Roll

An Immersive Game Experience

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Project Git Repository

http://gitlab.doc.gold.ac.uk/afior002/Andrea_Fiorucci_Final_Year_Project

Project Blog

https://rollgameblog.wordpress.com/

Project Twitter Account

https://twitter.com/Roll_Game_

I would like to dedicate this thesis to my loving parents and sister

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 19,500 words including appendices, bibliography, tables and has fewer than 140 figures.

Andrea Fiorucci

May 2017

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Personal

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Abstract

The increasingly more advanced and innovative discovery of new technologies has completely revolutionised our everyday lives. This particular fact deserves attention as many people are getting lost in this new Virtual World whereas others are not yet satisfied with the progress made and are constantly requesting more. The game industry, for example, requires a massive effort to produce high standard products in comparison with previous years. This is due to the appearance of new technologies such as motion recognition, 3D audio, Augmented Reality and Virtual Reality. Having said that, it is clear that simply playing a video game using standard joypads might not be enough for many users anymore. The future of video games is leading towards two fundamental concepts: Immersion and Interactivity. The purpose of this study is to investigate the key concepts of what makes video games more immersive and interactive and whether changes in the context of the same application play a fundamental role in terms of the overall game experience. The empirical part of this study was conduced in 2017 in London, over a period of nine months, where users were asked to play a 3D Isometric Adventure Game called Roll with two distinct controllers: a classical and well known Playstation 4 joypad, and a unique physical structure controller built exactly for that game. The project development period involved different stages, with the longest time mostly dedicated to both game design and physical controller implementations. This thesis examines and analyses how to deliver a substantial immersive and interactive game experience even without the use of advanced and expensive technologies. Furthermore, it explains the significant role of the context in which a game is played, how the inclusion of tangible feedbacks, such as water, or a combination of hot and cold air would affect the game perception. Finally, it examines whether adding a physical reward system compared to a digital high score would add replay value to the game and encourage users to play again. On the basis of the results obtained from user testing sessions and questionnaires filled in after each experiment, it could be concluded that playing the exactly same game under different circumstances was completely changing the users' experience. Tangible and perceivable feedbacks seemed to form a stronger connection between the players and the game, reducing the distance between Virtual and Real Worlds. In addition to this, the physical rewarding system drove most of the players to ignore the standard high score system and, instead, had them focused on obtaining the real price for completing the game.

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Introduction

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1.1 Overview of the System

Roll is an interactive game system which tries to narrow the distance between the Virtual and the Real World. It uses a combination of both hardware and software to create a unique controller and aims to both improve the standard games' interaction and deliver a more realistic and immersive experience for the users. Classified as an arcade game, Roll takes advantage of physical computing approach to highlight and bring to life what is mostly perceived while playing video games. The game consists of a 3D Isometric Adventure Game made in Unity 5 where users play the role of a solid heavy sphere with the main objective of reaching the end goal for each of three playable levels respectively called Green Countryside, Icy Snow, and Dry Western. On the basis of similar game applications like Super MonkeyBall and KULA World, players are challenged to activate traps, collect score points and remain safely on the platforms without falling down. What really makes this experience unique and immersive is a physical controller expressively built for the game. The physical controller is a double floor wooden structure with a forty-centimetre-diameter sphere enclosed. Roughly a third of the sphere comes out of the upper floor structure, allowing players to operate it as an input for the player sphere movements. The large solid sphere, in fact, sits on a set of three small trackball mice which allows free rotation in all x, y, and z axis. At any point during the game, users can select their game sphere colour design by twisting three potentiometers placed in the front panel of the structure. Each potentiometer corresponds to a specific colour component of an RGB LED strip positioned around the sphere. A combination of red, green, and blue lights can offer almost seventeen millions possible colour choices. This particular feature matches the light around the physical sphere together with the colour of the sphere in the game, creating a first immersive feedback for the players. To estrange users from the classic game input systems, in particular joypads and keyboards, arcade push buttons are used to navigate the whole system. The structure provides two yellow push buttons used for selection and main menu actions, and a bigger size RGB push button used within the game to activate objects and mechanics. The game presents different scenarios where natural elements such as water, fire, and snow are used to emphasise the overall game design. Roll uses exactly these elements to highlight the game environment and make the whole experience closer to reality. In fact, a water pump system is installed inside the structure to simulate a splash when players lose the game by falling into water.

In regard to both fire and snow elements, a similar interactive approach is used to accomplish real heating and cooling systems for the physical structure. When players get close to both warm or cold objects in the game, a relative temperature is also perceived through the physical sphere, all thanks to a switch which activates cold or hot air around it. The sensation of playing a game, knowing that some outcomes are also reproduced in reality, affects how users approach the game. Furthermore, by taking into consideration the example of a real water splash, particular actions in the game will be well planned and users will pay more attention when making specific choices in the game. The idea of setting only virtual rewards while playing a game like Roll would have detached the immersive atmosphere created by the system, leading users to only play the game a few times, if not only once. In order to add replay value to the game, in addition to a score and high score mechanics, Roll offers a physical price reward for players who complete the whole game adventure. The system used to achieve such a mechanic involves the installation of a circle-shaped cavity situated on the right hand side of the structure which opens only when the game is completed. Users can then collect their real prices and get physically rewarded for the ability proved while playing. This reward system does not only add replay value to the game for the same player but does also tempt others to try and achieve a similar level of completeness, thus initialising a challenge routine between each player. The combination of all these individual physical systems, together with the game environment and unique controller, is what makes Roll stand out from other games and sets both the level of interaction and immersion halfway between using classic input devices and using advanced technologies like Virtual Reality. In order to launch the application, it is required Unity5 Game Engine together with a library called Uniduino. The latter helps to set up a serial connection between Unity 5 and Arduino microcontroller, enabling the communication between the game and the physical components. Despite being a game, Roll has not been designed for commercial release. At the moment, it is only available as an application for Mac and it requires its physical structure in order to fully benefit from the game. A second version of the game is available to be played with a standard bluetooth joypad but some of the features are limited. On the other hand, Roll aims to be part of interactive game showcases around the World. So far, Roll was selected and took part at the Intel Buzz Workshop 2017 in London. Major events like GDC in San Francisco and Amaze in Berlin are some of the objectives that Roll will try to achieve in the following years.

1.2 Motivation

The opportunity to learn about a new area of computing science, together with researching and running experiments to find out which are the key elements to engage users when playing video games, was the main reason behind the development of Roll. The incredible step forward that technology has made in the past few years has grown interest in major game companies to invest a significant amount of money in producing incredible titles. Only analysing the difference between a title released few years ago and a title which has recently being released, it is extremely clear that game industries have come significantly far. When it comes to play most games though, even if they present unique concepts and amazing art designs, the overall experience is normally transmitted by the use of well known input devices such as keyboards, mice, and joypads. The latter are well established controllers and there is no doubt they can offer a great game interaction but sometimes all the effort put by companies to produce immersive titles is limited by the fewer actions allowed by these devices. Furthermore, there is still a significant gap to be covered in terms of both immersion and interaction before considering Virtual Reality where, for example, haptic feedbacks are not yet being fully developed. In conclusion, a strong interest to be able to capture a variety of game elements and bring them to life, together with offering a different way of playing video games, was the main motivation for this project.

1.3 Contributions

Roll is a product based on the confirmation and expansion of an existing model which combines video games together with interactive physical inputs. Although there are many other systems that use similar techniques, Roll is unique of its kind. A very detailed research has shown that there are only few games which use similar interfaces in regard to the player motion control. Roll, in fact, goes beyond the implementation of simply mapping the movements of the player to a bigger scaled version of a trackball mouse system and includes and combines multiple other physical features which elevate the game interaction and atmosphere to a different level. Furthermore, experiments are conducted to prove how it is possible to completely change the users' experience when playing exactly the same application simply by offering a more engaging way of playing. The latter is proven by recording users' expressions, thoughts, and statements while they play Roll using two distinct input interfaces, initially with the bluetooth joypad and successively with the physical structure. Answers are retrieved in the form of play testing, questionnaires, and direct observation. Finally, Roll helps expanding the physical computing approach community by offering open source project details published on Twitter and a personal blog.

1.4 Thesis Structure

The structure and content of this paper is organised as follows.

Chapter 2 provides a background and introduces the fundamental reasons behind the development of this project. It also examines all the research questions, focuses the study, and determines the methodology. Chapter 3 introduces the design process adopted for both the video game and the physical structure. Prototypes techniques applied are also provided in this section. Chapter 4 describes in details the implementation process for both video game and the physical structure. Furthermore, it reports the major problems encountered and the solutions adopted while developing the system. Chapter 5 explains different methods used for testing and system evaluation. From play testing sessions to questionnaire responses and data analysis, this section also lists and describes few locations where Roll was exhibited and evaluated. Chapter 6, provides a thesis conclusion and analyses the overall users' experience. It also compares the two different versions of the game input interface and provides some information in regard to the future plans for Roll application. Finally at the very end of the paper, under Chapter 7, a bibliography lists all the sources and information needed in order to successfully complete this project and to conduct an appropriate research.

2

Literature Review and Background

Contents

2.1 Introduction

Technology is rapidly improving and new interactive systems are constantly being developed and made accessible by a greater user group. This extremely complicated relation between humans and machines has involved a global collaboration in researching and implementing unique solutions in order to increase accessibility and reduce frustration when it comes to this unfamiliar collaboration between users and technologies. The game industry is fully aware of the potential discovered by this field and it is continuously trying to improve and come up with exclusive ways to interact and play with video games. Despite the incredible results achieved, technology has probably made a very big step in a short period of time and some intermediate discoveries may have not been fully tested and implemented yet. The transition from a classical 2D joypad interaction to Virtual Reality 3D interaction has left a lot of opportunities to create original ways of interacting with video games. Nowadays, the major problem is certainly not the fear of expecting a poor graphic, inconsistent design or inappropriate audio when playing video games but the redundancy of using a limited range of controllers to bridge the Real and the Virtual Worlds. Playing video games with standard input devices, already evokes strong emotional responses in users. Precisely for this reason, creating unique ways of interacting with video games would deliver greater emotion responses and improve the overall game experience. Luckily, there is a massive community of people who comes up with exclusive ideas when it comes to games' interaction. The latter is mostly supported by a field of Computer Science known as Physical Computing. Combining the beauty of virtual game environments and being able to reproduce some of its elements in reality through the use of physical materials is a valid solution to reduce the gap between players and games. There are lots of successful projects which have been already released and the website 'Shake That Button' turned out to be a great source of inspiration when developing Roll. Being different from other applications, Roll presents an original concept which increases the feeling of immersion through an easier but unique way of interacting with video games, with the aim to understand what makes them pleasant, exclusive, and closer to reality.

2. 2 Research Preface

Roll began as an attempt to develop an alternative and interactive controller for an isometric 3D adventure game. Immediately in the early stages of the project, it was very clear that the idea had a great potential to contribute to research and at least analyse and answer a variety of questions related to the field of game interaction. The following research questions explains different concepts which range from the definition of immersive games to the explanation of how we can improve the overall experience by including real feedback related to multiple human senses. Despite the fact that many companies are constantly trying to develop interactive applications, one of the major concerns is the failure to involve all five human senses with equal importance. Feel and touch for example are sill hot topics in the game industry nowadays. The analysis and research carried out for each question is based on both existing information and the results obtained by direct observation of users experiencing Roll.

2. 2. 1 Definition of Immersive Games

What is described as game interaction and how could we deliver a more interesting and immersive experience for players?

The study of player - video game interactions continues to be a very hard topic in research as they are very complex to define. In order to have a better understanding of the argument, we should first introduce the principle of interaction between humans and computers. In Computer Science, we can consider User Interaction to be an established relation between humans and digital screens. In particular, it is the process of how users send an input to a particular device and how the device sends a response back to the user based on the input previously received. People interact with systems every day and most of the time they will not even notice they are doing so, e.g. taking your regular coffee from a vending machine. The major interaction, though, occurs between humans and computers as they constantly interact with devices such as smartphones, media players, laptops, and desktop computers. The field of Video games is probably one of the biggest examples of human and computer interaction as there is a lot more than a simple exchange of inputs and outputs between the two. Most studies have in fact confirmed that video games do also affect people's feelings and emotions as a result of a particular experience. According to Katherine Isbister, "we don't talk in a sophisticated manner about games the way we do about films and books" and, for this reason, she wanted to highlight "the design innovations that enable games to affect users in new and emotionally powerful ways."[1] The most common aspect in games is players' ability to interact with a virtual environment, usually by means of a compact and portable device. Among all the different available controllers in the market, today standard joypads are probably the most known and used devices in the video game industry. There are different reasons why joypads have become so popular despite the huge market competition: firstly, they are charged at an affordable price but most of the success is due to their extraordinary compact design which makes them the number one choice for players. Although input devices like joypads, keyboards, and computer mice are extremely popular in video games, there are some drawbacks which mostly constrain the game experience due to their limitation when it comes to interaction.

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[1] Katherine Isbister, *How Games Move Us: Emotion by Design* (Cambridge, MA: MIT Press, 2016), accessed April 12, 2017, http://news.ucsc.edu/2016/03/isbister-book.html.

As BBC reporter Peter Ray Allison explained in 2014, controllers used to be such simple devices: "A single control stick and a few buttons were all a gamer needed to blast aliens or score a winning goal on the primitive, pioneering games consoles. But in the last few decades, they have grown up. They have become more intelligent, more pleasing to hold and use, and able to adapt to the increasing complexity of the gameplay they are meant to be controlling."[2] Technology and the game industry have grown even further from 2014 and it is very clear today that most players have more expectations than simply playing games with standard devices. Many attempts have been made in order to keep up with new technologies and new incredible ways of interacting with video games have been discovered: let us take Motion Controllers, Simulators, and Virtual Reality as an example. Although the latter have completely revolutionised the interaction with video games and opened up new doors for the market space, the incompatibility of blending these new technologies has, at the same time, slowed down the process of developing fully interactive and immersive experiences. For instance, Virtual Reality offers a 360-degree view but it lacks haptic feedbacks which instead could be experienced in a flight simulator installation. How could we then deliver a more immersive and interactive experience for players? Ten, twenty years ago we could have simply answered this question because a better graphic resolution, an improved sound, and a smooth gameplay, were all that was necessary to improve a game experience. Today, reaching a state of satisfaction for players is a way more complex goal to achieve as there are many more factors which influence the outcome of a game experience. Players want to experience video games in all their aspects: they want to touch, feel, smell, hear, and see all at once. The major goal for Roll Interactive Controller is to obtain a compromise between all these new ways of interaction with the aim to create a unique experience for players.

[2] Peter Ray Allison, "The surprisingly uses of games controllers" BBC, last modified December 12, 2014, http://www.bbc.com/future/story/20141212-press-x-press-y-fire-laser.

2. 2. 2 Alternatives to Virtual Reality

Virtual Reality is considered the highest form of immersive games nowadays; could we offer different alternatives?

Virtual Reality is considered to be a fairly recent technology especially in the field of video games. Actually, if we consider the purpose of Virtual Reality as a mean of creating the illusion of being somewhere else, the very first attempt of this concept dates back to 1812 when Louis-François Lejeune made a 360-degree painting in an attempt to entirely cover the viewer's field of vision, making them feel present at some historical event or scene. Since then, the concept of Place Illusion has generated interest in a variety of fields and a large number of research has been carried out in order to deeply understand the potential and possible use of such discovery. As Virtual Reality has found many fields of application which varies from Education, Military, Healthcare to Business, Sport, Media, and Films, the video game industry could not have been ignored. In fact, gaming is considered to be one of the highest field of application for Virtual Reality. In addition to Place Illusion, new concepts like Plausibility and Sensorimotor Contingency have been paired in an attempt to create different virtual scenarios which deceive people to believe they are in a real environment. Thanks to both science and technology development, Virtual Reality is a very hot topic nowadays and it seems to be the future of imaginary interaction and immersion. There are a range of systems that are used for this purpose and headsets like Oculus, Vive, and Playstation VR are certainly the most popular ones and mostly used for games development. These incredible pieces of technology are used to actually stimulate our senses together in order to create an illusion of reality. The operation of these devices is very straightforward: users wear the VR headset like a pair of glasses and they are instantly teleported in the imaginary World. A 3D game engine or software behind the scenes handles all the operations required to render the environment. Some headsets like the HTC Vive, for example, are more advanced than others and deliver an even more immersive experience; in fact, the interaction is not only limited to the exploration of a Virtual World with a 360 degrees field of view but these devices also track the forward and backwards head motion, hands location, the eyes gaze, and the body position in space which allows a reasonable freedom of motion.

Virtual Realty has definitely revolutionised the game industry and the way people interact with machines but like any other experimental new application, there are also some downsides regarding its use. Deceiving the brain by making people believe that they are in a different place than they actually think is an extremely difficult task to achieve. Despite the huge effort employed to create an immersive environment, the whole credibility could be interrupted by the lack of very small details which the brain interprets as not real. There are two fundamental principles which are very difficult to master in order to achieve a significant believability, as Mel Slater reports:

> The first is 'being there', often called 'presence', the qualia of having a sensation of being in a real place. We call this place illusion (PI). Second, plausibility illusion (Psi) refers to the illusion that the scenario being depicted is actually occurring.[3]

It was not so long ago that Virtual Reality applications where causing nausea and motion sickness due to a slow latency users experienced while testing some devices. Luckily, this unpleasant feeling has been solved today, thus reducing the risks of motion sickness to a small percentage. The lack of haptic feedbacks is also a huge constrain in terms of plausibility and it is one of the reasons why there is still a big debate regarding the efficiency of this technology. Finally, there is still one major hurdle virtual reality has to overcome: it is a very expensive technology and therefore it is not affordable by everyone. So, considering all the above-mentioned issues, is Virtual Reality really the highest form of immersive and interactive games nowadays?

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[3] Mel Slater, "Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments," *Philosophical Transactions of the Royal Society B* 364, no. 1535 (2009), accessed April 13, 2017, doi: 10.1098/rstb.2009.0138.

Most people would argue that nothing can be as immersive and interactive as Virtual Reality but the fact is, technology has grown too fast in recent years leaving behind an empty void where development in other forms of interactions have suffered and stagnated. Dave Szulborski explains how sometimes Virtual Reality lacks interaction in his book *This is Not a Game: A guide to Alternate Reality Gaming*:

> Perhaps a better example more akin to video games is a simple virtual reality environment a player can walk through, totally immersed in the artificial world via the virtual reality devices he is wearing. Although he can look around and move through the environment, he doesn't really interact with it in a meaningful way.[4]

Without any doubt, in the next few years, Virtual Reality will be the next generation of users vs computers interaction but it is always worth to explore and come up with different results. Roll offers an alternative solution and combines the classic components of a video game with the incredible science of physical computing. By infusing the two, Roll aspires to bridge the gap between playing on a digital screen with the analog world to create a more fulfilling and immersive game. It is designed to be immersive and interactive at the same time, in fact users can both interact with the system by the means of a physical controller and experience real life feedbacks from the game.

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[4]Dave Szulborski, "Game or Interactive Story?" in *This is Not a Game: A Guide to Alternate Reality Gaming* (Raleigh: Lulu, 2005), 20.

2. 2. 3 Experiencing Real Heat

Developers introduced new concepts to improve players experiences. In some applications users were experiencing real heat. What was the outcome of such experiments? Could Roll's heating/cooling system be a reasonable solution?

The exponential growth of video gaming technologies has triggered the desire of reducing the barriers between the digital and the analog worlds. Players have realised that the game industry has reached a level of development that few years ago was considered to be just dream. Exactly for this reason, playing a best selling video game on a 2D flat screen might not satisfy the majority of users anymore. They need more, they want to see the game leaving the screen and be surrounded by its virtual environment. They want to be the game.

> The convincing, immersive game world needs to be indifferent to the player and the player needs to feel like an intruder.[5]

In order to keep up with the market demand, developers introduced unique concepts to improve players' experiences. Graphic and Sound have already been mastered to a very interesting level with the introduction of high resolution screens, powerful rendering softwares, and 3D audio features. Understanding how human senses like smell, touch, and feel could be integrated in the experience while playing video games, has been one of the goals developers tried to accomplish. Both the game industry and several indie developers came up with original games and applications driven by human senses which included smell and taste: Planet Licker by Andy An, Azuria Sky, Otis Denner-Kenny, ohsqueezy and Nosulus Rift by Ubisoft are some examples of the result achieved. Although the community of indie developers produced further similar applications, professionals remained slightly sceptical regarding the possible success of this innovation due to a variety of problems and concerns raised during the development. That is exactly why the game industry suddenly decided to shift the focus on other aspects of the gaming market, leaving an open mystery on whether future development would have been considered. Back in 2012, Sony outlined a plan for a Temperature Feedback Motion Controller following the design of the Playstation Move Controller.

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[5] Adrian Chmielarz, "The secret of immersive game worlds," The Astronauts, last modified March 5, 2014, http://www.theastronauts.com/2014/03/secret-immersive-game-worlds/.

As described by Jonathan Fincher:

> the proposed controller would use alternating surfaces connected to thermal modules for either hot or cold to recreate various temperatures[6]

but unfortunately Sony never came up with a solid plan to manufacture this product. Since then, very few attempts have been made in regard to this original idea which could have probably added an extra step towards the concept of immersive and interactive games. Even though understanding all the possible reasons why this interactive mechanic idea has never been fully implemented is very tedious, due to the large number of both technical and theoretical factors which could have slowed down the development process, some assumptions could be made in order to better understand what made the game industry change its mind. First of all, heat dissipation is a very complex phenomena to implement and a proper functioning is strictly related to its context. Additionally, systems which deal with change in temperatures are always subjected to health and safety risks. Temperature feedback could really change the whole gaming experience but at the same time, if not implemented properly, it may produce exactly opposite results. Responses have to be very precise and must occur in real time. Applying heat and cold on a very small device such as the Playstation Move Controller could be then very tricky due to its restricted size and the effect produced might not be strong enough to be felt by the players. Finally, most games in the market place do not have any relations with temperature, decreasing the interest of buying a dedicated device. Despite failure seems to be the right word when it comes to temperature feedback in video games, Roll offers its own cooling and heating mechanic. Being a large structure arcade controller, it has enough space to dissipate and handle heat. A hidden hairdryer system blows hot or cold air directly on the sphere controller which at the same time responds to the game environment. The very first attempt failed as there was a considerable time delay on the temperature feedback. Using Peltier Cells, it was very difficult to manage the transition between blowing hot air and suddenly change to cold one as the system required some time to switch its temperature state. Even if Roll did not resolve a large scale problem in regard to the implementation of a temperature feedback on small devices, it nonetheless delivers a pretty accurate experience which could be taken as an inspirational starting point for future applications.

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[6] Jonathan Fincher, “Sony patents temperature feedback games controller,” New Atlas, last modified October 17, 2012, http://newatlas.com/sony-controller-temperature-feedback/24599/.

2. 2. 4 Contextual Game Experience

The context where a game is played is also a key point for a successful product. Would alternative controllers emphasise interest and completely change the game experience?

Video games are not only created with the purpose of entertaining users, they mirror developers' soul and reflect their emotions to the player. This is the key factor that really adds value to a game title and makes it stand out from the market competition. There are thousands of amazing games out there which, unfortunately, have not had success. Nowadays, creating games that have strong visual graphics has lost uniqueness in the industry as so many companies can achieve similar results. Therefore, other elements have to be taken into consideration in order to develop a successful product. It is unquestionable that the emotions experienced in games are mostly related to what we see and these visuals will probably be the first thing users recall when thinking back to a particular game. However, there are also less obvious aspects involved in the overall game experience which contribute to a title success. A fundamental concept, which is most of the time neglected and which is believed not to have a big impact on video games, concerns the space where a particular game is played and it is known as the contextual space. The surroundings in which a game takes place play an important role to ensure the success of a particular game experience.

"Play is contextual"[7]

Usually players do not even realise how their game experiences may vary from context to context as it is a subconscious process of the human brain.

[7]Miguel Sicart, "Play Is," in *Play Matters* (Cambridge, MA: MIT Press, 2014), 6.

Despite users are not aware of this brain mechanism, their satisfaction when playing exactly the same title may in fact increase or decrease depending if they play in different locations.

> Context comprises the environment in which we play, the technologies with which we play, and the potential companions of play. Context is the network of things, people, and places needed for play to take place.[8]

This assertion by Miguel Sicart, highlights the importance of a game context and it is not only confined by the location of where the game is played, but it also encloses the relevance of other potential characteristics which happen around the game and therefore it influences the outcome. A very explanatory example could be taken by everyday gaming situations. Say you are playing a horror video game in the middle of the day with full sun light striking your room, would it be a greater immersive experience if you were playing the same game at night with no lights at all? Or, would it be a different feeling if for instance some of your friends were sitting next to you while you are playing? Or even, what if you would play a multiplayer version of the game, interacting with your friends from a distance? A similar concept applies also when people play mobile games while sitting carefree on a bus, during their breaks right before a job meeting or when they comfortably play at home. Taking in consideration these few simple scenarios, it is undeniable that the success which contributes to video games is not only defined by their beauty or interesting gameplay, but it is a combination of multiple internal and external factors and the right balance between them. The exact same principle applies when it comes to interact with a particular game and it is strongly connected to how much interaction is allowed in that game and in which form it is presented to players. For instance, in a first person shooter game, a joypad device does deliver a great game experience but the same experience could be improved by changing the context of interaction by offering a gun-shaped controller. Roll, with its unique physical controller, tries to merge the game together with its surroundings in order to create a more complete immersive experience. The controller, in fact, is developed to recreate a variety of Roll game mechanics in real life with the aim of being straight away associated by players with the game it was built for. Players must be able to feel the game even outside the screen.

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[8]Miguel Sicart, “Play Is,” in *Play Matters* (Cambridge, MA: MIT Press, 2014), 7.

2. 2. 5 Game Replay Value

Rewarding players is a fundamental concept to take into consideration if we want to add replay value to our games. Score boards, Time boards are all well defined and tested features to solve this problem but would offering a physical price encourage players to come back and play again?

Have you ever wondered why a simple game concept idea can sometimes become a very successful and valuable product? Great praise is due to the game development process and the careful consideration of all the parameters that might affect the players' game experience. What is the secret to come up with a winning game recipe which becomes addictive for players? There are different key elements which must be taken in consideration in order to capture players' attention but everything revolves around a major concept mostly known as the game replay value. The latter is a combination of both visible and hidden mechanics which impel players to carry on playing after the game first attempt or even after the game completion.

> "[…] replay value, [is] a term used by game reviewers, marketers, and consumers to assess a game's potential for continued play value after its completion."[9]

In the example of other media like films and tv series, well known industry actors are used in order to grown the audience interest and, most of the time, the end of these cinematographic tapes leave some information unrevealed, thus encouraging users to have another go and watch future releases. The same strategy is used in the game industry but different parameters are manipulated for the sake of raising players' desire to carry on playing a specific title. The specified challenge of a game is one of the reasons why players spend hours in front of their favourite games. The more challenging a game actually is, the more interest is raised among players to try and beat the virtual world. Other important aspects which add replay-ability value include game completion and its randomisation. Most players, in fact, are attracted by the idea of having fully completed a game title and normally a reward is offered in case they do so.

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[9] Mark J. P. Wolf, ed., "replay and repetition" in *Encyclopedia of Video Games: The Culture, Technology, and Art of Gaming, Vol. 1* (Santa Barbara: Greenwood Press, 2012), 524.

Randomisation instead, refers to the unpredictability of some game scenarios; players are fascinated by the fact of not knowing the outcome of some decisions taken when playing. Although the above mentioned are some of the major key concepts which add reply value to almost every video game in the market, the situation has changed with the introduction of online gaming. This huge network of players has allowed developers to create even more addicting applications, consequently increasing the average playing time. Mobile games have the highest audience when it comes to online gaming. Ranking tables, prices, and the desire of being recognised as top players is part of the reason which contributes to gaming addiction. Some games want you to spend money to make it the top players' list and others, for example, set a time range to be waited in order to progress to the next game stage, unleashing the need of completing a particular challenge the following day. Even in mobile games the secret of success is not related to appealing graphics and interesting gameplay but how engaging the product is for players:

> What makes a great mobile game is that it can make your queuing experience at the most crowded local cafe seem *too* short, or that it can transform a subway commute into playtime you look forward to each morning.[10]

Besides virtual rewards and honours obtained for completing games, beating high scores and leading online ranking tables, the game industry also offers physical rewarding prices for the most skilled players. The majority of companies give away real prices for players who buy early or special game editions or subscribe and follow their products. The industry of arcade games cannot be omitted as it is the largest system which offers physical prices to the players. The game addiction is transmitted through the process of collecting paper tickets which are obtained by players in relation to their performances in a wide set of games. The paper tickets can then be exchanged with real prices. As the paper tickets can be aggregated, players are encouraged to win the largest number, in order then to exchange them with bigger prices. Without a doubt, either virtual and real rewards are fundamental to add a replay value to video games and the game industry has taken full advantages of this process.

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[10] Alexis Piperides, "How to Design a Mobile Game So Addictive It's Almost Irresponsible," Proto.io, last modified February 15, 2016, http://blog.proto.io/how-to-design-a-mobile-game-so-addictive-its-almost-irresponsible/.

Nonetheless, there is still an assumption we can make: what would happen if both virtual and real rewarding systems were included in a video game? Would players be more satisfied to obtain one type of reward over another or would they still aim to claim both? Roll tries to answer this questions as it includes a virtual high score system based on the amount of coins collected during the game adventure and offers a physical price for players who manage to complete the whole game. When the last level is beaten, a physical mechanic will open a wooden manhole revealing the winning price. Will players be pleased with the high score or will they give the game another go in the attempt to win the real price?

3

Design

Contents

3.1 Introduction

The first Roll design concept started in early September 2016 after the achievement of a considerable solid project idea. Taking into consideration all the different elements which characterise the final product, some concerning the software and other concerning the hardware, two distinct design approaches have been taken into consideration throughout the whole development process. Although the design process adopted to develop the game was completely different from the design process adopted to build the physical system, an iterative design model was used in both situations as a reference point.

Fig. 1. Example of a spiral iterative design model,
http://www.mindinventory.com/our-development-methodology.php

Iterative design involves a cyclic process of prototyping, testing, observing and refining a product. In the case of Roll, where the priority was to deliver a unique and immersive game experience for players, testing and evaluation were fundamental aspects of the iterative design process in order to obtain and analyse users feedback and adjust the system accordingly. The spiral model methodology (Fig. 1) seemed to be appropriate for the development of Roll as it gives equal priority to the major steps involved when designing a product, especially in regard to prototyping and evaluation sections. The spiral model was used through the whole development process in both the game and the physical structure design.

3.2 Game Design

Roll is a 3D isometric adventure game which presents a similar gameplay to well know titles like Super Monkey Ball by Sega and KULA World by Sony.

Fig. 2. Kula World game cover, https://en.wikipedia.org/wiki/Kula_World#/media/File:Kula_World_Coverart.png

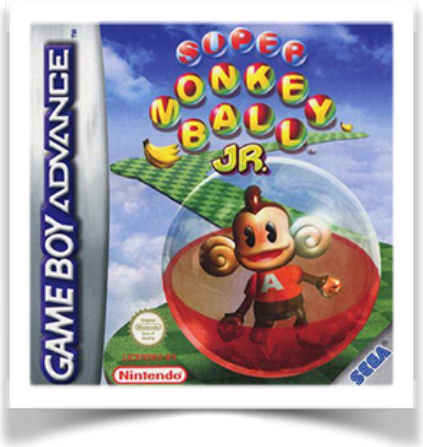


Fig. 3. Super Monkey Ball game cover, https://en.wikipedia.org/wiki/Super_Monkey_Ball_Jr.#/media/File:Super_Monkey_Ball_Jr._Coverart.png

The latter is the real inspiration behind the development of Roll as back in August 2016, after spending some time playing with it, a lack of immersive interaction between the game and its controller triggered the desire of recreating a unique similar game concept. Exactly as KULA World, Roll does not have a game narrative as the background story is not always necessary for this kind of level progression games. Instead, it primarily focuses on implementing interesting mechanics and puzzles with the aim of creating a fulfilling game experience for players. In the attempt of revolutionising the game interaction, Roll has been designed to be played without the need of any standard devices like joypads, mouses and keyboards. Exactly for this reason, the game is played with few and straightforward commands through the use of a physical controller purpose built for it. Despite not having a background story, an initial identity was required for the game. Few brainstorming sessions and the shape of the main game character helped to come up with the game title.

Different logos were designed in Illustrator to give Roll its first very identity.

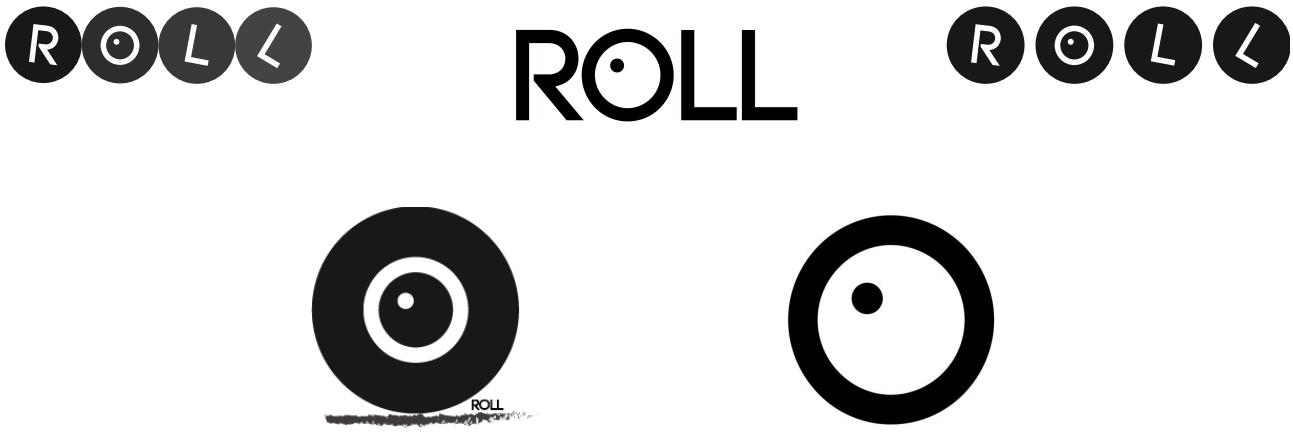


Fig. 4. Different logos designed in Adobe Illustrator.

Having in mind a very early concept of the physical structure interactive elements and the idea of implementing mechanics like real hot and cold air, real water splashes, and real lighting around the physical sphere, were shown to be effective when it came to think about all the possible game scenarios. These elements, in fact, could be included in one level but with a view of making the game more interesting and considerably long, the decision of making three different levels was taken. In order to be consistent with the implementation of the physical mechanics, a green countryside with rivers, a snowy village with low temperatures, and a dry western area with isolated campfires were chosen to be Roll three level thematics. Once the game background was finally established, the main focus shifted to the research of a suitable colour palette for the game graphics.

The methodology used to find an appropriate and consistent design and the success obtained in the research was mostly devoted in using a website called Pinterest to create a collage of similar images and get inspired by the gallery colour palette created.

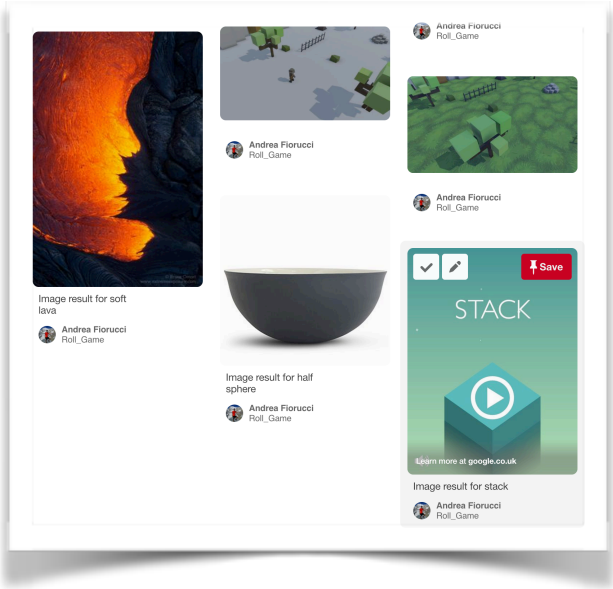


Fig. 5. Pinterest collection of images used to determine the colour palette, https://uk.pinterest.com/andyuni93/roll_game/

Fig. 5 represents part of the Pinterest collage made in the early stage of the project and the texture put together by that collection of 5 pictures turned out to be the starting point of Roll graphics design. Due to little knowledge and skills in being an artist, a low poly graphic style was the most suitable option for the project. The approach used to obtain an appealing game environment, was to create few assets using a combination of two 3D modelling softwares known as Maya and Blender and place the assets created in an empty 3D space to test their compatibility. Following different tutorials in order to learn how to use the mentioned modelling softwares required very long time at the beginning of the project.

Once all the basics were learnt and all the steps from modelling to exporting objects to their correct format started to be successful, the first 3D low poly assets were created.

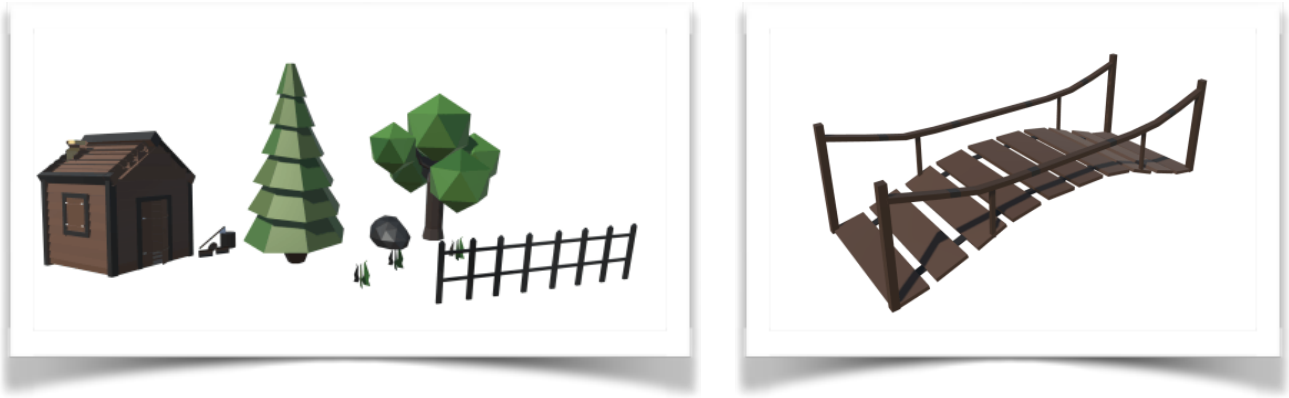


Fig. 6, 7. Green Countryside low poly assets made in Blender and Maya.

Using Unity 5 Game Engine for the development of Roll, a small amount of assets were added at the time in an empty game scene in order to test if they were consistent with each other. Only when the basic scene was analysed and approved, a new more advanced version of the same scene was created following a similar iterative methodology.

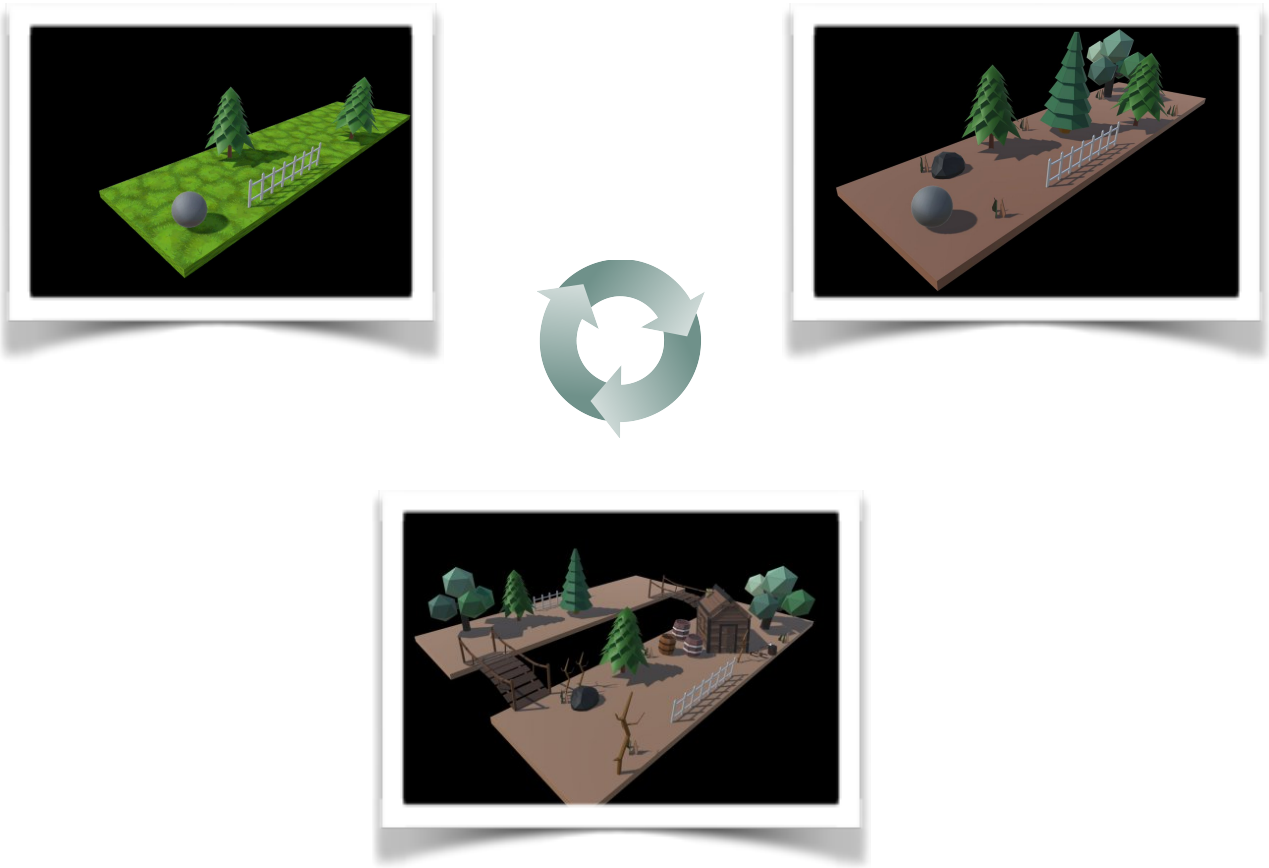
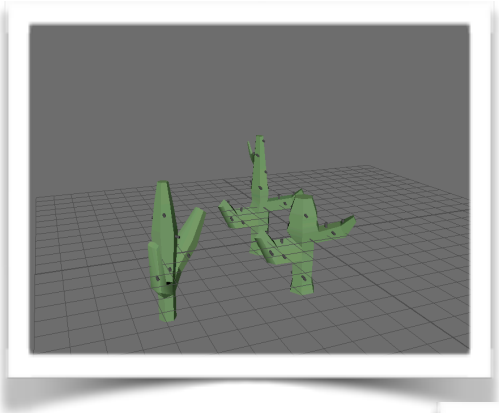
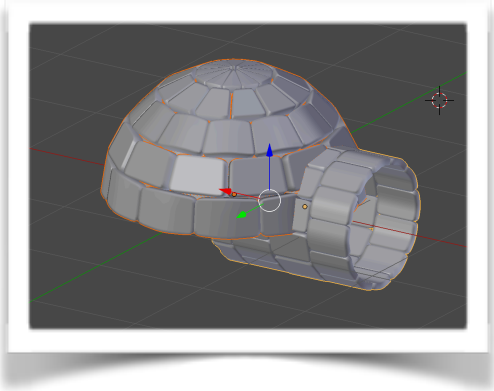


Fig. 8, 9, 10. Iterative method used to check assets consistency.

As the methodology used turned out to be very efficient and not excessively time consuming, more assets were created with a final count of around fifty models in roughly two months of development. The amount of assets were equally divided to cover the three Roll game level thematics.





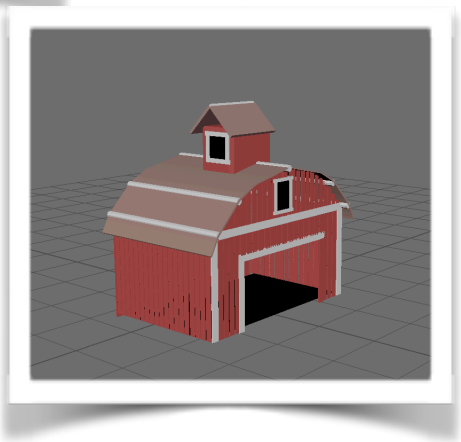


Fig. 11, 12, 13. Roll assets under development.

The copious amount of positive reactions regarding the models created was clearly a good sign and opened the doors for the next project task: level design. Having a large amount of models, in fact, helps a lot when it comes to level design but it is not the only requirement in most cases. Roll needed nice appealing levels in terms of graphics but at the same time each level should have been designed in order to take full advantage of Roll physical controller interaction. It all started with the layout of each level, roughly how long they were, their main structure and the amount of platforms needed for each specific section.

No assets were placed at the beginning but only the platforms level outline as shown in Fig. 14 and 15.

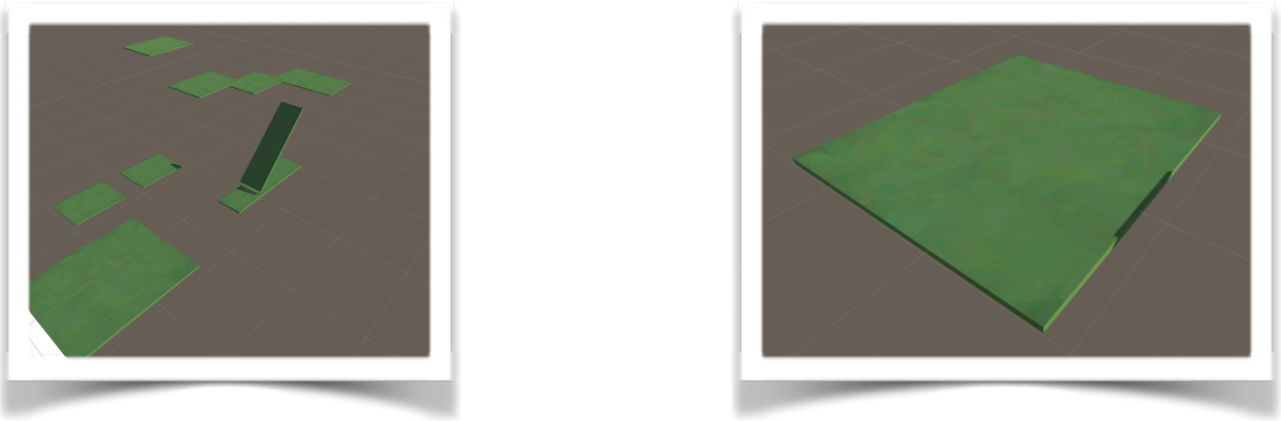


Fig. 14, 15. Level layout with empty platforms.

Once a reasonable amount of platforms were placed for each level, the focus switched to populate all of them with some assets previously created with the attempt of adding a better yet not completed style. In the example of the Green Countryside level, grass and trees were the first elements added to the empty platforms followed by the rest of the assets. Starting by adding background assets to make the platforms more interesting and successively adding more specific and complex objects to complete the game style was surprisingly a success even though simple low poly graphics was used.

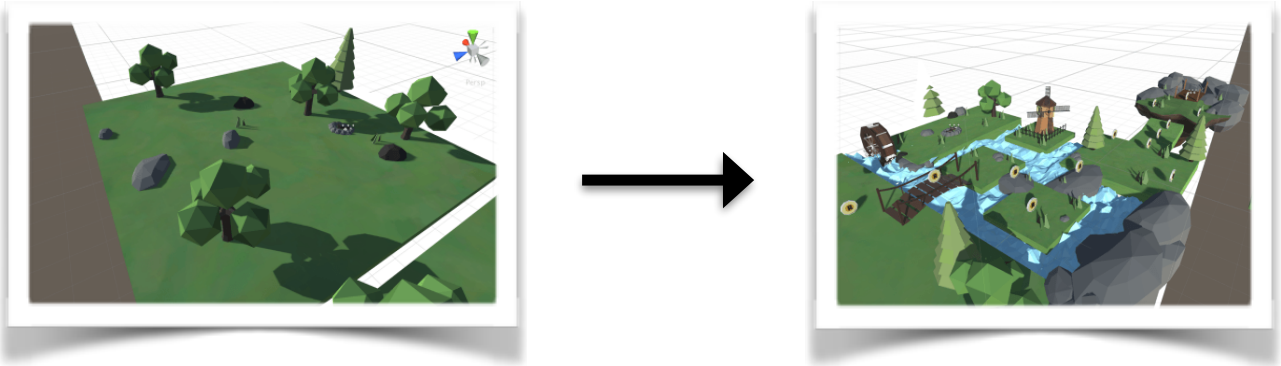


Fig. 16, 17. Level design workflow.

Following the same approach, each of the game thematics were designed to a very polished stage giving Roll its own virtual world to be explored. The final missing element was to add in-game mechanics linked with the physical controller. As most of the physical mechanics had already been decided, it was only required to think of different ways to link them with the game environment. The water splash mechanic would suggest to add some parts in the game where the player could lose by falling into water and this is exactly what was implemented in two of the levels: in both the Green Countryside and the Dry Western levels were added rivers and lakes for the purpose. A second important mechanic related to the physical controller was given by the possibility of the players to push a 10-centimetre-diameter button. A situation like this would expect the action taken by the players to trigger something in the game like traps or perhaps activating and opening secret passages. The Activate button was linked with different objects capable of being activated in the game and they were highlighted by a symbolic particle system. Players were trained to push the button each time they could spot the particle system. A variety of interactive objects were placed in each level including a cannon, a catapult, a cableway, and doors to be opened.

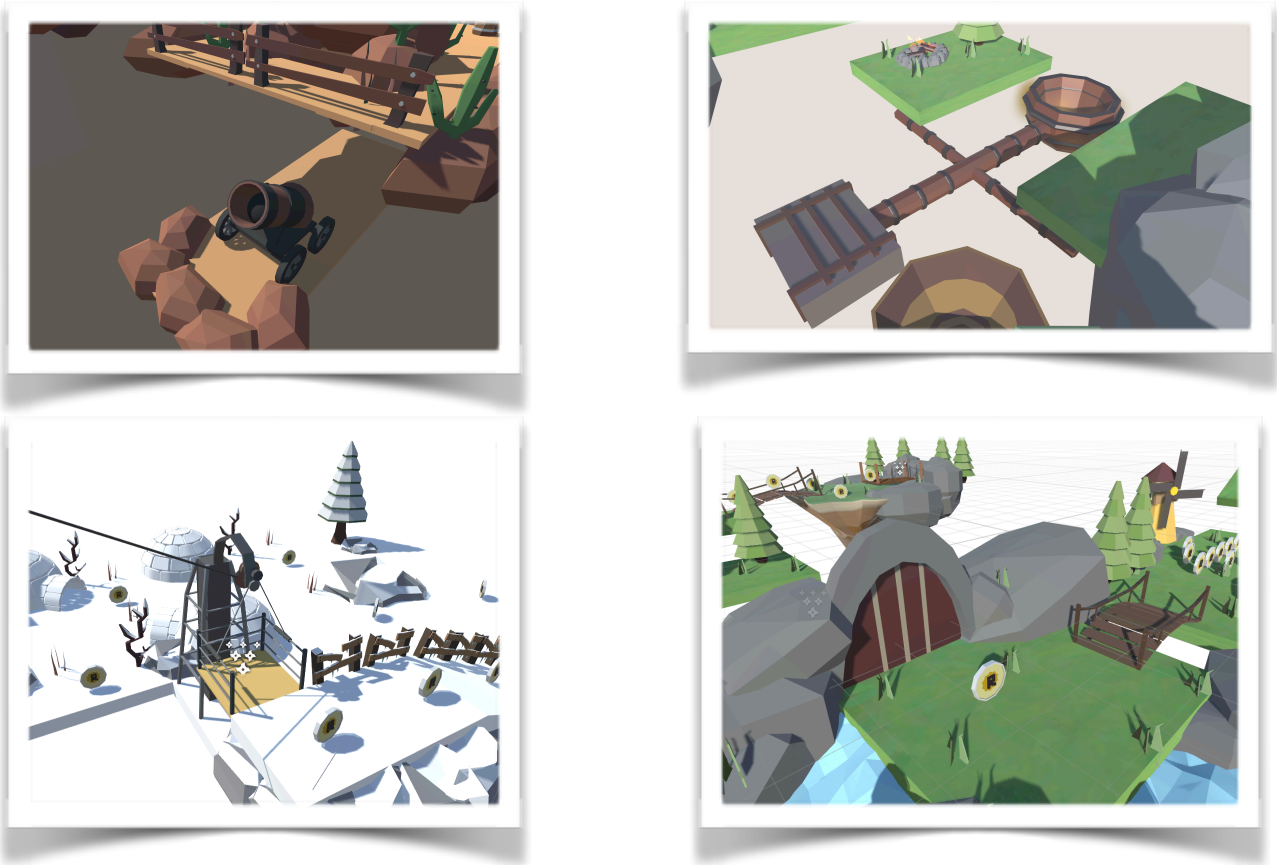


Fig. 18, 19, 20, 21. Different dynamic objects in the game.

Finally the last mechanic to be linked with the physical controller was the heating and cooling system. After testing different ways of triggering a real old or hot air flow, campfires seemed to be the right choice to simulate the mechanic very well. The snow level was self explanatory for the cold air mechanic. The campfires were implemented so that if the player would be at a certain distance from the fire flame, hot air would be activated. The combination of a consistent graphic style, the accurate placement of each asset across the levels and the game mechanics linked with the physical controller were all elements that all together contributed to the successful development of three finished levels for the game respectively called Green Countryside, Icy Snow and Dry Western.

Fig. 22, 23, 24. Green Countryside, Icy Snow and Dry Western game thematics.

Like any other game in the world, Roll needed a main menu screen to introduce the game experience. Even in this situation, an iterative process was adopted during development, starting with a white screen and plain text. The idea was to make a minimal introductory environment which would increase players' interest and invite them to press the start option. Arranging the main menu to give a quick preview of Roll environments seemed to be the right choice.

The menu itself was designed to contain few options and ended up having only three possible choices for the player: start the game adventure, go through the game credits, and quit the application.

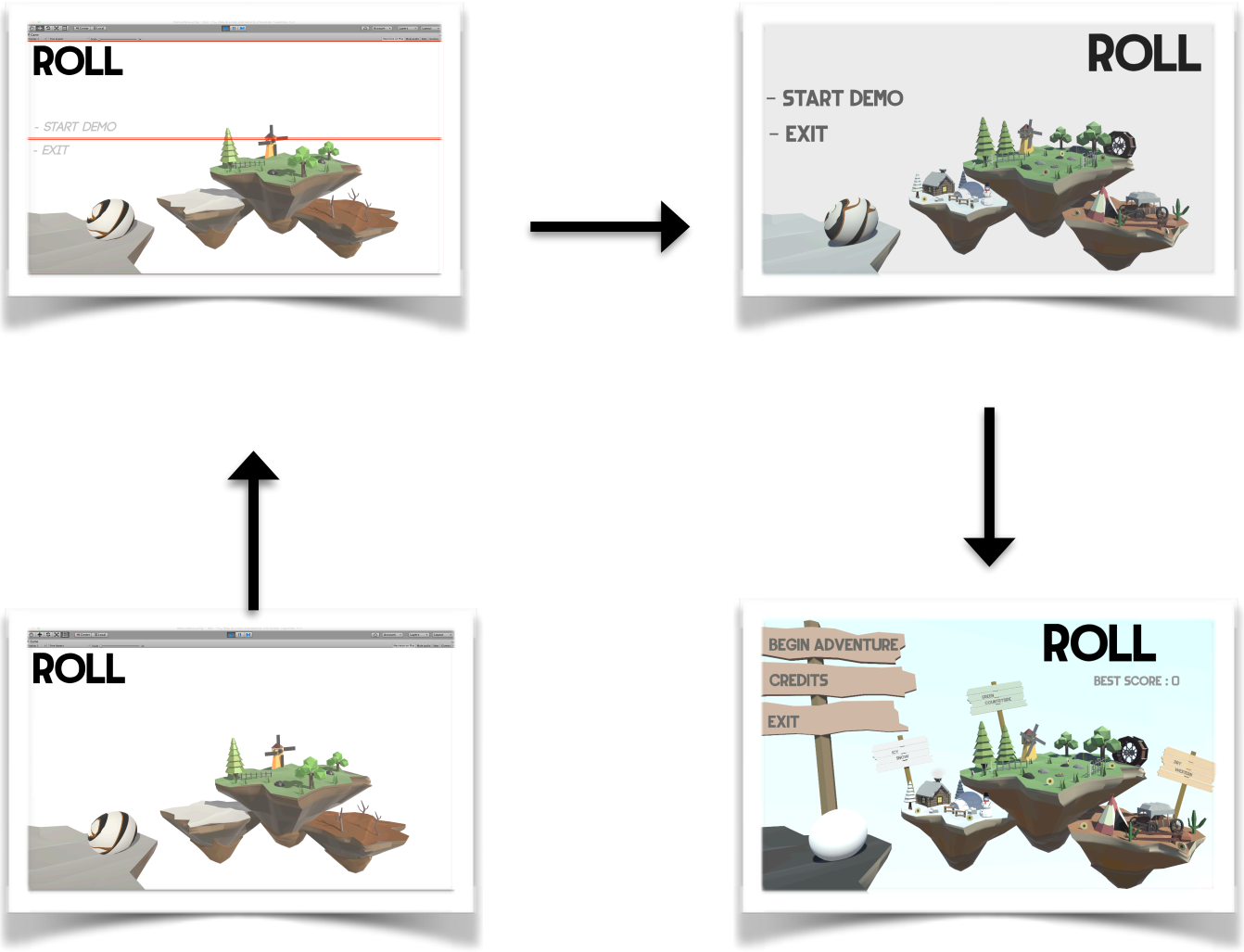


Fig. 25, 26, 27, 28. Main menu development workflow.

Again the main menu was designed so that it was possible to access each option without the need of a supplementary controller device but through the use of Roll physical controller. Taking advantages of the idea of rolling a physical sphere, players could have easily used the rotation mechanic to scroll the main menu options. Then, with the touch of a push button they could have simply selected one of the three possible options. In the case of beginning the game adventure and quitting the game application there were minor problems as the outcomes were very predictable. Instead, the credits option needed a way back once activated and, in order to maintain an intuitive user interaction, the same command used to access it was used to send players back to the original main menu. Camera animations were implemented to make more interesting transitions on each selection. Finally, the game high score was added and displayed just below the game title in the attempt of encouraging players to play the game and beat the top scorer. The game score system was designed with iconic pickable coins which were placed across the three game scenarios.

Fig. 29,30. Main menu credits section and pickable coin.

With the idea of giving players the chance of selecting their favourite sphere colour, a scene where they could manipulate the red, green, and blue components of the character mesh was created. The scene was designed to work together with the physical structure. As the possible final structure would have implemented potentiometers to change the RGB colour components, a visual mapping representing the potentiometers was added in the scene with the aim of creating an immediate understanding from players.

The colour selected in the game would match the real physical sphere one.

Fig. 31. Pick your colour game scene.

Most players, in particular the ones approaching gaming for the first time, are often confused when directly thrown inside a game, they need some explanation first. Even if Roll was designed to be very straightforward in terms of controls and rules of the game, a tutorial section was added to avoid any kind of confusion and reduce frustration later on in the experience. Instead of using still images to explain the rules of the game, which are normally ignored by most users, Roll offers a playable tutorial. The tutorial experience was designed to have clear text displaying each available action in the game, combined with a voice over to make sure players would understand the rules.

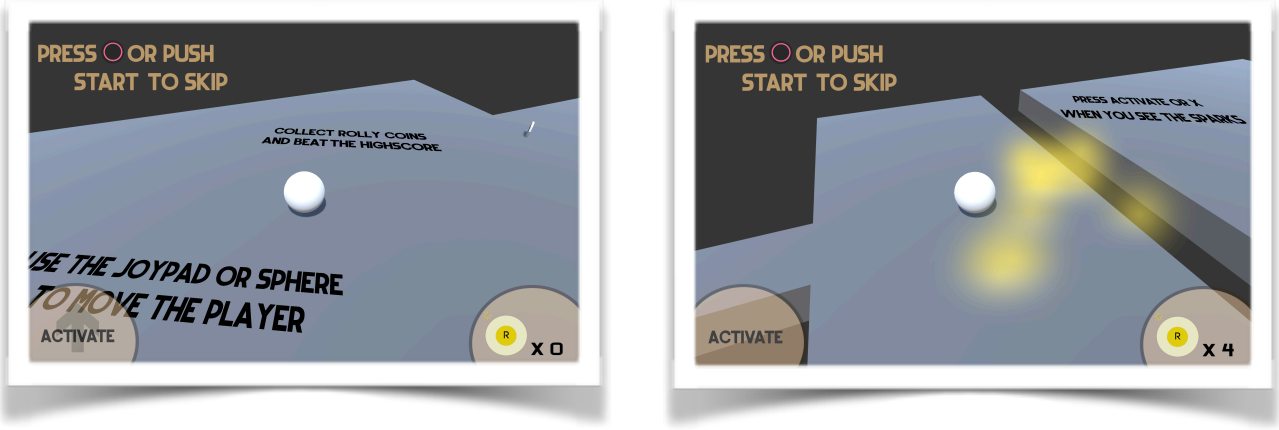


Fig. 32, 33. Roll game tutorial.

The final aspect to be designed was the graphic user interface, better known as GUI. The main challenge was to create a very immediate and minimalistic design which would suit the two game versions at the same time. Roll in fact, can be played using either a joypad or its own physical controller. As the physical structure original design idea would only have three push buttons and the player controller, the whole game should have been designed to work with the same amount of inputs. A main menu button, a start button, and a button to activate game objects were the only possible actions allowed in the game. Sketching different layouts on paper, testing them within the game and gathering feedback from users, really helped to come up with the final GUI layout that Roll uses today.

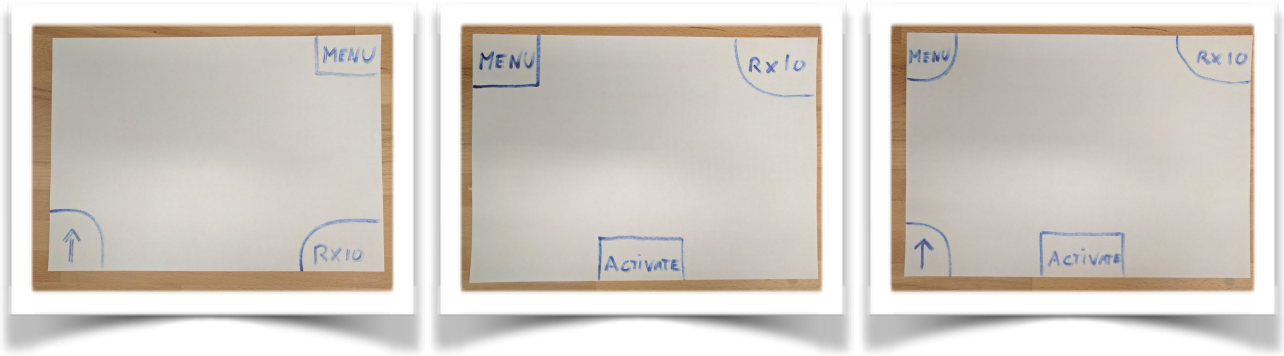


Fig. 34, 35, 36. Paper prototypes for the game GUI layout.

The main menu interaction previously implemented was used as the base line to create the in-game GUI. Two circles were placed at the bottom corners of the screen with one being on the left hand side displaying the sphere velocity direction with a spinning arrow, and one on the right hand side showing the player current score. As the player progressed through the different levels, it was crucial to let them know when a game object could have been activated.

In combination with the particle system displayed each time an action could have been taken, a clear Activate text was added inside the bottom left hand side circle, replacing the arrow each time the player was in the particle system range.

Fig. 37, 38. GUI layout implementation.

As with the rules of the game, the GUI was also added to the tutorial screen so that players would feel a very little difference from learning to playing the real game.

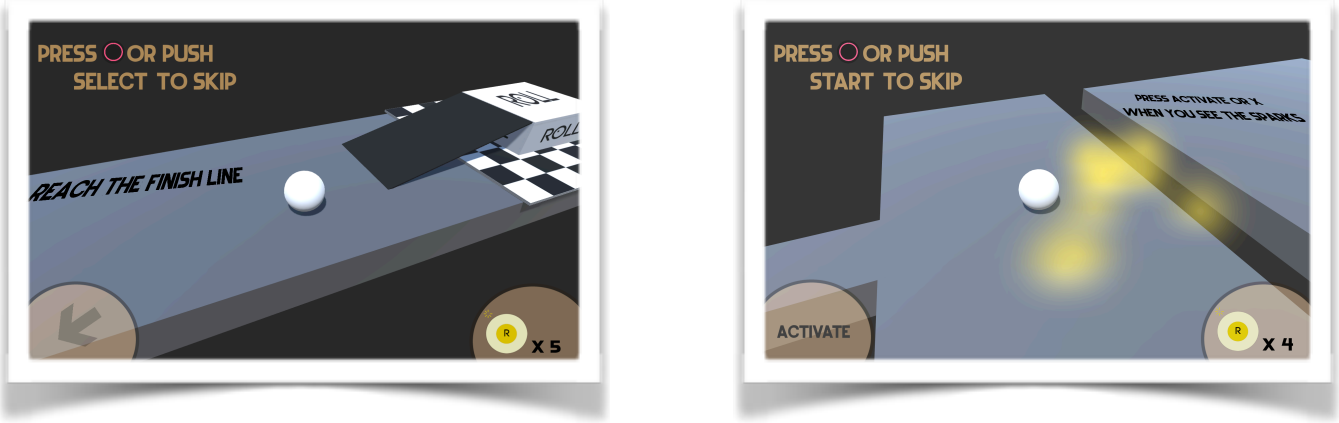


Fig. 39, 40. Game tutorial GUI layout.

Finally players could be distracted when playing video games or they might decide to stop playing for a little while. For this reason Roll could not have not implemented a screen pause menu. Being very intuitive, it allows players to pause the game, resume their adventure or be directed to the main menu and quit the application.

Fig. 41. Game pause menu.

3. 3 Physical Structure Design

Designing a physical controller or any kind of physical devices is very different from designing a video game and it requires a distinct approach. Users in fact will face a real, touchable product and they need to be able to use it without putting much effort in thinking how things might work. Roll physical controller design is based on Donald Norman's six design principles described in his book *The Design of Everyday Things*.

> When we interact with a product, we need to figure out how to work it. This means discovering what it does, how it works, and what operations are possible: discoverability. [11]

In chapter one of Donald Norman's book, discoverability is explained as the application of six fundamental design principles: *affordances, signifiers, constraints, mappings, feedback* and *conceptual model.* Taking into consideration the above-listed principles while designing a product, it resulted to be a very efficient method to make such a particular product easy to use and easy to learn. Although Donald Norman's principles were applied when designing the Roll game experience, they were extremely used as a reference when designing the physical controller. The very first focus interested primarily the player movements: how would have players controlled the sphere in the game? Initially, the idea was to control the movements with a long stick which would move in all directions. The problem of this first though was that a stick is not something that people often recall when thinking about round shapes. Instead, when we think about a sphere, ball or anything round, we immediately visualise the object rolling. This is an affordance, a sphere afford rotation; affordances tell the user which actions are possible by only looking at a product. Since the game requires players to roll a sphere, the second and final attempt was to design a physical rolling sphere to be used as an input for the sphere character movements in the game.

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[11] Don Norman, "Fundamental Principles of Interaction," in *The Design of Everyday Things* (New York: Basic Books, 2013), 10.

Such a mechanic resulted to be a very solid solution as it was easy to understand as users did not have to learn how to roll a sphere; everyone knows how to do so.

Fig. 42. 400mm diameter acrylic sphere.

The next step was to find a way to link the physical controller with the game possible interactions: traps activation, main menu options, and the game pause secondary menu. Unlike the design for the sphere movements, it was relatively easier to design a nice solution for this mechanic. Since the game can be entirely controlled using three inputs, three push buttons were used for the purpose. Now, push buttons afford pushing which is understandable by the majority of users but this would only haven worked if all the buttons would produce the same outcome. Since each button was designed for a specific action, a text explaining the identity of each one was added. Donald Norman describes this principle and calls it signifier. Affordances and signifiers are normally combined together to communicate all the possible actions allowed in a system and in which way or order they should be performed.

Fig. 43, 44. Arcade push buttons used for the physical controller.

The order and size of the three push buttons was also taken in consideration when designing the physical controller. The button which players would use more often, the Activate button, was positioned so that it was easier to reach and be pressed by players and its size increased in contrast to the other two push buttons.

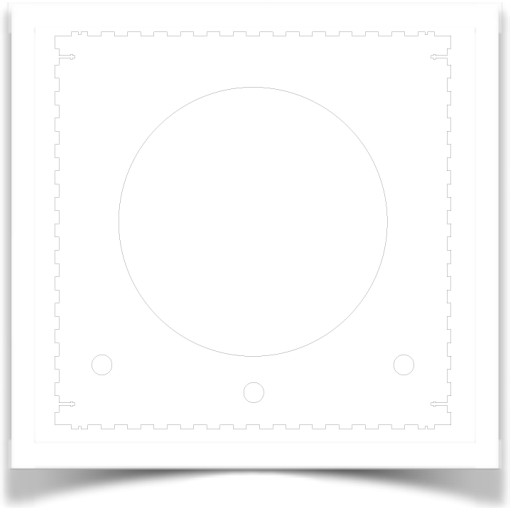


Fig. 45, 46. Physical controller push buttons layout.

When it came to design the system used to change the sphere colour, it was necessary to provide visual feedbacks of the colour selected. Three potentiometers were used to decide the amount of red, green, and blue lights to be combined in order to obtain the desired sphere colour. Although the final colour mixture was visible in both the game and the physical controller, players had no clue on the amount of light selected for each of the RGB components. As Donald Norman suggests, providing poor feedbacks will confuse users on the current state of a particular system. With the attempt of improving the colour selection, three halves tennis table balls were place just above the potentiometers. Each ball would have a coloured led inside and would show the amount of light being chosen for the corresponding potentiometer.

At this point, players were not only able to see the final colour mixture but also the amount of light for each of the single red, green, and blue colour components.

Fig. 47. Front panel of the physical structure.

The same methodology used to provide feedbacks when choosing the sphere colour, was also used to inform players which levels of the game had already been completed. The idea was that each time a specific level was successfully completed, a white LED would turn on next the corresponding game level name in the physical controller.

Fig. 48. LEDs used to provide level feedbacks.

Finally, the focus switched to the design of the remaining mechanics which would provide real life feedbacks through the physical controller. A water pump was positioned on the front panel in the attempt of splashing the player in case it would lose the game by falling into water. Similarly, hot and cold air would be activated in case the player was playing the snow level or in case they were rolling very close to a campfire.

Fig. 49, 50, 51. Water pump and heating/cooling system mechanics.

Once all the mechanics were singularly designed, it was time to combine them all together in a unique physical structure. With the use of Adobe Illustrator, a laser cut machine, and a good amount of wood, the whole structure design came finally together in a single solid product.

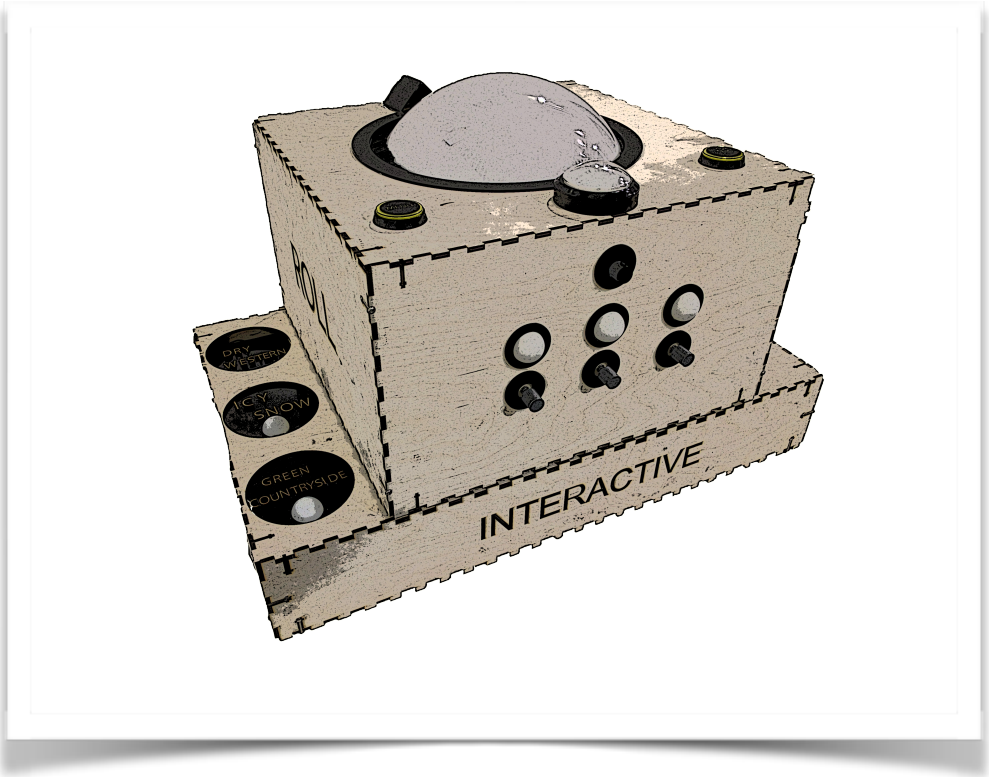


Fig. 52. Physical controller final version.

3. 4 Sketches and Prototypes

Designing a successful product is equivalent to find the best recipe for your cake; the process is very complex and it normally requires a very long time. Lots of mistakes are made during the development process and sketching and prototyping is a very useful method to prevent unexpected problems. It is a very cheap approach and it helps reducing the development time; it is better to change a mechanic in a piece of paper than change it in code. Since Roll required a combination of both hardware and software, cardboard sketches and prototypes were made through the whole process of both the game and the physical structure implementations. Sketches were mostly used while designing the game to help positioning game objects, make drafts of the game mechanics and have an immediate visual feedback of the content.

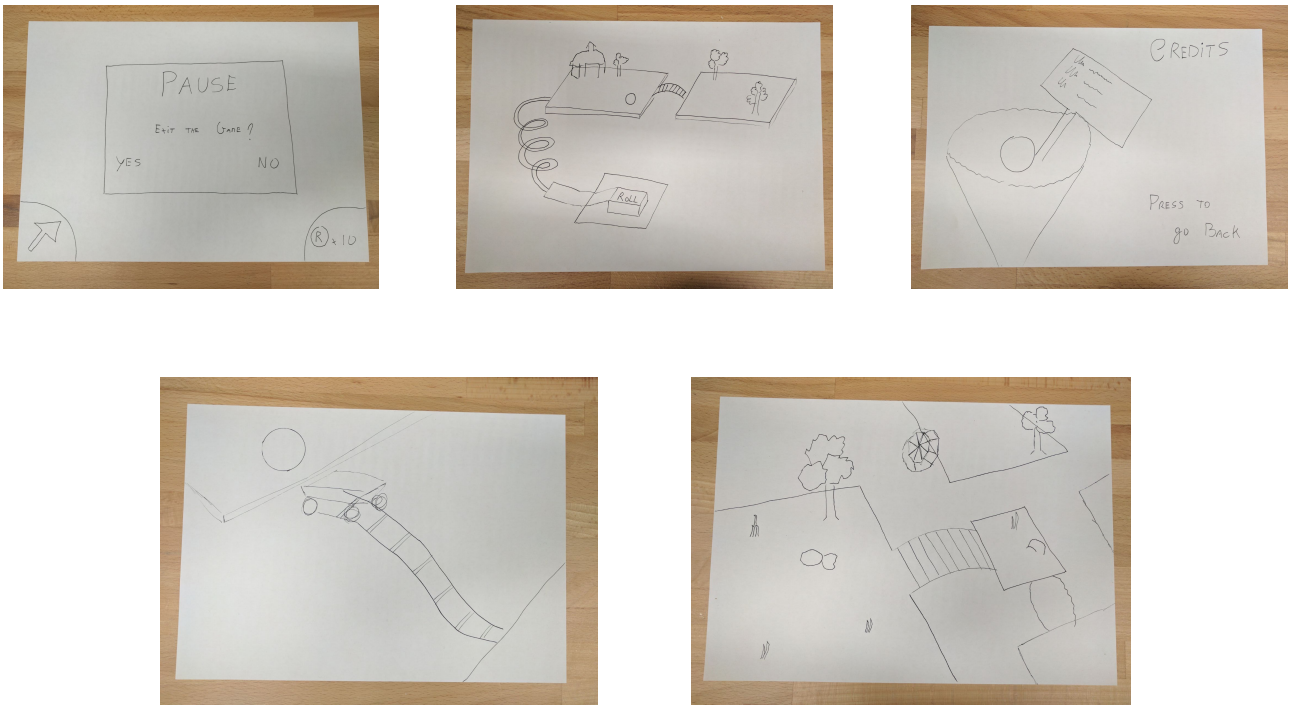


Fig. 53, 54, 55, 56, 57. Level design paper prototypes.

Cardboard prototypes, instead, were used while designing the physical controller. Each component was carefully designed, prototyped and only when fully tested, a high fidelity version was built.

Fig. 58. Physical Controller cardboard prototypes.

Two different versions of the physical controller were made, with the first one being a relatively playable product and the second one being the current controller final version. The first version of the controller only implemented few of the features available in the final version. It was missing the water pump system, the heating and cooling system, and the real price reward system. It had a relatively smaller size and, by being an early prototype, no much effort was put in the product's aesthetic.

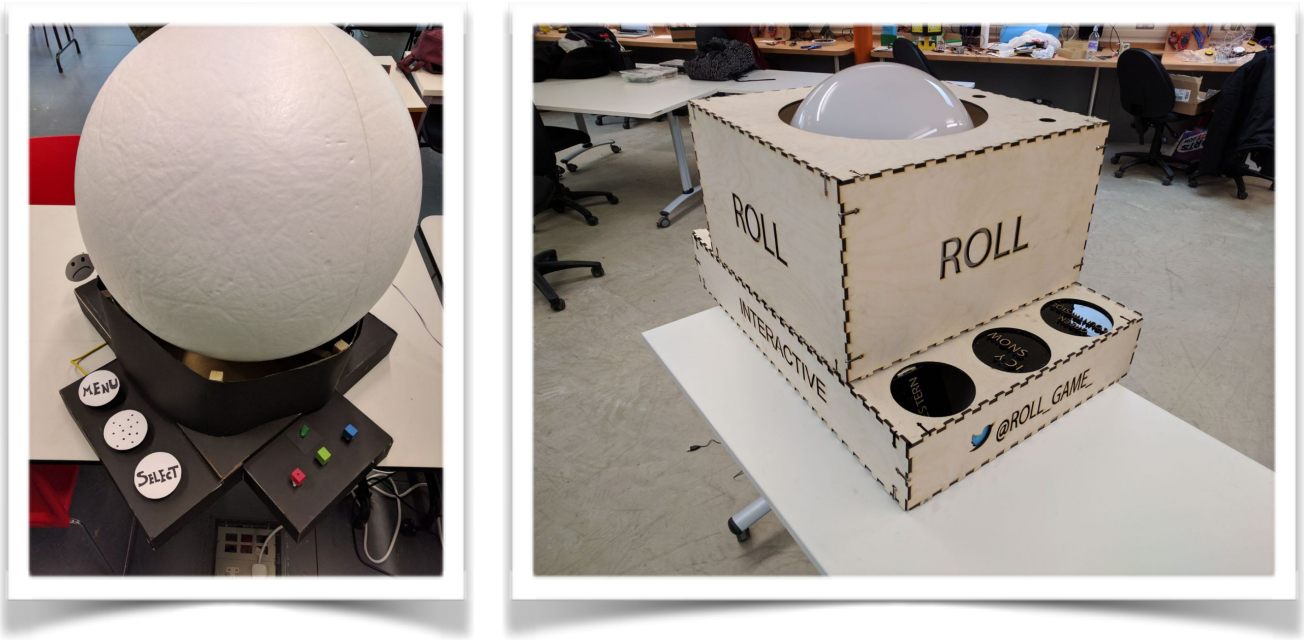


Fig. 59, 60. Prototype and high fidelity versions of the physical controller.

4

Implementation

Contents

4. 1 Introduction

The project implementation started in early October 2016 right after a solid preliminary concept design had finally been chosen. Initially, the focus was oriented in creating a playable version of the game and only later in the project the aim would switch to start building the physical structure. Unfortunately, due to limited amount of time allowed for the project, both the game and the physical controller implementations occurred at the same time. Having had some previous experience in the process required to make video games, the main worry was directed to the physical computing side of the system due to a little knowledge of electronics. For this reason, the first few moths of implementation were accompanied by various tutorials and books regarding electronics basics and game design. The time spent learning these new computing fields turned to be an essential part of the development process. Unity 5 Game Engine and Arduino micro controller were the two major contributors to Roll's development. C# was the programming language used to program both the game and Arduino.

Fig. 61. Hardware and software development tools.

During the development period, a large number of problems regarding both the software and the hardware of the system were encountered, in particular the ones related to the serial communication between Unity and Arduino and the reliability of the physical structure.

4. 3 Game Implementation

The game was entirely made using Unity 5 game engine and C# programming language. While spending the first few months designing all the game assets, the main priority was to find a way to set up a serial communication between Unity and Arduino so that I could use physical components to manipulate virtual game objects. Prototype tests were made with a very basic Unity 3D scene. Using a breadboard to wire up a circuit containing a single push button, the aim was to detect when the button was pressed and use that signal as an input to move a coloured circle by a certain amount in the Unity scene. The serial communication obtained with Arduino Integrated Development Environment was working correctly: every time the button was pressed, a serial message was sent from an Arduino script and received in Unity. Despite the method was working fine, it required the use of two programs simultaneously and the main issue turned out to be the huge time delay which occurred between the push button input and the output response on screen. The time delay averaged approximately around few seconds before a response could be recorded. In many applications, a couple of seconds time delay could be tolerable but unfortunately this is not the case of video games where players always need a quick time response based on their actions.

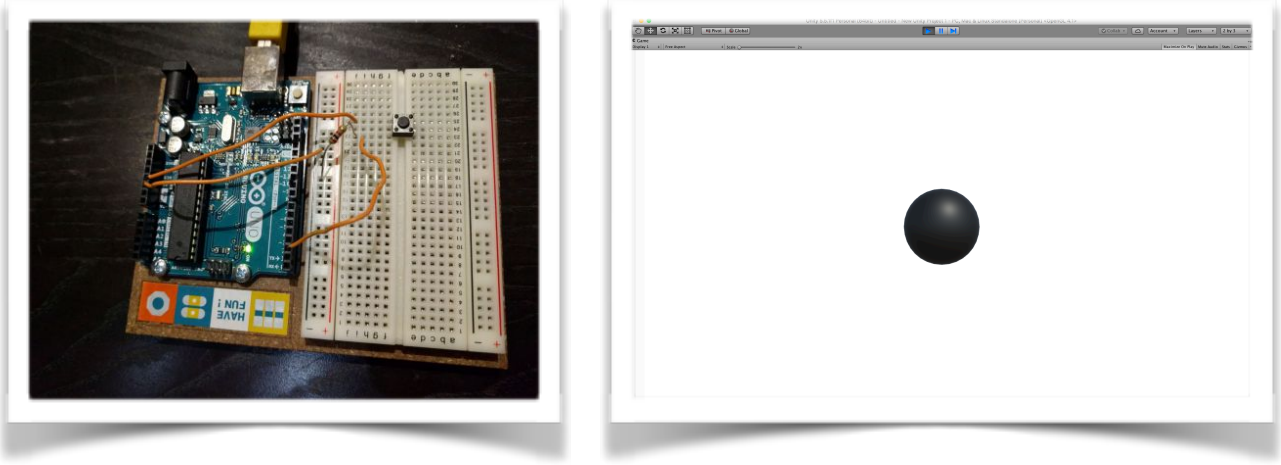


Fig. 62, 63. Push button circuit prototype and visual interaction.

No valid solutions where achieved while trying different ways to arrange the code in order to obtain the smallest delay when sending serial messages. While researching useful materials to help resolve or at least reduce the problem, a game development article revealed an application called Uniduino which turned out to answer the serial communication issue. Uniduino is a Unity package available in the assets store which allows to connect Unity and Arduino together without the need of any external programs besides Unity. Unfortunately, it is not a free plugin and all the libraries available for Arduino are still not supported but for the purpose of the project, it seemed to be the perfect solution. It took some time studying and understanding the functionalities of Uniduino but it paid off when almost no delay time occurred on the prototype Unity scene with the circle game object movement responding in real time when the push button was pressed. Programming Arduino inside the Unity environment was not anything new as the code structure and syntax were very similar to the one previously used when programming Arduino with its own IDE. Furthermore, most of the physical components used for the controller only needed a single on and off signal, solving the problem of not being able to use any Arduino libraries within Uniduino.

```
public class Colour_Picker : MonoBehaviour
{
    public Arduino arduino;
    // analog pin
    private int redPin = 5;
    // arduino object
    private int bluePin = 1;
    // analog pinß
    private int greenPin = 3;
    // analog pin


    private int _red;
    // how much red
    private int _green ;
    // how much green
    private int _blue;
    // how much blue

    private int pinOutRed = 3;// red pin output
    private int pinOutGreen = 5; // green pin output
    private int pinOutBlue = 6; // blue pin output

    void ConfigurePins ()
    {
        arduino.pinMode (redPin, PinMode.ANALOG); // reading analog pin one
        arduino.reportAnalog (redPin, 1);
        arduino.pinMode (greenPin, PinMode.ANALOG); // reading analog pin zero
        arduino.reportAnalog (greenPin, 1);
        arduino.pinMode (bluePin, PinMode.ANALOG); // reading analog pin two
        arduino.reportAnalog (bluePin, 1);
        arduino.pinMode(pinOutRed, PinMode.PWM); // set pin to pwm mode
        arduino.pinMode(pinOutGreen, PinMode.PWM); // set pin to pwm mode
        arduino.pinMode(pinOutBlue, PinMode.PWM); // set pin to pwm mode

    }
```

Fig. 64. Arduino pins code configuration using Uniduino.

Once few code examples compiled successfully, the focus was brought back to the game implementation. Having thought about the game interaction where players would move the main game character by the means of a physical sphere, the same interaction could have been used to navigate the game environment, including the main menu. Instead of using a mouse to select the different game options and detach players from the physical controller, the rotation of the physical sphere could have been used for the purpose. The main menu was probably the most difficult part of the game to connect with the physical structure. Different attempts were made to find an appropriate main menu interaction and the final solution was found by simulating the physical sphere rotation with a small trackball mouse. The trackball mouse rotation would act like the physical sphere to select the options and the trackball mouse click would act as the push button to complete the selection. The main menu options were set to change colour when hovered with the mouse pointer and would become active only once a mouse click was registered. In order to implement the mouse hover mechanic, the screen main menu was divided into three equal sections, one for each option, so that no matter where the mouse pointer was in the screen at least one option was always highlighted and could have been changed by scrolling the mouse up and down.

Fig. 65, 66. Game main menu and trackball mouse used for the interaction.

In the attempt to simplify the implementation process, a hierarchy of folders was created inside the Unity project. Each folder would contain a specific set of elements needed in the game: grouping together objects like game assets, scripts, textures and audio files really did speed up the game implementation.

Fig. 67. Unity folder hierarchy.

Since the trackball mouse turned to be a valid solution to simulate the physical sphere interaction, the same methodology was used to program the sphere movements in the game. Two 3D vectors were used to store the mouse's vertical and horizontal velocities which where then added to the sphere's rigid body game object position. The mouse rotation determined how fast the virtual sphere would rotate and move around the game environment. Initially, an empty scene containing only a flat terrain was created to test the movements mechanic. Even though it needed multiple adjustments, the game sphere physics was added using the built in rigid body component offered in Unity.

```
void FixedUpdate ()
{
    moveHorizontal = Input.GetAxis ("Horizontal"); // geeeting the mouse x axis
    moveVertical = Input.GetAxis ("Vertical"); // geeeting the mouse y axis
```

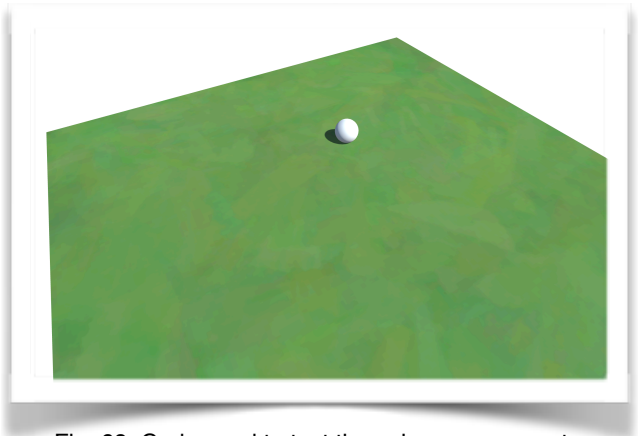


Fig. 68. Code used to test the sphere movements.

Some physics parameters like the sphere mass, the velocity of its rotation and the friction which it would produce touching the terrain, played a fundamental role when more objects were added to the scene. The terrain did not longer have a smooth surface and it was filled with uneven objects like bridges, rocks, and slopes. Exactly for this reason, the virtual sphere required more attention in regard to its physics and extra work was done to ensure a perfect balance between its velocity, friction, and mass.

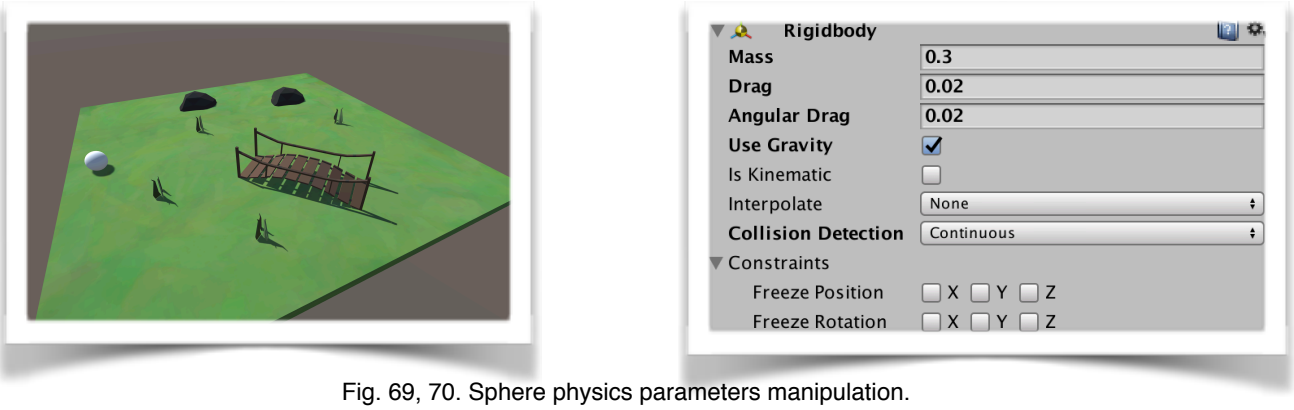


Fig. 69, 70. Sphere physics parameters manipulation.

Once the movements had finally been implemented, the game needed something which would turn it into a playable version. Balancing the virtual sphere within various sized platforms was a reasonable answer but not enough to begin with users play testing. The addition of a score system mechanic turned the game into not only a more playable version but it added competition to the experience. Golden spinning coins where randomly positioned across the prototype level platforms. Each time the player would pass by Rolly coins, this was the name given to the collectables, a script variable would increment and store a value corresponding to the number of Rolly collected. The score was then displayed using a GUI to provide players with visual feedbacks.

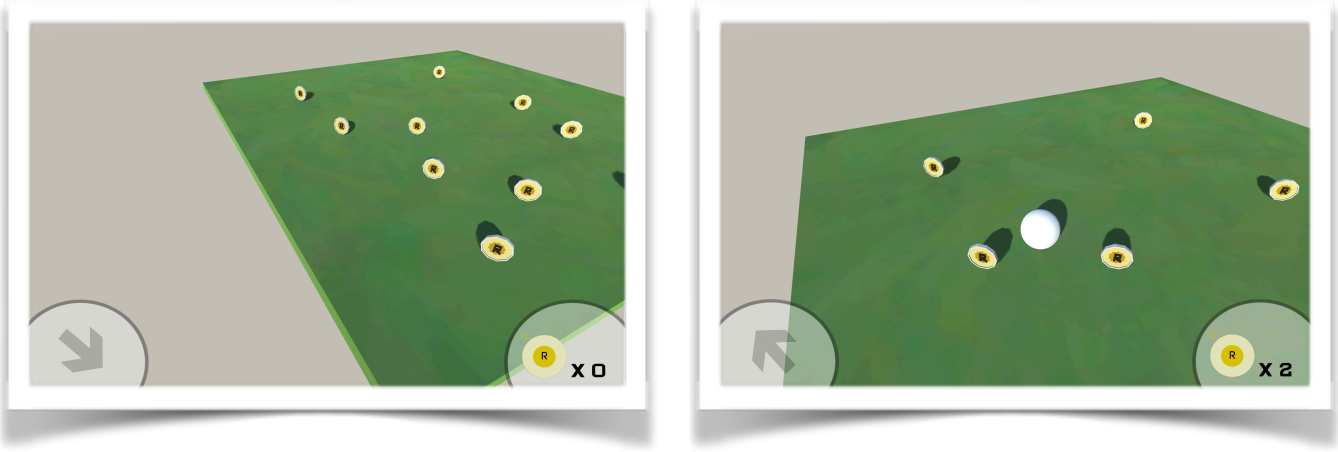


Fig. 71, 72. Score system graphic user interface.

When the score mechanic seemed to work perfectly fine, adding multiple scenes to the game caused the score variable to reset when going from one scene to another. Switching scenes was required for the implementation of Roll three levels as, having all the environments in a single scene would drastically reduce the game frame rate. The reason which caused the variable to reset, was related to the script which was handling the increment. Since the script was assigned to the player virtual sphere, each time a new game scene was entered, a new player object was created and therefore a new script attached to it. The script handling the score system should have been created only once at the beginning of the game and the variable keeping track of the score should have been accessed at any point in the game. Changing the score variable from a public integer to a static public integer made it accessible by other scripts and adding a function which would not destroy the score system script solved the issue of the score variable being reset each time a new scene was opened.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Score_System : MonoBehaviour
{

    public static int score_value;
    // staic so global varibale to keep track of the score

    void Awake ()
    {
        DontDestroyOnLoad (this.gameObject); // do not destroy score vaue across screen
    }

    // Use this for initialization
    void Start ()
    {
      score_value = 0; // setting it to 0 at the beginning of the game (done in Green Countryside level)
    }


}
```

Fig. 73. Code used to make the score variable available in the whole game.

As the score was saved across different scenes, a high score system was also created and displayed in the main menu section of the game. Each time the player would lose, the score was compared with the high score and in case it was higher it was stored and displayed.

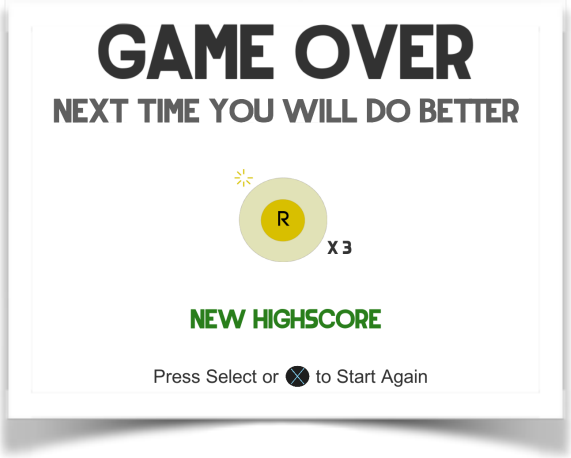
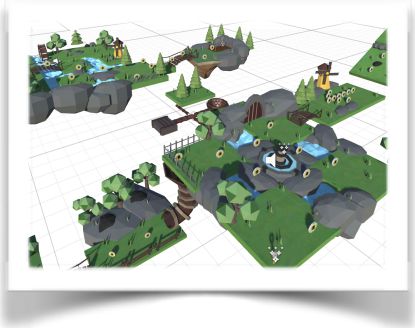
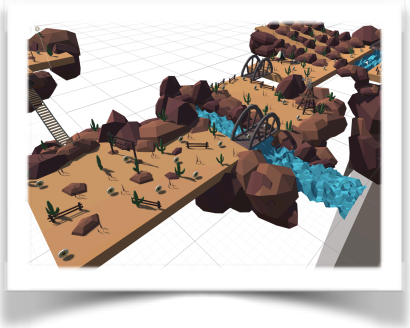


Fig. 74, 75. High-score system implementation.

Having the player movement and score system mechanics working correctly, it was only a matter of speeding up the process of modelling the game assets. As new models were created, they were tested and added to the corresponding level thematic.





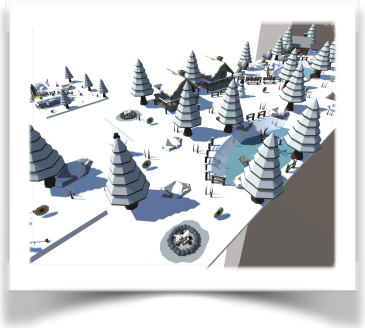


Fig. 76, 77, 78. Advanced level design.

A similar problem to the one encountered when implementing the score system came across when testing the serial connection with multiple inputs. At this stage of the project, having most of the assets completed and arranged in the levels, it was time to implement the in-game interaction with different game objects. Different static game objects like doors, lifts, cannons, passages, and catapults were programmed to be activated when the player was at a certain distance from them or when performing specific actions.

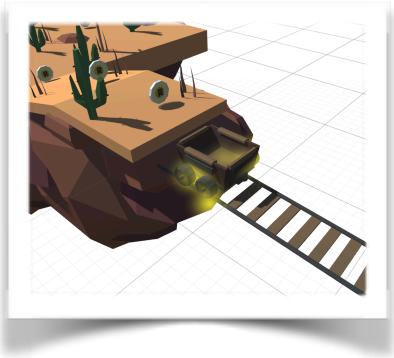
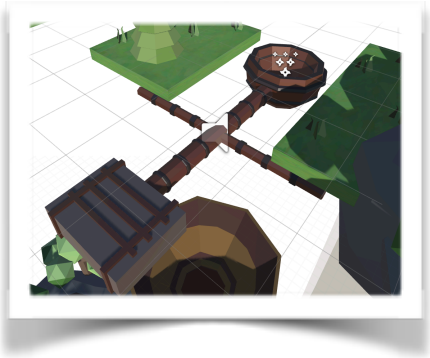




Fig. 79, 80, 81. Dynamic game objects.

Uniduino allows you to create an object of type Uniduino which is responsible to establish a serial connection between Unity and Arduino. When such a connection is established, the Uniduino object is visible like any other game object in the Hierarchy panel. Since the connection was required throughout the whole game and so across different scenes like the score system script, its initialisation script was modified with a function which would not reset the game object when a new scene was opened. The problem was that such a function already existed inside the Uniduino package, causing scripting errors and again a huge time delay in getting responses. The issue was solved by removing the function previously mentioned from the Uniduino script and by only creating one Uniduino object at the beginning of game application. By doing so, the implementation could carry on and all the Arduino pins needed for the physical controller where successfully coded to work within the game. As the code aimed to the game interaction was working, a PlayStation 4 joypad version of the game was also create so that users could start testing the application. The rest of the game development involved the implementation of the game winning and losing states and the initial tutorial. Players only have only life throughout the whole game and every time they lose, the game starts back from the first level.

Rewarding the players with a physical price in case they successfully complete the game removed the frustration of having only one chance per game played. GUI canvases were used to provide players with visual feedbacks in case they lost their game or they progressed to the next level.

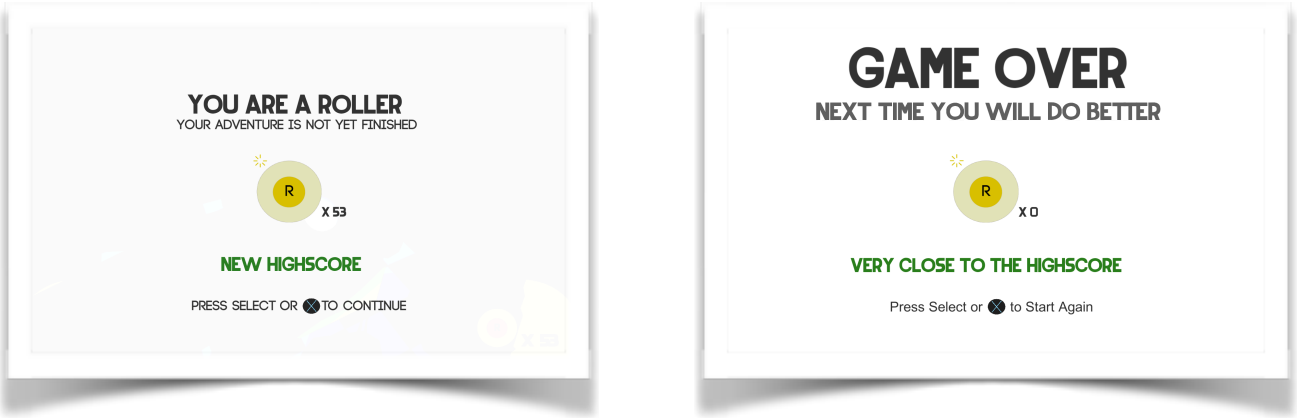


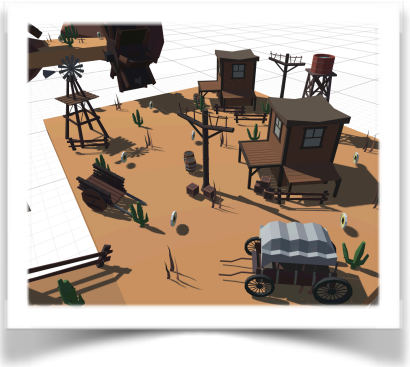
Fig. 82, 83. Winning and Game Over GUI layouts.

As mentioned before, the tutorial scene did not have a strong priority compared to the rest of the game mechanics and was implemented towards the end of the project. In the attempt of making an interactive tutorial, a very short playable level showing the game rules was created. In order to communicate the rules a combination of 3D text and voice over were used. The player is forced to follow a specific path which shows the main game mechanics. Each time the player passes a specific location, the audio corresponding to that location is played and it explains a particular game mechanic. The 3D text is placed according to the audio being played to make sure that players understand the main rules before starting the game adventure. It was necessary to insure that only one audio track was played at the time in order to avoid voice overlapping and confuse the players.

The tutorial was designed so that in case players would fall down the platforms, the virtual sphere would be brought back at the beginning allowing multiple attempts.

Fig. 84, 85. Tutorial 3D text and sound manager.

Once the tutorial scene was working correctly, the game started to have a solid structure and it was time to switch the project development to the physical controller. Even though the code written for the game was ready to be linked with Arduino, it was necessary to wait for the project physical side in order to verify its correct functionality. Meanwhile, a large number of assets were added to the game, turning it into a more interesting and fulfilling experience.



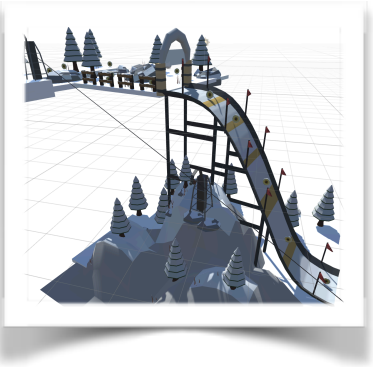


Fig. 86, 87, 88. Sections of finalised level design.

4. 4 Physical Structure Implementation

At the very beginning of the project, most time was spent researching and learning electronics and circuits theory, therefore the physical controller implementation began in early November, roughly two months after the project idea was finalised. As the system with the trackball mouse used to simulate the virtual sphere movements in the game delivered great results, the idea of using a similar mechanic for the large physical sphere was taken in consideration as one of the first development objectives. Using multiple trackball mice as a support base in which a 400-millimetre-diameter sphere could rotate in place, seemed to be a very quick and efficient solution. A wooden structure was hand crafted and three trackball mice where glued upside down in a circular pattern with the aim to hold the physical sphere and track its motion at the same time. The advantages of using a trackball mouse system allowed the successful implementation of the rotation mechanic without the need of Arduino micro controller. Connecting one of the trackball mice to the laptop through a USB cable was sufficient to get the correct virtual sphere motion in the game. Being only a prototype, the first physical sphere was made out of polystyrene and together with the wooden structure set off the development of Roll first physical controller version.

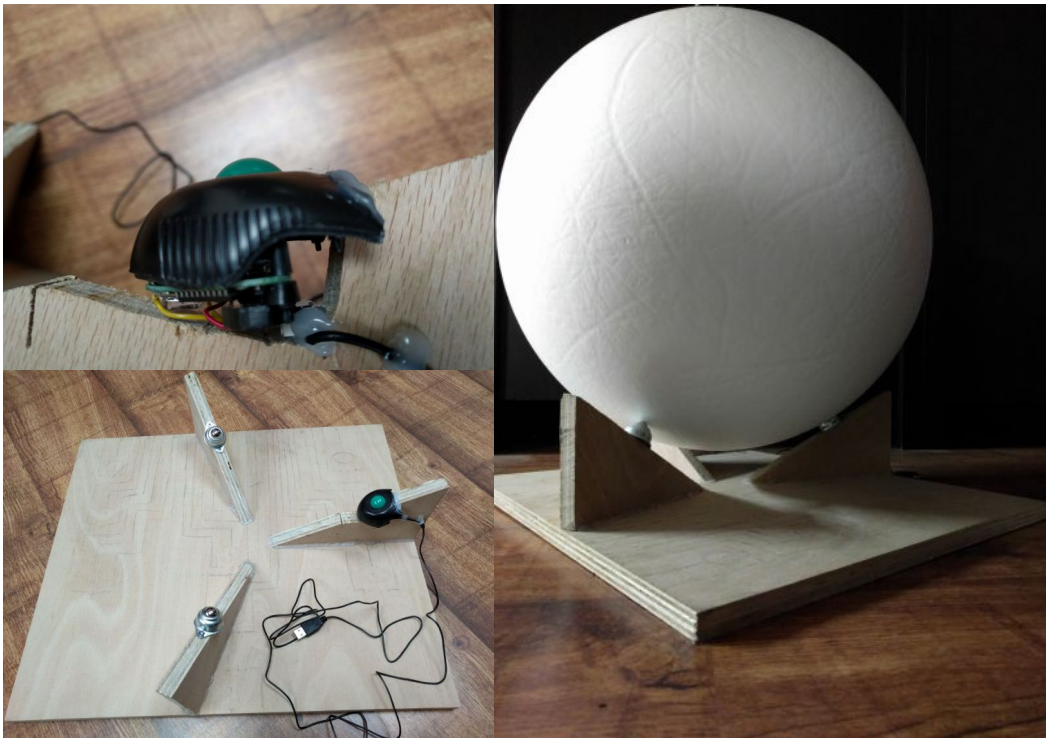


Fig. 89. Trackball mouse wooden structure prototype.

Subsequently to the physical sphere rotation structure, it was time to test the Arduino code made in Unity with some electrical components. With the aid of prototype boards, the circuit aimed to control the push buttons was wired up at first. Pull down resistors were positioned between the circuit ground and the Arduino pin receivers in order to eliminate possible floating signals. Using this technique Arduino was able to read a high value when the buttons were pressed and a low value when the buttons were left unpressed.

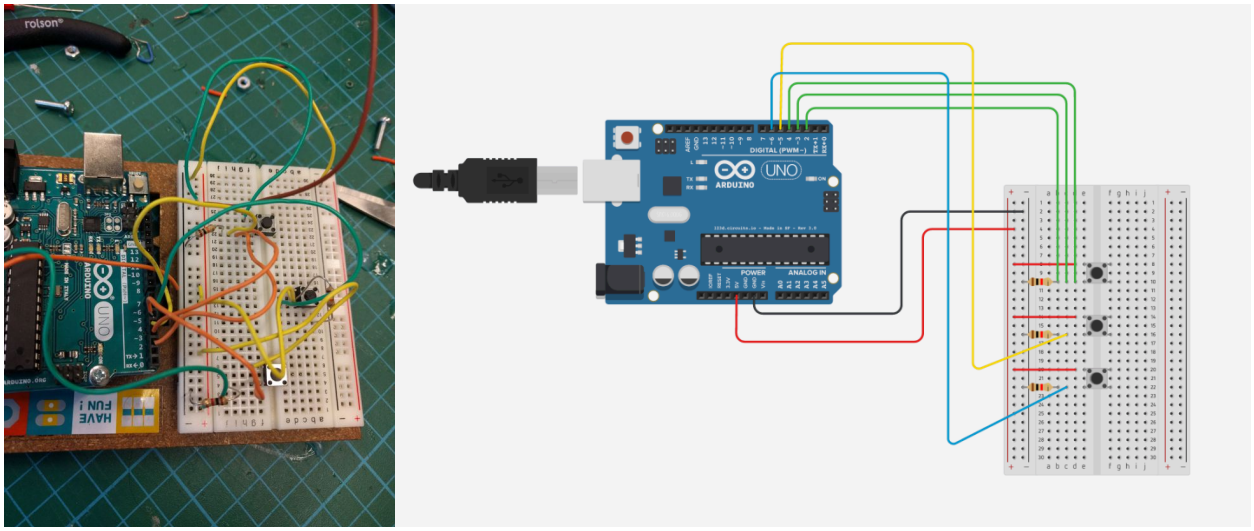
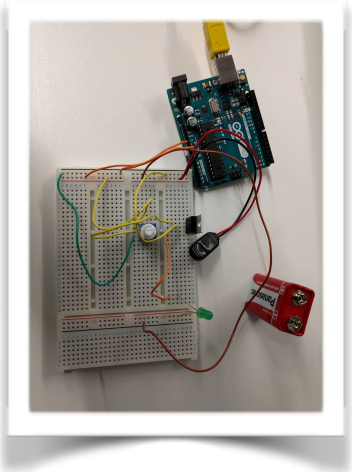


Fig. 90. Push buttons prototype circuit and schematic.

The next circuit to be prototyped and tested was the one related to the physical sphere colour mechanic. Right before the game tutorial scene, another scene was implemented where players could pick the virtual sphere colour and such a selection would also be reflected in the physical sphere. In order to offer a large range of colours, a red, green, and blue colour selection was created. Lighting up the 400-millimetre-diameter sphere required a reasonable amount of light which could be achieved with a 12-volt-LED strip. Using a higher voltage than the one provided by Arduino slowed down the development process as deeper learning of electronics was needed. Meanwhile, a 3-volt-RGB LED was used to prototype the circuit. Three potentiometers corresponding to the red, green, and blue colour components where wired in the prototype board so that each individual signal would be read by Arduino analog pins and interpreted in a range from 0 to 1023 values. Each analog reading was then digitally mapped with a new 0 to 255 digital range of values and sent to the corresponding RGB LED pin using a PWM signal.

At this point, it was possible to control the intensity of each colour components by rotating the potentiometers, hence allowing more or less current to flow through the circuit.



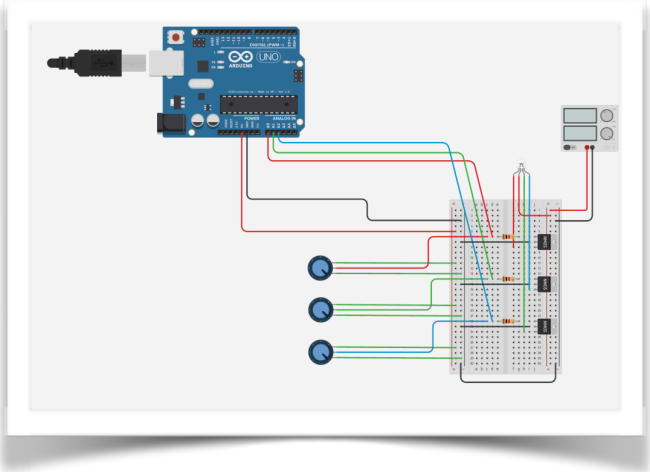


Fig. 91, 92. Potentiometer prototype circuit and schematic.

Once the circuit was fully tested with a 3v GRB LED, it was modified so that it would power up a 12-volt-RGB strip. Arduino can only provide a maximum of 5 volts and therefore it does not provide enough potential difference to run any electrical components which exceed its limit. The solution to power the 12-volt-RGB strip was achieved using transistors. Transistors are electrical components which require a very low voltage to open and close a higher voltage circuit. The PWM signal was then used to open each transistor gate accordingly to the value registered by each potentiometer, allowing the 12-volt circuit to turn on the LED strip. An external 12-volt power supply was used for the purpose.

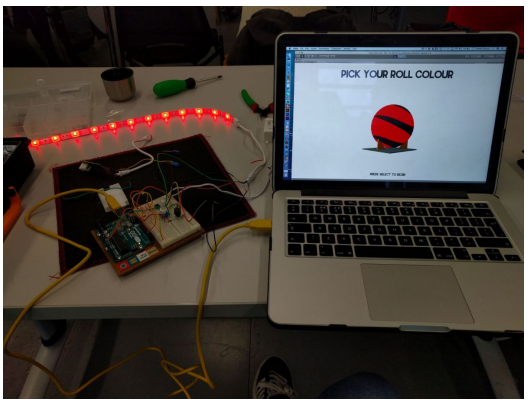


Fig. 93. Potentiometer prototype circuit with a 12-volt-LED strip.

The final circuit prototyped for the first Roll physical structure involved the use of a servo motor. The idea was to use the servo to control a smiley face when players would reach the end of the game. Acting like a flag, players could see the smiley face at the back of the structure once the game was completed. A wooden stick was attached to the servo and a 90-degree rotation would decide the smiley face visibility. If the game was still in play, the servo would stay still with a 0-degree angle and only rotate at 90 degrees if the game was successfully completed.

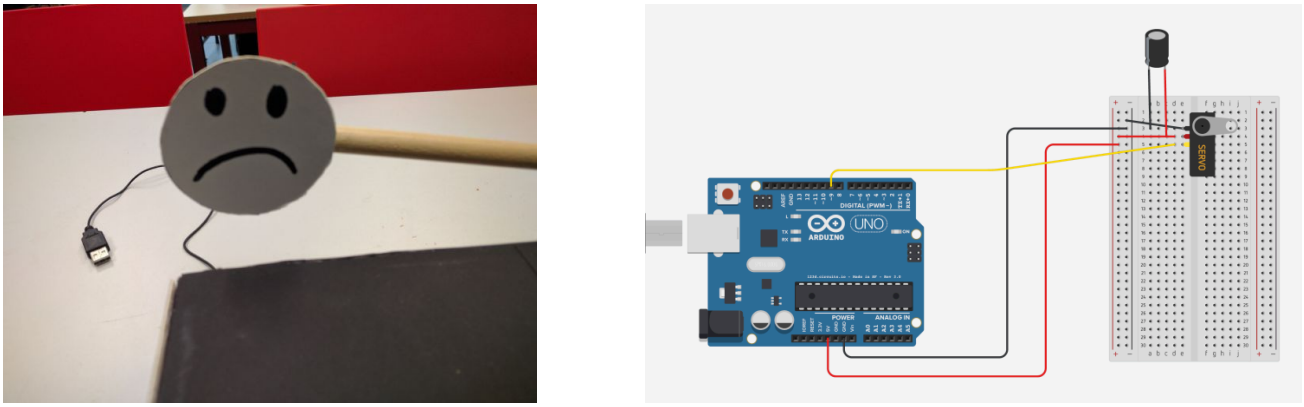


Fig. 94, 95. Servo motor prototype mechanic and circuit schematic.

Once each single circuit was tested using a prototype breadboard, it was time to solder all the components in a single schematic and place the whole system in the wooden structure previously made. Using multiple strip boards, each component was carefully soldered and placed in the right position. All the wires and Arduino were hidden at the bottom of the wooden structure.

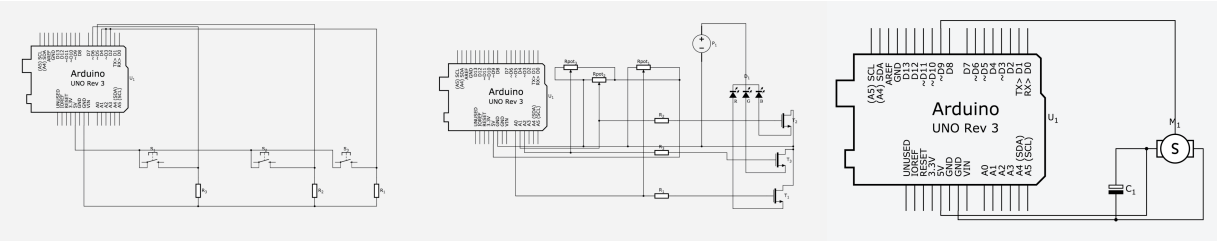


Fig. 96. Overall circuit schematic for the prototype version of the physical controller.

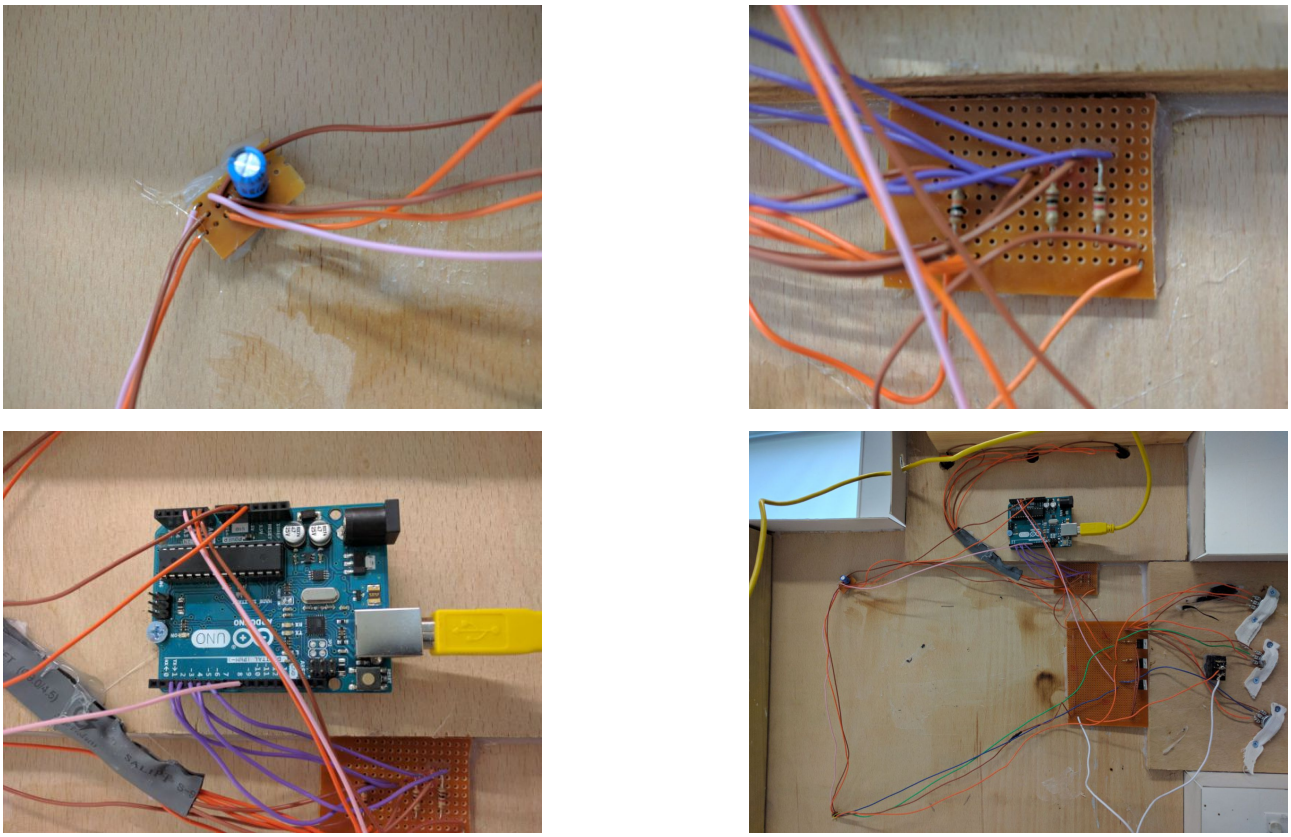


Fig. 97, 98, 99 , 100. Circuit soldering using strip boards.

The final prototype version of the controller included the main sphere controller, three potentiometers to change the sphere colour, three push buttons corresponding to specific interactions, and a servo mechanic to notify players when the game was completed. Arduino was powered using the USB cable for the serial connection and a 12-volt power supply was used to run the LED strip.

Fig. 101. Physical controller prototype version.

The positive completion of the first physical controller was immediately followed by user testing. Asking questions, recording opinions, and directly observing people playing the game were all fundamental moves to acquire useful information regarding the high-fidelity controller development. The high-fidelity version of Roll physical controller implementation started in early January and its new design was mostly based on what suggested by players who tried the prototype version of the controller. The use of a laser cut machine to design each section really helped to come up with a solid and pleasant looking wooden structure.

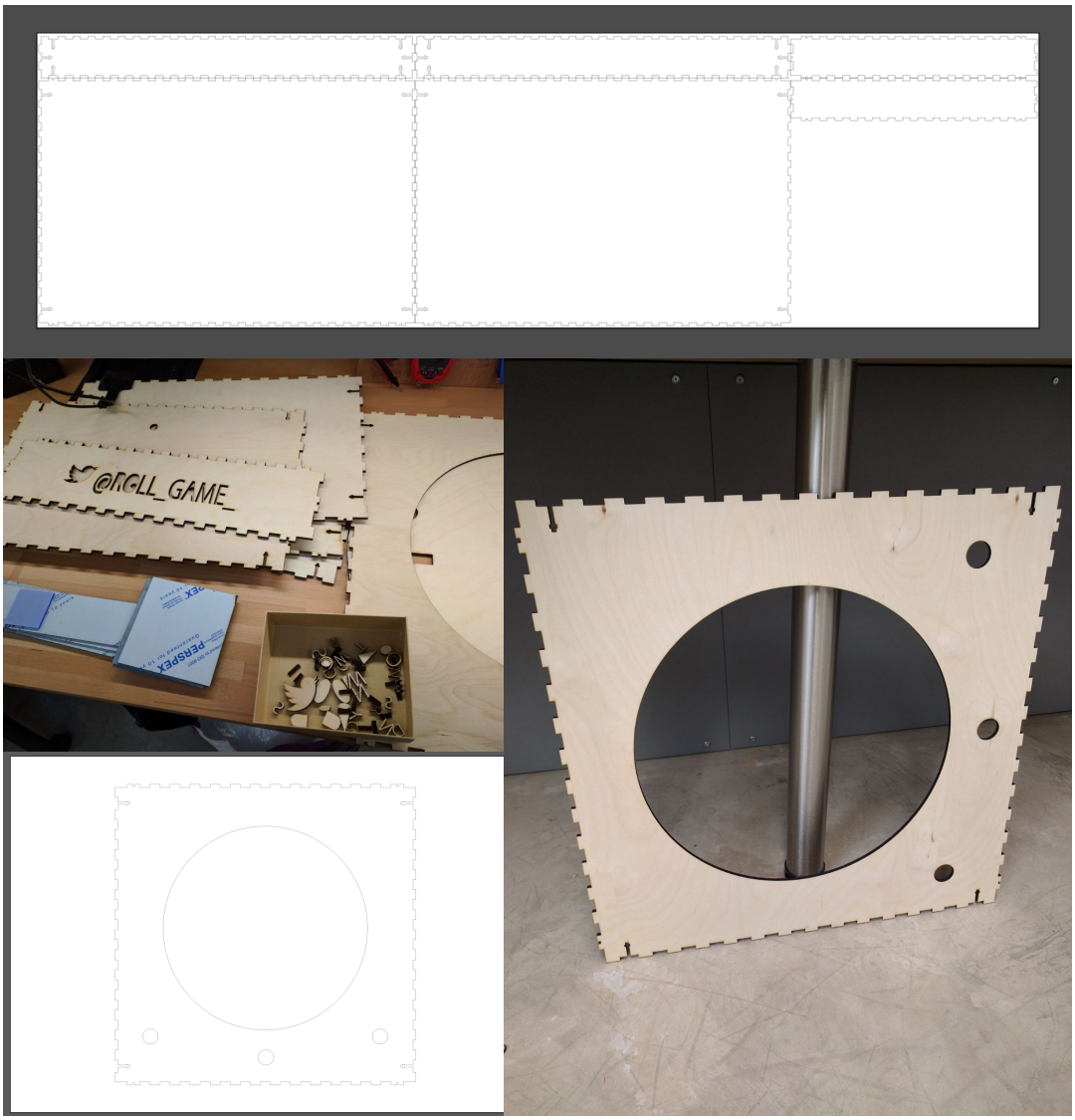


Fig. 102. Individual laser cut pieces and design for the physical controller.

Due to the nice results achieved in a very short time for the physical controller prototype version, a similar approach was used for the high-fidelity implementation with the addition of new mechanics and the renovation of already made ones. For instance, the trackball mouse system was kept and only redesigned using the laser cut machine. Adobe Illustrator was used in combination with the laser cut machine to create the new design. Differently from the first version, where the mouse holders were clued to the base of the wooden structure, the holders' design was improved and they were screwed to the base. The polystyrene sphere was replaced with a new acrylic sphere.

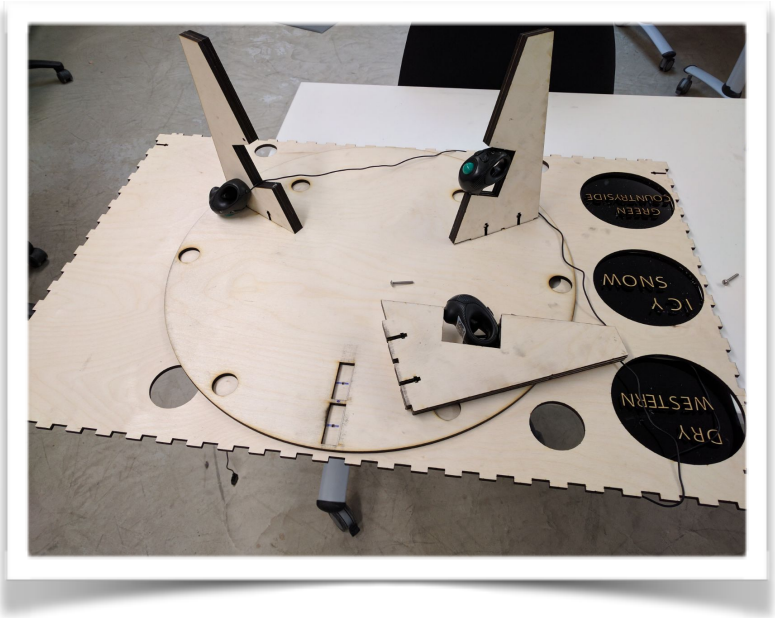


Fig. 103, 104. High fidelity mouse holders wooden structure.

The push buttons were replaced with professional arcade push buttons where the surfaces would light up thanks to LEDs installed inside them. The button used to activate elements in the game was modified so that it would have the same colour of the sphere.

This was done by substituting the white LED it had inside with an RGB LED, which was controlled by the same potentiometers of the 12-volt LED strip.

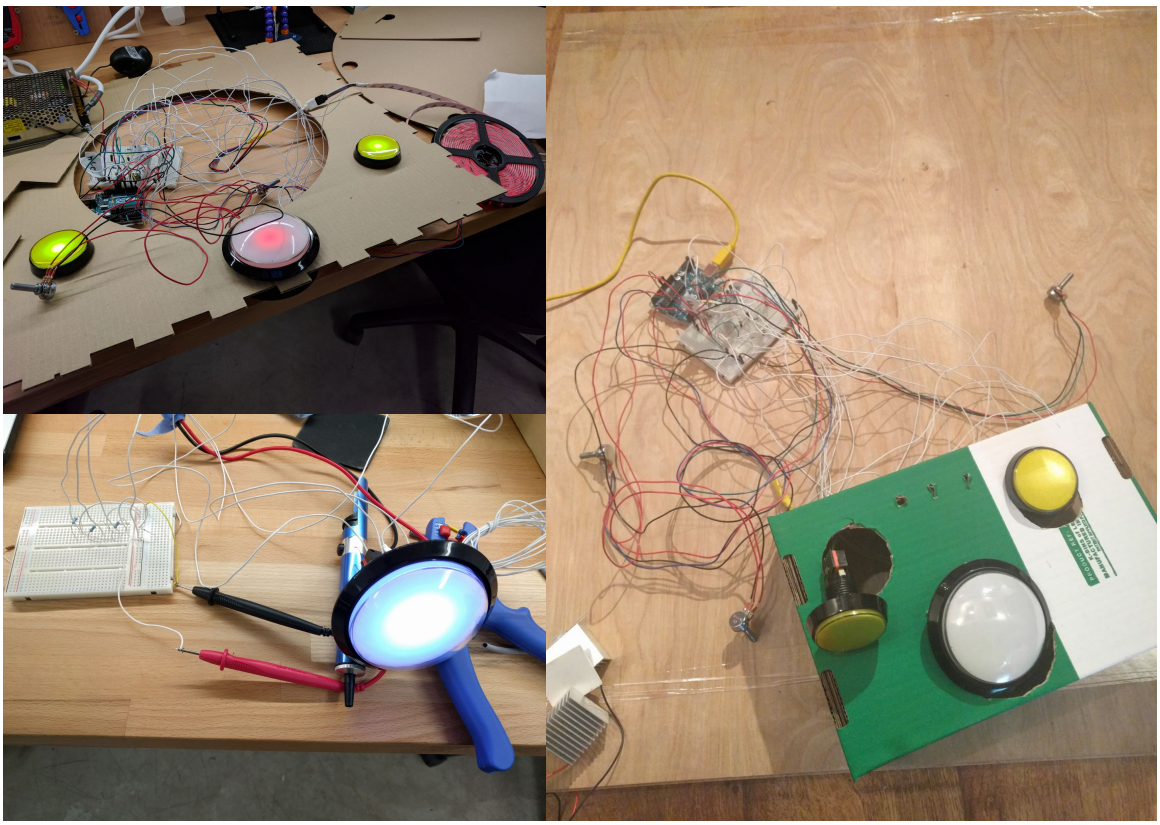


Fig. 105. Arcade push buttons and LEDs circuit prototypes.

The servo mechanic used in the first structure for the smiley flag was changed and designed to open a hatch in the new structure. When players would complete the game, the servo would rotate 90 degrees revealing the price contained inside the hatch.

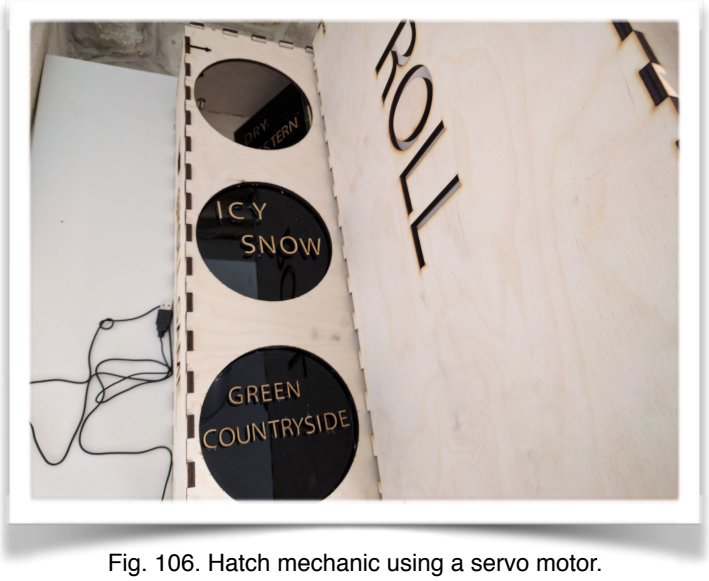


Fig. 106. Hatch mechanic using a servo motor.

More visual feedbacks were also provided for the players: the potentiometer mechanic was in fact improved so that players could see the amount of light selected for every single colour component of the RGB LED strip. Furthermore, additional LEDs were positioned next to the hatch in order to highlight which levels were completed.

Fig. 107, 108. LEDs feedbacks, side and front panels.

As long as improving previous mechanics, new physical systems were introduced in the new version of the controller: a water splash when players would fall in water, and a heating and cooling system reflecting the game environment. The circuit was again tested using a breadboard first and the whole mechanic was achieved using a jar full of water, a flexible plastic pipe and a 3D printed connector to create the right water splash. Using a transistor to control a 12-volts dc water pump, the water splash would be activated for 3 seconds when the player touched the water surface in the game. As the water in the jar would run out, a filling system using a fennel was installed next to the water container.

In order to make the water level in the jar visible, a hole was cut in one of the wooden structure sides and a blue LED was positioned on top of the jar.

Fig. 109. Water pump mechanic and design.

The heating and cooling system was probably the most difficult part of the project. Initially the idea was to use a combination of 12-volt turbine fans to blow the air inside a PVC pipe and Peltier cells to either heat or cool the air blown. The system was first prototyped using cardboard and successively implemented using the laser cut and a 3D printer.

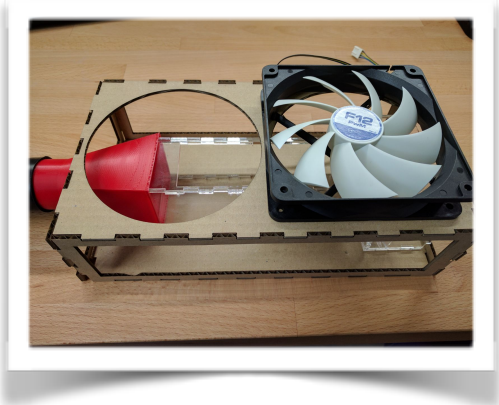


Fig. 110. Heating/cooling system cardboard prototype.

Two turbine fans would blow the air inside a rectangular chamber, which would contain three Peltier cells connected to their respective heat sinks. Passing through the chamber, the air temperature would then be modified before entering the PVC pipe thanks to a 3D printed connector. Cold air was achieved by simply turning on the turbine fans, whereas to obtain hot air the Peltier cell system needed to be tuned on using Arduino. In order to help with the heat dissipation, the chamber was provided with strong fans constantly blowing cold air. Unfortunately, the system failed as not enough heat was dissipated, causing damage to the Peltier cells.

Fig. 111. Heating/cooling system high fidelity acrylic structure.

Furthermore, the air blown was not strong enough to reach the end of the PVC pipe and change the physical sphere temperature.

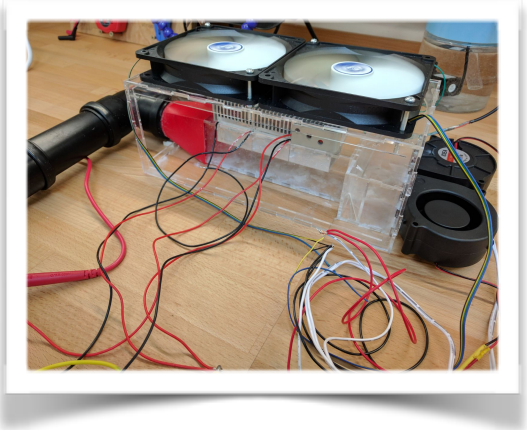
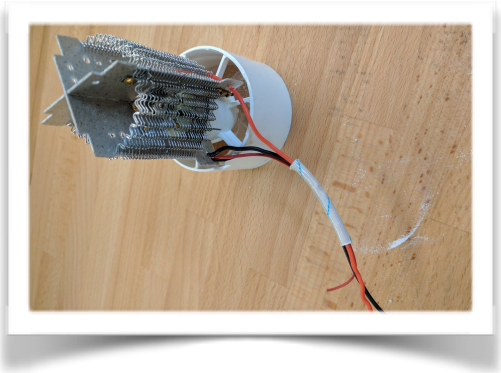


Fig. 112. Heating/cooling system final product.

Following the Peltier cells system failure, the idea of using a hair dryer was taken into consideration. The hair dryer was opened and the circuit was modified so that, using a relay board, it could be controlled with Arduino. Using two pins, a truth table for the hair dryer control was created. The truth table using two Arduino pins had 3 main combinations: no air was blown, cold air was blown using 12-volts to only switch on the hair dryer motor, and hot air was blown using 240-volts to switch on both the hair dryer motor and resistance. With this system, the air blown in the physical sphere was strong enough to be perceived while playing the game.



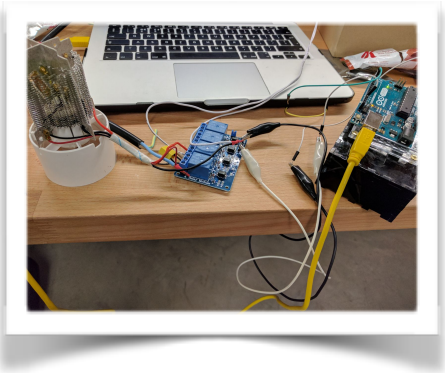
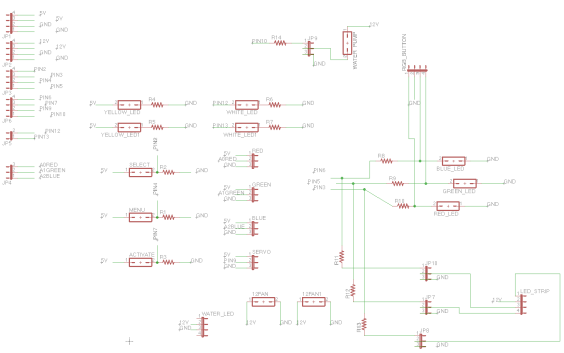


Fig. 113, 114. Hairdryer implementation and relay circuit.

Once again, when all the single electric components of the physical structure were tested, it was time to solder the circuit. Since the complexity of the system was increased if compared with the one developed for the first version of the controller, the decision of making a PCB was taken. The circuit schematic was first drawn on paper and successively imported in Eagle, a PCB design Software.



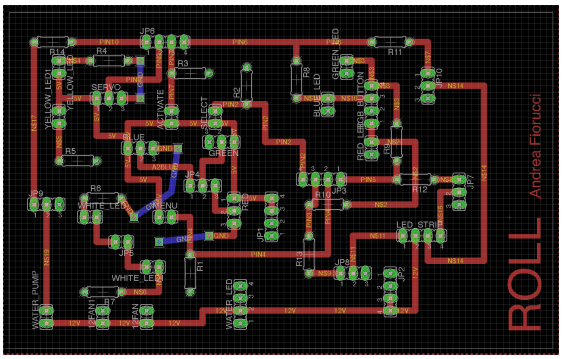


Fig. 115, 116. Final circuit schematic and PCB layout.

With the help of online tutorials, the schematic was then converted into a single layer PCB ready to be fabricated. After various attempts, the PCB was finally printed using the Roland SRM-20 milling machine.

Fig. 117, 118. Roland milling machine and Roll PCB,
https://www.rolanddg.co.uk/products/3d/srm-20-small-milling-machine

The final step taken in the final physical controller implementation involved assembling the whole wooden structure together and soldering the circuit. Differently from the prototype version of the controller, the high-fidelity version one was designed to be easily demountable and for the purpose, connectors were used to wire up the circuit. Crimping the connectors turned to be very tricky and this operation was executed twice as the first time no solder was applied to the wires, leading to a weak connectivity. The whole circuit was powered using Arduino for the 5-volt rail and a 12-volt 240-Watt switching power supply for the 12-volt rail.

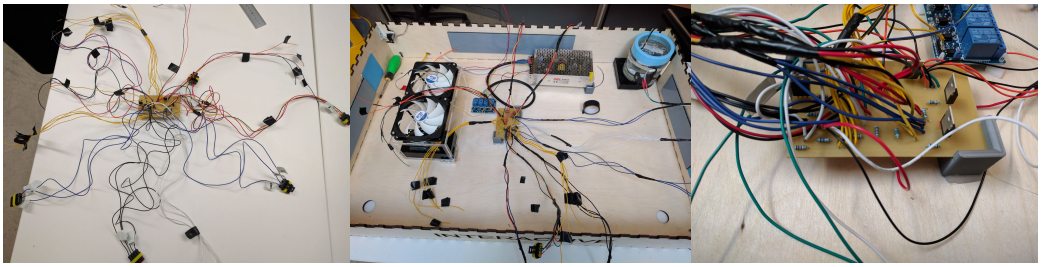


Fig. 119. Circuit Implementation.

Once the system was fully wired up, the structure was finally completed and the game code was polished to work with the structure. It was time to run some play testing and present the game to the players.

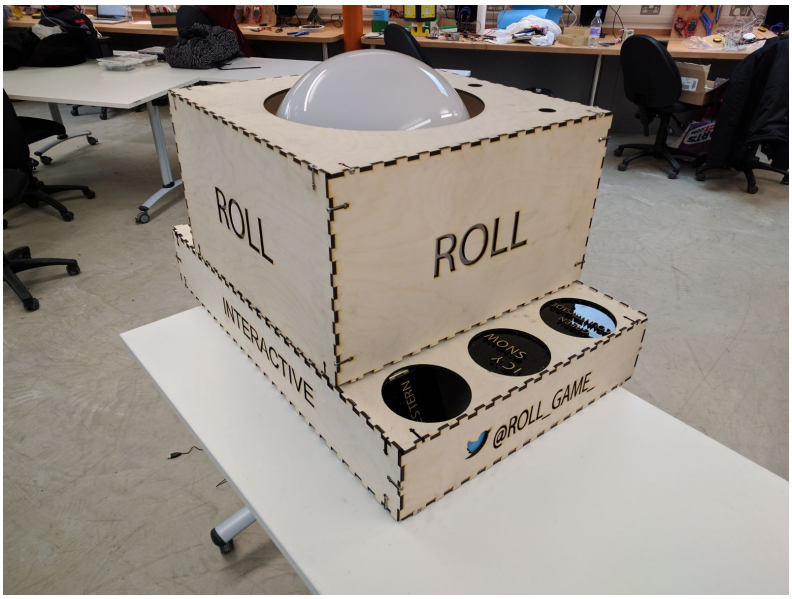


Fig. 120. Roll final high fidelity physical controller.

5

Testing

Contents

5. 1 Introduction

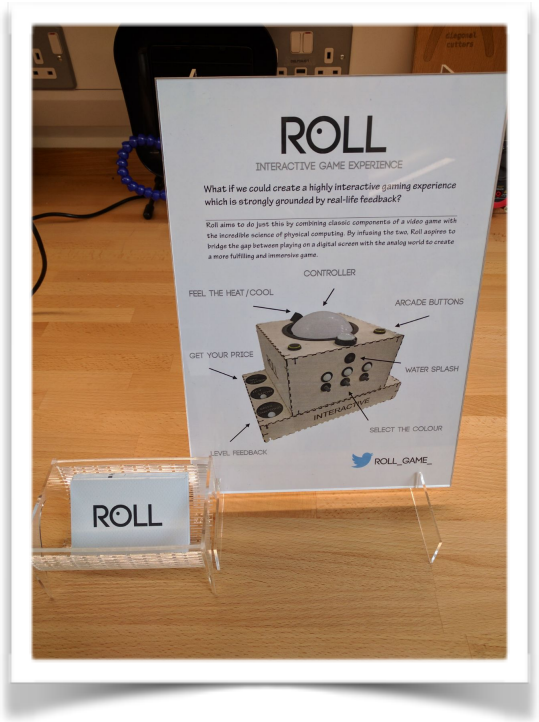
The secret behind the creation of a good product lies in the fact that a combination of techniques must be applied through the whole development process. Simply being a great designer, artist or programmer will not necessarily lead to success. The amazing creations we can produce with technologies are most of the times aimed for someone else, either a friend, an organisation, or a specific group of users. Despite our abilities to create successful products, users will always play an extremely important role as they will be the customers of that application. Exactly for this reason, one of the techniques which must be considered while designing a product is testing and evaluation. The greater is the number of feedbacks received on a specific application, the more it is possible to improve and adjust it to the customer expectations. There are different methods to retrieve data from users and the latter is divided into two main categories: qualitative and quantitative data. Since Roll required the combination of both software and hardware, it was not easy to test the application and different techniques were involved for the purpose. Participatory design was the main approach followed from the beginning of the project: users in fact were involved in the development process and took part in several testing sessions. Being a physical game, Roll could only be tested with a proper set up and could not easily be spread to many people. Questionnaires were created to get a general idea of the project status but most feedbacks and suggestions were obtained through direct observation and direct interviews after each testing session was completed. To raise interest, a weekly blog and a Twitter account were created with the aim of keeping users updated of any important change possibly made during the development process.

5. 2 Play-Testing Session

From the very beginning of the project, users were involved in various sessions. As long as playing different versions of the game, players had the chance to test Roll physical mechanics before they were added to the physical controller. Paper prototypes were an excellent solution to obtain useful feedbacks in terms of the game level design, the layout for the game graphic user interface and the difficulty encountered to navigate the game main menu, before the actual implementation. Mechanics like the physical sphere colour selection were initially prototyped using a breadboard and presented to the users. When the game reached a solid playable version, the first play-testing sessions were organised and the game could be played using a PlayStation 4 joypad. The decision of making a joypad game version was due to two main reasons: the game could be played even if the physical controller was not yet ready, and users could compare two versions of the same game played with different controllers and report the difference of both experiences. The major play-testing sessions were hold in relatively large rooms with the participation of other developers showing their products. Each tester was asked to play the game and loudly comment their thoughts as they were exploring the application. Using this method, it was possible to record most of the problems they encountered while playing and general suggestions about the game experience.

Fig. 121. Play-testing sessions with people trying the game.

Straight after the test, users were asked to fill in an online questionnaire and briefly explain what would they improve if they were developing the game. Business cards were positioned next to the game station together with A4 flyers explaining the purpose of the game and the physical controller development.



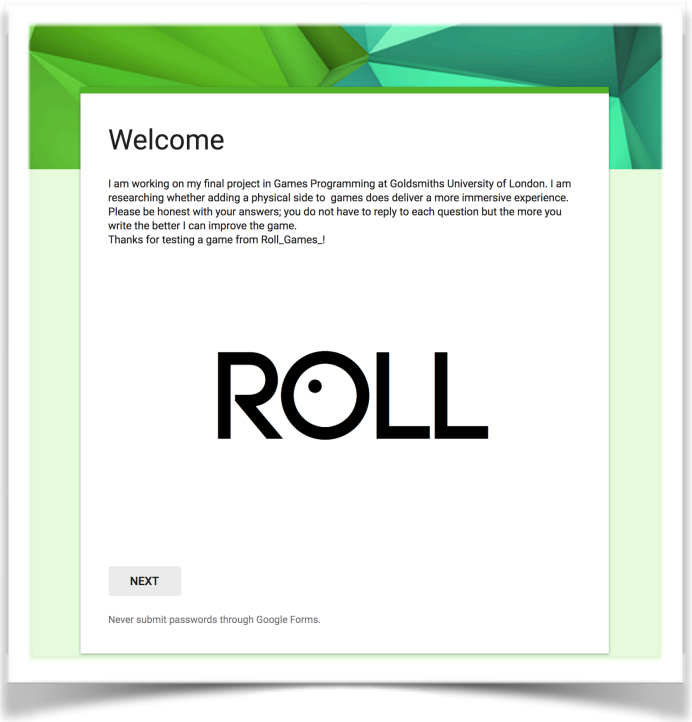


Fig. 122, 123. Roll business cards, A4 poster and questionnaire introduction.

The first physical controller prototype was tested in early January. The game was projected in a large wall and the controller positioned in a dark room to emphasise the structure lighting and create an immersive game context. Being only an early prototype, there was still a large room for improvements and user feedbacks were essential at that point in the project.

Fig. 124, 125. People testing the prototype version of the controller.

When it came to test the final version of the physical controller, a public event was created in collaboration with Kevin Dang, a creative computing student, in the attempt to reach a bigger audience.

Fig. 126. Play-testing session poster made in collaboration with Kevin Dang.

Unfortunately, while running some final tests right the day before the show was scheduled, the physical controller failed to work. The relay board used to control the hair dryer broke down, allowing reverse current to flow through the circuit, burning both the Arduino micro-controller and the laptop used to run the game. Luckily, the PCB and the internal circuit did not suffer from any damages. For how upsetting the situation was, in the end it turned out very useful to understand the danger of using high voltage and current for an application accessible by everyone, especially children. It took roughly a week to recover the physical controller and think of an alternative solution for the heating and cooling mechanic. While removing the hair dryer from the system, with the help of a digital multimeter it was discovered that the 5 volts coming from Arduino were not enough to support the current required by all the components. In addition, the relay board used to control the hair dryer did not manage to support the current driven, allowing reverse current through the circuit and Arduino. The circuit was then modified so that an external power supply was used to provide the necessary voltage and current to the 5-volt circuit. By doing so, Arduino was no longer driving too much current and was only responsible to enable and disable transistors.

The hair dryer was swapped with a 12-volt hair dryer and by using a combination of relay boards to isolate the higher current circuit, diodes to prevent reverse current, and a fuse to break the circuit in case of current overload, the problem was finally solved.

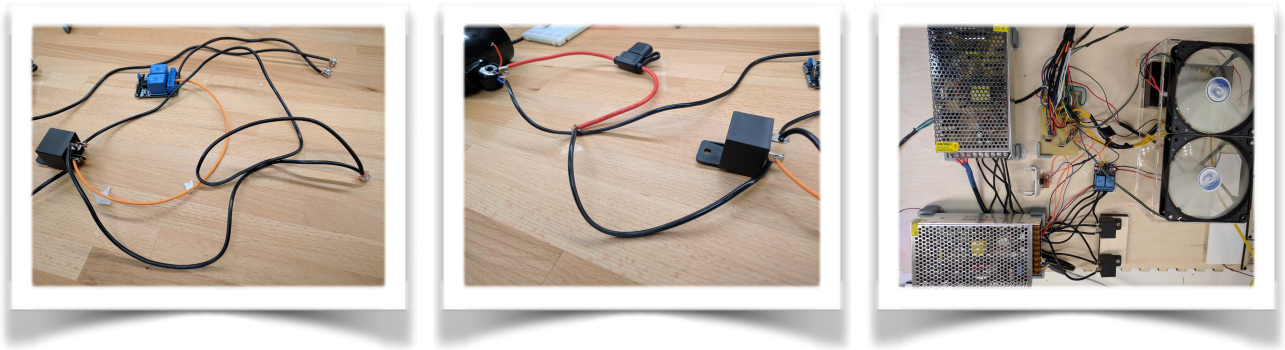


Fig. 127, 128, 129. 12 volts DC hair dryer circuit implementation.

A last-minute testing session had been organised and players could finally test a fully working version of the game, leaving once again useful feedbacks for further improvements.

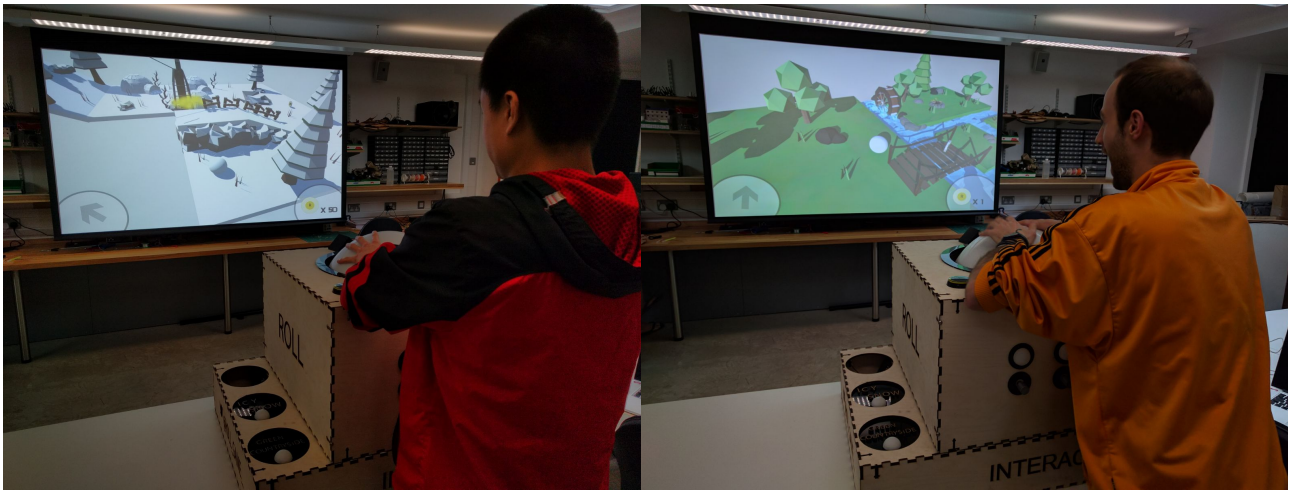


Fig. 130. People testing the high fidelity physical controller.

5. 3 Showcase

Intel Buzz Showcase Website: http://intelbuzz.bemyapp.com/2017/london/

In March 2107, Roll was submitted for the London Intel Showcase contest. Fifteen games were selected with the chance of winning a spot at the London developer showcase hosted by Intel. With great astonishment, Roll made it to the top fifteen and was showcased on April 8th. The event lasted for about four hours, with the participation of roughly 300 people among developers and amateurs. Each of the contestants was given a table to show their games and the possibility to receive useful feedbacks from experts in the Industry. As the physical controller had not yet been implemented, the PlayStation 4 joypad version of the game was presented on the day. Testers provided lots of positive responses and useful advices and seemed to show particular interest in the physical controller idea.

Fig. 131. Intel Buzz Workshop, London 2017.

5. 4 Feedback and Responses

Direct observation, questionnaires, post sessions interviews, and participatory design really helped to gather useful information throughout the whole development process. Paper prototypes highlighted a strong agreement among testers in terms of the game interaction and contributed to the final main menu and graphic user interface layouts. Initially, the main menu resulted too plain and not interactive at all. Most people suggested to add a light background colour and include some animated game objects to increase interest with the very first impact of the application. Cardboard prototypes were used to build sections of the physical controller and were used to test some electrical components like push buttons and potentiometers. Even in this situation, all the feedbacks received contributed to the implementation of the first version of the physical controller. Even though the latter was built following most users' suggestions, the first testing sessions highlighted major problems in terms of effectiveness: the product resulted difficult to learn and not very straightforward to use. The push buttons were far away from the players' position and the physical sphere rotation was very unstable, causing frustration while playing the game. Users were again involved in the implementation of the high-fidelity version of the physical controller. This time the combination of feedbacks received while developing the new structure and the previous results obtained from the play testing session turned to be a significant amount of data collected and were successfully used to finally create a valid product. The new physical controller in fact embodied the game at its best and the user interface resulted more clear and easier to use. Most of the feedbacks were also received while testing the PlayStation 4 joypad version of the game as it was easier to set up and have users to test it. Despite most of the players enjoyed the graphic style used for the game, some problematics were raised regarding the player movements and the introductory game tutorial. The analogue stick used for the sphere rotation was not mapped correctly as the game camera was tilt by 45 degrees, limiting the players to barely pass the first game environment.

In terms of the tutorial, almost every tester found really confusing the section explaining how to activate game objects. That section in fact, instructed players to push a specific button when hovering with the sphere on top of a yellow particle system. Once players pressed the button, they were expecting the game to respond to their action but zero feedbacks were provided, with the result of creating a very confusing situation in what should have been the instructions for the game. Tweaking and adjusting the game to the users' need was not only done based on post-game session interviews and direct observation but most of the changes were also implemented in response to the questionnaire results. Players were asked to fill in a questionnaire at the end of each session. Researching whether the physical controller delivered a more immersive game experience compared to the PlayStation 4 joypad version of the game required a very long and detailed survey. The latter was mostly composed by long-answers questions in the attempt to fully capture users' thoughts about their experience. Not many responses were recorder in the questionnaire as Roll could be only tested by participating to play testing sessions but with the combination of direct observation and interviews a reasonable amount of data was collected. The results of the questionnaire showed that the average age of testers ranged between twenty and forty years old, who mostly tried the joypad version of the game.

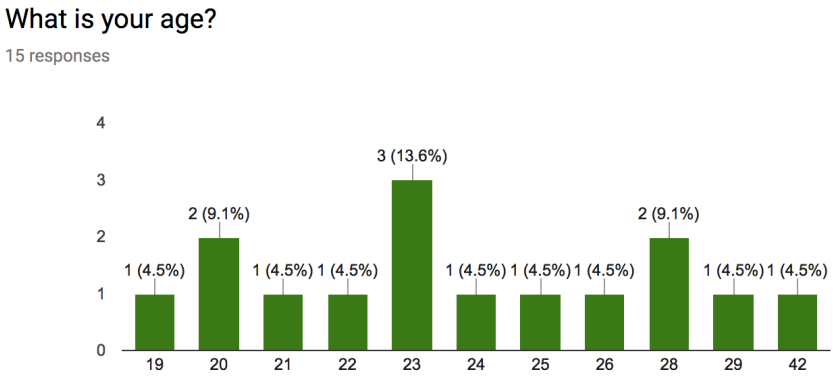


Fig. 132. Questionnaire results, users age.

The difficulty of the game seemed to be very well distributed on a scale from 0 to 10, with the average results being slightly over the half. As already been said, most players found the joypad controllers not very intuitive and quite hard to use. Furthermore, there were multiple concerns about the game tutorial.

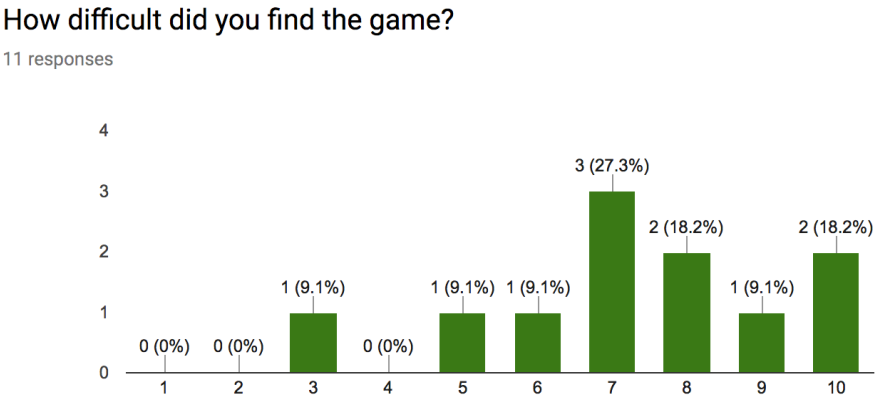


Fig. 133. Questionnaire results, game difficulty.

Despite this, most responses would recommend Roll to a friend and possibly purchase the application.

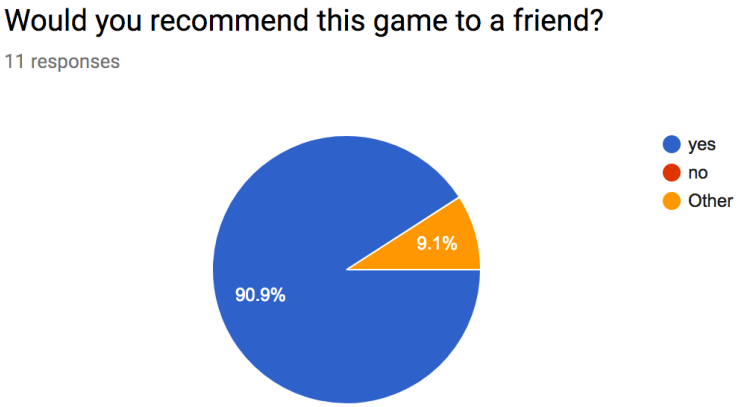


Fig. 134. Questionnaire results on whether users would recommend the game.

There was no doubt that the physical controller delivered a more immersive and interesting game experience compared to the PlayStation 4 joypad version of the game.

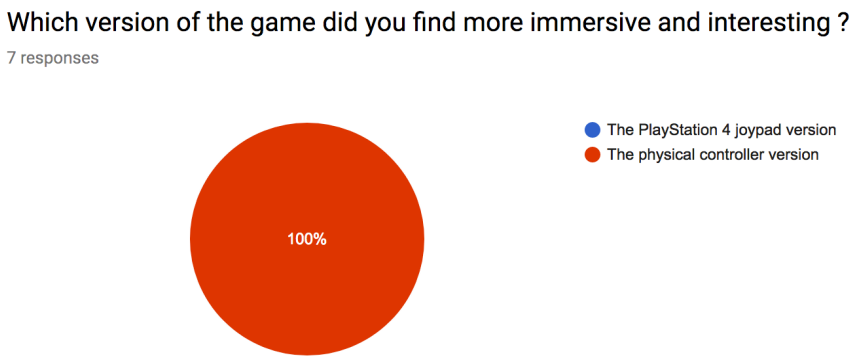


Fig. 135. Questionnaire results on which controller resulted more immersive.

All the data retrieved using different methodologies, the analysis carried out to prioritise development changes, and the opportunity to receive feedbacks in person were all fundamental aspects of the project evaluation and together helped to achieve a more polished version of Roll.

6

Conclusion and Future Work

Contents

6. 1 Overall Game Experience

Overall, Roll has demonstrated and shown an alternative solution to the gaming experience. Players felt really engaged in the game, showing a strong connection with the virtual environment. It has been proven that Virtual Reality is not the only way to make high immersive experiences and similar results could be achieved with less advance and expensive technologies. The experience resulted very engaging also due to the appropriate context in which Roll was exhibited and played. The physical controller increased users interest and desire to play the game, confirming the importance of the surroundings in which a game is played. It was also very evident that players manifested stronger emotions while playing the physical version of the game compared to the classic joypad version of it. The heating and cooling system, especially, added a unique feature to the application, revealing a rare game mechanic which has not been deeply considered and researched yet in the industry. Adding a physical rewarding system blinded users from the high score ranking as they were concentrating to finish the game and collect the physical prices. Simply reaching the high score was not longer the main objective for most players. This explained the game addiction created by implementing the physical price mechanic which made players forget about the high score system. In the end, Roll confirmed its originality as a game concept as most users found the game experience new and unique. Now that Roll is finally a working product, it is time to show it to a bigger audience.

6. 3 Future Plans

Roll will not end its journey right here; the plan is to improve its structure and find a solution to make it transportable. Showcases like A MAZE in Berlin and GDC in San Francisco are two of the major objectives for the following years. Furthermore, the plan is to create a portfolio of interactive games which features the incredible science of physical computing.

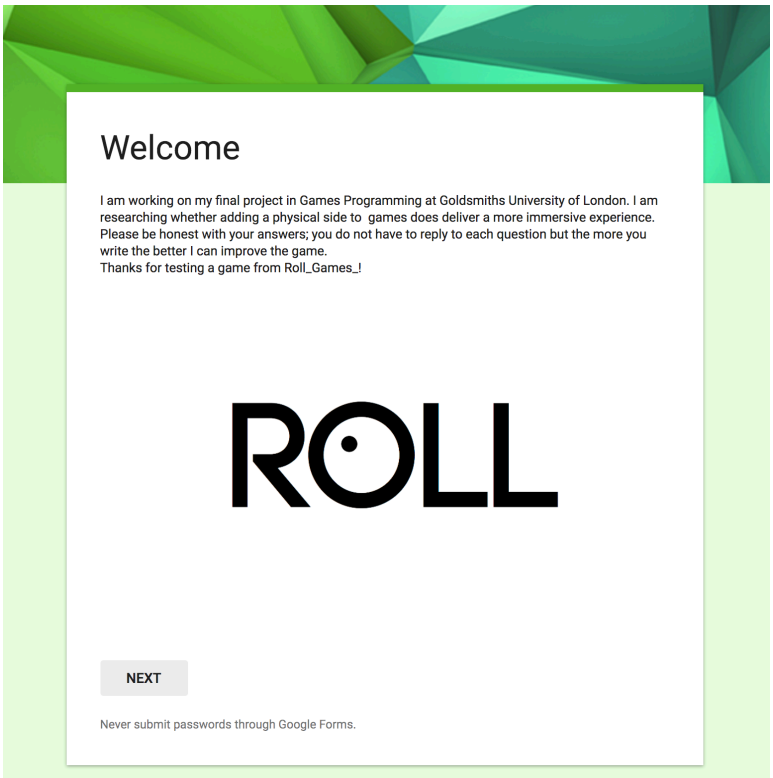
6

Appendices

Appendix 1

Roll feedbacks questionnaire:

https://docs.google.com/forms/d/e/1FAIpQLScRFImsWeGBtfOAbkFSu98CcywXLetFWUlKf4-XhF79K81r6A/viewform



General

General Thoughts

What is your name?

Your answer

What is your age?

Your answer

Which version of the game did you try?

- Joypad Version
- Physical Version
- Joypad and Physical Versions

Overall, what were your thoughts about the game?

Your answer

Was the game objective clear? If so, please describe.

Your answer

Was there anything that you found confusing or frustrating?

Your answer

Which aspects did you find to be the most and the least interesting in regards to the physical structure?

Your answer

Would you say that the Physical Version improve the game interaction and makes it more immersive? Please describe.

Your answer

Which version of the game did you find more immersive and interesting ?

- The PlayStation 4 joypad version
- The physical controller version

Would you say that Roll is ready to take part to arcade showcases?

- Yes
- No
- Other:

BACK SUBMIT

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Interface and Controls:

General feedbacks about the game controls and gameplay

Were the rules easy to understand and learn ?

Your answer

What did you think about the joypad version game controls? Did they feel right or confusing?

Your answer

What did you think about the physical version game controls? Did they feel right or confusing?

Your answer

Was there anything about the interface that you would change?

Your answer

Did anything feel awkward or confusing?

Your answer

Any thought about the introductory tutorial?

Your answer

BACK NEXT

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End of session

Summary about the overall experience

Describe this game in one word.

Your answer

Would you purchase this game?

- yes
- no
- Other:

Would you recommend this game to a friend?

- yes
- no
- Other:

What was missing from the game?

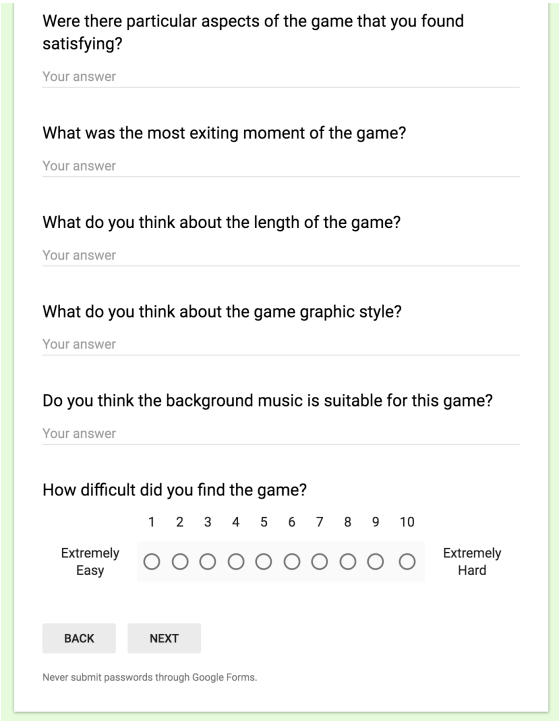
Your answer

How immersive did you find the joypad game version ?

Your answer

How immersive did you find the physical game version ?

Your answer



Were there particular aspects of the game that you found satisfying?

Your answer

What was the most exiting moment of the game?

Your answer

What do you think about the length of the game?

Your answer

What do you think about the game graphic style?

Your answer

Do you think the background music is suitable for this game?

Your answer

How difficult did you find the game?

	1	2	3	4	5	6	7	8	9	10	
Extremely Easy	○	○	○	○	○	○	○	○	○	○	Extremely Hard

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Appendix 2

Development tools

Software	Platform/Version	Programming Language
Unity 5	Mac OS/ Unity 5.5.1f1	C#
Uniduino	Unity 5.5.1f1/ Library	C#
Arduino	Mac OS/ Arduino Uno	C and C++
Blender	Mac OS/ Version 2.76	None
Maya	Mac OS/ Autodesk MAYA 2016	None
Fusion 360	Mac OS/ Autodesk Fusion 360, 2017	None
Cura	Mac OS/ Ultimaker B.V. Cura 2.4.0	None

7

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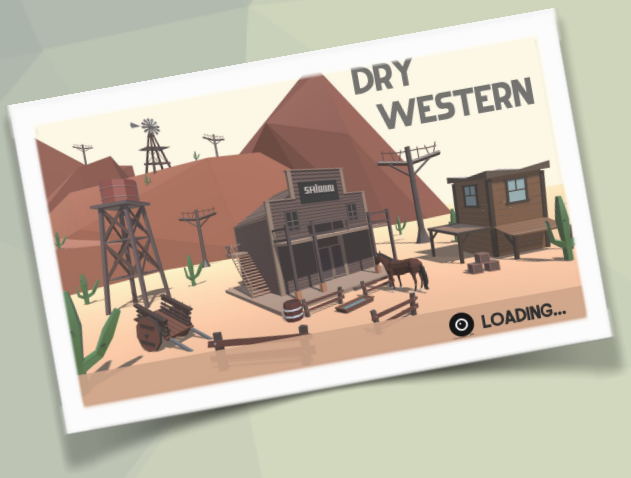

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