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

Charlie Lloyd-Buckingham

April 11, 2022

# 1 Acknowledgements

This is my acknowledgements.

# 2 Abstract

My project is about....

# Contents

# 3 Introduction

## 3.1 Context

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

On account of the digital nature of video games, as technology has evolved over the years so too has the hardware and methodologies for interaction used by gaming systems. Beginning in 1972 with the creation of the first home console, the Magnavox Odyssey, over the following years, gaming system manufactures have continued to push the perceived boundaries of interactive entertainment. In 2006, the Nintendo demonstrated to the world the potential of a motion controlled system the Wii. Following this, other console 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 impact of consumer virtual reality consoles with the Quest and Vive, while Nintendo is exploring new ways of using old technology with their Labo Toycon games. All of this has demonstrated that with the markets continued interest in new experiences, console manufactures and game developers will continue innovating new methods of interaction to for their players.

## 3.2 Research Problem

Specifically of note, there has also been a growing interest in the usage of electroencephalographic (EEG) and electromyographic (EMG) techniques being coupled with game engines for purposes of research. The use of games in biological and psychological research has been present for many years, due to the benefits gained from controlling how a subject interacts and is stimulated throughout a experiments lifetime. The act of reversing this dynamic and using these systems for the purposes of interacting with video games with the lens of entertainment has also been explored (Marshall et al. 2013), however we are still yet to see anything come out of this for the general consumer population.

## 3.3 Project Aims

It is with this in mind, that this paper proposes to continue with this exploration into the usage of EEG, EMG, and other additional input modalities for video games. By acquiring data from all devices and combining them, the hope is that with the right method for analysis, a single system will be able to attain and extract meaningful interactions from its users to be used with a game world. The creation of such a system will be the aim of the paper, along side this, two games will also be constructed, these will be used to demonstrate and verify that the system is capable of performing its tasks correctly from within a potential 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, a simple avatar controller, where the player will use motor imagery to control the limbs of a virtual avatar; the second game will use the system

to allow for adaptive difficulty based on the users state of mind, making tasks harder to perform based on how unfocused the system interprets the user to be.

# 4 Research

## 4.1 Literature Review

The existence of multi-modal input system is not unheard of, almost all modern first person console shooters use the input controllers 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 Gon (Silva 2014), he demonstrates that the inclusion of a multi-modal input system when 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 solution of combining multiple inputs for a singular interaction within a game has been around for a while. Even back in 2009 with the release of 'The Legend of Zelda: Spirit Tracks' (Nintendo 2009), multi-input controls where used. In which, to play specific tones on the games flute item, the player would be required to blow into the microphone and using the touch screen to move the flutes pipes into the center of the screen to select the tone. This interaction could very easily be performed using just the touch screen or even the Nintendo DS's buttons, much like how previous musical instruments in the franchise where implemented - Majoras Mask (Nintendo 2000). However, as stated by Gon, players will have felt a "feeling of empowerment" overcoming the set-pieces Nintendo designed, rather then just going through the motions of pressing the right buttons.

Before looking into EEG as a single piece of a larger multi-modal input system, we can look into how it can be used on its own with video games. The main usage of EEG based gaming is serous games, defined by Alvarez as a video game that is "intended to depart from the simple entertainment" (Alvarez, Djaouti, et al. 2011). This refers to the games built 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 participants emotions and satisfaction (Vourvopoulos 2013), screening for early signs of mental illness (Tarnanas et al. 2015), or cognitive rehabilitation (Alchalcabi, Eddin, and Shirmohammadi 2017). When using EEG, the data captured from the device can be interpreted in a multitude of different ways, depending on what is required. Games can be used to invoke the necessary mental state needed for event related potentials (Ahn and Lee 2011), or to provide real-time feed back when measuring changes in mental states (Liarokapis, Vourvopoulos, and Ene 2015) and motor-imagery (Ndulue and Orji 2019). It is however debated whether EEG technology is still in its infancy. When analysing the current state of BCI usability Rashid (Rashid et al. 2020) writes "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 Cattan when comparing information transfer speed writes ".In practice, this means that BCIs are unusable in traditional inputs, such as in keyboards or mice". On the over hand however, the lengths at which EEG has been able to allow for in game interactions have been reasonably impressive: from modifying the games difficulty through the users measured focus in Tetris (Liarokapis, Vourvopoulos, and Ene 2015); to using motor-imagery for walking around the streets of Ancient Rome in Rome Reborn, (Ndulue and Orji 2019) and piloting a space ship in Rock Evaders (Ndulue and Orji 2019).

The usage of EMG with video games has also been quite extensive. Serous gaming

within EMG has allowed for the research various topics, measuring arousal to stimuli using facial muscles (Schuurink, Houtkamp, and Toet 2008), to the effectiveness of myoelectric prosthesis training (Bessa et al. 2020); while there use outside of research has helped in patient rehabilitation, post injury (Gutierrez et al. 2020) (Schönauer, Pintaric, and Kaufmann 2011), strokes (Ghassemi et al. 2019) and other medical disorders (Labruyère et al. 2013). Though with a much smaller scope, entertainment focused EMG video games do exist. In large part to allow for motor impaired people to be given the option to play games, Kamau-Mugro states "focusing on neck EMG, would give more control to individuals with hand disabilities or SCI patient as a control scheme or an entertainment interface" (Muguro et al. 2020).

Having demonstrated that EEG and EMG can be used as uni-modal input systems, we can now explore their usage when combined with additional input modalities. Though the usage as a direct input for entertainment based gaming is lacklustre, serous games and EEG have been used for multi-modal analysis, using data from in-game events coupled with the EEG input streams (Sivanathan et al. 2014). This isn't to say however that inspiration for video game input system can't come from something else, there is a large portion of research in which multi-modal EEG and EMG systems have been used in the development for consumer prosthetics (Shi et al. 2019) and wheelchair controllers (Carlson and Millan 2013). These systems build upon the context for the data EEG and EMG provide, through the use of eye-tracking, computer vision and inverse kinematics (McMullen et al. 2013). With which expanding these systems from would otherwise be a somewhat inaccurate, cumbersome and slow, to real time viable real world solutions.

# 5 Methodology and Process

# 6 Conclusion and Future Work

## 6.1 Conclusion

## 6.2 Future Work

## References


[1] Jae-Sung Ahn and Won-Hyung Lee. "Using EEG pattern analysis for implementation of game interface". In: *2011 IEEE 15th international symposium on consumer electronics (ISCE)*. IEEE. 2011, pp. 348–351.

[2] Alaa Eddin Alchalcabi, Amer Nour Eddin, and Shervin Shirmohammadi. "More attention, less deficit: Wearable EEG-based serious game for focus improvement". In: *2017 IEEE 5th international conference on serious games and applications for health (SeGAH)*. IEEE. 2017, pp. 1–8.

[3] Julian Alvarez, Damien Djaouti, et al. "An introduction to Serious game Definitions and concepts". In: *Serious Games & Simulation for Risks Management* 11.1 (2011), pp. 11–15.

[4] Diogo Bessa et al. "Designing a serious game for myoelectric prosthesis control". In: *2020 IEEE 8th International Conference on Serious Games and Applications for Health (SeGAH)*. IEEE. 2020, pp. 1–5.

[5] Tom Carlson and Jose del R Millan. "Brain-controlled wheelchairs: a robotic architecture". In: *IEEE Robotics & Automation Magazine* 20.1 (2013), pp. 65–73.

[6] Mohammad Ghassemi et al. "Development of an EMG-controlled serious game for rehabilitation". In: *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 27.2 (2019), pp. 283–292.

[7] Alvaro Gutierrez et al. "Serious game platform with haptic feedback and EMG monitoring for upper limb rehabilitation and smoothness quantification on spinal cord injury patients". In: *Applied Sciences* 10.3 (2020), p. 963.

[8] Rob Labruyère et al. "Requirements for and impact of a serious game for neuropediatric robot-assisted gait training". In: *Research in developmental disabilities* 34.11 (2013), pp. 3906–3915.

[9] Fotis Liarokapis, Kurt Debattista, et al. "Comparing interaction techniques for serious games through brain–computer interfaces: A user perception evaluation study". In: *Entertainment Computing* 5.4 (2014), pp. 391–399.

[10] Fotis Liarokapis, Athanasios Vourvopoulos, and Alina Ene. "Examining user experiences through a multimodal BCI puzzle game". In: *2015 19th International Conference on Information Visualisation*. IEEE. 2015, pp. 488–493.

[11] David Marshall et al. "Games, Gameplay, and BCI: The State of the Art". In: *IEEE Transactions on Computational Intelligence and AI in Games* 5.2 (2013), pp. 82–99. DOI: 10.1109/TCIAIG.2013.2263555.

[12] David P McMullen et al. "Demonstration of a semi-autonomous hybrid brain–machine interface using human intracranial EEG, eye tracking, and computer vision to control a robotic upper limb prosthetic". In: *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 22.4 (2013), pp. 784–796.

[13] Joseph Kamau Muguro et al. "Development of neck surface electromyography gaming control interface for application in tetraplegic patients' entertainment". In: *AIP Conference Proceedings*. Vol. 2217. AIP Publishing LLC. 2020, p. 030039.

[14] Chinenye Ndulue and Rita Orji. "Driving Persuasive Games with Personal EEG Devices: Strengths and Weaknesses". In: *Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization*. 2019, pp. 173–177.

[15] Nintendo. *The Legend of Zelda: Majora's Mask*. [Nintendo 64]. 2000.

[16] Nintendo. *The Legend of Zelda: Spirit Tracks*. [Nintedo DS]. 2009.

[17] Mamunur Rashid et al. “Current status, challenges, and possible solutions of EEG-based brain-computer interface: a comprehensive review”. In: *Frontiers in neurorobotics* (2020), p. 25.

[18] Christian Schönauer, Thomas Pintaric, and Hannes Kaufmann. “Full body interaction for serious games in motor rehabilitation”. In: *Proceedings of the 2nd Augmented Human International Conference*. 2011, pp. 1–8.

[19] Ellen Lisette Schuurink, Joske Houtkamp, and Alexander Toet. “Engagement and EMG in serious gaming: Experimenting with sound and dynamics in the Levee Patroller training game”. In: *International Conference on Fun and Games*. Springer. 2008, pp. 139–149.

[20] Chunyuan Shi et al. “A Novel Method of Combining Computer Vision, Eye-Tracking, EMG, and IMU to Control Dexterous Prosthetic Hand”. In: *2019 IEEE International Conference on Robotics and Biomimetics (ROBIO)*. IEEE. 2019, pp. 2614–2618.

[21] Gonçalo Amaral da Silva. “Multimodal vs. unimodal physiological control in videogames for enhanced realism and depth”. In: *arXiv preprint arXiv:1406.0532* (2014).

[22] *Temporal multimodal data synchronisation for the analysis of a game driving task using EEG*. Vol. 5. Elsevier, 2014, pp. 323–334.

[23] Ioannis Tarnanas et al. “On the comparison of a novel serious game and electroencephalography biomarkers for early dementia screening”. In: *GeNeDis 2014*. Springer, 2015, pp. 63–77.

[24] Ali Osman Toktaş and Tacha Serif. “Evaluation of crosshair-aided gyroscope gamepad controller”. In: *International Conference on Mobile Web and Intelligent Information Systems*. 2019, pp. 294–307.

[25] Athanasios Vourvopoulos. “Brain-Controlled Virtual Environments-An evaluation study of Brain-Computer Interfaces for Serious Game Interaction”. 2013.