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ON

INTELLIGENT GAMES AND SIMULATION

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EDITED BY

Joseph Kehoe

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on

Intelligent Games and Simulation

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GAME ON_® 2017

Preface

Dear Participants,

We would like to extend the traditional Irish welcome of "Céad Míle Fáilte", or one hundred thousand welcomes, to everyone attending the 18th GAME-ON conference. This year's event is being hosted by the Department of Computing in the Institute of Technology Carlow, Ireland from the 6th of September until the 8th of September 2017.

We are delighted to be chosen to host this year's event and look forward to hearing about the latest approaches to all things related to simulation and AI in Computer Games.

We are particularly pleased with the keynote speakers who have agreed to talk at this conference. Brenda Romero is an internationally acclaimed game designer who straddles both academia and industry. As well as designing many seminal games she has also helped set up and run one of the most highly rated games design degrees in the world. This gives her a unique insight into both academia and industry. John Romero pioneered the first person shooter genre in computer games, has won over 100 awards worldwide for his games and is considered one of the best game designers in the world. Demid Tishin is also working on the leading edge of game design. He is CEO of "Fun Bakers", a game company pioneering a new genre of game simulation - Augmented Reality based games. All three speakers bring fresh perspectives alongside a wealth of experience and their talks will give attendees new insights into the future of Gaming.

This conference would not be possible without the input and effort of many people. This includes the participants who have submitted and will present papers over the course of the conference, the programme committee who have reviewed papers and helped organize the event and most of all Philippe Geril the behind the scenes driving force without whom this conference would not be possible.

I hope that you enjoy your stay in Ireland and find the conference interesting and inspiring.

Carlow, September 2017

Joseph Kehoe Institute of Technology Carlow, Ireland GAME-ON'2017 General Conference Chair

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SCIENTIFIC PROGRAMME

GAME DESIGN METHODOLOGY

BUILDING SUCCESSFUL GAMES: A COMPLETE ANALYSIS OF THE KEY FEATURES OF LEAGUE OF LEGENDS

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KEYWORDS: Game Design, League of Legends, MOBA, Game Development.

ABSTRACT

With the growth of online gaming market, new titles are launched and announced constantly. Massive Online Battle Arena, also known as MOBA, had a great increase in the numbers of players. According to a 2012 estimative, League of Legends is the most played game among a list of several famous titles. Riot Games, the developer of the League of Legends game, registered a total of 67 million registered users only in 2013 and 27 million active players every day, an increase of 125% over the previous year. The competitiveness and efforts of the developers has been notorious and essential for its success. We can associate the success of these titles to the great project design. Since it has been designed to attract new players and keep their level of fun, online games have features that is important to highlight. So on, the goal of this paper is to analyze the key features of League of Legends, such as conflicts, objectives and rules; and the dramaturgical aspects, such as characters, history, and immersion among others, in order to explore their game design and assist new developers with practices and game design organization.

INTRODUCTION

The seeking for fun through the media has become commonplace these days. This fun is found in computers, televisions, smartphones and especially in virtual games. League of Legends, also known as LoL or League by its players and adepts is one of the most played game of the moment. Is a game of the genre Multiplayers Online Battle Arena (MOBA) which according to (Yang et al.2014), the MOBA style is a subgenre of real-time strategy games in which the player has to make individual decisions and team decisions to complete the goals and ensure the match's victory.

Launched in 2009, LoL is steadily increasing the number of players over the years. According to (G1 2016), a website, Riot Games' MOBA reached 67 million users in 2013, a growth of 109% compared to the previous year. In the same year, the game had 27 million active players, a growth of 125% over the previous year, thus showing how profitable this title is.

In the work of (Yang et al. 2014), it is verified that there is growth in the market of games, according to a research done by (DFC Intelligence 2016), where the revenue of this market must reach 79 billion dollars until 2017. Soon there is no doubt that the trend is the appearance of new games of the genre, where producers seek a piece of that lucrative market.

With that said, our goal with this paper is to show all the game features according to three different game design methodology present in League of Legends, highlighting the correctness and errors of developers, to help new ones to come.

RELATED WORK

In this section, we will approach works related to the style of games MOBA and Game Design centered on the experience of the player, similar to the evaluation proposed in this work.

In (Pedersen et al. 2009) paper, an investigation was made relating three important aspects to the creation of a successful game. These are the parameters of phase creation in platform games, the characteristics of the individual gameplay and the player experience.

With a modified version of Markus Persson's Infinite Mario Bros, the authors developed a neural network model that maps the parameters previously mentioned. The difference of the modified version is made fixing some objects of the phase that are favorable for a good experience of the player, defined by the network.

The data collection was done online with thousands of internet players. And it was divided by three data types, they are: Controlled game characteristics, which are variables of the phase data, e.g. position of obstacles and enemies; The characteristics of the game, i.e. how the user plays during the game. Statistical resources such as the form and amount of times the player jumped, ran, died, etc. Were measured; The experience reported by the user, through a mandatory questionnaire that appears at the end of two pairs of moves, containing four alternatives with emotional aspects, explain the authors. By the end, the authors conclude that automatic generation of content will be of great importance in the development of games in the future.

In (Yang et al. 2014) work a similar investigation was made for the purpose of this present work. The authors pointed out that MOBA-style games are difficult for novice players, and that through game knowledge and practice, they improve the performance. The goal was to recognize and classify patterns of successful combat tactics in common among experienced and winning players. The sequence of combats in graphics has been modeled to extract patterns that come from positive results.

The game used was DOTA 2 (which originated from the modification of Warcraft 3 - Defense of the Elders (DOTA) map) pioneering game the MOBA category. This technique can be used to help in how players should work together to overcome obstacles in MOBA games and perhaps to teach younger players the skills needed to be successful in this type of games, say the authors.

THE GAME LEAGUE OF LEGENDS

League of Legends (Riot Games 2009) is an online game of the genre MOBA (Multiplayer Online Battle Arena). This genre is popular by its specific features, such as the number of teams, the objectives and the number of players. League presents different characters and play styles which makes it a fun and dynamic game. The most popular game mode is Summoner's Rift, which hold most of the players connected in a match of about 45 minutes.

League is a very dynamic game. It has over a hundred items and different characters which provides a unique experience for each player. Also, the combination of these items with each character develop hundreds of strategies of game, which makes League of Legends one of the most played game.

Its objectives include destroy the other team's Nexus, a magical structure located in the middle of the base. To achieve this objective there are several secondary goals to achieve, such as turrets and inhibitors, magical structures that protect the Nexus and are spread over the map into a symmetric axis.

PROPOSED METRICS

To analysis League of Legends game, we will use a mix of the metrics proposed by the authors (Fullerton 2014), (Sweetser et al. 2005) and (Bjork et al. 2004). By reviewing some different games, we noticed that the following features is the most important for online gaming in order to improve the players experience. The features extract by our reference material was *Player; Social Interaction; Clear Goals; Rules; Conflicts; FeedBack; Immersion; Fun; Accessibility; Challenge Level and Balancing.* Each of this feature will be explained in the following section. We are also going to link the definition of this feature with a League of Legends example, in order to exemplify and demonstrate its application in a successful online game.

ANALYSIS OF THE GAME DESIGN ELEMENTS

In this section, we will examine the game features of League of Legends. Among the topics in this section, we will make an in-depth analysis of the player, social interaction, clear goals, rules, conflicts, feedback, immersion, fun and so on, based on the proposed metric above.

Players

Most games have uniform rules for all players (Fullerton 2014). During League matches, on the Summoner's Rift map, players usually follow a pattern called role, where each player has their position and act in the game, similarly to football matches.

Each player chooses the position on the map that will play and remain most of the game, including the bottom route, top route and middle route (in each route has infinite wave of units (also known as minions) where the player who gives the last blow in the minions Is rewarded with gold) and jungle where the players of this position have to make mostly complex decisions such as helping another route in order to help it, knowing the right time to return the base to purchase items or even recover the health and the moment to enter the territory enemy (Ferrari 2013). The upper route consists of a player, who fights directly with the opponent of the same position, the same goes for the middle route. In the jungle, there are monsters and goals, and a player is in charge of staying there collecting gold and experience that the monsters provides to be able to help the other routes strategically to crush the opponent and achieve the objectives. Lastly, the lower route consists of two players, a marksman who aims to attack enemies at a distance causing a lot of damage, and the support, which plays the role of assisting the marksman, healing, protecting, among others things.

Social Interaction

According to (Sweetser and Wyeth 2005), it is very important that a game encourages social interaction as it is an important element for the player's enjoyment. For example, there are players who prefer to play their consoles with the presence of a friend. That's why several games implement PvP (Player versus Player) mode.

League of Legends, although it is a game in teams, players can set up teams and play together of their friends observed by (Johnson et al. 2015) players feel motivated by playing with their friends and also by their opponents causing teamwork a critical item to success. Riot Games also features events where there is a bonus for players who play in teams, encouraging players to team up with their friends and play against other teams.

Despite all the work the company has done for a good user experience, there are still many cases where players considered to be toxic (with bad behavior), end up harming other players' gambling, whether it is an ally or an opponent. The best example of this is when a player gives up playing and chooses to leave his teammates during the game. Everyone is harmed in this case because the game was designed to have five players in each team, so Riot Games provides methods to combat these toxic players.

One of the methods is the "Leave Buster", in which the system itself identifies when the player has been inactive for a long time in a game, warning that this is misconduct behavior and that there will be punishment if it occurs too many times. Another method is to use the players themselves to give the feedback of the match, in case he has a negative experience in this, he can report the user who harmed him at the end of the match. This concern with the community of players is a strong point of the company with the game. The company offers the Summoner's Code to improve their own conduct, a practice coming from the Korean e-sport is to type in the beginning of the game "good luck and have fun" and at the end of the match independent of the result "good game" decreasing the numbers of toxic players.

Clear Goals

For the clarity of the game, it is very important that the goals are well delineated. In (Fullerton 2014), the goals define what the player is trying to accomplish by following the rules of the game. According to the objectives, players can assemble strategies even before the game starts.

In League of Legends, the primary goal is to destroy the enemy nexus as explained in section three. The nexus is a magic structure that generates non-playable characters, known as minions. To accomplish the destruction of the enemy nexus, it is necessary to destroy the towers of the nexus and the inhibitor, which are protective structures of the Nexus. The destruction of these structures is defined as primary goals. The secondary goals are the Baron, which grants bonuses of skill power and physical damage for four minutes to all living champions; and the Dragons, each eliminated dragon grants each team member a permanent effect and can only accumulate five different effects. These non-playable characters give bonus effects to troops and characters and leaving them at the mercy of the opponent is not a good choice.

Rules

Playing a game is to engage in an activity aimed at provoking a specific state, using only permitted rules-means in which rules prohibit more efficient in favor of less efficient means, and where these rules are accepted only because they allow such activity (Suits 2014). The rules of a game define a set of actions that the player can or cannot do in order to achieve his goals (Suits 2014). In electronic games, rules can influence the mechanics of the system, for example to buy a level three item in the store, it is necessary to get together all items level two and one that make up that item and also have enough gold to purchase such item. For example, to acquire the item Trinity Force, you must first acquire the items Stinger, Sheen, and Phage, and have 333 gold to purchase this item as shown in Figure 1.



Figure 1 - Rule to Purchase an Advanced Item, Underneath each item there is the value to acquire it.

Conflicts

In an electronic game, we define as conflicts any action that makes it difficult to achieve a certain goal according to the rules of the game. (Fullerton 2014) classifies conflicts into three categories: obstacles, opponents and dilemmas. Obstacles in a game may be physical or mental. The physical obstacles in League, we can cite as example the terrain of the game. According to the thickness of the walls, certain spells interact in different ways. In the same way, the game strategy changes depending on the region of the game you are in. For example, if one team is accomplishing the goal of the Baron, the other team can contest jumping the wall or using spells that cross it, avoiding to approach the enemy team.

FeedBack

According to (Sweetser and Wyeth 2005), players should receive feedback at certain periods. She quotes that the player must be informed of each progress toward the goal of the game. For a better experience the player should also receive feedback on his actions, and be always in touch with his updated status or score.

In League of Legends this feature is very visible. For each important action of the user, all players in the match receive a notification on the screen alerting about everything that happens in the game. These notifications range from buying important items to achieving important goals like dragon, baron, turret and killing of enemies among others.



Figure 2 - System Feedback Message

Immersion

A brief definition of immersion as stated (Boas 2013) is to be deeply involved in an activity. In the case of League, the player controls a champion performing his duties, and this makes the user feel like he is the character, feelings similar to reading a book, brings a great immersion of the world in which he is. Other elements of the game such as ambient music, sound of skills, character story, 3D look of the world, contact with real people on your team also contribute to the player feeling immersed in the League of Legends universe and that their ultimate experience is reached.

Fun

According to (Fullerton 2014), playwrights' elements are responsible for connecting the player with the formal elements, keeping him emotionally involved with the game. The author also argues that it is often difficult to know whether the game is fun or not, asking players if the game is fun may not result in very relevant information.

In League of Legends, these elements are very well connected. Due to the balance of the elements of the game, the level of difficulty and abilities of the player, at the end of a match, the player is entertained with the game and ready to start another match.

Accessibility

Accessibility in electronic games is very important as it expands the range of players who can play. Colorblind players for example may have some bad experience due to the color distribution in their game and having accessibility options ensures a good experience for most players (IGDA 2004).

League of Legends has this accessibility option for players with some degree of color blindness, but players with other types of disabilities, such as deafness, are harmed by not being able to hear important game sounds such as the sounds of abilities and warning signs.

It is therefore recommended that games always have accessibility options so that players have a better experience as well as increasing the target audience and then attracting more players.

Challenge Level

An important feature of a successful game is knowing how to keep the challenge level compatible with the player's skills in order to keep the user challenged to improve their skills without making the game easy or boring. According to (Fullerton 2014), the level of challenge of a game is very particular to a user because it depends on their abilities as a player which makes it difficult to maintain the balance of matches. It is also important to emphasize that in the long run this game adapts to the level of the player and remains always challenging and fun in order to keep the players are also clients of the company that develops the game.

This feature can be represented in a challenge x skill flowchart. This chart included the League of Legends tiers representing levels of users as their abilities increase.



Figure 3 - Ability x Difficulty Chart

Therefore, when developing an electronic game project, it is important to analyze the growth plan of the player's abilities in order to keep the levels of difficulty of the games always challenging so that the game does not become repetitive, and the player does not get tired of the game and bored.

Balancing

As we saw in the previous topic, balancing the user's skills with the level of difficulty of the game is essential so that the game does not become frustrating or boring to teams. But balancing the different parts of your game is important to generate a higher quality end product.

In his book, (Fullerton 2014) states that balancing the game is important to make sure that the user's planned experience is achieved, so that the system behaves as planned and fair to all players. It also defines four areas of balancing, which are: variables, dynamics, starting position and skills. We will use these four areas in the following topics to show the balance of League of Legends.

Variable Balancing

This category includes the balancing of all numerical system configurations, for example: number of players can play per game, price of a particular item in the store, damage value of a spell, shield value of a given character, etc. In League, these characteristics are well defined. For example, the total number of players in each team is five. The price of the items is proportional to the character's growth throughout the game, getting money for troop and champion killings, or for accomplishing secondary goals such as destroying towers and epic monsters.

In order to keep these settings fair to all players, Riot Games constantly provides updates on the value of items, their base composition and the damage value of the characters' abilities, with an implicit focus on those changes, in order to make the player think about best strategy in that current version of the game

Starting Balancing

It is also very important that the game provides equal conditions at the beginning of the game. For example, in a race game, all runners start from the same point, giving chances of victory equal to all participants. Respectively, in League of Legends, all players start on their respective bases and can only leave after a certain amount of time the game begins. Other examples are the initial gold of each character, which is the same for all players. This feature gives equal conditions of victory to all players.

Skill Balancing

Skill balancing is responsible for maintaining a balance between the level of difficulty of matches and the skill level of the players. As described in the challenge level topic, balancing players' abilities with the level of difficulty of the game is responsible for keeping the game fun and challenging in order to prevent the game from becoming frustrating or boring.

In League of Legends the skills of the players are very well balanced, compared to other games of the same genre has some mechanics that the skill level is less required than other games for example in Heroes of Newerth (HoN) the minions can be denied to the opponent that is, the player can give the last blow in the allied minion denying the gold to the opponent, the existence of this mechanic in HoN and some other MOBA makes League become easier to be played since this mechanic is non-existent , because with this mechanics available in HoN new players tend not to play it again looking for mechanics easier at the beginning of the game. Each player has a coefficient that measures his abilities according to his performance in the games he has already participated. This coefficient is the MMR. This coefficient is used to maintain a balance in the matches, placing players with the same skill level playing each other.

Matches are set according to the Tier and the MMR of the team. As the user gains more victories in their ranked matches, their MMR points increase. Keeping balanced the level of challenge and skill level of the player. Therefore, as the level of battles increases proportionately to the level of the user's abilities, matches become always fun and competitive.

The MMR points also operates in the ranked game system. For example, Gold Tier 5 and Gold 5 players are expected to have an MMR of approximately 1449. If the player has a higher score, he will move up to higher levels faster to stabilize his link and his score. MMR.

In order to prove the importance of balancing the level of challenge of the game with the skills of the user, imagine the following scenario: a player with less ability, such as the Bronze tier, playing against a team of players with higher abilities like the tier Diamond and Master. The bronze tier player playing against diamond level players will find the game very difficult and frustrating due to the high level of matches and the lack of knowledge and skills compared to the diamond players. While top-level players will find the game easy and boring if they are playing against Bronze tier players.

CONCLUSION

As you can see, there are several design elements that should be taken into consideration when designing a successful game. Elements which lead to improve the final user experience. Among these characteristics, we can cite as an example immersion, which together with other elements such as history, mechanics, character among others becomes an important factor to popularize the game and ensure player satisfaction. It is notable that in all the elements presented, the company analyzed presented a satisfactory solution, showing that the architecture of the League of Legends project took into consideration several aspects of gameplay such as feedback, rules, conflicts, balancing, level of difficulty, among others. In this way, we can attribute its great success to its good design and to bring to the user a good gaming experience.

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COMMUNICATION VERSUS COMPUTATION: A SURVEY OF CLOUD GAMING APPROACHES

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ABSTRACT

There still remains many challenges in creating an effective and efficient cloud gaming operation able to handle the new release games of today. There are also many existing paths to creating a cloud gaming architecture. In this paper some of the different approaches, that are beyond that of just remote rendering, are analysed giving insight into the operational approach of each technology. Currently there is a growing number of initiatives in cloud game architectures that vary in significant ways. Although there are many varying technologies, with a lot of promises, the ultimate goal of a cloud game engine is something unique to what has been before. It really is about providing a modular and scalable approach but within a controllable and sandbox like environment.

INTRODUCTION

To date *Cloud Gaming* has experienced both success and failure in delivering cloud-based gameplay to gamers. These operations still face challenges in bandwidth usage, the effects of latency on gameplay experience and the costs involved when the numbers of users supported per server remains quite low.

Most games have a real-time requirement with very low latency to end-users, whom are quite sensitive to quality of the gaming experience. The game engines running these games tend to demand high amounts of resources to render successfully at the expected Frame-Rates (FRs).

Current game engines are *plugged-in* or *ported* to the cloud which, although feasible, often introduces many inefficiencies in an online networked environment that already has its own problems and challenges. The game engine integration approach also fails to leverage the mass amounts of computational power that may be available in a *cloud gaming* cluster.

In this paper the various methods that underpin current *cloud gaming architectures* are analysed with the goal to bring an understanding of the various approaches and their inherent advantages and disadvantages.

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WHAT IS A CLOUD GAMING PLATFORM?

A typical view of a *cloud gaming system* (see Figure 1) is one that renders the game scene on the cloud cluster and then transmits the encoded scenes to an end-user device via the internet or similar broadband connection. User input is taken from the end-user device and transmitted to the *cloud gaming cluster* so it can update the game state and render the next frame (see Figure 2). This architecture means that game-code is stored and executed on the server with the benefit of being able to deliver the game in a generic fashion suitable for a wider selection of end-user devices.



Figure 1: Cloud-Gaming Architectural Overview

In the *cloud cluster* an important differentiating factor is whether the system is created generically so it can plug into as many game products as possible. Alternatively the cloud gaming platform can be built to leverage internal game engine information and functionality for better performance, but this ties the solution to a particular game engine and therefore the need for porting the game product to that cloud gaming platform (Beer 2013). Creating a generic game plug-in system, that allows a wide range of games to be *plugged-in*, can negatively impact performance due to the additional steps required to capture game output as a black box process.

CLOUD FRAMEWORKS

Currently there exists a number of approaches that deliver game services from the cloud. The aim is to bring benefits a cloud platform gives other services, to games. This section will present core approaches used for delivering games from the cloud and discuss the associated advantages and challenges of each approach. The



Figure 2: A Traditional Video Streaming Architecture

suitability and successful application of each technology may depend on the original application and whether it can handle user interaction and dynamic scenes. A lot of current work has leveraged remote rendering technologies of the past and a survey covering interactive remote rendering systems has been done (Shi and Hsu 2015). Cai *et al.* (2016) has completed a more broad study at defining cloud gaming, the ongoing research and challenges. This paper focuses on highly interactive and dynamic scenes, that is the cloud gaming category of the model (see Figure 3), and explore the options and challenges in creating a cloud gaming platform.



Figure 3: Categories of Remote Rendering Systems and Applications (Shi and Hsu 2015)

STREAMING MEMORY PAGES

The memory page level of an application is streamed by sending memory pages as required by the user application. The approach uses a statistical method to help predict what pages are required next by the client application. The handling of the memory pages is done by a Virtual Machine (VM) layer on the client-side which communicates with the server to retrieve the previously virtualized memory page. This technique makes it possible to be cross-platform for end-user devices that have a VM available. This process was called *Cloudpaging* by *Numecent* (Ahiska 2015) and brought to gaming by a spin-off company *Approxy* (Ahiska 2012) that was later reacquired by *Numecent*.

Cloudpaging allows for the download of the files as they are required and even the subcomponents of a large executable file transparently in the background. This means that, although the application does not start immediately the first time, the application will start after downloading less than 10 percent with an example such as Adobe Photoshop starting after 6.5 percent. Cloudpaging presents a way where the transferred Cloudpages may be proxied locally to allow for client devices, that share the local network, to make use of this if the same application is being used and even play offline if all relevant pages are available. This type of approach may be more compatible with existing Content Delivery Networks (CDNs) used today.

Security is by encrypting the *Cloudpages* and ensuring the end-user does not have the whole application at any point in time. This still sends all material to clients and therefore could be argued that it would still be vulnerable to piracy activities. Latency, conversely, is much less of an issue as the application is running upon the client device and slowed only by the VM layer it runs within.

STREAMING OF FILES

This approach works at the file level of an application and focuses on downloading files as required by the client-side application. The transfer of files can be defined by the developer, defined by the levels of a game, anticipated statistically or via prediction methods on what files are required and when. The aim for all these approaches is to minimise the size of the initial download before being able to play, as well as effectively stream in the background without negatively impacting the game (see Figure 4). Sometimes file streaming is done at the block level of a file, avoiding the transmission of large files when only a part is required, which can be especially useful when it comes to efficient patching. The streamed game then runs natively, or within a thin layer to handle file requests, and therefore is not impacted by latency. Services such as AWOMO, InstantAction, and Triton are file streaming game services that are no longer in op-



Figure 4: Cloud Gaming File Streaming Architecture

eration today. InstantAction was focused on being able to deliver games directly within a web-browser in websites such as Facebook (DiStream 2004; Walkden 2009). Exent, which had been involved with the *Games@Large* cloud gaming research (Jurgelionis et al. 2009; Nave et al. 2008), had primarily relied on file streaming for their services where they had technology to layer in-game advertisements to make games freely available.

Eximion (2006) provided a cloud gaming tool-set called *Kalydo*, allowing the packaging of an existing game so that it could be progressively downloaded, enabling players to commence gameplay as soon as the minimum number of files required was available. Access was provided directly through a user's web-browser and a small plug-in. Games like the Massively Multiplayer Online Role-Playing Game (MMORPG) *Runes of Magic* had a download size of over 8 GB, but it started playing after downloading only 200 MB of the game.

An even more effective way to deploy a file streaming solution is to use a *player prediction* based approach for file streaming as done by Utomik (2015), which uses player behaviour to build a model for what files are going to be required when. Game Domain International (2006) had used a statistical approach for a A World Of My Own (AWOMO) where games would be provided in a Second-Life like world that was aiming to be the best place to buy and sell games (The Steam Review 2007). Valve's Steam (2011) also depends on file/asset streaming at the core. Using a Distributed File System (DFS), the system includes manifest objects that determine the order of when files are required to be cached locally. If multiple players share a device then Steam will share the assets of the game as well. Also a move to deliver games, not just to the PC, but also to devices such as

Smart TVs only required that the developer's game be compatible with a game controller (Newell 2003).

File streaming solutions aim to run natively and perform as though the gamer has installed them, once the initial download requirement is met. Transfer at the file level can mean specialist compression approaches that best suit the file-type, which can help maximise compression. Some file streaming solutions will run within a VM. The use of a VM may introduce a level of latency, but can enable playback of the game on different devices. Today there are a number of platforms in the cloud gaming space (see Table 1) that utilise asset streaming technologies and techniques in providing their service.

STREAMING OF GRAPHICS COMMANDS

The streaming of graphics commands, which is also referred to as *Graphics Streaming*, involves the intercept of graphics commands from OpenGL (Khronos Group 1997), Vulkan (Khronos Group 2017) or DirectX (Microsoft 2017) that are compressed and streamed to the client to be executed. The client is required to have a graphics processor capable of quickly rendering the image, which may not be appropriate for a Smart-TV, Set-Top Box (STB), or mobile device that has limited processing power. This is an advantage for a *cloud cluster* because it reduces the amount of processing it has to do and allows each server to support more users (Jurgelionis et al. 2009).

THINC used an approach of operating as a virtual video driver that captures, translates and sends render commands to thin-clients. THINC delivered superior performance over existing solutions of the time on both LAN and WAN environments to true thin-client systems where a Graphics Processing Unit (GPU) was not present (Baratto et al. 2005). Another example is the streaming graphics command architecture VirtualGL which intercepts OpenGL calls on the server to render the 3D parts on the server-side and then streams the resulting image frames to the client for playback (Commander 2012) using the GLS (OpenGL Stream Codec). The aim of the system was to allow for the visualisation of large datasets without having to send the data itself whilst also being able to share expensive rendering hardware more effectively amongst users. Pre-dating this were 2D streaming approaches on Unix-based X-server systems. Streaming graphics commands is a technology also explored in various projects to help handle complex scene renders by approaching this in parallel across multiple nodes in a cluster. Such research includes WireGL (Humphreys, Eldridge, et al. 2001) which led to the work on Chromium (Humphreys, Houston, et al. 2002). Later distributed approaches included OpenGL Multipipe SDK (MPK) (Bhaniramka et al. 2005) and ParaView (Cedilnik et al. 2006). Now with highly parallel servers, work may be more focused on having a larger number of games render on a single node but the methods used may be of interest in addressing the challenges of the server to client communication and latency. Game audio is also a consideration and normally streamed via a capturing, encoding and streaming process which can create challenges when trying to re-sync the audio to the visual on the client device.

The streaming of graphics commands can be viewed as a custom communication protocol. This approach often means developing a proprietary *codec* to allow the streaming of graphics content with the advantage of very little encoding effort being required. The disadvantage is that bandwidth is subject to FR (Stegmaier et al. 2002). High quality games present more of a challenge with large numbers of commands per frame requiring methods of compressing and caching commands to reduce network throughput (Eisert and Fechteler 2008; Liao et al. 2016).

There is also a dependency on the client device being sophisticated enough to render the graphical commands which may require the addition of a more expensive GPU hardware within the client device. This can also impact how cross-platform the graphics command stream can be and introduces inconsistencies between different client devices operationally. Even with this consideration, however, the cost to the end-user is often less than purchasing all the modern day PC hardware required to run the game at a similar level of graphics quality.

STREAMING OF THE VIDEO IMAGE

The streaming of a video game, which is known as Video-Streamed Games On Demand (VSGOD), involves the cloud cluster rendering the 3D world to a 2D image that is then captured, encoded and compressed into a video format before transmission. The client receives the stream and decompresses using a decoder to replay the video. The client captures input from the user to return to the server (see Figure 5). The advantage of this approach is that thin-clients do not require special hardware, such as GPUs, although they may have cheap decoder chips that support quick video decoding (Cheng et al. 2004; Holthe et al. 2009; C. Huang et al. 2013b). Research in the area of remote data visualisation is often informed by progress in fields like medicine where the use of MPEG approaches to help stream the rendered images is done and ways to improve the performance has been researched. The main focus was on the MPEG encoding and decoding process operating more effectively for 3D data visualisation. Of this the motion estimation algorithm component of MPEG was found to cost at least 50 percent of the time. Wallach et al. (1994) created an image representing the 2D optical flow of each pixel of the image to better the exhaustive search performed by the original encoder. Khan et al. (1996) presented a geometrical approach to calculating the mo-



Figure 5: Cheng at al.'s Remote Viewing 3D Data-sets Architecture

tion vectors which resulted in a set of matrix operations based on the viewer movement that allowed motion vectors to be easily calculated. Cheng *et al.* (2004) reduced processing time with GPU assistance, using the z-buffer and camera position change between frames to project current frame pixels of a block into the projection space of the previous camera position and in doing so calculate the vector difference in movement. If the pixels of the block were found to be a poor match then it was marked as occluded and normal MPEG-4 motion estimation would take place whereby this location would be a good search starting point. Cheng's work viewed large static 3D models that algorithmically may not work as effectively given a dynamic and interactive game environment.

H.264/AVC-based video codecs, considered as a possible improvement for the work of Cheng's, was used in later research by De Winter *et al.* (2006) to stream graphical output of applications to thin-client devices. They combined a traditional thin-client protocol with realtime desktop streaming to handle 3D games with a performance that surpassed the classic thin-client protocol alone. The main problem with 3D gaming is the reliance on GPU hardware for acceleration, this being a missing component on thin-clients.

Earlier work surveyed latency and performance of video streaming to mobile devices (Lamberti and Sanna 2007). Shi *et al.* (2010) went as far as to say that the only

Shi *et al.* (2010) went as far as to say that the only disadvantage of video streaming is the interaction delay or latency. This problem largely comes from the on-demand nature of gaming that is unable to benefit from the use of large video playback buffers (Choy et al. 2012). This motivated work in how the Quality of Service (QoS) could be used to help ensure a good cloud gaming experience. Research such as Quality of Experience (QoE) (Jarschel et al. 2013) where downstream packet loss, followed by downstream delay, were found as the most important factors for a good gameplay experience. Jarschel highlighted that specific QoS settings are required for the type of game content being delivered and that cloud gaming's sensitivity to downstream problems greatly impact image quality, which is readily perceived by gamers. Wang et al. (2010) faced even higher research challenges in the mobile gaming area in providing a consistent QoE that led to methods of dynamically changing rendering and encoding parameters to control the computation and transmission requirements. This work in the Cloud Mobile Gaming (CMG) area identified factors impacting QoE in a model entitled Mobile Gaming User Experience (MGUE) (Wang and Dey 2012). This was later expanded to the model of Cloud Mobile Rendering User Experience (CMR-UE), which combined research with a Content-Aware Adaptive Rendering (CAAR) algorithm and demonstrated to work effectively over 3G mobile networks (Liu et al. 2014).

HYBRID APPROACHES

A number of successful *cloud gaming* operations have taken an approach that combines different methods to obtain the best result. In the following sections will be presented some of the hybrid approaches used in the past and present.

VIDEO STREAMING AND CLIENT PRO-CESSING

Another technique is to perform some of the rendering on the server and then post-rendering or post-processing operations, that are generally limited by the thin-client's processing power. The approach of video streaming with post-processing steps is somewhat of a hybrid between the streaming of video and 3D graphics commands. Rendering of 3D graphics is still performed on the cloud servers while a range of optional post-rendering options can be performed on the thin-clients.

MODEL STREAMING AND POINT BASED STREAMING

One client post-processing approach is for the server to pre-select structural scene information in an optimised fashion for streaming to the client to perform the final visualisation stages. Such techniques may send selected 3D model's Level of Details (LODs) to reduce the amount of data for lossless compression and transmission to the client (Engel et al. 1999; Prohaska et al. 2004). Extremely large data-set techniques, that store data in a pre-computed hierarchical format, may suit static elements of a game scene but may need further development to support highly dynamic or destructible scenery (Prohaska et al. 2004).

Another method is to construct a point-based representation of the data from the scene's mesh-based models and match the density of the points produced to the client's screen resolution (Duguet and Drettakis 2003; Shi, Kamali, et al. 2010). Duguet and Drettakis's work demonstrated filtered delivery from 4.7 million polygons on the server to 1.3 million points received by the mobile Personal Digital Assistant (PDA) client. The client still performed rendering which included tasks like shadow mapping at 2.1 F/Sec (Frames per second) which would not have been possible otherwise (2003).

ENVIRONMENT MAPS, DOUBLE AND 3D WARPING

Environment maps, that are commonly used in gaming, is another approach where the server is responsible for generating based on the 3D scene to represent any view angle from a fixed point. This is seen in QuickTime VR (S. E. Chen 1995) with the streaming of a chain of environment maps to allow navigation and used in games from Red Orb Entertainment (Simon 1997) and work by Boukerche *et al.* (2006). The method allows for highly detailed pre-rendered scenery to be displayed to the user. The drawback to this is the difficulty in adding dynamic objects to the scene or in changing the lighting dynamically within the environment.

Chen et al. (1993) proposed the method of asynchronous rendering where the client can perform intermediate rendering, such as 3D Warping, independent of the server rendering step and therefore address latency issues. The approach used the z-buffer to re-render viewpoints that are a small change from the current position using an image warping algorithm that increased the responsiveness of the system but presented challenges in minimising image error (McMillan 1997). The technique required the server to send more information about the scene to the client but was found to have significant FR improvements where their examples present a server running at $5 \,\mathrm{F/Sec}$, whilst the client was running at $60 \,\mathrm{F/Sec}$ and maintaining a high level of quality (Mark et al. 1997). The research led to work with low-powered mobile devices and the aim of enhancing their 3D graphics abilities (Bao and Gourlay 2003; Chang and Ger 2002).

Another approach involved warping within the framework of the H.264 encoder video stream. This also delivered an increased performance of up to twice the FR upon the client and suggested that future improvements may involve the development of a custom *codec* (Giesen et al. 2008). Work built upon this used prediction of the next point of view which increased the effective range that the image warping could take place within (Shi, Kamali, et al. 2010). This approach is somewhat similar to *Double Warping* where two depth images are rendered and sent from the server to represent the current position and selected reference. The *3D Warping* process is done twice and the result is an interpolation between the two (Mark et al. 1997).

These various approaches discussed address latency in an asynchronous manner to the server but for highly interactive 3D game titles their use may be quite limited (Shi, Kamali, et al. 2010). The algorithms are still of interest as they may increase FR when dealing with client devices capable of high FRs and therefore the travel distance of in-game objects between frames being suitably minimised.

VIDEO STREAMING AND CODEC PERFORMANCE

At the heart of video streaming of games is the *codec* being used and how it is configured. There are a number of challenges with a *codec*'s performance when an application is highly interactive like that of a video game. Visualisation applications of large data-sets are an area where there has been development of interesting algorithms to enhance the performance of *codecs* or generally increase the responsiveness of a system. Critically a lot of these methods find their limitations when faced with complex and highly dynamic scenes such as those found in modern games.

One consideration is whether the server checks the type of client device and then pre-scales the imagery to match the client device resolution. This can have an impact when there is a lot of devices connected with small resolutions. In this case you do not want to waste processing time creating and encoding detail that is not visible on the client (Jurgelionis et al. 2009).

Enhancements to encoding can lower the delay and complexity which helps reduce issues from latency (Nave et al. 2008). As an example H.264 can perform encoding with CABAC (Context-Adaptive Binary Arithmetic Coding), that uses a form of entropy encoding used in H.264/MPEG-4 AVC video encoding (Said 2004), which increases the compression efficiency of the *codec* but has the negative effect of increasing the computational time at the decompression stage on the client (Eisert and Fechteler 2008). The processing time required by the *codec* on the server needs to share processing time with more than one game where each may need several streams created, encoded and transmitted (Jurgelionis et al. 2009). Off-loading processing requirements and reducing bandwidth use are desirable when trying to maximise the number of users supported per server.

Codec algorithms are sometimes not suited to be implemented in parallel form and therefore restricted from execution on GPUs efficiently. Jules Urbach from OTOY (2011) developed their own proprietary codec called ORBX to run well on GPUs encoding a 3D scene. Other motivations include handling higher video resolutions and colour depths where open standards such as Google's VP10 (Sharabayko and Markov 2016) and Kronos Group's OpenMAX (Group 2015) are helping achieve better performance.

3D GAME WORLDS - LEVERAGING SCENE KNOWLEDGE

When encoding video using the H.264 encoder there is approximately 50 percent of the processing time in finding and calculating the movement of motion blocks. The game engine's scene information can be used to know where these blocks are moving to and therefore greatly reduce the processing time required in this stage of encoding (Jurgelionis et al. 2009). The speed of video encoding can be improved via encoding objects further away from the camera at lower levels of quality (Noimark and Cohen-or 2003). It is also possible to selectively omit game objects from rendering on the server altogether and therefore reduce the encoding time and Bit-Rate (BR) required for transmission (Hemmati et al. 2013). Some of these techniques and algorithms have also been developed from a client post-processing view-point which can put more processing requirements upon the end-user device.

CLOUD GAMING PLATFORMS

The area of *Cloud Gaming* has been developed largely privately, avoiding open-source development approaches. Contrastingly *NetFlix*, that operates in the area of on-demand streaming of media for TV and films online, builds upon a number of open-source projects for their business platform (Hastings 1997). Today there are a number of platforms in the cloud gaming space (see Table 1) that utilise various technologies and techniques in providing their service.

In this section eight examples will be presented that cover open-source platforms called *GamingAnywhere* and *LiveRender*, ex-industry player *OnLive*, current industry players *Sony's PlayStation Now*, *Blade's Shadow*, *AirConsole* and *GameFly* (previously known as *PlayCast*), and results from an older European research project called *Games@Large*.

GAMINGANYWHERE

Currently there exists very little in open-source options for cloud gaming platforms, but one called *GamingAny-where* (2013) was made available by Huang *et al.* (2013). This follows a traditional approach of using readily available libraries to capture video and audio for streaming. The aim was for an extensible, portable and configurable platform made from open-source packages (see Figure 6).

Table 1: Cloud Gaming Operations

Platform	Link	Stream Type
$\overline{\text{Agawi (Google Buyout)}^b}$	-	Video
AirConsole	${\rm airconsole.com}$	Files
AWOMO (GDI Game Domain International) ^b	-	Files
CiiNOW (Google Buyout) ^b	ciinow.com	Graphics
Cloud Union	cloudunion.cn	Video
Community Cloud Development Kit ^a	github.com/monguri/CCDK	Video
Exent (FreeRide Games, GameTanium)	exent.com	Files
Gaikai (Sony Buyout) ^b	-	Video
GameFly (Merged with PlayCast)	gamefly.com	Video
$\overline{\text{GameNow}}$ (Ubitus) ^b	ugamenow.com	Video
Games@Large (Exent)	exent.com	Graphics/Video
$GamingAnywhere^{a}$	gaminganywhere.org	Video
Geelix LiveGames	-	Video
GFace (Crytek)	gface.com	Video
$\overline{\text{G-Cluster}^b}$		Video
Happy Cloud	${ m thehappycloud.com}$	Files
Instant Action $(GarageGames)^b$	-	Files
Kalydo (Eximion) ^b	-	Files
LiquidSky	liquidsky.tv	Video
$LiveRender^{a}$	${ m github.com/llfjfz/LiveRender}$	Graphics
NDS's Xtremeplay (Cisco Buyout)	-	Video
NVIDIA GRID	nvidia.com	Video
Numecent (Merged with Approxy)	numecent.com	Memory/Files
OnLive $1/2$ (Sony Buyout) ^b	-	Video
ΟΤΟΥ	ot oy.com	Video
PlayGiga	playgiga.com	Video
PlayKey	playkey.net	Video
PlayStation Now/Remote Play (Sony)	playstation.com	Video
Shadow (Blade)	shadow.tech	Video
Steam (Valve)	steampowered.com	Files
StreamMyGame	${ m streammygame.com}$	Video
t5 Labs	t5 labs.com	Video
$\overline{\text{Triton}/\text{Game xStream (DiStream)}^b}$	-	Files
Ubitus	ubitus.net	Video
Utomik	utomik.com	Files
		P 7 1

^aAvailable for developers as a SDK or open-source platform

^bOperation no longer available or discontinued

GamingAnywhere was found to have a per-frame processing delay of 34 ms which was three times faster than OnLive (Perlman 2011) and ten times faster than Tenomichi's StreamMyGame (Faria 2007) whilst transmitting lower levels of network traffic. The final image quality was better than OnLive and StreamMyGame at both 3 dB and 19 dB lower in final video quality respectively. The platform also supports clients that are observers which was a popular mode on services like On-Live where it could be delivered via a URL and viewed through players like VLC (VideoLAN 2010). The observer mode is where one encoded stream is shared with a number of users via a *unicast* method that is one of two modes *GamingAnywhere* supports. The other mode uniquely encodes streams for each game-player where the independent processing required may limit a server to a little over ten users comprising of twenty streams approximately (C. Huang et al. 2013b).

StreamMyGame offers end-users the ability create a MPEG-4 based streaming server of their own PC games to other devices in the home and includes abilities to record the gameplay and broadcast the games for spectators. The streaming typically has BRs of 4 Mb/s at XGA resolution. In the GameAnywhere platform communication can be layered on the Transmission Control Protocol (TCP) or User Datagram Protocol (UDP). UDP requires three streams which uses RTSP or Real-Time Streaming Protocol (Schulzrinne, Rao, et al. 2013) to deliver encoded frames over TCP along with two RTP or Real-Time Protocol (Schulzrinne, Casner, et al. 2003) over UDP streams for the audio and video. Over TCP alone the encoded frames, binary data and RTP/RTCP (Real-Time Control Protocol) packets for the audio and video are interleaved in the same stream



Figure 6: GameAnywhere System Architecture

and therefore only need one network connection instead of three (C. Huang et al. 2013b).

Huang *et al.* (2013) highlighted that they could improve their architecture by reducing the synchronisation overheads and by adding methods to better handle packet loss via a rate control algorithm for the varying quality of the remote player connections. Many approaches involve video encoding and decoding at various levels of compression and input resolution. The success of the compression, that if mismatched to the connection's feasible BR, can quickly lead to optical deterioration (Baun et al. 2010).

Later work involved the integration of Live555 (Live Networks 1997) library replacing FFmpeg (Bellard 2000) to enable an easier implementation of a system to dynamically control the FR and BR of the codec depending on the user connection. This resulted in 30 to 46 percent better performance results over their baseline implementation in data centre bandwidth challenged situations (Hong et al. 2015).

LIVERENDER

LiveRender is an open-source project (Liao et al. 2014) handling the streaming of graphics commands, model data comprising of vertex and indices, and the texture data in an approach (see Figure 7) they call Compressed Graphics Streaming (CGS). This is a technique that streams graphical commands but it attempts to address the use of this method for modern games where the number of draw commands and associated data becomes quite large. Liao *et al.* (2016) states that a game like Trine (Frozenbyte 2009) would consume an average bandwidth of 15 $\rm Mb/s$ when streaming graphics with only basic lossless compression applied.



Figure 7: LiveRender Compressed Graphics Streaming Architecture

The LiveRender approach incorporated caching of recurring graphics commands, geometry and texture data where the Least Recently Used (LRU) caching algorithm resulted in the smallest cache of well under 5000 elements with a hit rate of approximately 95 percent, compared to *First In First Out* (FIFO) at 40 percent and Least Frequently Used (LFU) at 5 percent. The compression of graphics commands are done both intraframe which benefits static models, and interframe which is beneficial for animating models. With the geometry data *LiveRender* leverages progressive algorithms that represent the models at different LODs and which utilised the *QSlim* algorithm by Garland and Heckbert due to the algorithms advantages of speed while maintaining model quality (1997).

The application of their compression and caching approaches achieved a saving of 52 to 73 percent with no difference in video quality whilst having the expected latency introduced. When compared to video streaming this offered a BR reduction of 40 to 90 percent whilst maintaining better video quality and lower response delay.

The performance of *LiveRender* was superior in bandwidth limited situations where at 5 Mb/s latency was approximately 118ms compared to normal graphic streaming taking approximately 39 ms longer, and video streaming having two to three times the latency of the compressed streaming approach. One of the reasons behind *LiveRender* being lower in latency than the com-

parable video streaming solutions is that as soon as the stream of graphics commands starts being received the client can commence processing each of the render instructions, and once the end of frame is received the image can be displayed immediately. An exception to this is in the situation of packet loss due to the use of TCP for communication, where a 10 percent loss would effectively double the impact of latency. Latency was impacted by their interframe interpolation method, this being where they could set how many derived frames (D frames) are created between original frames (O frames) where geometric data is not transmitted on D frames but instead interpolated. The results of having one D frame between each O frame was deemed optimal giving a bandwidth saving of 20 to 40 percent where any significant bandwidth savings disappears beyond two D frames.

ONLIVE

OnLive was the most famous of cloud gaming services starting in 2009, leading to insolvency in 2012 and then relaunching in 2014. In 2015 the company was brought out by Sony. The service delivered leading triple-A titles using their video streaming technology, although obtaining content from a number of publishers remained elusive (Hollister 2012; Lowensohn 2015). Financially they had faced challenges in the costly exercise of providing OnLive game consoles as well as localised data-centres throughout the world to maintain a responsive service. It was found that users need to be within a $1500 \, \mathrm{km}$ radius of a data-centre and have a connection capable of 5 Mb/s to experience good gameplay. This includes the connection latency being under 150 ms for general games and under 80 ms down to 35 ms for games such as a First Person Shooter (FPS).

Shi et al. (2015) stated that the cloud game streaming service OnLive was measured at 6.49 Mb/s on average when tested with Unreal Tournament 3 indicating that the bandwidth use was well above BRs such as with the x264 codec at 1.5 Mb/s for comparable quality. The research, furthermore, aimed to increase quality through the use of 3D warping and double warping techniques which they proposed should replace the original motion estimation stage of the codec. The OnLive operation relied on hardware encoders using their own proprietary compression technique.

PLAYSTATION NOW

Sony launched a new service called *PlayStation Now* in 2014 that allowed the delivery of older PlayStation 3 (PS3) games to be video streamed and played on the newer PlayStation 4 (PS4) console. The games are run and rendered in the cloud and sent to the PS4 requiring a connection with around 5 Mb/s in bandwidth (Sony 2014). At the same time technology allowing for games

to be streamed and played on different devices, that they called PlayStation Remote Play, would stream from your console to other compatible devices in your the home.

Today gamers can use the service to play both PS3 and PS4 games that *Sony* has to offer. The games can also be streamed and played on PCs and *Sony* Smart-TVs as well not requiring the need for a console. The payment model is subscription based that currently costs around \notin 17 per month and allows game progress to be maintained across devices.

SHADOW

A recent French start-up company Blade (2017) runs a service called Shadow that virtualizes Windows 10 desktops in high performance cloud powered hardware that consists of supplying a dedicated NVIDIA GTX 1070 GPU per user rather than NVIDIA's GRID(J. Huang 1993) division of GPUs amongst multiple users. The company raised \$57.1 million for their subscription based service that ranges from $\notin 25$ to $\notin 45$ per month (Dillet 2017). The service requires that you have a Fibre To The Home (FTTH) connection and can support a bandwidth of 5 to 25 Mb/s enabling the delivery of HD images at over $100 \,\mathrm{F/Sec}$ with a connection latency below 16 ms. Currently the average daily use per user is 2.5 hours for what is currently a more gaming focused subscription base. Like Onlive's later move they want to focus on attracting casual and business users as well.

AIRCONSOLE

AirConsole is a browser based service that started in 2015 that uses your smartphone as your game controller and turns your Smart TV, or web-browser, into the console. Due to the system relying on web-browser technologies, these games are written with tools like Flash, HTML5, Construct 2 or Unity3D, using their WebGL build option where game content is streamed as files to the web-browser cache. They currently have a free use and subscription, of \$2.99 per month, that disables advertisements and enables access to special content and early access to new games. The service has games that range from 1 to 8 players with a console like party game focus, where a subscriber's privileges are shared with other players in the same session (N-Dream 2015).

AirConsole has been active with the Global Game Jam and with competitions encouraging content creators to create or port games to the platform. The technique is the smart use of existing technologies although feedback on how modern day smartphones feel as a controller are mixed due to the current lack of haptic feedback these devices currently offer and some games may demand. AirConsole's use of mobile devices as controllers presents a latency challenge that they approach in reliable and latency minimising steps of first using *long* polling where controllers send server web requests that remain unanswered until the server has new information which the controller receives and immediately opens the next request, secondly change to WebSockets if able in the background, and finally use the least latent option WebRTC if possible.

GAMEFLY

GameFly acquired PlayCast in 2015 who emphasised the importance of being able to help users and enhance everyone's gaming experience. They see this as a layer that can provide hints and tips as overlay graphics (Beer 2011, 2013). This important point highlights that these systems should interact effectively and may involve the input from several separate servers. The same could be applied to the Graphical User Interface (GUI) layer of a game, which needs to remain the most readable and in most cases changes the least would suit being sent separately from that of the in game footage layer.

PlayCast's original VSGOD service launched as SingTel's ESC for customers in Singapore with fibre or broadband connectivity of 10 Mb/s and above. The games were executed, rendered and streamed in SingTel's data centres as a MPEG stream to consumers to play games using a PC or SingTel's exCite TV service (Beer 2011).

De Beer (2013) states that in making a success in cloud gaming the major areas of improvement are in streaming efficiency and game porting efficiency. The financial impact can be significant given how many streams are supported per data-centre server, this can be seen from *PlayCast* cost per user stream based on 100k subscriptions (see Table 2). This highlights how important the scalability of the technological components are to the viability of the business model. This includes being able to deliver effectively to as many different end-user devices as possible. Finally, and most importantly, is the gaming experience of the user with the perceived smoothness of gameplay and responsiveness or minimal latency.

Table 2: Streams per Server - Cost per Stream

Players (Streams) per	20	15	10	5	1
Server					
Overhead per Stream	\$9	\$12	\$19	\$37	\$185
per Month					
Overhead per Stream	\$0.5	\$0.6	\$0.9	\$1.9	\$9.3
per Subscription					
Viable Operation?	Yes	Yes	Maybe	No	No

GAMES@LARGE

From 2006 to 2010 a European funded project called Games@Large (G@L) focused on producing a platform

for streaming video games. This project aimed to be cross-platform and support a variety of devices from STBs and Handheld Devices (HDs) through to modern end-user devices including mobiles and computers. The G@L system communicates data for multiple games from a single server with low latency and employs enduser QoS. Depending on the end-user device this can be done either using a stream of graphical commands or a stream of image data where both are delivered using UDP based RTP(Jurgelionis et al. 2009; Laikari et al. 2010; Nave et al. 2008).

G@L GRAPHICAL COMMAND STREAM-ING

Graphical command streams rely on end-user device having the ability to handle things such as hardware acceleration in executing each of the DirectX or OpenGL commands successfully. The G@L project found this to be the lower latency approach between command and video streaming even with the use of TCP rather than UDP. The approach intercepted DirectX or OpenGL commands using delegate objects engineered to virtualize commands so as to avoid synchronous calls and therefore reduce the overall total number of commands required to serialise, compress and transmit (see Figure 8). They found games not to be playable when streaming graphics commands without compression and client-side caching mechanisms.



Figure 8: G@L OpenGL/DirectX Command Streaming Architecture

The end-user experience in G@L was found to clearly map to the FR of the game. With the streaming of graphical commands the FR is related to the network bandwidth being used and for high FR games the bandwidth ranged from 6 Mb/s at 20 F/Sec through to 80 Mb/s at 2 F/Sec making this approach not as viable when streaming multiple high-end games from a single server whilst at high FRs. Later experiments had quite wide ranging bandwidth usage results from 5.2 Mb/frame to 847 Mb/frame which at decent FRs is high. To address the performance problems work was done on both the lossless compression of the commands as well as the virtual representation of the graphics card upon the client-side (Eisert and Fechteler 2008). Video streaming overcame the FR to bandwidth challenge allowing multiple streams to be sent from a single server.

G@L VIDEO STREAMING

G@L video streaming (see Figure 9) uses standard H.264 (Marpe et al. 2003) video and HE-AAC-v2audio (Meltzer and Moser 2006) codec enabling delivery to a wide range of end-user devices where the time between creating the image frame and the user being able to view it is most critical. To synchronise the audio and video streams the RTCP sender report packets delivered in each channel and mapped to high-resolution NTP (Network Time Protocol) timestamps enabling the client to synchronise channels.



Figure 9: G@L Video Streaming Architecture

To help prioritise communication for low latency and high throughput, the G@L solution utilised WiFi Multimedia (WMM) subset of the *IEEE Wireless LAN* 802.11e (Mangold et al. 2002) standard for QoS approach to prioritise network traffic. This results in improving communication performance when low background network traffic is present due to the way QoS categorises the activity into four groups with appropriate prioritisation. Without QoS support on the network any other application would compete and detract negatively on the gaming experience, especially over a wireless network (Jurgelionis et al. 2009).

G@L aimed to achieve easy discovery of the networked services and used UPnP or Universal Plug and Play (Open Connectivity Foundation 2008) to achieve this. This resulted in the easy discovery of services available to client devices connected on the same network (Jurgelionis et al. 2009). The user input was encrypted on the client device using RSA (Rivest et al. 2009) encryption for the keyboard, otherwise data such as the mouse position would be sent unencrypted.

Now the G@L project only exists as publications but one of the main industry partners in the project, an Israel based company Exent (Levgoren 1992), is believed to be using the technology in a private business with their *GameTanium* mobile play service along with its *FreeRide Games* (Exent 2012) portal.

CLOUD CHALLENGES

The exploration of current research in the area of cloud gaming and reviewing what is currently best industry practise helps to form a picture of the challenges and problems faced by the world of cloud gaming. The immediate challenges of ensuring an acceptable gameplay experience motivated research into new services such as Quality of Experience (QoE) where downstream packet loss, followed by downstream delay, were found as the most important factors on the gameplay experience. Jarschel et al. (2013) highlighted that specific QoS settings are required for the type of game content being delivered and that cloud gaming's sensitivity to downstream problems is due to the impact on image quality which is readily perceived by gamers. In the following section the components of a cloud gaming architecture will be presented.

CLOUD GAMING COMPONENTS

From this survey there has been identified a number of challenges, opportunities and possible features that are presented as the components of cloud gaming (see Figure 10). The components cover functionality currently seen in existing cloud gaming operations through to proposed future features. There is still a major focus around bandwidth consumption and latency between the user's input to the response viewed on the user's screen.

Bandwidth demands can vary a lot depending on the amount of activity within the game but more importantly on the current and future resolutions of games where 720p (SD) needs approximately 5 Mb/s, 1080p (HD) at 10 Mb/s, 2160p (4K) at 25 Mb/s and 4320p (8K) at 85 Mb/s, where both 3D and VR versions doubling this. The increased speed of broadband will eventually be something that addresses this, but the need to have a very fast response between the time the



Figure 10: Overview of Cloud Gaming Challenges

user hits the key and the time the user sees the updated picture on their device is one that often means expensive set-ups of localised servers to ensure that latency is minimised. The latency can be greatly impacted by a bad connection, other traffic on the network or the use of a poor underlying protocol for transmission.

Costs for the operator is an important topic which encompasses all the aspects of running operational datacentres. This includes calculating the number of concurrent players, the geographical location of each of the data-centres, the quality of the game, frames-per-second and resolution.

THE IMPACT OF LATENCY

To deliver a great user-experience *latency* is highlighted as one of the big challenges to a cloud gaming system. For delivery of a game of the FPS genre a sub-100 ms Round Trip Time (RTT) is required as some studies found player accuracy and number of kills reduced by 50 percent with a latency of 75 to 100 ms, and players becoming annoyed at latencies around 200ms (Beigbeder et al. 2004). OnLive was found to differentiate server resources available on a game-genre basis to provide acceptable levels of latency based on the game requirements (K.-T. Chen et al. 2011). Research by Lee at al. (2012) produced a model of *cloud game friendliness* that analysed games on both how the screen changes spatially and the frequency of the player's input.

Chen et al. (2011) defined a methodology for evaluating the real-timeliness of cloud gaming systems to compare the performance of OnLive and StreamMyGame. This author found that StreamMyGame's level was not acceptable with encoding at 720p taking 400-500 ms and general performance twice as bad as OnLive which was acceptable if the network delay was not too great. The OnLive performance was thought to be due to specialist server hardware being used and emphasised the large investment cost for the hardware required.

Choy et al. (2012) further researched existing internet infrastructure and found that latency-sensitive cloud games need better infrastructure by equipping CDNs with the appropriate hardware. It was found that CDN edge-servers currently have low computational abilities and generally lack GPUs. Most CDNs are designed for large numbers of network connections and not the heavy processing required in running many instances of a game engine. NVIDIA appears to be supporting this view with their NVIDIA Grid aimed at supporting Cloud Gaming and the increased processing power through the addition of GPUs to this hardware.

Chen (2011) defined *real-timeliness* as the total of the following three components of *Network Delay or RTT:* time to deliver player commands to the server and return the matching screen to the client, *Processing Delay:* the time difference between a server receiving and responding to a client command, and *Play-out Delay:* the time difference from when a client receives information for a frame to when it is displayed on the screen.

Latency is one of the most talked about challenges. with the impacts of latency varying due to the differences in available bandwidth for each connected client (Shi, Hsu, et al. 2011). In this situation, being able to dynamically alter the BR via scalable image encoding is one approach that can help maintain responsiveness (Xu et al. 2013). One particular study compared *GamingAnywhere* with *OnLive* and the personal streaming service called *StreamMyGame*. The results clearly highlight how latency impacts the user's experience and therefore acceptance of a cloud gaming system. They also indicate how important latency improvements relate to the support of more users or streams per server and, therefore, making the service a feasible venture (see Table 3). Table 3: Components of Latency

Challenge	Factor
Image Render Time	Server Game Engine Image Construction
Image Buffer Access/Copy	Server Image Data Made Available/Captured
Image Colour Conversion	Server Image Colour Space Transmission Suitable
Video/Audio Encoding	Server Codec Settings and Buffering
Video/Audio Compression	Server Compression Settings
Video/Audio Packetization	Server Transmission Protocol
Transmission Time	Network Distance Traversed
Bandwidth	Network Connection Capacity
Packet Loss/Competing Traffic	Network Quality, RTCP, QoS, QoE
Video/Audio Decompression	Client Decompression Settings
Video/Audio Decoding	Client Codec Decoding Settings and Buffering
Video/Audio Rendering	Client Renderer SDK/Library
Image Buffering	Client Buffering (Double/Triple/Quad)
Transmission to Display Time	Client Transmission to Display Device (HDMI/VGA/DVI)
Display Refresh Rate	Client $30/60/120$ Hz and Response Time of Monitor
User Perception Time	Gameplayer Time to Perceive Results
Input Device Response Time	Client Controller/Driver Input (Wired/Wireless)

LATENCY - SERVER-SIDE ASPECTS

On the server-side the *GamingAnywhere* performance experiments clearly identified that the overall latency was 25 percent of *OnLive's* service (see Figure 11). This was a large difference but given this experiment it forms both a benchmark for future experimentation as well as an example framework on which to firstly establish further data-collection.



Figure 11: Huang's Server Comparison of *OnLive* to their *GamingAnywhere* Framework

It can be seen that there are several areas to improve outside of the game engine component itself. The actual retrieval of the image and conversion to a data format acceptable to the video encoding stage already costs 11 ms. The video encoding was the most substantial time consuming component at 14 ms but this was minimal given that the encoder acts more as a buffer rather than maximising *frame-by-frame* compression. The retrieval of the image from the game engine and conversion to the right colour space, costing 6 ms and 5 ms respectively, is an aspect that could be minimised if the system was built as part of the game engine itself.

LATENCY - CLIENT-SIDE ASPECTS

Although the OnLive client was far more competitive in performance it was still twice as slow as the GamingAnywhere client (see Figure 12). The system still requires 12 ms to go from the incoming data to a completed image displayed on the screen. The video decoding speed for the GamingAnywhere system, at just 6 ms, is considerably faster in producing a single frame. They used frame-buffering, for one frame, which consumed 1 ms while the image construction took almost as long as the decoding at 5 ms. Given this performance, the maximum FR would be around 80 F/Sec which is acceptable for all types of games.



Figure 12: Huang's Client Comparison of OnLive to their GamingAnywhere Framework

The impact on latency can also be changed through how the display of the client system is set up. The use of a VGA or HDMI cable can provide different impacts to latency given the monitor (Pohl 2012). Monitors have varying response times, and when this is combined with the screen refresh rate and the number of buffers used, it can have a dramatic impact to the overall latency measurements. Smart-TVs also have various image processing algorithms to enhance the picture that, in some cases, can be turned off via a *game mode* setting to decrease the TV response time. Disabling any *noise reduction* and *motion smoothing* options will also have the same impact.

Overall the framework offers an interesting structure and performance benchmark for initial developments. For future benchmarking, each of the components mentioned will need to be measured in creating a clear picture of where time is lost on the client.

MULTI-PLAYERS AND ADDITIONAL LATENCY

Multi-player games have an additional layer of latency to consider in coordinating interactions between users before rendering the results for streaming back to gameplayers. This can be addressed through geographically separating participants to reduce this overhead (Choy et al. 2012).

EFFICIENCIES OF MULTI-USER INTERAC-TIONS MANAGED CENTRALLY

By centralising all user interactions, in a MMO world for example, it is possible to complete multi-user interactions in complex environments that may lead to computational efficiencies (Baun et al. 2010). An example may be the pre-calculation of certain game environmental lighting that is not view-dependent.

Any data to do with the user, for example save games and character configurations, no longer needs to be saved to and transferred between devices (C. Huang et al. 2013b). This allows for players to instantly continue a game experience from any device supported without having to ensure that software or supporting data is available. The results also mean that games are often instantly playable from your last point and for single player experiences is identical to pausing and resuming a movie.

CONCLUSIONS

It is clear that the most important topics include how easily you can move a game onto a cloud platform along with the even more important topic of system responsiveness and user perceived quality of the service. The research gives insight to the design of the cloud game engine architecture along with the *GamingAnywhere* system providing a valuable benchmark for development evaluation.

The importance of platforms like *GamingAnywhere* and *LiveRender* enabling better research and benchmarks cannot be understated when large funded research projects, like G@L, have only an ageing collection of research papers left as evidence. The industry context presents quite closed approaches with companies like OTOY, GameFly, and CiiNOW developing private streaming systems. The contrasts of Gaikai's \$380 million sale and OnLive's demise both now apart of Sony and the PlayStation Now service that is continuing to grow.

The bigger picture is how game engines of the future, that sit purely in the cloud, may leverage this position to address the challenges identified in more inventive ways.

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CONNECTING COMPANY AND CONSUMER EXPECTATIONS IN GAME DESIGN: A FOOD SECTOR CASE

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KEYWORDS

Advergames, consumer preferences, food industry, game design, gamification, mobile games, monetisation.

ABSTRACT

Advergames and gamification represent a promising means of product differentiation for food companies in an oversaturated marketplace, as they enable engaging consumers with brands in a playful and fun way. This need of food companies to find novel gamified ways to lure new customers and involve existing ones has implications for game designers who are considering the revenue generation options of their game. This paper aims to develop ideas and design guidelines for games developers to collaborate commercially with companies interested in using games in brand engagement, with a special focus on the food industry. As a result of combining food company interviews and an online consumer community research, we present seven themes of importance that were found, and provide the overall descriptions of how they affect the design process of the game and how they could be taken into consideration during it.

INTRODUCTION

The biggest challenge food companies are facing in 2017 is how to differentiate their product offering in an oversaturated marketplace, reports FoodDive in its newsletter for food industry professionals (Heneghan, 2017). Advergames and gamification represent one promising way to achieve such differentiation, as they enable engaging consumers with brands in a playful and fun way (e.g. Celtek, 2010). This need of food companies to find novel gamified ways to lure new customers and involve existing ones has implications for game designers who are considering the revenue generation options of their game. If food companies realise the benefits of employing gamified marketing content, there is potential that they would adopt it in a strategic perspective, regularly engaging consumers with the brand. In such case, even long term prospects for collaboration between game developers and food companies may exist.

In this paper, we aim to develop ideas and design guidelines for games developers to collaborate commercially with companies interested in using games in brand engagement, with a special focus on the food industry. With this aim, we first discuss extant theory on game design relating to monetisation possibilities and present examples of gamerelated food marketing campaigns. Secondly, we conduct a comparative analysis on food companies' expectations and consumer wants on gamified contents with regard to food products and related services. Our analysis is based on qualitative data and it provides insight into how consumer and industry expectations match, and where there is a need for better understanding.

PREVIOUS RESEARCH AND PRACTICAL EXAMPLES OF GAME DESIGN IN FOOD INDUSTRY

As free-to-play (F2P) games in mobile markets have gained much ground, it has become necessary for game developers to consider the possible business models of the game already at an early stage of development in order to compensate for the reduction or disappearance of the upfront sales revenue. Currently, the main monetisation pathways for developers are selling in-game purchases and displaying short video advertisements that players can choose to watch in order to receive resources needed in the game (Hamari et al, 2017).

Indeed, advertising in games and with games has been discussed much in previous literature. Terlutter & Capella (2013) build a comprehensive framework based on previous literature for analysing advertising in digital games, covering in-game advertising, advergames and advertising in social network games. In their framework, they illustrate the individual factors influencing the psychological responses and behavior outcome in players toward the brand. According to Lewis & Porter (2013), the extent to which consumers consider in-game advertising appropriate or realistic varies between different types of games. In their research comprising 100 undergraduate students, sports and racing/driving games were considered by far the most appropriate for in-game advertising, whereas action/firstperson shooter games and strategy/puzzle games were considered particularly badly suited for it. Furthermore, there were significant differences between the sexes in the way they experienced in-game advertising: women were more likely than men to regard it as increasing the realisticity of the game, whereas men were more likely than women to consider it annoying or obtrusive (Lewis & Porter, 2013). Also, in-game purchases (or in-app purchases in mobile markets) have been studied previously (see Hamari, 2017 for review). Hamari (2017) expanded this field of research by studying in-game purchases from the perspective of how the game was designed to motivate the player to make them.

From the historical perspective, game design in F2P games can be seen as a contemporary manifestation of "Pay-per-Play" (PpP) design for coin-op games of the arcade era of gaming (Deterding, 2016; Rollings and Adams, 2003). In between these periods of PpP and F2P, sales in physical stores and to a certain degree in digital stores represented the main sources of revenue. The game design of this era could be seen concentrating on generating content that was engaging and fun for the players, so that they were willing to purchase the game from stores (Hamari, 2017). In that time, monetisation relied on getting players to purchase the game, contrary to the more current F2P model where games create opportunities for microtransactions in the form of in-app purchases, downloadable content, and such. The F2P model and microtransactions are not limited only to mobile games. Successful PC games such as World of Tanks and League of Legends are also F2P games that contain microtransactions. Formerly, Diablo 3, a non-F2P PC game, featured an auction house, where players were able to trade items with realmoney, and the game's publisher Blizzard would receive a commission on each transaction.

At the outset, we conducted a brief overview of the types of marketing collaborations that had been carried out by the food and gaming industries. Through online data search, we found examples of games and food product marketing in ingame product/brand placement (e.g. Zool and Chupa Chups), in-game product placement with in-game effect (e.g. Uncharted 3 [multiplayer], Metal Gear Solid: Peace Walker), external brand tie-in with in-game effect or special access to content (e.g. Call of Duty, Gears of War, Destiny), accessibility to product through game (e.g. Everquest II in collaboration with Pizza Hut), and advergames (e.g. KFC Snack in the Face, BK Sneak King). Many of the cases could be seen as food companies experimenting with collaborating with gaming brands in single marketing campaigns. The primary examples that were found of the use of games in food marketing on a more strategic level were related to the collaboration of soda and energy drink brands, such as Mountain Dew, Red Bull and Monster Energy, with action game franchises such as Call of Duty. Thus, there is an undeniable chance for further development.

METHODS

The data on companies' views were gathered by interviewing marketing managers of five of the largest food companies in Finland. The interviews followed a semi-structured format and concentrated thematically on games and gamification in the marketing context. In total, we had 12 questions in four themes: the state of gamification in marketing (3), the goal and target groups of gamified/digital marketing (5), collaboration and co-creation with other companies (2), and a miscellaneous theme for international campaigns and collection of user data (2). Each of the interviews lasted approximately an hour.

The first two themes formed the core of the interviews. The state of gamification theme was set to unravel what the companies in general know and think about gamification in marketing, what their vision for it is, and what kind of experiences they have about it and other "novel" means of marketing (e.g. social media, games and other digital channels). In the second theme, we probed for their opinions about the goals set for the gamified marketing efforts, especially in a digital context and to which product and target

groups they saw it as a relevant tool. Within this theme, gamification in the marketing context was also discussed on a more general level in order to find what kind of potential goals and roles the marketing managers saw for it.

The consumer data were generated in a netnographic consumer community during four months in autumn 2016. Netnography refers to ethnographic research conducted in online environments, thus relying on typical features of participants observation (Kozinets 2015). For instance, as suggested in ethnographic game studies the researchers were active and sentient participants in the social interaction (Brown 2015). During the online community, informants completed two kinds of tasks; 1) they kept private diaries (including written descriptions and self-produced pictures and films) on their mundane snacking practices, and 2) they performed 33 social assignments that covered various areas of snack consumption, digital game-playing and social media usage. In this paper, the analysis focuses in three of the social assignments participants conducted within this online community. In these three assignments, the informants discussed gamified campaigns, advertising appearing in digital games, applications and in channels of social media, and ideas for gamified usage of mobile phones in grocery stores. This yielded 175 pages of data.

The netnographic research was divided into three smaller online communities in order to ensure the formation of group cohesion. In each of the groups, there were 20 to 35 participants. The research question drove the recruitment of the participants from an existing consumer panel of 15 000 Finnish consumers (provided by a market research company). In total, there were differences in how, what type and how often they played digital games. Similarly, the manners and preferences of food consumption varied across the sample. Furthermore, the social demographics of the sample varied, for example including consumers from 18 to over 65 years old, having varied occupations, living all over Finland and having different kinds of households.

These two data sets were first analysed separately searching for key themes in each. The second round of analysis consisted of making comparisons between companies and consumers views in order to find out differences and similarities in between them. In the following, we discuss the main findings of both views.

FINDINGS

As we set out to assess food companies' views and marketing practices that may have an effect on gamified campaigns, the first matter to surface was brand compatibility. The companies expressed that any gamified marketing campaign would have to be in line with the major brand outlines of the company. For example, in the case of marketing taking place in collaboration with an existing game franchise, this would imply that its target groups and mindsets should be in accordance with those of the company. Brand compatibility is also of importance in the sense that the gamified campaign, possibly comprising e.g. graphical changes to the product, should not obscure the familiarity of the promoted brand or product in order to ensure that existing consumers will continue to be able to recognise the product on store shelves.

Similarly, consumers emphasised that in-game advertisements, advergames and other forms of gamified marketing should be in line with the brand of the company in question. In this case, consumers took positive look on such campaigns, seeing even that acquiring information of the brand in question via marketing could be useful when making consumption choices. However, there are limitations in acceptance of commercial messages as one our informants highlights, besides compatibility also the amount of marketing matters: "If there are too many ads, players will choose another game to play, and if the content of the ads mismatches with the game's content, parents are going to prohibit their kids from playing it" (female, 36-45 y). Indeed, it seems that the commercial material within games needs to be included into the game thoughtfully, and if watching advertisements takes too much time from playing, there is danger that player will not play the game again: "I don't mind if there are advertisements when they are included in the game in a subtle fashion. For example, in sports games, you can see advertisements in the same way as when standing in a real sports field. I find such advertisements annoying that interrupt playing for a too long time." (male 36-45 y). Even though commercial elements need to compatible with the brand in question and included smoothly within the actual game, also the transparency of the commercialisation of games seemed to be a demand.

Second, food companies commonly emphasised a focus on positive values. As consumers may be rather critical towards brand messages, the gamified solutions could focus on the public good, sponsored by brands. Thus, all the food companies suggested that their gamified campaigns should be educational and promote physical exercise and a healthy lifestyle. A gamified campaign should not convey a message that companies promote passiveness and encourage people to lie down on a couch in front of their television sets with a mobile phone in their hand. The views of consumers aligned with those of the companies. In fact, consumers were rather innovative and willing to come up with new ideas, for example, for mobile applications that would support consuming healthy, local, domestic and organic food as well as those preventing food becoming waste. "Such an app could be nice that could scan the barcode of a product and you'd get detailed information about it, including its origins. You could also choose what ingredients and countries-oforigin you'd like to avoid. This would make it easy to see whether a product belongs to your shopping basket or not.' (female 26-35 y). Similarly, ideas inspired by Pokémon Go supporting exercising emerged. It was also noted that gamified campaigns themselves should not produce excess waste, for instance in terms of encouraging consumers to consume more than they need.

The third area that was regarded as important was the gamified marketing needs to be in compliance with the specified target group, as positioning and targeting the

selected segment act as a basis of most marketing actions nowadays. However, the segmentation is not necessarily based on stable categorisations, such as age. Instead, what consumers are interested in, like health-oriented lifestyle, may define a target group. Consumers seemed to agree with companies that any gamified marketing should be specifically targeted towards their consumption preferences, and any mistargeted promotion is a source of irritation. Sometimes, consumers had so particular consumption habits that even they did not truly believe in the chances of receiving perfectly matching gamified solutions: "I could consider an application that would recommend various recipes that are tailored specifically for my personal limitations and ethical choices. However, as I'm rather demanding in this respect, I don't think the marketing people would like it :D" (female 36-45 y). Consumers wished often that they could decide themselves, for instance, what sort of commercials to watch while playing or using applications. "Games and applications that forcefeed advertisements could be developed so that it would be possible to choose areas of interest in the options. Based on them, you would receive advertisements only about topics that interest you. This way, they might not irritate so much." (male 36-45 y). This appears particularly in line with companies' views how segmentation is no longer conducted according to certain stable consumer profiles, but consumers' interests (and thereby segment) may shift over time. However, when it comes to children's consumption and playing, also stable segmentation criteria, such as family life cycle applies. For instance, applications for making shopping for groceries with the kids easier and more fun were desired, as well as tight restrictions for in-game advertising within children's games.

Fourth, based on the views of food company representatives, physical presence has played an important role in their marketing efforts. In the food industry, it is still commonplace to emphasise physical presence in different venues, such as fairs and gyms, where the companies usually conduct consumer tastings of new products. Even though tastings per se did not come up in consumer data, there were different ideas through which companies could enhance their presence through gamification, especially in grocery stores. For instance "I could use the mobile phone to receive information about offers and food tips of that particular store, in which I currently am. For instance, store-specific offers and advertisements could run on the screen while I'm doing my shopping.", describes one of our informants (male 36-45 y). Similarly, advergames could be applied to lure consumers to visit particular venues when food companies are physically present.

Fifth, the interview respondents underlined the importance of product accessibility. This implies that their products should preferably be available in all imaginable places where consumers could desire their product. The company respondents saw potential in games supporting the accessibility of their products. Also, consumers considered the accessibility of food products important. In addition, it seems that it is not enough that certain products and brands exist in several shopping locations, but consumers need to find them there. Many consumers presented ideas for different kinds of grocery store navigators or maps: "Such an application could be fun, that it'd have a map of the store and it'd instantly guide you to the product you're looking for." (female 18–25 y). Thus, the accessibility and finding the needed product appeared a commonplace problem that would call for a gamified solution both in familiar and unfamiliar shopping places.

Sixth, food companies saw the improved personalisation of the marketing message at specific target groups as a necessary development in food product marketing. This would preferably imply that consumers are able to define themselves what kind of messages they would be willing to receive. This kind of development would be needed in order to make the communication more relevant to the consumers, and avoid them from blocking or simply ignoring the communication in its entirety. Indeed, in order to make, for example, the shopping experience smoother, consumers were willing to share information about their shopping history, consumption preferences, locations and diets. For instance, consumers hoped to receive recipes of their favorite food products or products on sale while passing them by in grocery stores. Consumers also had some personalised wishes for applications, such as those that would inform them about how crowded stores are, when novelties arrive, prices of all the products, which is the shortest queue for cash register, and which products are available: "An application that would tell you e.g. in which stores certain products can be found. [...] Even if it wasn't possible to get a real-time status about the availability, it would be great to see whether a certain product is a part of the store's product assortment, when it was available for the last time, or when it's coming back to stock." (female 36-45 y). Consumers had noticed existing gamified targeted marketing communication, e.g. how searching something in Google generates specified offerings, how games include (ir)relevent product placement or other commercial elements, and how grocery stores had sent them e-coupons for products on sale. However, their reactions varied. In some occasions, these gamified contents were welcomed, whereas other times they might just cause irritation, especially when targeting or timing fails: "It doesn't irritate as long as I'm still interested in it, but after I've already made the purchase, you wouldn't bear to watch related advertising any more. You feel like screaming to Facebook, dunce, that's water under the bridge." (female 56–65 y).

Seventh, food industry representatives indicated that gamified campaigns could open possibilities for the retrieval of user behaviour data that could be utilised to segment specific kinds of consumer groups by combining information about the users' gaming habits and other online behaviour. This could make it possible to retarget marketing to different consumers. Through the collection of longitudinal user data, it could even be possible to deploy self-learning market segmentation, which would support the optimisation of marketing actions. Many times, consumers saw self-learning systems on their usual consumption patterns as aiding their daily routines: *"It would like that the phone could provide me the kind of offers that interest me. It would have to be*

based on profiling, because I don't want to be offered, say, baking products, as I never bake. The phone could offer new products that are compatible with my profile, e.g. a new protein bar that has been launched, or a low-carb quark." (male 36–54 y). Even though consumers were surprisingly willing to share information about themselves for commercial purposes, it was pondered and resisted: "Even if it would activate me to buy, I don't know if I want to be known so much about (purchase data + location data etc.). It could give reason for a negative reaction." (male 36–45 y).

DISCUSSION

Our goal was to understand how brand marketers from a specific domain (food industry) perceive games and gamified applications with regard to their products and brand, and, on the other hand, what kind of attitudes consumers have towards them. This was carried out in order to

- A. gain insight into the opinions of marketing managers of food companies on games and brand marketing,
- B. gain insight into consumer opinions on games and the marketing of food products,
- C. find connections and differences between the preferences of these groups, and
- D. connect these to the monetisation planning in game design for the mobile market.

As a result, we present design guidelines for how game design could facilitate game developers to form mutual value-creating customer relationships with food companies, e.g. in order to offer brand awareness for them through games. We focus especially on how game design could help building customer relationships and brand awareness in (adver)games and game-like concepts in mobile markets. The following table 1. presents the seven themes that companies and consumers had in common, and how they could be taken into consideration during the design process of the game.

Ineme	Companies	Consumers	Design considerations
	Congruity between		
	game IP and food brand,	Mismatch between game	Advertising as part of
	requiring also graphical	and ad, or too many ads	the game and visual
Brand compatibility	confirmity	drives away	design
	Connection with		
	educational values and	Emphasize personal values	
Focus on positive	promotion of exercises	sucha as ethical and healthy	Genre and values
values	and health	choices	presented
	Especially with lifestyle	Prefer actions that conform	Game analytics
Compliance with	and consumption	with their lifestyle and	combined with
target group	preferences of the client	consumption preferences	personal preferences
		Interested on tips and	Co-operation with
	Emphasis on product	information related to the	advertiser partner, and
Physical presence	tastings	location where they are	usage of analytics
Product	Broad (physical)	Interested on finding the	Co-operation with
accessibility	availability	product(s)	advertiser partner.
		Positive view on the	
Improved		advertisements based on	
personalisation of	related to compliance	analytics, but annoyed	
marketing message	with target group	when they are outdated	Improved analytics
	Interests are in lifestyle		
	and consumption	Willing to give information,	
Retrieval of users	preferences in longer	but also resists exploitative	Option to opt-out or
behavioural data	timespan	use	opt-in

Table 1: Opinions of companies and consumers linked with game design process options

Two of the first themes, "Brand compatibility" and "Focus on positive values" affect the whole design process from start to end. These themes need to be taken into consideration when designing the game's graphical look and the kinds of moods and values it conveys to the players. Also, the game's s genre and mechanics might contract with these themes. For example, if the game mechanics emphasize combat and fighting, it's hard to avoid the notion of violence, which is not usually connected to these themes. These design decisions need to be discussed with the partner that is using the end product in its marketing efforts.

Four of the themes were closely connected in terms of their relationship to designer activities. "Compliance with target group", "Physical presence", "Product accessibility" and "Improved personalisation of marketing message" all affect the design of the service or a game, especially regarding what kind of a data should be collected and analysed, and how the game should utilize the data. Beside the data analytics, these themes also require close collaboration with the company that is using the game or service as their marketing tool.

Our final theme is labeled as "Retrieval of users' behavioural data". In our study, consumers in general wanted to have more personal service or marketing, but they also wanted to protect themselves. To ensure that consumers can protect themselves from predatory practices, they should have ways to either opt-in to personalised service or to opt-out from it when they so wish. This could be seen as contradictory to the previous themes, but the third option, no choice given, could mean that some customers will not to use the application at all. It is worthwhile to notice that even the users opting-out are contributing to the data pool during their stay, whereas non-users naturally are not.

Based on our research, there are clearly great possibilities for mutually beneficial commercial collaboration between game developers and the food industry. Our results give direction for game developers to be able to present a greater value proposition in the eyes of potential food company customers. Further studies are needed of the implementation of the design considerations described with regard to the food industry in particular.

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CO-DESIGNING A GAME-BASED LEARNING PLATFORM FOR ACTIVE AGEING : THE CASE OF 'JUMP'

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Co-designing, Game-based learning, Active Ageing, Player, Prototyping, Games

ABSTRACT

Current advances in game studies and the emergence of games in non-entertainment contexts have led to an increased need for involving the end-users in a collaborative design process and that way linking the activities of playing to daily life context. The aim of this paper is to propose a framework for involving end-users in game design for active ageing and healthy lifestyles, based on an empirical study that was carried out with thirty-three adult learners aged 50 and over in the co-design of a game-based learning platform. The field research deployed an array of longitudinal methods, including surveys, group discussions, and participant observation. Findings suggest that such strategies as contextual inquiry, scenario building, future workshops and cooperative evaluation have revealed to be suitable for (a) aligning the learning goals and behavioral changes to game missions; (b) balancing the challenges to players' skills; and (c) defining the type of game conflict and resources to be used without compromising the view of digital games as an art form and creative authorship.

INTRODUCTION

The proliferation of digital games and the use of game design techniques and elements in non-entertainment contexts have led to an increased need for empathizing with the player and, therefore, understanding the player's context and the potential use of digital platforms to assist daily-life routines.

Although a considerable amount of literature has been published about Co-designing in games (e.g. El Mawas, 2014; Rice, Cheong, Ng, Chua, & Theng, 2012; Vaajakallio & Mattelmäki, 2014; Veloso & Costa, 2015) and their use in health-related changes and lifestyles (e.g. Baranowski, Buday, Thompson, & Baranowski, 2008; Lewis, 2007; McCallum, 2012; Papastergiou, 2009), there is much less information about the use of co-designing techniques applied to games that aim to encourage active ageing (Costa & Veloso, 2017).

Active ageing is defined by the World Health Organization (2002, p. 12) as "[...] the process of optimizing opportunities

for health, participation, and security in order to enhance the older adults' quality of life as people age." Given this definition that extends the health-related aspects that include both nutrition and physical, cognitive and social health, it is also necessary to encompass the variables of security and participation in society, when designing digitally-mediated approaches that aim to foster active ageing (Costa & Veloso, 2015). In addition, assessing the use of technologies in daily life and its impact on citizens' quality of life demonstrate an emerging challenge to the Human-computer interaction field by going beyond the mere aspects of efficiency, effectiveness, satisfaction or user/player experience.

The aim of this study is twofold:

- 1. Propose a framework for involving the end-users in game design for active ageing and healthy lifestyles, based on an empirical study that was carried out with thirty-three adult learners aged 50 and over in the co-design of a game-based learning platform;
- 2. Design a prototype of a game-based learning platform for active ageing that takes into account the co-design framework that is proposed.

The paper is structured as follows: Section 'Co-designing digital games' provides a brief overview of the importance of co-design and its relevance to game studies. The Method section covers the participatory design process, data collection, and ethical issues. Then, the framework for involving end-users in the game design process is proposed and its application in a game prototype is discussed.

CO-DESIGNING DIGITAL GAMES

For many years, game design has only been tested during the playtesting and post-production phases, without involving the end-users in the early design stages of the game development cycle (Costa, 2013; Costa & Veloso, 2017; Veloso & Costa, 2015).

In fact, co-design can be central to build empathy and establish a conversation with the end-users. If in the 60s and 70s, much of the development was product-oriented and the interface was quite neglected, in recent years jointly activities between users and developers have emerged as process-oriented techniques (Floyd, Mehl, Reisin, Schmidt, & Wolf, 1989; M. J. Muller, 2003; M. M. J. Muller & Kuhn, 1993) for fostering inclusivity, user experience, usability and 'look and feel'(Namioka & Schuler, 1993).

The term 'Co-design' or 'Participatory Design' refers to a set of techniques that can be used to actively involve the endusers in the design process (M. J. Muller, 2003; M. M. J. Muller & Kuhn, 1993). According to Abras, Maloney-Krichmar, and Preece (2004), it is a form of user-centred design that involves users as partners in the design process by fostering communication, teamwork, freedom to explore new ideas and thus providing new insights, different perspectives, and knowledge (Sears & Jacko, 2007). These techniques follow the philosophy "for, with and by the users" (Parra, Andrea, & Giacomin, 2012).

Considering the fact that games can be seen as an art form (Costikyan, 2002) and the team's creative authorship plays an important role in the development of such digitallymediated artifacts, there is a need to balance the level of involvement of the end-users and the creativity of the design and development team. Hence, there are different types of user participation that can occur in co-design, as pointed out by Lee (2008):

- 1. Public participation, in wich designers and experts, make attempts to assess the users' cognitive models with partial user involvement;
- 2. Design participation, in which designers and users are both equally involved in the design process;
- 3. Community participation, in which users are totally engaged in the design process and designers are only advisers without much interfering;

Depending on the level of user involvement in the design process, the following techniques can be used in order to assess users' sensations, knowledge, rememberability and expression (E. Sanders, 1999; E. B. E. Sanders, 2002): (a) thinking techniques (e.g. collage and brainstorming); (b) mapping and visioning techniques (e.g. low-tech prototypes, mock-ups); (c) techniques for understanding feelings (e.g. ethnographic, cooperative evaluation); and (d) techniques for storytelling and dreaming (e.g. strategic visioning, scenario building, games, stories, and drama).

METHOD

Setting and data collection

A participatory action research (PAR) was carried out and data was collected from March 2015 to December 2016 (2hour session per week). According to McIntyre (2008), this type of research demands commitment to understanding a certain problem and engagement in the search for a solution that is beneficial to society. In addition, the subjects of the research are strongly involved in a cyclical study, building alliances with the researcher (McIntyre, 2008). This study was carried out in the participants' natural context (University of Third Age) and included participant observation and group interviews.

In ensuring internal validity, the following strategies were used: triangulation of multiple sources of data collected (i.e. field notes, questionnaires, document analysis, and repeated observations at research sites).

The participants

The initial convenience sample involved in the design process consisted of 37 participants. The criteria for selecting the subjects were: (a) being aged 50 or older; (b) know how to read and write; (c) voluntary participation, and (d) interest in learning. Four participants did not satisfy the selection criteria. One did not fit within the age bracket whereas three did not complete all sessions. Therefore, the final convenience sample consisted of 33 participants. Considering the gender of the participants in the co-design sessions, sixteen were male (48.5%) and seventeen were female (51.5%). The average age of the sample was 67 years old (SD=7.06, minimum = 55; maximum = 82) and the majority had between 10 and 14 years of schooling.

We also involved a group of four experts in the fields of gerontology, psychology, education and social work, who validated the materials and surveys.

Finally, a group of 40 adult learners (including 12 of the Co-Design group) tested the game-based learning platform and discussed with the researchers the main design determinants to develop game-based learning platforms for active ageing, through cooperative evaluation. Considering the gender of the participants in the evaluative sessions, eighteen were male (45%) and twenty-two were female (55%). The average age of the sample was 71 years old (SD=6.47, minimum = 57; maximum = 89) and the majority had between 10 and 14 years of schooling.

Ethical issues

This study is part of the research project SeriousGiggle – Serious Games for triggering active ageing and healthy lifestyles (SFRH/BD/101042/2014), which has been approved by the Ehics Committee of the University of Aveiro (Resolution n.3/2015) that safeguards, among other things: (a) the informed consent of participants aged 50 and over, (b) voluntary participation; (c) involvement of the research team in the process; and (d) that the risks of participating in the study do not outweight the risks associated to the risks with the participants' daily lives.

A FRAMEWORK PROPOSAL

As shown in Figure 1, different stakeholders and Co-Design techniques were used in different phases of the development cycle of the game 'JUMP.' We divided these phases into:



Figure 1. Co-designing process of the game living system (Framework proposal)

- 1. Co-design Tools Used For The Game Embryo. At this phase, the process of ideation occurs, the experts in different domains validate the learning content and the players are strongly involved in the process, in order to meet their context and motivations. The co-design strategies used in this phase were Strategic visioning and future workshops, Scenario building, and Contextual inquiry.
- 2. The Lab Microscope. At this phase, personas are used based on the previous experience during the 'Game Embryo.' The users are not directly involved and the team's creative authorship is stimulated. Nevertheless, the contributes from the game team take into account both the end-users' context, values and requirements and the established learning goals articulated with the group of experts.
- 3. Verifying the game DNA. At this phase, a game prototype is presented and tested by a large number of adult learners, representative of the target group. The participants are asked to reflect on the design product, encouraged to criticize it and discuss the way the game

can encourage active ageing, using cooperative evaluation as technique (Dix, Finlay, Abowd, & Beale, 2004).

The co-designing tools were necessary to design the following domains of the JUMP game: (AC) Active ageing, lifestyles, and changes in behavior; (GT) Game techniques and game elements and (L) Learning.

In "Active ageing, healthy lifestyles, and changes in behaviour (AC)", contextual inquiry, expert review and strategic visioning and future workshops were used.

The use of contextual inquiry as technique had the purpose of assessing the participants' current practices, motivations and associated experiences to active ageing and changes in behaviour when learning about it. Although the contextual inquiry interview tends to be one-to-one (Holtzblatt, Wendell, & Wood, 2005; Namioka & Schuler, 1993), we used group discussions complemented with observation. The process was guided by the three main steps: (a) understand the participants' context; (b) dialogue with the users (partnership and interpretation); and (c) focus on the study (Holtzblatt et al., 2005; Namioka & Schuler, 1993).

Expert review was used to review both learning content relative to the different domains of Active Ageing (Health, Security, and Society) by assessing the quality of the learning goals, the content covered and its relevancy to Active Ageing, the risk of multiple interpretations or ambiguity in the use of terms, the language used, among other criteria.

Relative to the use of strategic vision and future workshops, this technique was transversal to all domains of the JUMP game (AC, GT, and LP), during the game embryo phase. As advocated by Sanders (1999), the aim of this strategy is to facilitate people's expression of their own ideas and dreams, through collaborative activities, visual cues or discussions and, therefore, we followed the steps of this technique, as proposed by Namioka and Schuller (1993): 1. Critique in which several themes and learning practices are introduced and discussed; 2. Fantasy in which participants have the freedom to explore new ideas and concepts and; 3. Implementation in which the ideas are converted to goals and they are adjusted to the existent resources and time.

In general, these techniques were used to find the users' concept of active ageing , preferred activities, and skills to practice. The participants were asked in each session to complete the following sentences: "Today I know..." and "I'd like to know more about..." The main aspects that were associated with active ageing were (Table 1): Functionality and contribution to society, health, willing and quality of life.

Table 1: Effects Matrix for coded statements

Definition of Active Ageing (N=33 coded statements)			
Themes	Ν	Exemplar quotes	
Functionality	16	'Practice different activities – <i>e.g.</i>	
&		sports, learning activities' – P1	
contribution		'Practice certain activities – either	
to society		physical or mental.' – P4	
Health	9	'Overcome the lack of clarity and	
		consistent definitions.' – P2	
		'Walk in life with adequate health	
		conditions.' – P6	
Wiling	4	'Have the desire to be helpful and	
		learn.' – P3	
		'Willing to live with less worries.' –	
		P29	
		'A man only ages when dreams	
		become wailings' – P36	
Quality of life	4	'Ageing with quality of life' – P8	
		'Living with quality in the post-	
		employment phase of life' – P10	

The motivation to practice both physical and cognitive exercises was to prevent health problems. The participants also found that support networks and simulations with the exercises to practice would motivate them to give it a try. Regarding physical exercises, the participants pointed out that breathing exercises and balance were the most needed and when surveyed about what they would like to be reminded in their daily-life routines, they stated their motivation to obtain information relative to nutrient-rich foods and how often they forget to drink water (the problem of dehydration).

The participants also expressed that traveling was their favourite activity and the skills they wanted to practice were: problem-solving, strategy, memory and attention, logic and reaction time, critical thinking and collaboration.

In "Game techniques and game elements", scenariobuilding, contextual inquiry, and strategic visioning and future workshops were used.

One of the main purposes of using scenario-building was to understand how the end-users solved problems. Firstly, they analyzed the problem and the rationale behind possible actions, then they defined a preventive plan/action and divided it into a set of strategies in order to achieve possible solutions. A one-way solution was not seen as interesting as multiple possible solutions to one problem. The following scenario was posed to the co-design group: "People are not aware of their rights. As a policy-maker and citizen, it is your mission to solve this problem." In two groups, participants involved in the co-design process have had about 10 minutes to discuss the problem and how to solve it. Figure 2 shows that solutions proposed to this problem were 'Encourage the search for information', 'Create awareness of NGO's interventions' and 'Retain human rights' by simulating a scenario, in which the player can interfere and change it.

Not being aware of own rights (lack of purpose/life in community)

Encourage the search for information Create awareness of



Educate to human dignity (Perceived threats to human security)

NGO's interventions Retain human rights

Simulate a scenario in which we have to interfere

Figure 2: Illustrative example of the application of the problem-solving, using scenario-building (Solution presented by the Co-design group)

Observation and contextual inquiry were used in order to understand the end users' interaction patterns. We observed that these participants were non-familiar with game conventions and use the cursor to move and point whereas the keyboard is solely used to write. Point and click interactions were expected.

The same techniques were used to understand the main requirements relative to the narrative form, game resources, and other game elements. Players stated that the fairest rewards to win in a game are those relative to someone's progress in the story and mission achievements when compared with other types of rewards (e.g. rewards relative to the exploration/discovery of places, rewards linked to social activities or rewards linked to the learning content). History-related narratives and history-based characters explored in visual novels can be an added-value to the gameplay experience as these participants like to establish a link between the learning content with history, cultural heritage and/or arts.

In terms of the challenges' structure, multiple levels for the same challenge should be provided. As these participants read all the information before starting something new and then they like to discover by themselves, game instructions/rules should be presented at the beginning and then remember the rules with contextual help/tips in the middle levels and encourage 'discover-it-yourself' in the final levels. These observations are interconnected with the purpose of understanding 'the learning context/preferences' presented in the 'learn' domain.

Finally, in "Learning", contextual inquiry, and expert reviews were mostly used in order to understand the end users' motivation for learning, define the learning goals and understanding the learning context/preferences. As a consequence, participants have revealed that their main motivations to learn were: foster life-long learning (maintain the mind active) and improve self-esteem, selfconfidence, cognitive capacity and personal fulfillment. They also understand better if analogies are established with previous knowledge (scaffolding – level) and images are presented (aesthetics).

Collectively, the application of these techniques in the different phases and domains of a game-based learning platform enabled the co-design of the digital game 'JUMP.'

The Roadmap to Co-designing games

As aforementioned in the framework proposal, the roadmap to Co-designing games can be divided into the following phases: The Game Embryo, The Lab Microscope, and Verifying the Game DNA.

The Game Embryo covered the following themes: Active ageing, healthy lifestyles and changes in behaviour; Learning; and Game techniques and Game elements.

In terms of 'Active ageing, healthy lifestyles and changes in behaviour', a group of experts were firstly involved, aiming at defining the content sessions that would be subjected to discussion with the participants. They were given the materials and a form to assess the quality of the learning goals, the content covered and its relevancy to Active Ageing, the risk of multiple interpretations, among other criteria.

A group of 33 adult learners at a University of Third Age were then involved in order to discuss the meaning of active ageing (Table 1) and the implication of designing solutions to encourage active ageing. The plan of sessions were divided into the following activities: Presentation of the Research Project, Debate on Physical Activity for active ageing; Debate on Nutrition for active ageing; Debate on Cognitive activity; Debate on the Sense of Security; Debate on Participation in society; Debate on the process of Learning; and Interaction with Information and Communication Technologies. The participants' context was also observed on-site in a 2 year-period, using field notes, group discussions, and questionnaires.

The same process occurred relative to the theme of 'Learning' with the purpose of understanding the end-users' motivation for learning, defining the learning goals, and understanding the learning context/preferences.

For the game techniques, the observation was used to analyze interaction patterns; group discussions, and surveying were used to assess the narrative form, game resources and game elements; and scenario-building was used in order to understand how the end-users solve problems.

After this iterative process of the 'Game Embryo', the next phase was the 'Lab Microscope.' In this phase, the game prototype based on both the team's creative authorship and a set of personas that took into account the data collected during The Game Embryo.

Finally, verifying the Game DNA involved playtesting with a larger group of participants. The participants were given a list of challenges and discussed both the game strengths and weaknesses or suggestions for improvement.

JUMP: A CO-DESIGNED GAME-BASED LEARNING PLATFORM

The digital game 'Jump' has the purpose of demystifying ageing bias and encourage a positive attitude towards the ageing process, through active ageing and healthy lifestyles.

The game storyline is: "Sul, the fisherman of the city, is tired of getting stuck to a routine that he never got used to. Depressed and isolated, Sul has to face the storyteller Nubel, who forces him to a time travel experience, in order to recover values and a significant meaning to his own life."Although this storyline is a result of the team's creative authorship, we offered the possibility to travel to different places as game activity (Figure 3), as the participants pointed out this to be a favourite activity during the co-design process. Therefore, time traveling involved the following scenarios: 1) Paris, 1948; 2) Hizen, 1709; and 3) London, 1895.

In addition, visual novels are presented as cutscenes (Figure 4) and the way to advance in the narrative can be either through a click or key pressing.

When the players choose 'Paris, 1948' (Figure 5), the missions related to human security and human rights are introduced. This era was chosen in order to create awareness of the role of institutions in human rights as discussed during the co-design sessions, through the use of history-based symbols and characters (e.g. Palais de Chaillot, Eleanor Roosevelt) and history-related narratives



Figure 3: Game Menu - Players' Journey to different places



Figure 4: Example of a game cutscene



Figure 5: Paris, 1948 (Palais de Chaillot)

This game level contains a Word Soup with different threats to human rights and a minigame that consists of associating different types of human rights to a set of images randomly presented [Retain Information/Human Rights, Encourage the search for information and Stimulate the Players' attention].

In Hizen, 1709 (Figure 6), missions related with physical and cognitive activity are introduced. This era was chosen in order to discuss the importance of controlling the body and the mind through the art of being a Samurai.

The minigames used had the purpose of training strategy (Figure 7) and simulating physical exercises (Figure 8). These minigames had different levels in order to get the player familiar with the challenge and then foster a 'discover-it-yourself' attitude. The discourse used in the game is also aligned with the end users' main motivations to play: 'Prevent health problems.'



Figure 6: Hizen, 1709 (Hizen Torii)



Figure 7: Minigame - Training Strategy



Figure 8: Minigame - Simulate physical exercises

The progress in the game is based on the mission achievements (Experience bar), the amount of water drunk (Water bar) (Figure 9) and progress in the story (Screen at the end of each scenario level with a ticket and the points achieved).

Finally, London 1895 introduces a set of missions related to Nutrition and Participation in Society. This era was chosen in order to experience some scenarios of malnutrition and violation of basic human rights. This level embodies the following minigames:

1. Get medicines to overcome the lack of nutrients (minigame) (Figure 9): Sul has to talk with Thomas Richard Allinson about the reasons of malnutrition in poor children, who work in the factories. The main goal is to find food rich in a certain vitamin, aiming at producing the best medicines to 'help in vision and cell

growth', 'function of the nervous system, blood, muscles and heart', 'prevent cataracts and relieve eye strain', 'repair DNA', 'help to alleviate anxiety and depression', among other scenarios.

2. Remain unnoticed in the factory of Mr. Atlas and rescue a group of children from labour work. Sul has to find an uniform in order to be unnoticed in the factory. The uniform is in a container mixed with other false containers. In the false containers, there are the bacterias of the deadliest diseases in that age – tuberculosis, cholera, and tifo. The main objective is to remember where the container with the uniform is when the containers shuffle.



Figure 9: Minigame - Nutrients

Overall, the design strategies of the game 'JUMP' were based on the co-design techniques previously mentioned in 'A Framework Proposal' and the team development strategies. The experts' reviews on the learning content were also taken into account.

COOPERATIVE EVALUATION

After the co-design process and the game development, a cooperative evaluation with 40 adult learners was followed. This evaluation had the purpose of identifying the main strengths and problems when experiencing the co-designed game platform, and understanding the way this game-based learning tool could encourage active ageing and healthy lifestyles. Therefore, the participants were asked about the main strengths, weaknesses, and suggestions for improvement in the game as well as the way the game platform could encourage active ageing.

Relative to this latter question, a set of categories were used based on the first evaluation with the co-design groups' answers and then ranked for each category presented in Figure 10 Not at all, Moderately and Extremely for all groups (co-design and evaluation).

Strengths of the game

Relative to the game, participants liked the graphics, narrative and found it easier to interact with the mouse cursor. The participants stated that the game was motivating them to act upon the information. They liked the idea of traveling through time during the game and the game music. In London, they were interested in checking the food that contained a certain type of vitamin and were motivated to repeat and advance on the game with the use of the immediate messages 'Congratulations' and end screens of each level with the points obtained. These were some of their statements:

"Wow, I'm impressed. The idea of traveling in time and exploring different cities and historical facts in a game was very good."

"Thank god there is no need to use the keyboard in order to play the game. This is simple."

"This music is very good. I like it very much."

"I like these type of games: word soup, Sudoku, word games and this game that you presented is the type of game that I'd play but as I use the computer only when I need it, I regret that wouldn't even try. [...]."

Game weaknesses and suggestions for improvement

In terms of the game weaknesses, the game processing was slow on some computers and difficulty was verified in the strategy game 'Connecting the dots' in Hizen, 1709. The information provided was neither clear nor provided in a timely manner.

"How do I connect the symbols? I have clicked on the temples. Oh, I need to click on the symbols first. Ok, I get it. You can go'

"Before playing, I guess it is necessary to introduce the game, prepare us to play the game"

Difficulties were also observed in the scenario of Paris, 1948 in which clickable areas were not distinguished from other elements of the scenario.

"Ok. I'm in Paris. What do I do now?" "That man is weaving me. How do I approach him?"

The minigames did not enable the player to retrieve the information provided during the minigames, forcing him/her to replay in order to have access to that information. Moreover, the exercises could be more diversified, with difficulty levels and bio notes should be provided.

"I missed the food that contains vitamin D. How can I go back to get that information? Do I need to replay?"

"Ok. I finished. They were easy. We could have done these and other exercises outside"

"Who is Sul? Who is Thomas Allinson? I need to be remembered of the story - Ok, it was presented in the beginning but I almost forgot: it was something about time traveling but it is all that I can remember, though"

In a nutshell, these were the main aspects that the end-users stated that the game could improve: (a) Reinforce the number of hints and tutorials; (b) provide a way to retrieve information without the need to replay the game; (c) present the bios of the characters, history-related facts and places and (d) reinforce the link established between games and daily life activities. The data obtained from both participatory design techniques and the evaluation process of both platforms have also revealed that games can foster active ageing by encouraging metamemory, problem-solving and confidence to solve daily-life problems; motivating the players to participate in the community through social graphs and invitations; demystifying ageing bias through storytelling and imagery- based techniques (Figure 10)



Figure 10: Determinants to develop game-based learning for active ageing

These determinants found in this study are in accordance with the central concepts that support the positive computing theory and thus with the use of digital platforms to foster mental health and psychological wellbeing (Calvo & Peters, 2014). In other words, the Payers' confidence to solve dailylife problems refers to the Autonomy/Agency principle; the Positive attitude towards Ageing refers to Compassion whereas Find solutions to Problems is related to a sense of competence and participation in society is related to the sense of connectedness (Calvo & Peters, 2014).

CONCLUSION

This paper set out to propose a framework for involving endusers in game design for active ageing and healthy lifestyles. The proposed framework relative to the co-designing process of the game living system was divided into the following phases: Co-design Tools Used For The Game Embryo; The Lab Microscope and Verifying the game DNA.

In 'The Game Embryo', the co-design strategies used were 'Strategic visioning and future workshops', 'Scenario building' and 'Contextual inquiry' as in this phase, the process of ideation occurs and other experts in different domains and players are involved in the process.

In 'The Lab Microscope', the users are not directly involved and the team's creative authorship is stimulated. Personas are used based on the previous experiences during the 'Game Embryo.'

In 'Verifying the Game DNA', a game prototype is presented and the participants are asked to reflect on the design product through the use of cooperative evaluation. Based on the participatory action research that was carried out with 33 adult learners at a University of Third Age, findings have suggested that such strategies as contextual inquiry, scenario building, future workshops and cooperative evaluation have revealed to be suitable for (a) aligning the learning goals and behavioral changes to game missions; (b) balancing the challenges to players' skills; and (c) defining the type of game conflict and resources to be used without compromising the view of digital games as an art form and creative authorship.

When designing digital games for active ageing, these were the main aspects that the end-users stated that the game could improve: (a) Reinforce the number of hints and tutorials; (b) provide a way to retrieve information without the need to replay the game; (c) present the bios of the characters, history-related facts and places and (d) reinforce the link established between games and daily life activities

Data obtained from both participatory design techniques and the evaluation process of both platforms have also revealed that games can foster active ageing by encouraging metamemory, problem-solving and confidence to solve daily-life problems; motivating the players to participate in the community through social graphs and invitations; demystifying ageing bias through storytelling and imagerybased techniques

Further research is being carried out in order to understand the interrelationship between the perception of wellbeing and quality of life and the use of the game developed in comparison with a similar digitally-mediated tool (i.e. online video-based course). In addition, a more thorough analysis of the experiment within the 'Positive computing theory' is also needed.

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GAME DESIGN AND GAMIFICATION

TO GAMIFY OR NOT TO GAMIFY? ANALYSING THE EFFECT OF GAME ELEMENTS TO FOSTER PROGRESSION AND SOCIAL CONNECTEDNESS

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KEYWORDS

Motivation, Game Elements, Postgraduate Research Students

ABSTRACT

A central challenge for postgraduate research students in research-study is the difficulty of being isolated. The longterm consequences of isolation lead to a slow progress in research-study and less socialization among research students. Recent research has shown that using gamification techniques can provide a significant impact in motivating learners. The purpose of this study is to investigate the effect of the game elements in fostering progression and social connectedness among postgraduate research students. There are plenty of game elements that can be applied in a gamified learning system. We identified particular game elements from literature, proposed a gamified system model incorporating Self-Determination Theory (SDT) and developed a prototype of an app guided by the User-Centered Design (UCD) process. We focused on the overall effect of the game elements such as motivational value concerning postgraduate research students' experience and satisfaction. We conducted an evaluation of our prototype, comparing the effectiveness of our gamified prototype to a basic non-gamified prototype. We found that the gamified prototype, particularly the game elements, was statistically significant in creating a motivational value to users to progress on their research journey. Users showed their interest in using social game elements to connect socially with other research students.

INTRODUCTION

Postgraduate students on taught Degrees can easily measure their study progress e.g. marks, points and grades in the class tutorials and continuous assessment. On the other hand, postgraduate students on research Degrees study their own research topic. Because of this, they can feel isolated/lonely (Haque et al. 2017a). Loneliness is not only a psychological condition (Cacioppo et al. 2008) but can also have a long-term effect. Lonely people are more likely to feel stress (Miller 2011). A higher level of stress increases the risk of heart diseases and other risk factors such as high blood pressure or high cholesterol. Scientists from Harvard Medical School and Massachusetts General Hospital have confirmed the connection between stress and heart attacks. Postgraduate research students could begin to experience increased loneliness (Ali and Kohun 2006). Being isolated for a long time and the lack of connection in the research study can bring adverse effects on research students e.g. serious health issues, delay in completion of their research degree and in the worst case, dropping out from the research program (Haque et al. 2017a). Therefore, there is a strong need to help research students progress in their research journey as well as connecting with other research students. Several determinants affect the completion time-frame for the research program including academic progress, attendance, mode of financial sponsorship and chain of friends, family and research peers as well as the teams' norms which provide some form of support necessary for progression. It can be fundamentally assumed that sense of progress and sense of social connectedness are vital antecedents to successfully completing as well as achieving fulfilment for any research study. One promising approach to improve these two factors is Gamification, an emerging area of research which has strong commercial potential. Analysts estimated the gamification area will be worth \$5.5 billion by 2018 (Markets and Markets 2013). Game elements such as progress graph have shown to motivate users to progress on their writing. An example, to motivate users to progress in writing, Grammarly (Grammarly 2017) sends a weekly email to track their weekly writing update through daily writing activity, mastery and vocabulary. Game elements such as reward points/badges have shown to build a social connection among users. An example, Health Month (Health Month 2016) has the option to let users select health-related behaviour for a month and users can lose/gain points/badges within a social platform.

The purpose of this study is to investigate whether game elements within a gamified system can create a motivational value to the postgraduate research students on their sense of progression and social connectedness. Little empirical evidence has been collected on using game elements to address the difficulties of progression and social connectedness among the postgraduate research students. Our study is envisioned to fill the gap by answering the key research questions: *i) What is the effect of using progression* game elements on postgraduate research students' sense of progress on the postgraduate journey? and ii) What is the effect of using social game elements on postgraduate research students' sense of social connectedness?

To answer the research questions, this study follows the User-Centered Design (UCD) process to develop a prototype of an app and a pilot study based on this prototype. We developed two prototypes: one gamified for the experimental condition and one non-gamified for the control condition. The pilot study follows quantitative and qualitative approaches. To do this, established motivation theory by Deci and Ryan - Self-Determination Theory (SDT) was selected from the literature. In line with SDT, people (e.g. postgraduate research students) can be motivated extrinsically through the fulfilment of three basic competence psychological needs (autonomy, and relatedness) that are influenced by autonomy support. Previously, a system model was introduced (Haque et al. 2017a) by using these psychological needs influenced by autonomy support to motivate postgraduate research students to progress in their research journey and connect socially with other research students. Based on the system model, we designed a gamified prototype using User-Centered Design (UCD) process. We applied particular game elements identified from the literature to design a gamified prototype (Haque et al. 2017b) and found that leaderboards and ranking badges bring negative impacts to users. This study aims for more accurate results in terms of using the progression and social game elements to promote progression and social connectedness among postgraduate research students. We hypothesize that H1) Progression game elements can have a significant effect in creating a motivational value to postgraduate research students' progression in their research journey, and H2) Social game elements can have a significant effect in creating a motivational value to postgraduate research students' social connectedness with other research students.

This paper is organized into five Sections. In Section I we present an introduction. In Section II we describe the literature review. In Section III first, we describe the methodology. Then we explain the results, discuss them (Section IV) and draw conclusions (Section V) from them.

LITERATURE REVIEW

Motivation

As stated by Self-Determination-Theory (SDT), people can be motivated intrinsically and extrinsically (Deci and Ryan 2000). To avoid misperception, we called 'people' in this study postgraduate research students/users/participants etc. According to SDT, postgraduate research students can be motivated intrinsically to progress in achieving their research goal and socially connect with other research students through fulfilling the three psychological needs of competence, autonomy and relatedness that are influenced by autonomy support. The psychological need autonomy means the sense of having the choice to assess one's societal atmosphere and delivering choices corresponding to perform a task. An example, being able to choose a daily task i.e. a 300-word to reach a short-term/weekly goal in writing a literature review.



Figure 1: Approach of SDT sequence

Competence means the sense of managing a task to complete such as the ability to write 300-word daily to complete a section of a literature review. The last psychological need relatedness means the sense of managing to join with others such as interacting with postgraduate research students over a daily coffee break. Therefore, the SDT is a promising approach to overcome the problems of progression and social connectedness among the postgraduate research students. Postgraduate research students feel happy to perform tasks and thus, motivate intrinsically. On the other hand, they are extrinsically more motivated to perform the task since they want to achieve to some degree from finishing the task such as rewarding them with points/badges to write sections of a literature review. Amotivated research students do not show interest to perform any task.

Value of Gamified System

Value from the perspective of users can be described as benefitting individuals who are users e.g. postgraduate research students. Scholars substituted the term 'benefits' with 'experiences'. The value should be recognized in the context of the users' experiences. Experience is the basis of value concept (Heinonen and Strandvik 2009). Thus, the value can be defined as positive experience obtained by users. Users sense positive experience through receiving service or application of a system from application providers. Through using a service/application, the value is realized (Gronroos 2008) such as a gamified system with particular game elements that can add value to users (e.g. postgraduate research students to progress in their daily writing and social connection among other students). Value is embedded in users' everyday experiences (Heinonen et al. 2013). The value of a gamified system is perceived and determined by users while using the application (Lusch and Vargo 2014). A positive experience can result in increased users' satisfaction that leads to competitive advantage (West Monroe report 2015). Users' satisfaction mean whether a gamified system meets users' expectation. Users' satisfaction reflect expectations and experiences that users have in a gamified system. Users' positive experience can be measured by capturing the users' satisfaction. Therefore, users can be satisfied through receiving game elements as rewards and sense positive experience in doing activities in a gamified system.

The Experience of Gamification

Gamification concerns the application of game elements to non-game contexts to make an application more engaging and fun (Deterding et al. 2011). Scholars describe the experience of gamification as a used experience in nongame context that the user perceives as gameful (Kari et al. 2016). This study focuses on the experience of game elements on the postgraduate research students. Gamification is an actual process to influence users' behaviour and use of an application (Law et al. 2011). Gamification influences users to motivate themselves although differences can occur between game elements and individuals (Hamari et al. 2014). In terms of progression and social connectedness among postgraduate research students, game elements in a gamified system can bring the experience of gamification by influencing them through motivational impact. Recently, we used possible game elements to design to a theory-driven system model to accomplish a set of tasks. In this study, we applied the proposed theory-driven gamified system model (Haque et al. 2017a) to develop a prototype. We measured the effect of the game elements. In the next part, we describe the possible game elements and how we fit them to develop the prototype of an app guided by the UCD process.

Game Elements

Social interaction (social

display menu, leaderboards, ranking badges) Progress (progress bars

graph) Surprise (gift, voucher)

Based on the literature search we found the following possible game elements.

Game Elements	Reference
Assessment (points, badges, feedback, goals)	Chen and Michael 2005; Kim and Shute 2015; Wilson et al. 2009

Prensky 2001

Owen 2004; Fullerton 2014

Fullerton 2014

 Table 1: Possible game elements (Haque et al. 2017a)

Table 1 represents examples of possible game elements. We selected these game elements as these deal with progression and social interaction to set and accomplish a goal. We assume that these game elements will promote progression and social connectedness among postgraduate research students lowering the sense of isolation.

Assessment is the measurement of completing a goal in a system. Users within the system should be able to perceive connections between their activities to enhance their performance and the connections are built up by three assessment formation (completion, in-process and mentor evaluation (Chen and Michael 2005). Completion is a type of assessment by asking a question to the users (Chen and Michael 2005) e.g. asking (YES/NO) if they write 300 words as a daily task. In-process assessment emphasizes the processes e.g. stages to complete postgraduate research students' task. Lastly, mentor or supervisor evaluation is

comprised of completion and in-process assessment. Social interaction refers to creating a connection among the other postgraduate students and colleagues. Socializing activities can be facilitated by technological tools (Prensky 2001) e.g. a social display platform of a system by which users can perceive and share their activities. The progress of postgraduate research students means their daily task completion and a gamified system can support postgraduate research students to track their activities through badges/achievements/movement to next level task. Achievements or badges and progress bars can be added when postgraduate research students write and submit a section of literature review for a research/conference paper into a gamified system. The system could have progress bars e.g. LinkedIn has progress bars to motivate users to fill up account info, level bars e.g. from level 1 to level 2 after submitting a task.

A prototype was developed previously by using these game elements incorporates with the psychological theory SDT (Haque et al. 2017b) to which the game elements leaderboards and ranking badges were criticized by the users. This study develops a prototype of the working system enabling postgraduate research students to experience the sense of progression when performing their daily task and the sense of social connectedness when connecting with other research students.

METHODOLOGY

User-Centered Design (UCD) Process

UCD is an iterative process to design an application of a system based on how it will be used by the users. The UCD process has the following steps: Empathise, Define, Ideate, Prototype, and Test.



Figure 2: User-Centered Design (UCD) process

We conducted the first iteration of UCD (Haque et al. 2017b). In the Empathise stage, 15 postgraduate research students were interviewed. Participants are pursuing their research study at MRes and PhD level (12 from Institute of Technology Carlow, Ireland and 3 from European Universities). They expressed their thoughts to experience the lack of progression (87% participants) and lack of social connectedness (80% participants) and showed their interest in a personalised social tool. Based on the results we observed from this stage we established a problem statement *'Postgraduate research students feel a lack of progression*

and lack of connectedness in their entire research journey. An assistive progression tool with added game elements might support them setting their goal for progression and can help them to experience more playfulness and fun by interacting with other postgraduate research students'. The above POV (point-of-view) has drawn our attention to building a prototype by utilising the definition of "deeper game elements" (Enders and Kapp 2013), integrating game design principles in addition with game mechanics. The goal was to fit the most applicable game elements. Two versions of the prototype were built using progression and social game elements to explore the reaction of the users in response to using these game elements. The game elements were points/badge, goals, surprise gifts/vouchers, progress bars and graphs, motivational notes, social display, messaging menu-bar, leaderboards and ranking badges. The overall experience of the users after testing the possible game elements informed us that users valued the game elements mentioned above except leaderboards and ranking badges. Users wanted to experience simple colour on the prototype, private leaderboards and messaging of online colleagues. However, based on the qualitative results of testing, we planned to analyse the overall effect of the game elements in a gamified prototype.

Description of Prototype

We developed two versions of the prototype (gamified and non-gamified). The gamified one has a login page. After logging in via Facebook or sign in or sign up, the progression stage appears. The screen has a button to set a goal for the milestones - Draft Literature Review Section, Study Design, Conference Paper and Use Needs. The goal can be set as a commitment to a goal, definitely will do it, will probably do and probably will not do it. There are home screen buttons to go back to the home menu to start with the milestones. After pressing a milestone e.g., a Draft Literature Review Section, a new screen appears that allows users to set their goal i.e. short goal (one-week writing: 1500 word), mid goal (four weeks) and the long-term goal (four months or more). Users can upload their daily task by pressing the arrow button that appears on the right side of the screen. This will allow users to monitor their overall progress (new screens appear with points and badges earned so far and to see the progress bar and graph). The next step is to let users connect with other research students via a social display platform. Users can choose their preferred research colleagues to send messages and invites them to go for a coffee break as well as reveal gift/voucher through scanning QR code built on the individual profile.



Figure 3: Print screens of gamified prototype (Screen 1: Progression stage- users can go back to the main menu using home button, set their goals from weekly to yearly such as selecting short goal that will help users to set goals for a week, and users can upload tasks into milestones Lit Review Outline, Study Design, Conference Paper and Thesis Paper due to Complete; Screen 2: Progression timeline- Users can view their progress so far on the highlighted bars to fill, dotted circle fill to reach the final level, and helpfulness points and badges after completing daily task; Screen 3: Overall weekly progress bars and graph based on users completion tasks; Screen 4: Social display menu- Research colleagues who are online to meet for a coffee break or a chat; Screen 5: Users can message others or invite to meet and scan the QR code through a colleague to reveal surprise; Screen 6: gift/voucher for a coffee after scanning the QR code with a colleague's smartphone)

The non-gamified prototype also has a login page. This prototype is simple to use and has a flow to select the milestone and upload tasks step-by-step. The main difference is that it does not have game elements included in the progression stage and socialization stage. Users do not receive any rewards (points, badges) or track their progress (progress bar and graph) after uploading their daily task as well as no gift/voucher (motivational note/coffee voucher via QR code) to get connected with colleagues.



Figure 4: Print screens of the non-gamified prototype (Screen 1: Progression stage- users can choose their milestones. They can upload everyday task on Literature review, Methodology and Research Paper Submit. Screen 2: Social display-menu appears with research colleagues' name to which invitation can be sent to the colleagues)

Method

The experiment has been done based on the initial test of the first iteration of UCD. We aimed to analyse the effect of the game elements in a gamified prototype based on the results of the quantitative and qualitative analysis. We recruited participants to complete tasks using prototypes of the system.

Participants.

To recruit the participants, an invitation email to take part in the study was sent out to 45 postgraduate research students residing in Ireland, Finland and USA. All of them were enrolled at MRes or PhD level. Out of those, 35 participants responded to participate in the pilot study. However, 7 participants informed us they would not attend the pilot study session due to their busy time schedule in terms of delivering their research progress report. We planned to conduct the pilot session by fixing a prescheduled appointment with the rest of the 28 participants. Nevertheless, 7 participants dropped out as they were very busy in their professional and personal life (such as writing an abstract, generating lab report, weekly progress outcome report to the supervisor/mentor, shifting to a new home, joining a new industry etc.). Finally, we concluded our pilot study with 21 active participants (7 females and 14 males) aged 24-37 years (N=21).

Procedure and materials.

Participants were asked to use two prototypes (gamified and non-gamified) but we did not mention to them which one is gamified or non-gamified. A total of 20 minutes had been allocated for each participant to use these two prototypes. Smart devices (iPad/iPhone) were used to run the interactive prototype system. Participants were not given any strict time limits to finish using the prototype. Though these were not the actual working system and therefore we asked the users to pretend while using them. The tasks for them were to perceive the usability issues of the two prototypes and to see which prototype helped them to feel motivated to progress in their research journey as well as connecting with other research students. After using the prototypes, postquestionnaires were provided to them to fill out, the Intrinsic Motivational Inventory (IMI) approach (Ryan 1982) was used to design post questionnaire to measure the motivational value of the gamified prototype of an app to the users. We used this value as the variable (factor) to design the IMI post-questionnaire. This post-questionnaire was used to analyse data quantitively. For the qualitative approach, participants were asked how to do they find the prototypes and compare accordingly.

The purpose was to perceive the usability issues of the gamified prototype in comparison with the non-gamified and how users value access to the gamified prototype specifically the value of the game elements. Several game elements have been applied to the progression and socialization stage. Progression stage included choices to upload postgraduate research students' daily task (300-word) and track their progress activity through earning points, progress bars and graphs. The socialization stage included choices using the social display screen i.e. networking with research students and messaging them to meet for a coffee break or a chat.

RESULTS

Quantitative Results

Participants filled up a post-questionnaire form. The questionnaire had a 7 point Likert scale of -3: 3 corresponding to Not at all True: Very True. As mentioned before, the Intrinsic Motivational Inventory (IMI) approach was used to generate questions that were related to the usability of the prototype system i.e. value or usefulness in doing an activity. Participants filled two similar post-questionnaire forms for the experimental condition (gamified prototype) and control condition (non-gamified prototype). We compared the motivational value on how

users believe that the activity (progress in their research journey) could create value for themselves while using progression tasks within the prototype systems.



Figure 5: Means and standard errors. Users of the gamified prototype valued activity to progress in their research study significantly (1), compared to non-gamified prototype (2)

We found that participants in the experimental condition (gamified prototype) believed significantly in creating value to motivate their activity overall compared to controls. Experiment: M=5.15, STD=1.09; Control: M=4.6, STD=1.43, (See Figure 5). Because we found differences, therefore, this increase in overall value leads us to believe the activity progress in research journey in the experimental condition.

Table 2: Self-reported agreement to statement about believing activity to progress in research could be of some value to themselves where answers were on a 7 point Likert scale of -3: 3 corresponding to Not at all True: Very True

Type of prototype	Mean rating	STD rating	p-value
Gamified	5.15	1.09	.03
Non-Gamified	4.6	1.43	

We found that p-value = .03; .01> p-value <.05 (significant level = * = low). This implies the difference between experimental condition and control condition is statistically significant. As the number of participants was only 21 and therefore, the p-value might increase in accordance with the increasing number of the participants.

A similar analysis was applied to compare the motivational value on how users believe that the activity (connecting with other research students) could create value for themselves while using progression tasks within the prototype systems.



Figure 6: Means and standard errors. Users of the gamified prototype valued activity to connect with others (1), compared to non-gamified prototype (2)

We found that participants in the experimental condition (gamified prototype) believed to create value to motivate their activity overall compared to controls. Experiment: M=4.75, STD=1.45, Control: M=4.3, STD=1.66, (See Figure 6). We found a small difference between the experimental and control condition (mean was higher in the experimental condition).

Table 3: Self-reported agreement to statement about believing activity to connect with others could be of some value to themselves where answers were on a 7 point Likert scale of -3: 3 corresponding to Not at all True: Very True

Type of Prototype	Mean rating	STD rating	p-value
Gamified	4.75	1.45	.07
Non-Gamified	4.3	1.66	

We also found p-value = .07 (No significant value). The difference between the average of the experimental and control condition is not statistically significant.

Research Hypotheses Results

The quantitative data gathered from the response of the users indicated the following result concerning our hypotheses.

Table 4:	Hypotheses	confirmation

Hypotheses	p-value	Support
H1	.03	Yes
H2	.07	No

Results from the p-value showed us that users' response was statistically significant. Results demonstrated that users were interested in using the gamified prototype and they felt motivated to progress in their research journey. Although users enjoyed social game elements and the gamified prototype motivated them it did not significantly cause them to make a social connection with other research students.

Qualitative Results

All participants reported feeling beneficial after using the gamified prototype. They felt that the gamified prototype was more valuable than the non-gamified one. E.g., "I like the first one". "I felt that the system could motivate me to progress and connect". We received some valuable feedback in terms of the future design of the gamified prototype. A few participants reported that the gamified version should have "A bit of freedom to set own goal e.g. if I want to choose my goal as lab test then 300-word cannot be a choice" i.e. to facilitate the psychological need *'autonomy'*. Three participants reported that the simple flow". "The other version was a bit lengthy to use". "Home button was making me confused".

Most participants reported that they tried to interact with others via the prototypes but were less motivated. One participant did not want to connect with others and skipped using the social display on both prototypes. Some participants were not really feeling connected when using both gamified and non-gamified prototype due to their participants personality. These were developers/programmers who were studying in the gamification field. This informed us that this prototype has no significant influence on the social connectedness of participants who are predominantly active researchers in gamification as they are within the gamification research domain. Social display to connect with others on the gamified prototype was likeable by the participants - "QR thing is interesting". "Coffee voucher and the motivational note were good". However, they suggested to add few things for the future version of the prototype - "For social connection - putting something for a common topic of interest/same level of skills like 'matchmaker' does''.

Our future aim is to seek the game mechanism as the social game elements used in the social display of the gamified prototype was not making any effect on users even though they enjoyed the game elements. The future social connection platform in a gamified system could have some sort of fun activities such as regular coffee meeting in relation to organizing soccer match.

LIMITATIONS AND FURTHER RESEARCH

Based on both quantitative and qualitative analysis, we have concluded that the gamified prototype needs to be updated. This can be done through running few iterations of UCD process and quantifying the effect of each of the game elements in the context of three psychological needs: autonomy, competence and relatedness of SDT. Since we applied both progression and social game elements, the progression game elements seemed to have more effect on motivating the users to progress on their research journey. However, users found the social game elements (social display, gift/voucher, QR code) interesting but had less effect on motivating them to connect with other research students. More study is required on how to apply the social game elements to make a social display platform in a system more attractive for users to get connected with other research students.

The number of the participants was low for analysing the data statistically. A larger number of participants could show the precise effect of the game elements. The study was conducted based on the prototype which was interactive but not the real working system. Also, users used the prototype system for 20 minutes. On the other hand, the future working system will be developed so that users can use it for up to three months. Therefore, using the working system for a longer period might bring different effects.

This is a work-in-progress paper. The result of the study has informed us in developing a new version of the gamified prototype to fit the social game elements in accordance with users' expectations and experiences. The new gamified prototype should also follow a simple flow of tasks and should have options for users to set their goal independently e.g. updating their daily lab experiment task instead of a daily 300-word goal. We will then analyse the quantitative effect of progression and social game element. The IMI approach will be used for scaling data on the effect of each of the game elements in relation to the three psychological needs of autonomy, competence and relatedness. After receiving the information on the quantitative effect of each of the game elements, we will develop a working gamified system that can motivate users to write a literature review and to build an emotional connection among postgraduate research students, sharing thoughts and experiences.

CONCLUSION

This paper seeks to analyse the effect of game elements to support postgraduate research students' progress in their research journey as well as connecting socially with other postgraduate research students. We developed a prototype guided by UCD and then compared it with a basic nongamified one. Users valued gamified prototype to progress in their research path. Users found game elements as a rewarding approach to motivate them and thus they sensed positive experience to pretend to do tasks in the gamified prototype. In this study, we have been able to gamify our prototype system by using the progression game elements to encourage the postgraduate research students to progress on their research journey. Social game elements were also appreciated by the research students with minor positive effect to connect with other research students. The overall effect of the progression and social game elements was positive in terms of users' satisfaction. The results of this study can be used to improve the effectiveness of using game elements in designing a real-time working gamified system.

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The Formation of Studying Habits in Third Level Students through the Use of Gamification

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KEYWORDS

Gamification, studying, habits, habit formation

ABSTRACT

The act of studying for many students can be a strenuous, uninteresting and are extrinsically motivated to study even though they are intrinsically motivated to partake in the course they choose. In order for students to study they must acquisition an area to study in, choose a topic to study and obtain required information. Then they must fend off the temptations of social media and the call of friends and family. Irish colleges are seeing sizable percentages of students failing to reach second year in math based courses. Studies show students use methods of study that do not aid them to retain information, they need for exams. Gamification is possible path for solving this issue. Gamified systems when designed correctly can motivate and engage users to use the system and continue to use it. Game elements such as social play, progression and feedback to name a few will be utilised to engage students with their studies and motivate them to study using methods that better aid in retention.

INTRODUCTION

Apart of many third level courses involve students being tested on the course content that is delivered to them by the lectures. The problem comes when students resorts to methods of studying that do not allow them to retain such information for extended periods of time. Another problem is that education must grapple with the rest of students' lives.

These are all areas students may be more motivated to commit to than studying. Because of this, students may form studying habits that are not congruent with high academic achievement. There are some tools that allow students to study though they require a large set-up on the part of the students.

BACKGROUND

This section we will cover the literature reviewed in the research of this topic. The main subjects of review are Gamification, Habits and studying. We will cover gamification, some of the elements we will and will not use and their effect on people behaviours, habits, what they are and how they are formed and studying, what is involved, some distractions from studying and some of the best methods of studying.

Gamification

To begin this discussion, first we need a definition for gamification. Gamification has multiple different definitions though the definition we use is one "*the use of game elements and game-design techniques in non-game contexts*" (Werbach & Hunter 2012, Deterding et al. 2011).

Games involve many different elements. Points, badges and leader boards, are the most regularly used game elements (Werbach & Hunter 2012). There are also game progression, streaks, feedback and timers to name another few. However, if the system you set about designing is not designed with the end user involved, you may not get the results you wish.

Tools such as Quizlet, Quiz up, Peerwise, Kahoot! and Socrative allow students to study online (Quizlet 2007, Quizup 2013, Peerwise n.d., Kahoot! 2017, Socrative 2017). Quizlet allows people to create flash cards, though this only allows people to study terms and definitions and does not allow them to apply the concepts they represent. Quiz up is a social media quiz system that allows users to answer and create quizzes on a multitude of different topics, yet it does not lend itself to studying as it is not possible to store other information. Peerwise is similar to Quiz up, though it also has similar problems, it allows students to create questions and though they must prove that the question is correct and other students can vote on the usefulness of the question.

Kahoot and Socrative are systems that allow teacher to give students quizzes in class on their mobile devices. Kahoot! though is more based on competition with the top three students for each question being displayed. All these systems we just deliberated have the similar issues, in that they need lots of previous work before they become useful. Our system will grant students the easy to jump on and study without requiring a long set up time which can lead to activities not being done (Csikszentmihalyi, 1997). Csikzentmihalyi used the example of teenagers who enjoy playing basketball, do not always play because of the difficulty of setting up a game to play.

Habits

Habits are behaviours that are acted out automatically when an event triggers the associated behaviour in our minds. Habits are simple behaviours we all have. Ouellette & Wood (1998) defines a habit as a need to perform a repeated action in similar contexts.

When forming habits, the behaviour requires frequency and consistency when attempting to form a habit (Lally et al. 2010, Lally & Gardner 2013, Ouellette & Wood 1998). This is needed so the mind can associate the cue with the behaviour. Though the automaticity of acting out the behaviour is the deciding factor on the strength of the habit.

One method of forming habits that seems to be useful is Implementation intention. Which is a method of planning a habit by following a "In situation Y, I will do Z" (Gollwitzer 1999, Holland et al. 2004). These have been found to easy the creation of recycling habits (Holland et al. 2004).

A digital method of tracking habit formation we found was an app called Habitica. This app requires the user to create goals of behaviours they wish to form. Then the user is required to update the app whenever they complete the behaviour. They system states that they will track the strength of the habit, though this system tracks the number of times the users completes the behaviour though it does not track the automaticity of the user acting out the behaviour.

Study

Students tend to rely on methods of studying that do not aid them in retaining information over time (Kornell & Bjork 2007, Hartwig & Dunlosky 2012) e.g. Rote reading and writing. Also, those who wish to obtain a good job or to pass the course are more likely to be utilising learners and so work just enough to pass the course and never learn the subject for the sake of learning it like internalising learners (Bigs,1979).

One method that has been seen to be useful improving students level of retention of information is regular testing (Kornell & Bjork 2007, Hartwig & Dunlosky 2012, Bjork et al. 2013, RoedigerIII & Karpicke 2006). Kornell & Bjork (2007), Hartwig & Dunlosky (2012) survey students and discovered while the high achieving students used selftesting regularly they were using it in the wrong way. They used it as a means of gauging how much they knew on the topic and not as a method of improving their retention of the information. Other studies have shown that testing regularly can improve a student retention of information over extended periods of time (RoedigerIII & Karpicke 2006).

37.7% Students in Ireland in a ISSE survey in 2015 were found to spend 1 to 5 hours a week preparing for class.

ISSE(2015) defined preparing for class as homework, studying, working on lab work "studying, reading, writing, doing homework, lab work, analysing data, rehearsing and other academic activities". This lends credence to how little time many students may have to spend on their education.

A survey by Glanville (2014-2015) found that many of his students reasoning for not studying as much as they think they should range from having a job to their social lives. As mentioned in the gamification section a lot of studying

app require a lot of pre-work before they become useful to students. Pre-work taking up time they don't have to spend, as they spend it doing other activities such as socialising with friends and working. This allow does not allow for the formation of useful studying habits.

SYSTEM/DESIGN APPROACH

The system we are creating is a browser/app based system, that allows students to study whenever and wherever they wish. Also, the students will be able to create notes and read lectures slides and other materials they require in order to study

In designing this system, we are using the Human Centred Design (HCD) process (Stanford, 2010). It is a design process that involves the end users from the beginning that requires us to discuss the subject with the end user and discover any pain points. Then we need to define problems they may have. Develop ideas that may solve these issues, create prototypes and test these.

Features





From interviews we conducted, students requested an easier method of studying, the information broken up, be able to test themselves, something with more feedback and goals. We also found that the students enjoyed the multiplayer aspect of many games. For this system, we choose to create a system that employed the ability to read slide from the lectures so the students will be able to top up their knowledge on the topic, also they will be able to write personal notes for the particular topic they are reviewing. They will then be able to test their knowledge of the topic. Due to positive research into the effectiveness of testing on student's ability to retain information, we choose to make testing/quizzes a large part of this system. We will combine the results from answering these questions to show the students how they are progressing through the information and giving them feedback on what answers they may get incorrect. This allow them to focus what they may need to study. However, this information will not decide what questions they will get so information they already know is constantly being tested.

The quiz system will come in to forms, single player and multiplayer. Both forms will have a range of question types e.g. multiple-choice questions, fill in the blanks, connect the information etc. The main difference other than playing with other players are the game modes that come with playing with multiple people. We will have game modes that involve users working together to answer the questions, team versus games and a game mode that involves users giving incorrect answers as possible correct answers to confuse the other players.

Another feature in our system will be allowing and encouraging students to create goals for them to complete and work towards. In the same vain as goals students will be able to create reminders for themselves to study. This will aid in the formation of the studying habit as the habit should form around the cue of the notification. We will also employ streaks to give students badges for being a consistent studier.

DISCUSSION AND FUTURE WORK

As discussed in the study section students find it difficult to find time to study and from interview they find it arduous to study as there are lots of materials required to be brought together. We believe that our system will allow student to study whenever they have time and can study where ever they wish.

However, our system will have some problems the browser based system will require an internet connection. Also, this system needs to on board student to using the system and show the students that it is valuable to them otherwise they may not use the system either at all or very little.

We plan to implement all the elements discussed mentioned in time for the 2017 - 2018 academic year. The study will run for at least two months to give the system enough time to take effect. Also, we will be running multiple quiz events to observe if existing game concepts can aid in students studying.

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BIOGRAPHIES

Gavin Clarke worked for four years to earn a honours bachelor's degree in Computer games development from the Institute of Technology Carlow. He has had an interest in video games for most of his life and he because of this he wanted to learn how to make them. He has worked in gameCORE since finishing his BSc and has worked on two different projects before starting work on an MSc.

Joseph Kehoe received his BSc in Computer Science in 1990 and his MSc in 1992. He has worked in education at both secondary and tertiary levels. He has worked as a consultant in industry and ran his own company doing consultancy, training and custom software development for a number of years.

He is course director of the BSc in Software Development and has previously been course director of the BSc in Computer Games Development. While acting as head of department of Computing (2002-2004) he completed the first programmatic review of the department, set up the summer school in computing and helped set up the Computer Games Degree. He lectures to all levels and is currently joint leader of the gameCORE research group in IT Carlow.

Daire Ó Broin holds a Ph.D. in Computer Science from Trinity College Dublin, which focussed on approaches to developing the conditions of flow. He has been a lecturer at IT Carlow since 2008, where he teaches on the Computer Games Development programme. His research interests include increasing engagement and intrinsic motivation in games and learning.

GAME AI

HAIFU (HYBRID ARTIFICIAL INTELLIGENCE FOR UNITY)

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KEYWORDS

Artificial Intelligence, Artificial Neural Networks, Genetic Algorithms, video games

ABSTRACT

HAIFU (Hybrid Artificial Intelligence For Unity) is a plug-in for video game developers made to be used in Unity. Its main purpose is to offer the opportunity to integrate an entire self-teaching system within a video game through an easy-to-use and friendly interface (Figure 4). The users will be able to use a complex artificial intelligence system without writing tons of code. The plug-in uses Artificial Neural Networks trained with Genetic Algorithms which results in a system that does not need to have data in advance. It also has a large variety of setups to choose the best way of training such as neuron's activation function or individual's crossover method.

INTRODUCTION

Although artificial intelligence (AI) is a very important part in video games, it is not where the majority economic resources go because developers usually care more about the graphics quality. However, there had been some video games that had an extraordinary AI, like *Half-Life, Halo* or *Thief* (Whatever happened to video game AI? - IGN). This plug-in attempts to be a solution for those developers who have not many economic resources, so their projects can have a complex AI easily at low cost. Currently, the video games' AI is based mainly on Finite State Machines (FSM), Decision Trees (DT) and Artificial Neural Networks (ANN).

HAIFU aims to achieve the following goals:

- To allow the developers the possibility of creating a complex AI system that combines Artificial Neural Networks with Genetic Algorithms (GA) without writing tones of code.
- To have a graphical user interface (GUI) (Figure 4) simple and friendly that lets the developers to create the system with different setups.

- To be a portable system that can operate in any video game.
- To allow the developers to use their own algorithms for the system training.

This paper contains the following sections:

- Related works. This section contains a comparison between HAIFU and the others similar systems found on the Unity Asset Store.
- Application. This section contains a system overview will showing what is HAIFU and which is its theoretical basis. Next, its architecture will be shown to see how the user-side and the system-side interacts. At last, its features will be listed to show its setup possibilities.
- Results. This section contains the results obtained from the system training for several problems.
- Conclusion. This section contains a summary from this paper and a brief mention to future works.

RELATED WORKS

Looking into the Unity Asset Store for AI based plugins, there is just one that uses ANN trained with GA, called Artificial Life (Artificial Life - Asset Store). This plug-in is intended to drive various bots to get as much food as possible (as shown in its description). This means that it is a very restricted plug-in and cannot be used in whichever video game, while HAIFU is a plug-in intended to be used in any video game that needs an AI system that controls non player characters (NPC). In addition, this plug-in does not have a specific interface, but has some public attributes that can be changed. On the other hand, HAIFU has got a specific GUI made for Unity to provide the developers an easy way to setup the entire system. Finally, this plug-in does not have as many configurations as HAIFU has in order to change how the system will be trained and how it will act. These things all together make HAIFU a system more complex, portable and easy to use.

Features	HAIFU	Artificial Life
Specific GUI	1	×
Portable between video	1	×
games		
Multilayer perceptron	1	1
Genetic training	✓	1
Population count change	1	1
Neurons' activation func-	1	×
tion change		
Selection method change	✓	×
Crossover method change	✓	×
Replacement method	1	×
change		

Table 1: Comparison Table

APPLICATION

What is HAIFU

HAIFU is a plug-in that combines ANN with GA. It is written entirely in C# and compiled with .NET 3.5 framework to be compatible with Unity. HAIFU creates a collection of ANN that will form the population used by GA, so each ANN is called "individual". HAIFU uses a GA to avoid the need of having a previous dataset of inputs and their associated desired outputs, since it would be very costly for the developers to create such dataset. To achieve this, the plug-in uses an interface called IFitnessFunction that must be implemented by a developer's script. The interface defines just one function called Evaluate() and must determine how each neural network's performance is evaluated during training. Leaving this function to be implemented by the developers allows the plug-in to be portable to any video game. HAIFU has a GUI to provide developers an easy way to set up the system, but it also can be done through code. Besides, HAIFU uses different interfaces that makes possible to change the methods used to train, even letting developers use their own methods.

Artificial Intelligence Algorithm

The neural network type used is a multilayer perceptron (Du and Swamy 2013) (Figure 1) where the number of layers and the number of neurons per layer are defined through the GUI (Figure 4).

The neurons of the input layer, just pass the inputs to the following layer. The neurons from the hidden layers and the output layer compute their output using their inputs, weights, bias value and activation function (Koehn 1994) defined through the GUI (Figure 2, Equation 1).

$$y = f(u + \omega_1 x_1 + \dots + \omega_n x_n) \tag{1}$$







Figure 2: Neuron

The activations functions implemented (Du and Swamy 2013) are:

- Threshold function.
- Sigmoid function.
- Bipolar Sigmoid function.

HAIFU uses the neural network's weights and bias values as chromosomes, so when two parents are combined, the neural network resulting has weights and bias from both of its parents. The selection method, the crossover method and the replacement method are set in the GUI (Figure 4) to determine which algorithm will be used in each training stage (Figure 3).

The selection methods (Castillo et al. 2003) implemented are:

- Elite selection method.
- Random selection method.
- Rank selection method
- Roulette wheel selection method
- Tournament selection method.

The crossover methods (Castillo et al. 2003) implemented are:

- Double point crossover method.
- One point crossover method.
- Uniform crossover method.

The replacement methods (Fiszelew 2002) implemented are:



Figure 3: Training Algorithm

- Generational update replacement method.
- Elite replacement method.
- Random replacement method.
- Tournament replacement method.

This hybrid model allows the developers to train the neural network without data, but creating a fitness function that evaluates the neural network performance. This fitness function will be different for each video game, so it is very important to define it well.

The genetic training obtains an optimal ANN as a result. It combines the neural network's weights and bias values, but does not change their topology as the NeuroEvolution of Augmenting Topologies (NEAT) algorithm does (Stanley and Miikkulainen 2002). However, this feature will be implemented in the future.

Architecture

On the user-side, there is the GUI made for Unity (Figure 4) with the aim of being as easy to use and friendly as possible.



Figure 4: Graphical User Interface

It is divided into several parts:

- 1. An unmodifiable text field that shows where is going to be saved the serialized model.
- 2. A layers list to set the number of layers for each ANN. For each layer, a number of neurons is specified.
- 3. Two lists to define the maximum and minimum inputs and two lists for the maximum and minimum outputs. These values will be used to work with normalized values.
- 4. This part allows to set the preferred mathematical function to be performed by each neuron and the alpha value of the sigmoid functions.
- 5. In this part, the user can set how many individuals, there will be within the population, the selection method, the crossover method, the mutation rate and the replacement method.
- 6. This button creates an object from the Haifu class with the set up chosen and serializes it into a file.

In the system-side the information from the GUI is used to create an instance of the Haifu class. This class is the center of the system (Figure 5) and is the one used by the user. It uses interfaces and abstract classes to modularize its structure, so when an option is chosen in a pop-up field from the GUI (e.g. Selection method field), it only changes how the algorithm will perform.



Figure 5: Data Flow Diagram

Features

The system features are:

- A specific GUI (Figure 4) made to create the neural network and define the algorithms that will be used during training.
- The ANN type is a multilayer perceptron (Figure 1).
- There are three activations functions available to determine the neuron's behavior (Equation 1).
- There are five selections methods to determine how the parents will be selected to produce the new generation.
- There are three crossover methods to determine how the parents' chromosomes will be mixed to produce a new individual.
- There are four replacement methods to determine how the new generation will replace the old one.
- The Haifu class is the center of the system and is the one that interacts with the game and coordinates all the system functioning.

• The system uses an interface called IFitnessFunction that must be implemented by an user script to implement the method that will evaluate the neural networks performance.

Although a GUI is provided to facilitate the creation of the system, both parts are decoupled enough to allow the core system to be created through code and be used outside Unity.

Additionally, the developers can set up their own activation functions and algorithms for genetic training just creating a class that implements the right interface and assigning it to the haifu object loaded from the serialized model. This is made this way to ensure the maximum flexibility for training, since a correct set up is very important to obtain a good neural network.

For training, the user must write some code to load the serialized model, provide it the necessary input data, use the output data computed and determine how many times and when to create a new generation.

RESULTS

Pong

HAIFU has been tested on the classic game Pong (Figure 6). The main purpose was to obtain an ANN able to control one paddle correctly. The game was created using Unity. The following setup was used: Layers number: 3. Neurons per layer: 2; 2; 1. Minimum inputs: -4.7; -4. Maximum inputs: 4.7; 4. Minimum outputs: 0. Maximum outputs: 1. Activation function: Sigmoid. Sigmoid alpha value: 1. Population size: 30. Selection method: roulette wheel. Crossover method: uniform. Mutation rate: 0.25. Replacement method: elite.



Figure 6: Pong made in Unity

The ANN that controls the paddle determines if it has to
go up or down. The fitness function returns how many times did the paddle hit the ball. After 3 generations, an optimal, individual results to be invincible.

Cannon

Secondly, the system was tested in order to find and optimal ANN able to determine the correct velocity and angle to shoot a ball, that is affected by the wind, to a target in a 2D scene. The following setup was used: Layers number: 7. Neurons per layer: 1; 4; 4; 4; 4; 4; 2. Minimum inputs: -9.8. Maximum inputs: 9.8. Minimum outputs: 7.07; -1.54. Maximum outputs: 21.47; 1.54. Activation function: Bipolar sigmoid. Sigmoid alpha value: 1. Population size: 500. Selection method: roulette wheel. Crossover method: uniform. Mutation rate: 0.25. Replacement method: elite.

For this test, the ANN resulting after 100 generations was capable to shoot 94% of times within a range of 25 units from the center of the target (Figure 7).



Figure 7: Shoots

CONCLUSION

With the results obtained from the training, the system's power and flexibility has been exposed since it was created using the GUI and obtained an optimal individual. However, for more complex problems, the genetic training may has some problems like the premature convergence (Castillo et al. 2003). Premature convergence may occur when an elitist policy is used (e.g. Elite selection method) and a very superior individual appears, what causes that all the offspring is generated with its genes. One thing that counteracts this effect is the genetic mutation, which ensures the population diversity.

Future Works

- To implement more neuron activation functions.
- To implement more selection, crossover and replacement algorithms for genetic training.
- To integrate within the system self-organizing maps (Guthikonda 2005) to gather data, learn from the user and retrain the neural network.
- To implement the ANN's topology changing during training.

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An Evaluation of Fast Multi-Layer Perceptron Training Techniques for Games

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KEYWORDS

Multi-layer perceptron - MLP Error Back Propagation - EBP Resilient propagation - RPROP Random-Minimum Bit Distance Gram-Schmidt - RMGS Artificial Neural Network - ANN Artificial Intelligence - AI

ABSTRACT

Despite the rise of Artificial Intelligence (AI) in games leading to the adoption of many academic techniques, multi-layer perceptron (MLP) neural networks have bucked this trend and have rarely been used in a game scenario. This is normally due to long training and development times using the standard error back propagation (EBP) training technique. The purpose of this investigation was to compare alternative training techniques to EBP in order to see if they can be used to promote the use of MLP in games.

The application created to serve this purpose was a 2D top down racing game with three different training techniques to control the AI, including EBP, resilient propagation (RPROP) and Random-Minimum Bit Distance Gram Schmidt (RMGS), in which, each training technique was put through three tests.

Through these tests, it was shown that alternative training techniques, although not as accurate as EBP, reduce the training time drastically. The tests also concluded that in a racing game scenario the alternative techniques could also compete with EBP, with the RMGS training technique being the best in every test except accuracy.

This project has shown that MLP could easily be utilised in game scenarios using these alternative methods and would not require the lengthy training times of EBP.

INTRODUCTION

Artificial intelligence (AI) has been at the absolute core of video games since the beginning, as Alex Champandard (2004) states "since the days of Pong and Pac-man artificial Intelligence has played an undeniable role in computer games." AI has been fundamental to keeping computer games engaging and enjoyable. Because of this, game AI has continued to develop and evolve over the years, slowly introducing more academic techniques into the field and adapting them to suit what will make the game the most fun. Games have easily been able to adopt some of the main concepts of academic AI. Ranging from rule-based systems,

in which rules for the AI are written out in full and the programmer must account for every possibility, to some of the more complex techniques such as genetic algorithms, which requires very little programming and allows the AI to evolve on its own to find the optimal solution to the problem. One type of academic AI that has been an outlier to this trend is Artificial Neural Networks (ANN). ANNs have been around for a very long time; with the original "Logic Threshold Unit" being proposed by Warren McCulloch and Walter Pitts in 1943 (Stanford University 2000). However, due to their computational demands and long training times, they have never really found a permanent place in games.

There have been a number of attempts to implement ANNs into video games, but have only been used in very niche parts of games to do something that a far less complicated game AI technique could have easily achieved. There are a number of drawbacks to using a neural network for controlling the game AI; including that if offline training is used, then once the network has been trained, its knowledge is fixed and it can no longer learn at runtime. Online learning allows this kind of adaptation, but the majority of learning algorithms for neural networks are unsuitable and must be revised for real-time processes (Charles and McGlinchey 2004).

The key problem with implementing an artificial neural network in a game is the training time. It takes hundreds of iterations to train the network, so if any adaptations have to be made or the training data was incorrect the entire process will have to be stopped and restarted with updated training data. Hence there have been attempts at different methods of training a neural network in particular, the multi-layer perceptron (MLP) neural network, has had many different training methods proposed to speed up its famously long learning time. Methods such as Quick Propagation and Resilient Propagation reduce some of the issues with Error Back Propagation (EBP) and are "batch" methods (Champandard 2004) which inevitably speed up the process. However, they do not reduce the time significantly.

The algorithm that this paper will mainly compare to error back propagation is the "Random-Minimum Bit Distance Gram-Schmidt" (RMGS) method (Verma 1997). The training time for this particular method is negligible as it trains the entire neural network in one iteration instead of hundreds. It is noted that this method is not as accurate as other methods. However, in a game scenario, it is actually beneficial in some cases for the AI not to be 100% accurate; otherwise, the player would never be able to win. Since this method only takes one iteration to train the network, there is potential for MLPs to be used and trained dynamically during a game, and if it is feasible and accurate enough, it may finally initiate an interest in the use of this mature technique in games. This paper aims to prove that feasibility.

LITERATURE REVIEW

It has been proven that MLPs can control a car in a racing game. For example, Colin McRae Rally 2 utilises this for its game AI to make sure the car follows a racing line. However, training MLPs takes a lot of time and thus they are rarely used in games.

Racing games can be identified as excellent grounds for testing MLP networks, as there are many potential inputs to process for driving a racing car around a track. For this kind of neural network, as the number of inputs increases, the harder the network has to work. This will test the Random Minimum Bit Distance Gram-Schmidt (RMGS), Resilient Propagation (RPROP) and EBP thoroughly.

Multi-Layer Perceptron Network

The MLP is one of the most well-known and used artificial neural networks. It is classified as a "feed-forward" ANN that has the ability to map sets of input data to output data. Figure 4 shows an example of how an MLP network looks.



Figure 1: An example of a Multi-Layer Perceptron Neural Network (Kawaguchi 2000)

A simple description of the network is that values are passed to the input layer, the values are processed by the hidden layers and are returned through the output layer. The neurons that process the values in each layer (except the input layer) work by receiving all of the outputs from the previous layer, multiplying them by corresponding weights, then summing all of the resulting values together, and finally, feeding this sum into an activation function to create the output of the neuron.

Figure 5 shows the process for each neuron:



Figure 2: Symbolic Illustration of Linear Threshold Gate (Kawaguchi 2000)

Many activation functions can be used in an MLP network. They range from fairly simple ones such as the linear threshold function, as seen above, which only triggers if the input passes a certain value to more complex functions such as the "sigmoid" function", which the following equation describes:

$$S(t) = \frac{1}{1+e^{-t}}$$
 (1)

This allows for the neuron to always activate, but with varying output values. Figure 6 shows the activation curve of the sigmoid function:



Figure 3: The sigmoid activation function (Buckland 2016)

The threshold activation function is used in combination with some newer techniques to create spiking neural networks, which aim to more accurately model the brain.

Training Methods

Error Back Propagation

The error back-propagation method is the most common training method for MLP neural networks. The basics of the technique were first proposed in 1960 by Henry J. Kelley in terms of control theory, however it has been noted that "it's importance was not fully appreciated until a famous 1986 paper by David Rumelhart, Geoffrey Hinton and Ronald Williams" (Nielsen 2017). Firstly, each of the weights in the MLP network are set to small random values. Then the first values of training data are passed through the MLP network to give an output. The network then calculates the error of the current output compared to the desired training data output using the "square error" function shown in equation 2:

$$E = \frac{1}{2} (target - output)^2 \qquad (2)$$

The error is then used to calculate a delta value. This delta value is used to firstly adjust the weights of the output layer; it is then passed backwards to the hidden layer, which will calculate a delta value for each neuron in the layer for weight adjustment. This process is repeated for all of the hidden layers, working backwards from the output layer until the entire network has been corrected. The reason for the delta being calculated at the end of the network and being passed backwards is that any interaction with the network is only available via the input and output layers, therefore the error can only be calculated once the data has been passed through to the output layer. The entire training process is repeated for the all of training data multiple times until the calculated error reaches a minimum (Bourg and Seemann 2004). This process is known as the *delta rule* and *Back* Propagation.

EBP is known as the steepest decent method (El-Sharkawi, Marks and Weerasooriya 1991) for finding the minimum of a function; this is due to it using the optimisation method gradient decent. The process of gradient decent is a way of reaching the minimum of a function by updating the parameters in proportionally to the gradient at the current point. (Ruder 2016)

Another training method that relies on gradients heavily is Resilient Propagation.

Resilient Propagation

First proposed by Mark Reidmiller and Heinrich Braun in 1993 Resilient Propagation (RPROP) aimed "To overcome the inherent disadvantages of pure gradient-descent" (Reidmiller and Braun 1993). Reidmiller and Braun found that their training method outperformed the classic EBP with ease and other training techniques such as "Quick Propagation" and "SuperSAB". RPROP works somewhat similarly to EBP in the sense that all the weights are updated depending on a calculated error. However, RPROP does not update the weights until all of the training data has been seen; therefore, it is known as a "batch algorithm". As the weights are not updated after each piece of training data an "error gradient" must be calculated for each neuron. This is done by passing all of the training data through the network and calculating a gradient for the error at each neuron. Once this has been completed, the weights are then adjusted accordingly in relation to the gradient of error that has been calculated (Champandard 2004). Although the weights are adjusted in relation to the gradient, the gradient does not decide the size of the step used to update the weight. Thus eliminating any problems that involve a too large weight adjustment. The general theory is very simple, as Champandard states "If the slope goes up, we adjust the weight downward. Conversely, the weight is adjusted upward if the gradient is negative." And if neither of these are true, the algorithm has found a minimum and therefore no weight update is needed. Equation 3 demonstrates the process of identifying the step determination:

$$\Delta w_{ij} = \begin{cases} -\Delta_{ij}(t) & if \ \nabla E(t) > 0 \\ +\Delta_{ij}(t) & if \ \nabla E(t) < 0 \\ 0 & otherwise \end{cases}$$
(3)

With Δw_{ij} being the step, Δ_{ij} being the update value and $\nabla E(t)$ being the gradient of the error for all of the training samples as t is the current epoch.

Champandard shows that using equation 4 the new update value can be calculated:

$$\Delta_{ij} = \begin{cases} n^{+} * \Delta_{ij}(t-1) & if \ \nabla E(t) * \nabla E(t-1) > 0\\ n^{-} * \Delta_{ij}(t-1) & if \ \nabla E(t) * \nabla E(t-1) < 0\\ \Delta_{ij}(t-1) & otherwise \end{cases}$$
(4)

With n^+ and n^- being constants with $0 < n^- < 1 < n^+$. This means that if the gradient is still going in the same direction, the step size is increased, and that if the gradient changes direction, the step size is decreased. If neither of these criteria match, the step size is left alone.

The Random-Minimum Bit Distance Gram Schmidt Method Hypothesized by Brijesh Verma (1997) the method makes use of supervised and unsupervised learning for training the output layer and the hidden layers respectively. As stated by Verma "The proposed solutions are much faster and without local minima because they use direct solution methods". This makes the implementation of the method far more complicated but, once completed, the training time is negligible compared to error back propagation and resilient propagation as it trains the entire network in one epoch.

There are two mathematical processes employed, which are: the Minimum bit distance method and the Modified Gram-Schmidt process. The layers that both of these techniques are used to train are shown below in figure 4.

W1 is trained by setting all of the weights to random small values. W2 is trained via the minimum bit distance technique and W3 is trained via solving linear equations using the modified Gram Schmidt method.



Figure 4. Structure of the RMGS network

The Minimum Bit Distance (MBD) as seen below is a simple measurement in vector similarity (Verma 1997):

$$MBD(x,w) = \left| \left| \underline{x} - \underline{w} \right| \right| = \sqrt{\left(\sum_{i=1}^{n} (x_i - w_i)^2 \frac{i}{n} \right)}$$
(5)

 \underline{X} is the input vector and \underline{w} is the weight vector for the neuron, *n* is the number of neurons in the layer and *i* is the current neuron. This equation simply takes the magnitude of the vector created after the weight vector is taken away from the input vector. To make sure that similar vectors do not give the same output the value of the equation before taking the square root is multiplied by the current neuron divided by the total number of neurons in the layer.

Once the network has been trained, the network can be used similarly to a normal network, however the minimum bit distance must be carried out for the second hidden layer on any input. This type of processing is part of a new generation of MLP networks called Deep Learning Neural Networks (Marr 2016) in which multiple layers use different processing calculations and different activation functions to calculate the output of the network.

METHODOLOGY

The focus during the designing of the game was to make sure that it would be able to test the effectiveness of each MLP training technique fully. After reading of Jeff Hannan's use of an MLP to control the driving in Colin McRae Rally 2 (CodeMasters 2000), it was apparent that a top down racing game would provide the perfect environment for such a test. The game was developed using the Games Education framework (Clarke 2017) with the Box2D physics engine (Box2D 2017), which provides accurate physics for the game environment and allows for very simple and effective raycasting calculations. These were chosen as it would allow for the use of the C++ programming language, and allow for a good implementation of the MLP network from scratch. .

The inputs for the network that the car uses are as follows: its current angle in comparison to the next waypoint, the current angle of its tires, the distance it is away from each side of the track and its current speed. All of these variables must be normalised to values between 0 and 1 in order to be passed into the neural network. Multiple techniques and calculations are done on different variables of the car to allow this to happen.

To get the value of the Angle in comparison to the next waypoint: firstly, the current angle of the car is compared to the angle of the waypoint to get the difference in radians. This value is checked by using the modulo function of 2π to calculate the angle within 1 turn. This is because Box2d continues to add to the angle instead of resetting to 0 if it goes above 2π . Finally, the value is then divided by 2π to get a value between 0 and 1.

The current angle of the tires is far simpler, they are divided by $\pi/2$ and 0.5 is added. This is because the tires are limited to turning $\pi/4$ in either direction, therefore when divided by π /2 they will give a value between 0.5 and -0.5. Thus adding 0.5 will bring that value between 0 and 1.

The current speed input is calculated by dividing the car's current speed by its maximum speed, giving a value between 0 and 1.

The distance to the side of the track variable is calculated using raycasts. This is similar to how Yee and Teo used raycasts in their "Spiking Vs Multi-layer perceptron neural networks" paper (Yee and Teo 2015). However, less raycasts are used and they are only used to locate the horizontal positioning of the car in relation to the next waypoint. As shown in figure 5 this is done by casting a ray out for each side of the car parallel to the angle of the current waypoint. This is represented by two red lines being drawn from the centre of the car outwards at the angle of the waypoint, red boxes are drawn where the rays collide with the barriers on the edge of the track.



Figure 5: AI raycasting from the centre of the car

These rays are then added together to get a distance from one side of the track to the other. The length of the left raycast is then divided by this value, thus giving a value between 0 and 1 representing the horizontal positioning of the car with 0.5 being in the centre, 1 being all the way to the right and 0 being all the way to the left.

Once all of these values have been calculated they can be passed into the MLP.

The outputs of the network are flags mapped to the directional keys for controlling the car, an output above or equal to 0.5 means that the button is pressed down and an output below 0.5 means it is not.

The output of the network is interpreted similarly to the AI in Colin McRae Rally 2 (Buckland 2004) in that each output neuron represents an on/off flag controlling the car. By only giving the AI access to the same controls as the player, it creates a fair race.

RESULTS

Each training technique was tested in three different ways to provide sufficient information in grading their effectiveness. The first of which was testing the speed at which the network trains, the second was a time trial race around the track and the third put each technique up against a human tester, in which they answered a survey on completion of the race, the following is the results of the first two tests.

Training Results

The difference in training times (see Table 1) varies massively between each of the training techniques. As shown below the average training time of EBP is the longest, RMGS taking the shortest amount of time by far and RPROP being inbetween these. Both EBP and RPROP were run for 5000 iterations and because RMGS can only be trained in one iteration, it was only run for one. The number of iterations that EBP and RPROP were run for was decided through trying to give EBP and RPROP enough time to have trained properly, but not be over trained and unable to generalise. The dataset provided to the networks had a size of 10000 training pairs. Both EBP and RPROP were structured with the layout of four input neurons, fifty neurons in the hidden layer and four neurons in the output layer for the purposes of this test. The RMGS was structured with four input neurons, four neurons in the first hidden layer and fifty neurons in the second hidden layer and finally four output neurons. This was done because as discussed in section 3; the RMGS training technique involves a second hidden layer.

Table 1: T	raining	time	and	accuracy
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Training	EBP	RROP	RMGS
Technique			
Average	14:03.34	8:23.96	0:01.28
Training			
Time			
(m:s:ms)			
Accuracy	84.6%	78.8%	70.2%
Once			
Trained			

Time Trial Results

The time trial results were recorded using the in game lap timer and any laps the car could not complete were discarded. Table 2 shows the results of this test:

Technique	EBP	RPROP	RMGS
Average Lap	41.5	43.0	37.5
Time (s)			
Number of	4	6	3
Laps that			
were reset			

Table 2: Average Lap Time

The results show that the fastest around the track on average was the RMGS training technique followed by EBP and then RPROP. The RMGS technique also had the lowest number of laps that had to be reset, thus definitely being the best technique for this particular test.

CONCLUSIONS

It is evident that the RMGS technique was the best performing technique in all stages of the testing, other than its accuracy and its training consistency. The EBP would definitely place second in this comparison as its ability to train to high accuracy and a consistent success rate along with being the second best rated in the Questionnaire results and having the second fastest in lap time. The RPROP training technique would be a definitely last place as it received the worst results in both the time trial and questionnaire results along with coming second in both training time and training accuracy.

This project clearly demonstrates that some alternative training techniques have the potential to replace EBP in the training of a MLP neural network in a situation where high accuracy of the network is not necessary.

It also found that there is potential for a MLP networks to have the majority of control of the AI in a game.

FUTURE WORK

There are many directions that future work on this project could be taken.

Firstly, testing the AI's performance on other tracks would be a very interesting test of the actual effectiveness of the training. Since the networks have been trained on data that should be transferable to other tracks as long as they are set up similarly to the track used.

The AI implementation in this application has been developed to be modular, thus allowing for easy implementation into more racing cars in the game or other applications by only adding a few lines of code. Therefore, implementing the use of the RMGS training technique in another situation would also be a very interesting direction this work could be taken. Especially into different game types like platforming and fighting games as these require completely different judgement by the AI and would likely test the effectiveness of the technique very well. The way in which all of the training techniques have been implemented in this particular application means that they can easily be plugged into another application and as long as training data is provided, they would be able to take control of the AI.

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Procedural Play Generation According to Play Arcs Using Monte-Carlo Tree Search

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KEYWORDS

Monte-Carlo Tree Search, Procedural Play Generation, Fighting Game, Puppet-Master AI

ABSTRACT

More than a million spectators watch game streaming platforms such as Twitch every month. This phenomenon suggests video games are a powerful entertainment media not just for players but for spectators as well. Since each spectator has personal preferences, customized spectator-specific game plays are arguably a promising option to increase the entertainment value of video games streaming. In this paper, we propose an Artificial Intelligence (AI) that automatically generates game plays according to play arcs using Monte Carlo Tree Search (MCTS). In particular, we concentrate on fighting games and drive MCTS to achieve specific hitpoints differences between characters at different moments of the game. Our preliminary results show that the proposed AI can generate game plays following the desired transition of game progress.

INTRODUCTION

Twitch, a popular game streaming platform, is followed by more than a million spectators every month. This phenomenon suggests video games are a powerful entertainment media not just for players but for spectators as well. Typically, spectators watch game plays suitable to their needs; for example, some spectators may prefer game plays in which the game is cleared quickly while others may prefer watching tight matches. Overall, this means that, because of the diverse preferences, personalization of game plays has the potential to increase the entertainment value of game streaming.

Recently, Thawonmas and Harada proposed the novel concept of Procedural Play Generation (PPG) (Thawonmas and Harada 2017). Their goal is to generate game plays automatically, using one or more Artificial Intelligences (AI), and to recommend those plays to spectators according to their preferences. As a first step toward realization of this concept, in this paper, we focus on an AI that can generate game plays that follow a given game progress.

Recent years have seen an increase in research on game AI both from academic and industrial researchers. Among the techniques achieving the highest results is Monte-Carlo Tree Search (MCTS). MCTS has achieved high performance in many games, including several realtime games (Ishihara et al. 2016, Browne et al. 2012). Most of the research on MCTS focuses on producing stronger and stronger agent players; however, MCTS can be used to optimize decisions towards different goals. Because MCTS does not require training and can adapt to different situations on-the-fly, it is a promising option for generating customized game plays for entertaining purposes.

In this paper, we propose an AI that can automatically generate various game plays using MCTS. We focus on fighting games, and we use the FightingICE platform (Lu et al. 2013) for our tests. In particular, we focus on different ways in which a game can progress; these are called Play Arcs (PA). In the context of fighting games, a reliable way to assess the current progress of a game is the hit-points (HP) difference between the characters. We use an evaluation function for MCTS that targets the desired HP difference, and vary this target HP difference throughout the game. This technique can be used to generate games that follow different PAs, which can accommodate different spectators' preferences. The proposed AI is a "puppet-master", controlling all characters in the game in order to unfold the desired PA; we call this type of AI a Puppet-Master AI.

GENERATING GAME PLAYS ACCORDING TO PLAY ARCS USING MCTS

Related Works

Studies in controlling multiple players have been conducted not only in games but also in narrative generation (Kartal et al. 2014, Nijssen and Winands 2013). However, these studies focused on turn-based systems, where each character takes turns to perform his/her action. Fighting games, on which this work focuses, can



Figure 1: An overview of PM-MCTS

be reasoned as real-time asynchronous systems where each character determines its own action separately and performs the action when possible. As a result, we need an approach that continuously monitors both players to find when either can conduct a new action and then determines an appropriate action for that player.

Sanselone et al. (Sanselone et al. 2014) propose a similar approach in that they use MCTS in a multi-player asynchronous system. However, they applied their MCTS to an edutainment game with a longer expected response time than fighting games. In the next section, we describe our approach to tackle this challenge.

Proposed Approach

An overview of the proposed Puppet-Master MCTS (PM-MCTS) is depicted in Figure 1. In the tree, each node represents a choice for either of the characters (circle: P1; square: P2). MCTS builds such a tree starting from an initial state, defined by information such as, among others, HP, energy, coordinates, and action of each character and remaining time in the game. Each edge represents a decision point (an action) for a player and an arrow indicates a state transition that follows the execution of that action.

As with normal MCTS, PM-MCTS comprises four steps: selection, expansion, rollout, and backpropagation. It is worth reminding that every node of the tree contains the value from the perspective of both characters, as well as a counter of how many times the node has been passed through. The four steps of PM-MCTS are explained in the following section.

Selection

The tree is descended from the root node following a thread of promising nodes until a leaf node is reached. In order to balance the estimate of the "value" of a node (defined below) with the possibility that the estimate may be inaccurate, a commonly used approach is Upper Confidence Bounds (UCB1) applied to Trees (UCT) (Kocsis and Szepesvári 2006). UCT minimizes "regret",

which is the difference between what could have been gained by always choosing the best child node (which is not known) and what was actually gained. The formula that UCT uses is:

$$\mathrm{UCT}_{i} = \overline{X_{i}^{p}} + C \sqrt{\frac{2\ln N}{N_{i}}},\qquad(1)$$

where $\overline{X_i^p}$ is the average value of action *i* from the perspective of player *p*, the one whose node is being evaluated; N_i is the number of times action *i* was tried at the node; *N* is the sum of N_i for all actions (action *i* and its sibling actions) and C > 0 is a constant.

Expansion

After a leaf node is reached, if the leaf is within depth D_{max} and has been visited at least N_{max} times, all children for the leaf are created, one for every possible action. Notice that the root already has its children when the process starts.

Rollout

The chain of actions encoded in the path root–leaf is run by a simulator, followed by a chain of random actions. Notice that the simulator only executes each action when the character has finished performing the previous action. The outcome of the rollout is evaluated from both characters' perspective, using the following formula:

$$\overline{X_i^p} = \frac{1}{N_i} \sum_{j=1}^{N_i} \operatorname{strength}_j \times \operatorname{PA}_j, \qquad (2)$$

where strength_j represents how close the simulation is to a victory for the character and is calculated by Equation (3), and PA_j represents the difference between the desired HP difference (determined by the PA) and the HP difference achieved in the simulation and is calculated by Equation (4).

$$\operatorname{strength}_{j} = \operatorname{oppHP}_{j}^{root} - \operatorname{oppHP}_{j}^{rollout}, \qquad (3)$$

where $oppHP_j^{root}$ and $oppHP_j^{rollout}$ represent, respectively, the opponent's HP in the root node and after the *j*-th rollout. The more the opponent HP decreases, the higher is this value.

$$PA_{j} = (1 - \gamma) \left(1 - \tanh \frac{|\text{diffHP}_{\text{ideal}}^{\text{leaf}} - \text{diffHP}_{j}^{\text{leaf}}|}{S} \right) + \gamma \left(1 - \tanh \frac{|\text{diffHP}_{\text{ideal}}^{\text{rollout}} - \text{diffHP}_{j}^{\text{rollout}}|}{S} \right)$$
(4)

where diffHP^{leaf}_{ideal} and diffHP^{rollout}_{ideal} represent the ideal HP difference of the characters at the corresponding time; diffHP^{real}_j and diffHP^{rollout}_j represent, respectively, the HP difference of the characters in the leaf node and after the *j*-th rollout. In addition, *S* is a scale parameter, and $\gamma \in [0, 1]$ is a discount rate. PA_j spans in the range from 0 to 1, where 1 means that the ideal PA has been generated. The parameter γ balances the value of the leaf node and the predicted value. The lower the HP difference between the characters, the higher is PA_j (between 0 and 1).

MCTS normally evaluates the state after the random rollout, but this has high variance, so to normalize for that we also consider the leaf node which is closer in time (less variance) to the current time and not random.

Backpropagation

The value from the perspective of each player, computed after a rollout, is propagated backward from the leaf node to the root node. In this process, the values for both characters are updated in each node along the path and the counters are increased accordingly.

PM-MCTS performs this process until one of the characters requests its next action. When this happens, it selects the child of the root node with the highest \overline{X}_i^p value.

The aim of the evaluation function of PM-MCTS is to balance between following the trajectory dictated by the PA and the believability of the performance of the players. If only the PA term were considered, the characters could behave excessively against their interest, and this could destroy the suspension of disbelief in the spectators. For example, in a PA in which P1 needs to lose HP with respect to P2 (e.g. 15 to 45 seconds in Figure 2 (a)), P1 will deliberately try to be hit to follow the PA. Such actions will appear unnatural for the spectators and cause them to lose interest in the game. To avoid this, the strength term compromises believability with PA targeting.

EXPERIMENT

We conduct an experiment to verify whether our proposed AI (Puppet-Master AI; PMAI) can generate game plays according to given PAs. We use the FightingICE platform (Lu et al. 2013) as a testbed; FightingICE has

Table 1: The parameters used in the experiment

Notation	Meaning	Value
C	Balance parameter	0.025
N_{max}	Threshold of the number of visits	10
D_{max}	Threshold of the tree depth	10
S	Scale parameter	10
γ	Discount rate	0.5

been used for AI agent competitions in the recent years. We attempt to generate three kinds of PAs shown in Figure 2. We run 50 games for each PA. The parameter settings for the PMAI are shown in Table 1. These parameters are set empirically through a pre-experiment. Actions in PM-MCTS are 56 actions available in FightingICE.

RESULTS

The comparison of ideal PAs with generated PAs, averaged over 50 games, is shown in Figure 3. In Figure 3, the horizontal axis indicates the game progress in terms of time (seconds), and the y-axis indicates the HP difference between the characters at a given time. The red line represents the ideal PA, the green line represents the PA generated by PMAI, and the error bars indicate the standard deviation of the HP difference at that time in generated PAs. We can see that generated PAs mimic the target PAs quite closely even though PMAI seems to have more difficulty when the slope of the target curve changes. These results suggest that PMAI can generate game plays according to a given PA.

However, the standard deviation of the HP difference seems to grow larger after the mid-point of the game in the Play Arc I and II. This is caused by player p executing a powerful attack called special attack that makes the PA value in Equation (2) fail to counterbalance because of the other term's magnitude. Notice that the special attack requires a large amount of character energy and can therefore only be performed late in the game.

We conduct a second experiment to test whether PMAI can generate game plays according to PAs even if their form suddenly changes during the game. The three PAs used in this experiment are shown in Figure 4. We set another PA as the ideal PA after the mid-point of the game. For example, the PA of Figure 4 (a) consists of two PAs; the first half of the game is the PA of Figure 2 (a), and the latter half of the game is the PA of Figure 2 (b). We run 50 games for each PA like the previous experiment.

Figure 5 shows the performance of PMAI when following these curves. Again, the figures show averages over 50 games along with error bars. The figures show that PMAI can track the sudden changes within a few seconds, suggesting that it is robust to erratic PA curves.



Figure 2: An overview of Play Arcs



Figure 3: Comparison of ideal PAs with generated PAs



Figure 4: An overview of combined Play Arcs



Figure 5: Comparison of ideal combined PAs with generated PAs

CONCLUSION

The PPG system needs an AI that can generate game plays that follow a given game progress curve, called Play Arc (PA). This is then used to generate games tailored to specific spectators, according to their preferences. In this paper, we propose the "Puppet-Master" fighting game AI (PMAI) that controls both characters in the game to automatically generate various game plays using MCTS. The experimental results show that PMAI can generate PAs that track target PAs quite closely, even when said PAs exhibit sudden changes in their shape.

A limitation of this work is that the evaluation function of PMAI, detailed in Equation (4), only considers the HP difference. While, arguably, this could be the most important element, other elements could be taken into account, such as the distance of the characters, their energy or the number of combos executed. Also, we only focused on the generation of game plays according to given PAs, with no consideration on whether or not generated game plays entertain spectators. In future work, we plan to conduct user studies to evaluate the entertaining value of various PAs.

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GAME VR

INTERACTIVE EDUCATIONAL CONTENTS DEVELOPMENT FRAMEWORK AND ITS EXTENSION FOR WEB BASED VR/AR APPLICATIONS

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KEYWORDS

Development Framework, Web Technology, 3D Graphics, Virtual Reality, Augmented Reality

ABSTRACT

This paper treats one of the activities of ICER (Innovation Center for Educational Resources) in Kvushu University Library of Kyushu University, Japan. It is the development of educational contents using recent ICT for enhancing the educational efficiency in the university. Especially, this activity focuses on the development of attractive and interactive educational contents using 3D CG. So, the authors have already proposed a framework dedicated for the development of Web-based interactive 3D educational contents and introduced a couple of practical educational contents actually developed using the proposed framework. For developing more attractive educational contents using Virtual Reality(VR)/Augmented Reality(AR), the authors added new functionalities to make the framework possible to develop Web-based VR/AR applications. This paper introduced this new web-based VR/AR application development framework.

INTRODUCTION

This paper proposes a web-based VR/AR application development framework for attractive and interactive educational contents. This research is one of the activities of our center called ICER (Innovation Center for Educational Resources)[www.icer.kyushu-u.ac.jp/en] in Kyushu University Library of Kyushu University, Japan.

Efficient education will be achieved with attractive educational contents that would be realized by the most recent ICT like 3D CG because current students sometimes called video game generation are used to operate such contents. However, there is the problem that the development of such contents requires technological knowledge and programming skills but usual teachers do not have such knowledge and skills. Teachers need any tools to make it easier to develop attractive educational contents that use the most recent ICT. So, we have already proposed a framework dedicated for the development of Web-based interactive 3D educational contents (Okada et al. 2016a, Okada et al. 2016b). In general, attractive educational contents should include various types of media data like audio, videos and 3D geometry data with their animation data besides texts. The proposed framework supports such media data. In some cases, there are story-based contents to follow an instructional design. The framework also supports such story information.

As case studies, we have developed two educational contents with the proposed framework. One is for teaching certain ancient manners of the ceremony called 'Kanso' taken in the ancient building 'Gosyo' in Japanese history study, and the other one is as tourism information about a certain ancient building called 'Korokan'.

These are web-based contents so that they are possible on various platforms such as iPhone, iPad, and Android tablets besides standard desktop PCs. This is significant for BYOD (Bring Your Own Device) classes and Mobile Learning. However, for this, touch interfaces should be supported. So, this time we introduced functionalities of touch interfaces into the framework. Furthermore, to make it possible to develop more attractive contents than them using VR/AR, we also introduced new functionalities to the framework. Among of them are a stereo view, a device orientation and geolocation interfaces, and a camera interface for tablet devices and smart phones. By supporting these functionalities, it is possible to develop web-based VR/AR applications.

The remainder of this paper is organized as follows: next Sec. 2 describes related work. We briefly explain the proposed framework, its design and functional components in Sec. 3, and introduce the two actual contents currently we have been developing. In Sec. 5, we explain details of newly introduced functionalities for developing VR/AR applications. Finally, we conclude the paper and discuss about future work.

RELATED WORK

There are many development systems and tools for 3D contents. Some of them are commercial products like 3D Studio Max, Maya, and so on. Although these products can be used only for creating 3D CG images or 3D CG animation movies, usually, these cannot be used for creating interactive contents. As a development system for 3D interactive contents, there is IntelligentBox, a constructive visual software development system for 3D graphics applications (Okada and Tanaka 1995). This system seems very useful because there have been many applications actually developed using it so far. However, it cannot be used for creating web-based contents. Although there is the web-version of IntelligentBox (Okada 2013), it cannot be used for creating story-based contents. With Webble [www.meme.hokudai.ac.jp/WebbleWorldPortal/], it is possible to create web-based interactive contents through simple operations for authoring and of course, possible to render 3D graphics assets. However, it does not have functionalities of IntelligentBox.

There are some electronic publication formats like EPUB, EduPub, iBooks and their authoring tools. Of course, these contents are used as e-learning materials. However, basically, these are not available on the Web and do not support 3D graphics.except iBooks. iBooks supports rendering functionality of a 3D scene and control functionality of its viewpoint. However, story-based contents cannot be created using it.

From the above situation, for creating web-based interactive 3D educational contents, we have to use any dedicated toolkit systems. The most popular one is Unity, one of the game engines [unity3d.com/], that supports creating web-contents. Practically, using Unity, we have developed 3D educational contents (Sugimura et al. 2014, Sugimura et al. 2015) for the medical course students of our university because Unity is a very powerful tool that supports many functionalities. However, the use of Unity requires any programming knowledge and skills of the operations for it. Therefore, it is impossible to use Unity for standard end-users like teachers. As a result of the above, in this paper, we proposed the framework(Okada et al. 2016a, Okada et al. 2016b) explained in the next section.

PROPOSED FRAMEWORK



Our targets are web-based interactive 3D educational contents. Such contents should have any story. Each story is realized with several 3D scenes consisting of several architecture objects like buildings and houses, and several moving characters like humans who have their own shape model and animation data. Firstly, such 3D assets data should be prepared. Next, contents creators have to define a story for the content as one JavaScript file called 'Story Definition File'. In our proposed framework, the requirements for creating a content are 3D assets data and 'Story Definition File'.

Figure 1 shows functional components of the proposed framework consisting of main components (Main.html) and sub components (AnimationCharacter.js). The main components include functions related to architecture objects and functions related to AnimationCharacter objects represented as moving characters. The sub components include the constructor of new AnimationCharacter class and its member functions. Besides main and sub components, our framework uses Three.js [threejs.org/], one of the WebGL based 3D Graphics Libraries as subsidiary components.

When developing a story-based interactive 3D educational content with the proposed framework, a teacher has to prepare one story definition file and 3D assets for it. See the papers(Okada et al. 2016a, Okada et al. 2016b) for more details.

CASE STUDIES

As case studies, we have developed two interactive contents with the proposed framework. One is for teaching certain events and ceremonies taken in the Imperial court called 'Gosyo', including ancient manners of the Emperor called 'Tennou' and Cabinet members called 'Daijin' and 'Daiben' and so on as Japanese history study. Especially, now we focus on the story called 'Kanso'. The other one is for teaching a certain ancient building called 'Korokan' to tourists visiting to our 'Fukuoka' city as tourism information.

'Kanso' content of Japanese history study



Figure 2: Screen shot of 'Kanso' content and its architecture

'Kanso' is one of the ceremonies taken in 'Gosyo'. 'Kanso' includes various types of manners of 'Tennou' and 'Daijin, etc. In Japanese history study, students have to learn such manners by reading old documents about 'Kanso'. However, it is very difficult to understand the manners from the old documents.

Using this interactive 3D educational content of 'Kanso' shown in Figure 2, it becomes easy for students to understand.

In Figure 2, there are three houses called 'Seiryoden'(left), 'Shishinden'(middle) and 'Jinnoza'(right). Figure 3 shows two different scenes at 'Jinnoza' and at 'Seiryoden'. As moving characters of 'Kanso', there are seven characters, i.e., 'Tennou', 'Daijin', 'Shi', etc. Each moving characters are implemented as instances of AnimationCharacter class in JavaScript. AnimationCharacter has its several animation data prepared as dae format files. For this content, we prepared around 100 dae format files. To reduce the cost to prepare these data files, we employ 3D human pictograms for the shapes of moving characters. Since their colors are different, it is possible to recognize each characters. The texts displayed in white colour at the upper-middle position of the two scenes explain the behaviours of the moving characters. By reading the texts, the students can understand the manners in 'Gosyo' more deeply with looking at the manners as 3D CG animations.



Figure 3: Two screen shot of 'Daijin' and 'Shi' at 'Jinnoza' (upper) and 'Tennou' and 'Daijin' at 'Seiryoden'(lower)



Figure 4: Screen shot of 'Korokan' content and its architecture

'Korokan' content about ancient building as tourism information

Figure 4 shows screen shots of 'Korokan' content that is for teaching a certain ancient building called 'Korokan' to tourists visiting to our 'Fukuoka' city as one of the sight-seeing spots. In fact, the building does not exist and only its remains exist. We have been developing this content as one of the collaboration works with our 'Fukuoka' city government. The upper part of Figure. 4 shows a certain scene of the building and the lower part of the figure shows a screen shot of displaying one of the image files related to the building. Tourists can walk through the scene virtually using this content on their own PC and maybe become attracted to 'Korokan'.

FUNCTIONALITIES FOR VR/AR APPLICATIONS

This section explains newly introduced functionalities that are a stereo view, touch interfaces, device orientation/motion interfaces, geolocation interface and a camera interface for tablet devices and smart phones. By supporting these functionalities, it is possible to develop web-based VR/AR applications.

Stereo view support

The JavaScript program for the stereo view is very simple within Three.js as shown in the below because Three.js provides StereoEffect.js and you can read this file in your HTML file and can call effect.render(scene, camera) for the stereo view instead of calling renderer.render(scene, camera) for the standard view.

```
----
```

<script src="js/effects/StereoEffect.js"></script>

renderer = new THREE.WebGLRenderer();
// for Stereo
renderer.setPixelRatio(window.devicePixelRatio);
container.appendChild(renderer.domElement);
effect = new THREE.StereoEffect(renderer);

if (stereo_on) {
 effect.render(scene, camera);
} else {
 renderer.render(scene, camera);
}

۶ -----

Touch interfaces

The JavaScript program for touch interfaces is also simple as shown in the below because HTML5 supports 'touchstart', 'touchend', 'touchmove' events and you can access x-, y-positions of your touch fingers by event.touches[*].pageX and event.touches[*].pageY, here, * is the index of your fingers.

var onTouchStart = function(event){

event.preventDefault();

if (event.touches.length > 0){

// operation for touch start

// event.touches[0].pageX

```
// event.touches[0].pageY
}
var onTouchEnd = function(event){
  event.preventDefault();
  if (event.touches.length > 0){
     // operation for touch end
    // event.touches[0].pageX
     // event.touches[0].pageY
  3
}
var onTouchStart = function(event){
  event.preventDefalult();
  if ( event.touches.length > 0 ){
    // operation for touch move
    // event.touches[0].pageX
    // event.touches[0].pageY
  }
}
```

window.addEventListener('touchstart', onTouchStart, false); window.addEventListener('touchend', onTouchEnd, false); window.addEventListener('touchmove', onTouchMove, false);

Device orientation/motion interfaces

The device orientation/motion interfaces are simple but useful in a JavaScript program of HTML5 as shown in the below because there are 'deviceorientation' and 'devicemotion' events, and you can access the device orientation/motion of your smart phone by event.alpha, event.beta, event.gamma, event.acceleration.x, event.acceleration.y, event.acceleration.z.

```
var onDeviceOrientation = function(event){
  event.preventDefalult();
     // device orientation
     // event.alpha
    // event.beta
    // event.gamma
  }
}
var onDeviceMotion = function(event){
  event.preventDefalult();
    // device acceleration
    // event.acceleration.x
    // event.acceleration.y
    // event.acceleration.z
  1
}
```

window.addEventListener('deviceorientation', onDeviceOrientation, false);

window.addEventListener('devicemotion', onDeviceMotion, false);

Geolocation interface

The JavaScript program for geolocation interface is also very simple within HTML5 as shown in the below because HTML5 supports navigator.geolocation variable and navigator.geolocation.getCurrentPosition() function, and you can access the device geolocation of your smart phone by position.coords.latitude and position.coords.longitude.

```
// when succeeded
function successGeoFunc( position ){
    // position.coords.latitude
    // position.coords.longitude
}
// when error
function errorGeoFunc( error ){
    // error.code
}
function gps_on(){
    if ( navigator.geolocation ){
        navigator.geolocation.getCurrentPosition( successGeoFunc,
errorGeoFunc , optionGeoObj );
    } else {
        alert( "Your device cannot support geolocation.");
    }
......
```

Camera interface

For developing web-based AR applications, we have to manage video camera images in real-time on a web browser. There is WebRTC project that provides browsers and mobile applications with Real-Time Communications (RTC) capabilities via simple APIs. Using WebRTC, it is possible to manage video camera images on a web browser and to develop web-based AR applications.

Practical use cases



Figure 5: Snap shots of 'Korokan' with a stereo view on a smart phone(upper), VOX+ 3DVR goggle(lower left) and Poskey blue-tooth gamepad(lower right)

The upper part of Figure 5 shows a snap shot of 'Korokan' content with a stereo view on a smartphone, the lower left

part is a picture of VOX+ 3DVR goggle and the lower right part is a picture of Poskey blue-tooth gamepad. Using this type of 3DVR goggle, web-applications on a smartphone that support device orientation interface and geolocation interface, and display the stereo images of 3D graphics, come to be Virtual Reality application. Although our framework supports touch interfaces for tablet devices, those interfaces cannot be used when using VOX+3DVR goggle because a tablet device is put inside the goggle and the user cannot touch it. To compensate this inconvenience, our framework supports Poskey blue-tooth gamepad input. Instead of touch interfaces, the user can move in a virtual 3D space through the gamepad operations.



Figure 6: EPSON Moveiro BT-300 AR smart glasses

Figure 6 shows a picture of EPSON Moveiro BT-300 smart glasses. This is a see-through type display glasses that supports 3D mode of side-by-side, touch interfaces and device orientation interface. Therefore, the walk-through in 'Korokan' content similar to the case of VOX+3DVR goggle and Poskey blue-tooth gamepad is possible without any additional device. Furthermore, using geolocation interface, this 'Korokan' content becomes AR application because 'Korokan' CG images seen from the same viewpoint as the geolocation data can be automatically generated and those are displayed on the real scenes seen through the glasses.

CONCLUSION

In this paper, we proposed the framework dedicated for the development of web-based interactive 3D educational contents. The framework supports the most recent Web technologies, i.e., HTML5 and various JavaScript Libraries including WebGL. Our purpose of this framework is to make it possible to easily develop story-based interactive educational contents. This paper briefly explained the framework, its design and functional components. Furthermore, this time, we added several new functionalities in order to make the framework possible to develop webbased VR/AR applications. In this paper, we also described their details.

As future work, we will try to ask teachers to use the proposed framework for actually developing web-based interactive 3D educational contents as VR/AR applications to clarify the usefulness of the framework.

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AN EXPERIMENT DESIGN: INVESTIGATING VR LOCOMOTION & VIRTUAL OBJECT INTERACTION MECHANICS

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KEYWORDS

Virtual Reality, Locomotion, Virtual Object Interaction, Experiment, Gooze.

ABSTRACT

In this paper, we describe an experiment outline on investigating design and user experience related aspects of several virtual reality locomotion and virtual object interaction mechanics. These mechanics will be based on consumer hardware like a common game controllers, an infrared hand and finger tracking device, VR hand controllers and an omnidirectional treadmill. Corresponding related work will contextualize and motivate this research. The projected experimental study will be based on user test sessions with a specifically developed 1st person VR puzzle horror game, called Gooze. A hybrid approach of self-assessment, in-game parameter tracking and session observations will be proposed for the investigation. Statistical analysis methods will be suggested to evaluate results. Furthermore, this paper will give an overview of the game and elaborate on design, gameplay and user experience related insights of already conducted informal pre-studies with it.

INTRODUCTION

Merging previously established game types, e.g. like 1st person shooters, with the capabilities of modern virtual reality (VR) is not a trivial task. Various aspects of game design and development like high rendering performance, attractive gameplay, sophisticated user experience (UX), usable design and diverse hardware setups are among the challenging areas. Related to several of these areas are two outstanding challenges: controlling locomotion and interacting with virtual objects in VR. 1st person locomotion in VR is problematic, as previously established paradigms of controlling movement in games often leads to simulator sickness in VR players, "when visual cues do not match other sensory modalities" (Jerald 2016). E.g. the common mechanic of using two analogue sticks on a common game controller to turn and move, directly ported to VR, likely leads to nausea in a lot of users (Riecke and Feuereissen 2012 and Yao 2014). On the other hand, interacting in VR with virtual objects can lead to exciting experiences and open up lots of new gameplay possibilities, but is also confronted with a variety of fundamentally different hardware setups. To deliver an as good as possible experience for players, it seems essential to offer several virtual object interaction mechanics. In the following, this paper will outline some possible combinations of consumer technology based VR locomotion and virtual object interaction mechanics and in which way they will be evaluated in a projected experimental study.

RELATED WORK

The following will inform on related works regarding VR locomotion and virtual object interaction, as well as the chosen platform of the proposed experiment, the specifically developed game Gooze.

Locomotion

Reddit lists 24 different VR locomotion mechanics, categorized into teleportation, motion, roomscale and artificially based ones (2016). These different approaches lead to the assumption, that providing an attractive gameplay, while solving simulator sickness caused by locomotion is not only a technical issue, but rather a challenge in design. Our experiment will investigate the most prominent mechanics, develop individual integrations, compare them and eventually provide case based recommendations for developers and designers.

On the basis of "travel time, collisions (a measure of accuracy), and the speed profile" through a virtual environment (VE) consisting of orthogonally arranged corridors, Ruddle et al. (2013) evaluated different locomotion mechanics like using a joystick, actual walking in VR and using industrial linear and omnidirectional treadmills. Their study "illustrates the ease with which participants could maneuver in a confined space when using an interface that was 'natural'" like using an omnidirectional treadmill or walking completely freely (Ruddle et al. 2013). Furthermore, user issues with translational movements seem to be inherent in abstract interfaces "(e.g., a joystick, keyboard or mouse) ... irrespective of whether or not an immersive display is used" (Ruddle et al. 2013). By comparing these previous findings with the corresponding UXs of our projected experiment, prospective outcomes will be contextualized on a different level.

More concerned with UX of locomotion mechanics, Bozgeyikli et al. conducted an experiment comparing point and teleport, walk-in-place and joystick locomotion mechanics (2016). Their findings indicated, that their implementation of a point and teleport mechanic is "an intuitive, easy to use and fun locomotion technique", while reducing simulator sickness to minimum (Bozgeyikli et al. 2016). Although closely related to our projected experiment, using the almost consumer ready game Gooze as a testing platform, instead of an experiment application, and additionally comparing locomotion via omnidirectional treadmill, will differentiate our experiment. Relating to testing consumer ready omnidirectional treadmills, Cakmak et al. have introduced the "Cyberith Virtualizer" (2014). This device consists of a low friction base plate and a pillar structure holding a vertically movable harness for the user. Strapped into the harness a user then walks over the low friction surface on the spot. Sensors provide data on the user's orientation, current height and movement speed, to be interpreted into locomotion commands (Cakmak et al. 2014). Though the Virtualizer is a very sophisticated omnidirectional treadmill, we will use a slightly inferior, but nevertheless similar treadmill called ROVR (Wizdish 2017) instead, because of availability issues.

Virtual Object Interaction

There seems to be a lack of literature investigating solutions for complete virtual object interaction mechanics, instead of dedicated sub tasks like virtual object selection or transport.

E.g., the literature survey by Argelaguet et al. is concerned with a plethora of virtual object selection mechanics using mostly industry and research based hardware (2013). They come to the conclusion that, "Although 3D interaction techniques for target selection have been used for many years, they still exhibit major limitations regarding effective, accurate selection of targets in real-world applications" (Argelaguet et al. 2013). They argue, that current limitations arise through a combination of "visual feedback issues" (e.g. occlusion and depth perception in stereoscopic 3D) and "inherent features of the human motor system" (e.g. neuromotor noise, Argelaguet et al. 2013). Argelaguet et al. propose that designing 3D interaction mechanics with improved efficiency, would involve developing novel "strategies for controlling the selection tool" and enhancing provided visual feedback (2013). We further agree with Argelaguet et al., that "in the real world selection tasks are mixed with other primary tasks such as manipulation and navigation" and should in turn be evaluated not only in isolation, but in a more holistic manner. This will be the case with our proposed experiment.

Kim et al. investigated virtual object interaction (grabbing and transporting) with a hand and finger tracking device in the context of causing "awkwardness and manipulation difficulties" in users, which they named "VR interaction-induced fatigue symptom" (2014). Their study inferred e.g. duration time, maximum grip aperture and the number of trials and errors to induce "fatigue and difficulties in manipulation" (Kim et al. 2014). Their design guidelines include enhancing object "contact cues" through sensory user feedback and adjusting the "input action strategy" and the viewpoint (Kim et al. 2014). The latter aspect will likely not be feasible to control in a completely dynamic VR application and although the input action strategy might be optimized to some degree, the game's gameplay for the projected experiment will still require certain durations of grabbing and interacting with objects. Nevertheless, it seems reasonable to take Kim et al. 's "Conceptual interaction model for grasping control" (2014) into account in the further design process of the game Gooze.

Gooze

Gooze is a single player 1st person horror VR game (see Figure 1), based on a real derelict sanatorium. The user needs to solve

puzzles, by interacting with objects to flee from scary creatures from room to room, e.g. like using a loose bedpost as a lever to break open a padlock on a door. For that, the player needs to explore the surrounding by walking around and to grab, carry and use interactive objects with each other. He or she will be supported by subtitles, visualizing thoughts of the player character and giving subtle hints regarding the puzzles.



Figure 1: Stereoscopic Screenshot of Gooze, showing the player's hands, tracked with a Leap Motion controller

While living through a horrifying atmosphere of decay and surreal entities, the player will not be provided with any weaponry. To create this atmosphere, Gooze subtly creates pressure in players, by playing with different room settings and limiting light sources. E.g. the ceiling light in Figure 1 can be grabbed and turned to temporarily light up a corner of the room. Once you have done that, you need to explore that corner more thoroughly in semi-darkness though, as you cannot take the light with you. Inspiration for puzzles, rooms and textures was gathered during a two-day expedition to the derelict Grabowsee sanatorium near Berlin (Jüttemann n.d.). Built on the Unity 3D game engine (Unity Technologies 2017), Gooze uses the Oculus SDK (Oculus VR 2017a) for VR. Though some features are already implemented, in its next iteration, it will provide several input options. Eventually, these will include support for common game controllers, the Leap Motion controller (Leap Motion 2017), the Oculus Touch hand controllers (Oculus VR 2017b) and the Wizdish ROVR (Wizdish 2017) omnidirectional treadmill.

Insights of informal Pre-Studies



Figure 2: Photograph of one informal Pre-Study

A simple evaluation of simulator sickness has been performed during one pre-study with the game (see Figure 2). After each of the 40 sessions, ranging between 5 to 15 minutes, the current user was asked to assess any present nausea on a scale from 0 to 10 (10 relating to feeling extremely sick). Although, not creating scientifically exploitable results, this method led to an estimation of how well this previous iteration of Gooze was accepted in terms of simulator sickness, which was really well when looking at 90% of users placing themselves in the lower third, of which the majority did not feel any nausea at all (65%). The nausea level score's mean and standard deviation were 0.825 ± 1.466 (see Figure 3 and Table 1).





Table 1: Nausea Ratings

Further pre-studies also uncovered several relevant insights regarding the game's design, gameplay and UX. E.g., in an earlier iteration of the game a gaze based virtual object selection and a controller button based interaction mechanic with the selected virtual object was offered. Switching from this, to a more natural mechanic of tracking player hands with a mounted Leap Motion controller (see Figure 2) and using these hand representations for object selection and interaction hugely effected the feel of the game and its UX. Seeing one's relatively accurately tracked hands and fingers much improved the game's chance to induce presence (International Society of Presence Research 2000) in a player. On the other hand, these studies and the prior development phases also uncovered the need for a robust grabbing mechanic. However, this could not be solved by simply making use of physics colliders attached to the hand representations, as without actual haptic feedback and the underlying imprecisions of Unity's physics engine, virtual objects would just be pressed through the virtual hands. Instead, a semi-automated grab mechanic seemed more reliable. With this, a grab parameter of a virtual hand, defined through its pose, would be checked and if in a certain range of an interactive object, the object would be snapped into this hand in a predefined pose, most likely for the object. E.g. a polaroid is more likely to be held with 2-3 fingers at one of the corners, instead of holding it like an apple in the palm of a hand. Though not being a perfect solution, this mechanic was accepted and understood well by users.

Another important finding was, that using a combination of a common game controller for locomotion, and a Leap Motion controller for virtual object interaction, does not work well together. Gazing at your hands on the common controller when walking around the VE unwantedly created possibly obstructing virtual hand representations. Additionally, needing to push buttons and analogue sticks on a common game controller while carrying a virtual object, by holding your physical hand in front of you, seemed very awkward for players.

Finally, the play sessions approved the game's general gameplay mechanic and its look and feel was supported well by players with a liking for the horror genre.



EXPERIMENT DESIGN

Locomotion & Virtual Object Interaction Mechanics

The following combinations of mechanics do not have to be discrete, but can also be recombined, filtered or extended, depending on the design and objective of a game, in which they should be applied. Nevertheless, these combinations have been chosen for evaluation, as they likely correspond to real-world use-cases in terms of VR hardware setups and seemed appropriate for the game Gooze. For stereoscopic 3D VR vision, all of them incorporate an Oculus CV1 head mounted display (HMD) and corresponding tracking equipment.

In the hardware setup of Figure 4a, participants will sit on a swivel chair, providing the freedom to physically turn while also simulating a seated gaming situation. A common game controller will be used to perform in-game locomotion and virtual object interaction.

In the setup of Figure 4b the participant will be standing and a Leap Motion controller, mounted to the HMD, will track his or her hands and fingers. Locomotion can be performed via a point and teleport mechanic with one hand, while the other hand can be used to interact with virtual objects.

The setup of Figure 4c is almost identical to Figure 4b, except two Oculus Touch hand controllers will be used to point and teleport and interact with virtual objects instead.

Finally, in the setup of Figure 4d, the participant will use a Wizdish ROVR omnidirectional treadmill for locomotion and two Oculus Touch controllers for virtual object interaction.

Experiment Methodology

All participants will be introduced to the experiment's subject and procedure and ethical consent and general gaming and VR related information will be collected from them.

In a within subject experiment design, each participant will be asked to play the game Gooze. While doing so, each one will go through all experiment phases and try out the previously mentioned hardware/mechanics setups (see Figure 5). The order of these setups will be pseudo randomized via the Latin





square method. Each phase will last for 5 minutes. After each phase, the game restarts itself. The whole process will be video recorded to capture any remarks or relevant user behavior, for later analysis. Also, various in-game parameters, e.g. like locomotion and turning speeds, as well as the number of object drops and the individual order of setups will be tracked.

Once all phases have been completed, a self-assessing experience questionnaire will be filled out by the participant. Each setup will be processed in a repeating section: The igroup presence questionnaire (igroup 2016) will establish an individual presence rating, participants will further be asked for a 7 point Likert scale rating of the current setup's ability to support the gameplay of the game and one for their individual enjoyment. Additionally, each setup will be rated for simulator sickness on scale between 0 to 10 (for comparable results with previous data). Finally, participants will be asked to choose a preferred setup and they will be provided with several free text fields to give comments specific to setups and the game in general.

Once all participant and tracking data has been processed into a single database, it will be statistically analyzed for significant mean differences between setups. These results will be analyzed for possible cross correlations and then be interpreted in parallel with the gathered qualitative data. Finally, possible design and development guidelines will be extrapolated.

EXPECTED EXPERIMENT LIMITATIONS

Due to the experiment's projected design and complexity, it may not be able to uncover fine grained insights on sub tasks of virtual object interaction like object selection, grabbing, carrying and using. Though qualitative free text answers of participants may or may not give relevant insights related to specifics of design or implementation of mechanics, the focus of the study will be on openly comparing the UXs of those mechanics. Furthermore, again due to the already complex within subject design of the experiment, it will not be possible to acquire entirely discrete simulator sickness ratings for each locomotion mechanic. Possible bias will be attenuated though, by using a Latin square randomization for the order of setups per participant and by interpreting qualitative participant data in parallel.

CONCLUSION

In this paper, we illustrated the need to investigate two challenging areas of VR gaming, namely locomotion and virtual object interaction. The reduction of simulator sickness to an absolute minimum is essential to deliver a pleasant VR experience and locomotion mechanics are tightly linked to this challenge. Related work suggests needed investigations of different mechanics in the context of design and UX. On the other hand, related work on virtual object interaction seems to be specifically concerned with sub tasks and does not investigate corresponding mechanics in a holistic way.

In turn we proposed to conduct a within subject experiment, to compare four different setups of combined mechanics, by letting participants play the specifically developed game Gooze. Afterwards they will self-asses their individual UXs and the design of the game. After processing and analyzing the gathered data, any findings will be extrapolated to form corresponding design and development guidelines.

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GAME CHARACTERS

BELIEVABILITY ASSESSMENT FOR FIGHTING GAME AI

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KEYWORDS

Turing test, cosine similarity, game AI, believability.

ABSTRACT

We describe two methods of analyzing human and AI play style patterns in an arcade fighting game. The first is the application of a Turing test to study game characters' behavior. The second is the calculation of a cosine similarity between "behavior fingerprints" consisting of sequences of individual actions or combo chains. The main goal of this study is aimed to find an approach that helps to determine the believability of game AI. Our experiments with Universal Fighting Engine environment and its built-in AI system demonstrated that both people and AI agents exhibit different play styles, and AI agents are virtually indistinguishable from human-controlled characters.

INTRODUCTION

Most types of computer games implement AI logic in some form. According to Dill, the purpose of game AI is to support a certain player experience (Dill, 2013)). AI plays the key role in supporting players' entertainment; too weak or too strong AI can reduce the overall quality of a game. In certain game genres an AI system is supposed to imitate human behavior. This ability is especially important if AI controls human-like characters or replaces real players.

One of the problems of designing human-like AI is to find actual criteria of human-likeness that can be used to distinguish characters controlled by human players and by AI. One of the possible solutions is to adapt *Turing test* (Turing, 1950) for game AI assessment, i.e., to rely on human evaluation of the believability (Livingstone, 2006), (Gorman, Thurau, Bauckhage, & Humphrys, 2006). Alternatively, it is possible to test human-likeness by comparing behavior patterns of an AI system with those of human players, as shown in (Tencé & Buche, 2008) and (Mozgovoy & Umarov, 2010).

We discuss both approaches for analyzing play styles and believability of game characters in an arcade fighting game. The first approach is a Turing test-inspired series of player evaluations performed by people watching pre-recorded game clips. The aim of this approach is to investigate human ability to discern individual players and to separate AIcontrolled and human-controlled characters. The second approach uses an automated evaluation algorithm that builds a "behavior fingerprint" for each game character. The fingerprints are then compared to reveal similarities and differences between the players and between human- and AIcontrolled characters. The experiments show that each player in our game possesses recognizable behavior traits, but separating humans from AI agents is difficult.

In our experiments, we use a publicly available fighting game engine called Universal Fighting Engine (UFE). During game sessions, players can operate game characters by controlling six attack buttons and four direction keys. In addition, the players can make game characters perform special actions such as fireball and uppercut by using key combos.

UFE contains a built-in AI system called *Fuzzy AI Add-on* that uses fuzzy logic to evaluate the information of the scene and calculate the desirability of each given action, translating the AI decisions directly into user input. In the experiments we use three AI-controlled characters, based on different Fuzzy AI settings: 1) very easy; 2) normal; 3) impossible.

TURING TEST FOR PLAY STYLE ANALYSIS

To verify whether human players show unique play styles and whether human players are distinguishable from AIcontrolled characters, we prepared two types of a Turing test.

Matching game clips test

We asked a group of testers to watch five game clips, each showing a match between a player A-E and a random opponent. Players A-C were controlled by three different persons, while Player D and Player E were controlled by the Fuzzy AI system set to a very easy and normal modes respectively. Next, we asked the testers to watch five more clips showing the same players A-E playing against random opponents. Finally, the testers had to accomplish the following assignments:

- 1. To identify pairs of clips showing the same players A-E.
- 2. To identify whether each character A-E in the latter five clips is controlled by a person or by an AI system.

A tester gets one point for each correct pair or answer, and we perform the experiment twice. Therefore, the best possible score is 10 for each question, and the total number of clips each tester has to watch is 20.

Grouping game clips test

For this test, we prepared 15 clips showing each of the players A-E fighting against a random opponent three times. Players A-C were controlled by three different persons, while Player D and Player E were controlled by the Fuzzy AI system set to normal and impossible modes respectively. We have showed these clips to the testers, and asked them to:

1. Group together three clips of to the same player A-E.

2. Classify the players into the "human" and "AI" groups.

The tester gets two points for each correct group of three clips belonging to the same character and one point for an incomplete group of two correct and one wrong clips. Therefore, one may score up to 10 points in this task.

When the tester correctly marks a group of three AIcontrolled charcters as "AI group", we add three points to the score. When the marked group contains only two AIcontrolled characters, we add two points. Therefore, the tester can score up to 15 points in the second assignment.

Turing test results

We carried out the "Matching game clips test" with the help of 10 testers. All of them are male students, 21-22 years of age, having vastly different experience with fighting games, ranging from "no experience" to "over 100 hours".

Our experiments show that the testers possess different guessing abilities: three testers scored 7-8 points, four testers scored 5-6 points, and three testers scored only 2-4 points. Interestingly, the outcomes of the assignments seem not to be related. For example, tester 1 scored well on the first ("matching-1") assignment, but performed poorly on the second ("matching-2") assignment. Similarly, tester 6 got a high score for the second assingment, but showed average result on the first assignment. Furthermore, the lack of experience in playing fighting games did not significantly affect the results. For example, tester 8 indicated that he has no experience of playing fighting games, and yet he got a high score in the first assignment. The ability of people to identify distinct play styles in a fighting game becomes apparent in comparison with the random guessing algorithm that provides "baseline" scores, obtained by running the algorithm 200 times (Table 1). It is also clear that the abilities of individual testers are highly dispersed.

	Human Evaluation				Random Guess			
	M1	M2	G1	G2	M1	M2	G1	G2
Average score	5.3	5.0	4.7	8.6	1.9	4.8	2.1	7.5
Standard deviation	2.0	2.4	2.5	0.9	1.4	1.6	1.2	1.9

Table 1: Matching (M) and Grouping (G) test scores

The results of the second ("Grouping game clips") Turing test were obtained with the help of 9 testers from the same initial group of testers. These results are generally consistent with the first "Matching game clips" test. Again results of the individual test assignments seem not to be related. For example, tester 6 scored poor in the first assignment, but was able to get a high score in the second assignment. The results further prove that game experience does not help: the testers 6 and 8 indicated that they have "over 100 hours of play" experience, but still scored poorly in the first assignment.

To summarize the results of the Turing tests, we may note that on average people consistently beat random guessing algorithm in play style-related assignments: 5.3 points vs. 1.9 points in the first test, 4.7 points vs. 2.1 points in the second test. However, people performed only marginally better than the random algorithm in the task of identifying AI players.

AUTOMATIC IDENTIFICATION OF PLAY STYLES

We also analyzed player similarity in Universal Fighting Engine by comparing behavioral fingerprints, obtained with two different methods. The first method represents fingerprints as vectors of probabilities of individual actions in a certain player's game log. The second method represents fingerprints as matrices of probabilities of two consecutive actions in the game log. The obtained fingerprints are compared with cosine similarity measure (Nguyen & Bai, 2010). In order to compare matrices, we first convert them into vectors by rewriting matrix elements row after row.

The experiment was performed as follows.

- 1. We organized a tornament for five human players A-E and three AI opponents, controlled by Fuzzy AI with different difficulty settings (Ve: very easy, No: normal, and Im: impossible).
- 2. These players played three matches against each possible opponent, and the game logs were recorded.
- 3. We used game logs to calculate behavior fingerprints of the game characters, and compared the fingerprints against each other. To evaluate the consistency of behavior of the same characters in different matches, we compared their fingerprints obtained on different game logs and averaged the results.

UFE implements 33 actions, so an individual actions-based fingerprint consists of 33 elements. Similarly, a fingerprint obtained on two-action combos, consists of 33×33 elements.

Results of cosine similarity analysis

The Table 2 (lower half) shows player style similarities calculated using a cosine similarity value for vectors of probabilities of individual actions. In general, we can see high similarity scores between the fingerprints of the same player, and much lower similarity between the fingerprints of distinct players. The only exception is the pair C-D, having a higher similarity score than than D-D.

The upper half of the table shows player cosine similarity values obtained for the combo chains-based fingerprints. These values are comparable to the ones shown in the lower half, so the method based on the combo chains gives no significant improvements. The similarity of distinct players' fingerprints is ≈ 0.5 on average, while the similarity of different fingerprints of the same player is ≈ 0.8 on average.

The idea to calculate characters' fingerprints on the basis of action combos was motivated by the suggestion that such fingerprints would include more data and thus supposedly would imrove the results (i.e., different players will get lower similarity scores, while the same player in different matches will get a higher score). However, it turned out that the difference obtained using these two methods is marginal.

Furthermore, there is no significant difference between the results obtained for human- and AI-controlled characters, which reinforces the observations made during our Turing tests: it seems that separating human players from AI players is indeed difficult.

Table 2: Cosine similarity values(lower half: individual actions; upper half: combo chains)

Α	0.81	0.45	0.31	0.34	0.47	0.44	0.44	0.44
	0.80							
В	0.40	0.84	0.36	0.55	0.65	0.71	0.43	0.69
		0.78						
С	0.20	0.28	0.85	0.66	0.60	0.31	0.43	0.36
			0.96					
D	0.25	0.38	0.78	0.68	0.61	0.52	0.50	0.53
				0.73				
Е	0.49	0.60	0.70	0.62	0.73	0.55	0.50	0.58
					0.74			
Ve	0.46	0.55	0.41	0.50	0.53	0.90	0.50	0.70
						0.73		
No	0.45	0.27	0.54	0.54	0.45	0.60	0.79	0.59
							0.91	
Im	0.48	0.51	0.45	0.55	0.50	0.73	0.81	0.79
								0.85
	Α	В	С	D	Е	Ve	No	Im

CONCLUSION

It was interesting for us to apply two different approaches in this study: automatic and human assessment. The main feature of a Turing test is direct involvement of target users. They judge game AI subjectively and ofen inaccurately. However, human perception is the ultimate judge of the resulting quality of game atmosphere and character believability. One of the main challenges for a successful Turing test is to engage enough testers to get adequate results of evaluation (however, there are no established recommended group sizes). A major downside of a Turing test is caused by the limits of typical human abilities, and may lead to incorrect results. In particular, tiredness that occurs if the amount of video clips is big enough may distort judgement. Next, the testers cannot keep track of a large number of agents and still make correct decisions. Thus, it becomes impossible to evaluate large sets of agents and lengthy game sessions. Therefore, a Turing test has low sclability. However, we have to emphasize that the analysis of human impressions is the only direct way to evaluate perceived believability and play style similarity.

The cosine similarity method has its own advantages. It provides the same stable reliability for any number of agents to be evaluated. The main disadvantage of automatic methods lies in their indirect and unreliable way to imitate human perception. With this approach there is always a chance to miss gameplay elements, ignored by the used algorithm, or to treat as significant certain details, ignored by people. Our experiments revealed that the characters in Universal Fighting Engine exhibit distinct play styles, distinguishable both with Turing tests and automatic assessment procedures. However, it is much harder to distinguish human- and AI-controlled characters. We cannot explain this observation reliably, but most probably it means that either Fuzzy AI is indeed human-like enough to be difficult to uncover, or most reasonable game strategies are relatively straightforward and thus leave little room for individual improvisation.

The results of automated play style analysis agree with the Turing tests thus proving that our evaluation algorithm is adequate for this task. We can suggest that automated assessment is inevitable for large number of game characters and long game sessions, but smaller-scale Turing tests are necessary to prove that the chosen method agrees with human evaluation. We hope that the present work will provide some insights into the nature of human behavior patterns in a fighting game, and will be helpful for futher development of human-like AI in this genre.

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AFFECT AND BELIEVABILITY IN GAME CHARACTERS – A REVIEW OF THE USE OF AFFECTIVE COMPUTING IN GAMES

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KEYWORDS

Affective computing, virtual agents, believability, NPC.

ABSTRACT

Virtual agents are important in many digital environments. Designing a character that highly engages users in terms of interaction is an intricate task constrained by many requirements. One aspect that has gained more attention recently is the effective dimension of the agent. Several studies have addressed the possibility of developing an affect-aware system for a better user experience. Particularly in games, including emotional and social features in NPCs adds depth to the characters, enriches interaction possibilities, and combined with the basic level of competence, creates a more appealing game. Design requirements for emotionally intelligent NPCs differ from general autonomous agents with the main goal being a stronger player-agent relationship as opposed to problem solving and goal assessment. Nevertheless, deploying an affective module into NPCs adds to the complexity of the architecture and constraints. In addition, using such composite NPC in games seems beyond current technology, despite some brave attempts. However, a MARPO-type modular architecture would seem a useful starting point for adding emotions.

1. INTRODUCTION

Artificial intelligence (AI) has been, and continues to be, one of the most popular fields for investigation in computer science. Alan Turing's question "can machines think" raised scientists curiosity and a tremendous amount of research has been conducted to investigate the possibility of a human-like machine. This includes various forms of software; chatbot, embodied conversational agents (ECA), virtual agents (VA), autonomous agents (AA), game companions, non-playing characters (NPC), extending to expressive and social robots. Relevant research in AI aims at creating intelligent virtual agents (IVA) and improving their behaviour to reach a human-like level. IVAs can increasingly be found in various virtual environments like intelligent learning, interactive storytelling, and games (Mott and Lester 2006; Aylett et al. 2009).

However, intelligence not only refers to how the machine can "think" or solve problems, but has been recently broadened to include emotional and social intelligence as well. Requiring the agents to act autonomously and intelligently with the user and with other agents in a manner similar to how a human would act entails them having to possess rich emotional and social behaviours (Dias and Paiva 2013). This involves how an agent perceives and expresses thoughts, how its surroundings influence its mood or emotional state, and how this affects its decision making and behavioural patterns.

Affective computing is the computer science field concerned with creating emotional machines; machines that can understand and express affect (Picard 1997; Hudlicka 2008; Yannakakis and Paiva 2014). It is evident that including a personality dimension in machine interaction increases the level of human-likeness and draws audience's attention more. In games for example, an NPC is exciting if it displays self-directed moves, and conveys its ability of smart decision making in gameplay. However, it would be more interesting if it had the ability to smile or laugh in response to the player's actions, or even argue with them, as opposed to just follow them around. In addition to the NPCs simulating humans in terms of life-likeness, intelligence, and empathy, adding an extra level of interaction to the game logic enables the NPCs to be more natural and perceive their environment with their emotions. This can enrich the sense of *believability* of the characters from the player's perspective (Mahmoud et al. 2014).

Games provide the perfect domain for affective interaction and understanding of the affective loop; systems that are able to elicit, detect, and respond to the emotions of users (Yannakakis and Paiva 2014). On one hand, users (players) are open to negative feelings like frustration, fear, or anger, making games the source of a broad spectrum of emotional responses and patterns, more than any HCI platform. On the other hand, by having emotions drive the design process for different genres, the player experience can be improved and even tailored to each player via affective-based interaction. In addition, affective-based interaction in serious games can significantly extend their applications and impact.

This paper discusses the need to incorporate an affective dimension into the design of intelligent game agents, focussing on how modelling emotions affect agent believability. Section 2 discusses emotionally intelligent systems and how affective computing fits into games. In section 3, believability criteria of VAs are investigated and design issues of believable NPCs are discussed. Section 4 reviews some frameworks that combine emotional models into agent architecture for games and other applications. Discussion and conclusions are presented in section 5.

2. EMOTIONALLY INTELLIGENT AGENTS

Recognising and reasoning about affect (Sollenberger and Singh 2012) enables the development of systems with higher intelligence (Gratch and Marsella 2003), enhanced user interfaces (Bickmore et al. 2007), and more effective learning environments (Marsella et al. 2000). A relatively recent development in *expressive AI* (Mateas 2001) is creating VAs that are capable of understanding users' affective states through social and emotional intelligence. This requires recognition of human emotions and the generation of associated affect and behaviour (Lisetti and Hudlicka 2014). Designing affect-based systems require addressing the following issues (Clavel et al. 2017):

- Adding emotional model(s) into the agent architecture.
- Defining the role of emotions in the decision making needed to obtain believable reactions.
- Assigning the generated emotion(s) to expressive behaviour(s).

A typical intelligent agent involves a means for collecting knowledge from its surroundings, a decision making mechanism, and a means for executing those decisions. Hence, the design of an emotionally aware system requires interoperable models between the sub-systems of affect detection and expression, as well as models of the relation between emotions and generated social functions (Clavel et al. 2017). According to (Lisetti and Hudlicka 2014), emotion-based architectures include a subset of the following components:

- i. *Sensors*: must be able to show, to an appropriate contextbased extent, the human emotional state, expressed in unimodal or multimodal cues. These include facial expressions, gestures, vocal intentions, sensorimotor cues, autonomic nervous system signals, and natural language. The agent captures and interprets these affective signals and translates them into the most probable affective state of the user.
- ii. *Decision-making algorithms*: these differ based on which emotion theory, or combination of theories, is adopted in the architecture. The result of this process may influence the agent's affect state as well as its expression of emotion.
- iii. *Actuators*: used to control anthropomorphic embodiments associated with affect modalities. In other words, for the agent to express its own affective state, emotions, and other signals influenced by that internal state, it must have some means like a 2D or 3D, text-based, or audio expressive channels.

Games are a natural application of affect leading to the emergence of affective games, or affect-aware games, and the need to deploy emotionally intelligent agents into games. In analogy, three elements of game design should be addressed (Hudlicka 2008):

- Sensing and recognition of players' emotions.
- Modelling emotions in game characters and user models representing the players.

- Tailoring the game responses in return by generating affective behaviour in characters and avatars, to enhance their realism and believability.

Adopting affective computing principles directly into games demands that players be monitored and their emotions identified and contributed to gameplay. Game controllers have to be equipped with multimodal sensors to collect player's physiological and social signals, and the game logic has to include emotion modelling and recognition algorithms. In addition, the resulting emotion must alter the game content somehow to elicit more emotions in the player. Implementing a fully closed affective loop in games seems to be out of reach with current technology and perspectives, although some major game companies began working on adding affect to their productions (Emotional Video Games 2011). Therefore, designers usually address affect through an open loop via level design, game character, and gameplay. (Yannakakis and Paiva 2014; Rosenkind 2015; Warpefelt 2016) include examples and analysis of some commercial games that incorporate affect as part of their gameplay or characters.

It is important to note here that for a game character, the intelligent agent model should not require producing a "perfect" agent, but rather, for better human resemblance and higher believability, it is more natural to have the flaws and dysfunctionalities of the human affect phenomena incorporated into the model (Lisetti and Hudlicka 2014). For example, an agent may go the wrong way if it is experiencing a state of "confusion" or "stubbornness". Also if used for training purposes, goal conflicts, neuroticism, and bad decisions, may be a requirement for more realistic scenarios. Moreover, modelling more aspects of humanness adds depth and complexity to the agent's character, which in turn has a positive influence on the audience's engagement and experience. Complex behaviour makes observers assume complex internal processes. Hence, a correlation is inferred between perceived emergence and suspension of disbelief and the more the agent appears complex to observers, the more they perceive it as believable. This means the agent design must focus on creating diverse complex behaviour and avoid repetitive robotic ones (Rosenkind 2015).

In essence, for interactive games, the involved computer character is required to be believable to make the player willing to suspend disbelief, regardless of the degree of realism. This involves characters who are naturally presented with conflicts and challenges, are flawed, or not at their best (Lisetti and Hudlicka 2014). In the next section, the term believability is discussed in more detail, along with the challenges of designing believable NPCs.

3. AFFECT AND BELIEVABILITY DESIGN

Dating back to the early work of animation, literature, and films, the term believability was described by (Bates 1994) as the illusion of life that permits suspension of disbelief. People are lead to believe that the characters they view/read/interact with are real in the sense that they do not reject the story because they disbelieve what they perceive (Lee and Heeter 2015). However, for digital games, characters do not necessarily have to be credible or reasonable for the players to suspend disbelief. Table 1 summarises believability principals collected from the literature and it is clear how affective dimensions comprise a main asset of a believable character. Whereas designing traditional AI is concerned with competence and objective assessment, believable agent design involves personality, audience perception, and characters, with a basic level of competence (Mataes 1999).

Apart from a few, most studies acknowledge that agents possessing the suggested qualities are desirable for making players interact with them more. Nevertheless, some NPCs are required to appear more or less advanced than others, and hence may only need to possess a combination of qualities depending on their role and functions in the game. Moreover, these qualities must be incorporated into a narrative to make sense and appear realistic. This again, depends on the game genre and what type of NPC the player is interacting with. It is pointed out that NPCs should elicit some form of affordances to be persuasive (Warpfelt 2015). In essence, the appearance, behaviour, and affordances of the NPCs should imply to the player what to expect and how to interact with them, all of which, contribute to the believability and playing experience. Also, (Rosenkind 2015) claims that virtual agent believability should focus on the perception of the character. In other words, a distinction is to be made between player believability, and character believability (Livingstone 2006).

3.1 AI and Believable NPCs

Player believability assumes the user is aware of the character not being real and there is no illusion of life or suspension of disbelief to break (Togelius et al. 2013). However, the observer should be convinced that the autonomous agent is being navigated by a human controller. In this context, design issues are often more concerned with traditional AI goals of planning and behaviour modelling, as opposed to adding personality to characters.

The majority of current AI is scripted, using finite state machines for decision making, and standard search and navigation algorithms. For commercial games, the most commonly used method for behaviour modelling is rulebased approaches (Ji and Ma 2014; Akbar et al. 2015; Feng and Tan 2016), which do not allow NPCs to evolve and capture new knowledge, and ignore the possibility of developing adaptive agents and more emergent behaviour. Though it has been pointed out how challenging it can be for developers to introduce academic AI into games development, there have been some trials that make use of academic research in games. This includes the use of behaviour trees in Halo 2 (Bungie Studios 2004), goal oriented action planner (GOAP) in F.E.A.R. (Monolith Productions 2005), multi-layered hierarchical task network (HTN) planner in Killzone 2 (Guerrilla Games 2009), evolutionary algorithms (Harrington et al. 2014), and Adaptive Resonance Theory (ART) networks (Feng and Tan 2016). Some tournaments exist for encouraging and testing new efficient approaches for player believability, like the 2k BotPrize (Hingston 2010) and the Mario AI Championship (Togelius et al. 2013). It is worth mentioning that player experience and familiarity with the game affect their perceived believability, as their knowledge of the "usual" AI patterns will vary.

3.2 Character Believability

Character believability requires a high degree of realism in various features; appearance, behaviour patterns, and dialogue (Togelius et al. 2013). With the huge advances in graphics and animation, the degree of visual realism of NPCs can reach impressive levels. However, this is often hindered by the rather simpler implementation of a behaviour model for the agent, which is often based on one of the techniques mentioned above. This certainly affects the believability of the agent and renders the game experience disappointing (Kersjes and Spronck 2016).

Problems of NPCs usually lie in their lack of convincing social and emotional behaviour raising the need for a robust affect module within the agent's architecture. Developing an integrated architecture would ideally require developing models for the theory of emotion, social relation, and behaviour, and combining the theories into an overall model (Lisetti and Hudlicka 2014). Ideally, it would be like adding an affect module to a MARPO agent (Laming 2008). This is a complex process and in practice, theories are often simplified and assumptions are made about the architecture to facilitate implementation. Adding more dimensions to the components, e.g. modelling more emotions, deeper personality, complex planners and behaviour patterns, clearly adds more depth to the character as much as complexity to the system. Perhaps if such a model exists, it will be hindered by current technology limitations. A good example of what future emotional characters in games might look like is the Milo prototype that was presented by Peter Molyneux and Lionhead Studios at TEDGlobal in August 2010. The AI details were not revealed but simulation seemed to have a psychological profile evident in some "boyish" actions from Milo (Meet Milo 2010).

Table	1:	Believability	Reau	irements	for	Virtual Agent	s
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(Mateas 1999)	(Loyall 1997)	(Gomes et al. 2013)	(Lee and Heeter 2015)	(Bogdanovych et al 2016)
Personality	Illusion of life:	Awareness	Appearance and	Appearance
Emotion	Appearance of goals	Behaviour Understandability	behaviour	Personality
Self-motivation	Concurrent pursuit of goals	Personality	Personality	Emotional state
Change	Parallel actions	Visual impact	Goals	Liveness
Social relationships	Reactive/responsive	Predictability	Emotions	Illusion of life
Illusion of life	Situated	Behaviour coherence	Social relations	Consistency
	Resource bounded	Change with experience		Change
	Exists in social context	Social expressiveness		Social relationship
	Broadly capable	Emotional expressiveness		Awareness believability
	Well integrated			Environment awareness
	-			Self-awareness
				Interaction awareness

Although combining all the discussed requirements into a single model may seem more complex than achievable, there are various attempts towards emotionally believable characters. In section 4, we present some existing architectures that combine affective modules into the agent's design for better social interaction, and hence, more believable behaviour.

3.3 Believability Assessment

Finding a standard way to evaluate the believability of a game character can be problematic as no unified definition or set of qualities exist for it. Even with a clear set of believability requirements, there is no way to determine the weight of each quality to the overall character believability. What can be evaluated to an extent are players' opinions regarding the character's behaviour, interaction, the relationship it managed to forge with them, and the whole experience.

Player experience can be measured through subjective, objective, or gameplay-based approaches (Yannakakis et al. 2008; Mandryk et al. 2006; Asteriadis et al. 2008; Pedersen et al. 2010). It is also argued that in many cases, it is better to judge the character's believability from a third-person perspective (Togelius et al. 2013). In addition, (Rosenkind 2015) suggests combining traditional user experience research techniques from HCI, with the believability metrics mentioned earlier. It also acknowledges the fact that no research in game testing focusses on game context or investigates the inconsistency between agents design and player perception. This is opposed to testing user experience in games which have been addressed in several studies, none of which however, used believability metrics to evaluate player-NPC interaction. For the game industry, combining performance metrics (gameplay data) with self-reported metrics (user responses) have become popular (Rosenkind 2015)

It is worth noting that the majority of the surveyed models presented in section 4 used questionnaires of Likert scales to assess the tested qualities by asking the players about how "they felt" during the experiment, or compare the character to its base version.

4. AFFECT-AWARE VAs AND NPCs

Several research efforts attempted to incorporate emotional and social aspects into virtual agents and NPC design. Such models are preferred to scripted agents that cannot change or adapt to surrounding events.

Koko (Sollenberger and Singh 2012) is a service-oriented middleware that helps incorporate affect recognition into games. It is intended to be used as an extension to existing game/applications that seek to recognise human emotions. Koko offer a domain independent framework for modelling human emotions but can be used to model NPC emotions as well. It was used in BooST mobile application and the educational game Treasure Hunt.

The Social Signal Interpretation (SSI) framework (Wagner at al. 2013) is a tool for recording and recognising human's social and affective signals. It complements existing tools and offers an online recognition system from multiple modalities. Its interface allows for interoperability and support of various sensing devices and was used in several systems like E-Tree (Gilroy et al. 2008), and EmoEmma (Cavazza et al. 2009). Again, this is an emotion recognition system, hence can be used in combination with other believability systems as an input module.

An architecture that allows Interpersonal Emotional Regulation (IER) (Dias and Paiva 2013) incorporates three emotional intelligent skills into agents: generation and expression, reasoning, and regulating emotions. The agent determines the relevance of an event, models social attractions to the surroundings, and uses a planner to create goals and actions to achieve them through two types of strategies. The suggested model is claimed to be generic and flexible to be adapted to different contexts. Tested in a scenario of Neverwinter Nights 2 (Obsidian Entertainment 2006), players perceived the NPCs employed with the model as friendlier. Authors state that this experiment did not validate the proposed model, but rather proved that employing emotion regulation helps establish friendship relations with NPCs in different ways.

The Virtual Human Toolkit (Hartholt et al. 2013) is a collection of modules, tools, and libraries, integrated into a framework and open architecture for creating ECAs. It includes speech recognition, natural language understanding, audiovisual sensing, and nonverbal behaviour understanding. These inputs combined with the internal state enables the agent to create communicative input. The toolkit is released to the research community and is considered one of the earliest attempts to integrate human simulated capabilities into a larger framework. Although authors acknowledge the toolkit is capable of creating several types of VA, like QA characters and virtual interviewers, no experiments were presented in this regard. Also the use of a rule-based planner seems too simple.

The work by (Mahmoud et al. 2014) tried to mimic human behaviour by proposing a visual perception system for NPCs along with short term memory. This limits the amount of information the NPCs have access to about the environment, resembling the restricted human capabilities of perceiving their surroundings, which influence the agent's behaviour with "natural" uncertainty, reluctance, and reasoning. The strategic planning component was implemented using a hierarchical task network (HTN). The system generated the perfect plan for handling a car crash scenario, hence may not be suitable for game characters according to the discussed believability criteria. Moreover, it has been tested on only a single scenario, and although the system could come up with an ideal plan in real time, a change in the environment can cause some conditions to cease; affecting the planning process. Authors argue that providing more methods and operators may eventually generate the perfect plan successfully. The study did not assess the believability of the NPC following the proposed system.

The FAtiMA (Fearnot Affective Mind Architecture) (Dias et al. 2014) is a generic and flexible architecture for emotional agents, with what the authors believe is the minimum set of functionality. It enables incorporating several appraisal theories. The framework has two main components, the core and the modules. The core layer does not commit to any particular method used, and behaviour is added by implementing desired functionalities as components on the core. All components are designed to be interchangeable and loosely coupled. The core architecture has two processes: the appraisal derivation evaluates the relevance of the event to the agent and determines a set of appraisal variables (likeness, desirability, etc.), and the affect derivation combines the appraisal variables with appraisal theory to produce an affective state (mood, emotion). FAtiMA is claimed to be the first step in creating standards in emotion modelling. It was compared against similar systems like FeelMe (Broekens and DeGroot 2004) and the EMA model (Marsella and Gratch 2009) but only on a theoretical basis. No experiments or scenario tests were presented.

The Emotionally Realistic Social Game Agent (ERiSA) (Chowanda et al. 2014) exploits the player-agent relationship in terms of social signals (facial expressions, gestures, and voice), personality, and emotions, to propose a modular framework. It includes sensing, interpretation, behaviour generation, and game components. A generic formulation of action selection rules is presented and modelling agent personality was based on the OCEAN model (Saucier and Goldberg 1996). The social relations were based on two variables; like (depends on emotion of the agent towards the player) and know (affected by how many times the agent met the player). Emotions were modelled as a function of personality and social relations over an average of events. Using two SEMAINE characters (Schröder 2010; McKeown et al. 2012), ERiSA was tested in The Smile Game (Chowanda et al. 2015), where a player's objective is making their opponent laugh with "attacks" of jokes and facial expressions. Authors claim the game to be a good case study since gameplay is simple yet elicits rich nonverbal interaction between player and agent. All studies showed that the virtual agents were reasonably good in evaluating facial expressions, albeit a little slow. This is the first integrated framework for social and emotional game agents. Existing (previous) frameworks proposed a generic model for IVA, but none presented a model for relationships between player and agent and used it to generate behaviour rules. The behaviour generation process is dependent on player emotions from video input stream and the social relation between him and the agent, based on their familiarity with each other. Also, machine learning could be used to learn new attack patterns and store them for future use. Furthermore, ERiSA was investigated and evaluated in a RPG scenario (Chowanda et al. 2016). The experiments aimed at testing the effect of having a game agent capable of perceiving and exhibiting emotions, supported with the ability to develop simple social relations over time. Participants had to complete a short Skyrim quest, and results showed that players were more emotionally engaged and immersed in the game with the NPC employing ERiSA as opposed to its base version.

The work by (Kersjes and Spronck 2016) adapts a simplified version of personality model of (Ochs et al. 2009), omitting attitude and social relations and describing the agent only by its personality and emotional state. An agent's

personality affects the intensity of event-triggered emotion, and hence its emotional state, which in turn, determines its expression of behaviour. It was tested with a game in which a human player interacts with three NPC; extrovert, neurotic, and neutral. It concluded that players can indeed distinguish personality difference based on facial expression; hence, adopting a personality model can help game developers create a high variety of virtual characters. The study only used facial expression to express agent's behaviour after events, and with only two sets of emotions. It may be true that it is over-simplified, but at least this work partially verified Ochs model, which was purely theoretical and was never tested. It did not address the limitations of Ochs though.

The General-purpose Intelligent Affective Agent Architecture (GenAI3) (Alfonso et al. 2017) describes a Belief-Desire-Intention (BDI) agent architecture (Rao and Georgeff 1995). This is an extension to Jason architecture (Bordini, and Hübner 2005) but does not commit to a specific cognitive theory, so different emotional and behavioural models can be implemented through it. Hence, it is considered interoperable with the applications adopting Jason, and suitable for a variable range of scenarios.

A CAD (contempt, anger, and disgust) model is proposed in (Dastani and Pankov 2017) for specifying what motivated such emotions and the behaviour they elicit when established. Integrated to a moral emotion model of BDI, this architecture houses the process of emotional generation in agents and the goals and behaviour that follow in a unified model.

5. DISCUSSION

5.1 About the Models in Section 4

Design: The majority of the reviewed frameworks focus on computationally modelling affect and behaviour based on an emotion theory (the most common is the appraisal model), and associate the resulting affects with a limited set of behaviours. It shows that the challenges mostly lie in the system complexity and response time, hence, the frameworks are largely empirical and research-oriented. There is little evidence of incorporating AI techniques in implementing the affective module and it is mostly a direct association between emotion and behaviour. Utilising machine learning in affective computing for AV design can improve its believability. For example, allowing the NPC to learn the most suitable emotion to express or the appropriate behaviour in certain situations.

Test: A number of models were never tested in actual interactive environments. When tested. а short game/interactive scenario is implemented and tailored specifically for the developed architecture. However, no details are often given about the behaviour control process or the techniques used to execute it. Usually a set of rules, a game prototype, or a game engine, is used to execute the behaviour, and were specifically designed for a certain genre or specific scenario. The majority of tests were always limited in context and audience (even non-gamer participants were from the same domain).

Assessment: Measuring *perceived* believability is the most common, which is based purely on agent's behaviour. All evaluations of character believability were questionnaires.

5.2 Conclusion

Human players usually prefer playing with, or against, other human players rather than AI agents due to the unpredictability in human gameplay behaviour (Mahmoud et al. 2014; Miles and Tashakkori 2009). Repetitive and predictable behaviour makes games less challenging and discourages players. The design of a computer agent often focusses on perfecting the intellectual abilities of the agent which may not be the most representative attribute for its believability. A 'God-like' behaviour may also be considered non-believable (Mahmoud et al. 2014). Recently, an evident shift in research tends to incorporate affective models into agents' architectures to achieve a more human-like performance.

Creating machines that can mimic human beings involves modelling traits that make us human. This largely means recreating human interactive abilities by modelling sensing, interpretation, thinking, emotions, reactions, planning, memory, mood, personality, to mention a few. The considerable amount of resources and specialised knowledge required for mimicking the essences of human interaction is extensive. In addition, the above capabilities should not be developed in isolation, but rather, integrated into a larger system, and further into systems of systems, presenting complexity and dependency in research and implementation (Wagner at al. 2013).

This clearly is cumbersome, and the aim to improve the agent's ability leads to extremely complex systems. The work in (Warpefelt 2016) used the GAM (Warpefelt et al. 2013) to create an NPC model that describes the minimum required complexity to successfully implement a believable version for this type of NPC. Even with the appropriate knowledge and resources, an intelligent believable system can still be complex, costly to develop, lack a standard framework, and the design principles are often domain specific and difficult to generalise (Wagner at al. 2013). This is why existing research often attempts to simplify the architecture to model only a subset of qualities, or have separate modules with few features. Moreover, very few of the existing frameworks address the role of appearance in the believability of the character, which often leads to participants getting confused about the agent's expressions.

An issue often neglected in the research of VAs is the ethical implications of implementing affect in artificial systems. Mostly, persuasive agents should be able to reason about their own actions from an ethical perspective because the possibility of analysing users' emotions facilitates manipulating their affective state, especially for the elderly and underage (Clavel et al. 2017). However, this may not be the case for games, particularly when the character's questionable ethical profile is part of its role.

It is probably too ambitious for an agent to possess all suggested believability qualities at once. Moreover, it is clear that there is overlap between several qualities. In some experiments, audiences tended to miss certain qualities during testing due to confusion or unawareness. This inclined the experiments to isolate the tested qualities to be properly presented allowing relevant valid feedback. As for test settings, the most promising scenario was short game quests where the NPC possessed two emotions, and could forge social relations with players through four actions (Chowanda et al. 2016). This shows that, with sufficient technology and resources, emotionally intelligent and believable game characters are attainable.

Research in believable agents applies as well to the field of robotics, and expressive and social robots are gaining popularity on both research and consumer levels in fields like entertainment, healthcare and education.

Perhaps it is true what the discussion above indicates; production level is still not there yet. However, incorporating emotions into a MARPO-type modular structure seems the most reasonable answer to creating an AI architecture for an intelligent agent..

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SERIOUS GAMING

GLOBAL STRATEGY GAME: A SERIOUS GAME FOR TEACHING INTERNATIONAL BUSINESS

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KEYWORDS

Blended Learning, Global Strategy, International Business, Online Game, Simulation

ABSTRACT

The Global Strategy Game is a serious game for blended learning classes in international business. It serves as an appetizer to introduce three relevant topics on competing in the global marketplace: (1) the assessment of the corporate's strategic environment, (2) the evaluation of opportunities to expand internationally and, (3) the implementation and execution of a corporate and market entry strategy in a competitive environment adhering to agglomeration and deglomeration effects. Based on the four P's of marketing (price, promotion, product and placement) and the AAA framework for global strategies (adaptation, aggregation and arbitrage), participants take decisions in a round-based game to enter the European market, compete against each other and increase the value of their respective enterprise in the industry of wearable smart devices. As part of a blended learning class, each round is being played before the sit-in lecture followed by the debrief and theoretical concepts addressed in the classroom.

INTRODUCTION

Blended learning is a widely accepted and pushed teaching method at universities (Oh and Park 2009) combining face-toface (offline) lectures with additional online activities (Reay 2001). This hybrid teaching approach accounts for the impact of digitalization on education and students' changing learning behavior as digital natives (Barnett 2008). Serious games are one prominent element in blended learning classes which complement the traditional sit-in lectures. Several studies highlight the effectiveness of the game-based approach in business education (Feinstein and Cannon 2001), especially if it is tailored to the students' skill level (Mislevy 2011) and if it is holistically integrated into the curriculum (Hanlon, 2008). Despite its effectiveness, a recent study by Lopes et al. (2013) recognizes that the game-based approach, on business education, lacks advanced computer techniques, holistic integration of business theory and practical, long-lasting learning outcomes.

The Global Strategy Game picks up on those shortcomings and presents an approach that focuses on a close link between international business and its playful experience. Many large corporates fail in implementing a global strategy and entering new markets (Yoder et al. 2016). The Global Strategy Game has been played in various executive post-experience programs to serve as a risk-free environment to test global expansion strategies in a business war game like environment. Experiencing the trade-offs of strategical and tactical decisions supports the understanding of the theoretical concept of competing in a global marketplace.

In a round-based game, participants, without prior expertise in international business, make corporate decisions to enter the European market in the industry of wearable smart devices. Equipped with an annual budget, they plan and execute their expansion strategy to enter Europe in competition with their colleagues. After the game has been played, the participants are ranked based on the accumulated profits and profit growth. In an alternate process, the participants play one single round (online) followed by the face-to-face lecture (offline) comprising of the debrief of the round and the academic content explained in class. The educational content is consecutively revealed in the game to support the participants on mastering the next round. The game is played in three rounds, successively covering the theoretical concepts of:

- 1. Analyzing the strategic environment of possible entries in a heterogeneous market environment using appropriate frameworks (PEST, Porter's Five Forces).
- 2. Evaluating and deciding on a corporate strategy (Global Standardization Strategy, Transnational Strategy, International Strategy and Localization Strategy) in a competitive environment using the strategic positioning framework (value/price and price/cost).
- 3. Assessing and executing market entry strategies (Contract, Joint Venture, Merger & Acquisition, Greenfield) on agglomeration and deglomeration effects of the primary and supporting elements of Porter's value chain (Sourcing, Production, Sales and Research and Development).

The corporate decision areas split into strategical and tactical ones. Strategical decisions are long-term oriented, difficult to repeal and typically involve sunk costs, while tactical decisions are short-term focused and aim to support the strategic moves. The strategic decisions comprise of where and how to enter European markets. The tactical moves of the 4 P's of marketing (price, promotion, product, and placement) are used to exploit the economic opportunities once entered a market and to support the overall global expansion strategy. The remainder of the article highlights the learning outcomes and theoretical background addressed by the Global Strategy Game, followed by an explanation of the game mechanics and it interlinks to international business theory. Finally, recommendations on the debriefing and challenges are presented and summarized to emphasize how interrelated economic models and theories can be gamified.

THEORETICAL BACKGROUND

The Global Strategy Game, henceforth referred to as GSG, is a serious game to prepare students in a playful way for using frameworks of international business. It is a browser based online game played in three rounds. Each round serves as a preparation for the subsequent sit-in lecture. One round consists of a set of decisions carried out over a period of 60 to 90 minutes. Once a team or individual (representing a firm) logs into the online game, the decisions can be entered, results market reports and briefings are displayed. The game hosts up to ten competing firms entering the European market, and each company can be represented by either an individual student or a group of students. In the face-to-face lecture, the instructor debriefs on the previous game round and addresses the particular topics of international business to prepare the students for the next round. The learning outcomes are two layered:

International Strategy

- Use the PEST framework and Porter's five forces framework to assess the opportunities of entering specific countries in Europe.
- Formulate an expansion strategy based on pressure for cost reductions and pressure for local responsiveness or the AAA framework on adaptation, aggregation, and arbitrage.
- Align the structure of the company (vertical and horizontal integration) with the respective expansion strategy.

Competitive Strategy

- Experience the advantages and disadvantages of market entry modes (Contract, Joint-Venture, Merger and Acquisition, Greenfield) and the impact of path dependency on strategy execution.
- Evaluate agglomeration and deglomeration effects of staying ahead of the competition
- Align the tactical decisions of a firm with the strategic ones and anticipate the company's relative strategic position to its competitors using value/price and price/cost.

To increase the value of an enterprise one has two options: (1) increase profitability and (2) increase profit growth. The first option is stimulated by cost reduction and price increase due to added product/service value. Profit growth can be achieved

by selling more in existing market and entering new markets. The GSG offers a playground to test profit growth strategies by opening new markets first and increasing the firm's profitability by strengthening its later.

Markets in Europe are not homogeneous but are widely diverse, and differ in terms of their society (culture, consumer behaviour), economy (labour cost, GCP growth rates, disposable income, subsidies), politics (stability, regulation), and technological sophistication (white- and blue-collar workers, advances in digitization, and infrastructure). An appropriate framework for evaluating the advantages and disadvantages of a country is the PEST (Political, Economic, Social and Technological) framework by Fahey and Narayanan (1986). Once potential markets, which fit the company's resources and capabilities, are identified, a strategy has to be defined. Such a strategy is driven by pressure for cost reduction on one dimension and pressure for local responsiveness on the other dimension. This leads to four different strategies: (1) The global standardization strategy focuses on profit growth by repeating economies of scale and economies of learning across locations. (2) The transnational strategy tries to achieve two targets, focusing on the profit growth by replicating cost advantages across locations and increasing the profitability by differentiating and adjusting to the local market needs. (3) The localization strategy aims to increase the profitability by targeting and adjusting local consumer preferences. (4) The international strategy is best suited if pressure for cost reduction and local responsiveness is low and the firm can sell its domestic product/service abroad with minimal local customization.

Similar to the framework presented by Hill (2011), the AAA framework by Ghemawat (2007) can be used to assess a global strategy. The AAA framework provides three different strategies: (1) The adaptation strategy focuses on local customization to increase market share, (2) the aggregation strategy aims to standardize across markets to achieve economies or scale, scope and learning and (3) arbitrage exploits location specific advantages by decentralizing specific parts of the value chain to different locations. Participants experience the trade-off between those strategies and the impact of stretching a firm too far by pursuing everything.

The next step for entering a market is evaluating on vertical or horizontal integration based on Porter's five forces industry assessment: Buyer power, Supplier power, Industry Rivalry, Potential Entry, Substitutes (Porter 2004). Depending on the degree of power among other market players one has to decide if the firm should pursue vertical integration (upstream and downstream market) to secure resources and capabilities or horizontally to achieve economies of scope. Subsequently, a global expansion strategy involves the decision on the mode of entry: Exporting, Contracting, Licensing, Franchising, Joint venture and Greenfield (wholly owned subsidiary). The advantages and disadvantages of each mode of entry are modeled according to Hill (2001).

The decision of the mode of entry is accompanied by agglomeration and deglomeration effect. Depending on the type of department (*Sales, R&D, Production, Sourcing*) that is setup in the new market, network effects arise. For instance,

the degree of labor pooling and knowledge spillover depends on the spatial and technical distance between the product and the local industry (Marschall 1920). Different perspectives exist on this topic: Glaeser et al. (1992) emphasize that these effects are due to specialized industry clusters, while Jacob (2009) argues that innovation and cost reduction stem from diversified industry clusters.

Once a firm has decided on the strategic elements, tactical decisions regarding the four P's of marketing: price, product, place, promotion (Kotler and Keller 2006) must be aligned with the global strategy. To assess the relative strategic position in a competitive environment, the value/price and price/cost framework by Porter (2004) can be used. It helps to anticipate the competitors' generic strategies of price/cost focus versus differentiation.

Within the GSG game, a firm has the possibilities to enter three different regions, and each region has three different market segments: (1) hardware of the wearable smart device, (2) the wearable smart device itself and (3) and software for the wearable smart device. In total, one can enter up to nine different markets with various political, social, economic and technological advantages and disadvantages, which mimic the real-world positioning.

GAME MECHANICS

Game Setup

The focus of expansion is the European Union: Northern Europe, Eastern Europe, and Central Europe. Each region consists of three market segments: *Upstream, Main,* and *Downstream.* The *Upstream* segment focuses on the resources and input materials for producing smart electronic devices. Primary sales for smart devices concentrate in the *Main* segment. Complementary products and services are offered in the *Downstream* segment. Within each segment, firms compete on more or less differentiated substitutes in materials, products, or services (cf. Figure 1). Accumulated expenditures in primary and secondary firm activities define the relative importance of each segment within a region and subsequently influence the competitive price level expected by customers.

Game Flow

Equipped with a budget, a firm can enter any of the *Upstream*, *Main*, or *Downstream* markets in Northern, Eastern, and Central Europe by setting up special facilities through market entry with a *Contractor*, *Joint Venture*, *M&A*, or *Greenfield* in the respective markets. Further tactical revenue-related and cost-related activities improve the firm's sales and cost position. The effects of these activities are measured in dimensionless indices:

1. Revenue indices show the impact on sales either by increasing market volume, market share, or product value or by stealing market share from competitors. All revenue-related indices are measured relative to the competitors' indices.

2. Cost indices reflect the firm's cost side. A lower cost index represents a lower cost position.



- Figure 1: The Market Environment Multiple regions with three segments per region and *n* competitors.
- 3. The price index: A higher price index reflects an elevated price, and a lower price index corresponds to a lower price. The difference between the combined cost indices and the price index is the firm's contribution margin.

Increasing or decreasing a revenue-related or cost-related index incurs specific investment costs per index point. These market-specific investment costs are subjected to diminishing marginal returns. However, these costs can be decreased by setting up *Sales*, *Production*, *R&D* or *Sourcing* facilities through *Contracting*, *Joint Venture*, *M&A*, or *Greenfield*, in the respective market. A stronger market commitment through higher sunk-cost investments implies a larger decrease in the cost per index point. Economies of learning foster the accumulation of cost reductions over time. However, a stronger commitment through sunk-cost investments increases the firm's risk due to reduced flexibility and location lock-in, because once a facility has been set up in *M&A* or *Greenfield* mode, it cannot be shut down immediately when unprofitable or sold in a second-hand market.

In addition to the cost per index point decrease, specific facilities and their respective entry modes exhibit network effects (externalities) based on agglomeration and deglomeration that are closely linked to the competitors' moves (cf. Figure 2):

- 1. Firm network effects are based on the ratio of specific facilities (e.g., *Production / Sales*).
- 2. Market-related network effects stem from the concentration (including all competitors) of particular facilities in a market.

Firm performance depends on the company's skill to craft and execute its strategy by aligning decisions and appropriately responding to its rivals' moves. The company with the highest cumulative profits after the last round in conjunction with a steady and sound profit growth wins the game.



Figure 2: The impact of network effects on advancing revenue- and cost-related indices (R&C indices).

Revenue-related and Cost-related Activities

For the ease of use, the effects of activities are denoted as positive \bigoplus and negative \bigoplus correlations. For each market (region/segment) a price has to be determined. The price level in each market is defined by a price index. The price index is measured as an average price in Equation (1) and relative to competitors in Equation (2) per market segment.

Average Price	\ominus Market Size	(1)
Relative Price	\ominus Residual Demand	(2)

How customers perceive and appreciate your product is reflected by the Value Index, measuring the value created for customers. The Value Index is a composite index derived as the average of the Localization Index and Innovation Index. The Localization Index is region-specific and describes how your product is tailored to the needs and preferences of the local customers. The Innovation Index represents all qualitative and innovative features of your product. The combined value-price ratio of a company relative to its competitors' ratio defines the market share.

Relative Value-price \bigoplus *Residual Demand* (3)

The impact of promotion efforts is measured by three indices: *Branding Index, Advertisement Index,* and *Local-Connect* Index. All three indices are market-specific (region/segment). The cumulative expenditures of all competitors, active in specific market, define the market's importance relative to the other markets in a region. Investing in the *Branding Index* in Equation (4) increases a firm's residual demand which reflects customer loyalty. Spending on the *Advertisement Index* in Equation (5) increases or decreases the market volume. The *Local Connect Index* in Equation (6) represents a firm's strategic investments into building market barriers that reduce rivals' market shares.

Relative Branding \bigoplus Residual Demand	(4)
Average Advertisement 🕀 Market Size	(5)
Relative Local Connect \oplus Rivals' market shares	(6)

Variable costs are represented by the Variable Cost Index which is based on the average of the Modularization Index and the Production Cost Index. The firm-specific Modularization Index measures how much a firm uses a platform strategy in production. Modularization decreases the cost per unit for all products. The Production Cost Index is set per market. Some markets offer cost advantages resulting in an incremental decrease in the Variable Cost Index. The contribution margin per unit is determined by the difference between the Price Index and the Variable Cost Index.

Market Entry

A firm has four different types of facilities: *Sales, Production, Sourcing,* and *R&D.* Setting up a facility in a new market leads to demand and cost benefits. Firms can enter any of the nine markets using different entry modes: *Contracting, Joint Venture, M&A,* and *Greenfield.* Different market entry modes are associated with different investment costs and annual running costs. Higher commitment to a sunk cost mode of entry implies increased cost, but also larger benefits in cost/index-point reduction.

Agglomeration Effects

Setting up a facility in a new market leads to demand and cost benefits. Different market entry modes are associated with different investment costs and annual running costs to be announced in each round's economic forecast. Higher commitment to a sunk cost entry mode implies higher cost, but also larger benefits in cost/index-point reduction.

Firm-related network effects as stated in Equation (7) and (8) are considered across all markets for facilities owned by a firm.

Production/Sales \bigoplus Modularization	(7)
$R\&D/Sales \bigoplus$ Innovation	(8)

Market-related network effects depicted in Equation (9) - (12) are based on facility concentration levels of all players active in a market.

<i>R&D</i> Concentration \ominus Localization	(9)
Sales Concentration \oplus Branding	(10)
Production Concentration \ominus Local Connect	(11)
Sourcing Concentration	(12)

The intuitions are: Monopolies are less likely to innovate. Therefore, high agglomeration (low concentration) fosters innovation and knowledge spillovers and labor pooling. They are more likely to create loyal customers. In a market, with many competitors (high agglomeration/low concentration) product branding is more difficult. Monopolies are less likely to cater to local needs. Hence low concentration fosters labor pooling. However, they are best able and hence most likely to exploit their market position in sourcing in their own best interest. Therefore, in a market with high agglomeration, the sourcing advantage vanishes.

Market importance

While different regions do not interfere with each other, market segments (*Upstream, Main*, or *Downstream*) are related. The relative amount of investments from all firms in R &C indices and facilities in a specific market segment determines its relative importance. A higher relative importance of a segment increases market size, and vice versa.

BRIEFING AND DEBRIEFING

At the beginning of each round, the participants access an economic forecast that provides macro- and microeconomic information on the different regions and market segments in Europe via the online game interface. The challenges for the first round are: (1) Assess the given information and identify potential entry points, (2) Define the firm's identity and strategic goal(s), (3) Formulate the firm's strategy without indepth knowledge about the competition and (4) Take risks versus playing safe (Type of Entry Mode, Focus versus Diversification).

In the debriefing part, the instructor can focus on the frameworks to structure information such as PEST, Porter's Five Forces and the AAA framework. The challenge of the second round is to push a global strategy on standardization, integration, and coordination. How much should a firm standardize across locations? How much should a company integrate its competitive moves across areas? How much should a firm concentrate activities in a few locations and coordinated across them?

Presenting the respective frameworks to navigate in an international environment and assess the trade-offs between strategic moves can be the content of the subsequent lecture. Typically, participants lose focus on their initial entry strategy if they realize what the competition did. In the final round, the participants experience the impact of path dependency on decision-making. The territory becomes limited, and competition can follow a race to the bottom or top on the 4P's of marketing indices. Using Porter's value/price and price/cost dimensions helps to identify the strategic position of the competitors and to anticipate their next moves.

SUMMARY

The article presents a blended learning approach comprising of an online game before class followed by sit-in lectures covering the content of international business. Playfully, participants experience the complexity of expanding internationally, the trade-offs of strategic alternatives and the difficulty to align strategical and tactical decisions. The game addresses concepts and frameworks such as PEST analysis, Porter's five forces, AAA framework, value/price and price cost concepts and externalities. Applying these concepts in a competitive environment and obtaining direct feedback on the performance complements the face-to-face lecture with a hands-on experience addressing the students' needs in an increasing digitalized society.

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LEVERAGING PERSONALISED FEEDBACK AS A MOTIVATION TOOL IN ACTIVE GAMES

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ABSTRACT

Obesity and specifically childhood obesity is already a major health issue especially in developed countries. One contributing factor which also poses a health risk in itself, is physical inactivity. The emerging area of Serious Games has the potential to help combat these issues by introducing activity into an otherwise sedentary lifestyle. This research aims to explore the effect of a number of factors on children playing an exergame (a game which aims to provide exercise through fun).

Our overall results indicate that players found our developed exergame enjoyable. In addition, they reported a positive motivational effect from trying to achieve higher scores with repeated play in order to beat their own and their fellow classmates' scores.

INTRODUCTION

Two major modern day health challenges that are facing the global population are the seemingly related issues of obesity and physical inactivity. According to WHO Fact sheet No.311, which was updated in June 2016, the worldwide prevalence of obesity more than doubled between 1980 and 2014, with 1.9 billion adults being overweight. Of these, 600 million are obese which is an alarming 13% of the world population. An estimated 41 million children under the age of 5 years were overweight or obese. In Ireland, childhood obesity is fast becoming an epidemic with an estimated 1 in every 5 children being classed as obese (Mannix 2011). This trend will see 42-63% of these children go on to be obese adults. Adolescence who are obese face increased mortality and morbidity rates regardless of any possible weight loss later in life.

Identifying the root cause of obesity is complex. The fundamental cause is a higher energy intake (food) in relation to energy output (activity). The influences that shape this current widespread imbalance have been attributed to a number of factors including poorer diets and an increase in physical inactivity. The trend of an increase in physical inactivity in the global population is alarming and one which requires an immediate response. One solution is to offer additional support to encourage activity. A common issue with this response is that like traditional exercise plans, the activity plateaus or stops once the intervention or extrinsic motivations are removed. This body of work contributes to the area of exergames by attempting to analyse the factors that affect the motivation of children playing an active video game. It proposes that once identified, these factors can be used in the core design of further active games and offer an opportunity for players to increase their personal motivations to become active, which it is hoped will be a pathway leading them to a more active lifestyle with more traditional exercise.

The direct contributions from the research are a set of results and conclusions regarding the efficacy of aspects of game design to encourage or motivate children to play. Results are presented that pertain to rewards, scores and competition among peers which can form the basis for further research. The results obtained highlight the potential for the use of active games to influence motivation and the possibility of using such games as a step towards partaking in more strenuous traditional exercise and a more active lifestyle.

Furthermore the game design and implementation can be used by fellow researchers. The code and documentation is available to any researchers who wish to pursue research in this domain.

RELATED WORK

In this section, we briefly review work in the domain of exercise games and the important related factors of game immersion, motivation and enjoyment.

Exergames

Serious games is an emergent field of research focused on the use of games designed for any purpose other than mere entertainment. A specific use of serious games is in the area of physical fitness and exercise, and this concept has been referred to as exertainment or exergaming. Michael and Chen explain this concept as referring to an attempt to make physical exercise more attractive by association with video game imagery (Michael and Chen 2006). The combination of video games with physical activity is a promising tool in the battle against childhood obesity, as it may be able to overcome some of the obstacles involved. The advantages it has over traditional physical activity routines would be the attractiveness of a familiar video game technology, easier access to an exercise environment, and, if properly designed, a more fun centered experience.

One paper found that the use of exergames increased activity and reduced sedentary behaviours, and has a considerable potential for the encouragement of active and healthy behaviours (Lamboglia et al. 2013).

Motivation

When considering the idea of physical intervention to tackle obesity and inactivity, it is important to consider the topic of motivation. What factors influence people to choose to be more active or not? Motivation is an abstract concept to explain behaviour - it is what causes a person to want to repeat a behaviour (or not) and can be divided into two different types known as intrinsic (internal) and extrinsic (external) motivation.

According to Deci and Ryan, Self-Determination Theory (SDT) represents a broad framework for the study of human motivation and personality (Deci and Ryan 1985). SDT defines intrinsic and extrinsic sources of motivation and also explains how social and cultural factors can shape, by either fostering or thwarting, the various forms of motivation. In their work, Deci and Ryan define intrinsic motivation as the doing of an activity for its inherent satisfactions rather than for some separable consequence (Ryan and Deci 2000). It is the self-desire to try new things, face new challenges and to gain knowledge from this. It is long-lasting and selfsustaining. Extrinsic motivation refers to the performance of an activity in order to attain a desired outcome and it is the opposite of intrinsic motivation. Normally extrinsic motivators come from external sources outside of the individual. Such motivators may come in the form of a reward, or indeed the threat of punishment for not showing the desired behaviour.

One final theory we mention is flow theory. Flow is an optimal psychological state that has been described by Csikszentmihalyi (Csikszentmihalyi 1990) and describes the point at which a person becomes totally involved in an activity and experiences a number of positive experiential characteristics, including freedom from self-consciousness and great enjoyment of the process.

Immersion

When dealing with video games and the gaming experience, the notion of flow leads to the concept of immersion. Immersion is a term that is used widely in modern games and it is paramount to the user experience.

In their work on a grounded investigation of game immersion, Brown and Cairns (Brown and Cairns 2004) presented a theory of the division of immersion into three distinct levels: engagement, engrossment and total immersion. Each level presents new barriers that have to be overcome in order to reach the higher level of immersion. The first level, engagement, has an initial barrier which is referred to as access, and relates to a gamer's preference. The level itself, refers to the process of getting a gamer to commit time, attention and effort to play. The next level is engrossment in which a player must invest some emotion in to playing the game based on the construction elements of the game – visuals, sounds, task and plot. To reach total immersion, Brown and Cairns suggest that the barriers of empathy and atmosphere must be overcome, at which point players express presence in the game.

In their investigation into game immersion, Pasch et al carried out research on movement-based video games (Pascha et al. 2009). Their approach was to explore the motivational reasons that would impel regular gamers to chose movement based controls, and secondly how they conceptualise their experience with those games. Their work attempted to map the players' feedback on motivation to the two main models of immersion referred to earlier in this section. They had two interesting findings. One was that when the motivation the gamers had was to relax, they allowed their bodies and selves to be immersed in the game, gaining enjoyment from the movements. Conversely, when the gamers were motivated to win, they reduced their movements to just what was necessary to achieve this. This had the effect of reducing the actual physical activity effort required.

Fun and Enjoyment

One common factor that is regularly mentioned in the previous section is the importance of player enjoyment in games, and how it is linked to player motivation and game immersion.

Takatalo et al. attempted to analyse the difference between pleasure and enjoyment in digital games (Takatalo et al. 2008). The results from their theoretically grounded study identified the difference as pleasure being received when one feels competent whereas enjoyment also required a challenge. In reaching these findings, they disclosed a process whereby the elements of competence and challenge, are combined with emotions to form concepts, which shape pleasure and enjoyment.

If exergames are to truly serve as a tool in the promotion of a more physical active lifestyle, then further research is needed in the area of measuring the enjoyment levels of games and its overall effect on motivation. Mellecker et al. concluded that this research was required to help shape and design exergames (Mellecker et al. 2013).

Competition

The challenge aspect of a task has a major effect on a player who loses interest if a game is too much like work. However, the same task when played with a competitive edge can itself be more interesting. This can be as simple as introducing a defined goal, increasing difficulty over time, using real-time sensor feedback to adjust game parameters and provide feedback on progress over time. Lison et al. conducted research to determine whether adding a competitive component to playing active video games impacted physiological and psychological responses in players (Lison et al. 2015). Their results show that opponentbased games appear to improve children's perception of exertion and affect when compared to single play.

OVERVIEW OF GAME

Choice of Game

The main component involved is an age-appropriate active game on which the study can be based. We took the decision to design our own game to include all the fun elements of a normal game with an emphasis on the active movement of the player. The design was then used to develop a prototype game. To expose players to physical exercise we created a game based on a controller which supports Natural User Interface (NUI).

Technology Used

The game was intended to be developed using accessible and inexpensive technology. For this reason, we decided to use a Microsoft-based solution using the Microsoft Kinect Sensor, C# programming language, Kinect Software Development Kit (SDK), XNA Game Framework and Microsoft Visual Studio Integrated Development Environment (IDE). Using these technologies allowed us to develop and compile the game software on a standard Windows PC. The same codebase can be used to compile for both Windows PC and the Xbox game console. The sensor was compatible with both PC and Xbox and it is relatively inexpensive.

Design

The exergame which we designed, will be a single player game as this is again aimed to encourage activity without having the constraints of finding another person to play. The game design has to appeal to players of all fitness levels, although it needs to focus on those with low physical activity levels. The game will put the player under time pressure by playing against the clock which makes it a simple yet fast paced game. To ensure movement we decided on a design in which the player simply hits objects on the screen with an avatar which will be controlled by the NUI. The player must hit the object before it moves off screen. Rather than progressing on to different levels, the player would be rewarded for high achievements by extending game time and also by making the difficulty level slightly harder.

The difficulty level is achieved by altering the characteristics of the object, namely:

- Scale: The object will become smaller as the difficulty increase
- Time Before Movement: After an object appears on screen, it will remain stationary for a set period before beginning it's escape. This stationary period will decrease as the difficulty increases
- Escape Speed: When an object is escaping it will move at a rate which increases with difficulty

Respawn Time: After an object has been touched or escapes, there is a period of time before it respawns.This time period will decrease as the difficulty increases

The design incorporates some further fun game elements such as music and sound effects. In addition there are a number of different themes for the object and backgrounds which are chosen in options by the player. After a game, the player is presented with some feedback. The level of detail in the feedback is controlled via a game menu option, and is used to evaluate the effects of feedback on motivation during the experiments

Once the game was fully implemented it went through a series of testing stages to identify bugs or flaws in design or implementation. It was then trialled to ensure suitability for purpose. Once this was achieved the game was ready for use in our experiments.

EXPERIMENTS AND RESULTS

Participants

We chose to conduct the experiments in one single visit to a primary school, and to target children in the 9-10 year age range. This age bracket was selected as suitable, based on the results of our initial field tests, given the physical requirements and hand to eye co-ordination needed to play the game along with the necessary comprehension abilities to provide usable data for the questionnaire. In total 20 children partook in the experiments and were asked to provide some background information on their personal habits in relation to physical activity and gaming. Nearly 70% of respondents indicated that they are active for over 3 hours daily. On exposure to video games 25% responded that they played each day, while 40% indicated that they rarely or never played video games.

Measures

The experiments are divided into three separate rounds with each round using a different version of the game. Each round is designed to gather specific information to explore separate hypotheses. There are two means of collecting data – the objective game data is stored electronically on the computers. In addition, a series of paper based questions which each child is requested to answer following each round; these answers provide us with subjective data. Following the three rounds of play, the children are asked a number of further questions about their general exposure to, and enjoyment of, video games and physical activity. To enable the statements of opinion to be directly translated into numerical data, all paper based questions are based on either Likert scales or a multiple choice format.

The children were organised into groups of 4-6 children with an average of 40 minutes per group. From these groups, we received data for 141 recorded games and 20 completed questionnaires, which we analysed in the following results section.

Results

Throughout the experiments the children involved responded positively to the game with all eager for repeated play. The first aspect was the feedback of the player's own score at the end of the game, and whether they had desire to play again in order to beat their own score. Most reported that this had a positive effect on their motivation (Figure 1).



Figure 1 Motivation Result of Beating Ones' Own Score

The second aspect of the game involved giving a bonus round when a high hit rate was achieved. This had a much more pronounced effect with virtually all respondents reporting that it encouraged them to play again and try harder (Figure 2).



Figure 2 Motivation Result of Getting a Bonus Round

When asked about the motivation to play again in order to try to beat their classmate's scores, there was a much greater motivation level reported, -with the vast majority rating this at the highest point (Figure 3).



Figure 3 Motivation Result of Beating Classmates' Score

On the competitive aspect, when asked whether the player would like to play again to try to achieve a higher ranking, 75% of the players indicated that they would like to achieve that (Figure 4).



Figure 4 Motivation Result of Achieving Top Ranking

CONCLUSIONS

During the experiments, we gradually introduced various features of the game. The feature changes included increasing the game length to 90 seconds, enabling a bonus round option for performance and also extended the detail in the end of game feedback. In our analysis of the data that was collected after carrying out the experiment, we found the feature which had the largest impact on motivation appeared to be the bonus reward level. This was also observed during the experiment, as children could be seen to keep an eye on the metrics during the game in order to qualify for the bonus rounds. These bonus levels are a common feature of video games, and when it forms part of the design of active games it has the potential to offer a further increase in physical activity and energy expenditure.

The data also indicated an increase in motivation as the children tried to beat their own score which was presented to them in the post-game feedback. We analysed this feature further, and when we compared this motivation rating with their highest scores, we found the positive motivation was present in the full range of scores achieved. This can be seen as a very positive finding as the children would be drawing on more intrinsic motivation in their desire to increase their own score, regardless of how successful they were.

We found that these new features added a further increase to players' motivations. The one that had the highest impact was that of trying to improve your own score in order to beat your classmates' scores. This reaction to the competitive element is a very positive result. A related result also showed that 75% of the children indicated a positive increase in their motivation as a result of trying to reach the top ranking. It is interesting to note that the motivation to beat the players' own score was not rated as highly in this set of experiments, although this could be explained in part from the presence of the more competitive element of beating someone else instead. Once again the overall rating to enjoyment of the game was very high. We can draw a number of conclusions from our research and results presented thus far. Firstly, the use of video game technology has the potential to entertain children. Secondly, the blending of this technology with physical activity in active games retains this fun element appeal to children. Thirdly, if this fun element remains a core design principle, then it has the potential to encourage an uptake of use of these games. Fourthly, we found that of those who were exposed to our games, our active game prototype held an appeal to all children regardless of their present physical activity habits. Most importantly was appealing to those who partook in little or no exercise.

Fifthly, we found, that throughout our data, the use of game rewards in the design resulted in an increase in player enjoyment and motivation. This encourages repeated use of the game and an increase in effort during the games. If the game design has incorporated basic physical exercises in to game play then this will provide some health benefit to the players.

Sixthly, we found that the use of post-game feedback has a huge effect on the motivation of players. The use of this type of feedback to present competitors scores and a ranking system, offered a competitive element and we found it was the most influential motivational factor from our set of experiments. Based on all these findings, we may conclude that this competitive aspect is most crucial in the overall design of an active game, and we feel that it will sustain the repeated use of the game over a longer period.

FUTURE WORK

The direct contributions from the research are a set of results and conclusions regarding the efficacy of aspects of game design to encourage or motivate children to play. Results are presented that pertain to rewards, scores and competition among peers which can form the basis for further research.

We conclude this research work with a brief overview of some of the limitations of this work, in addition to future work that could be carried out to further investigate the importance of feedback as a motivational tool in active games.

Firstly, further testing of experiments could be carried out with this prototype. The additional testing should incorporate much larger test groups, repeated over a prolonged period and there is scope to find test groups in different socioeconomic areas, especially in areas of population that are found to have lower physical activity rates. Secondly, further research is needed in to the possible benefit of playing this game, such as measuring the caloric burn rate involved in playing the game (short term) and impact on general health/weight (long term).

Thirdly, given the positive reaction to the competitive elements, there is scope to incorporate an online and/or

social media element which would allow scores to be shared with less restrictions. The use of this online data would require further experiments to be carried out to test their effectiveness. Fourthly, the questionnaire could be further refined to gather extra background information on habits, and if the experiments were expanded and repeated as per suggestion 1, then this data could be analysed to see if a trend emerges.

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