

Controlling Player Avatars in Game Worlds using Multi-Modal Input Systems

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1 Acknowledgements

This is my acknowledgements.

2 Abstract

My project is about....

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3 Introduction

3.1 Context

Throughout the history of the games industry, game makers have been exploring new ways to deliver their players unique experiences. This has come in the forms of the narrative decisions within a game’s story, stylistic decisions through the game’s art and, as a focus for this paper, the interaction systems designed around the player’s influence within a game’s world.

On account of the digital nature of video games, as technology has evolved over the years, so too has the hardware and methods of interaction used within gaming consoles. Beginning in 1972 with the creation of the first home console, the Magnavox Odyssey, over the following years, video game console manufactures have continued to push the perceived boundaries of interactive entertainment. In 2006, Nintendo demonstrated the potential of a motion controlled input system with the Wii. Following this, other manufactures also began to expand into the technology, with Microsoft developing the Xbox Kinect and Sony the PlayStation Move. Nowadays, companies like Oculus and the HTC corporation are exploring the market of consumer virtual reality headsets with the Quest and Vive, while Nintendo is showing off new ways of using old technology with their Labo Toycon games. All of this has demonstrated that with the market’s continued interest in new experiences, console manufactures and game developers will continue innovating new methods of interaction for their players.

3.2 Research Problem

There has also been a growing interest in the usage of electroencephalographic (EEG) and electromyographic (EMG) techniques being coupled with game engines for the purpose of research. The use of games in research has been invaluable for decades, due to the control gained over how a subject is stimulated throughout an experiment’s lifetime. The act of reversing this dynamic and using these systems for the purpose of entertainment has also been explored (Marshall et al., 2013), however there is yet be any product viable for consumers to play.

3.3 Project Aims

It is with this in mind, that this paper proposes to continue with the investigation into the viability of EEG, EMG, and other additional input modalities within video games. By acquiring data from all devices and combining them, the aim is for the creation of a single system capable of attaining and extracting meaningful interactions from it’s users for control over aspects of game world. Along side this, two example games will also be constructed, these will be used to verify if the system is capable of performing it’s tasks correctly and potentially demonstrate a working example from within a use-case environment.

3.4 Project Objectives

To get this system working, data from each device will need to be accessed live and streamed into the Unity game engine where a pre-trained artificial neural network (ANN) will be used to decipher a meaning suitable for the given game. From this the two games will be developed: the first will have the player use motor imagery to control the limbs of a virtual avatar; the second game will use the system measure the users state of mind, allowing for adaptive difficulty depending on the focus of the player.

4 Research

4.1 Literature Review

The usage of multi-modal input systems is not unheard of, almost all modern first person console shooters use the input controller’s built in gyroscope, in addition to the right joystick to control the direction of the players camera. This multi-input system allows much more finesse when aiming, resulting in the players having a more enjoyable experience (Toktaş and Serif, 2019). In the work put forward by Silva and Amaral (2014), they demonstrate that the inclusion of a multi-modal input system compared to a uni-modal input system can make video games perceivably more enjoyable, “it can be used to increase the feeling of empowerment on the player when using certain abilities, or to intentionally make in-game actions more difficult by demanding more physical effort from the player”. Though gyroscopic-assisted aiming is a more recent phenomenon, the concept of incorporating multiple input systems for singular interactions within gaming has been around for a while. Even back in 2009 with the release of ‘The Legend of Zelda: Spirit Tracks’ (Nintendo, 2009), when using the flute, players would be required to both blow into the DS microphone and use the touch screen to play specific tones. This interaction could have very easily be performed by mapping tones to regions on the touch screen, or pairing each tone to a button on the Nintendo DS, much like how previous instruments in the franchise have been implemented, E.g. ‘The Legend of Zelda: Majoras Mask’ (Nintendo, 2000). However, as stated by Silva, players could have a “feeling of empowerment” overcoming the set-pieces Nintendo designed, through this added multi-modal challenge.

Before looking into EEG as a part of a larger multi-modal input system, a focus on how it has been used on its own within video gaming will be explored. Games using EEG most commonly occur in the form of serious games, defined by Alvarez and colleagues (2011) as a video game that is “intended to depart from the simple entertainment”. This refers to games built for research, education and rehabilitation. Whether this is just for providing an environment for the comparison between different electroencephalographs (Liarokapis, Debattista, et al., 2014), evaluating a participant’s emotions and satisfaction (Vourvopoulos, 2013), screening for early signs of mental illness (Tarnanas et al., 2015), or cognitive rehabilitation (Alchalcabi et al., 2017).

The data captured from EEG can be used in a multitude of ways, depending on what is considered important for a given experiment. By using games it is then possible to focus on these targeted aspects of EEG: allowing for the invocation of responses necessary for measuring event related potentials (Ahn and Lee, 2011), or to provide a real-time environment capable of demonstrating the changes in mental states (Liarokapis, Vourvopoulos, et al., 2015) and motor-imagery (Ndulue and Orji, 2019).

However, it is debated whether EEG technology is still in it’s infancy. When investigating the current state of brain computer interfaces (BCIs) usability in the context of information transfer rates (ITR), Rashid and colleagues (2020) write “In spite of the many outstanding breakthroughs that have been achieved in BCI research, some issues still need to be resolved... the existing BCIs offer somewhat poor ITR for any type of effectual BCI application”, while in Cattani’s (2021) comparison, they state “In practice, this means that BCIs are unusable in traditional inputs, such as in keyboards or mice”. To the contrary, EEG technology has already been used within for video games as an interactive medium: from modifying a game’s difficulty based on the focus of the player with Tetris (Liarokapis, Vourvopoulos, et al., 2015); walking around the streets of Ancient Rome using motor-imagery in Rome Reborn (Ndulue and Orji, 2019); to piloting a space ship in Rock Evaders (Ndulue and Orji, 2019). EEG has shown its potential as a possible use for video game control.

The usage of EMG within video games has also been quite extensive. EMG based serious games have permitted the research of various topics, from measuring arousal to stimuli using the muscles in the face (Schuurink et al., 2008), to the effectiveness of myoelectric prosthesis training (Bessa et al., 2020). While their use outside of research has aided in the rehabilitation of patients, suffering: post injury (Gutierrez et al., 2020) (Schönauer et al., 2011); strokes (Ghassemi et al., 2019) and other medical disorders (Labruyère et al., 2013). Though much more infrequent, entertainment focused EMG games do exist. In large part with they goal for allowing people with motor impairments to have the opportunities to play games, Kamau-Mugro (2020) states “focusing on neck EMG, would give more control to individuals with hand disabilities or SCI [Spinal Cord Injury] patient as a control scheme or an entertainment interface”.

Having investigated the viability of EEG and EMG as uni-modal input systems, an exploration into their combined usage alongside other additional input modalities can be performed. Though the appearance of entertainment based multi-modal EEG and EMG systems are infrequent, multi-modal serious games using EEG and EMG are a lot more common. An example of which is Sivanathans (2014) work on multi-modal EEG analysis, in which data from in-game events was coupled with the EEG input streams to allow for a greater understanding of the results. Though there isn’t many instances of multi-modal EEG and EMG based video game systems, that isn’t to say inspiration for these systems cannot come from elsewhere, the majority of research in which multi-modal EEG and EMG systems have been built for is in the development of consumer prosthetics (Shi et al., 2019) and wheelchair controllers (Carlson and Millan, 2013). These systems pull from the data streams of EEG and EMG and by using eye-tracking, computer vision and inverse kinematics (McMullen et al., 2013) are able to allow for finer control over hardware systems that on their own EEG and EMG wouldn’t be able. By adopting a similar approach, these real world solutions can be used with virtual controllers instead.

5 Methodology and Process

5.1 Introduction to the project

The project was created in the Unity game engine, the two mini-games chosen were a simple repeating sequence game and a implementation of the game Breakout [Citation Need]. The sequence game was chosen due to it not requiring accurate or high response inputs, this allowed it to be perfect for the possibly inaccurate readings of motor imagery. While breakout was chosen due to it's simplicity and ease for increasing game difficulty through the changing of ball speed.

5.1.1 Mini-game: Sequence

In the repeating sequence game, players would be required to repeat back a sequence of colours shown to them by 'activating' similarly coloured crystals. This was done using a combination of 'Motor Imagery EEG' and EMG, where the player would be given control over an avatars arms by looking in a direction and thinking about moving one half of there body. This would trigger a response from the game, having there avatar reach forward and touch a crystal.

[Add Figure]

5.1.2 Mini-game: Breakout

In Breakout, the player is given direct control of the paddle using the 'A' and 'D' on the keyboard. When the player is giving a lower level of focus the ball will increase its velocity, while the opposite is true when the player begins to focus more. Much like the original, the aim of the game is to destroy all the blocks.

[Add Figure]

5.2 EEG and EMG

5.2.1 Keras and Keras Tuner

To decipher the meaning given from the EEG and EMG data, the solution of a Neural Network was required. This was accomplished using a Python library called Keras, an interface library for Google's TensorFlow library. Motor Imagery data from [Citation Need], was then downloaded, this data was originally in .edf format and was first converted to the .csv format for easier human readability, after which was then supplied to the networks for training.

This however gave some what lacklustre accuracy when used, so in addition the use of hyper-parameter optimisation was used. The library used in this project to do this was KerasTuner, the purpose of which was to search for the optimal design of a network: changing the types of activation functions, number of layers and size of these layers; to allow for a much more accurate model.

[Add Figure]

5.2.2 Barracuda

After creating several reasonably accurate models using [Citation Need] and [Citation Need] data. The next step was to import these models into Unity. Unity has its own built in packages for Neural Networks, these being Unity Machine Learning Agents and Barracuda. The former focuses mainly on NPC AI, while the later can be used for almost any type of network, however required said network be in the .ONNX format. Due to the usage of this projects ANN's being classification based, Barracuda was the obvious choice, however the Keras produces networks of the .h5 format, as such a conversion was required. To do this, another python program was written to convert between .h5 and .ONNX models using the Keras2Onnx library. With this a script could finally be written within Unity to allow for the in-game real-time usage of these models.

5.3 LSL

5.3.1 Integration

To receive the data from the input devices, the use of the LSL protocol was required. Specifically for this project the 'liblsl-Csharp' package [Citation Need] was used. This was imported into Unity and several scripts were then written to allow for the listening and broadcasting of different data types. To test whether this was working different devices on the network were then used to display the data using the 'Brain Vision LSL Viewer' application.

[Add Figure]

5.3.2 Online Data Spoofing

With the cross-device communication working, the next stage was to create a script for spoofing potential online data. This would be used to see if the neural networks generated by Keras Tuner were working in the engine correctly. Offline data supplied by the dataset used previously from the network's training, though not used directly in it, was then attached to Unity through a script, in the format of .csv's. Each frame, this script would publish the next lines content over the network, allowing for faked online EEG and EMG data.

5.3.3 Testing the models

[Add Figure]

- 1) Setup of Unity enviroment for VR (Describe the game).
- 1.5) Show figure of game, and input devices
- 2) Two Mini Games (Sequence) - Introduction
- 2.5) Show figure of devices,
- 3) Two Mini Games (Breakout) - Introduction
- 2.5) Show figure of device and how they connect and are used,
- 4) I began by using python - (tensor flow, keras) - to classify EEG data using motor imagery to decide between a left and right motion.
- 5) To get a more accurate network I looked into KerasTuner, a hyper peramiter optimisation library for Keras.
- 6) LSL streams used for aquiring and writing data.
- 7) Offline processing and spoofing "online data" (reading CSV files) and writing the data over the LSL network.
- 8) Combining Barracuda with LSL.
- 9) Sequence games implementation.
- 10) Breakouts implementation.

6 Conclusion and Future Work

6.1 Conclusion

6.2 Future Work

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