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ON

INTELLIGENT GAMES AND SIMULATION

 $\text{GAME-ON}_{\mathbb{R}}\,\text{2016}$

EDITED BY

Helena Barbas

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Preface

Dear Participants,

It gives me the greatest pleasure to welcome you to the Faculdade de Ciências Sociais e Humanas – Universidade Nova de Lisboa, and to the 17th edition of GAME-ON, which we are hosting between 13th. and 15th. of September 2016.

We are most pleased to host you, dear conference participants, and learning from your specific approach to game research, whether it is focused on game design, education, training and simulation, artificial intelligence, gamification or on procedural and online gaming.

Moreover, we are exited to host three excellent keynote speakers, namely Prof. Luís Moniz Pereira (NOVA LINCS, Caparica) – who will talk on Games with morality, centered in agent ethics together with Miguel Calejo (InterProlog Consulting), and Prof. Paulo Simões Rodrigues (CHAIA, Évora) – with Through the looking-glass: gaming pre-earthquake Lisbon, Post-human heritage and the crisis of humanities, showing how virtual reality and gaming technology has dramatically changed the ways we perceive and represent reality. Also, we are happy that the programme is supplemented with some young people presentations' showing off winning ideas in gamification.

I would like to express my gratitude to all those who have contributed to this event: firstly to those who have submitted papers, and who will present them over the next couple of days and; of course, and above all, to Philippe Geril who is and has been the driving force behind GAME-ON; and to the programme committee who have reviewed papers, and contributed to organising this event.

I hope that you will have a great time in the warm city of Lisbon, and will find the conference interesting and inspiring.

Lisbon, September 2016

Helena Barbas CICS.Nova – FCSH-UNL GAME-ON'2016 General Conference Chair

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SCIENTIFIC PROGRAMME

GAME METHODOLOGY

BEYOND VERSION CONTROL - INSPIRATIONS FOR NEW GAME DEVELOPMENT PIPELINES AND FUTURE GAME ENGINES

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KEYWORDS

Game Development Methodology, Game Engines, Game Development Tools, Version Control Systems

ABSTRACT

Collaboratively editing game worlds and the underlying asset version management techniques present us with many challenges when using a traditional Version Control System (VCS). This paper suggests a new method that will aid in the tracking, branching, and selection of asset versions within a game development pipeline. A prototype has been developed which demonstrated improvements in both productivity and usability providing greater visibility of incremental asset changes and alterations to their relationships which equated to approximately a 30% better user experience when compared to an existing industry VCS.

INTRODUCTION

In our last publication a focused prototype was developed around the Quality Assurance (QA) processes of a game development pipeline (Engels and Grigg, 2015) where the process of finding, recording and communicating product issues was done all within the game engine environment. The aim was to evaluate the improvements gained when the approach is to remain as much as possible within the game engine. This experiment was part of a bigger vision of how game development pipelines (see Figure 1) and future game engines, that may live in the cloud, will function for improved productivity.

Previously we have shown that it is not only possible, but allows developers to stay within the game engine to quickly find and resolve problems leading to substantial productivity gains. This paper continues on that concept of what a game production environment of tomorrow would look like given a collaborative editing platform and how the underlying versioning of assets and product releases could be handled. The research question posed: Would a new innovative approach to asset versioning, review, comparison and selection provide improvements in a game development production pipeline?



Figure 1: Architecture of the prototype system.

VERSION CONTROL SYSTEMS

Version Control Systems (VCSs) are widely used in the games development industry and there is an abundant amount of resources for the use, operation and management (Loeliger and McCullough, 2012; Wingerd, 2005; Vesperman, 2006; Pilato et al., 2008). There are also similar resources for supporting tools that gives these systems more features or makes them more user friendly, an example of this is the version management client Tortoise (Harrison, 2011). Currently there is little research into the underlying mechanisms, models and methodologies behind a VCS.

We see the game industry as an iterative development environment, however, this is not something that permeates all aspects of the game development pipeline. Game developers always look to move forward, where the old is replaced with the new, and the broken replaced with the repaired. In situations where the latest version of an asset is found to be inadequate, or technically create a problem, it is then *rolled-back* to be replaced by a prior version or the problem is addressed and the new version of the asset is *added*.

VCS PRACTICALLY

VCS software is used to store different versions of an asset to a shared central repository that is remote and secure to that of the end-user's computer. Originally tools from the software development industry focused on the effective storage of text files that contained things such as source-code, meta-information, or configuration details. A lot of these tools faced challenges in moving from a source control model to a larger asset management function where assets in game development included binary files and extremely large files.

The operations of a VCS includes *adding*, *removing*, *replacing*, and *obliterating* (the permanent removal) at an asset or file level. At the sub-asset level then *updating* parts of the asset may include changes to lines of a text file or positions of vertices in a model. Actions can also include *reverting* where this is the *replacing* of an older version of the asset. Tools that accompany or are apart of the VCS may allow asset *locking* to prevent changes to the same file at the same time and *comparison* to review their internal changes or visual differences of an asset. To help manage a group of assets that are associated, in a release for example, then *labeling* or *tagging* is used. This can be viewed more generally as meta-data that is kept on assets within the repository that for some VCSs is often customisable.

More complex operations to assets such as *renaming*, *copying*, *moving*, and *restructuring* (altering the underlying folder structure) lead to further challenges and complications such as the creation of large numbers of duplicate assets or assets that are quite similar. A recent example of this was from the developer CD Projekt RED's Witcher 3 project where an example of 2600 texture assets had found 300 potential duplicates and 13 identical assets (Krzyscin, 2016).

Finally these systems need most of these operations to be performed manually to ensure that the assets make it into the VCS but can also lead to missing or lost assets if not performed properly. Loh worked to devise a formal model to address some of these complicated VCS issues, for example, conflicting assets where both a developer's local asset has changed and also the remote version by another user (Loh et al., 2007). Others have formulated models based on a patching perspective (Angiuli et al., 2014) in work connected to open-source projects such as Darc (Hoffmann, 2004).

Perforce (Cowham and Firth, 2013) is a leading Distributed Version Control System (DVCS) in the game industry (see Figure 2) and in 2008 was then used by 18 of the 20 top game developers (Aguirre, 2008). Perforce is used at game companies such as EA (Electronic Arts, 1982), Ubisoft (Ubisoft, 1986) and Nintendo (Nintendo, 1889). The company describes their tool as "an enterprise version management system in which users connect to a shared file repository. Perforce applications are

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Figure 2: Perforce P4V - client-side VCS application.

used to transfer files between the file repository and individual user workstations" (Wingerd, 2005). With the use of meta-data Perforce is able to store information on different asset versions, permissions and change-logs. Perforce, SVN (Pilato et al., 2008), and GitHub (GitHub, 2008) are VCSs that allow developers to use branching where another version of the project can be developed and tested in parallel with one or more other branches. Applying the use of branching for the first time often requires training for the concept to be properly used. Perforce takes this a step further with streaming where there are rules and relationships between branches that aims to reduce the merging between branches by half due to a straight copy relationship in one direction (Perforce, 2012). The example of streaming is a step closer to automating some aspects of a VCS.

Finally a VCS does not automatically capture all changes made but this is something that a collaborative development environment incorporates at the core. Examples today are services such as Google Docs (Google, 2007) aim to capture all changes while also being able to show the history of changes and revert if required. We propose a different way of doing this with version control automation to review, compare and select assets to be combined and used in a project.

VCS AUTOMATION

Automatic versioning allows everybody in the development team to use branches to its full potential. The branching in the prototype is on a per asset basis and will automatically determine the number of the assets from the server side. Developers would not need to lock assets as new versions are saved to the server, and assets will not be overwritten, but start a new branch.

A project build consists of asset versions and these can be *swapped*, *updated* and *replaced* throughout the development process. Auto-branching will allow a developer to branch without thinking of the concept of branching. A revision of a file will also not state that this is the latest file, it will only give its position within a particular branch. An older file can have a higher revision than a younger file and vice versa, this happens as versions and branches are established to the files that are already on the server. Versions of assets on the server can always be retrieved from the server to be used in other parts of a project.

When an asset is saved a function is called to hash the byte data of that asset into a MD5 encrypted key. The file will then be copied to an upload buffer folder where it will be temporarily stored to receive a callback from the server for *uploading* or *deleting*. The client will first send the MD5 hash to the server and check if the file already exists there. If it does then the server will send the delete action back to the client. If the opposite is true then the server will add the hash to the database and check what version the server needs to receive, which can be determined by looking at the last uploaded version from the developer. All server interaction of the developer are stored in the database which also includes the last upload and download requests for assets. From here we can determine the version that the new asset needs to get by looking at these assets (see Figure 3).



Figure 3: FTP file upload handling.

For this prototype automatic branching is to be handled by using four numbers, an example of a version given to an asset could be (1.0.3.5). The first number indicates the Trunk that the given asset is in which is (1) for (1.0.3.5). The next number is the *Parent Trunk* which is (0) for (1.0.3.5). The third number is the *Branch* that the asset is in which is (3) for (1.0.3.5). The last number is the *Revision* number of the asset which is (5) for (1.0.3.5). From these numbers we can determine the origin and direction of the asset, for asset number (1.0.3.5)we can determine that its origin is (1.0.3.4) if *Revision* (5) of (1.0.3.5) is the first revision of the branch then the origin would be (1.0.?.4) where the question-mark is not required to indicate the origin of the given asset. For the direction we simply increase the *Revision* number, for example (1.0.3.5) to (1.0.3.6). If the system notices that there is already a version (1.0.3.6) then the automatic branching operates and give the asset the number (1.3.?.6), where the question-mark will be determined by the amount of branches in the (1) Trunk. Figure 4 shows the version numbers that an asset will receive and how the branching could look for an asset.



Figure 4: Asset version branching diagram.

EXPERIMENT

For the server-side of the prototype a Virtual Machine (VM) using VirtualBox (Oracle, 2007) was used to run a CentOS 7 (CentOS Project, 2004) operating system (see Figure 5) for an image that can be run locally on a server or deployed to the cloud. The server also had Perforce installed for obtaining a comparison for the experiment. Unity (Unity Engine, 2005) was the game engine used, although the system is designed to be engine agnostic, as this was the most suitable solution for the development of the prototype (see Figure 6). The server-side of the prototype was developed with NodeJS (Node.js, 2009) and uses Socket.IO (Socket.IO, 2014) for

the communication between client and server. A MongoDB (MongoDB, 2009) database was setup for data storage. The extendability of MongoDB was ideal for use as the data within the database can grow rather quickly. The FTP was used for uploading and downloading files to and from the server and on the client-side a FTP client library (Otom, 2012) was used to accomplish this. Connection to the Unity Engine was done by using a Dynamic Linking Library (DLL) file written in C++ that would connect to the server and transfer data.

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Figure 5: VM running CentOS 7 server.



Figure 6: Unity 5 auto-versioning prototype.

For the experiment users were asked to find and review pictures from both Perforce and the prototype, after which a questionnaire was completed. The questionnaire was based on the System Usability Scale (SUS) (Patrick et al., 1996) and consisted of twelve questions of which two are open. The other ten questions are on a scale of one to five with five being the most positive.

RESULTS

Participants were excited by the new approach that was handled by the prototype within their production environment. To keep the test as accurate as possible we focused on the asset revisioning and retrieving feature. The results from this show that participants would



Figure 7: User results from the prototype use.

rather use the new improved way of working embodied in the prototype and that there was little need for support and explanation for its operation. Perforce was perceived as much more complex and some participants were having a hard time understanding it. All participants agreed that both tools were very useful within the game industry, however, the results showed that the prototype scored an average of 30% higher than Perforce, which is a significant increase.

The findings show that an automatic versioning approach to game assets has a positive influence on the way developers work. Assets within the game development pipeline do not need to be manually committed, or assets locked, which avoided a number of problems. For large milestones developers no longer needed to be reminded to commit missing or updated assets. The research in this document has shown that developers embraced this new way of working that removes a lot of the overheads of a VCS.

DISCUSSION

The branching functions in a traditional VCS was particularly challenging for certain developers as training or support was required. The automated prototype allowed developers to not worry about this while still having the benefit of using a branching system inherently. This approach opens up the option for Producers, Team-Leads, and even the possibility for an Editor role in being able to *review*, *compare* and *select* different assets for a given release.

Additionally people in more of a management or directing role could join the collaborative environment and not only annotate the end result but also the steps involved in the alteration of assets in, for example, the structuring of a game level. For certain assets the dependencies on other assets can lead to errors when retrieving and combining these resources, for example, when an asset is linked to assets that do not exist in the client project. These problems are in part handled when the transfer of the missing file is the solution but when deeper dependencies are involved, such as the number of required parameters in a script function, then a smarter VCS approach in combination with smarter engine architecture may be the solution.

CONCLUSION

We conclude that the use of assets versions that can be reviewed, compared and selected is not only feasible but beneficial for the development process of games. It allows for quicker iterations and multiple development branches where different developers can use and edit the same assets. They do not have to worry about branching and corrupting assets for other developers, which provides a more relaxed way of working. Developers can get together within the software they are using and try out things without interfering with each other, show the new edits to team members and obtain feedback within the software that they are most familiar with. These edits can then be added to the already working build of the game and be reviewed by a producer or lead within the company. All versions of assets have the incremental steps of the asset changes recorded which can be retrieved from the server at any time. Existing VCSs may record incremental changes to non-binary formats but fail to capture useful incremental changes to binary assets of operations that relate to the organisation of assets together.

FURTHER RESEARCH

Some assets are sensitive to changes and have dependencies that if not met may break a build. One approach could be the improvement of the underlying model where these dependencies are incorporated into the VCS. These dependencies, in combination with an automated testing system, could be refined to be more sensitive to build and play errors and may possibly feedback to the version and branch information in defining *operational subsets* of assets.

In creating a more engine agnostic approach the development of an Unreal Engine (Epic Games, 1991) or CryEngine (Crytek, 1999) version may help test and improve the existing prototype.

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'EPHEMERALITY' IN GAME DEVELOPMENT: OPPORTUNITIES AND CHALLENGES

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KEYWORDS

Ephemeral Computation, Artificial Intelligence, Videogames, Procedural content generation

ABSTRACT

Ephemeral Computation (Eph-C) is a newly created computation paradigm, the purpose of which is to take advantage of the ephemeral nature (limited lifetime) of computational resources. First we speak of this new paradigm in general terms, then more specifically in terms of videogame development. We present possible applications and benefits for the main research fields associated with videogame development. This is a preliminary work which aims to investigate the possibilities of applying ephemeral computation to the products of the videogame industry. Therefore, as a preliminary work, it attempts to serve as the inspiration for other researchers or videogame developers.

INTRODUCTION

Ephemeral Computation (Eph-C) (Cotta et al. (2015)) can be defined as the use and exploitation of computing devices of ephemeral (i.e., transitory and short-lived) nature in order to carry out complex computational tasks.. Eph-C is a concept proposed inside the frame of a project, coordinated between several research groups, from different universities, called "Bioinspired Algorithms in Complex Ephemeral Environments" (Ephemech project https://ephemech.wordpress.com/) which has been funded by the Spanish Ministry of Economy and Competitiveness (Ministerio Español de Economía y Competitividad). This project aims to establish the theoretical basis and foundations to define the concept of ephemeral in computation. Its objective is to define the foundations of efficient (and scalable, in certain forms) systems design to provide services for managing ephemeral resources in complex systems. Specifically, it focuses on providing evolutionary computation capabilities to treat transitory behaviors. The definition of transitory behavior and the entities or resources it associates to, is something that is being studied within the project. The reality is that there are many problems associated with treating ephemeral resources, but we are convinced that there are great benefits also. Even though the mentioned project treats Eph-C from a general point of view, this paper focuses on analyzing the possibilities of Eph-C within the game development industry. The belief is that this industry can benefit greatly from this new paradigm, as it could be applied to most of the processes which are part of videogame development. One of the main objectives of ephemeral computation is to effectively use highly volatile resources whose computational power would be otherwise wasted or under-exploited. Think, for example, about the pervasive abundance of networked handheld devices and tablets not to mention more classical devices (such as desktop computers) whose computational capabilities are often not fully exploited. Hence, the concept of ephemeral computing partially overlaps with cloud computing, ubiquitous computing, volunteer computing and distributed computing. It exhibits, however, its own distinctive features, mainly in terms of the extreme dynamism of the underlying resources, and the ephemeralityaware nature of the computation. It therefore has to autonomously adapt to the ever-changing computational landscape, not just trying to adapt to the inherent volatility of this landscape but even trying to turn it into an advantage.

Figure 1 represents a conceptual map that relates Eph-C and other computation paradigms, as those mentioned previously, and provides some indications/ideas about possible practical applications/areas inside the industry of videogame development (more comments on it are given in Section).

This paper is therefore a preliminary work, with which we intend to initiate a discussion about the possibilities of Eph-C in the videogame development industry.

VIDEOGAMES AND 'EPHEMERALITY'

The application of artificial/computational intelligence to games (game AI/CI) has seen major advances in the last decade and has now become a separate research field in itself (Lucas et al. (2013)). In general terms, it is about adding Artificial Intelligence techniques to videogame development which can result in areas of great interest, both for academic use (as it exploits a new practical field of research) and industry (which benefit from many of the research proposals which improve the development process reducing costs, providing sources of inspiration to industry professionals or extending



Figure 1: Related Concepts and Applications

the life of commercial games, to mention just a few). There are many lines of research that have arisen from the possibility of applying AI techniques to the videogame development process. (Yannakakis and Togelius (2015)) and (Lucas et al. (2015)) suggest some principal lines of research such as AI-assisted game design, computational narrative, procedural content generation, non-player-character (NPC) behavior learning, NPC affective computing, believable bots, social simulation, and player modeling, among others. Many of the problems that arise in these areas require creativity. It is not enough to just solve them competently but also to do so in the way a human would. Many interactions and relationships emerge naturally in games which creates a complex system that is usually not easy for a human to understand but can provide interesting results from a human perspective (Sweetser (2008)). Moreover, many games have an ephemeral nature, which is hard to manage computationally. Some game assets (i.e., game contents, NPC behavior/game AI, game goals and even game rules) can be seen as volatile in the sense that one cannot guarantee they will reoccur. Thus, it makes sense to consider creating them ephemerally.

The recent boom in casual games played on mobile devices means that both the design and gameplay of games demand resources that appear and disappear continuously while the game is being played (Lara-Cabrera et al. (2013)). This is precisely what occurs in the so-called pervasive games (i.e., games that have one or more salient features that expand the contractual magic circle of play spatially, temporally, or socially) where the gaming experience is extended out in the real world (Montola et al. (2009)). Playing games in the physical world requires computations that should be executed on the fly in the users mobile device and taking into account that players can decide to join in or drop out of the game at any moment. This is common in most multiplayer games.

We should, however, not just focus our attention on this specific genre of games as Eph-C can be applied in many areas of the gaming universe as shown in Figure 1 (note that this figure contains a preliminary schema that will be extended with more detailed information in the future although now it provides an overview of the underlying idea under the Eph-C paradigm). It is not unreasonable to think about the concept of *Ephemeral Games* as those games that can be only played once or that expire in some way; one can find many reasons for their creation such as: economic reasons (e.g., the player is expected to demand extensions of the game in the future) or creative aspects (e.g., provide unique game experiences by playing a game with irreversible actions). In addition, one can think about ephemeral goals/events that temporarily exist in games as these appear (and disappear) as consequences of the actions and preferences of the players. These goals/events are usually secondary (as the main goal is welldefined and related with the primary story of the game) but help to significantly improve the gaming experience and thus they are critical in increasing user satisfaction (incidentally, the maximum objective of games). Another issue to consider is the reversibility of players actions. Many games give the player the option to save the current state of the game, so they can reload it later. This means that players do not have to face the consequences of their actions as they can always go back to a previous state. While this is useful (and desirable) in a number of games, it is also true that it poses a significant drawback in certain types of games like multiplayer online games (e.g., first-person-shooter, real-time strategy, or role-playing games, among others) where the actions of one player can affect the game's universe and thus affect other players. Goals, players' alliances, and even rewards have to be rearranged according to the game in progress which lends temporality to the nature of game. This transitory essence of games provokes important problems that are difficult to manage computationally, and where and how to create the volatile features of a game is a question that remains open and Eph-C can help to solve/mitigate.

We have then coined the term 'Ephemerality' to identify the ephemeral nature of a high number of entities in the real world, and more specifically in videogames.

CHALLENGES FOR EPHEMERAL COMPUTATION IN VIDEOGAMES

Although the objective of this paper is not to exhaustively cover all the possible challenges in the videogame context, it is possible to define possible applications or fields that could also benefit. The 10 key areas for the future of AI in videogames, according to a consensus of experts on Dagstuhl's seminar of AI in videogames (Yannakakis and Togelius (2015)), are: Non-player character (NPC) behavior learning, Search and planning, Player modeling, Games as AI benchmarks, Procedural content generation, Computational narrative, Believable agents, AI-assisted game design, General game AI, and AI in commercial games.

In the following sections, we make a preliminary approach to show how Eph-C can affect each of these different areas. As we have discussed, we believe that ephemeral computing has great potential to be applied on these areas.

Non-player character (NPC) behavior learning. The main objective in this area is to obtain AI controlled players capable of learning how to play the games as they play, a problem solved in different approaches (reinforced learning, artificial neural networks, decision trees, etc.) (Muñoz-Avila et al. (2013)). Although it is true that videogames have stable and well defined mechanics (although not necessarily easy to learn), it is also true that the appearance of secondary objectives or even the creation of new challenges (in the form of mini-games that have nothing to do with the main game) could negatively affect the learning process. In this context, ephemeral computation can help lower the negative impact. Thus, Eph-C could improve the learning process of these agents by adding the perception of ephemeral events or game states, in such a way as to not affect the global learning or,

conversely, exploit them to develop a better strategy.

Search and planning. Search and planning are common tasks to most for the *bots* or agents in videogames. These range from finding an optimal route to an objective, to planning a sequence of actions to achieve its objectives. Although the scientific literature is full of approaches to address this problem (Botea et al. (2013)), it is true that, in a context where planning can be done in the short or long term, the incorporation of measures that allow agents to adapt to the appearance or disappearance of obstacles, objectives, enemies, characters, or any other object that affects their actions is useful. Adapting search and planning algorithms to these new circumstances, allowing them to jump to new areas of the search space, could improve their results.

Player modeling. One of the greatest challenges in the videogames is to obtain models that represent a human player, whether they are behavior models, cognitive, emotional or based on other characteristics (Yannakakis et al. (2013)). A better understanding of players enables the development of dynamic games which adapt to each player, resulting in a unique experience for each player, even when playing the same game. The perceptions, emotions, or behaviors of a player can change over time, they can even suddenly change in a short space of time, resulting in ephemeral behaviors(or another aforementioned characteristic). The benefit of applying ephemeral computation to this area is twofold: adaptation of the models to these ephemeral behaviors, or ephemeral event (or any other content) generation to surprise the player and cause a previously anticipated reaction based on the model.

Games as AI benchmarks. Generally, videogames provide an excellent experimentation benchmark, as they permit modeling and simulating any kind of circumstance (real or hypothetical) where different agents can interact and modify their surroundings. For example, there have already been a great number of events where different AI methods have competed against each other within the framework of a videogame (Togelius (2016)). The results obtained in these competitions may allow designers to make some generalizations. Moreover, although AI techniques are developed and evaluated in videogame development, their results can be extrapolated to other fields, or they can inspire other researchers who apply these techniques to other contexts. One of the most recent and popular is the success of Google (actually, a company supported by Google) in the application of deep learning techniques in the videogame universe (David Silver et al. (2016);Mnih, Volodymyr et al. (2015)).

One of the possible problems is that these simulated environments are frequently deterministic (or partially, at least) and they behavior is known from their development. By adding ephemeral and spontaneous events, these environments can be brought closer to the real word, where it is not always possible to know what is going to happen. In this way, by increasing the complexity of these environments, more robust AI can be achieved and their extensibility to other realistic environments can be increased

Procedural content generation. Procedural content generation (PCG) is an area in constant evolution and expansion, reaching any kind of videogame resource such as game maps, objects, missions, character behaviors or even sound or textures (Shaker et al. (2015)). To this end, different methods have been used, but evolutionary or genetic algorithms are one of the most used, because of their speed in generating and managing large quantities of possibilities. Thanks to the addition of PCG, development costs can be greatly reduced, or additional features can be added because a game whose contents have changed can be replayed. Usually, contents are generated to be stable and persistent, therefore, raising the possibility of including ephemeral content within procedural generation could open up a new range of possibilities to enrich the subsequent game experience. As ephemeral content, many different options can be considered, like emergent objectives, resources with limited lifetime, temporal abilities associated with players/enemies/NPCs, or even the game story itself (as described below).

Computational narrative. Automatic generation of rich and consistent narrative is one of the great challenges for AI in videogames (Horswill et al. (2014)). Even if first seems to be just another content type (and included in PCG) narrative has special attributes and constraints. Therefore, it deserves its own area of expertise, as an attractive and consistent narrative is more of an art form than a mere functionality. The fact of assessing the possibility of including narratives or just fragments with limited lifetime, which could appear and disappear spontaneously, would signify a new way of creating narrative for videogames.

Believable agents. Sometimes, it is not enough to create agents capable of fulfilling certain objectives or behaviors, but also their behavior needs to resemble human behavior closely enough to make their artificial nature unnoticeable (Philip Hingston (editor) (2012)). In a similar way as the Turing Test, there is a test that evaluates agents/bots/NPCs humanity in a videogame context (Hingston (2009);Polceanu et al. (2016)). Human nature is not always easy to simulate, as AI controlled agents always tend to find the optimum way to achieve their objectives, something that is not always true for humans. The emotional and instinctive nature of humans leads us to take unexpected and, occasionally, completely illogical actions from a computational point of view. The possibility of generating those emotions or behaviors in an ephemeral way for the agents could improve their ability to imitate the unpredictability of human behavior

AI-assisted game design. Another great challenge for AI is taking it to a higher level, not only using it for content generation or NPC behaviors, but for the game design itself.

Table 1: Relationships between Ephemeral Computation Ap-
plications (Adaptation vs. Generation) (Eph-C/A, Eph-C/G)
and Key Research Areas of AI on Videogames

Research area	Eph-C/A	Eph-C/G
Non-player character (NPC) behavior learning	•	
Search and planning	•	
Player modeling	•	•
Games as AI benchmarks	•	•
Procedural content generation		•
Computational narrative		•
Believable agents		•
AI-assisted game design		•
General game AI	•	

Several approaches can be found in the literature which address this feature. Game rules or the definition of game mechanics can be automated (Togelius and Schmidhuber (2008)). These rules and mechanics could also be imagined as ephemeral, being transitory or permanently disappearing. As mentioned, it would be possible to think of completely ephemeral games, with limited life time or only being able to be executed once. This could bring us new and unique gaming experiences. This line of research can be complex but highly motivating.

General game AI. Usually, AI for games is developed under specific circumstances to meet certain objectives associated with specific games. This makes them very difficult to reuse in a different context other than the one they were developed for. A new recent research line proposes developing NPCs capable of learning and playing successfully, different games without being designed specifically for any of them (Liebana et al. (2016)). The main focus is on developing algorithms which allow optimizing the game strategy in different games without making any changes to the algorithms. The only source used is the information from the game rules and players' observation. We have already talked about the possibility of ephemeral events, resources or objectives. They would make this learning process much harder. The way of adapting these AI controlled algorithms to these new types of resources is an interesting but pending line of research. It remains one of the main issues due to the lack of proper ephemeral game definition.

SUMMARY

Based on the above, we can observe that ephemeral computation applications in the different key research areas of AI in videogames can be divided into two principal groups: *Adaptation* (modifying structures and algorithms to consider ephemeral nature of resources) and *Generation* (generating ephemeral contents to reach new objectives or improve the gaming experience). In Table 1 the relationships between these two types of applications (Adaptation and Generation) with different research areas are shown.

We would like to highlight that this work is a preliminary approximation. Therefore the table above is not meant to be definitive and will probably be updated and extended with results obtained from future research in these areas.

CONCLUSIONS AND FUTURE WORK

This paper has presented just some of the numerous possibilities to incorporate the new concept of ephemeral computation to key AI research areas in videogames. The work presented here represents our own starting point as ephemeral computation is an innovative paradigm in itself, and its application to the game development industry is a world only just being discovered and explored. This emergent paradigm opens up a new range of options, which can be interesting research focuses for new videogame (or any another area) research approaches.

Some of these new research lines have been presented in this paper, and we hope that this can serve as an inspiration to other researchers interested in this promising paradigm.

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A STUDY ON CLASSIC GAMES WITH SIBLING RELATIONSHIP: INVESTIGATING FACETS OF GAME ELEMENTS AND THEIR INFLUENCES ON GAME PLAYERS' EXPERIENCES

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KEYWORDS

Game Mechanics, Game Design, Gameplay Experience, MDA Framework, 6-11 Framework.

ABSTRACT

This study analyzes games with sibling relationships, which we define as games with similar core mechanics and the same, improved, or evolved game elements. We examined the evolution tree formed by these games and analyzed their individual attributes the using mechanics-dynamics-aesthetics framework and the 6-11 Framework to establish the contextual relationships among them. Next, starting from the evolution tree, we explored the changes in aesthetics among the games in addition to concepts such as root, branch, inheritance, generation, and complexity. At present, the analysis of the Qix series games has presented some interesting observations and issues.

INTRODUCTION

The rapid growth in the game industry has spurred considerable research on games from the perspectives of entertainment, media, education, society, and culture. Various events launched by the industry and academics in the US have also provided impetus to sustained progress in the industry. For instance, the experimental game design promoted by Carnegie Mellon University and the concept of independent games, which escaped the conventional model of centralized development in large game companies, both included various social events that provided the momentum for industry progress and transition. Taiwan lacks this energy as well as the resources for basic academic research. Game designers with basic professional knowledge should be familiar with the characteristics and distinctions of various types of games as well as an in-depth understanding of their design elements to grasp the influence of said elements on gameplay and feelings of the players. The author's recent teaching experience has shown that game testing and play trials are not enough to divulge the core design elements of a game; actual participation in the game development projects is required for game designers to gain a more profound experience and realize their design ideas using breakthrough technology. We observed that many games, such as the famous role-playing games, Final Fantasy series, have certain connections with each other, such as being set in the same world or part of the same story. Others, such as the side-scrolling games, Mario Brothers series, have numerous sequels due to the widespread fame of the game characters. Among these various types of connections, we paid particular attention to games with sibling relationships, which we define as games with similar core mechanics and the same, improved, or evolved game elements. By examining games with sibling relationships, we endeavored to understand how game variations influence the gameplay experience of players and convert such knowledge into game design expertise.

THEORIES OF GAME DESIGN

Game design theories are still in the development stage, and relevant research has yet to construct a complete framework. Studies in this category generally examine the concepts or procedures of game designers to accumulate knowledge and experience concerning game design. Most researchers agree that the discourse proposed by Roger Caillois over half a century ago is the earliest origin of such theories (Caillois, 2001), the English version of which is provided in Caillois (2001). Caillois used the word "game" to cover a wide scope, covering all play activities, and used four Greek root words to construct the fundamental models of gameplay: agon, alea, mimicry, and ilinx. Salen and Zimmerman (2003) gave modern interpretations for these four models: agon refers to competitive games, such as chess, sports, and other competitions; alea refers to games based on chance or probability, mimicry encompasses role-play or fictitious games, such as theater or any activity that involves the imagination, and *ilinx* means any games that produce a physical sense of dizziness, such as children spinning around at the same spot until they fall down. Caillois further categorized games on whether they allow creative freedom or are restricted by rules, which are paidia and *ludus*, respectively. The former is unstructured play, in which the game play process has no formal rules, whereas the latter is structured play, which continually provides difficult challenges.

From the modern perspective of game design, Bateman and Boon (2005) re-interpreted the luck and skill in Caillois's game-based framework as toyplay and gameplay, which are easier to understand. When people participate in toyplay, they do not have to follow the rules and they are not restricted. The best example is SimCity, which sold over 16 million copies and is essentially a toy for players (even adults). In such games, the game designers allow players to perform their own tests and experiments and assist them in executing their intended actions easily. Bateman and Boon (2005) indicated that the two primary design principles of such games are simplicity and attention to detail. If the game concepts are simple enough, the players can play naturally without any restraints. Grand Theft Auto similarly focuses on many details and supports players to engage in toyplay in a natural manner. For instance, when a player sees a taxi and opens the car door, the game instantly presents a series of relevant missions, and when any weapons are picked up, a hint is given that killing missions can be completed. However, these numerous additional details in the game also necessitated a considerable amount of manpower and funds. The greatest difference between toyplay and gameplay is the presence of clear rules and restrictions. Bateman (2009) stated that game rules can come in a number of forms and that each has its own limitations, such as how to move, what actions can be taken, how to receive rewards, and the benefits of rewards. Although game designers attach considerable importance to the establishment of game rules, a widely accepted approach on how to effectively design a game has yet to found.

Hunicke, LeBlanc, and Zubek (2004) proposed the mechanics, dynamics, and aesthetics (MDA) framework. By their definition, mechanics refers to the specific components that describe the game on the level of data representation and algorithms; dynamics indicates the behavior displayed during the game after the mechanics are executed based on player inputs and outputs, and aesthetics is based on a broad concept of the emotional responses triggered in players by interactions between the players and the system. The MDA framework is one of the most widely known theories in the foreign game industry and was used as the core teaching material for game design workshops held by co-author Marc LeBlanc at the world-famous Game Developers Conference (GDC) for fourteen consecutive years (2001-2014). In the two-day workshop at GDC 2012, three games (Sissyfight, The Three Musketeers, and Us vs. It) served as the three cases for paper prototyping. LeBlanc (2012) used the MDA framework to describe Sissyfight, which focuses on schoolyard fighting. The mechanics of the game include turn-based strategy, self-esteem points, public communication, and concurrent action execution (action cards and target cards). Via the mechanics, the game converts the cards, tokens, and objects into player feelings. With regard to dynamics, all of the players compete with one another and randomly attack opponents under the same conditions. Each player must constantly assess the current game situation before choosing what action to take. If a player realizes that other players are about to win the game, they may choose to attack those in the lead. When the game mechanics execute the actions, a new game situation is produced. The players experience the following aesthetic qualities while playing the game: fellowship (negotiation, cooperation, and betrayal between players), challenge (which requires tactics and problem-solving abilities), and narrative (dramatic tension). Marc LeBlanc further proposed eight types of fun that fall within the realm of aesthetics: sensation, fantasy, narrative. challenge, fellowship, discovery, expression, and submission, which can serve as the primary objectives of designers in game design.

To extend and improve the MDA framework, Robert Dillon, a professor at the Singapore campus of the DigiPen Institute of Technology, proposed the 6-11 Framework for game design and analysis (Dillon, 2010). As Marc LeBlanc noted, the aesthetics in the MDA framework are not limited to the eight types of fun listed above; the 6-11 Framework therefore further included emotions and instinct as two additional aesthetic elements. These included the six emotions that humans have (excitement, sadness, pride, joy/happiness, anger, and fear) and eleven instincts that can be displayed via games (survival (fight or flight), self-identification, greed, protection/care/nature, aggressiveness, revenge, competition, communication, curiosity, and color appreciation). Dillon (2010) used some classic arcade games and innovative independent games as examples to demonstrate the mutual effects between the emotions and instincts of players during gameplay. While the MDA framework only presents what aesthetics that games can serve and give players unique experiences, the 6-11 Framework uses emotions and instincts to perform further analysis on why games are fun.

HISTORICAL ANALYSIS AND GAME ELEMENT ANALYSIS OF CLASSIC GAMES

We selected games with sibling relationships from various game platforms, including arcades, consoles, computers, and mobile devices. Our analysis of game elements was primarily based on the four major elements proposed by Schell (2008) (mechanics, story, aesthetics, and technology) and two other elements that we felt had influence on gameplay experience (interaction and social interaction). Each of the six elements plays an important differentiating role. For example, for two games with similar core mechanics, differences in the other five elements can still lead to different gameplay experiences and feelings. In this study, we explored the Qix series games:

<u>**Oix series:</u>** The core mechanics of these games involve fencing-off and claiming territory. All of these games were released between 1981 and 2011. While not very widely known, they present unique evolutions in game elements. We also included the topic of erotic games and their influences on gameplay experience.</u>

We begin our game element analysis with the nine games in the Qix series listed in Table 1. The year that each game was released is listed in brackets after the name of the game. This series began with the arcade game Qix [1981], the core mechanics of which require the player to control a cursor (which represents the player) and fence off and claim parts of the playfield under enemy threat. The player must claim more than a set proportion of the playfield (such as 75%) to pass a level, and the enemy generally comes in the form of a boss and their minions. In later games, Gals Panic [1990] introduced considerable modifications to the gaming mechanics, including a meter gauge to guide the rhythm of gameplay, more types of bosses and attack patterns, additional challenge stages, a lucky roulette game between stages, and stage items. Furthermore, Gals Panic is categorized as an erotic game, replacing the original blank background of Qix with silhouettes of sexy women or, if the meter gauge falls below 6 bars, other odder figures (such as an octopus or ninja). The corresponding aesthetics

brings rich color schemes and erotic elements to the game but also inserts some nonsensical ideas. In a time when the personal computer and the internet had yet to become popular, the entertaining effects of Gals Panic paved the way for over a dozen later versions, including the less censored S and SS series. Dancing Eyes [1996] extended the erotica of Gals Panic while ushering in the 3D game era. With the enhancement from 3D models and animation, the story line and aesthetics gave players a whole new gameplay experience. The game mechanics of Dancing Eyes widened the 2D fencing-off mechanics of Qix to a 3D network. If the path that the monkey, which represents the cursor, takes forms a closed region, the said region is exposed. The 3D polygons in the stages are mostly the female model's clothing or other objects that encircle her, such as boxes, fruit, or shower curtains. In addition to its innovative gaming mechanics and 3D technology, Dancing Eyes has unique story lines and aesthetics. However, it also possesses a major flaw in terms of human-machine interaction in that players often suffer from motion sickness when gaming. The other games in the Qix category all give players different gaming experiences depending on their game mechanics, story lines, aesthetics, realization technology, human-machine interaction, and social factors.

Year	Game	Platform
1981	Qix	Arcade
1981	Volfied	Arcade
1990	Gals Panic	Arcade
1995	Twin Qix	Arcade
1996	Dancing Eyes	PlayStation
2000	Qix Adventure	Gameboy
2006	Qix++	Xbox 360
2009	Cubixx Minis	PlayStation 3
2010	Fortix	Computer

RESULTS AND DISCUSSION Structure of Evolution Tree of Qix Series

We first use the games in the Qix category to explain sibling relationships. Among the nine games listed in Table 1, demos of the older arcade games could be played on simulators, and the newer games could be purchased for consoles (such as Microsoft Xbox and Sony PlayStation 2) or computers. We could not find demo files for Dancing Eyes [1996], Qix Adventure [2000], and Qix++ [2006], but after searching for games, we added ZoninRun [2012], a Qix clone developed by hobbyists. Thus, we were able to play seven of the nine games.

We adopted the approach recommended by Juul (2007) and first established the evolution tree of these seven games (Figure 1). As can be seen, Qix [1981] is connected to the six games on the right via solid lines, which indicates significant influences in terms of the core fencing-off mechanic (over a certain proportion) and boss-and-minion mechanic. Gals Panic [1990] and Fortix [2010]) are clearly connected in the fencing-off mechanic (Gals Panic presents the sexy parts of beautiful women in the background, whereas Fortix shows forts or bases). Less apparent mechanic connections (dashed lines) were also observed between Volfied [1981] and Fortix [2010] in terms of stage items and between Gals Panic [1990] and Zoninrun [2012] in terms of backtracking.



Figure 1: Evolution Tree of Qix Series

To cultivate game design capabilities, it is worthwhile accumulating knowledge regarding various types of games and their history. For example, Kochanov (2008) pieced together the history of real-time strategy games, and Juul (2007) traced the entire development history of match-three games. In contrast, the evolution tree constructed in this study focuses on games with similar core mechanics and clear contextual connections. We concentrated on determining the influence of various game elements on gameplay experience rather than examining the history of game development.

Case Study Using the MDA Framework and the 6-11 Framework

After constructing the evolution tree of games in the Qix category, we took the ancestral Qix released in 1981 as an example to demonstrate how the MDA framework (Hunicke et al., 2004) and the 6-11 Framework are used to analyze games. The MDA framework divides games into three aspects, breaking games down based on mechanics, viewing gameplay experience as the aesthetics to be achieved, such as sensation, fantasy, narrative, challenge, fellowship, discovery, expression, and submission, and the constantly changing dynamics between the player and the system during gameplay. The GDC game design workshops held each year use the MDA framework for paper prototyping; it is simple and thus widely known in the north-American game industry. However, the MDA framework does not work well with the evolution tree for detailed analysis, which is needed for exploration of the sibling relationships between games. As shown in Figure 2, the 6-11 Framework can provide a more detailed interpretation of the aesthetics in the MDA framework using the relationship between player emotions and instincts. The solid lines indicate the influence of player instincts on emotions during gameplay, whereas the dashed lines present the influence of player emotions on instincts. The dotted lines exhibit relationships between emotions or between instincts. For more details, please refer to Dillon (2010).



Figure 2. Relationship Between Emotions and Instincts of The 6-11 Framework, Adopted From Dillon (2010)

The analysis of Qix [1981] is as shown in Figure 3. With this game serving as the root of the evolution tree in Figure 1, the remaining games evolved from the core mechanics of this game. In Figure 3, the darker and lighter blocks respectively present the mechanics and dynamics of the MDA analysis. The defined core mechanics include life elimination, traversing patterns of enemies, fence-off playfield and enemies, and scoring and speed reward. Players control the cursor to fence off parts of the playfield, and the gradually increasing percentage of claimed territory serves as the score. Once the score exceeds a set value, the player passes to the next level. During the game, a single large monster (Qix) and several small monsters (Sparx) present threats, and if the enemies touch the cursor, then the player loses a life point (3 in total). As the game progresses, the dynamics keep changing, including proliferation of enemies, a countdown timer, territory claims, and escape. The unframed text is the aesthetics portion; under the interpretation of the 6-11 Framework, Qix arouses the emotions of greed and fear by provoking the players' instincts to hoard and self-identify, and then sequentially provokes other instincts and emotions.

The seven games in the Qix category in Figure 1 were all analyzed in this manner. For the results of the games other than Qix, please refer to Appendix. The sibling relationships among these games can be compared using the solid lines (influences that are more apparent or have a wider scope) or dashed lines (influences that are less apparent or have a smaller scope) in Figure 1. Next, we compared these games using the eight aesthetics in the conventional MDA framework. We believe that all serial games present a degree of challenge: by framing certain areas of the screen, the games test the eye-hand coordination and responses of the player. Volfied and Fortix are respectively set in science fiction scenes and the middle ages, and as players pass each level, they can experience the narrative aesthetics. The erotica in Gals Panic and the science fiction in Volfied enable the players to immerse themselves in fantasy aesthetics. Twin Qix allows players to play against one another, enabling fellowship, and the unique 3D setting in Cubixx Minis gives players the feeling of discovery.



Figure 3: Analysis of Qix [1981] Using MDA Framework and 6-11 Framework.

Defining Sibling Relationships Among Games

The analysis of the two prior sections, allow us to proceed to an investigation of games with sibling relationships. We analyzed the games using the MDA framework and the 6-11 Framework. Analysis of the evolution tree of the Qix games in Figure 1 led to the identification of several interesting phenomena. First, all games with similar cores have a root game that is the oldest in the series. In this case, the root game was Qix, which could be traced back to the arcade game era. Branches extend from the root and can be analyzed using the aesthetics of the MDA framework. The first branches extending from Qix lead to Volfied and Fortix, both of which have elements of challenge and narrative. The next are Volfied and Gals Panic, which have elements of challenge and fantasy. The last two branches lead to Twin Qix, which has elements of challenge and fellowship, and Cubixx Minis, which has elements of challenge and discovery.

For the next inheritance, we define relationships with more than two levels. In the Qix category, the most significant example is the relationship among Qix, Gals Panic, and Dancing Eyes. Except for Qix, the games have erotic elements. To explore the sibling relationships between games, we examined examples with more than two generations and analyzed them using the MDA framework and the 6-11 Framework. The elements in the detail analysis of different games may show either addition or subtraction. Currently, the newer game in most case analyses present the addition circumstance in elements. The connections that serial games form in evolution trees also exhibit varying degrees of complexity. Other than the Qix series games, we are currently still in the process of analyzing match-three games and side-scrolling games based on concepts mentioned previously and hope to establish a more complete theoretical foundation.

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PROMOTING RECIPROCITY-BASED COOPERATION BY DUAL LAYER GAMIFICATION

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Gamification, Cooperation, Reciprocity, Image Scoring.

ABSTRACT

This paper presents a conceptual platform of gamified systems with a dual layer structure and reports on the prototype implementation for promoting reciprocity-based cooperation in targeted social contexts. Level 1 gamification is intended to leverage our innate ability to support cooperative relationships by engaging in altruistic behavior towards those who exhibit altruistic behavior, and the addition of Level 2 gamification is intended to induce gameful experience by a diversity of strategies. Coupling of these two layers can promote intrinsic motivation for performing altruistic behavior and at the same time making others perform altruistic behavior. We report on the prototype implementation of the platform and the knowledge gained from its preliminary evaluations repeated since July 2013.

INTRODUCTION

Digital games have pervaded our daily life and human culture on an unprecedented scale while analog games have existed in human culture since the dawn of recorded culture (McGonigal 2011). Furthermore, they are growing beyond entertainment. *Gamification* is a relatively new term whose first documented use dates back to 2008 (Deterding et al. 2011), and can be defined as using game elements, game mechanics, and game thinking in attempt to engage people, motivate action, promote learning, and solve problems in nongame contexts (Deterding et al. 2011; Kapp 2012; Seaborn and Fels 2015). The typical gamification approach is based on adding game elements (e.g. points and badges) to make a target task more engaging.

While gamification is more and more employed in the design of digital services, interfaces and interactive systems, gamification is widely criticized by academic and game designers. Deterding summarized the criticism towards the existing gamification just adding a layer of game elements rather than taking a systematic approach to the design of the experience: not systemic, reward-oriented, not user-centric and pattern-bound (Deterding 2013).

Recently, aiming at the users of popular and typical gamified applications (Foursquare, Nike+ and GetGlue), Rapp investigated qualitatively how the most common gamification techniques impact users' subjective experiences (Rapp 2015). The result was that as their familiarity with the gamified features increased, participants characterized the usage of the apps as repetitive, static and scarcely rewarding.

Simply stated, based on these criticisms and findings, gamification which merely adds a layer of game elements motivating through external rewards promotes a simple behavior pattern that does not require learning or thinking and is unable to maintain the level of engagement.

Responding to the criticisms and aiming for the best utilization of gamification, this paper presents a conceptual platform of gamified systems with a dual layer structure. We report on a prototype implementation focusing on creating an opportunity to observe and learn own and others' altruistic behavior and further to promote altruistic behavior in targeted social contexts, and also on its preliminary evaluations.

RECIPROCITY-BASED COOPERATION

One of the most significant problems in interdisciplinary research fields, including evolutionary biology, ecology, economics and sociology is to explain social behaviors such as cooperation (Darwin 1871; Hamilton 1996; Arita 2012). Cooperation seems to be difficult to reconcile with natural selection. Why should one individual help another under Darwinian natural selection?

Theoretical explanations for the evolution of cooperation are broadly classified into two categories, although both are not mutually exclusive: direct fitness benefits and indirect fitness benefits (West et al. 2011). A cooperative behavior yields direct fitness benefits when the reproductive success of the individual who performs the cooperative behavior is also increased while a cooperative behavior can be also explained by indirect fitness benefits if it is directed towards other individuals who carry genes for cooperation (Hamilton 1964).

Reciprocity is a key mechanism classified into the first category whereby the evolution of cooperative or altruistic behavior may be favored by the probability of future mutual interactions. There are again two types of reciprocity: direct and indirect (Figure 1). Direct reciprocity is a tit-for-tat exchange of benefits by two individuals. Therefore, the evolution of cooperation by direct reciprocity requires repetitive interaction presumably in a small group. In contrast, indirect reciprocity occurs when an altruist is rewarded by third parties for behaving generously towards others, in other words, A helps B, making it more likely that C will later help A. Furthermore, another type of indirect reciprocity can be identified if an act of altruism causes the recipient to perform a later act of altruism in the benefit of a third party, in other words, A helps B, making it more likely that B will later help C. The former is referred to as downstream reciprocity while the latter upstream reciprocity.

Theoretically, the evolution of cooperation based on upstream reciprocity is considered to be difficult. For example, Nowak and Roch showed that upstream reciprocity enables the evolution of cooperation only in combination with another mechanism such as direct reciprocity or spatial reciprocity (the effect of forming clusters on the promotion of cooperation dynamics) (Nowak and Roch 2007). Hereafter, we refer to downstream indirect reciprocity simply as indirect reciprocity.



b) Indirect reciprocity (left: downstream, right: upstream)

Figure 1: Classification of Cooperative Reciprocity: a) Direct, b) Indirect (left: downstream, right: upstream)

The most influential model for indirect reciprocity (Nowak & Sigmund 1998) was based on a simple reputation measure called *image score* that increases when the individual is observed to give aid. Evolutionary simulations using randomly chosen pairwise encounters between members of a population showed that cooperation could be established through discriminatory strategies which helped those with higher image scores.

Besides the theoretical work towards understanding the evolution of the cooperative behavior, many studies with behavioral experiments have provided strong support for indirect reciprocity based on some kind of reputation system. Milinski and others performed the experiments in which subjects could transfer money to a third-party without the possibility of direct reciprocation and showed that reputational incentive works well at maintaining high levels of cooperation (Milinski et al. 2002). Wedekind and Milinski also showed that in an experimental setting, participants of the high image score received money more frequently than those with a lower image score (Wedekind and Milinski 2000). Furthermore, according to reputation-based cooperation theories, individuals should be more cooperative than when alone. It was indeed shown that even under conditions of anonymity, presenting participants with stylized eyespots on a screen (Haley and Fessler 2005) or a robot constructed with objects that are obviously not human with the exception of its eyes (Burnham and Hare, 2007) make them cooperative.

PROMOTING COOPERATION BY DUAL LAYER GAMIFICATION

Basic idea

Aiming for the best utilization of gamification, we extend the basic gamification scheme (Figure 2) and design an abstract platform with a dual-layer structure utilizing gamification (Figure 3). Level 1 is designed to directly promote a targeted behavior of users using typical game design elements (e.g. points and badges), while Level 2 is designed to interact with Level 1 by manipulating the elements of Level 1, possibly resulting in affecting the behavior of users indirectly.

In this paper, we describes a prototype termed *DERC* (Dual layer gamification Encouraging Reciprocity-based Cooperation) as an instance of the dual-layer gamification scheme, in which altruistic behavior of each user is intended to be promoted by quantifying and sharing the image score of each member (in the context of indirect reciprocity). The supposed dynamics caused by adding Level 2 mechanics (i.e. betting on the change in other's image score) is not straightforward in general. As is described later in this section, a reasonable behavior induced by it is to promote altruistic behavior of (non-altruistic) others.



Figure 2: Basic Gamification Scheme



Figure 3: Two Layer Gamification Scheme

Level 1 gamification

Image score, that is one of the core elements of the theory of indirect reciprocity, is quantified and shared as *points* in Level 1 layer. We seem to have a psychological disposition helping

the image scoring mechanism work and thus making altruistic behavior adaptive, to a greater or lesser extent. In this sense, gamification here is used for leveraging our innate ability to support cooperative relationships between humans instead of creating some new motivation to do a target behavior by offering an extrinsic reward.

In the Level 1 system (Figure 4b)), each user anonymously approves some behavior from another user as altruistic. When User A approves User B as the most altruistic member towards A (or the people including A), some proportion of points (10% in the prototype) of A is moved to B. All users select a user every set timing that depends on the situation the gamified system was introduced (e.g. every after meeting or until Friday night every week). If a user does not select, one of the users is selected randomly.

The approval of altruistic behavior completely depends on its recipient, and this uncertainty can create an opportunity for thinking and learning concerning how to perform better altruistic behavior, in contrast with the case of simple money systems with a certainty (Figure 4a)). The adopted point-collection mechanism can also create a specific innate drive to increase own points other than pure motivations which typical gamification systems create (e.g. respects from others and self-actualization). As the increase in points of B is proportional to the points of A, B is better off doing altruistic behavior to a user with more points. Therefore, if a user wants to increase the probability to get altruistic behavior, she should increase her points in some way.



b) Level 1 Gamification of DERC

Figure 4: Basic Operations in a) Simple Money System, b) Level 1, and c) Level 2

Level 2 gamification

Adding Level 2 gamification can give users a gameful experience by manipulating the points of users in Level 1. For this purpose, in the prototype, we introduce a betting system applied for predicting which user will increase her points (Figure 4c)). Specifically, users can bet their arbitrary points on a user likely to increase her points by the next set timing. When selecting, the odds (multiplier) are assigned to users and are presented to all users. If her prediction is correct, she will

receive her bet points multiplied by the odds corresponding to the user she bet on. Otherwise, she will lose a half of her bet points.

A possible behavior which Level 2 system can generate is to increase the probability of an increase in the points of the User A whom she bet on by assisting A in performing altruistic behavior. As an additional mechanism, the system assigns greater odds to persons with fewer points. The intention of this design is that users who are not altruistic should have more opportunities to become altruistic. Suppose that this gamified system is introduced for making regular discussion more fruitful and User A just bet on User B. A successful strategy for A to increase the points of B should be to bring up a subject concerning programming in the next meeting if he is good at programming.

Loop dynamics induced by dual layer gamification

Engagement is the most important aspect all gamification projects aim at. It should be attained using some continuous loop dynamics. Figure 5 (left) shows a basic loop dynamics consisting of motivation -> targeted action -> reward. Gamification projects tried to achieve the loop dynamics, which, however, seems very difficult as is shown by Rapp (Rapp 2015).





The platform has a dual-layer structure shown in Figure 5 (right), which expands the strategies of users and aims at achieving a loop dynamics to promote intrinsic motivation by
providing users with gameful experience. Users are promoted to consider and learn what kind of behavior will be positively accepted by each specific member or how the advantage of each member is utilized. It should solve or reduce the patternbounded problem resulting in a decreasing the intrinsic motivation of users.

In general, this type of mutual surveillance or evaluation using gamelike techniques can increase the psychic cost (i.e. the uncomfortable sensation of being watched and measured) which might stifle creativity and flexibility (Manjoo 2014). However, multiple ways of scoring including approved altruistic behavior and successful betting, and anonymity and randomness in approving altruistic behavior can decrease the psychic cost. For example, a user with a high score is not necessarily altruistic, but might be just good at betting.

PROTOTYPE IMPLEMENTATION AND PRELIMINARY EVALUATIONS

Prototype implementation DERC

DERC was implemented as a web application using HTML, PHP and Java script. The database component was implemented using SQL. Users can access DERC to see the change of her own points, select the most altruistic user to her or select a user she wants to bet on. According to the approval of altruistic behavior and the success of betting, points of all users are updated at the fixed timing. Odds are assigned on an equal interval basis with 1.2 to the member with the most points and 3.0 to the member with the fewest points.



Figure 6: Screen Shots of User Interface

DERC can be introduced into basically any kind of social groups where altruistic behaviors are needed. It will be

customized depending on the situation into which it is introduced. Hereafter, two cases are assumed in the explanation. In Case 1, DERC is introduced to some organization or community in order to increase altruistic behavior in not specific but general social relationships, and in Case 2, DERC is introduced to regular meetings to activate the discussion.

The DERC user interface is specially designed for use with smartphones and tablets (Figure 6). In case 1, by the end of the period, each user selects a user who is most altruistic towards her during the period, and, if she wants, bets some her points on a user who is likely to increase his points during the next period considering his odds. In Case 2, after each meeting, each user selects a user who said something most useful to her during the meeting, and, if she wants, bets some points on a user who is likely to say something good in the next meeting also considering his odds. The administrator user interface allows a person who introduced DERC to the group or organization to see the status of system utilization and the usage history of each user (Figure 7).



Figure 7: Screen Shots of Administrator Interface

Preliminary evaluations

We have conducted preliminary evaluations with the prototype DERC seven times since July 2013. The first four evaluations were very preliminary in the sense that their purpose was to develop and improve the basic design of the platform, and the users were the approximately 20 volunteers in our laboratory. The targeted situations were general social relationships (three times) and discussion at meetings (once). The recent three evaluations were conducted with approximately 10 volunteers each from ACE (action group for cross-cultural exchange) in Nagoya University (twice) or GRAMPUS, Nagoya University American football team (once), all targeted to general social relationships. Each of the recent three evaluations conducted questionnaire surveys two or three times: before (, in the middle of) and after each period, which asked the change in the consciousness, attitude and

behavior concerning altruistic behavior from various perspectives, mainly using a multiple choice format.

The results of the conducted evaluations, especially with the current implementation described above, can be summarized as follows.

- 1) Almost all users enjoyed the gameful experience and few users felt the psychic cost.
- 2) Approximately a half of the users did an altruistic behavior promoted by DERC.
- 3) Successful Level 2 gamification needs successful Level 1 gamification. In other words, the motivation to access DERC and increase her points supports the consideration of the betting. After realizing that, we implemented a badge system from which badges can be obtained by satisfying various conditions (Figure 8).
- 4) There was a diversity of strategies to get points. For example, some users focused more on Level 1 (performing altruistic behavior) and some more on Level 2 (successful betting).
- 5) It was gradually shown that making a person make another person be altruistic is difficult more than we had thought. Few users behaved as our Level 2 design intended. However, we believe that this type of process of trial and error itself is essential to improve social relationships, for example, from the perspective of *action research* (Reason and Bradbury 2007).
- 6) Some unexpected comments were obtained in questionnaire responses, including the one that the user became altruistic towards non-users and out of the period, affected by DERC. Although there is no intention here to generalize this comment, it would be important when considering whether the enhanced motivation was intrinsic or extrinsic (Ryan and Deci 2000).



Figure 8: List of Badges (left) and Fulfillment Conditions to Unlock Them (right)

CONCLUSIONS

This paper proposed a platform of gamified systems with a dual-layer structure, responding to the criticisms that conventional gamification simply with a layer of game elements promotes a simple behavior pattern that does not require learning or thinking and is unable to maintain the level of engagement. We focused on the promotion of altruistic behavior in daily social contexts and presented preliminary evaluations of the prototype implementation. The implemented prototype was designed primarily for promoting cooperation based on the theory of indirect reciprocity with image scoring. However, we believe that emphasizing the altruistic behavior by quantifying and sharing the image score tends to have a positive effect on other mechanisms including direct reciprocity and upstream indirect reciprocity.

The most familiar difficulty when understanding the evolution of cooperation or designing a better society (e.g. mechanism design) is the free-rider problem. In the proposed system, altruistic users tend to increase their points, and the users whose behaviors are not approved as altruistic are considered as free riders. At the same time, there is another way for increasing points and furthermore, being free riders without seeming to be free riders: betting. However, the most successful strategy of free riders is to let other free riders be altruistic. Utilization of free riders for eliminating free riders might be the most remarkable feature of DERC.

The platform could be extended in several directions. We are implementing real-time version of DERC for stimulating discussions, in which during meetings, using a small dedicated device each participant approves a remark of another participant as altruistic, and it will be recognized by vibration of the device. Another promising direction might be incorporation of population structure (groups) expecting the effect of multilevel selection (Ichinose and Arita 2008), or consideration in the game dynamics, of mental representation (e.g. theory of mind) (Arnold et al. 2015).

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GAME DEVELOPMENT

MARKOV CHAIN IN ELECTRONIC FIGHTING GAMES

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MECHANICS OF A FIGHTING GAME

ABSTRACT

There are different ways to perform decision-making process within a game.

In the genre of fighting, it is essential that these choices are the best possible, as well as the experience of physical player becomes more intense. In this work, a new decision mechanics that uses different techniques for choice of actions, will be displayed. This mechanic has the aim of supplementing the existing decision-making processes, and thus making the characters in the game Street Fighter. These are controlled by artificial intelligence more cohesive in choosing its actions during the match, thus leading to a more realistic, fun and challenging game.

INTRODUCTION

Second in the global ranking entertainment, just behind cinema, the gaming market makes billions of dollars worldwide (BNDES, 2014). Just like other technology, games modernize day by day and because of this, new interaction techniques are required.

Fighting games are an example where new interaction techniques are required. In them, the physical player should battle against your opponent using the best strategy to win the match.

During the game, the player must always think about what action to take in order for their movements to be the best as possible. However, it is possible that the player sets a pattern in the opponent's actions, and so the game becomes mechanical and monotonous. In those circumstances, the player knows exactly what to do in order to win the game.

In the next sections of this paper, we will discuss the concept of game mechanics, focusing on mechanics of the game Street Fighter. The operation of a state machine and predictive algorithms such as Minimax and Markov Chain will also be discussed with the latter being the main point of the discussion. Thus applying the theorems of this technique in a Transition Matrix probabilities mapped upon the game Street Fighter in order that decisions taken during matches are more real than those currently obtained in the game. For building an astonishing game, a great idea and a welldefined design along with efficient mechanics are essential. The mechanic of the game defines what the player can do while playing. The predominant mechanical define the genre of the game (LIMA, 2013).

When it comes to genre, throughout the years the market has categorized certain areas, such as action games (Shot, platform, fighting), adventure, strategy, RPG, sport, simulation, game board, puzzle, and others.

Each of them has a different method of interaction hence distinct mechanic, a fact that provides the diversity of types of games found lately.

A great feature that should be taken into account putting together a good game mechanics are, the definition of how the match will be conducted. Among the examples, turn-based and stochastic games can be found. Turn-based games are those in which a player performs your move and your opponent can only act when the player indicates the end of his action. Games such as chess, naval battle and others, can be categorized as turn-based games.

In stochastic games, the actions made by the player do not depend directly and exclusively on your opponent (MONTEIRO and SANTOS, 2007). In other words, both players of that match may carry out independent actions, a fact that allows possible predictions of movements, no matter what the opponent does.

A good example of stochastic game would be the fighting game, which is one of the most currently popular style of games. They provide, in addition to entertainment, situations where quick thinking by the players is fundamental.

There are different types of fighting games on the market, each with its own differences. However, they all have the same essence, whereby characters confront against each other until one of them beats their opponent. The enemy character, or real player can be controlled by a computer (single player games) or by another person (multiplayer games).

As noted by (JUNIOR et. Al., 2013), the use of finite state machines were extremely wide, especially in the field of fighting games in which opponents had a finite number of drives and behaviors from predefined conditions which were planned for them.

A state machine is a finite automaton that defines, by an action of the opponent, what the character should do in the game. Figure 1 shows a possible finite state machine associated with the character Ryu from the Street Fighter game, where the black circle is the initial state.



Figure 1: Finite state machine of one of the characters from Street Fighter

This method is simple to implement, but can generate a problem for this kind of game, as it is possible that the physical player after a few rounds, can find a pattern in the game and therefore predict the AI actions thus making the game predictable.

To illustrate the mechanics proposed in this paper, the Street Fighter 2 genre fighting game created in 1992 by Capcom (CAPCOM 2016), will be used.

PREDICTION IN GAMES

There are methods in Artificial Intelligence that are applied, in order to identify the possible next steps of a game.

Forecasting the possible events becomes more important for the progress of a game. In other words, if the system knows the possible actions the player can perform as a counter attack or defense. He can then, calculate whether or not, the player is going to perform the next round of events.

This situation also happens in other games such as chess and tic-tac-toe, where players study beforehand, their actions and the possible consequences thereof. It weighs whether or not they can be achieved, thus creating a more precise strategy.

Taking the chess as an example, where the player's actions directly depend on the movements of their opponents, it is possible to trace the projected movement through the Minimax algorithm.

Minimax

As (COSTA AND BOTURRA, 2008) says, Minimax is the decision support that can be applied to games for situations where you have the victory of one of the players or a tie by both of them. Known as predatory games, they assume that the victory of a participant entails the defeat of its/their opponent (s).

The Minimax develops a decision tree with all the possibilities to move from the current state of the game to the next step. After creating a tree, a search in depth is performed by checking the best next movement for the player in order to win the game.

Markov Chain

(TRIVEDI 2006) ensures that any discrete set of states where there is a probability of transition between them, not dependent on the previous states and discarding the time factor, is called a Markov chain. This being represented by the transcription as a matrix of all the probabilities of transition between states.

This technique was developed, by the Russian Andrei Andreyevich Markov and for many years was used in economics. But for a few years now, researchers have begun to use this procedure in various fields such as biology, social sciences, games, etc.

For the application of a Markov Chain algorithm it is necessary first that we set up a transition probability matrix and a vector containing the initial state (Figure 3).

$$A_{0} = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$$

The vector A0 shows the current state, that is, where you find the number 1 which is the current state of the problem.

Already the matrix B demonstrates a transition matrix between three states where the probability of being in the state and I is kept at 50%, while living in states I and II goes to 20% and so on.

Where the array and the defined vector says that the next state $A_{1 \text{ is}}$ given by the matrix multiplication $A_{1 =} A_0 * B_1$

$A_1 = [0.5 \ 0.2 \ 0.3]$

To calculate the next states we can simply repeat the operation developed for the first transition, and to forecast n states forward, we can calculate them one by one or use the property of the Markov chain that says that $A_n = A_0 * B^n$.

A PROPOSAL FOR USING MARKOV CHAIN IN THE STREET FIGHTER GAME

Starting from a fighting game, where two players face each other, both with their fighting and defense techniques, until only one remains standing, a new way to manage the actions taken by the character managed by computer -as defined above, as player A will be proposed.

This new mode presented will provide the actions of the player A, making the more coherent decisions and thus making them seem more real.

This mechanical decision revolves around two devices: first, the possible state table game and secondly the transition matrices for techniques such as Markov chain which can be applied to the selection of the best action to be followed.

Transition Matrix Associate

The Street Fighter II game was used as the basis for our research, because it was where pre-defined states based on the game can be found. These states were generated, from combinations made using a classification of certain features of the player and his opponent.

The chosen characteristics were, the standard of living of the player A is classified in High_Life if it is above 50% and Low_Life if it is under 50%, the distance between them, either far or closer, and the state of the player B, attacking or stopped. After the classification of features, these were cross referenced, in order to get the combinations of possible states which can be found in the game. These combinations generated a fixed state table (Table 1) where, throughout the match, every action that player A is performing will be analyzed in order to know in what state the game is, and thus knowing the best possible decision to be taken.

Level of <i>player</i> A's life	State of <i>player</i> B	Distance of <i>player B</i>	Matrix associated
low	attacking	closer	1
low	attacking	far	2
low	standing	closer	3
low	standing	far	4
high	attacking	closer	5
high	attacking	far	6
high	standing	closer	7
high	standing	far	8

Table 1: Combinations of features. Each combination is associated with a specific transition matrix

Each game state is associated with a specific transition matrix (Table 1, column 4), which is provided as the basis for the next move of the player A.

A transition matrix is a transcription, in tabular form, of a finite state machine. It represents the probability of transitions between the states from one point that can occur.

Using transition matrices, Markovian techniques can be applied, to select a best action, even forecasting the next step of the player.

For the construction of the matrix, some of the parameters of the characters in the game Street Fighter, were used, which are: away, approach, jump, throw a certain object, launch a special spell (an example is the Hadouken, characteristic magic of character Ryu), defend or strike.

For each game state, a specific transition matrix is designed that can maximize the performance of player A.

Execution

To illustrate the mechanics, a situation in a game of Street Fighter will be simulated. For this example, the characters Ryu and Chun Li will be used, whereby Player A, is handled by the computer, while player B, is handled by the physical player, respectively.

At a certain point, the life of the player A is around 60%, and the life of the player B is 30%, both players are standing and player B is far from the player A.

In this particular case, the game state is [High_Life, standing, far] (Table 2). For this state, is associated with a transition matrix of number 8. The matrix is designed, specifically for use in this state of the game, in other words, using it, player A is more likely to perform the best action, leading him towards a possible victory.

The Ryu character originally can perform punches, jumps, kicks and uses his magic to cast the Hadouken. The

Chum Li character can also give punches, jumps and kicks, but her special attack is Hyakuretsu Kyaku (leg lightning).

In this game, at the state in which the game is, player A has a higher percentage of life than player B. He can be daring in his punches, trying, for example, the approach to apply some physical action (kick or punch).

A state machine is the representation of all the actions that the character can perform from that point onwards. These actions can also be described, by a transition matrix (Table 2).

enosen for the example.							
	Move Away	Approximate	Jump	Throw	Special	Defend	Hit
Move Away	0.1	0.05	0.05	0	0.1	0	0.1
Approximat e	0.45	0.1	0.55	0	0.2	0.2	0.15
Jump	0.05	0.05	0	0	0	0.1	0.05
Throw	0	0	0	0	0	0	0
Special	0.2	0.3	0.3	0	0.4	0.3	0.2
Defend	0	0.2	0.1	0	0.1	0.1	0.2
Hit	0.2	0.3	0	0	0.3	0.3	0.3

 Table 2: Transition Matrix 8 associated with the game state chosen for the example.

Player A has a vector that maps his current actions, such as if he moved away from the opponent or if he struck him, etc.

Each vector index is a parameter of actions that can be performed, that is, away, closer, jump, throw, special, defend and strike.

Whenever an action of this player is requested, this vector will be valued with 1 if the player has performed such action and 0 if he has not accomplished such a feat.

Using the technique of Markov Chain, this vector will be multiplied, by the transition matrix associated with the current state of the game (Table 2). This multiplication results in a new vector, which indicates which are the next steps to be taken by player A.

According to the example reported to the execution of this mechanics, in which the player is still far from player B we have: Away: yes; Approximate: no; Jumped: no; Throw: no; Special: no; Defended: not; Hit: no;

From this information, the vector probability for player at this time can be described as:

[1, 0, 0, 0, 0, 0, 0]

After the multiplication of the resulting vector transition matrix, the new vector is obtained.

[0.1, 0.45, 0.05, 0, 0.2, 0, 0.2]

From the information of the resulting vector, the system can decide, which is the best action to choose.

According to the outcome, there is a 45% chance that approach is the best intervention to make. Secondly, we obtained a tie between striking and special, with a 20% chance of likely and, thirdly, to keep still (remain in the same state) with has a 10% chance of likelihood. If the use of combos (set of actions) are allowed in the game, just assume that player B stood still, or did not perform any action from its part and multiply the vector resulting from the transition matrix associated with the new state of the game. In this example, the first action of the player A was to approach his opponent. Thus, assuming that the opponent stands still, we now have the state of play [High_Life, standing, near]. The matrix associated with this setting is the number 7 (Table 3).

Table 3: Transition matrix 7 associated with new game state configuration.

	Move Away	Approx imate	Jum p	Throw	Spec ial	Defend	Hit
Move Away	0.05	0.05	0.1	0	0.15	0.3	0.2
Appro ximate	0.3	0.05	0.3	0	0.05	0.05	0.05
Jump	0.05	0.2	0	0	0.1	0.1	0.1
Throw	0	0	0	0	0	0	0
Speci al	0.4	0.05	0.4	0	0.1	0.05	0.05
Defen d	0.15	0.15	0.15	0	0.2	0.2	0.4
Hit	0.05	0.5	0.05	0	0.4	0.3	0.2

Multiplying the second vector and the transition matrix of the new situation of the game, the vector obtained is [0.06, 0.08, 0.13, 0, 0.11, 0.19, 0.34] showing that strike has a greater chance of likelihood, with 34%.

All mechanics are illustrated in Figure 2, which shows the possible options in the first iteration, and from the choice of actions, a new range of possible procedures.



Figure 2: Representation of the possible actions to choose in the first and second processing a new range of possibilities is developed.

CONCLUSION

The Minimax, algorithm always generates the best decision to be made, but for this, it needs a high level of processing to generate the tree of possibilities. And it can still be stuck at a maximum or minimum local point.

While the Markov Chain, may provide better options for action a few steps forward, even with interference from opponents, a transition matrix is required to do so. This transition matrix, should be built, by a game designer, who is an expert in that particular game, because the entire game is based on the movements dictated by the aforementioned.

With this work it was noticed that it is possible to develop complex mechanical using simple techniques, that are not burdensome to implement.

The Markov Chain mechanics were chosen because of the possibility of implementation and the ease of possible adaptation, that is, such as changing some parameters on selecting the game features, both for the construction of the game state table and for the transition matrices. That mechanics can be applied to any game where there is a character controlled by a physical player that aims to defeat an opponent, controlled by the computer.

This project opens up a range of possibilities because, due to its easy adaptability, you can use it in many other games with the same degree of difficulty for modeling the mechanics of the game, taking into account games that previously made use of state machines which are part of fighting games. This is so because a state machine to be modeled, is required to generate a probability transition matrix.

The transition matrix generated for the states are the same machine that was used for the application of the Markov chain. This fact makes the Markov chain a better option rather than using the state machine. Once modeling the work would be the same, as the probability transition table. Nonetheless the final result obtained using the Markov chain, would be closer to reality, as shown in the case of the state machine, which is easier to create sequences of predictable patterns.

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MIDPOINT DISPLACEMENT IN MULTIFRACTAL TERRAIN GENERATION

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KEYWORDS

Multifractal, Terrain, Procedural, Fractal, Generation

ABSTRACT

Midpoint displacement methods (MPDM) – originally introduced as stochastic parametric surfaces – have been used to create approximations of fractional Brownian motion in the past. With multifractals it is possible to create more realistic looking fractal terrain than with fractional Brownian motion, and also with more parameters to affect the generated terrains. This paper studies whether it is possible to generate multifractal terrains using the MPDMs. As a result, we introduce different methods that are significantly faster than using the spectral synthesis algorithm.

INTRODUCTION

The research on multifractals was initially started from the seminal work of Mandelbrot (1969, 1974), although they were named as multifractals later by Frisch and Parisi (1983) describing hierarchies consisting of sets, which have different Hausdorff-Besicovitch dimensions (Mandelbrot 1982). Pietronero and Siebesma (1986) proved that multifractals can be created with random multiplicative processes, for example by using multiplicative random walk.

These approaches using partially different terminologies originating from studying multifractals, turbulent cascades and multiplicative processes were tied together by Meneveau and Sreenivasan (1987) to produce the idea that multifractals can be created by using multiplicative cascades, which is the terminology used in the context of multifractal terrain generation.

Multifractal terrains have been previously been created with multiplicative cascade in spectral synthesis (Ebert et al. 2002), and by using Lévy noise in the Fourier synthesis method (Pecknold et al. 1993). These are based on the additive methods, that are used create fractional Brownian motion.

The simplest MPDM used in this paper is the wireframe MPDM (Musgrave 1993) also known as the triangular edge subdivision (Miller 1986) or Carpenter Mountains (Smith 1984). The second more advanced method is the "Diamond-Square"-scheme by Fournier et al. (1982). The third scheme we use is the "square-square" unnested subdivision by Miller (1986).

We begin by introducing the MPMSs and height calculation used in our study. This is followed by a comparison of the methods based on different metrics and final conclusions based on the comparison.

METHODS

The multifractal terrain generation algorithms in this paper consist of two parts. Their implementation is designed so that these two parts can be used interchangeably between all variants of each part.

The first part is one of the different MPDMs that make the three nested loops of the algorithms and the type of interpolation used to calculate the initial value for the new points. The three loops determine the order in which the points are used as a point of reference for the interpolations. The interpolations then use that point to find the absolute coordinates of the other points, and their corresponding height values, based on the relative locations of the other points used in the interpolations. The initial value for the new point is then calculated based on either the average or the weighted sum of the values of the points used in the interpolation. (Musgrave 1993; Ramstedt 2008)

The second part tells how the resulting value for the new point is calculated. In the case of a normal monofractals the calculation is entirely additive; in the case multifractals, the calculation is multiplicative. Heterogenic multifractals contain both multiplicative and additive operations, and by setting the parameter that controls the influence of the multiplicative operations to zero, they become entirely additive and, thus, produce a monofractal terrain having a single Hausdorff-Besicovitch dimension. (Ebert et al. 2002)

In the implementation, the random values for the point calculations are based on Gaussian distribution centered at zero. This entails that small height deviations are more likely than extreme deviations.

Midpoint Displacement Methods

Wireframe Midpoint Displacement Method



Figure 1: Triangle edge subdivision

The first step in calculating wireframe MPDM is to calculate the lengths of the sides of the height-map, which are equally long. The length of the sides is calculated with Equation (1), where l is the length of the side in number of points and n is the number of iterations. After that, an area in memory is reserved for the height-map, which will contain the square with sides of that length.

$$l_n = 2^n + 1 \qquad (1)$$

The second step in initialization is generation of random values for each four corners of the height-map.

After the initialization the actual iteration starts that consists of three nested loops. On each of the iterations in the most outer loop the step-size is halved. Step-size tells how far apart the points of calculation are from each other in the height-map. The first step-size, used in the initialization, is the size of the total height-map. Next, the inner loops are executed, and, finally, in the iteration new scale for height displacement is calculated. It is this rescaling of the height changes relative to the scale of the distances between the points, which creates the power law necessary to create the fractal terrains (Miller 1986). The iteration of the outmost loop stops when step-size 1 has been processed.

In the two inner loops all the points of references are iterated through and used for the interpolation. The points of reference are the current step-size apart from each other. The points in the bottom and right edges of the height-map are never used as the point of reference; however they are used in the height calculations in the interpolations.

In the interpolation three new points are generated, these new points can be seen on the right-side in Figure 1, which illustrates that five new points are generated, but the points in the top and left side are only generated for the points in the top and left edges of the entire height-map. The point of reference in each interpolation is the point in the top-left corner, the location of each point used in the interpolation is either 0, half, or full step-size to the right or down from it. The initial height-value of the new point is the average of the two points that are the end points of the line, where the new point is in the middle of. All these lines can be seen on the left side in Figure 1. This initial height-value is then used in the height calculation of the new point.

Diamond-Square Midpoint Displacement Method



Figure 2: Diamond-square subdivision

Diamond-square MPDM is otherwise same as the wireframe MPDM, except that on each step-size the points of reference are looped through twice, each time using a different interpolation. Here, those interpolations are named after the

shape of the interpolation; they can be also named based on the shapes they create.

The first interpolation is the square interpolation, shown in Figure 2 on the left side. In the square interpolation, simply one new point is generated in the center of the four points connected by the dotted cross-section in Figure 2. Height is then calculated for this new point using the average of the four points as the initial value.

The second interpolation is the Diamond interpolation. In the Diamond interpolation, the point of reference is not actually used in the height calculation, it is just used to determine the locations of the points in the interpolation. Two new points are generated in every interpolation, marked as x on the right-side in Figure 2. The points on the left and top are only generated in the left and top edges of the entire height-map. The new points get their height value as the average of the four surrounding points, marked by the dotted cross-section on the right side in Figure 2. For the new points at the edges of the height-map, the average of only three points is used. As we can see from Figure 2, the two points on the right and left that are used to calculate the average are the just generated points from the square interpolations. The two points that are top and bottom are from the previous iteration of the scale.

Unnested Subdivision Method



Figure 3: Unnested subdivision method

The unnested subdivision is more different from the wireframe MPDM and the diamond-square subdivision, than they are from each other.

The first step in the unnested subdivision is to create a memory area of size three-by-three filled with nine random values. These points are the square-shaped points in Figure 3.

After the initialization the actual iteration starts. The outmost loop in unnested subdivision is different from the one in Wireframe MPDM: instead of halving the step-size in every iteration, the step size is incremented by one at every step. The iteration of the outmost loop stops after the selected amount of iterations has been completed.

Inside the outmost loop a new height-map is generated on every iteration. The first step is to set the height-map generated in the previous iteration as the reference heightmap for the iteration currently being calculated. Then, the length of the sides of the new height-map is calculated with Equation 2, where l is the length of the side as amount of the vertexes and n is the iteration. After that, the total number of the vertexes in the new height-map is calculated by using Equation 3, where a is the total area as amount of vertexes and n is the iteration. The total number of points is then used to reserve the memory area for the new height-map.

$$l_n = 2 \cdot (l_{n-1} - 1)$$
(2)
$$a_n = (2^{(n+1)} + 2)^2$$
(3)

Next, all other points in the old height-map are iterated through except the ones on the bottom and right edge of the old height-map. The points being iterated are used as the points of reference for the square-square interpolation. After the points have been iterated through in the two inner loops, new maximal height displacement is calculated, and the size of the height-map for the next iteration is set as the size of the newly created height-map.

In the square-square interpolation, four new points are always created. The initial height values for the new points are calculated as weighted sum in 9:3:3:1 ratio based on the relative location of the new point to the points in the old height-map. How the interpolation is done can be seen in Figure 3. The values of the new points are stored in the new height-map. Of the four points from the old height-map used in the interpolation, the point of reference is the point in topleft corner.

With the same amount of iterations the height-maps created with the unnested subdivision are slightly smaller than the height-maps generated using the other two MPDMs.

Height Calculation

The height calculations used are mostly based on the ones invented by Musgrave (Ebert et al. 2002). The height calculation is what determines if the result is a monofractal or a multifractal.

The parameters for height calculation are the roughness exponent, initial frequency, monofractality quontient, maximal height displacement and the type of the height calculation. These are set in the initialization of the height calculation. Also in the initialization the initial value of scaling factor is calculated.

Additive

The additive height calculation can only be used to generate monofractals. This is the normal method of height calculation originally used in the MPDMs.

In the additive height calculation the initial value from the interpolation is simply added to a randomly generated value from a Gaussian distribution centered on 0.

The change of scale in height is done on every iteration of the most outer loop. The scale is changed by multiplying the previous value of variance of the Gaussian distribution with scaling factor s. For additive height calculation s is calculated by using Equation 4, where r is the roughness exponent. For additive height calculation it is necessary to calculate the value of s only once at the initialization. The accurate connection between roughness exponent r, Hurst exponent and fractal dimension was not studied in this paper. However, larger r results in higher fractal dimensions.

$$s = 2^{-r} \qquad (4)$$

Simple Multiplicative

The first experiment in this research was attempt to simply change the addition to a multiplication in the height displacement. As a result the height values escaped quickly to extreme changes in height, creating a very jagged terrain.

This problem was improved with a different way of scaling the variance of height changes in scale iterations. The new way of change in variance is calculated with Equations 5, 6 and 7, where f is frequency, n is the iteration, s is scaling factor, r is the roughness exponent, σ^2 is variance. The initial frequency is 0,5.

$$f_{n+1} = f_n \cdot 2 \quad (5) s_{n+1} = f_{n+1}^{-r} \quad (6) \sigma_{n+1}^2 = \sigma_n^2 \cdot s_{n+1} \quad (7)$$

Heterogenic Multifractals

Musgrave's Multiplicative Calculated at a Point, Statistics by Altitude and Ridged height calculations were implemented for MPDMs in this study (Ebert et al. 2002). The Bounce-Back height calculation was created in this study as a new form of multifractal height calculation. The goal in its creation was to remove the unrealistically common pits from the terrain, and make all changes in the terrain to raise the terrain. The results heights h_r are calculated repectively with Equations 8, 9, 10 and 11. Where ξ is a random value from Gaussian normal distribution, s is the scaling factor, n is the iteration, h_i is the initial height from the interpolation. The monofractality quontient m is used to control how close the multifractal will be to the additive monofractal.

$$\begin{aligned} h_r &= (|\xi| + m) \cdot s_{n+1} \cdot h_i & (8) \\ h_r &= h_i + ((\xi + m) \cdot s_{n+1} \cdot h_i) & (9) \\ h_r &= h_i + s_{n+1} (m - |\xi|)^2 & (10) \\ h_r &= h_i + ((|\xi| + m) \cdot s_{n+1} \cdot h_i) & (11) \end{aligned}$$

COMPARISION AND CONCLUSION

The multiplicative spectral synthesis methods are commonly used to generate multifractal terrains. Therefore the computation speeds of the multifractal generation methods presented in this paper were compared against the corresponding spectral synthesis versions by Ebert et al. (2002). The difference compared to those spectral synthesis implementations, was that instead of using Perlin noise Simplex noise was used, which is more advanced and faster version of Perlin noise. (Gustavson 2005)

The calculations were done using the same computer under the same conditions. The implementations were done using C++ language. The accuracy of the implementations is 64-bit floating point numbers and signed integers, except for the simplex noise which was using 32-bit floating point numbers. Each method was run ten times and the averages of these results are in Table 1. The iterations were run for 15 iterations when using the MPDMs, generating height maps the size of 32769×32769 vertexes, the result height-map of the unnested method was slightly larger: 32770×32770 vertexes. The spectral synthesis methods were made to generate 32769×32769 size height-maps, and as result they needed to be iterated only for the maximum of 14 iterations of octaves, iterations beyond that would have exceeded the Nyquist limit (Ebert et al. 2002).

Table 1: Comparision of Calculation	on Times in Milliseconds
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Wireframe	Additive	36730.7
Wireframe	Multiplicative	37191.0
Wireframe	At Point (8)	38145.6
Wireframe	Statistics by Altitude (9)	38171.5
Wireframe	Bounce-Back (11)	38710.8
Wireframe	Ridged (10)	38198.6
Wireframe	Average	37858.0
Diamond-Square	Additive	40580.3
Diamond-Square	Multiplicative	40669.7
Diamond-Square	At Point (8)	45125.5
Diamond-Square	Statistics by Altitude (9)	44391.3
Diamond-Square	Bounce-Back (11)	44869.1
Diamond-Square	Ridged (10)	44492.7
Diamond-Square	Average	43354.8
Unnested	Additive	51220.8
Unnested	Multiplicative	51461.7
Unnested	At Point (8)	53281.0
Unnested	Statistics by Altitude (9)	54073.6
Unnested	Bounce-Back (11)	54676.8
Unnested	Ridged (10)	54437.0
Unnested	Average	53191.8
Spectral Synthesis	fBm (4)	1002687.1
Spectral Synthesis	Multiplicative	1051458.4
Spectral Synthesis	Ridged (10)	3082298.4

The differences in speed between the MPDMs are not very large. The average execution time of Diamond-square was 15% longer than that of the Wireframe MPDM, and the execution time of the unnested subdivision was 40% longer than that of the Wireframe MPDM. All of these methods were extremely faster than the spectral synthesis methods. When comparing the simple additive and multiplicative methods, spectral synthesis method calculated 28 times longer than the Wireframe MPDM. In the case of the more complex Ridged height calculation, spectral synthesis took 67 times longer to calculate than MPDMs on average. This difference is significant since at this level of resolution, the spectral synthesis methods are only capable of being used for preprocessed terrain generation, while the MPDMs are fast enough to be used in runtime terrain generation.

Table 2: Height Calculation Average Times in Milliseconds

Additive	42843.93
Multiplicative	43107.40
At Point	45517.37
Statistics by Altitude	45545.47
Bounce-Back	45709.43
Ridged	46085.57

From the average times of the height calculations in Table 2, it can be seen that all the different types of height calculations are of the same degree in speed. Fastest height calculation is the Additive, and The Simple Multiplicative being the close second. The slowest is The Ridged height calculation, but the difference is only 7.6% compared to the Additive. Thus when MPDMs are used the height calculation makes lesser difference than the choice of the MPDM.

The unnested subdivision creates useable terrains with all height calculations, although with many of the height calculation and parameter combinations create jagged and spiky terrains. For the more advanced multifractal height calculations the results are equal to those generated by the spectral synthesis methods, and free of artifacts. However in spectral synthesis it is possible to set the terrain to be of any size, and the amount of iterations is not dependent on the size and the lacunarity is not static.

The other two MPDMs, however, have the problem of having artifacts in the terrain (Musgrave 1993).

From these results we can conclude that it is possible to generate multifractal terrains using midpoint displacement methods. Also, the much faster computation speed of MPDMs makes runtime generation of multifractals possible on significantly larger scale than by using spectral synthesis.

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GAME AI

AN INVESTIGATION OF TWO REAL TIME MACHINE LEARNING TECHNIQUES THAT COULD ENHANCE THE ADAPTABILITY OF GAME AI

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KEYWORDS

Artificial Intelligence (AI), Adaptive Game AI, *Q*-Learning, *N*-Gram Prediction.

ABSTRACT

Developers strive to create innovative Artificial Intelligence (AI) behaviour in their games as a key selling point. Machine Learning is an area of AI that looks at how applications and agents can be programmed to learn their own behaviour without the need to manually design and implement each aspect of it. Machine learning methods have been utilised infrequently within games and are usually trained to learn offline before the game is released to the players. In order to investigate new ways AI could be applied innovatively to games it is wise to explore how machine learning methods could be utilised in real-time as the game is played, so as to allow AI agents to learn directly from the player or their environment. Two machine learning methods were implemented into a simple 2D Fighter test game to allow the agents to fully showcase their learned behaviour as the game is played. The methods chosen were: Q-Learning and an N-Gram based system. It was found that N-Grams and Q-Learning could significantly benefit game developers as they facilitate fast, realistic learning at run-time.

INTRODUCTION

There are a wide range of characteristics that can be used to categorise how intelligence can be represented within computer programs. Definitions of intelligence include the ability to make a decision based on information that has been obtained from the world or the ability to solve problems. Others would argue that for something to be recognised as intelligent, it must be able to exhibit evidence of learning and adaptation (Bourg and Seemann 2004a), something which has rarely been seen in games before. Agents that are able to constantly adapt could completely change the landscape when applying AI within games. Therefore, when considering how games should evolve in the future, it is wise to take into account AI that learns and directly reacts specifically to each player.

The opportunity for increasingly complex AI techniques in games is improving as computational power in consoles and computers evolve (Bourg and Seemann 2004b; Vasquez II 2011). Recently, the games industry has been heavily focused on improving the graphical quality of games,

however AI is now one of the main elements of a game that allows it to stand out and make a real impact on the market. Unique, interesting, and impressive AI is becoming the main attraction of games (Schwab 2009). In particular, AI learning methods and the use of machine learning techniques within games during run-time is a largely unexplored territory in game development, but a popular field of research for academic uses (Dill 2011). There is a wealth of potential in applying machine learning techniques to games, as this could lead to having AI agents that adapt their behaviour to the current player and give a unique, personalised experience. Utilising learning techniques would allow AI agents to give unique reactive behaviour in response to individual players, which in turn could provide the distinctive breakthrough a game needs to give it a competitive edge. In addition, this would combat the problem of interactions with Non-Playable Characters (NPCs) becoming boring and predictable as a game goes on, which regularly leaves room for exploitation of the NPC behaviour and actively diminishes the challenge of the game (Bourg and Seemann 2004a).

It is extremely rare but not unheard of for games to utilise machine learning methods at run-time. NERO (NeuroEvolving Robotic Operatives) is a game that allows players to use Artificial Neural Networks (ANN) to train agents to fight other NPC agents (NERO Team [no date]). However, it would be beneficial to investigate how behaviour could be adapted when the AI is learning from the players own behaviour during a game.

These learning techniques could provide agents with completely tailored behaviour and reactions towards players. There is a possibility that AI agents learning from player behaviour could be detrimental to the gameplay, but on the other hand it could open up so many opportunities for different types of games and even the possibility of unique games that will stand out in a competitive market. Not only that, but using these techniques could increase the shelf-life of a game due to the many different ways to play it that this would provide (Stanley et al. 2005).

The focus of this paper is the utilisation of different AI learning methods that will allow AI agents to adapt to individual players' playing styles as the game runs in realtime. The paper aims to record the process and evaluation of developing, designing and comparing two different machine learning techniques in order to present methods that are well suited, and can be realistically implemented, within games. The overall aim is to investigate if, and how, implementation of agents that learn can give each player a unique, tailored experience when interacting with them.

Machine Learning

There are several methods that facilitate learning, and the choice of which to use is largely application dependent.

Supervised learning is a technique often used for backpropagation in Neural Networks and Decision Trees (Mathworks [No date]). Supervised learning uses training data provided to it in order to adjust internal parameters (such as weights) to provide the desired output. This technique is useful only if the desired output for the training data is known.

Unsupervised learning is a technique commonly used in methods such as Self Organising Map Neural Networks (SOM), Adaptive Resonance Theory Neural Networks (ART), clustering algorithms such as *K*-Means and predictive techniques like *N*-grams. AI systems use this technique to categorise data by independently observing, and finding patterns or similarities in the inputs (AI Horizon [no date]).

Reinforcement learning allows the AI agent to autonomously learn through experiencing the world, obtaining rewards or punishments given in response to their actions, which then influences their future decisions. Examples of Reinforcement Learning include *Q*-Learning, SARSA, and Temporal Difference Learning. The goal of the AI agent is to try different actions in order to make decisions based on which one gives them the largest reward (Whiteson 2007).

Supervised learning is less suited to games than reinforcement learning as it requires a human expert to determine the desired outputs for the agent, and this limits the ability to learn during the course of a game (Whiteson 2007). Reinforcement agents learn as they independently gain more experience from the world and do not require a human to guide their behaviour, allowing real-time learning without the need for human intervention.

METHODOLOGY

With a wide selection of learning models to choose from, this paper looks at two in detail that each have distinctive approaches to learning, are relatively easy to apply and are therefore appropriate for real-time applications; Reinforcement Learning as utilised in *Q*-Learning, and Unsupervised Learning as seen in *N*-Gram prediction.

Reinforcement Learning

Q-Learning was developed by Christopher Watkins in 1989 (Watkins and Dayan 1992), and relies on experience based knowledge to focus on making optimal decisions based upon the outcome of interactions in the world (Poole and Mackworth [no date]). It is a type of reinforcement learning for AI agents that uses trial and error to learn more about the world, actions, and consequences. AI agents carry out actions, and based on the outcome they are given a value as a 'reward' or 'punishment' so that the agent can record this and try to make a more optimal decision next time (Watkins and Dayan 1992). The agents check and update the Q-Value, which is a function of the current state and the chosen action, based on the experience they gain as they continually attempt to solve specific problems. The Q-Value is increased if the agent is rewarded in order to improve the probability of the agent choosing that action again when in the same state, whereas for punishment the Q-Value is reduced to make it less likely that it will be chosen (DeWolf 2012). The agent eventually learns the optimal policy by recurrently attempting actions in each state and finding the best Q-Value for that particular action-state pair (Poole and Mackworth. [No date].

Q-Learning has four parts for every decision: The initial state, the action taken, the reward, and the new state to which the agent has moved. Each action can be represented by this sequence and the agent's knowledge of the game space only changes when it carries out an action and lands in a new state. This means the agent learns from its interactions and the consequences it experiences in order to improve and make better decisions. An example of this method being used are AI programs that can learn how to play video games, such as Google's Deep *Q*-Network program (Lewis 2015), however this could be integrated into agents within games in order to learn from the player.

The Q-Value that represents how effective an action is in a given state is calculated using an iterative process in order to refine the Q-Value estimate (Poole 2010) as shown in Equation (1) below:

$$Q_{n+1}(S,A) = (1-L)Q_n + (LR)$$
(1)

where S is the current state, A is the action chosen, L the learning rate and R the reward value. The above rule uses the reward given along with the learning rate in order to determine the new Q-Value. The learning rate is a value between 0 and 1 that determines how much affect the current Q-Value has on the newly calculated Q-Value. The larger the learning rate, the more influence the reward has on the new Q-Value, and the less effect the current Q-Value has. For the test game, tuning the learning rate to produce the best outcome resulted in a value of 0.5. This learning rate was suitable as the Q-Value relied equally on both the current Q-Value and the reward, which allowed the agent to learn quickly as well as reliably. Reward values are dependent on the result of the action, so as to determine the appropriate value that will encourage or deter an action from happening again. For this application the reward values given for the various actions are reliant on the health changes of the player and agent, and are shown in Table 1.

Reward values were designed to appropriately encourage the agent to learn from its mistakes, and to aim towards higher rewarded actions throughout the game. The Q-Value is calculated each time the player performs an action, so that the Agent counters this with the action given by the Q-Learning algorithm. The action with the highest quality value in that state is chosen when the action is being determined, which ensures that the agent is performing the most desired action in retaliation.

Unsupervised Learning

N-Grams are a type of unsupervised learning technique used in order to learn patterns in sequences. Through the use of string matching, the current actions of the player are compared to a record of the previous sequences of actions to find identical sequences for prediction (Tucci 2014). Sequences are stored in a window of size *N* to be checked. For example a 4-Gram records the frequency of a sequence of four actions, and when the player next performs the first three actions the fourth is predicted (Millington and Funge 2009). When predicting, the most frequent action that follows a sequence of the player's current actions up to a window of size N - 1 is chosen. It is important however that the size of the window is suitable for the range of actions available to the player. If the window size is too small predictions will be less accurate as there is not enough history to check, whereas if the window size is too big predictions will be less accurate due to randomness in the history and sequences are less likely to be matched to an *N*-Gram (Tucci 2014).

Table 1: Reward Table

Result	Reward Value	Reason
Both Player and Agent were not hit	0	No reward given for no effect on Player or Agent
Player and Agent damaged each other	0.3	Small reward given because damaging the Player is a positive action, however not given full positive reward because Agent was damaged also.
Player damaged, Agent safe	1.0	Largest reward given because damage caused to player, but Agent took no damage
Agent damaged, Player safe	-1.0	Largest negative reward given, because Agent took damage while Player did not
Agent hit, but health did not change	0.7	Large positive reward, as this means the Agent blocked the attack correctly
Player hit, but health did not change	-0.5	Negative reward, as this indicates the player blocked the attack successfully

This technique is sometimes used in combat/fighting games, as it finds patterns in the input or sequence of events by looking at their history as they happen, and can therefore react specifically to the player's current action (Millington and Funge 2009). This means a co-operative AI agent could imitate the player's style to benefit the player in game play, or an enemy AI agent can adapt its style uniquely against each player. It is a type of learning algorithm that would lend itself well to games where the player has a specific style they use for game play, because the *N*-Grams could then use the player's input history to learn their patterns and hence adapt to the player (Vasquez II 2011).

Developing the Test Game

The design and creation of the test game was heavily focused on what kind of game would provide instant, realistic, and clear learning abilities in AI agents if machine learning was used to control their behaviour. When reflecting on the criteria needed for the game, a 2D Fighter game with an AI controlled opponent, similar to Street Fighter (Capcom 1987) or Mortal Kombat (Midway Games 1992), was chosen.

The player interacts with the game by pressing controls that correspond to moves the player can make. Both the player and the AI agents can move around the screen in order to get close enough to attack the other, or to move out of their range. A screenshot of the game while it is running is shown in Figure 1. The moves that the AI agent and player can perform are: jump, crouch, move, punch, low kick, high kick, low block, and high block. The advantage of demonstrating the agent's learning capabilities in this type of game is that it is clear to see how the agent's knowledge improves over time. For example, the player might punch the agent, and the agent will take damage. All the agent will know is that its upper body was hit, and it lost health. As its knowledge improves and it tries different moves in response to this, the agent should learn strategies such as blocking its upper body when the player punches, or punching the player back. This type of reaction shows the player how the agent has been learning from its experience during the fight. Based on the effect of the players move on the AI agent, the agent can learn to predict or counter those moves more effectively as the fight progresses.



Figure 1: Screenshot from the Game

EVALUATION

Qualitative Evaluation

In order to evaluate the machine learning methods implemented in the test game a questionnaire was developed with the aim of gathering information on their effectiveness. The questionnaire was created using Google Forms that testers could fill in online, and the game's test build was distributed via a download link on Google Drive.

Quantitative Evaluation

The quantitative testing focused on the technical side of implementing the machine learning techniques. Technical qualities to be tested were inspired by the prominent computer scientist Pieter Spronck's list of requirements for successful online learning algorithms. In the paper 'Online Adaptation of Game Opponent AI in Simulation and In Practice,' Spronck et al. state that online learning methods must be "Fast, effective, robust, and efficient" in order to be successful in a real time environment (Spronck et al. 2003). Therefore, the following aspects of each method were evaluated:

- Processing speed during run-time (Evaluation of speed and efficiency)
- Accuracy and error (Evaluation of effectiveness and robustness)

Qualitative Results

Twelve testers participated in playing the game and completed the questionnaire, which was split up into three sections:

- Section 1: *Q*-Learning (6 questions)
- Section 2: *N*-Grams (6 questions)
- Section 3: Comparison (12 questions)

Testers were asked to indicate their thoughts on the behaviour of the AI Agent using a Likert scale from 1 to 5; where 1 meant did not agree at all and 5 meant they agreed extremely. In addition, several other questions were posed to gain more insight into the testers' decisions, the results of which are included below. The following aspects were examined:

Realistic: It was important to ask for the testers' opinions on how realistically the agent behaved, as AI in games needs to be highly believable in order to be immersive, whereas unrealistic AI agents can discourage players by frustrating them.

Intelligent: The AI agent needed to act or give the illusion of intelligence to the player, so that the agent's decision making seemed logical and understandable and thus prevented the player from losing immersion in the game.

Reactive: All players take their own approach when playing games, therefore in order to be truly adaptive the agent had to feel as though it reacted to the player's own method of playing.

Interesting: The AI agent needed to be interesting to the player. If it exhibited boring behaviour, this would lose the players attention quickly and would not entice them to play the game.

Enjoyable: Lastly, the agent's behaviour needed to provide enjoyable behaviour to the player as enjoyment is the primary focus of video games. If the enjoyment of a game is increased by using learning algorithms for agents, this would be a clear sign that adaptable AI in games would be beneficial for future games.

Figure 2 shows the results of the question evaluating the Q-Learning agent, whilst Figure 3 shows the results for the N-Gram agent.

Realism

In answer to the question "Which method did you find to be the least realistic?" the results were 50-50. So there was no overall preference for either method

What is your opinion on the behaviour of the Q-Learning driven AI Agent?



Figure 2: Results for Q-Learning Agent Attributes

What is your opinion on the behaviour of the N-Grams driven AI Agent?



Figure 3: Results for N-Gram Agent Attributes

Intelligence

Each tester was asked to state to what extent they felt that the agent displayed evidence of learning while playing the game. The results are compared in Figure 4.

Did you feel that the robot displayed evidence of learning from it's experience whilst playing against you?



Figure 4: Pie Charts Displaying How Testers Felt About the Intelligence of the AI Agents

The polls found that on average, O-Learning's intelligence value was 3.58 out of 5, whereas N-Grams value was 4.16. Furthermore, looking at the charts in Figure 4 it is evident that testers felt the robot utilising N-Gram based learning was significantly more intelligent than the *Q*-Learning robot; 97% stated that the N-Gram robot displayed evidence of learning and only 58.3% stated the same for the Q-Learning robot. Expanding on their choices, testers explained that N-Grams exhibited learning more clearly because it learned how they played the game, and testers had to change their own tactics in order to defeat the robot. For Q-Learning, some felt that the robot did exhibit intelligence clearly as it learned from its mistakes and began to block, attack and counter appropriately against the tester's actions. However, some felt that Q-Learning would have been able to show better intelligence if the agent had a longer time to learn because it did not learn as fast as the N-Gram agent. On the other hand, when fighting the N-Gram agent testers found that it learned so quickly that they had to try and outsmart the agent during the fight as it soon became difficult.

What is interesting is that two players noted behaviours that they believed displayed the *N*-Gram agent's intelligence which were not actually true. These testers noted that the *N*-Gram robot would 'change its tactics,' and 'employ tactics,' to sabotage the players fighting style. This is fascinating because artificial intelligence in games is largely just an illusion, as players make connections in their head as to how the AI agents are thinking based on what they observe. The *N*-Gram agent does not change its tactics throughout the game, and merely gains more information about the player to make more precise predictions, however the behaviour exhibited by the agent gave players a stronger illusion of intelligence.

Reactivity

Testing the reactivity of the agents was important as one of the main aims of the project is to explore how machine learning methods can enhance this aspect of game agents. In the poll, the *N*-Gram agent again held a higher average value for its reactivity, with its value being 4.5 and *Q*-Learning's value being 4.25. To explore this further, the testers were asked to select which agent they felt was the most reactive, the result of which is shown in Figure 5.

Out of the two learning methods, which did you find to be the most reactive?



Figure 5: Pie Chart Displaying How Testers Felt About the Reactivity of the AI Agents

As shown in the pie chart, a substantial amount of testers chose the N-Gram method to be more reactive than Q-Learning. This highly suggests that N-Grams is well suited for quick learning in games during real time, as testers easily identified this as the most reactive method to play against. Testers who chose Q-Learning for this question noted that they believed the *Q*-Learning robot was more prepared for their actions than the N-Gram. In addition, they felt that it learned to react quickly and was reactive to their individual play style. However once they identified a technique they could use, the robot became too easy to defeat. Testers who selected N-Grams as most reactive collectively stated that the N-Gram robot seemed to learn a lot faster, as well as providing a much more difficult challenge. One tester stated that the N-Gram robot behaved like it knew what they were going to do next, as well as delivering the feeling of playing against an experienced human player. This is a great prospect for games with NPC opponents or allies, as humanlike AI characters can help to increase immersion and the player's enjoyment of the game.

Interesting

In terms of how interesting testers found each method, *N*-Grams again won out but only slightly, with a value of 4.16 on average out of 5 compared to *Q*-Learning's 3.75 average value. A high value for how interesting testers found both methods is beneficial, because it is important for players to take interest in AI agents in games as they are generally what help the player engage with game play and story elements of a game. One tester stated that *Q*-Learning still acted unpredictably and exciting even after it had learned, which helped to keep the fight interesting. Another explained that the *N*-Gram agent was a lot more interesting because of the greater challenge it provided as well as how fast and efficiently it learned.

Enjoyable

The testers' opinion on how enjoyable a learning method was is of course a personal preference when it comes to playing games, however it is important to look at a wide range of players with different tastes to understand how the implementation of learning could affect them. On average, Q-Learning had an average value of 3.75 out of 5 for how enjoyable they found fighting the robot, whereas there was a small increase in the average value for *N*-Grams which had a value of 3.83 out of 5. The testers were additionally asked to identify which method they found most enjoyable and why, and there was no particular preference shown.

Learning in Games

In the final section of the questionnaire, testers were asked general questions on their opinion of learning AI agents in games to determine if this type of AI would appeal to them in the future.

Firstly, testers were asked whether they believed that the ability to learn made the AI agents in the test game more realistic and reactive in comparison to agents in other games they had experienced. Every tester responded positively to this question, with most citing games wherein the AI agent's behaviour can be quite illogical and easy to trick or exploit. Players mentioned these games and how agents that learn from the player would avoid the problem of repetitive, boring or exploitable AI by instead being unpredictable and surprising the more it learns about the player. Testers noted that in multiplayer games, humans do learn from their enemies or their allies and base their own play style on what they have learned for their own benefit. Therefore, AI agents that too can learn would be able to exhibit this realistic, human like behaviour. One player additionally stated that a learning AI could help to improve the difficulty level of a game substantially by tailoring it to individual players to improve their game play experience. This illustrates the many ways that games could improve player's interactions with AI agents or systems.

In order to get an impression of what players are looking for in future games testers were asked if having learning AI agents in these games would appeal to them and the overwhelming response was 100% yes.

Quantitative Results

Processing Speed

In order to test and compare the processing time of the learning methods implemented, the evaluation and optimisation tool within Unity, the Unity Profiler, was used. To gain an overall idea on how the processing time for each learning method compared, a sample of ten processing times for each method were recorded and then averaged in order to find the mean processing time required to carry out learning. Figure 6 shows the results.



Figure 6: Bar Chart Showing the Comparison Between Processing Times

As evident in the above chart, Q-Learning was faster than N-Gram by about 45 milliseconds, and while this is a small difference this could have a much larger knock on effect in other games if the methods were used to control more agents, or to learn a wider range of knowledge. In comparison to N-Grams, Q-Learning has a relatively smaller amount of variables to search through in order to make decisions which could contribute to the reason why Q-Learning is faster. This is because during the N-gram based learning, the script has to check through every listed sequence that has happened and every action in that sequence in order to find matches for predictions. This list grows as the game goes on. However, for *Q*-Learning the script is only required to search through a list of 8 potential actions based on the state which is given to them by the AI robot script. This would reduce the processing time as there are less values or variables to search through to find the optimal action.

Of course, in future implementations each method's effect on the performance of a game could be improved further by using optimisation techniques such as threading. Nevertheless, it is always important and preferred that the efficiency of AI methods implemented in games are as fast as they can be so that they do not have a negative effect on the game's performance.

Accuracy and Error

To investigate the effectiveness of the methods, the amount of errors that were made were recorded over time in order to show if learning was taking place. Ideally, the error should decrease as the AI agent experiences more events during the game as this would display how the method stores more accurate knowledge as time goes on.

The errors of the *N*-Gram based system and the *Q*-Learning method were compared with each other in order to determine which has the higher rate of success when choosing its actions to counter the player. To determine the error for each method the percentage of incorrect decisions the AI agent made during the fight was calculated. For the *Q*-Learning method an error was when the agent made a 'wrong,' decision by selecting an action that would lead to a negative reward. For the *N*-Gram method, the error was based on whether the predicted action matched the actual action used by the player. To compare the error percentages, the error was recorded over 25 player moves (game events) to indicate how well the agent learned. Figure 7 displays the results for this test.





As shown clearly above, both methods have a similar learning rate at the start despite the Q-Learning method beginning at a higher error percentage. However as time goes on and the learning rate slows, the Q-Learning rate levels out at a higher error percentage than the N-Gram based system by becoming flatter at around 20%, whereas N-grams achieves this at 10%. In addition, throughout the graph the N-Gram method always has a smaller error

percentage which demonstrates that the method is slightly more efficient at learning than the Q-Learning method as it tends to make less mistakes as time goes on. This supports the comments of the testers of which a majority stated that the N-Gram agent felt more intelligent and reactive compared to the Q-Learning agent. However, because the game is a fighting game that requires clear input and reactive output constantly this result could simply be indicative of N-Gram prediction being more suited for this style of input and learning. Q-Learning takes slightly longer, however this could be beneficial for different games that require a more subtle or natural sense of learning. Moreover, both methods show a decrease in the error percentage as they experience more events which shows that they both successfully learn and improve the AI agent's behaviour throughout the game. This in turn illustrates how both methods would be beneficial when implemented in games to clearly display the intelligence of the agents and increase their reactivity.

DISCUSSION

Real-time Concerns

One of the main problems that the project looked to explore was how agents could learn directly from the player whilst the game is played in real time without having a negative effect on the performance of the game. The project found that players did notice the AI agent learning from their actions during run time and they found this to be interesting and enjoyable, illustrating that the N-Gram and Q-Learning methods were both effective in facilitating fast learning. By exhibiting behaviour based on the knowledge that the AI agent had learnt from the player in the short, 45 second game, it is clear that machine learning methods are suitable for adapting agents as the game is being played. However, it is incredibly important to carefully plan what the AI agent is able to learn, as well as how the agent will change its behaviour based upon this information. It is much safer to utilise machine learning in games to select the decisions that the agent should be capable of making rather than giving the learning methods free control over all behaviour of the AI agent. In this way, the game play is still unpredictable and exciting without causing unstable or illogical behaviour.

It was found that *Q*-Learning was the most efficient out of the two tested methods as shown above, however it was also the method that took longest to learn in comparison with the *N*-Gram system. The *N*-Gram system required a longer processing time than *Q*-Learning, however the majority of player testers preferred this method as it felt the most realistic and seemed to learn faster. This is also reflected in Figure 7 wherein the *N*-Gram agent had a lower error percentage throughout, illustrating that it was more successful in predicting the players moves than *Q*-Learning was in choosing the most rewarding move to make.

The Player Experience

In order for the application of machine learning methods to be beneficial and a worthwhile innovation in games, the AI had to enhance the realism and reactivity of the agent towards players, as well as exhibit human-like intelligence. AI within games should satisfy one goal, which is to help to 'create a compelling experience for the player (Dill 2011).' The qualitative testing found that 100% of testers would welcome real time learning agents in games in the future, citing reasons such as how the ability to learn improved the realism and challenge of the test game as well as the reactivity of agents. Many testers explained that they believed innovation in AI is the future for games, and learning is just one of many aspects that could change and enhance the player's engagement with games. This illustrates the relevance of this project and the research undertaken, because in the current games industry environment developers are constantly looking for new ways to entice and provide fun for gamers. The qualitative information gathered in the project is strong evidence in support of the statement that machine learning can be applied to games to improve the realism and reactivity of AI agents.

An area of the results that was unexpected was how some testers felt that when the AI agents behaved too intelligently, this actually negatively affected their game play experience. These testers signified how the speed of the AI agents learning actually changed how much fun or frustration they got from the game, in addition to how much chance they felt they had to beat the AI robot. N-Grams was found to be the most reactive method as well as the fastest learning, however many players stated they disliked this behaviour as they felt their efforts were futile in fighting it and this removed the element of fun. On reflection, it is important that the AI agent's intelligence is balanced so as to still provide unpredictable behaviour, but should not be too intelligent or reactive that they can anticipate every move of the player. This frustrates players as they feel there is no point in playing the game if there is no chance of winning. Testers suggested that a larger element of randomness could improve the learning methods as it would make their behaviour seem slightly more natural. This is because players often make mistakes or switch up their tactics while playing games, and this not only would benefit the player in terms of showing them there is a higher chance for them to win but it would also benefit the agent by giving them human-like intelligence, along with human-like fallibility.

Future Work

While the learning methods implemented in this project focused on learning reactions to the player through game play, machine learning could similarly enhance many other areas of games. For example, area or terrain generation could be autonomously created by utilising machine learning and could give randomised locations for the player in each play through. In addition, areas such as narrative, graphics and networking may benefit from machine learning (Graepel and Herbrich 2008). Experimentation into using machine learning in different ways could lead to more optimal methods of creating content for games.

As discussed above players noted that the difficulty of the game seemed to depend on how fast the AI agent could learn to counter the player. In this sense, a game that utilised learning agents as enemies could adjust their learning rate depending on the difficulty the player prefers or simply to ensure that the game remains a challenge even as the player improves. This would be a useful and interesting way to adjust the difficulty of a game instead of simply changing health values and damage values to make games harder. As the game becomes more difficult, the AI agent could learn different types of information about the player that were not previously available to them, and this would keep the game play challenging as well as unique.

CONCLUSION

The findings of the project have shown that integrating AI learning in a game is a worthwhile task for developers, as it greatly enhances the behaviour of AI agents as well as the player's engagement with the game. Players found that the learning ability of agents led to exciting, unpredictable and realistic behaviour that enhanced their immersion and enjoyment of the game. Yet, documentation and tools on the subject of machine learning in relation to games are lacking or often focused on offline learning rather than online learning. It is likely that machine learning in games would be a more common occurrence if game engines created tools to allow developers to easily utilise learning in games. In addition, documentation on how machine learning methods could be applied to games that focuses on the type of learning the method utilises and to which game genres each is best suited would be useful. The benefit being that it would help to increase developers understanding of online learning and encourage them to investigate using it, as right now many developers deem it too great a risk. Nevertheless, taking such a risk could result in a ground-breaking game with revolutionary game play.

For more details on this investigation, including experimenting with ANN, please refer to Bennett 2016.

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Production of Emotion-based Behaviors for a Human-like Computer Player

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A*, Computer player, Model, Human-like behavior, Emotion, Transition, Mario.

ABSTRACT

The current performance of computer game players is highly promising and efficient in terms of strength, but the behavior of such strong computer players is not promising for the entertainment of human players. For example, in a famous video of a computer player for Infinite Mario Bros., the Mario character shows highly precise movements and no hesitation in his decisions. Such a behavior looks too mechanical; in other words, it is too strong and not entertaining. Human behavior is easily inspired by emotions, such as fear of an enemy or enjoyment in collecting a reward. Behaviors often change, even in the same game and same match. Thus, we propose the design of a human-like computer player with five emotional behaviors: "Safety," "Hurry," "Greedy," "Enjoy," and "Habit." These behavior models reflect human behaviors, which are inspired and affected by an emotion, such as fear, anxiety, or enjoyment. According to these models, we propose simple rule-based switching to handle the transition between models.

This article mainly presents the implementation of the Safety behavior model, which reflects human fear and anxiety. The model was evaluated using the Turing test.

INTRODUCTION

The ideal goal of the academic study of computer games is to make a suitable computer opponent for humans. To achieve this goal, strengthening the computer player is the first and major aim of the research. Currently, the triumph of computer players, such as "Deepblue" (Campbell et al. 2002) and "AlphaGo," (David et al. 2016), over human professional players proves their performance. In addition, in modern computer games, such as Starcraft, computer players have become strong enough to win against intermediate human players. These successes show it is perhaps time to focus on other issues related to computer players, such as education or entertainment.

There are various uses of a computer player in video games. Sometimes computer players are developed to control another character, such as a partner or an opponent, to entertain human players. The design of a computer player with suitable behaviors or strategies is difficult, and it becomes a heavy burden for developers. Thus, efficient algorithms, such as the path-finding algorithm A* and the learning algorithm TD learning, are introduced to generate behaviors or strategies to reduce the load of developers' work. Currently, the performance of computer game players is highly efficient, but the behavior of strong computer players is not promising for the entertainment of players. For example, a famous video of a computer player for Infinite Mario Bros. (the public domain clone of Super Mario Bros. of Nintendo) was published in website YouTube 2009 on the (https://www.youtube.com/watch?v=DlkMs4ZHHr8). The video shows an excellent Mario character, which is controlled by a computer. Each of its actions is highly accurate and instantaneous. Such a behavior looks remarkably mechanical. In this case, a human observer only acknowledges that the player is controlled by a machine. However, in the case of two-player games (e.g., fighting games like Street Fighter http://www.capcom.co.jp/sfv/) or multiplayer games (e.g., shooter game like Unreal Tournament 2004), where a computer player simultaneously plays with human players, humans might suspect they are being cheated, and the entertainment of the game will be harmed because of the unnatural behaviors of the computer player. Hence, the production of behaviors that look natural to humans, called human-like manner, is essential to enabling computer players to entertain human players.

Many approaches have been taken to produce human-like behaviors, such as directed learning in a first-person 3D shooter game (Schrum et al. 2011). In 2013, Fujii et al. introduced a new approach to producing human-like behaviors based on biological constraints. The player exhibits actions that are similar to human players' actions. However, to produce human-like behaviors for computer players, changes in behaviors during the game due to emotions are needed to be concerned.

For example, in Super Mario Bros., the main goal is to clear a stage within a limited time. In the beginning, the player tries to reach the goal as fast as possible. Nevertheless, after some coins are found and the player acknowledges there is still enough time, he or she might ignore the main mission and try to collect coins, which is a sub-objective of the game. He or she might be inspired by greed or enjoyment. Such a change in behavior is inspired by human feelings or emotions. Hence, the production of behavior transitions is important to produce a human-like behavior.

We propose an idea to represent the behaviors of human players, who are affected by their emotions, in several behavior models, as well as a simple transition to produce human-like behaviors. Behavior models are proposed to provide different play styles, and they can be explained as follows:

- "Safety" reflects the anxiety and fear of the player when on guard.
- "Hurry" reflects careless speedy actions, when the player worries about the remaining time.

- "Greedy" reflects the enjoyment of humans when they find rewards.
- "Enjoy" reflects enjoyment and interest, such as killing enemies continuously.
- "Habit" reflects unintended behaviors, such as pressing repeatedly the jump button.

This article presents the implementation of the Safety model, which is based on the A* algorithm. We also present a sample of the Greedy model and the Hurry model, and the guidance of switching between these models using simple rules is considered. The research evaluation was conducted by applying the Turing test, which conforms to the evaluation method of the Mario AI Competition 2010.

RELATED WORKS

The topic of the human likeness of machines is an interesting topic in the field of philosophy of the mind and cognitive science. The research in this field has been discussed widely since Alan Turing proposed the Turing Test in his article "Computing Machinery and Intelligence" (Hingston 2010). Until now, the definition was unclear. In the field of computer games, the study of human-like behavior (also known as believability) has interested many researchers. As far as we know, the definition of human-like behavior is still ambiguous, even in the special case of computer games. Considering the word "believability," the literal meaning is that something can be reasonably believed by someone. Togelius et al. defined player believability as when "someone believes that the player, who controls the character/bot is real, i.e. a human is playing." This is related to the case of video games, such as Starcraft and Super Mario Bros., where either a computer player or a human player can control a character in the game. The player observes the behavior and judges whether a human player is playing (Togelius et al. 2012). The effects of believability/human likeness can be classified into two levels. In the case where humans do not participate in the game (i.e., in one-player games), such as Infinite Mario Bros., the unnaturalness of the computer player may be harmless. On the contrary, in two-player or multiplayer games, where a human player simultaneously plays with a computer player, and when the computer player is assigned as a partner/opponent of the human, unnaturalness will directly harm the entertainment of the game.

Fujii et al. proposed a human-like computer player with biological constraints. These were applied to Q-learning and the A* algorithm in the Infinite Mario Bros. test-bed game. It was shown that the proposed agent could be more human-like than both the novice and expert human players.

However, human behaviors are easily affected and inspired by emotions, such as fear, anxiety, or enjoyment. For example, in a situation where the Mario character is in an invisible state (the effect of a game item for a short period), the player enjoys killing as many enemies as possible. In contrast, if the character is surrounded by a large number of enemies, the player might hesitate to move forward or backward due to fear and anxiety. Some approaches introduce emotions to machines; for instance, Canamero presents a paper on emotion for behavior control, which discusses the importance of including emotion in machines so the system has a better communication ability and flexibility (Canamero 1997).

We aim to produce computer players with transitions between behavior models that appear to be inspired by emotions. The usual practice in this area has been focused on the human likeness of behaviors in overall game play, whereas our approach produces transitions between multiple behaviors. Each behavior model produces a specific human-like behavior inspired by human emotions or feelings (e.g., anxiety, fear, etc.), and the transition model afterward decides an appropriate moment to change the behavior to make it looks like a human transition.

PROPOSED METHOD

In a modern-style game, not only a single goal but also many sub-goals are given and available for challenge. In the case of the Super Mario Bros. series, the major goal is to reach within a time limit the stage's goal located at the rightmost of the stage. Players have other optional tasks of collecting coins or beating enemies, though they are not necessary to clear the stage. The player is able to challenge any goal that he or she prefers, but the player must respect the major goal. Thus, the player will exhibit transitions between several local behaviors. For example, at the beginning of the stage, the player's movements are at ease, so he or she can enjoy collecting coins, or the player can control Mario carefully when he encounters many enemies. After a while, when the time has almost run out, Mario's movements become faster and riskier to clear the stage in time. Our research interest is in creating a human-like computer player with transitions between emotional behaviors. The usual practice in this area has been focused on the human likeness of behaviors in overall game play, whereas our approach produces transitions between multiple behaviors. Each behavior model produces a specific human-like behavior inspired by human emotions or feelings (e.g. anxiety, fear), and the transition model then decides the appropriate timing to change the behavior, which looks like a human transition. We propose a research framework, as described in two layers: the "Behavior Model" and the "Transition." The research is conducted using the Mario AI benchmark as a test bed. The implementation was conducted in the Java environment. The Behavior model includes five elementary models (i.e., "Safety," "Hurry," "Greedy," "Enjoy," and "Habit"). Each was designed to simulate a specific behavior, which is likely influenced by an emotion. However, the naturalness of each model is significant to produce human-like transitions. Thus, in this article, only the Safety model and the guidance of the Greedy and Hurry models will be described. The implementation of each behavior model is hand-coded, in other words, unsupervised, and based on the A* algorithm.



Figure 2: Safety, Greedy, and Hurry models

A* algorithm in Mario

The A* algorithm is a well-known path-finding algorithm. By using the best-first search, A* finds the path with the lowest cost from a start node to a goal node. To compare traversal paths, a cost function for A* is defined and used:

f(current, goal) = g(start, current) + h(current, goal) (1)

Where f(current, goal) is an estimated total cost of a current node, which is the sum of g(start, current); the actual cost from the start node to the current node; and h(current. goal), the heuristic estimation from the current node to the goal.



Figure 1: Possible nodes for A*

In the Mario AI competition, Baumgarten presented an efficient controller using a modified A* algorithm, which computes possible trajectories of Mario. The video of the controller was published and has been viewed over 600,000 times in a short period because the performance is excellent, and the behavior is far more from human players.

The algorithm expands the path by nine actions, as shown in Fig. 1 (i.e., left, right, jump, dash/fire), where g(start, current) is defined as the time that the controller used to reach the current position and h(current, goal) is the estimated time from the current node to the goal with the current speed (Togelius et al. 2010).

Our idea of the Safety model and two samples, one being the Greedy model and the other being the Hurry model, is shown in Fig. 2.

The first and the most important behavior is the Safety behavior. Most of the time, human players try to play safe, so their character can survive and move toward the goal. Based on this kind of behavior, our Safety model is created, and it allows the character, in this case Mario, to move steadily and carefully. In addition, the character is able to recognize dangerous areas, and it hesitates to move forward until the dangerous turn into a safe area. The area changes from dangerous to safe if the enemies are killed or they disappear. The second behavior model is Greedy. While the Safety model forces the character to pay attention to the enemies, the Greedy model leads the character to the locations of coins. Instead of moving toward the goal, the character moves to the location of a coin. This is only one example related to the Greedy model, where the character will only move to the coin's position.

Similarly, an example of the Hurry model would be making Mario move as fast as possible to reach the goal without paying any attention to enemies or coins. We explain the mechanism of each model in the next part.

Safety Model

Maslow explained the motivation of humans in a hierarchy of five layers of needs. The term "Safety" has been used to describe the needs of health, well-being, and safety against adverse impacts. Moreover, the need for safety can influence a player's behavior. While playing a game, movements can be affected by anxiety or fear. For computer players with perfect control and information, precise actions, such as evasion from an enemy by one pixel, are possible. Nevertheless, beginner and intermediate players are aware of their imperfect controls and perceptions. Thus, a safer movement, such as keeping distance from each enemy, is preferred.

The safety model imitates such a behavior by introducing a "dangerous area" to the A* algorithm. The "dangerous area" surrounds each harmful object (Figure 3), so the safety model controller intends to avoid the object and the "nearby area." The heuristic function of the A* algorithm is defined as:

$$h'(s_t) = S \rightarrow R/h'(s_t) = RP_t + MP_t - h'(s_{t-1})$$
(2)

Where *s* is the state of the game at frame *t*, RP_t is the penalty from real damage that Mario takes in frame *t*, and MP_t is the penalty from the virtual damage from the dangerous area, as shown in Fig. 1. There are many kinds of harmful objects, so there are also many kinds of dangerous areas. For example, fast-moving enemies should have a wider area compared to slow or fixed objects. If we compare the two areas shown in Fig. 1, the left has an isotropic area. On the other hand, the right one has no virtual damage over the enemy. This is because some enemies can be stomped on, and in such a case, Mario is not damaged.



Hurry Model

The major goal of Super Mario Bros. is to clear the stage by travelling to the rightmost end of the stage without being killed. In each stage, 300 seconds are given, and after 200 seconds have passed, there is a warning sound and the background song will quicken. Afterwards, the player will be aroused and try to clear the stage as fast as possible. Sometimes the player might ignore remaining coins, give up on killing enemies, or even ignore damage that does not kill Mario immediately, such as in the "Fire" or "Big" state. Thus, we proposed the Hurry model to display such behavior. The implementation is based on the A* algorithm of Baumgarten, including the concept of the dangerous area, which smaller than in the Safety model.

Greedy Model

In the Mario game, coins and items are rewards that provide some benefits to Mario. Collecting coins adds to the score of the player, and for every 100 coins, the player gains an additional life. Items give to the player not only a score, but also a status upgrade from Small to Big or to Fire. Sometimes the player's attention might be drawn to these rewards. Our Greedy model imitates such attention to rewards. This behavior reflects the enjoyment of humans when they obtain a benefit. The main idea of the Greedy model slightly differs from the Hurry model. The target of path finding is set to coin locations and item locations, instead of the real goal. For instance, in Super Mario Bros., we assume (x_g, y_g) and (x_{ci}, y_{ci}) , where (x_g, y_g) stands for the coordinate of the goal and (x_{ci}, y_{ci}) stands for the coordinate of the coin with the index i. As a result, the Mario character will change its target to the coordinate of coin *i*, and only when coin *i* is collected will the target change to the next coordinate of coin i+1. When there is no coin left in the area around the character, the target changes back to the coordinate of the goal. Finally, by using the A* algorithm for path finding, we were able to make the character move to the expected target.

Enjoy Model

Sometimes the player might face some challenging situations that are unnecessary to solve to clear the stage. Yet, the player might enjoy such a situation. In the case of the Mario game, if the player is able to stomp continuously on enemies without falling to the ground, the score will double for each kill. The challenge may provide a big score, but it is not necessary to clear the game. We present the interest and enjoy emotions in this model.

Habit Model

We found that for some human behaviors, it is impossible to identify the purpose or even the reason for the behavior. Often, human players produce actions having no aim or benefit, such as the player jumping all the way while running, even though there are no enemies or obstacles in the game scene. The behavior might occur by instinct or sometimes with the player's intention. We defined such a behavior as the Habit model.

Switching Model

Human behavior is more complicated than we can imagine. To illustrate, at a specific period in the game, a human player uses the Safety style, but after a numerous rewards appear, the player changes to the Greedy style and begins to collect as many rewards as possible. Hence, we propose this model based on the idea that human players change behaviors during the game. The mechanism of this model is simple. It is the combined models of two or more individual models, which we already introduced in the previous part. To change between models, a set of rules is used as a switch. If the information in the environment around a character meets the condition, the character is able to change to an appropriated behavior model. For example, if the number of coins is greater than three, the Greedy model is activated, or if the number of enemies is greater than five, the Safety model is activated. When one model is activated, others are disabled.

EXPERIMENTS

The assessment of each model incorporated the Turing test method of the Mario AI Championship 2010. We want to confirm the human likeness of the Safety model and the possibility of the idea as an extra. The preparations were done by collecting the replay from a human intermediate player. The player was asked to play the game in 10 stages, with four various instructions.

"Please clear the stage as safely as possible"

"Please clear the stage as quickly as possible"

"Please clear the stage and gather as many coins as possible" "Please play at will"

In the same set of stages, the replays from the "Safety model player" were collected. We also implement a sample Greedy model that aims to collect coins, a Hurry model that aims to clear a stage as quickly as possible, and simple rule-based switching for these three models.

We employed 15 human subjects whose mean age was around 20–30, who have experience with the game, and who know the rules of Super Mario Bros. The subjects were asked to observe pairs of non-label replays. Then, they have to answer the following question:

"Q1: How expert is this player?"

"Q2: Does the action of this player look natural?" The answers to each question were based on a 5-point Likert scale. Subjects were asked to compare replays one by one, such as to compare a human player with a safety instruction to a Safety model computer player or a human with a greedy instruction to a Greedy model player. The displayed orders are random and each type appears 37–38 times.

Experimental Results

The results of the experiment are shown in following chart



Figure 4: Score of naturalness of a behavior

The Safety model shows behaviors that are believable to the subjects. The frequency of a score of naturalness higher than 3 is almost equal to a human play with a safety instruction. There are some differences between the model and the human player. The most common reason that subjects presented was that "there are nearby coins that should be collected but they are not." Next, the performance of the Hurry model is lesser than that of the human player with a hurry instruction, but the gap between the naturalness scores is not large. However, the Greedy model, which does not consider any risk or danger, showed a significantly lower score compared to the human with a greedy instruction.

We also implemented rule-based switching to switch among the Safety model, the Hurry model, and the sample of the Greedy model to confirm whether believability will increase if a computer player produces many behaviors. The results show improvement in the Switching model compared to only the Greedy model or only the Hurry model, but it is still lower than the Safety model. The main reason is that overall performance depends on the quality of all individual models. Considering human plays, evaluations are high in the case of the free will instruction and the greedy instruction. The reason is that people tend to play in multiple styles (they play safe even when collecting coins). It might be said that the player with multiple behavior types looks more human-like than those with a single behavior do. Thus, behavior transitions are important for making a believable computer player.

CONCLUSION & FUTURE WORKS

We are able to confirm our hypothesis in the Safety model. Staying safe is a significant behavior among human players, which refers to maintaining distance from enemies and avoiding risky play. This important behavior makes a computer player appear more human. The result of the Turing test has shown that the believability of the Safety model is almost closely equal to a human player. However, there is still a claim from subjects about a lack of some behaviors, such as "searching for coins or items." These are related to our original hypothesis, where the human-like behavior contains multiple behavior types. In this article, we introduced Hurry, which involves risky play, and the simple Greedy model, which ignores all enemies. The quality of their believability in the Turing test is low, but after we combine them all using simple rules, there is an improvement in believability.

We also verified that the player with multiple behavior types looks more human-like than a single-behavior player does. This also conforms to our hypothesis stated at the beginning. Thus, our future work will concentrate on the believability of the Greedy model and the Hurry model, as well as on a better transition between these models. Additionally, a learningbased transition will be analyzed in the near future.

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GAME VR

VIRTUAL REALITY 3RD PERSON CAMERA BEHAVIOR MODES

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KEYWORDS

Virtual Reality, 3rd person, Camera behavior mode.

ABSTRACT

We describe and evaluate five different level design independent modes of handling camera behavior in the 3rd person game LizzE – And the Light of Dreams in Virtual Reality. The behavior of the different modes will each be illustrated in detail. To evaluate the modes A: *Fast circling*, B: *Lazy Circling*, C: *No Circling*, D: *Blink circling* and E: *Buffered pulling*, an experimental study with 33 subjects was conducted. An analysis of the resulting data will show why *Buffered pulling* seems to be the most promising of the examined modes. We elaborate on the quantitative and qualitative hybrid experiment design and methodology. Eventually the advantages and disadvantages of the five tested modes are discussed in terms of supporting the gameplay, player enjoyment, in game performance and the tendency to induce nausea.

INTRODUCTION

When conceiving a Virtual Reality (VR) game, one might quickly think of digital games in 1st person perspective because of the fundamental properties of VR Head Mounted Display (HMD) technologies. At this point the essential properties focus on translating the natural movement and rotation of the human head into the application. But VR games offer more than just the ability to intuitively move the head of the playable main game character. Among other possible game genres, 3rd person perspective games bring up interesting gameplay and design opportunities (e.g. having to look around a corner for the main character or various forms of communication between characters and the player entity/the stereo camera rig). However 3rd person perspective VR also poses significant challenges in terms of camera behavior. The critical need to avoid nausea or simulator sickness opposes most formerly traditional techniques of moving the camera in relation to the main character. Getting the camera movement and rotation right (Hurd and Bettner 2014) for the majority of players is crucial for engaging them in the game and prolonging play in the virtual environment. This becomes even more important when developing games for VR, as people tend to experience nausea more quickly and with increased intensity when wearing an HMD. For these reasons we wanted to explore the question: "In which ways can 3rd person VR games work for a broad audience?"

To evaluate different camera behavior approaches in 3^{rd} person VR in a "lifelike" manner, we decided to utilize a realistic use case. As complete source code access was a requirement, we chose LizzE – And the Light of Dreams as our primary game platform (see Figure 1) (FIERY THINGS 2013). To provide reliable and reproducible results in terms of damage points inflicted by attacks, we modified this hack and slay game to resign of any corresponding random range behaviors.

For VR applications, it is important to provide a high and steady frame rate. By removing some effects and lowering the default rendering quality, we achieved steady 60 fps in VR mode, with enough buffer to cope with any possible spikes in performance usage. Though relatively low at this point (Oculus recommends 90 fps for their upcoming CV1 HMD), this frame rate also made screen mirroring and thus the parallel video recording of the user and the game possible for our experiment setting. Furthermore, the camera behavior modes we wanted to explore in this experiment, should be level design independent and only relying on their algorithms and not manually placed waypoints or similar strategies. Hence, the relatively unrestricted, in all directions explorable level design was kept for the user test as is.

The remainder of this paper is structured into six different sections. The section "Related Work" will consider related work of this field. In the section "Experiment Methodology" we will describe the details of how the experiment was conducted and which observable variables were gathered per participant. The section "Camera Behavior Modes" will illustrate the different approaches of the five camera modes. We will list the extrapolated findings from the data in the section "Results". In the section "Conclusion" we will elaborate on our interpretation of these findings. Based on the tested camera behavior modes and our findings about them, we will offer developers an implementation recommendation. The section "Future Work" will cover possible next steps in research and implementation.

RELATED WORK

Reducing nausea and simulator sickness while maintaining an attractive gameplay does not only pose challenges for Virtual Reality, but for other sorts of developments too. The experiment on "Altering Gameplay Behavior using Stereoscopic 3D vision-based video game design" (Schild et al. 2014), explored among other topics, the effect of stereoscopic 3D on simulator sickness of subjects, while playing a 3rd person flying game, either in "side-scrolling view" or "behind-view" perspective. Schild et al. did not register a



Figure 1: Screenshots of LizzE - And the Light of Dreams, Non-VR Version (left) and VR Version (right)

significant impact on simulator sickness, when using a constant perspective with an UI optimized to reduce parallax changes in vision, while using the side-scrolling view without a constant change in depth animation. The behind-view with a lot of depth animation on the other hand, did show an impact on simulator sickness (Schild et al. 2014).

In terms of very detailed evaluation of simulator or motion sickness in the aeronautic industry, the Simulator Sickness Questionnaire is widely used (Kennedy et al. 1993). It features 16 different questionnaire items on a scale of 0 to 3, which result in the two latent variables "Nausea" and "Oculo-motor" (Kennedy et al. 1993).

In "The Benefits of Third-Person Perspective in Virtual and Augmented Reality?" the advantages and disadvantages of third person and first person views are compared in the context of Augmented and Virtual Reality (Salamin et al. 2006). They argue that, 3rd person perspective is usually preferred by users "for displacement actions and interaction with moving objects while the 1st person view is required when we need to look down or just in front of us for hand manipulations with immobile objects" (Salamin et al. 2006). Furthermore, 3rd person view seems to improve evaluation of distances and the anticipation and extrapolation of the trajectory of mobile objects. This seems to be due to the "… larger field of view provided by the position of the camera for this perspective. The user can thus better appreciate the situation and the distance." (Salamin et al. 2006).

Other studies support the notion, that the reduction of perceived self-motion illusions ("vection") (Riecke and Feuereissen 2012) seems very important when trying to reduce nausea (Yao 2014). Switching from passive observation to actively controlling locomotion significantly impaired vection, as vection onset latencies were raised and vection occurrence was reduced (Riecke and Feuereissen 2012). However, Riecke and Feuereissen's experiment also showed that the relevant parameter to reduce vection was not interactivity in general, but instead the specifics of the active motion control used (a Gyroxus motion chair for some sort of flying simulation). This seems to imply the benefit of using more natural inputs instead of metaphorical devices like joysticks or gamepads.

The game studio Playful (2016) recently released the popular 3rd person VR game "Lucky's Tale", a game very much in the spirit of Super Mario 64 and Banjo-Kazooie (Hurd and Reiland 2016). While developing the game, they were trying different approaches of creating an attractive gameplay and level design but also reducing the possibility for nausea to a complete minimum. Their solution was a combination of reducing user locomotion in general, mostly aiming locomotion away from the user and a clever more linear level design that does not require a lot of turning around (Hurd and Bettner 2014; Hurd and Reiland 2016).

Additionally to the pure functionality and usability of camera behaviors for users, they certainly also drastically affect the visual style of a medium. In filmmaking, camera movement is used to control pace, point of view and rhythm in a scene (Joshi et al. 2014). By manipulating camera movement, viewers or users can be pulled into scene or get disconnected from it and its characters (Joshi et al. 2014). Furthermore, "Camera motion, as a stylistic choice, is often so powerful that it can be the primary memory of a film or video ..." (Joshi et al. 2014), or other medium. For experimental design reasons, we did not examine these stylistic characteristics though.

LizzE – And the Light of Dreams did not offer any cut scenes or interactive dialogues in the context of this experiment. But as these possible game aspects are often occurring, further research is needed on how to implement these, specific for VR. In a non-VR context, Galvane et al. (2014) looked into narrative-driven camera control to create cinematic replays of digital games, with little to no manual adjustments. Instead of using an idiom-based technique, as in a stereotypical way of shooting a specific action, their approach is independent of the type of action happening (Galvane et al. 2014). Their technique is reliant on a certain game engine, specialized on dialogue and the computation and interpretation of importances of dialogue parts. Though this approach seems highly reasonable for dialogue heavy games, it comes with the requirement of manually extending the meta data to the dialogues and the related game engine. "Using a physically based model to control cameras offers a practical way to avoid unrealistic camera movements and ensures continuity." (Galvane et al. 2014) seems like an interesting technique for camera movement, which also might be viable for VR, though would need further research.

Reviewing related work has shown a lack of literature in the specific area of camera behavior modes in Virtual Reality. Our study will step in this gap, illustrate several approaches and evaluate them.

EXPERIMENT METHODOLOGY

The experiment hardware setting consisted of one Apple MacBook Pro (Mid 2012) with 2.6 GHz Intel Core i7 CPU, 16 GB RAM and NVIDIA GeForce GT 650M graphics card. As the primary input device we used a Microsoft Xbox 360 controller and for the HMD the Oculus Rift Developer Kit 2 (DK2) and corresponding position tracking camera. The experiment software was using the Oculus Runtime and SDK for OS X v0.5.0.1-beta and was running on OS X v10.11.5. Furthermore were all user test sessions video recorded with a common video camera.

The subjects were verbally and textually informed of possible health and safety issues, as well as the ethical usage of their data in the context of this research. By filling out the first part of a questionnaire, the participants agreed to the experiment terms and provided basic information about themselves and their experience with digital games and VR. The main goal for the subjects was communicated as eliminating as many enemies as possible, while themselves maintaining as much health as possible (see Figure 2). Furthermore, it was made clear that for experimental reasons, the participants could not die in game.



Figure 2: Experiment Application's first Screen

The procedure of the user test is explained to users as following: The experiment will go through six different modes. Each will last for 3.5 minutes and reset the game automatically afterwards, resulting in a total session duration of ~ 21 minutes.

The first mode will be non-VR and use the default camera behavior, so subjects can make themselves familiar with the original game first. Subsequently the five different camera behaviors will be tested in VR. The order of these modes will be pseudo random after a Latin square sequence for each participant. Between each mode, users are presented a screen showing the identifying character and title of the mode about to start (e.g. "Mode A: Fast circling"). Additionally, while playing, a countdown is visible, showing the remaining time of the current mode. Once all modes are finished, participants take off the HMD and are presented with the session specific order of the modes. This helped the subjects remind themselves when filling out the remainder of the questionnaire. A shortened example of the procedure and the different camera behaviors can be watched at: https://vimeo.com/wiedemannd/vr3rdpersoncamerabehaviors

In the questionnaire, subjects were asked about all VR modes on a 7-point Likert scale if they enjoyed e.g. "Mode A: Fast circling" and in a separate question if it supported their gameplay. Furthermore, they had to directly specify their preferred mode for the game LizzE - And the Light of Dreams and their preference "in general". Two free text questions asked about "How did certain VR camera behaviors affect the way you played the game?" and "Any thoughts about the different VR camera behaviors?". Finally, subjects were asked "Did you feel any nausea during the test, or right afterwards?" on a scale from 0 to 10. Due to the experiment design, nausea could not be ranked separate for each mode directly. This and the availability of previous data on a scale from 0 to 10 resulted in using this simpler nausea evaluation, compared to using the more complex Simulator Sickness Questionnaire (Kennedy et al. 1993).

Additionally, participants and their gameplay were video recorded during their session to capture any verbal remarks and gaming behavior.

Furthermore, aside from the mode order, the experiment application tracked the following in game parameters for each session per mode: *dealt damage, lost health, dealt damage/lost health ratio, kills, pseudo deaths and kills/pseudo deaths ratio.* From this data the following variables were extrapolated: *1st best VR mode in dealt damage/lost health, vorst VR mode in dealt damage/lost health, worst VR mode in dealt damage/lost health, sills/pseudo deaths, 2nd best VR mode in kills/pseudo deaths and worst VR mode in kills/pseudo deaths.*

CAMERA BEHAVIOR MODES

All tested camera behavior modes are level independent and thus only relying on their individual algorithm. Due to the nature of the game LizzE – And the Light of Dreams, a reduction of depth animation, as described by Schild et al. (2014) was not feasible.

The following illustrations and visualizations will describe the different modes on the X-Z coordinate plane.

To simplify visualizations, a *VR Rig* symbol was used, which stands for two cameras that render a stereoscopic and for VR optimized image to the screen (see Figure 3). The *VR Rig* also generally supports and handles 360° X-Y-Z head rotation and X-Y-Z head position translation (limited by the DK2's position tracking camera's frustum and distance). The

playable main character is symbolized by the *Char* figure and looks into the direction its arrow is pointing to on the X-Z plane.



Figure 3: Explanation for VR Rig Symbol

Mode A: Fast circling



Figure 4: Mode A: Fast circling Visualization

Fast circling, which is also the default camera behavior mode of the original non-VR game, is based on Unity's standard asset ThirdPersonCamera controller from 2013. The *VR Rig* is attached to the main character in a fixed distance. Moving the character into any direction immediately pulls or pushes the *VR Rig* with it. Turning the character will quickly circle the *VR Rig* in an animated way behind the character again with a mild damping (see Figure 4).

Mode B: Lazy circling



Figure 5: Mode B: Lazy circling Visualization

Lazy circling uses the same algorithm as Fast circling, only with partly different parameters. When rotating the character, the VR Rig circles slowly behind the character again. This is accomplished by adjusting the parameters angularSmoothLag from 0.2f (Fast circling) to 2.8f and angularMaxSpeed from 100f (Fast circling) to 18f. This results in a clearly stronger circling damping (see Figure 5).

Mode C: No circling



Figure 6: Mode C: No circling Visualization

No circling has the same fixed distance and position translation behavior to the main character as modes A and B do. The difference is the *VR Rig* does not circle around it, when turning the character (see Figure 6).

Mode D: Blink circling



Figure 7: Mode D: Blink circling Visualization

Blink circling as the modes A, B and C keeps the same fixed distance and position translation behavior to the main character. The circling is restricted to three evenly distributed and fixed camera angles around the main character at 0° , 120° and 240°. When turning the character, no immediate circling is performed. Only after the character's rotation corresponds to a new angle for more than 2 seconds a blink will be performed. In a blinking manner, the screen will very quickly fade to black. Then the *VR Rig* will be teleported in a non-animated way to the corresponding position and turned in the corresponding direction (see Figure 7). Afterwards the screen will very quickly fade back to the game environment. The complete duration of this process takes 0.25 seconds and feels very much like a blink.
Mode E: Buffered pulling



Figure 8: Mode E: Buffered pulling Visualization

Buffered pulling uses a very different approach. The character does not keep a fixed distance to the *VR Rig*, but can instead walk freely inside a buffer zone around the *VR Rig* without pulling or pushing it. Once the character reaches the border of the buffer zone, the *VR Rig* will get pulled with it, like on a leash. Turning the character has no effect at all on the rotation of the *VR Rig*. The user needs to physically turn (e.g. preferred in a swivel chair or standing), in order to look at the character, when it walks into a very different direction (see Figure 8).

RESULTS

The experiment was conducted with 33 participants (total n = 33), from which 23 were male and 10 were female. Ages ranged from 26 to 76 years and averaged at 31 years. According to the statement "I am an experienced digital game player", 19 were rather inexperienced (< 4 on 7-point Likert scale) and 14 rather experienced (>= 4) subjects, with a mean of 3.39. Rather little experience with VR noted 27 (< 4 on 7-point Likert scale) and rather more experience with VR only 6 (>= 4) of the participants, with a mean of 2.33. 17 subjects noted, they were playing digital games between "less than once a year" and "once every some months", whereas 16 noted they would play digital games between "once a month" and "every day".

The answers to the direct question "Which VR camera behavior did you prefer (specific for the game LizzE)?" ranked mode A: *Fast circling* on the first place with 30.3% and mode E: *Buffered pulling* on the second place with 27.3%. Whereas the answers to the direct question "Which VR camera behavior did you prefer (in general)?" ranked mode A and E together on the first place with 24.2%. As will be described later on, these results need to be interpreted with great care though. For a full comparison of the answers to these two questions see Table 1.

Table 1:	Directly	chosen	Camera	Behavior	Mode	Preference

	LizzE	In general
Mode A: Fast circling	30.3% (10)	24.2% (8)
Mode B: Lazy circling	18.2% (6)	18.2% (6)
Mode C: No circling	9.1% (3)	18.2% (6)
Mode D: Blink circling	15.2% (5)	15.2% (5)
Mode E: Buffered pulling	27.3% (9)	24.2% (8)

Two chi-square goodness-of-fit tests (Laerd Statistics 2015a) were conducted to determine whether an equal number of participants would choose either mode A, B, C, D or E as their LizzE specific and general preference. The minimum expected frequency was 6.6 in both cases. The chi-square goodness-of-fit tests indicated that the distributions of mode preference by participants in this study were not statistically significantly different (LizzE specific: $\chi^2(4) = 5.030$, p = .284, general: $\chi^2(4) = 1.091$, p = .896). Two additional chisquare tests were conducted with combined data of mode A + B, because of their similarity and mode C, D and E against a distribution of equal proportions for LizzE specific and general preference. The minimum expected frequency was 8.3 in both cases, due to the reduction from 4 to 3 degrees of freedom. In the case of LizzE specific preference, the chisquare goodness-of-fit test indicated that the distribution of mode preference in this study (with combined mode A + Bdata) was statistically significantly different ($\chi^2(3) = 11.970$, p = .007). In the case of general preference, the chi-square goodness-of-fit test indicated that the distribution of mode preference in this study (with combined mode A + B data) was not statistically significantly different ($\chi^2(3) = 5.909$, p = .116).

Though Fast circling was ranked very high as a directly chosen preference, it scored last rank with a mean of 3.15 on a 7-point Likert scale, when asked if participants actually enjoyed using it. Some subjects specifically noted increased simulator sickness, the need for heavy concentration, the need to actually close the eyes while circling and avoidance of rotation altogether. Furthermore, one participant had to completely discontinue the experiment while playing in Fast circling. Other subjects described it with the following words: "... extremely nauseating, after this mode all other modes were affected", "... is nearly impossible to play for a longer time (motion sickness).", "... very unpleasant." and "... was 'too fast' / confusing for an inexperienced player". Only four participants noted something positive for this behavior mode, mostly because it was similar to traditional non-VR behavior. Fast circling was also clearly ranked last in in game performance when comparing the dealt damage/lost health ratios (by 42.42%) and kills/pseudo deaths ratios (by 36.36%).

Lazy circling ranked better than *Fast circling* in terms of enjoyment (mean of 4.09) and support of gameplay (mean of 4.15). Though some described it as pleasant, still similar sometimes strongly nauseating effects were observable during other user sessions. One subject described it with the following words: "I didn't like lazy circling and I see no use for this mode, especially while playing a fast game like hack&slay ...".

The data shows that participants with VR experience (>= 4 in 7-point Likert scale; n = 6) were more likely to directly choose *Fast* or *Lazy circling* as preference for LizzE (83.33%) and in general (66.66%). The same is true, when looking at the direct choice of preference for LizzE (64.29%) of participants with gaming experience (>= 4 in 7-point Likert scale; n = 14).

In the context of an, in all directions freely explorable level, *No circling* understandably ranked last in support of game-

play (mean of 3.15). Subjects mention the uselessness of this mode when in need of turning, because of the level design: "... made it nearly impossible to play the game properly, because you can't always see the enemies / bullets", "I was a bit lost in no circling camera view because I couldn't see the way. So I tried more to focus [on] the way than on the enemy.", "Mode C is unplayable" and "... bad for orientation. Couldn't see the enemy.".

Blink circling leads the ranking in in game performance. With 27.27% each, it scored the best and second best rank in dealt damage/lost health ratios and with 36.36% the best rank in kills/pseudo deaths ratios. Opinions about this mode were mixed: "Blink circling was most comfortable as I didn't feel dizzy." and "blink circling was the most comfortable ...". But subjects also mentioned disorientation through blinking, the need for heavy concentration and blinks feeling too random: "... seemed more like a handicap to me, because it seemed to happen randomly", "The blinking-mode was ok at some spots but worst at others.", "I did not like and understand the Blink Circling because it didn't feel natural to me. The game just forced a different camera angle on me, abruptly.", "... spontaneously switching the point of view. That was absolutely weird." and "Blink Circling very abrupt, unexpected change of view". Because of the orientation problems, it does not come unexpected that Blink circling ranked second last in support of gameplay (mean of 3.6), one rank above *No circling*.

Buffered pulling clearly scored first ranks in player enjoyment with a mean of 4.48, as well as support of gameplay with a mean of 4.27. Most participants mention their delight about the need to physically turn. Participants mostly described this camera behavior mode as very pleasant and really enjoyable. Some furthermore noted: "The buffered pulling mode seemed more intuitive to me ..." and "buffered pulling was the most realistic one". The more critical participants mentioned sometimes losing sight of the main character and the inherent issues of physically turning, like pulling cables and the requirement for either a swivel chair or to stand up: "... a little obstructive because I ran out of my field of view sometimes", "Having to stand up and completely turn around to make the camera turn was gameplay wise rather hard to do since I just sat on a couch.", "With [mode] E the gaming experience was different and not so easy.", "Buffered pulling [was] only bad when [the] character is in the center and one has to look downwards.", "Buffered pulling was much more difficult, as I always had to look around to find the character and the cable of the glasses as well as sitting on a [swivel] chair was not optimal." and "Freedom of movement was limited by the cables.". In terms of in game performance, it scored the first rank in second best mode in kills/pseudo deaths ratios with 42.42%. Additionally 44.44% of subjects with stronger nausea (≥ 7 on a 0 to 10 scale; n = 9) preferred Buffered pulling specifically for LizzE.

For a full comparison of the results in enjoyment and support of gameplay see Table 2.

No gender specific results could be extrapolated.

For a complete listing of all captured and extrapolated data, feel free to contact the first author.

	Enjoyment	Support of
		gameplay
Mode A: Fast circling	3.15 ± 1.906	3.90 ± 1.860
Mode B: Lazy circling	4.09 ± 1.627	4.15 ± 1.482
Mode C: No circling	3.64 ± 1.966	3.15 ± 1.679
Mode D: Blink circling	3.73 ± 1.825	3.61 ± 1.580
Mode E: Buffered pulling	4.48 ± 1.805	4.27 ± 1.663

Table 2: Means ± standard deviation of Camera Behavior Mode Enjoyment and Support of Gameplay on a 7-point Likert scale

A one-way repeated measures ANOVA (Laerd Statistics 2015b) was conducted to determine whether there were statistically significant differences in enjoyment between the five different modes. There were no outliers and the data was normally distributed, as assessed by boxplot and skewness and kurtosis analysis, respectively. Enjoyment scores were normally distributed for mode A with a skewness of .433 (SE = .409) and kurtosis of -1.354 (SE = .798), for mode B with a skewness of -.202 (SE = .409) and kurtosis of -.946(SE = .798), for mode C with a skewness of .125 (SE = .409) and kurtosis of -1.185 (SE = .798), for mode D with a skewness of -.094 (SE = .409) and kurtosis of -1.118 (SE = .798) and for mode E with a skewness of -.687 (SE = .409) and kurtosis of -.679 (SE = .798). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(9) = 8.347$, p = .50. Enjoyment scores were statistically significantly different between the different modes, F(4, 128) = 2.725, p = .032, partial η^2 = .078 and partial $\omega^2 = .040$.

Another one-way repeated measures ANOVA (Laerd Statistics 2015b) was conducted to determine whether there were statistically significant differences in support of gameplay between the five different modes. There were no outliers and the data was normally distributed, as assessed by boxplot and skewness and kurtosis analysis, respectively. Support of gameplay scores were normally distributed for mode A with a skewness of -.138 (SE = .409) and kurtosis of -1.604 (SE = .798), for mode B with a skewness of -.645 (SE = .409) and kurtosis of -.459 (SE = .798), for mode C with a skewness of .463 (SE = .409) and kurtosis of -.674 (SE = .798), for mode D with a skewness of .248 (SE = .409) and kurtosis of -.422(SE = .798) and for mode E with a skewness of -.160 (SE = .409) and kurtosis of -.627 (SE = .798). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(9) = 12.550$, p = .185. The analysis could not lead to any statistically significant changes in support for gameplay scores between the different modes, F(4, 128) =2.417, p = .052, partial η^2 = .070 and partial ω^2 = .033.

CONCLUSION

In which ways can 3rd person VR games work for a broad audience? Though this might be similar for all VR applications, to keep a broad audience playing a 3rd person VR game, it is essential to eliminate causes for nausea and simulator sickness as much as possible, while still maintaining an attractive gameplay. Utilizing a well-accepted camera behav-

ior mode in terms of enjoyment and support of gameplay seems to be one of the most important steps. Conceiving and implementing individual viable solutions still pose significant challenges, but some approaches tested in this study clearly show great potential, whereas others seem incompatible for a broad audience in VR.

Though this study could not always elicit statistically significant quantitative data, in combination with the qualitative and observational results we extrapolated the following relevant conclusion.

When looking at the experience levels of subjects in gaming and VR, we argue that preferences to *Fast* and *Lazy circling* might be related to the already established familiarity to traditional camera techniques used in popular non-VR games like Super Mario 64, World of Warcraft and Banjo-Kazooie. Simple acclimatization with other camera behavior modes over some time might change their opinion.

The *No circling* approach, though reducing the vection effect, was clearly unusable for a level design that encourages exploration into all directions. A more linear level design like in Lucky's Tale (Hurd and Bettner 2014; Hurd and Reiland 2016) can make it a viable approach though.

In the case of *Blink circling*, nausea did not seem to be a significant problem compared to other modes, as it drastically reduces the vection effect. Furthermore, it offers a way of playing without requiring a swivel chair or physically standing up. It seems reasonable to expect better acceptance by users of this approach, once players have spent a longer time using it and were getting a better feel for when blinks will occur. As subjects were kept naive about the different camera behavior modes (except for their titles), some sort of explaining visualization and/or subtle tutorial could also help.

In this study, the *Buffered pulling* approach showed the greatest potential. The vection effect was reduced to a minimum through requiring natural movement (Riecke and Feuereissen 2012) and utilizing the buffer zone. Thus participants felt little to no nausea. Even though this is not true for all subjects, physically moving delighted the majority of them and increased their feeling of realism and presence (Lombard and Ditton 1997) in the game.

This collection of camera behavior modes is not at all exhaustive, but coming from the gathered findings of this experiment, when developing a 3^{rd} person VR game with a freely explorable level design, we recommend implementing fine tuned versions of *Buffered pulling* (default) and *Blink circling* (optional). This gives the users the possibility of playing the game either through physical movement or more stationary on a couch for example. Adding some sort of optional *Fast* or *Lazy circling* mode for traditionalists might be alluring, but a clearly visible warning of highly possible simulator sickness would be strongly recommended.

FUTURE WORK

Though thematically a bit more distanced, investigating users' perception of visual stylistics, as Joshi et al. (2014)

describes, in relation to usability of different camera behavior modes, could lead to an interesting parallel investigative lens in this field and would extend the findings in user experience of this study.

In case of *Blink circling*, the experiment showed the need to improve on supporting the orientation of users. Enhancing the user interface (UI) might be a viable solution. Adding a well designed compass-like "north indicator", for example to the outer edge of the viewing field could possibly help. Furthermore, a circle shaped, watch face like timeout indicator should improve expecting blinks and make their occurrence less random. The advantage of an UI solution is also the simplicity to make them optional for the user.

Experimenting with different fixed angle configurations (e.g. steps every 90°) for *Blink circling* could also be an interesting research direction.

Buffered pulling showed a similar demand in UI enhancement. Though, instead of indicating north, the outer edge of the UI could indicate the position of the main character instead, when this one runs out of sight. For the rare case, when the main character walked directly below the user, it might be interesting to experiment with automatically circumnavigating the main character around the user's center position or slightly pushing the VR Rig away from the character. The latter approach is likely going to increase the vection effect and might cause nausea, which would imply great caution with it.

Looking in more detail at the different session mode orders of this experiment might possibly bring up correlations to other outcomes.

Adjusting the experiment design could lead to other interesting findings. For example designing a level in the shape of a big spiral staircase could force more but also steadier camera turns. Restricting enemies to one single type would make tracking of in game performance data more uniform. A stricter more defined selection of subjects could lead to more aligned results.

Looking at and conceiving of other camera behavior modes is surely worth more research as well. For example a mode in which the user needs to manually control the circling with the second analogue stick seems logical. Furthermore, interesting results seem likely, when stepping away of the concept of algorithm only camera behavior modes. Testing modes, that utilize scripted level dependent camera angles, promises interesting results as well.

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"STOP THE ROLLER COASTER!" - A STUDY OF CYBERSICKNESS OCCURRENCE

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Cybersickness, Oculus Rift, Virtual Reality.

ABSTRACT

The increased demand for virtual reality applications with head-mounted display has aroused the interest on electronic games. These human-computer interface devices enable the users to mix the real and the virtual worlds, stimulating the sense of presence of the body in a synthetic scenario and therefore producing a new perception of body, space and even the reality in which it is inserted. However, the constant use or the experience in a poorly designed virtual environment may affect the user's health, providing, for example, cybersickness. This disease is associated with a dysregulation of the body's balance system and may cause nausea and headache. The aim of this paper is to analyze some of the probable causes of this disease, investigating and defining the speed of the scenarios in the 3D virtual environment. All experiments are conducted by means of different positions and speeds. Perceptions of users are collected through qualitative means (forms) and quantitative (extracted from Brain Computer Interface emotions) for further analysis. The metrics for the use of virtual reality defined here may help developers to reduce the user discomfort and minimize the effects of cybersickness.

1 INTRODUCTION

According to (LaViola 2000) an important problem with the current virtual environment (VE) while using virtual reality equipment, is the propensity for some users to feel some symptoms of motion sickness during the playtesting stage or some time after.

During the years 70, 80 and 90 it was developed several researches on displays of equipment for virtual immersion, these advances were the result of researches for military, industrial advances and entertainment use as defined by (Kiyokawa 2007).

In early 90's the development of equipment and virtual reality systems occurred fast because of the search to deploy this technology in industry, public and domestic environments (Sharples 2007).

This growing demand on virtual reality technology enabled a significantly rapid advancement of this technology. This advance allowed a few years ago, the public access to equipment that transmit the sensation of virtual reality such as some models of virtual reality goggles.

Have you ever experienced motion sickness while playing on Oculus Rift? In theory, with its high refresh rate and low latency most people should not feel sick. However, it takes some time to the person's body to fit on a virtual reality environment, especially for games where the character is running or rotating, while your body is sitting in the real world. Virtual reality can affect people differently. Therefore, it is necessary to resurface tests with people in different age groups.

According to (Davis et al. 2015), an important step in controlling cybersickness effects is the development of a simple objective metric. Most existing measures either rely on self-reporting or more expensive and complex objective measuring systems. The development of objective measures for cybersickness is an important step in understanding the causes and the effects on participants, as well as assisting attempts to improve the design of both the technologies involved and the environments being developed. These measures can assist in scientific aspects and improve the experience of users.

Researchers at the Federal University of São Paulo developed a research on virtual reality for the Treatment of Motion Sickness. According to (F. Freitas 2014), vestibular rehabilitation through Virtual Reality (RVRV) can be used for treatment and aims to recreate environmental changes, stimulating the sensory systems to adjust reflexes involved in postural control and the equilibrium strategies. Randomized patients tried two types of treatment to motion sickness. One of the groups was subjected to treat with Vestibular Rehabilitation by Virtual Reality (RVRV) and the other group through buccal rehabilitation (RV) with Cawthorne and Cooksey protocol (CC). The author also said that, with the RVRV a superior result with RV were performed by CC protocol for the aspect of self-perception of dizziness. However, regarding the aspects of quality of life and post urography parameters, both methods have been effective, despite the earlier results by RVRV.

At the School of Design, Communication and IT, of the University of Newcastle, researches conducted a survey which sought to discuss the growing interest in virtual reality games. In this research they asked to report possible relations of virtual reality using goggles with cybersickness. According to (Davis 2015) the review of the key issues related to cybersickness and their impact on the condition is reported. This includes a discussion of individual, device related and task dependent factors related to cybersickness. This research concluded that games with higher levels of visual flow has a significant possibility of causing cybersickness.

Certainly the issue is complicated as experiences of cybersickness vary greatly between individuals, the technologies being used, the design of the environment and the tasks being performed (Johnson 2005). This paper aims to conduct an analysis of the relationship between the use of virtual reality goggles and cybersickness, proposing a metric to use virtual reality goggles minimizing the effects of cybersickness.

2 CYBERSICKNESS

Motion sickness, commonly called cybersickness is an intolerance to movement resulting from conflict between vestibular sensory, visual and proprioceptive during passive movement of vehicles or movement of the visual field with the motionless body.

According to (Davis S 2015), cybersickness is another subset of motion sickness experienced by virtual reality users where they appear to be moving in the virtual scene while actually remaining stationary. Cybersickness is the motion sickness caused in virtual environments, its main symptoms are: nausea, disorientation, postural instability and other visual symptoms. Some factors influence the intensity that varies from each participant, the virtual reality system, virtual environment, the task performed, soak time, all of them can affect both the incidence and the severity of cybersickness.

Pregnant women, people with the need for corrective eye lenses or people who have diseases that cause nausea and dizziness are more likely to suffer from the effects of cybersickness.

(Kruk 1992) says that these individual factors might provide a further barrier to commercialization of virtual reality equipment as there needs to be consideration for a wide range of participants. Furthermore, particular users with health problems or under the influence of drugs and alcohol may have higher susceptibility to cybersickness symptoms

3 METRICS FOR EVALUATION

For this paper we analyzed methods to evaluate existing metrics used to measure the effects of cybersickness and its complications with virtual reality equipment. After studying the current methods to diagnose cybersickness we developed a method to evaluate the results obtained in the experiments.

3.1 Existing Metrics

After researching methods to diagnose and study the effects of cybersickness, according to [Davis S. ,2015], it

is subjective the task of rating of nausea, dizziness, headache and other symptoms which is reported by the user during interview sections after the playtesting section. In related studies the most used way to analyze and measure the nausea and the symptoms of cybersickness are through questionnaires that are made to the participant during the experiment. The questionnaire aims to relate the person's discomfort level over time. It asked the participant during the experiment their discomfort level according to a table previously defined to the participant. The question must be asked with the same time interval in all tests so there is a concise result. Based on tables, we made an average of the results of the experiment.

In the table we use as a basis the researchers sought to show the participant's discomfort relationship over time. The first line was the time set, the change in time was two minutes to each question, and the participant answered every two minutes your level of discomfort. In the first column were placed each participant identification numbers, so the table listed the restored over time to the practitioner

3.2 Metrics Created for This Project

For the evaluation of the experiment and comparison of individual results we prepared a table that contained a ratio over time with the participant's discomfort level, figure 2. The participant should report every two minutes what your level of discomfort that level should range from zero, for no discomfort, to ten for high discomfort with nausea and strong sickness, some of the symptoms of cybersickness. For each table, a chart was created with the average of the amounts reported by all participants. Seeking more accurate results and as a second form of evaluation we also used a Brain User Interface (BCI) to obtain information about what the participant felt throughout the experiment. For all tables taken from BCI we also made an average chart representing all participants. Thus it can be performed total evaluation and comparison of the results in the tables of the questionnaires and the one provided by the BCI.

If the participant feel extremely sick or a discomfort that prevent him from continuing the experiment, the participant could drop out at any time requesting the removal of the equipment.

Participant	Time						
Participant	2 min	4 min	6 min	8 min			
1	6	5	4	5			
2	5	6	6	6			
3	7	7	7	7			
4	7	6	6	7			
5	5	5	5				
6	0	0	0	1			
7	2	2	3	1			
8	2	3	3	3			
9	4	4	5	0			
10	7	7	7	8			

Figure 1 - Model of the Table used on Experiments.

4 MATERIALS AND METHODS

For this project we used virtual reality Oculus Rift for an immersion in a 3D environment, the BCI for an accurate analysis of the results obtained and Unity as a game development tool. We conducted a survey which a sample of participants played the games.

4.1 Oculus Rift

"In 2012, virtual reality has started to move to private and local industry applications and into the mainstream commercial spotlight" (Davis, 2015). This change may associated with the launch of be Oculus Rift. Facebook CEO Mark Zuckerberg envisions the device as a new communications platform to enhance everyday social experiences (Zuckerberg 2014). It uses a pair of screens displaying two images side by side, one for each eye. A pair of lenses is placed on top of the panels, and focusing the image remodeling for each eye, thus a 3D stereoscopic image is created.

4.2 Brain Computer Interface (BCI)

These devices have the function to transmit signals f rom the brain to be able to repair lost functions, such as hearing, movement of a limb. This equipment allows us to better understand the stress levels, relaxation, excitement and some other sensations that the participant during felt the experiment. "The success of device this the is easv adaptation to the brain." (Moreira, 2015). For this work we used the Emotiv Epoc+, which is a BCI device with 14 sensor inputs that are placed on the head to capture electromagnetic waves produced by the electrical activity of the brain cells." (Duvinage et al, 2012)

4.3. Unity

An IDE created by Unity Technologies, used for game development, similar to Blender or Torque Game Engine. We used the free version Unity 5.3.5f1 to develop the games used on the tests.

4.4 Developed Games

Two games have been developed for the experiments, both in the first person, with speeds pre defined. In the game, the participant is sat and not physically moving, most of the sets of movements were performed only by the game. The only movement reserved for the participant was the movement of the head, because due to the use of Oculus Rift that provides virtual reality the participant was immersed in the game scene. While moving his head, the player will be able to see the entire virtual environment providing a better immersion experience.

4.4.1 Roller Coaster

In this game the character is positioned on the first seat of the roller coaster, where it can easily get a view of the entire map and the tracks before him. The roller coaster has curves, ascents and falls that provide the participant an experience closed to a real roller coaster. Integrated into the Oculus Rift, the sound such as a real roller coaster was transmitted to the player though headphones, for a better ambiance play passing to the participant an intense feeling of real immersion in the virtual environment.

The average speed set for the roller coaster cart was 24,32m / s. For the experiments, we made three versions of the game changing only the speed.



Figure 2 - Roller Coaster Game

4.4.2 Twister

In this game the character is positioned in the center of the platform which spins in a certain speed. Because the environment is virtual it was possible to put a fast rotational speed of 95.5 m / s, because the participant does not suffer the effects of gravitational force and no other real physical force effect, only the possible effects of cybersickness.



Figure 3 - Game Twister Environment

5 EXPERIMENTS

To realize the three experiments was used the same computer and selected a fixed group volunteers which people dismissed who were suffering from symptoms of cold or flu, infections in the eye or ear, pregnant women, people who may have claustrophobia, epilepsy and vertigo and people who needs corrective lenses. The group participating in the experiments were composed of four women and six men, three of them already had experience with Oculus Rift. Participants used the Oculus Rift and the BCI equipment simultaneously for a better evaluation of their state of discomfort while immersed in the games. The low, medium and high speed applied in each game with the participants, had a duration of eight minutes, and every two minutes the participant was asked to measure their level of discomfort giving the score from zero through ten. The first evaluation was the application of the roller coaster, with speeds of 11.8 m / s, 24.32 m / s and 52.31 m / s respectively. In the second experiment day participants were immersed in the twister and subjected to application velocity 28.3 m / s 50.5 m / s and 95.5 m / s, respectively, challenged similarly in both experiments.

During the experiments it was made a 10 minutes' pause in each game speed transitions to avoid that the participant was immersed in the next step under great influences effects of the previous stage.

After the end of each experiment was observed and collected the data provided by BCI.



Figure 4 – Experiments

6 **DISCUSSION**

In the first experiment we used a different approach which the users were submitted to the roller coaster game faster speed will slow where most of the participants did not feel great discomfort of changes to the following speeds, claiming that they were already sick with the first speed and this sickness remained the same. We conclude that to obtain better results the right way to vary the speed is leaving the slower speed and increase the speed gradually.

The chart below presents the average of the experiments 1 and 2. The experiment 1, on a continuous line, represents the roller coaster speeding up while the experiment 2, the dashed line, represents the roller coaster slowing down.

Analyzing the table on figure 9, it is demonstrated what has been done. The continuous line represents the average discomfort level of the participants remained nearly constant with this one may notice little change graph. In the remaining three dotted lines it is represented the participant's level of discomfort increasing during the experiment at each level, the level of discomfort higher speed showed significantly increased thus having some participants requested to discontinue the experiment due to dizziness and nausea. Thus we believe that increasing the speed gradually with time reflects in increased discomfort when compared to the experiment in which the speed regressed.



Figure 5 – Experiments 1 e 2 Graphs

In the table on figure 10 it is shown the average results of the discomfort level during the third experiment. Inm this experiment, the participants pass through the twister game, the speed increases at three levels during eight minutes. It may be noted that when starting a new higher speed than the previous participant had a greater level of discomfort, it decays to spend time at the same speed, but to increase the speed discomfort made to increase. With this we believe in virtual reality experiments in which the user is performing the movement to turn the scene the tent discomfort to remain constant over time since the speed does not change, increasing significant. At low speeds discomfort may even decline over time due to the setting movement and a constant speed.



Figure 6 – Experiments Results Graph

At the end of the experiment, the participants who already had some experience with Oculus Rift did not show elevated symptoms of cybersickness, since participants who had no previous experience with the Oculus Rift reported.

Participants who had no experience with the Oculus Rift was noticed a great level of excitement, pink line on the graphs generated by BCI. With BCI graph can also be noticed variations in the levels of frustration, green line due to the discomfort felt by the participant. Picture 7 shows the average of the results obtained by the BCI.



Figure 7 – BCI Graph for Roller Coaster Game.

7 CONCLUSION

With these experiments we noticed that the time and speed influence to provoke cyber symptoms disease. It is advisable that developers give a right attention to the movement's speed so the games do not become unpleasant and so fail to achieve their goals and thus become tiresome. We note that each participant reacted differently submitted the speed, so the desirable speeds should be between the middle and fast to try to mitigate the effects of so cybersickness.

In future work we plan to conduct more experiments with different virtual environments and long-term experiments, to make more accurate and precise measurements so determine appropriate speeds to decrease the discomfort caused by cybersickness on specific applications.

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SERIOUS GAMING

GAMES: THE IMPORTANCE OF BEING EARNEST

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KEYWORDS

Serious Games; Digital Game Based Learning; Digital Humanities; Human-computer interaction

ABSTRACT

Video games are driving technological and societal advancements that serve gamers and non-gamers alike from entertainment to edutainment. Video game software is one of the fastest growing industries in the worldwide economy. 75% of the most frequent gamers believe that playing video games provides mental stimulation or education. Recent cognitive theories confirm that gameplay affects the brain. So, inspired by Oscar Wilde's "boutade" on his comedy *The Importance of being Earnest:* «we should treat all the trivial things of life seriously...» this paper proposes to justify why all games should be deemed very serious.

INTRODUCTION

Together with computers and software, the video industry, its customers and its technology have greatly advanced in the past decades. From a solitary white dot on a black screen (*Tennis for Two*, W. W. Higinbotham, 1958; *Pong*, Atari, 1972), analogical or DOS based, games became multimedia colourful worlds, dramatic and interactive experiences, currently enhanced by cloud computing and mobile access.

Entertainment software is now one of the fastest growing industries in the worldwide economy. Video games are driving technological and societal advancements that serve gamers and non-gamers alike: from leisure time to education, to health, to business or politics. Individuals or groups of family and friends now send their cartoon avatars soaring through multi-dimensional virtual worlds.

Today games create new worlds where players can manipulate and change their environment through realistic animation and unique motion-sensor controllers; they can be played simultaneously on several continents by millions of contestants. Devices for the young are used by senior citizens, bring families together and train corporate professionals. Video games have been transformed from a diversion for the few into a mass medium, helping people live, learn, work and, of course, play.

As the user population increased, market forces have driven developers to make games more accessible to this new, miscellaneous audience. The greater than ever demand for knockouts has translated into the explosive growth of the industry, which is one of the best performing sectors of any national economy – China (24,5%) being the largest video game market at the moment, with the U.S.A. (23,6%) and Japan (12,45%) as runners up (Statista 2016).

According to the Entertainment Software Association (ESA 2016) some 23.5 billion dollars was spent on video games in the USA alone, more than twice over since 2006 (\$ 7.3 billion). This supersedes PricewaterhouseCoopers' best expectations up to 2019: «Social/casual gaming revenue will exceed traditional gaming revenue in nine markets (...) creating a US\$ 22.52 billion market by 2019». They also estimated that «The single biggest shift in total video games revenue will come as countries such as India and South Africa see social/casual gaming revenue overtake traditional gaming revenue by 2019».

According to Newzoo the global online game market has reached \$ 99.6 billion in 2016 – mobile in itself generating 37% of the income - humbling the financial trend spotter's wildest visions for consumer spending on digital distribution and virtual items.

The EU is also aware of this boom. ERA has open calls for Gaming and Gamification in the H2020 programs.

Studies for the last 10 years confirm that the average gamers are 35 years old, have been playing for 13 years, and half of them are female (ESA 2016). Besides, gamers who are playing more video games than they did three years ago are spending less time on board games (43%), watching TV (37%) or going to the movies (37%). The average week time spend with MOGs (multiplayer online games) or MMOGs (massively multiplayer online game) is of about 6,5 hours per week. And one of the conclusions that supports the intended thesis – that all games are/ or have to be considered "serious" – comes also from the fact that 75% of the most frequent gamers believe that: «playing video games provides mental stimulation or education» (ESA 2016:6).

This paper aims to be a speculation over the main topics raised by the lack of a flawless terminology and ontologies regarding the issue of games and "serious" games. It addresses the problems that had to be faced, and solved, during the preparation of two practical "serious" games' projects – InStory (2006) and PlatoMundi (2009). Furthermore, it aims to stress the upsetting fact that non-serious games are being used for learning purposes taking no notice of the most recent cognitive theories about active learning processes. So, inspired by Oscar Wilde's "boutade" on his comedy *The Importance of being Earnest*: «we should treat all the trivial things of life seriously...» it proposes to justify why all games should be deemed very serious.

VIDEO GAMES AND EDUCATION

With computer and video games corporations posting record sales – over cinema and TV – entertainment software companies are creating jobs and producing revenue for communities across the nations (Harding-Rolls 2007).

Ten years ago, BBC News, interviewing Mike Griffith, reported that video games are poised to «eclipse» all other forms of entertainment and, relating to the evolution of games themselves, enhanced the importance of narrative content, as «games are no longer pre-set trips through linear mazes, they are becoming a legitimate story-telling medium that rivals feature films». Still from the other side of the Channel, BAFTA (British Academy of Films and Television Arts) devised a new Award for Video games in 2012, with as many categories as cinema and TV.

The economic and research potential of making games, "serious" or otherwise, more appealing is impressive (Statista 2016) and education is one of the fields that is benefiting from humans' constant demand for more intelligent and interesting games.

Research development in academia

From the incipient, pioneer, academic research groups – like <*e-Adventure*> (U.T. Complutense, Madrid, 2003) making a platform to facilitate the integration of educational games and game-like simulations in educational processes; or in Portugal, the European project *e-vita* – proposing new approaches to problem-based and contextualised learning; knowledge-transfer mechanisms integrating Game Based Learning [GBL] turned into huge research networks, like The Center for Computer Games Research (with Espen Aarseth); The Video games Research Networking; or Kids On-line.

In 2014 MMO has become a Science - Attila Szantner and Bernard Revaz, the founders of Massively Multiplayer Online Science, hope to use video games to drive research.

The first Studies by ADL Initiative (U.S. Department of Defence) have proven a skill increase of 100% in trainees using games (Blunt 2007; 2013).

This success has generated an interest in the industry's educational and career opportunities greater than before, and led game design to enter the academia - i.e., as M.I.T. Game Lab.

New and very successful degree programs can be found everywhere: «Increased demand for game development courses at leading universities is offering a new career path for veteran game designers; as teachers» (Campbell 2014). Naturally, governments everywhere started investing hugely in the sector of Digital Economy Development.

Games as a teaching device

Educators are progressively recognising more the impact of entertainment software and utilising games as a teaching device. The use of computer and video games, from favourite leisure activity, became a critical and still-emerging educational resource, the next generation potential learning tool.

The most recent "serious" games are now being used to impart knowledge, develop all kind of skills in people of all ethnicities, genders and ages (Blunt 2013). From the classroom to national organizations, the use of games is becoming a key fixture to teach and train students, employees, and the public in general.

But the power of video games for learning has to be harnessed, and the items built in accordance with the science of learning. From start developers of educational games aimed to target the desired learning outcome, and then designing the game to achieve that target; they also had to consider third-party users of their applications who support, augment, and monitor player progress.

The challenges are significant for DGBL (Digital Game-Based Learning). Designers demanded pedagogical support, Faculties could do with assistance during development and carrying out of DGBL, and students needed supplementary encouragement throughout implementation, just as it happened in its beginnings with online learning. This also meant that institutions had to train help desk staff, provide documentation (FAQs, configurations), new procedures, and course materials.

Computer and video games have become successful global vehicles to teach important values, in the social, historical or political arenas. But a focused robust program of research and experimentation is essential to enhance development of DGBL by stimulating transfer of the art and technologies of video games to education and learning systems.

Games and "serious" games – (un)definitions –taxonomy - ontology

The first Wikipedia entries defined "serious games" as: «a term used to refer to a software or hardware application developed with game technology and game design principles, for a primary purpose other than pure entertainment.

The "Serious" adjective is generally appended to refer to products used by industries like defense, education, scientific exploration, healthcare, emergency management, city planning, engineering, religion and politics».

This characterization and posterior ones entail several flaws – starting with the concept of «game».

Designers themselves do not agree about a pure exact meaning and define it by negatives. It is not a puzzle, because puzzles are static and games interactive; it is not a toy, because toys are interactive, but a game has goals; it is not a story, because stories are linear and games are not; it is not art, because the arts play to a passive audience and games require an active participation.



Figure 1: Identification of "serious" games, D. K. Schneider

Something similar occurs within programming, as it covers several areas: graphics, scripting, sound, music and voice; networking; use of controls; AI (Artificial Intelligence).

Also, there are no clear rules – a gold standard – to tell a good game from a bad one. The cataloguing is empirical, according to genres, and results from satisfaction with playability, the immersion or pleasure provided – all three idiosyncratic. Besides, many games blur the taxonomic lines where they are included, blending strategy with action and role playing, for instance. It is critical, therefore, to understand not just how games work, but how the different types of games work, and how game nomenclatures can be aligned with learning nomenclatures.

Stéphane Bura, co-founder of Storybricks and author of the MMORPG *EverQuest* series (1999-2016) summarizes the problem: «There are no universally accepted truths, only opinions about what makes a great game, whether or not video games are an art form or whether there is an effective method to teach video game design. We lack ways to compare games in an objective manner, ways to describe them in a shared language. Without proper description, there can be no true understanding. Success in video games still hinges on applying traditional techniques copying, marketing, luck, or genius. And even if success is achieved, there's no guarantee that we can know why it happened. Arts and sciences have rules and laws, not just techniques. But what are the rules of video game design? Where is our redox law? Our perspective rule? Our theory of relativity?» (Bura 2008).

From the researchers perspective (Boile, Hainey et. al. 2015) the literature review systematizes but does not advance much.

All this is not surprising because, in spite of its huge development in the most recent years, computer and its related sciences are in their infancy. Classifications are yet hybrid of previous practices – programming, graphic art, cinema, and storytelling – now all fused in the new tentative idea of "transmedia". Ontologies, systematizations are in the making. And it is the discovery of this New-found-land that attracts most practitioners and researchers.

DGBLearning and (mis)use of games

Educational games range from online versions of chess or specially designed board games to highly stylized virtual environments in which users create personas and explore new worlds. By playing "serious" games, students can learn about the food chain, memorize the periodic table, or perfect their multiplication skills. They can solve a complex math problem, test scientific theories, or gain understanding of an historical event or culture.

Being still young, DGBL is not an exception in ambiguity in what regards games rules and taxonomies. For the moment, there are three sorts of games in use: a) Commercial educational video games, known as edutainment, that teach specific basic skills (Math Blaster, Pajama Sam and Dr. Brain recently re-casted from an old scientist into a young genius); b) COTS (Commercial off-the-shelf) entertainment titles used randomly by schools for education (Age of Empires or Syd Meyer's Civilization for History; SimCity for civil engineering; CSI for forensics, not to refer all the possibilities offered by Second Life) - this group has to include Microsoft's latest (2016) attempt to transform Minecraft into an educational game, for free, probably to compete with LEGO's very successful and expensive MINDSTORMS and Education EV3 – which could also be included in the next category; c) Academic games used for training and education (Gamelearn), some without the graphic glamour of the above (The EIS Simulation).

A review of DGBL literature shows that, in general, educators have adopted three approaches for integrating games into the learning process: have students build games from scratch; have educators and/or developers build educational games from scratch to teach students; and integrate COTS games into the classroom. This latter is the riskiest attitude, either for pedagogical, psychological or intellectual reasons. First of all, because COTS are made for the big market and do not take any particular teaching or learning theories into consideration; secondly, they may worsen the difficulty some students already have in distinguishing games for play, from games for work; and also, among other numerous motives, because the information, historical or other, given by the great majority – either in text or in context – is not acceptable by scientific standards.

For instance, *Colonization* (Syd Meyers) has been criticized, among other things, because it ignores slavery and, to win, the player has to exterminate all native tribes. In *CSI*, the game as in the TV series, the lab processes (and corpses) are glamorized; in *Age of Empires* the bulk of historical information was gathered in children's books and regarding geographical data – the «hallmark» of the series – the user, in «Random map» mode, plays on a map based «very loosely» on a real world area. *Age of Mythology*, is a spin-off of the previous, in a much reduced mythological space, with only three main gods per civilization.

The developers do not accept to be criticized for these content blemishes as they present them as fantasy games. But some of these games have been a-critically used in the classroom for learning purposes.

ALL GAMES AFFECT THE BRAIN

Scattered among the defenders and opponents of the use of video games as learning tools is the idea that games affect the brain – positively and therapeutically for some, developing aggressivity and violence to others. In both cases video games, or all games implying any kind of action/activity, modify the cognitive functions. All – demanding responses and receiving feedback – involve some form of active learning, sometimes reinforced by the repetition of tasks and rewarding in points or badges. Since old Rhetoric times that *repetitio est mater studiorum* – repetition is the mother of study/learning – and *repetitio est mater memoriae* – repetition is the mother of memory.



Figure 2: How a Gamer's brain is supposed to work

Studies confirm the development (at different levels) of visual acuity, temporal processing, attention skills, short term or working memory, fluid intelligence and multitasking – some lasting for up to six months.

Where does learning occur in (serious) games

Learning in (serious) games (Blunt 2013) occurs at four levels: Game mechanics (replica of the real world); Goal / mission (fighting a particular type of problem plus the strategies to win); Context (supports the learning objectives in time to solve the several levels of the problem); Challenge (tools and activities to overcome a particular objective). These are the steps that constitute any game, and are embellished and overstressed in the commercial ones.

From the industry of e-learning programs the three top cognitive science-based recommendations for success are: a) engage active recall (use of short term memory) to promote deeper learning; b) foster metacognition – "thinking about one's thinking" – as a kind of self-reflection to help the concepts become more memorable (use of long term memory); c) implement spaced repetition at customized intervals in accordance with learner confidence levels and memory spans (long term memory).

One of the discoveries – attributed only to "serious" games – is that: «playing some types of video games produces significant and long-lasting enhancements in a variety of cognitive functions.

The scope and scale of these beneficial effects has prompted many research groups to test efficacy of video games in realworld contexts such as in rehabilitative settings or in job related training (Green, Bavelier 2015). This study, centred on action video games and cross sectional experiments, is an example of the theories that only "serious" games provoke changes in perceptual, attentional and cognitive skills. And let's slip a very interesting issue: «recent work has suggested an alternative viewpoint wherein action video game experience, rather than producing immediate benefits on new tasks, conveys upon users the ability to more quickly and effectively learn to perform new tasks. In other words, action video game players have 'learned to learn.'» (Green, Bavelier 2015:105). In spite of this, they agree with the hypothesis of «utilizing off-the-shelf action video games for practical purposes --- either in rehabilitation or for job related training.» (Green, Bavelier 2015:108).

Violence and ethical issues

The 2015 Game Award for Best Fighting Game was attributed to *Mortal Kombat* X – where Cassie Cage is supposed to interact (and fight against) her parents (Sonya Blade and Johnny Cage) exploring a new (bloody) graphic aesthetics.



Figure 3: Cassie Cage - Mortal Kombat X

In 2016 among the top 20 selling video/computer (mature) games come *Call of Duty: Black Ops* [1st. – mature First Person Shooter/ 1st. BAFTA 2016 - a single player heist plot, that can use torture (waterboarding); *Grand Theft Auto V* [6th. /8th. – 3rd. BAFTA 2016: «with a penchant for carnage and violence» (Hoggins 2013), also accused of being «a nasty example of misogynist clichés» (Campbell 2014).

Allegation that games develop (at least) violent tendencies and criminal behaviour (*Mortal Kombat, Doom, Grand Theft Auto, ManHunt*,) as well as addiction (*EverQuest*) particularly amidst the players of MMORPGs has not subdued. There is an *Index* of banned video games, institutional rating systems (i.e. the American ESRB, the European PEGI), and Support Groups like OLGA (On-Line Games Anonymous).

On the other hand, some video game developers have tried to fight this kind of moral panic: from a Christian perspective – *Noah's Ark, Left Behind: Eternal Forces* (that battle and kill non-Christians who are fighting for the Anti-Christ), approved by Christ Centered Gamer, i.e., or not: *Roller Coaster, Food Force* (Unesco), environmental (*Climate Challenge*) or even with social issues (*Ayiti: The Cost of Life*) all far from being interesting or marketing successes.

Reputable scientific studies do support both sides – there is no doubt that games have potential to foster ethical thinking and discourse. Ethics is the practice of enacting a judgement (moral in the case) to achieve a better life; it is the process of making choices in accordance with individual freedom of options, with the goal of becoming a better (good) person.

Videogame avatars distribute themselves between good and evil. Usually their actions are too simplistically determined at survival level (to kill/be killed). But games and simulations might be rich in ethical options.

The subtlety or complexity of moral dilemmas can be embedded in content, via storytelling (the narrative bifurcation) coupled with AI – either establishing preferences through abducibles, and implementing choice mechanisms combined with other formalisms for decision making (Moniz Pereira, 2009, 2016); or using prospective logic programming (following either the double or triple effect reasoning) to model moral dilemmas: «as they are able to prospectively look ahead at the consequences of hypothetical moral judgments. With this knowledge of consequences, moral rules are then used to decide the appropriate moral judgments. The whole moral reasoning is achieved via a priori constraints and a posteriori preferences on abductive stable models» (Moniz Pereira 2010).

EDUTAINMENT AND LEARNING THEORIES

The learning outcome from the educational use of video games seems promising, in spite of some methodological flaws (lack of control groups; short exposure time), contradictory results, and assessment issues yet to be dealt with. Some studies have contributed to attest its positive influence with flying colours (Blunt 2006); others – civilians or not – are more skeptical (Hayes 2005).

No one questions that video games affect humans and that humans can learn from video games. But concerns arise when considering the particulars: a) the use of ill-defined terminology; b) Methodological flaws (research on different tasks, age groups, and types of games, i.e.); c) Overgeneralization (the effectiveness of one game in one learning area for one group of learners cannot be extended to all games in all learning areas for all learners); d) Doubts if the learning outcomes refer to content or playability; e) Lack of proper design of instructional objectives; f) Assessment and testing issues. The focus is not on software or hardware matters anymore, but on content. And the problem is to know what content will have to be created to deal with these gaps, and by whom.

Some believe that this is the teacher's responsibility; others suggest that the more students are responsible for their own learning, the more they will learn. Without any doubt there is some content that will not be realistic for students to address on their own; and surely the teachers may function as consultants, but they cannot all be transformed into game designers, in spite of game designers having been transformed into pedagogues. Maybe within this last proposition lies the justification for the (fallacious) idea that users play to feel emotions, and game design is experience crafting for the purpose of emotion engineering.

The approaches to edutainment have mostly been tainted by traditional (analogic) learning theories, namely Behaviourism (Pavlov, Thorndike, Watson, Skinner), Cognitivism (Bode, Miller, Sweller), Constructionism (Piaget, Papert, Kafai) and the Socio-cultural approach (Bruner, Vygotsky) on the way to Blended learning (Heinze, Procter).

In what regards edutainment – closer to games – the main questions have to do with interactivity, original trade-offs (playability) and intrinsic/extrinsic motivations (immersion).

These referred main approaches depict a series of problems that inform and are being (separately) studied by game and interactive-fiction studies (Egenfeldt 2008; 2011), but which seem to contaminate DGBL with a set of dispensable dichotomies: what is edutainment (learning/playing; drilland-practice/construction); where does the user agency lie (freedom/control; with/without teacher/narrator intervention). In another set of dichotomies (Bura 2008) the term «control» is replaced by «mastery», where freedom «deals with measuring choices and opportunities for choices» and «mastery deals with measuring skills, their acquisitions and their uses».

The most recent educational cognitive theories – namely the ones defended by Hélène Trocmè-Fabre, based on brain functions, types of memory, and attention spans (Trocmé-Fabre 1999; 2004) or the studies of Jeroen G.W. Raaijmakers (Raaijmakers 1988; 2003) – although inspired by and inspiring the new efforts for mapping the brain (i. e. The Human Connectome Project) - have not yet been pedagogically considered.

The natural conclusion is that video games in edutainment have something to offer that sets them apart from the existing educational practices, and so, have to ask for new responses in this domain. Also, and in spite of the huge differences, games are very similar between themselves in the fact that – serious or not – they all interfere with (known) brain functions. So, it is very important to be serious about games.

CONCLUSION

Entertainment software is now one of the fastest growing industries in a worldwide economy. Video games are driving technological and societal advancements that serve gamers and non-gamers alike: from leisure time to education, to health, to business or politics.

The evolution of game studies from research centres to large networks grow on a par with the demand for game developing courses in academia – some taught by successful game developers aware of game mechanics but ill prepared for pedagogical contents.

The concepts behind games, and "serious" games, are not yet clear and have been defined by refutations. This negatively affects DGB Learning – from both the teacher and the student perspectives. Concerning edutainment per se, the empirical research suffers from lack of systematization, theoretical and methodological flaws.

The traditional learning theories fall short and are inadequate for this new medium; and the cognitive studies' advances regarding education have not yet been fully applied. In technical terms, new challenges are imminent with the exploration of augmented reality, ubiquitous game interaction (Martins, Correia, et al. 2008) and SR-Learning (Martins, Sommerer, 2008) and the expected developments in brainmapping.

The adjective "serious" annexed to games – and the respective research – has been based on the (mis)conception that only some games affect the brain. However, either due to the fact that game construction and mechanics are similar for edutainment or entertainment, or that the practical use and process of gameplay always affect the brain, all games should be considered "serious".

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GAME-BASED LEARNING IN MOBILE TECHNOLOGY

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KEYWORDS

Game-Based Learning, Mobile Technology, Html5, Tablet, Language Learning, co-design.

ABSTRACT

In the last decade, a huge number of studies on gamebased learning have revolutionized education and Information Technology (IT). The purposed research consists in a project, aiming to prove the efficacy of mobile game-based learning for language education. We ended up developing a language learning game with the most innovative HTML5 framework in order to author an engaging learning game suitable for any devices. In order to provide a deeply involving learning experience, a codesign methodology was adopted for the development of the game "Learn German with Mr. Hut". Thus, co-design sessions were extremely useful for the development of all the parts of the game. In this paper we describe a first step of our project. Future work consists in involving the codesign focus group to test the game. Post-testing questionnaires would be administered to pupils in order to assess the efficacy of our project. The main expected result would be the assessment of the potential of a mobile game based project to improve foreign language learning. Moreover, we expect that the theoretical framework we developed would be useful and potentially effective for the development of further learning projects.

INTRODUCTION

Currently, the role of games has been re-evaluated and reconsidered in a new reading key. In the last decade, various researches show that games provide an effective educational support. In addition to that, game-based learning (GBL) environment arouses students' motivation, improving learning processes and goals (Prensky, 2001). It has been shown that motivation influences students' learning approach, relating to a high quality of learning outcomes (Deci & Ryan, 2000; Kyndt, 2011; Trigwell & Prosser, 1991). The increase of Mobile Technology may be considered as a further enhancing strategy for learner's involvement in the learning context (Hildmann & Hildmann, 2009). Moreover, previous researches show the effectiveness of game-based learning with reference to the innovative co-design methodology, which allows learners to participate actively into the development of the game in all its parts. In this paper, we present a game-based learning research, which is based on mobile devices. In order to prove the effectiveness of our project, we have developed a learning game in HTML5 code, which focuses particularly on foreign

language learning. We also adopted a co-design methodology approach, which represented an added value for the development of our mobile game-based learning project. Future work and background framework will be explained in more detail below.

1. GAME-BASED LEARNING IN MOBILE TECHNOLOGY

Games naturally support education, providing some of the important characteristics needed for most the achievement of an effective learning process. In addition to that, the development of technology and the recent explosion of mobile devices' use have been changing traditional didactic approaches, promoting innovative and more engaging learning environments. Prensky (2001) argues that computer and videogames are possibly the most engaging pastime ever. According to Prensky's (2001, p. 1) view, this is due to a combination of different elements, composing and characterising games, such as enjoyment, involvement and motivation. The game particularly the videogame - can be considered as a "highly interactive experience" (Prensky, 2001, p. 2). While fun puts the learner in a relaxed context, furthering a high receptive frame of mind for learning (Prensky, 2001, p. 5), technological devices provide a multi sensor stimuli (Hildmann & Hildmann, 2009), empowering emotional responses and involvement. Inter-activity represents one of the core elements of the game-based learning environment, which is mainly provided by mobile devices. This implies that game-based learning contexts provided by mobile technology can increase learner's involvement, who concretely experiences a highly motivating context, which consequently supports effective learning and positive final goals.

1.1 Game-Based Learning

The real value of game-based learning is to create meaningful learning experiences (Kapp, 2012). Gamebased learning contexts offer an engaging learning experience, encouraging learners to a positive and motivating approach towards learning contents. As studies show that motivation has a deep influence on learning processes (Kyndt, 2011), the mechanics of gamebased learning environment are closely aligned with the model of the Self-Determination Theory (SDT) (Deci & Ryan, 2002). According to Deci and Ryan's studies (1985), an engaging learning implies intrinsic motivation, which is considered as the state of doing an activity for the pleasure, inherent satisfaction and enjoyment (Deci &

Ryan, 2002). According to Deci & Ryan's theory, it is "integrally connected to the need for competence and autonomy" (Deci & Ryan, 2002, p. 13) and strictly influenced by relatedness. In other words, to be motivated simply means "to be moved to do something" "Because intrinsic (Deci & Ryan, 2000, p. 54). motivation results in high-quality learning and creativity" (Deci & Ryan, 2000, p. 55), it is closely linked to learning through experience (Kirkpatrick, 2008). According to Kolb (2014), experience represents the core element of the learning cycle (Kolb, 2014). The Kolb's theory of experiential learning is based on Dewey's theory (1998) of experience, explaining the organic connection between education and qualitative experience (Dewey, 1998). Studies and researches show that successful didactic processes build upon opportunities of activity (Piaget, 1951) and creativity (Vygotskij, 2004), which are both provided by games. In addition to that, the experiential education aims to combine "multi sensor stimuli with practical learning as well as making use of emotional incentives and learning strategies in order to facilitate development" (Hildmann & Hildmann, 2009, p. 173). This implies that, as virtual contents' structure employs and offers a combination of various forms of media and emotive stimuli that actually reduce cognitive load (Moreno & Mayer, 1999), a game-based learning environment concretely represents an innovative way to motivate and enhance apprenticeship, its processes and its goals (Antinucci, 1993).

1.1.1 Co-design Methodology

In the game industry, co-design sessions are useful in gathering opinions and ideas from the target group, in order to create a game, responding to players' interests. Moreover, as the Psychological Ownership Theory (POT) by Beggan (1992) explains how the relation between the object (the game) and its owner (the pupil) is deeply marked by emotions, pupils' may consider the game as "their" own creation. Emotion is one of the basic elements for motivation (Prensky, 2001). Therefore, codesigning may represent an innovative way to increase involvement, enhancing pupils' learning final goals. The idea of co-design methodology as a learning motivator is tackled in various researches. All, Van Looy and Nunez Castellar (2013), in their discussion about their educational location-based game, for instance, highlight that co-design sessions were useful in exploring opinions of the target audience and broadening the designers' perspectives. In addition to that, enabling learners to be self-directed learning designers represents an efficient way to involve students in learning processes (Laerke Weitze, 2015).

1.2 Game-Based Learning In Mobile Technology

The ownership and the use of mobile devices have been changing learning arrangements (Marengo & Pagano, 2016). The enhancement of the innovation of GBL environment is due to the increasing use of mobile

devices in GBL contexts. Hildmann (2009) in his framework argues that an appropriate use of mobile devices can useful support educationalists' work, enhancing positive learnings' outcomes. The Framework for the Rational Analysis of Mobile Education (FRAME) model by Koole (2009) describes mobile learning as a "process resulting from the convergence of mobile technologies, human learning capacities, and social interaction" (Koole, 2009, p. 25). According to Marengo and Pagano (2016) the expression 'Mobile learning' (Mlearning) "is a blend derived from mobile and learning" which "means learning using mobile devices such as PDA, mobile phone, digital audio players, digital cameras, voice recorders, etc.". Mobile technologies and multimedia inter-act with human learning processes, facilitating learning activities. Previous researches show the effectiveness of mobile game-based learning about teaching/learning different subjects and disciplines. The research study conducted by Marengo and Pagano (2016) focuses on the HTML 5 adaptability on mobile devices through the creation and testing sessions of a business game, showing that tablets are the most suitable devices to use the application. Manuela Feist (2009) has developed the game-based learning application Journey to the Galapagos Islands about Charles Darwin and his theory of the evolution (Feist, 2009). Kukulska-Hulme (2009) notices the deep impact of the daily use of mobile devices on learning and highlights the new engaging ways of learning that this new technological phenomena offers to learners. All, Van Looy and Nunez Castellar's project (2013) exploits the basic mobile phones applications in combination with the mobility of traffic safety, in order to develop an educational location-based game. Kristian Kiili et al (2013) have developed a first and fourth grade mathematics game suitable for smartphones and tablets. Their case studies show a positive attitude of student's about the game and its tasks. The concept of inter-activity as a learning enhancement builds upon the comparative analysis of multimedia's elements of the Theory of the Dual-Coding Systems. dealing with the adaptive functions of nonverbal and verbal systems (Paivio, 2014) that deeply contribute to learning processes. This is notably strong in regard to language evolution and learning. As neurological and linguistic studies demonstrate that dual-coding memory is implicated in language learning (Cardona, 2010), the use of mobile devices fits well for language apprenticeship (Cardona, 2010). Sandberg, Maris and de Geus' project (2011) shows the effectiveness of using mobile technologies for learning English as a second language and, in particular, it highlights the positive approach of students towards the use of smartphones in learning contexts.

2. METHODOLOGY

A mixed approach was adopted. On one hand, a qualitative approach was adopted in developing the project game "*Learn German with Mr. Hut*" and for codesign sessions' questionnaires. On the other hand, a

quantitative method was adopted in exploring background habits of learners about learning through games during the co-design sessions.

2.1 Co-design Sessions

In order to provide to learners an involving learning environment, we decided to engage learners in the codesign process. Co-design sessions aimed to explore the learners' interests, in order to build a deeply motivating learning game project. Co-design sessions based on questionnaires, asking learners:

- to express their habits about playing at videogames using IT (PC, tablets, smartphones), their preferences, their tendencies and their opinions about learning didactic contents through game-based environments;
- to give their opinions about some characters that our team had previously projected and drawn -.

2.1.1 Participants

A focus group composed by pupils ranged between 6 - 12 years of a primary school in Conversano (Italy) was selected for the co-design sessions. 46 pupils from a Year 2 class (27) and a Year 5 class (19) took part in the project. Pupils are Italian speakers without any German language skills.

Table 1: Number of Participants per Years Class and Genre

Year Class	Male	Female
Year 2 Class	13	14
Year 5 Class	10	9

2.1.2 Co-designing Procedure and Results

A daylong session took place in the Secondo Circolo Didattico "Via Firenze" School - Conversano (Italy). Each pupil has been given a tablet with the questionnaire on display, so that he or she could start answering the questions and co-designing the project. The results show that more than a half of pupils have access to consoles, tablets and smartphones for gaming. The findings that the 66,7% of pupils uses smartphones and the 71,1% uses tablets is particularly interesting. Moreover, these results show how pupils concretely prefer mobile devices to PC or consoles for gaming. In addition to that, the 97,7 % of pupils wants to learn school subjects though games. Both these findings are of great benefit to our research. On one hand, they confirm our expectations about the potentiality of games in learning contexts; on the other hand, they assess the huge ownership and usability of mobile devices by children. During the co-design sessions, we also showed pupils some drawings, asking them to express their opinions and impressions. In other words, it was about choosing the characters for our game. Our

contribution can be considered as merely graphic because we just proposed some characters without attributing them any specific role. It was up to them to propose for each drawing the role sought. So, children expressed their opinions about the characters, describing them in the average as "funny, laughable and nice". This approach was extremely useful for attributing a specific role in the game to each character and we finally implemented these results during the development stage [2.2].



Figure 1: Type of Device Used for Gaming



Figure 2: the % about Learning through Game

2.2 Game Development

During this stage, the research team focused on the development of the game. The research team involved in these steps are researchers and developers of Osel s.r.l. (Open source e-learning): a spin-off company of University of Bari involved in "e-learning revolution", an innovative way of re-think e-learning design methodology and technical production. The development team was involved in some main phases:

- Storyboarding
- Graphic design and development
- HTML5 coding and output
- In vitro test

Starting from what emerged during the co-design process, screenwriters have built the storyboard, composing a complete script of texts and speech, which would be then submitted to the scrutiny of the development team for additional brainstorming and approval of the technical feasibility. The storyboard was used in the later stages as a guide to follow to ensure that the output is in accordance with the technical and didactic provisions. In the phase of graphic development, the designers made the graphics and produced scenarios in accordance with the game theme. Once the graphic was ready, it was assembled inside a fully responsive or adaptive interface that allows the enjoyment of the game in any web browser from both desktop and mobile. As the co-design results show, the development process was mobile centred, in particular suitable for tablets. The complete interface was developed using HTML5 coding with SCORM (Shareable Content Object Reference Model) output. The SCORM format is suitable for any e-learning platform (LMS) and helps to track student activity and performance inside the learning object and through the learning platform. After the development process and when the game was released, the research team started an "in vitro" test, in order to assert the functionality and consistency of the project with the expected content, which was previously defined in the process of analysis and design. In this phase, testers and developers reported and fixed some bugs and changes based on the performances and usability measured on different devices on which the game will be distributed to improve user experience. During this stage, we focused also on the choice of educational games and characters. implementing the results of the co-design sessions in the development of the game. At the end of these stages, the game package was ready to be distributed for the following part of the research.

3. THE "LEARN GERMAN WITH MR. HUT" GAME

The following paragraphs will describe the game "*Learn German with Mr. Hut*".

3.1 The Description Of The Game

The game builds upon a narrative structure. It is divided into two sections: 1) cutscenes; 2) interactive game. During the cutscenes, the player is explained the circumstances in which he or she is going to be involved in. During the interactive game, the player is given the opportunity to take the choice between male or female avatars and Mr. Hut guides the learner throughout this educative adventure to the discovery of German language, leading him or her through the different levels and didactic contents of this engaging experience.

3.1.1 Didactic Material

The purposed project is composed of three levels with one didactic game each (Spot the difference game in Level 1, Memory game in Level 2 and Drag & Drop game in Level 3). The gamified contents are common objects and simply words, which are strictly linked to each pupils' everyday life. In Level 1 and Level 2, the learner are shown on display short taglines with the grapheme of the corresponding word at each correct click. At the same time, the audio recording the phoneme of each word is surrounded whenever the learner clicks correctly. In this way, the pupil can quickly associate the phonemes with the graphemes, both referring to the same object. The Level 3 consists in a final test, including all the learning objects of the previous levels. It is extremely useful to assess the quality of learning, based on the correct or the incorrect match of the objects with their equivalent words. A final "report card" will show the number of incorrect moves/matching for each level.

4. CONCLUSION AND FUTURE WORK

Starting from a transdisciplinary comprehensive framework, our project aims to explore the efficacy of game-based learning environments through Mobile Technology and assess the effectiveness of the innovative co-design methodology as a further involving strategy for learning. Our background framework involves different fields and disciplines, such as IT, Computer Science, Education, Psychology and Neurophysiology. The purposed study may be considered as a first step of our project. Nevertheless, it is important to underline that it is about creating a new framework by crossing disciplinary boundaries and combining them into a research project, which is based on IT and mobile devices. As already mentioned above, the project game "Learn German with Mr. Hut" is not yet been tested. Future goals include the test "in vivo" of the game project. It consists in involving the co-design focus group in hands-on testing sessions. Post-testing questionnaires would be administered to pupils, in order to allow children to express their opinions and views about the project. This second phase would be useful to assess the efficacy of the mobile game-based learning strategy combined with a co-design methodology, which can useful support learning processes and enhance learners' motivation and involvement. Therefore, the present study can be considered as a starting point for further works.

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FOOD-RELATED GAMIFICATION: LITERATURE REVIEW

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ABSTRACT

Food-related games and gamified services is an area that has still received relatively little attention in scientific research. In our literature review, we find out that the scientific literature in this domain examines the phenomenon from the point of view of marketing, educative purposes of healthier living, and healthcare. Particular topics often being in the focus are weight management for children and advergaming as a promotional channel towards young people. Commonly, studies conclude that gamification has an effect in bringing a change in the behavior of the targeted user. However, the studies are currently able to present results based only on short-term empirical experiments or the experiments are even missing. In order to receive more reliable data about the true effectiveness of gamification, longer-term experiments would be needed.

INTRODUCTION

Gamification is the application of game design principles for the purpose of engaging users with a chosen service or products (Deterding et al. 2011). Gamification has been used by various industries and researchers to study and leverage the effect it has on the human behaviour, e.g. in areas of education and marketing. Gamification is utilized in order to engage and motivate the users to concentrate on the subject matter. The term itself was coined by Nick Pelling back in 2002 (Marczewski 2013), but the earliest known example of this kind of an activity dates back to 1910 when Kellogg's cereals offered the Funny Jungleland Moving-Pictures book free with every two boxes bought by the customer (McCormick 2013).

In this paper, we explore the utilization of gamification and digital games in food-related studies through a systematic literature review (Grant and Booth 2009). This is done to gain understanding into 1) in which food-related areas games and gamification are utilized, 2) what are the motivational design elements utilized and 3) what are the results reported.

The paper is organized as follows. First, how the review was conducted. In the next section, we summarize our results in four different categories and examine the design elements utilized. Finally, the results are discussed and findings concluded.

METHOD

In order to find out the adequate number of relevant articles, several search words were tested. In the end, the chosen search words were "gamification" and "food" for the article databases. Google Scholar was also decided to be utilized, but there the search words were decided to be "gamification" and "food industry", since "food" only provided too wide results. In addition, Gamification Research Network, which is a free reference manager in Mendeley for gamification enthusiasts to share the research articles, was utilized without search words. The searches were conducted between 7th April and 16th and the number of results from each database are presented in Figure 1.



Figure 1. The Research Process

The found articles were gone through with the following inclusion criteria:

- the utilized language was English,

- the type of the text was a scientific article or a book (e.g. thesis works were excluded),

- the article included a description of a game or gamified elements, and

- the article was related to food or eating: e.g. food education, advergaming for food, diets.

The research method can be divided into two rounds, as presented in Figure 1. In the first round two researchers went through the results of the searches and based on the title decided whether the article is relevant. If the title was not explicit, also the abstract of even some parts of the article could be examined. In the second round, the researchers went through the results from the first round, reading the whole article and rechecking whether it was relevant or not. In order to avoid researcher bias, it was mostly a different researcher checking the articles than in the first round. After the second round, there were 20 articles left.

RESULTS

Food-Related Areas

From the selected articles five were related to marketing, five related to education and ten related to healthcare, such as obesity or diabetes.

Marketing (N=5)

The main share of articles concentrating on the use of gamification in the marketing of food products focused on games designed to advertise specific products (advergames), and the use of advergames for product or brand promotion to children in particular. The research perspective was thus more often societal, rather than business-driven. Besides providing information regarding the effectiveness of gamification that could be used e.g. by marketers, this topic is characterized especially by discourse regarding the ethicality of promotion to the target group of children, as many times advergames endeavor to promote nutritionally poor foods (Harris et al. 2012, Kelly et al. 2015, Thomson 2010; 2011). The importance of regulatory measures to restrict this type of promotion is underlined (Harris et al. 2012, Kelly et al. 2015, Thomson 2010; 2011). Harris et al. (2012) notice that while there was no significant difference in the number of children and adolescents visiting food company websites, children represented a significantly higher proportion of the visitors to the advergame websites of food companies. According to the research conducted (Harris et al. 2012, Kelly et al. 2015), advergaming is able to increase preference for the food products promoted at least in the short term. Kiraci and Yurdakul also noticed that players may even prefer advergames where the brand forms a central part of the game (Kiraci and Yurdakul 2014). However, there is a need for more longitudinal and robust research on the effects of advergaming, and it could be of interest to conduct more research on the use of gamification for other types of promotion besides advergaming as well.

Nutritional education and life-style changes(N=5)

The articles of nutritional education and lifestyle changes concentrated on changing the eating behavior of children and educating teenagers about nutrition, but included also an article about educating in recycling.

The target of gamified solutions described in three articles was to change the eating behavior of children, such as picky eating (Kadomura et al. 2013), slow eating (Kadomura et al. 2013, Lo et al. 2007) and fruit and vegetable consumption (Jones et al. 2014). A "playful tray" decreased the negative behavior of all parents and three out of four children in the test group (Lo et al. 2007). The consumption of vegetables increased in the school days the children were challenged to eat more of them (Jones et al. 2014). Jones et al. noted though that the results were not long-lasting: on the days the challenge was not utilized, the consumption of the vegetables did not increase. The concept of a fork, which could recognize different food items, and a mobile application in article (Kadomura et al. 2013) had been proven to work, but no empirical research of the effects of this approach had been conducted.

Educating teenagers about nutrition was discussed in two articles. Nutritional knowledge was questioned from the teenagers playing a game and correct answers were rewarded with better abilities in a game in (Dunwell et al. 2015). Also the responses in the focus group interviews were positive. Similarly, having incorporated game mechanics into food consumption recording, the user engagement of the piloted service was seen to have improved (Caon et al. 2015). Yet another objective for gamified mechanisms was to motivate participants to recycle and reduce the amount of food waste (Comber et al. 2013). There the participants quickly lost interest in the gamified mechanisms, but the service resulted in significant changes in the social aspects of recycling and in improving awareness about recycling and food waste behaviour.

Healthcare (N=10)

Many of the gamified solutions in the articles focused on obesity prevention. Two articles describe gamified solutions aimed for children, and in both of them the completion of small real-life tasks and quests related to healthy choices are rewarded (Hu et al. 2014, Durga et al. 2014). Durga et al. found out that players were likely to repeat actions that aligned with their existing routines, and these recurrent tasks were a strong motivator for participants to continue to log in their activities. However, Durga et al. concluded that the game content should evolve in order to attract the players to find out new healthy things they can do in the game, instead of stinking on the same repetitive actions. Hu et al. did not yet conduct any empirical evaluation of the effects of their solution.

In a gamified intervention program aiming to prevent obesity, González et al. set out to examine a gamified program including nutrition education and physical activity (González et al. 2016). After the eight-week intervention, biometric measurements showed little change in the participants, but the children were described as eager to implement the activities, see their weekly progress and receive feedback, and the results indicated an improvement in the lifestyle of the children. Kamal et al. conducted a survey about their software application for obesity prevention: positive changes were seen in individual determinants but not on social determinants (Kamal et al. 2014). Focus group discussions revealed that the social aspects could be tackled e.g. with better system intelligence for displaying the most interesting posts of other people. Obesity prevention was targeted also through the prevention of snack cravings: Hsu et al. found that the users that managed to perform the imagery tasks within their mobile application efficiently consumed fewer snacks or were more likely to choose healthy snacks (Hsu et al. 2014). Pannese et al. also described a system for obesity prevention providing support for moving towards healthful behavior through gamified daily life processes, however, it was still in conceptual development phase (Pannese et al. 2014).

Besides obesity, also diabetes and eating disorders were the targets of gamification. User satisfaction was queried in two articles. In (Tregarthen et al. 2015), an application for the treatment of eating behaviours through logging the food

eaten was downloaded over 108 000 times, 89% logged at least three meals and 84% rated the application five out of five. According to a questionnaire for the 30 beta version users, (Burda and Novák 2015), the users were mostly satisfied with the application meant for diabetes compensation. Chuang et al. also presented a concept for a service aiming to provide social connectivity, selfmanagement through personalized recommendations and health analytics for diabetics, and gamification is utilized to make tracking more enjoyable and rewarding. In the first nine-month period, there were 146 registered users, the tracking module was the most attractive part of the system (Chuang et al. 2014).

Gamification

As gamification mechanisms, motivational design elements are often utilized. Table 1 presents the motivational design elements found in the articles, according to Weiser et al. (Weiser et al. 2015), with the addition of time constraint (Hamari et al. 2014). Three of the articles (Harris et al. 2012, Kelly et al. 2015, Kiraci and Yurdakul 2014) described various gamified solutions, and are thus excluded from the table.

It can be clearly seen, that the utilization of points, credits and levels, as well as assignments, quests and goals is favored in food-related gamification. These can be seen to be simple and easy ways to introduce gamification. In addition to the mentioned motivational design elements, some of the described solutions went further and implemented more complicated game mechanics, such as a story evolution during game play (Jones et al. 2014, Durga et al. 2014, González et al. 2016). In four games also social elements were utilized (Kamal et al. 2014, Tregarthen et al. 2015, Durga et al. 2014, Chuang et al. 2014).

CONCLUSIONS

This paper found that the main areas related to food where gamification has been studied are marketing, healthier living (nutritional education and lifestyle changes), and healthcare (e.g. obesity and diabetes). The most common motivational design elements that were deployed were assignments and points. The studies commonly showed that gamification can be applied in various food-related scenarios and the empirical results displayed a change in the behavior or mindset of test subjects in accordance with the objectives of the games or gamified services. However, there was no evidence of these effects extending further than the duration of the short-term studies. Also, many of the articles focused on the description of the gamified application or service, and the effects of the gamification were left out of scope. Therefore, we recommend that more longitudinal studies be conducted to assess the effectiveness of gamification within this domain.

	Story	Time constraints	Assignments, Quests and Goals	Points, Credits, Levels	Achieve- ments or Badges	Virtual Goods	Leaderboards and Collections	Friends, Teams and Groups	Reminders
(Comber et al. 2013)				x	x		x	x	
(Thomson 2011)					x	х			
(Thomson 2010)							x		
(Caon et al. 2015)				x	х	х			
(Kadomura et al. 2013)		х		x					
(Dunwell and Dixon 2015)				x					
(Jones et al. 2014)	х		x					x	
(Lo et al. 2007)			x						
(Durga et al. 2014)	х		х	x					
(Pannese et al. 2014)									
(Gonzalez et al. 2016)	х	х	x	x	x		x	x	
(Hsu et al. 2014)			x						
(Hu et al. 2014)			x	x	x	х		x	
(Kamal et al. 2014)			x	x			x		
(Tregarthen et al. 2015)			х			Х			x
(Burda and Novak 2015)				x		х			x
(Chuang et al. 2014)			x						

Table 1. Motivational design elements.

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DESIGNING AND TESTING AN EDUCATIONAL GAME ABOUT FOOD FOR SCHOOL-AGED CHILDREN

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KEYWORDS

Game design, gamification, serious game.

ABSTRACT

Food and eating is something very mundane, sometimes even an afterthought. Yet they have a great impact on issues concerning health and the environment. This paper describes the design and testing process of a game for children between the ages of 7 and 12. The purpose of the game is to teach children about the health and environmental aspects of food and be entertaining and educational. The first version of the game design was created based on a questionnaire. This version was then tested with classes which participated on the questionnaire. Based on the feedback from testers, the second version of the game was created and tested again with new classes. Based on the feedback, the children enjoyed the game, but further research is needed about how well the game supports the intended learning activity.

INTRODUCTION

Environmental issues are portrayed prominently in people's daily lives, while health-related issues such as obesity (World Health Organization 2015) are all the more common. Both are directly affected by the food industry (Guinée, et al. 2006), which consumers have control over through choices they make in everyday life. Making the right choices is still difficult, when taking into account several variables, such as diets, environmental issues and healthy nutrition. This problem is approached from the viewpoint of educating school-aged children to do more environment and health conscious decisions, and possibly affecting their families.

There are existing games that have been designed to cause a change in people's behavior related to food. One example of them is the The Fatworld by Persuasive Games (2008). Sadly this game is not anymore available for play, but the goal of the game was to show the relationships between nutrition and factors like budgets, governmental subsidies, and trade regulations. In many cases the games created for educational purposes concentrate on narrower range of subject, like the Nutrition Game (Cooper 2007). The purpose of this Second Life game was to show to the players the impact of different foods on health, especially concentrating on the effects caused by fast foods. As a part of this multidisciplinary study, gamification is being used to improve the education process about the nutritional, ecological and regioeconomic effects of food. Gamification is defined by Deterding "as the use of game design elements in non-game contexts" (Deterding et al. 2011), and its use in education has been previously researched (Surendeleg et al. 2014).

The first section introduces how the development process started, explains how and where testing was conducted, and describes the test subjects. After this, the developmental phases of the game are explained. The section explains the technical basis of the game, the design process and what questions had to be answered during the process involving several testing and improvement cycles. The last sections discuss the outcome of the process, and how well the design has achieved enjoyment.

GAME DEVELOPMENT

The design process began with a food-related questionnaire which 479 children from 17 different Finnish schools between the ages 9 and 11 answered. The questionnaire among other questions, included questions about what they would like to see in an educational game about food. Based on these answers the first version of the game was designed and implemented by the team.

Testing in Classrooms

Classes participating in the testing were chosen from those that answered the initial questionnaire and the selection was based on the location of the schools, i.e. which were close to the developers. The first version was tested with three classes of children from two schools in South-Western Finland during the autumn 2015, approximately a year after the questionnaire. Based on the feedback from the children as well as on the impression of several professionals in food related areas, the second version of the game was developed and tested in two new schools during the spring of 2016. The feedback received from testing was further reviewed and included in the development process.

The tests in actual classrooms were informal events held during regular school classes. On average, one software developer and two experts on food and health education represented the team during sessions. In the beginning of the session, a lecture was held about nutritional health, and about the ecological and regioeconomical impact of the food industry. It was followed by a brief presentation about game development and games in general.

The testing itself was done on tablets supplied by the school. The children were then observed while playing the game, and notes of their comments and of any bugs found were made. A short, informal interview was conducted with the whole class after the testing: the class was inquired whether they liked the game, and what kind of improvements they would like to have.

Technical description

HTML5 was chosen as the implementation platform, due to its availability on most mobile devices. Construct 2 was picked as the main development tool after an evaluation, due to its perceived ease of use. Initially, creating a 2Dgame project is rather simple in Construct 2, but more complicated logic is harder to create, due to its graphical programming system. For increased complexity, Construct 2 allows users to write plugins in JavaScript.

Story of the game

In the game, the player is a cook in a school of animal-like characters. In the beginning of each day in the game, the player has to make healthy and environmentally conscious decisions while purchasing groceries from the store (Figure 1.). After the store, the player prepares the food in the kitchen which is presented in following Figure 2. Then the food is served to the characters which can have different favorite foods, allergies, and diets, which the player has also to consider. This cycle --shopping, cooking, serving -- is repeated for a predefined amount of days, after which the game ends. After the final day, player is shown relevant data, e.g. levels of health and happiness of the characters.



Figure 1. The Store View



Figure 2. The Kitchen View

Initial game design

Following the initial questionnaire results, a rough design of the game was created. The game was prototyped using paper prototypes, and then implemented as a text-based Python-program. Two developers worked on the design full-time, but design meetings by the project team, consisting of two software developers, a graphic designer, two game researchers and a senior software researcher, was held approximately bi-weekly. A few design meetings with extended project team with three additional experts of food nutrition and health-related pedagogy was also held.

The design was meant to be both entertaining and educational, as it has been shown that student engagement increases learning (Trowler 2010). Since the game was targeted for class environment, one essential design goal was to engage the player for a few game sessions but not necessarily longer. This helped to keep the design simple and decreased the amount of necessary content.

The game can be thought of as a management game where the player has to manage a finite amount of money and keep the characters happy. The player has to take different things, such as health, diets and ecological footprints, into consideration while shopping for food items.

Different foods can be found on different shelves, such as the dry shelf. Selected groceries are then bought and transferred to the storage menu that is found in the kitchen view. In the kitchen view, the player has to make sure they cook each food item the proper way, and that they don't burn them. Food can be prepared using any of the available methods, e.g. by using deep-fryer, frying pan, cooking pot, or none of them. Prepared foods are then moved to the plates. There are two plates in the kitchen: the normal plate from where the food is fed to the characters without diets or allergies, and the special plate from where the food is fed to the characters with diet restrictions. Finally, the dining hall view visually shows the characters walking to the plates and consuming the food accompanied with their reaction to the servings. When designing the initial version of the game, several decisions had to be made about how different foods, diets and allergies were presented:

Nutritional information. The amount of data utilized was vast: there are over 20 different fields for over a hundred different groceries. The data was created by experts based on real data. Some of the data, such as taste, is subjective.

Diets and allergies. Diets and allergies were a core principle from the beginning of the project for educational purposes to understand the diversity of humans as food consumers. Only a vegetarian diet is included so far, but diets such as a fish diet and fruit diet were experimented with. From allergies fish allergy and coeliac were included along with lactose intolerance which although is not an allergy, mechanic-wise it is handled the same way.

Portions and serving. It was discussed whether foods should be combined into pre-made recipes or whether they should be handled as individual items. It was decided that individual foods would work better due to easier implementation and four individual items could convey the plate model idea well. This design decision also turned out to make the game more playful and creative, which seemed to increase the fun factor of the game.

Prices and units. Food item units in the game are symbolic, mostly to aid gameplay. Since there are no clear units for food items, prices had to be normalized by portion, meaning that the price of one potato is the same as the price of potatoes needed for one portion. It was discussed early on whether prices should be static or random. The decision was to keep them static to simplify gameplay and design.

Character statistics. Designing a system for the characters to represent their statistics from eating food was challenging. The system could not be too complicated, as it would not be able to convey clear cause-and-effect relations. On the other hand, too simple a system would not be interesting and would be too easy to optimise by players. It was decided to not go on a macronutrient level, but rather have each food affect the three statistics: happiness, healthiness and fullness. These three variables should be enough to show that while unhealthy food can be filling, it will still make you sick in the longer run.

Second version

We received a plethora of ideas for features and improvements from the first tests. These ideas were discussed with the design team, along with other improvements noted during the development process, to form the new feature backlog. Requests that came up more than once included the ability to earn more game currency, and the possibility for characters to visibly suffer and get dropped from the session.

In the post-test design meetings, the design team tried to think of ways to improve the inclusion of the ecology and regioeconomical aspects. To achieve this, team discussed several features, such as a special outdoors trips, international grocery weeks, and a regional bonus days. As always in development, there were many ideas and feature requests, but only a fraction could be implemented within finite time, and these ideas were left out from this version. Grocery expiration info and the characters not showing up after being dissatisfied for too long. These features were added to the second version due to feedback from participants.

Changing the eating system to better represent the Finnish nutrition recommendations, which state that vegetables and fruit should cover half a portion with a protein source and a side dish covering the rest (The National Nutrition Council 2014), was a request from the a group of specialists related to the field of health and nutrition to which the game was presented to. After making changes to the game, it was tested again with new groups of students. The tests were conducted with the same methods as the earlier tests. Table 1 contains feedback from these tests.

 Table 1: Observations, feature requests, design decisions and added features of the first version

Observation	Feature	Design-	Implemented
	request	meeting	feature
	-	decision	
	Visual	Showing	Scene that
	character	character	shows changes
	feedback	state through	to characters'
		icons and	statistics
		dialogue	
	Characters		Unhappy
	should die or		characters
	get ill		disappear
	A tutorial or		A quick
	guide		tutorial
		Paying for	Grocery
		food waste	expiration
			system
		Improving	Improved
		the eating	eating system
		system	
Possibility			Food can be
to move			thrown into
foods			trash from
around after			plate
putting on			
plate			

Feedback from second version

After making changes to the game, it was tested again with different students. The tests were conducted with the same methods as in the earlier tests. Table 2 contains feedback from the tests.

Table 2: Feedback from the second version

The character with the special diet was difficult More animal characters should be added More foods should be added More money in the beginning and the ability to earn money The tutorial was not very clear There should be more game scenes There should be kitchen utensils The game was too hard The game was too hard The game was easy The oven was hard to use Dragging food from storage to trash should be possible Possibility to prepare same food in several cookwares Possibility to move foods between plates There should be recipes Clicking cookware was difficult

Similarly to earlier tests, new requests were made by participants. These and other improvements have been moved to feature lists reserved for potential future versions of the game.

DISCUSSION

When evaluating the game design in regard to test feedback, it becomes clear that some features, such as the ability to earn more money, should be implemented. It also tells about the need to balance the amount of starting money, as so far this has been neglected. Requests for more game assets, such as characters and foods, were usual forms of feedback. While it is something to consider, adding more assets would not add much in terms of value to the game and is something that players tend to request no matter how many assets a game already has. One of the design objectives was to make the game fun, which seems to have succeeded, according to feedback.

Often gamification in education is achieved through leaderboards and badges that promote competition, and add little actual substance to the teaching process (Deterding 2012). This can sometimes be worse than nongamified teaching (Hanus and Fox 2015). In this case, the game had engaging gameplay and visuals that helped to convey ideas to the students. Further studies on the game's effects on learning will be done.

CONCLUSIONS AND FUTURE WORK

This paper introduced the design process of a food-related educational game and the feedback it received from testing, and how feedback was included in the game. Feedback received from testing made it clear that many improvements could be made, but that the game was also well-received by the students. Although the game tries to teach about the ecological and regioeconomical aspects of food, it mostly covers the topic of health, and this should be improved in the future.

Other future work includes further assessment of the feedback and observations, and adding and refining some

of the features listed in feedback. So far only the game's enjoyability and engagement has been assessed through observations and interviews, but little work has been done in terms of researching its educational potential. Thus, further studies will be performed to research the game's effectiveness in learning.

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SUICIDE AND OTHER DANGERS OF 'GAME OVER'

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KEYWORDS

Computer games, representations of death, suicide, Game Over

ABSTRACT

The idea of death became an indispensable requisite in video games: to kill or to be killed in virtual reality has become acceptable – together with other kinds of violence. This article intends to be a reflection of one of the issues regarding gameplay, specifically the concept of death and suicide present in computer games – in particular in its connection with the GAME OVER button, and some of its implications.

INTRODUCTION

We live in the technology and communication era. The new media represent another way to express the human need to control nature, as a way to dominate the present and create the future [Correia 1997].

The Internet, as an organized network, has the ability to interconnect all computers allowing the human's data exchange throughout the world. One of its primary practices has been entertainment, namely the use of games – of every kind and type – by everybody – from adults to children. And sometimes with harmful consequences.

This article intends to be a reflection of one of the issues regarding gameplay, specifically the concept(s) of death and suicide present in computer games – in particular in its connection with the GAME OVER button, and some of its implications.

ADDICTION AND DEATH OVER GAMES

The News headlines' are proficuous about the dangers of gameplay, usually associated with extreme cases addiction [Kohn 2002; Lam 2010; Looper 2016]. Some result from mere self-neglect, others refer to real death in real life: murder and suicide: «On December 27, 2004, Xioyi left a suicide note saying he wanted "to join the heroes of the game he worshiped." The thirteen-year-old then jumped off a tall building after playing World of Warcraft for 36 hours straight» [Lam 2010].

The concept of suicide to be employed here refers to the act of intentionally causing one's own death (as denoted in Medical Dictionaries).

There is a vast literature addressing the importance of videogame's violence and its impact on adults and children lives [Alves 2016]. But the literature about suicidal issues in itself is still scarce [Messias 2010; Roque 2014; Clark 2014]. It mixes-up sadness with suicidal tendencies as a result of gameplay, sometimes not considering the opposite approach that people can resort to gameplay to compensate for sadness and depression.

Probably in the near future it will be possible to reach sounder results through a greater cooperation between the different areas of knowledge. These phenomena studies need to include families and educators, and enhance the prevention for the born digital youth dealing with the dangers of virtual environments

A TAXONOMY OF DEATH IN VIDEOGAMES

The aforementioned headlines usually refer to suicide over a game. Gameplay addiction in itself should become a new conceivable risk factor for impulsive actions and suicide. However, there should also be stated a difference between suicide resulting from gameplay, other usually so-called "virtual suicides" (broadcasted live via internet), and the representations of suicide within videogames.

For the moment it is possible to create a tentative taxonomy concerning death inside videogames. The main problem with this over presence is that it trivializes the death concept.

The "usual" player's death / Loss of lives

The "usual" player death/loss of lives is inscribed in gameplay mechanics. Since pinball machines the players are allowed a finite number of attempts – lately translated into "lives" to depart from the arcade platforms.

This loss of life (lives) can instill a wrong idea about death, convening that it is a temporary state and even enjoyable [Queiroz 2014]. Children and teenagers identify with their fictitious game characters, and might believe that it is possible for them also to die and revive as their persona do [Cyrulnik 2012].

Games in which characters commit suicide

In the great majority of action/fighting games players kill humanoid characters. In some MMORPGs – like *League of Legends* – characters in roleplay kill each other for points. In other's – like *Assassins Creed* – the main task assigned to the player is to complete the assassination of a public figurehead.

Although not so frequent, the act of taking one's own life is also present in some games. In the *Final Fantasy* series some characters commit suicide. In *Anathema* the characters, initially perfectly sane, can be driven to suicide and die: once transformed in Shroud (dead) they will instigate others to the same practice. In the *Syndicate* series (III - 2012) it was included a "suicide app" inside the hero's head – Miles Kilo – as well as his opponents: «one of the three breaching methods available to the player in the single-player mode, and affects the chip of the target making him commit suicide by either shooting himself or detonating a grenade in his hands.» [Suicide wiki 2012].

As an extreme and old (2002) case there is the *Suicide Bombing Game*, also known as *Kaboum* – available via Newgrounds, uncensored or censored.



Figure 1: Suicide Bombing Game - Kaboum

The plot is very linear: a suicide bomber is in the street, with people passing by, and the user makes him explode with the mouse cursor killing everyone around. Against his critics, the author states: «By the way, I'm not jewish, I'm not an arab, and I'm not a terrorist. I have little interest in what goes on in the middle east so I don't share any extreme views. I just think people who blow themselves up are stupid. That's all this game is. If you found this offensive, tell your friends! If you are DEEPLY offended by this game then you're way too fucking sensitive for my taste and I hope that you've been scarred for life».

This game had a remake in 2012 with the application *Suicide Bombers* (An Angry Soldier Grenade Shooting and Battle Cartoon Game - by fun free Action Games, age rating 9+). The objective in each level is to destroy all of your enemies with a limited number of "sweet" grenades.



Figure 2: Suicide bombers – Angry soldier grenade

Other two recent examples that cannot be ignored – among at least 10 Apple apps named "suicide" - are *Suicide Sheep* and *Suicide Pig*.

In the first (2011, rated 9+): «an angry pirate is trying to destroy the world by mounting a huge dynamite on the sweet, little sheep and transforming it into a SUICIDE SHEEP».



Figure 3: Suicide Sheep

The second (2014 – rated 4+) is advertised as follows: «Little pig is ready to play to with you. (...) specially designed for kids. Here you have care for pig give him pleasant bath and then dress him with different clothes from tons of clothes. Its great features make this game one of the best game for girls and boys bringing joy and laughter every step of way».



Figure 4: Suicide Pig

From the same year – non-rated, and also offered as a Google app - is *Squishy the suicidal pig*: «where you play as Squishy, a pig in a yellow sweater who's trying to reach his parents in animal heaven by completing his deal with the devil.»



Figure 5: Squishy – the suicidal pig

GAME OVER

Replacing the formula «play again», GAME OVER is probably the most famous phrase in the world of video games, whether old or new. It first appeared in the 1950's, also in pinball machines, and the concept defines itself because – reading or hearing these words - every player knows that it means that the game is lost.

Games themselves also migrated from arcade to computers - as Pac-Man in the 1980's – with the respective technicalities.



Figure 6: Game Over Pac-Man

Sometimes the screen could glitch and loop while giving off very annoying siren and alarm sounds [Red Alert].



Figure 7: Game Over

From the screen, the function has also jumped to computer keyboards. Some have been transformed and adapted to different kinds of games -i. e. shooters with several types of guns - to ease the process.



Figure 8: Gamer keyboard with choice of weapons

Others have included a Game Over/Skull and tibias as a specific key - a suicide command, said to be for fun, to allow a quick level reset, or an escape when the current level is left in an unsolvable state.



Figure 9: Game Over/Skull and tibias

The identification of the Game Over option with a "suicide" button has been trivialized from the beginning - since *MoaikuN* (1990) – and "naturally" replaced for what is considered to be a funny icon.

The concept of Game Over became an extension of the idea of death. The gamer can do as she pleases with simulated lives, as in this case death is always virtual and not real as in nature. The fact that one can die and stay alive at the same time is an interesting feature only possible in games, not so much in novels, films or literary works.

THE SUICIDE BUTTON

The way Media depicts suicide may have a negative effect, with high volume, prominent, repetitive coverage glorifying

or romanticizing suicide having the most impact [Wolfersdorf 2011].

The trigger of 'suicide contagion' or copycat suicide is also known as "the Werther effect", named after the protagonist Goethe's novel *The Sorrows of Young Werther* (1774) whose self-inflicted death was epidemically emulated by many admirers of the book.

The idea of death became an indispensable requisite in video games: to kill or to be killed in virtual reality has become acceptable – together with other kinds of violence [Martinez 2009]. With recurrence and replication players get used to it, sometimes even amused by it and cease to even realize this detail, but the truth is that there is a kind of tacit acceptance of these two dangerous factors.

In these circumstances the role of educators and the surrounding society is important, because it is at an early age that the individual's personality is formed, and it is necessary that children and the young ones learn to differentiate right from wrong.

PLAYING IS LEARNING

The issue is so much more crucial because of a dichotomy: games can be dangerous, have certain risks; but games can and have helped the child's cognitive development [Turkle 1989]. The ability to solve problems, to establish and exchange ideas with other players means that there is a willingness to interact with these technological elements.

Games are used as working tools in schools because through gameplay children can improve their concentration, memorization and advance their vocabulary acquisition.

The educational improvement of games has increased with software evolution and superior graphic quality. But also with a greater attention to the language used in contents: computer games' language is being adapted to the game type and target audience. Design and image quality have become more realistic or elaborated, making use of special effects and seductive icons, making games more fascinating as age increases, in order to seduce the public.

Games can even have a therapeutic effect, as the personal frustrations are enacted and released via the characters on the screen, leaving the subject more relaxed and calm.

Playing is learning, and also means to develop in terms of autonomy.

CONCLUSION

The internet and new media have a broad public, in varied styles, social backgrounds, ages and interests. Each user has a proper way of interpreting and expressing herself.

Concerning video games, each user has her own theory of the game, and strategy to reach the end of the game successfully. Games have positive and negative aspects. It is important to know how to get the most of the fun without being controlled by the machine. Some of the literature argues that the existing violence and death representation in games does not contaminate the players, because the tendencies are innate and idiosyncratic. However, surely there is a factor of influence in the banalization of the concepts of death and suicide.

In itself society is not yet suitably prepared to face increased violence, insecurity, the very phenomenon of suicide.

In spite of the amount of research on the subject – mostly from a sociological or medical perspective - any kind and all types of suicide are still an enigma.

Children and teenagers have to be aware of death – but not with overloads of information through TV, films and now video games. This should inspire an extra educational care with the representation of suicide in virtual media.

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Coordination and Synchronization Tool to Support Caretaking of Senior Citizens in Social Events

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ABSTRACT

In this paper, we investigate the requirements and challenges of developing coordination feature for our health monitoring and communication tool. OldBirds is a unique cross-platform application for caregivers to assist senior citizens in their day-to-day activities. The application applies gamification principles to persuade caregivers in long-term use. On the other hand, we aim to promote elderlies quality of life while using the system. Social activity is one of the aspects which can improve the quality of life while aging. We conduct a qualitative study to investigate salient factors in the design of the coordination feature. In order to fulfill the requirements of real life use cases, we plan to follow a specific case scenario. Developing a case scenario is the approach to design new elegant features in the application that suit end-users. Initially, we evaluate various social event scenarios through interviews and qualitative studies. A bus trip scenario is evolved as a popular setting for many social events. The bus trip scenario is designed with all the predefined sub-events in OldBirds environment to validate specific quality attributes of the proposed feature.

INTRODUCTION

United Nation World Population Aging report in 2013 indicates the fertility rate is decreasing from 1950 to 2050 all over the world from five children per woman to two children per woman, and in the same time interval, life expectancy has increased from 40-50 years, to 70-80 years. Furthermore, the population of people aged over 60 is estimated to be around two billion people in 2050, and the proportion is increasing from 7-8 percent to more than 20 percent in 2050. (United Nation Report 2013) Lack of professional caregivers to provide real-time support to senior citizens, and promoting elderlies' social lives are the main challenges we are going to mitigate. Dow et al. (2013) believe older adults tend to live independently in their home, and they can maintain active motor skills as long as their mind work actively. The quality of life is another attribute that needs to be maintained to support aging in place. It requires involving senior citizens in activities and social interaction to uphold both physical condition and quality of life. The above-mentioned activities prevent development of dementia and memory decline such as Alzheimer's Disease in the early stages. (Middleton and Yaffe 2009, Dow et al. 2013)

The quality of life can be described as the degree of satisfaction which is felt by older adults in various aspects of their lives. Social activity is one of the aspects which can improve senior citizens' quality of life and general health condition. Prior research studies investigate the correlation between quality of life and mobility. Furthermore, enough mobility and capability for active traveling have a strong positive effect on health condition and quality of life. (Musselwhite et al. 2015, Farquhar 1995)

Lack of mobility and social activity decreases health condition, and quality of life consequently. While isolated life behaviors occur along with aging, providing solutions for traveling and social activities can promote life satisfaction. These activities should be accurately designed for senior citizens to provide intended leisure and satisfaction. (Batra 2009)

Månsson (2007) conduct a study regarding assistive tools and technologies to support people with dementia in Scandinavia. According to the study, customized and personalized aiding tools can efficiently support maintaining the functionality of senior citizens suffering from memory decline or physical impairment. The multi-user tools should support aging in place, safety, and privacy. They can assist the users to navigate in different environments and provide support in urgent conditions such as fall accidents. Furthermore, they can improve the treatment and individual care, as well as maintain social interaction. The elderly-user-friendly design has positive effects on user's mood. By categorizing caregivers and patients in different groups, and providing different privilege level, security concerns can be addressed. On the other hand, the performance can be improved by involving volunteers, professionals, friends and family in caregiving tasks. (Månsson 2007)

Literature study on monitoring and teleassistance systems to support senior citizens shows that there is a wide range of tools and systems available. iCare is a real-time mobile health monitoring system to monitor the health condition of older adults continuously. It can be considered as a personal health information system to provide users with medical guidance. Another example is iSenior, which additional to continuous health monitoring such as the record of heartbeats, provides notifications and alerts for activities and potential accidents. These tools perform in the home and outdoor environment, while supporting localization, being unobtrusive, customizable and easy-to-use. The monitoring concept, and a communication platform are the basic elements of teleassistance systems. (Rodrigues et al. 2013, Lv et al. 2010)

OldBirds application is our cross-platform monitoring and communication tool to support remote caregiving of senior citizens. The requirements and development steps are previously published. It is a gamifed application to persuade caregiver to participate on caregiving tasks. We applied basic principals of gamification and serious gaming in design of health-care tool. Assistive tools which work as a bridge between elderlies and caregivers to promote quality of life, not only needs monitoring and communication feature; they also need coordination system to assign tasks, and arrange Lack of coordination feature of OldBirds events. application is notable in early phase of pilot tests. Despite the extensive development in monitoring and communication features, coordination feature is still in preliminary steps. We aim to improve our telepresence tool to support coordination tasks for senior citizens to promote their social interaction. Regarding the increasing population of the target group and lack of caregivers, the desired tool should enable one to many caregiving support. The system should provide senior citizens with psychological attitude for being part of the community to improve life quality. In current phase, the proposed system simulates social activities of senior citizens to evaluate the performance and usability through case scenario. For that purpose, we need to investigate requirements for timing and coordination aspects of special social activities. (Firouzian and Nissinen 2013)



Figure 1: The caregiver can simultaneously monitor multiply senior citizens, and text or call them.

Coordination task is defined by providing answers to three specific questions which are 'What is needed?', 'where is it needed?' and 'who needs it?'. We investigate a bus trip scenario by interviewing the organizers to answer these questions, and implement the social event as a case scenario for our monitoring tool. (Tatham et al. 2016)

TELEASSISTANCE TOOL

The OldBirds is a unique solution for bringing new technologies and everyday caretaking together. It provides a cross-platform application for caregivers to monitor and assist senior citizens in their day-to-day activities. This open-source application can be very useful, especially for senior citizens suffering from memory or physically impairing illness. The caregiver UI includes the location of the senior citizens avatar on a map and windows for texting and calling tools (Figure 1). Hovering the mouse over an avatar brings an information box to visibility, which contains relevant health and personal information regarding that particular senior citizen. (Firouzian and Nissinen 2013)

Figure 2 demonstrates scene of the latest version of the OldBirds (version 2.0), which is designed with an isometric view and applied video game mechanics. The solution can be run on various platforms; such as the web, smartphones, wearable/touch devices and VR gears. These platforms are becoming increasingly popular commodities and thus easily accessible. Senior citizens may interact with their caregivers, such as family members and nurses using any of these smart tools. The application also provides the caregivers the possibility to locate and if necessary give instructions or directions for their respective senior citizen via customized teleassistance tool. It increases the general safety and quality of life for citizens who need assistance in their everyday life. (Ponrasa et al. 2014)



Figure 2: The application provides caregivers with a isometric view of home and city scene. Coordination, personal and health data is associated to avatars.

The OldBirds 2.0 application is strongly influenced by profound research studies of Yamamoto et al. (2010), Pulli et al. (2007) and Ikeda et al. (2011). The application runs on web browsers, and GPS is integrated within the solution to provides caregivers current location of the senior citizens. Caregivers can also find relevant health information about the senior citizens from the user interface of the application. The information can be found through avatar which appears on a map of the caregivers screen. The teleassistance tool was added as a new and required feature to the version 2.0 for providing amicable interaction between the caregiver and senior citizen.

The application was implemented using Unity as the development platform, which is a cross-platform game engine widely used for building various commercial video games. It provides a smart asset system which makes importing and prototyping of the application easier and variability due to its multiplatform properties. Programming languages C# and JavaScript were used for developing OldBirds application. However, there were some challenges with the code structure during the development phase. One major obstacle was translating and rewriting the code from JavaScript into C#. The change was necessary to assure the upgrade would meet required standards. During translation phase, the code was rigorously commented, and the overalls of the project codes were extensively documented. (Jian-song 2011)

Our application was developed and improved iteratively using design science research method (DSRM) and action research method. Steps of DSRM include identifying problem and motivation, defining the solution objectives, design and development, and finally evaluation step. The Scrum methodology was used under Agile framework to assure that the application



Figure 3: The communication panel includes VOIP call. It provides conference call to many senior citizens at the same time.

development is standardized, each phase is carefully measured, absorbs feedbacks and reflects users needs iteratively. OldBirds 2.0 project consists of a game engine, work flow engine, integration development, and application interface. (Peffers et al. 2006)

In action research method the social process has the most important role in the whole research process, It while research and community are cooperating. is pragmatic and cooperative because the action and interaction are involved in the research process. The action research method explains more specifically social attitudes. In this approach as the data collecting methods are usually interviews, surveys, and observations, researcher produces new knowledge that is scientific through different phases. The first phase in the method is planning. The second phase is taking action and the third phase is observing. The last phase is reflecting. These steps are followed in design of different case scenario and new feature in OldBirds application. Planning phase includes qualitative studies and interviews, to develop elegant features based on end-users' requirements. Then observation and evaluation, through usability studies and interviews, inform us about flaws in the system that need to be eliminated. (Bilandzic and Venable 2011)

The new feature that was implemented in OldBirds version 2 was customized communication tool. Our teleassistance tool allows the caregiver to contact multiple senior citizens at the same time and possibilities to give instant consultation (Figure 3). Our teleassistance system allows senior citizens to receive audio, video, and SMS. The caregivers can receive senior citizens location data in real-time, and they have the possibility to provide assistance and participate in interactive telepresence (Figure 4). Respectively, senior citizens have their own user interface for texting and calling,



Figure 4: The communication panel includes instant messaging. It provides template message to be sent to one or many senior citizens.

which can be operated via smartphone and/or wearable devices. These features allow caregivers to make sure the citizen do not roam off-course when traveling outside their home.

The main tool in constructing the artifact was Unity 3D, which is an editor used mainly in creating games, but can be extended to basically everything in computer sciences. The editor allows quick playing, testing and editing which makes the development process fast. Importing external files or content objects (e.g. models, textures, audio or scripts) is made easy with the asset importing function. Unity supports 3D package importing for the most 3D applications. It also has an online asset store, including free and paid assets to be used in game projects. Currently, there are 23 different platforms that Unity extends to, including mobile, consoles, Windows and Linux.

OldBirds version 2 includes a waypoint system in character movement. The path of the character can be controlled using waypoints. The waypoints are the main role in designing a scenario in the game environment.

Our teleassistance tool helps senior citizens to feel more secure, self-confident and to live longer in their own homes independently. It helps to minimize the possible isolation and to maintain senior citizens mental health in good condition. The coordination feature to organize a simple social event is described in next sections.

PROMOTION IN SOCIAL LIFE

In order to support coordination in a social event by an ICT solution, requirements such as roles, time, location, logistic, and responsibilities should be investigated. We conduct qualitative study and interviews with senior citizens, event organizers, and caregivers. The focused and semi-standard interviews are two types of inter-

views conducted in this study. The focused interview is conducted after presenting various scenarios of social events with some general questions. After providing sample text, picture and video scenario, semi-standard interview aims to find answers to specific questions which are designed based on requirements, such as 'To whom would you think a specific social event is useful?' or 'What are the process to organize a short bus trip?' or 'What is not needed in the text, picture and video scenarios?'. Furthermore, interviewees answer set of open questions to provide us with fresh ideas. Open questions describe how a social event should start and end. (Flick 2009)

A bus trip scenario is designed based on interviews as a social event that needs coordination. To facilitate organizing task with the help of ICT tools, we investigate existing solutions. There are existing tools to arrange activities in a group of people who are socially connected in the virtual world. These tools provide suggestion to the social events based on users interests or locations. The main limitation is that existing tools provide information based on the data that is shared by connected people. In case of the elderly user group, coordination needs detailed information about time, place, logistic and health condition of isolated senior citizens. (Shen et al. 2016)

Interview with activity organizers of Kokkola Parish Union (Finland, Kokkola), reveals most of the activities are weekly and short as a couple of hours. They include trips to different regions and meeting places for coffee, singing and chatting. Organizer needs to confirm senior citizens' attendance beforehand and finds most suitable time for them. Safety instruction should be provided for each specific trip. The number of attendants varies, but it can be up to 40 senior citizens while some of them may suffer from mild cognitive or physical impairment. A query needs to supply requirements such as walking aids, wheelchair, and drugs. The personal information and requirements differ based on senior citizens health condition, while in most cases they need to be consulted with personal caregivers. Then, the information about places to pick up is shared, and due to lack of communication system, this step happens to be time-consuming and problematic. An example trip includes picking up, visiting a church, lunch, sightseeing and coming back home.

A scenario is defined as a real life story for people committing to an activity to accomplish a goal. It justifies the processes of the action and different elements of the activity such as setting, actors and objectives through simulation. The setting is the core of scenario which is the bus trip in our social activity, and the actors are the senior citizens, instructors, bus driver and different placeholders. The actors can have several objectives to accomplish during setting, and in our scenario, the social interaction is the main goal. (Carroll 2000)

The communication system is the heart of organizing tool to support different dimensions of coordination such as roles, time, location, logistic and responsibilities in the different context of routine life or emergency situation. We implement bus trip scenario into our existing communication and teleassistance tool to prepare OldBirds tool for a real life challenge. Moreover, the running scenario by OldBirds tool is monitored by activity organizers for further evaluation.

IMPLEMENTATION OF EVOLVED CASE SCENARIO

Groupware is defined as a collaborative software, which is designed to achieve a common goal by integrating coevolving human and tool systems. Groupware applications categorize in three groups of communication, collaboration, and coordination. Communication tools such as instant messaging and VOIP integrate unstructured interchange of information. Collaboration tools include the voting system which provides a common goal through facilitating a rich collaborative environment. Coordination tools assist users to achieve the common goal through coordinating different jobs for each user. (Johnson-Lenz and Johnson-Lenz 1991)

Shared calendar facilitates arranging, scheduling and sharing events in a broad network such as Internet. An invitation-based shared calendar is a convenient approach to share events. The basic concept is to synchronize all individual calendars with a network calendar. GCS (Groupware Calendar System) organizes personal and social calendar simultaneously. GCS can be managed individually and provide different types of access for modification of events. (Nomura et al. 2013, Palen 1999)

The behavior of a group of older adults in a crowded place is complicated, and Virtual Human Crowds simulation can help to study it. Musse and Thalmann (2001) present ViCrowd model based on Hierarchical Model in real-time simulation of Virtual Human Crowds to project various types of behavior. ViCrowd concentrates on the emergency situation while we want to simulate elderly adults behavior in everyday life. Delta time is another important factor in the design of a scenario story, and it is vastly used in game development. (Musse and Thalmann 2001)

We implement the waypoint system along with delta time variable to observe movement speed of game objects in OldBirds scene. Waypoints are defined for different game objects and avatars, and they are



Figure 5: An example pop-up panel to input general information about an event.

loaded from a workflow engine which is attached to a simple SQL database server. The predefined waypoint information is stored for all the game objects, and they are loaded and attached to the birds avatars to simulate movement of avatars in the city environment. (Ponrasa et al. 2014)

The main coordination task of a remote caregiver or organizer is to monitor all the birds during and shortly before and after the event. So, the caregiver can monitor multiple senior citizens with the different persona in a simple event such as grocery store shopping or more complex social event such as bus trip to another region. The client applications on handheld devices also connect to the database to receive information regarding the upcoming event.

In our specific bus scenario, waypoints define different routes from senior citizens' homes to a specific visiting place. Furthermore, different characteristics and persona are defined for avatars based on realistic characters. It includes general and detailed information such as health condition information. Google calendar inspires the design of our calendar user interface, and our social calendar is designed with a wide overview of the upcoming individual or social events. While organizer creates or modifies an event, the communication panel can be used to call, or send messages to multiple senior citizens. The main principals of user interface design are considered to facilitate interaction of caregiver and the system. The event management panel provides different pop-up windows (Figure 5) as user interface with a short description in each field. The scenario validates usability of proposed coordination tool, by creating a social event and passing confirmation process and monitor avatars during all the sub-events a bus trip.

CONCLUSION

Oldbirds tool can be categorized as a groupware application with communication and coordination features. It provides remote caregivers with the scene of city environment and birds avatars. The avatars indicate different senior citizens, and they feed the caregiver with general and detail information about senior citizens, such as health condition or location. We implement coordination feature in our existing monitoring and communication tool (OldBirds) to facilitate organizing the social event. In the first step, we evaluate different social event scenarios through interviews. Then we evolve a bus trip scenario which is a popular setting for many social events. Finally, we implement the scenario in OldBirds tool with all the predefined sub-events. We integrate a workflow engine and database to generate waypoints for object movement in the city environment. The organizer can keep the track of multiple senior citizens persona while creating or modifying a social event regarding the requirement. We firmly believe the social interaction is an efficient approach to promoting health in older adults.

Developing case scenario is the approach to design new elegant features in the application that suit end users. We proceed abovementioned steps to design the coordination feature, so it can fulfill the requirement of real life use cases.

Based on the interview with activity organizer, the bus trip was divided into different sub-events. Our future work includes a qualitative study and interview with senior citizens and activity organizers to evaluate the usability of coordination feature in OldBirds application. Furthermore, it reveals steps that are missed in the developed coordination tool, and it can be implemented in future work.

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