aimed at medical applications [37], such as helping disabled people to recover a means of interaction with their environment and surroundings [33]. Recently there has been increased interest in the study and development of BCI for multimedia applications such as video games [7,17]. BCI can also provide subjective, time-aligned information such as the user's affective state [26], allowing for game adaptations that enhance the gaming experience [38]. In this paper we focus on the latter type of application of BCI.

Brain signals can be acquired using various non-invasive measurement methods such as electroencephalography (EEG), magnetoencephalography (MEG), near-infrared spectroscopy (NIRS), or functional magnetic resonance imaging (fMRI) [9]. In the area of healthy user BCI research, EEG has become an especially popular method, due to its relatively low cost and its high temporal resolution [52,54].

A variety of inexpensive devices have recently become available to the gaming market, mainly aimed at collecting peripheral input for analyzing a person state of mind, including the Emotiv EPOC headset which has 14 sensors. The Emotiv headset was shown to provide readings less accurate than a medical EEG system [48] but adequate accuracy for gaming applications [2,14]. The Emotiv Affective suite has been used in a number of research applications [26]. For example, in intelligent tutoring systems where the excitement and frustration recorded from the headset has been shown to reflect users' explicit feedback [29]. The Emotiv Affective suite was also used to identify users' affective states (e.g., excitement or meditation) and facial expressions, and to control an avatar in the well-known online game, World of Warcraft (WoW) [45]. Harris et al. [23] presented a tool to detect frustration during gameplay, that was also utilized in several additional studies [18,4,19]. Nacke [34] introduced physiological measures and techniques for game evaluation in the context of games user research (GUR). GUR comprises a collection of methods that allow game designers to bring their creations closer to the initial vision of the player experience.

2.2. Computing affective state from brain waves

Affective state is often discussed in the literature with respect to two main dimensions: the unpleasant-pleasant (also called *valence*) and activation-deactivation (also called *arousal*) [44]. A variety of intermediate affective states can be located along these two dimensions as presented in Fig. 1. When investigating highly emotional content, one may take into consideration both arousal and valence [30].

2.3. Dynamic difficulty adjustment

It is widely agreed that games should strive to keep players on the golden path between boredom, where the game is too easy, and anxiety, where the game is too difficult (Fig. 2). This is often called the Csikszentmihalyi flow [10]. Achieving the optimal flow can be done by adjusting the difficulty level of the game.

Many games offer various difficulty levels. For example, a player can choose a stronger or a weaker artificial intelligence (AI) algorithm for the non-player opponents. Choosing the optimal difficulty level, however, might not be trivial, requiring multiple trial and error games. Furthermore, as the player learns to play the game and becomes more experienced, he/she will likely need to increase the difficulty level constantly so as to continue to be challenged by the game. On the other hand, when the game presents novel challenges to the player, some players may want to lower the difficulty level [46,47,28].

The difficulty level can be modified in various ways. When playing against AI, the difficulty level can be increased by using more sophisticated AI algorithms that make better choices. This is a popular approach in board games such as chess or backgammon. An easier method commonly used by game developers is to modify the player attributes. For example, in real time strategy (RTS) games the resources required for constructing buildings or training soldiers can be reduced, thus reducing the difficulty level. In first- or third-person combat games the amount of damage players affect upon each other can be modified.

In contrast to static difficulty adjustment set by the player, DDA allows the game mechanism to automatically modify the difficulty level

[1] https://www.emotiv.com/.

[2] In this paper we use the term "affective state" rather loosely to refer to the output of the Emotiv EPOC headset.

[3] Boot Camp is a Unity open source demo. The game is an example of a 3rd person shooter set in a modern day scenario. http://u3d.as/content/unity-technologies/BootCamp/28W.