Application of spatiality to puzzles video games focused on emotional learning in Unreal Engine 4.

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T as in Troy?

-No Gabriella, T as in TFG finally finished.

Acknowledgments

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Abstract

The hereby document represents the Final Report for a bachelor's thesis on Video Game Design and Development. The following work consists of the design and development of a puzzle video game focused on introspection and emotional learning. The project is in the development of a puzzle video game based on space as the structure that forms the backbone of the entire project, making its mechanics, its narrative and its history depend on it, thus giving it superlative importance both to its spatiality and verticality. The game will be developed in Unreal Engine 4 for PC; The player will be placed inside an interior space categorised as the mind in which he must solve the puzzles in order to get out to the outside world.

KEYWORDS: Puzzles, spatiality, Unreal Engine 4, emotional learning.

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CHAPTER 1

Introduction

Contents

In this section we will talk about the bases of the video game, everything that is composed as an initial state or starting point. We will talk about the expectations, the motivations and about the references sought and applied studies to compose a good base on which to carry out the entire project.

1.1 Work Motivation

The main motivation for this project was to create spaces that I felt were entirely my own, a haven of peace in which to find myself and a starting point from which I could relax, act and recreate myself. It is intended to carry out an introspective project, a look into the mind and a projection of the emotions and cognitive distortions experienced, to carry out a path towards understanding and towards action and change.

In this project, space is the main tool to create everything else through it, making the mechanics, the story and the flow of the game itself depend on it.

1.2 Objectives

The main objective is to develop in Unreal Engine 4, a technical demo of minimalist interior spaces through which the player will have to solve puzzles depending on the space, in order to advance to new rooms.

After overcoming the entire internal world, you will be able to access the external world to be able to meet again with one of its parts.

1.3 Environment and Initial State

The initial state, as in any project, is pre-production, a state in which the entire idea and conceptualization of the world must be built and the ideal perspective from which to approach the project must be found. The correct look required a previous study, both of the settings and mechanics as well as of the story. For this, certain branches of architecture were investigated, such as neuroarchitecture and biophilia, which were discussed in their corresponding paragraphs.

1.4 Related Subjects

- VJ1216 - 3D Design
- VJ1218 - Hyper Media Narrative and Video Games Analysis
- VJ1221 - Computer Graphics
- VJ1222 - Conceptual Design of Video Games
- VJ1226 - Character Design and Animation
- VJ1227 - Video Games Engines

CHAPTER 2

Planning and resources evaluation

Contents

This chapter is structured in two sections. The first one will describe the initial planning as a table and the course of the work that has been followed in an orderly manner. The second one will explain in detail the cost of implementation that this project would entail.

2.1 Initial Planning

The table that will appear below (Table 2.1), shows the objective planning divided into three phases segmented by hours: pre-production, which encompasses all the documentation and conceptualization of the project, production, which is made up of the creation of scenarios, characters, programming, and post-production, which encompasses the final finish, realization of the memory and preparation of the presentation.

DESIGN ART PROGRAMMING	Estimated hours
PREPRODUCTION :	**114h**
References searching.	2h
Scenarios conceptualization.	10h
Character conceptualization.	25h
Conceptualization of playable mechanics.	5h
Conceptualization of puzzles.	20h
Story / narrative conceptualization.	5h
Interface conceptualization.	2h
Documentation on emotions and its representation in space.	20h
Documentation on composition and its psychological influence	10h
Creation of an artistic style.	15h
PRODUCTION :	**178h**
Character modeling.	40h
Materialization of the characters.	10h
Characters animations and rigging.	19h
Modeling of the scenarios.	35h
Materialization of the scenarios.	5h
Gravity programming.	10h
Puzzle programming.	8h
Level programming.	4h
Player movement programming.	2h
Mechanics programming.	15h
Interface programming.	3h
Camera programming.	2h
Simple narrative scene creation.	10h
Creation of stage and characters' particles.	15h
POSTPRODUCTION:	**27h**
Memory design in LaTeX	2h
Writing of the report.	20h
Preparation for presentation.	5h
TOTAL ESTIMATED:	**319h**

Table 2.1: Table of the initial planning.

2.2 Estimated Cost

In this section, the cost of developing *Blooming Emotions* will be estimated, analysing its dimensions. It is difficult to show the exact amount, but an estimate can be made in this regard. To develop the technical demo, over 4 months of development, and with an estimated workload of 300 total hours, it is obtained that the developer should work 75h/month. It is estimated that a Junior Video Game Programmer, with less than 3 years of work experience, can expect an average salary of around 21,500€ gross per year (1,791€ per month) for full-time (150 hours per month) work []. Having to do 75 hours of work per month , it represents an estimate of 895.83 € (1791€ X 75 hours / 150 hours) gross per month. To carry out the complete project, therefore, it would be approximately 3583.33€ (895.32€ X 4 months). In addition, it would have to pay for the corresponding licences of the programs used in its development.

- Publish game on *Steam*: 95.14 €.
- *Unreal Engine*: Free but takes 5% of the profits.
- *Photoshop*: 19.97€/month.
- *Audacity*: 0€.
- *Mixamo* : 0€.
- *Blender*: 0€.
- *Quixel Bridge*: 0€.
- 3D models from *Epic Games MarketPlace*: 0€.
- Hardware used during the development(*MSI GS63 7RE Stealth Pro*):1.630,38€

Finally, the estimated cost would be approximately 5388.73€.

Chapter 3

Research and References

Contents

3.1 Game Concept

The maximum reference for the proposal of this project was *Manifold Garden* (Figure 3.1 (b)), a puzzle game in which space is sought to have a predominant role over the gameplay. In this game, you have to use gravity to overcome certain challenges, using mechanics similarly as *Portal* (Figure 3.1 (a)), another of the great references of this project. In this, certain cubes have to be positioned on the pedestals in order to move on to the next area. Combining both mechanics and showing a more introspective story like in *Gris* (Figure 3.2(a))video game, another narrative and another point of view is composed that Blooming emotions intends to reflect.

(a) Portal

(b) Manifold Garden

Figure 3.1: References for game concept

3.2 Narrative Design

The narrative design of *Blooming Emotions* aims to focus on cognitive distortions and rumination through dialogue and playable space. The story begins with interior spaces that are similar to each other, showing the space of the mind as a sensory prison and tomb of emotions. The goal is to get out of it, being able to access the space of life, a field in which to reconnect with a part of you that was previously lost. In this space it is intended to show the opposite of the space of the mind, making nature, flora and fauna play a very important role and providing great sensory and emotional value to the narrative.

To do this, *Blooming Emotions* drinks from a lot of games that are benchmarks for their narrative, such as *Gris* or *Journey* (Figure 3.2), both treating the concept of travel as a symbol of overcoming and duelling.

(a) Gris

(b) Journey

Figure 3.2: References for narrative design

3.3 Artistic Design.

The artistic design was the most complicated part to combine since it was intended to make two very different styles that could coexist within the same environment. On the one hand, in the space of the mind we wanted to compose a sober, austere and minimalist style, to make the player often feel cloistered within the space, but at the same time not seem too decadent. It had to be a diaphanous and very uncluttered space, as a symbol of the mind as a vast and static space, as well as clean and simple.

For this purpose, two boards were created on Pinterest (Figure 3.3), one about the internal world and the other about the external world. In the internal world, form is sought through architectural spaces and geometric design proposals to compose well-defined spaces. This is supported by the documentation that was made on the neuroarchitecture, which will be explained later.

For the scenarios of the external world, much more organic forms were chosen and biophilia was incorporated into the environments to give them much more richness. In turn, it will be explained in detail later.

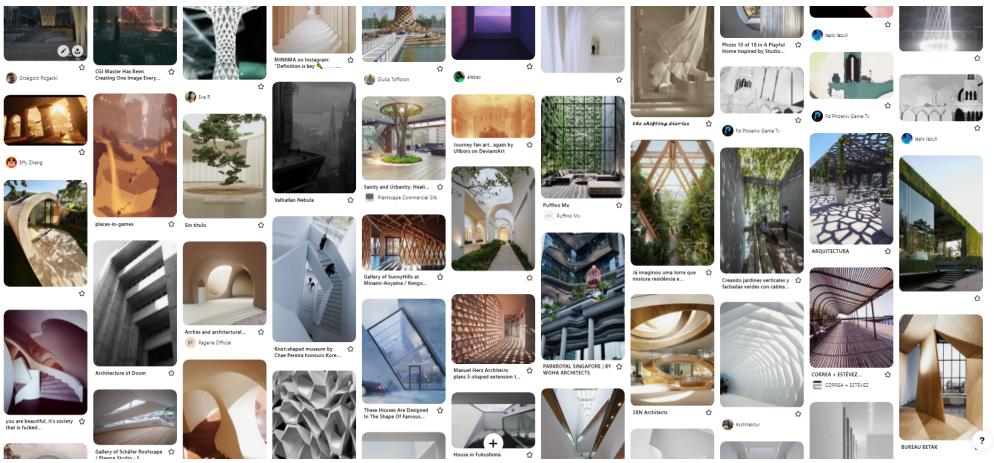


Figure 3.3: Board of internal world in Pinterest.

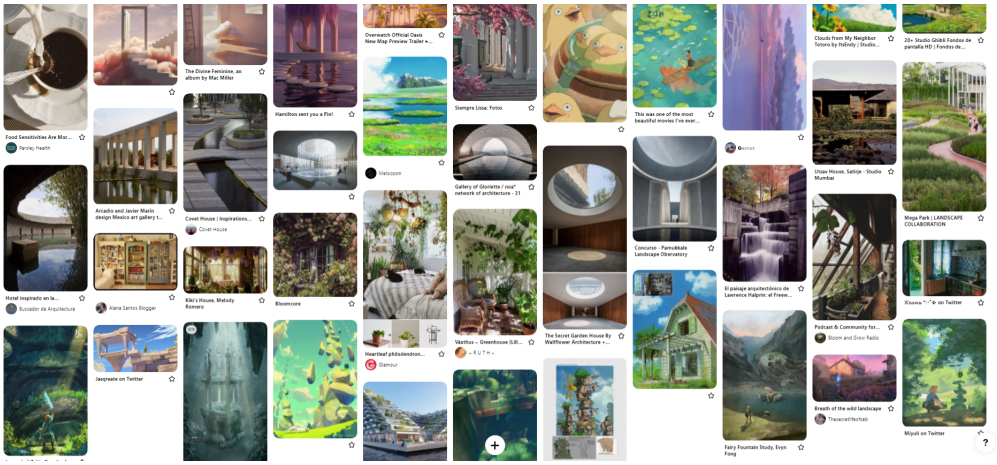


Figure 3.4: Board of external world in Pinterest.

3.3.1 Neuroarchitecture.

For this artistic style, the field of neuroarchitecture [3] was deepened with crucial questions such as: can space modify our behaviour? Can it modify how we feel, or how we interact with it? For all of these questions, neuroarchitecture says yes. From the Salk neuroscience institute, *"Rusty" Cage* wrote a prologue for the book *Brain Landscape* [4] with these lines:

"I affirmed that architectural design can change our brains and affect our behaviour, the structure of the environment, the house we live in, the places we play, the buildings we work in, can change our brains and affect our behaviour. By designing, architects can affect our brains."

Neuroarchitecture aims to delve into the fact that there is a back and forth between what space proposes and how the mind decodes it[4]. Currently, ways of monitoring brain activity are known, which areas are activated and deactivated in order to understand what these causes and effects are [8], in order to be able to definitively, with our design act or our project act, influence positively or not, within the head of the users of these spaces. Neuroarchitecture throws out the theory that comfort in front of a space is given by the power one has over it.

Likewise, spaces with a high height promote abstract thinking and therefore more creative thinking. In the same way, a lower space and more content causes a greater concentration. In addition, it shows that the main form of social relationships is through the gaze, regardless of technologies or social networks. When looking at another person, mirror neurons are activated that are related to empathy and imitation, proof of this is the learning of a child in front of her parents. For this reason, in isolated or closed spaces, it is more complicated to create a bond with others and with it, have less control of the space.

In turn, neuroarchitecture [9] investigates how forms affect our brains. The amygdala of the brain is a structure related to fear, so it is activated when the user is in a moment of panic or feels insecure. Neuroarchitecture discovered that in acute forms, the amygdala is much more active than in rounded forms.

Finally, from the genetic point of view of our evolution we are still cavemen. Our genetic formation was modified over thousands of years, adapting to the environment, a natural world, with its flora and fauna. In that environment, we were in permanent contact with nature. Barely two hundred years ago, since the industrial revolution, human beings have been confined to artificial spaces such as factories or offices. All this causes a reaction in our body, a number of disorders from sedentarism with all its cardiovascular diseases, musculoskeletal disorders to amounts of phobias or amount of toxins that are breathed by synthetic and artificial materials that lead to allergies, etc. The view to the horizon or the contact with the natural light that regulates our biorhythm, help to have a closer contact with nature. Likewise, textures or natural patterns also help this.

Based on what was explained above, all these characteristics are interwoven in the video game. The player will always have only one way to go, so it will not have control over the space. To solve puzzles, it is intended to enhance its creativity, so wide and high spaces will be chosen. However,it will be made to feel cloistered as the player will only listen to the squirrel (a part of itself) until the player can see it in the space of life, in order not to be able to reconnect with itself in the mind space. The latter will be made up of elements mostly of sharp edges in order to activate the amygdala in the brain, while in the space of life they will be above all more organic forms. In relation to the latest treatment in the space of mind, there will be many windows so as not to cause such confinement.

At last, in Figure 3.5 is shown how neuroarchitecture influences real life, with buildings such as the Shanghai Natural Science Museum or the Jewish Museum in Berlin, both structures use neuroarchitecture with completely different objectives.

(a) Natural Sciences Museum at Shanghai

(b) Jewish Museum at Berlin

Figure 3.5: References for narrative design

3.3.2 Biophilia

On the other hand, to compose the space of life, it was intended to compose spaces in which biophilia [5] was present, giving much more life and dynamism to the environment. To do this, the gaze was focused on *Studio Ghibli* [6], animation studio par excellence, creator of films such as *My Neighbor Totoro*, *The Secret World of Arriety* (Figure 3.6(b)) or *Spirited Away* (Figure 3.6(a)). In these feature films, nature takes on superlative importance and they helped the narrative to have much more power[7].

(a) Spirited Away (b) The Secret world of Arriety

Figure 3.6: Studio Ghibli references

To show the importance of biophilia and about biophilic design, we have to go back in time, to our genetic past. For thousands of years, our DNA has been in permanent contact with nature, we are programmed to respond positively to natural spaces.

Scientists have discovered genetic links that illustrate how humans have adapted their biological response mechanisms to natural environments. Several responses to natural systems are hidden in our makeup and to get positive reactions in our physiology and psychology. That's why today when we find ourselves in nature we automatically feel more relaxed. Our molecules respond to biophilic design [12]. Exposure to contact with wood for ninety seconds lowers the release of stress hormones in our body.

In a 2019 study participants performed written tests in furniture settings with white surfaces and as shown wood surfaces. It was found that taking tests in rooms constructed with a moderate balance of wooden surfaces can reduce our cortisol levels to thirty-eight percent. Taking tests in rooms on wood surfaces affects our mood, motivation, stress and even fear.

Similarly, in the same furniture study, scientists found that heart rates drop significantly with wood. This can lead to a steady reduction of five to ten beats per minute, which substantially affects our health in a very positive way.

For this reason, it will delve deeper into what principles make up biophilia and the applications in front of the space that are intended to be found in the project.

Principles of biophilia.

- Environmental features.

  Using recognized features of the natural world, the first principle is multisensory interaction with the space surrounding society. These interactions can range from heat, sight, smell, touch, and any other clear and unique natural presence. Introducing green spaces into living spaces adds colour, texture, and a sense of visual calm. People often have some houseplants on their desks to liven up their work environment. This can be seen on a larger scale as a patio or green wall in the built environment. Biophilic design requires a repeated and constant engagement with nature. The presence of water enhances the visual, auditory and tactile experience through elements such as fountains, pools, ponds and water jets.

- Natural patterns and processes.

  The second principle focuses on sensory experiences with complementary transitions and contrasts. Any space is considered successful and sustainable with the application of biophilia. A variety of sensory experiences can be produced to help lower blood pressure, elevate mood, and improve overall health. Tactile and visual sensations can be evoked through the use of different materials, colors and textures. In terms of design principles, color changes and their transition from one space to another can be impactful, blue and green can be associated with calm, and red and orange can be associated with vibrancy. These contrasts unconsciously attract a person and even increase productivity.

- Light and space.

  Light and space can evoke a sensory response for people of whatever character they choose. Light and shadow have a positive effect on the human mind, and changing the quality of light can produce soothing rhythmic changes that improve visual comfort throughout the day. For example, the dynamism of shadows and the intensity of light created by openings, pergolas and skylights provide the opportunity to create a warm atmosphere. The light brings warmth and heat to the space. It can help regulate indoor temperature. These ideas are some that mimic the natural environment. Daylight and seasonal light, moonlight and starlight, bioluminescence are natural phenomena. While accent lighting, circadian colour references (white light during the day, no blue light at night) are some artificial ideas of light that simulates space.

- Place-based relationships.

  This principle implies designing taking into account the cultural, spiritual, ecological or historical relationship. Mind-body relationships have been studied for centuries and scientists, researchers, and spiritual guides have often referred to a tangible space as an important component in one's life for growth.

- Evolved human-nature relationships.

  Environmentalism can be broadly defined as an ideology or social movement. It focuses on fundamental environmental concerns. In biophilic design, the man-nature relationship has been explored through the extraction of natural resources and the prevention of environmental hazards in habitat management and restoration. All architecture and interior design must be done with the environment in mind, putting the relationship with man and nature as the highest priority.

- Biomorphic Shapes. It is also beneficial to add components that look like nature. In the cases where it's impossible to include actual features of nature, using components and shapes that look like it can be just as effective.

  Biomorphic shapes can include any kind of shapes or patterns found in nature. Inspiration can come from trees, leaves, mountains, seashells, fossils, and more. It can be even create textures that are naturally found in nature to make them more realistic.

Chapter 4

Game Design

Contents

4.1 Flowchart

The game is made up of four main scenes: Main Menu, Options Menu, Pause Menu and Game.

- The Main Menu is the home screen of the game, the first screen the player will be in contact with. In it, it shows three different options, start a new game, go to the Options Menu or exit the game.
- In the Options Menu it is able to change the quality of the graphics and the volume of the game. Finally, it is possible to return to the main menu.
- In Pause Menu the player will have different options such as going back to the Main Menu, going to the Options Menu or removing the game completely. When the player is on this screen the game will stop completely and time will stop running showing the player a blur on the game screen.
- Finally the game screen, this is the main screen where the player will be, since it is where the whole story takes place. From it,it is accessible the Pause Menu.

In the schematic below shows the flow of the game.

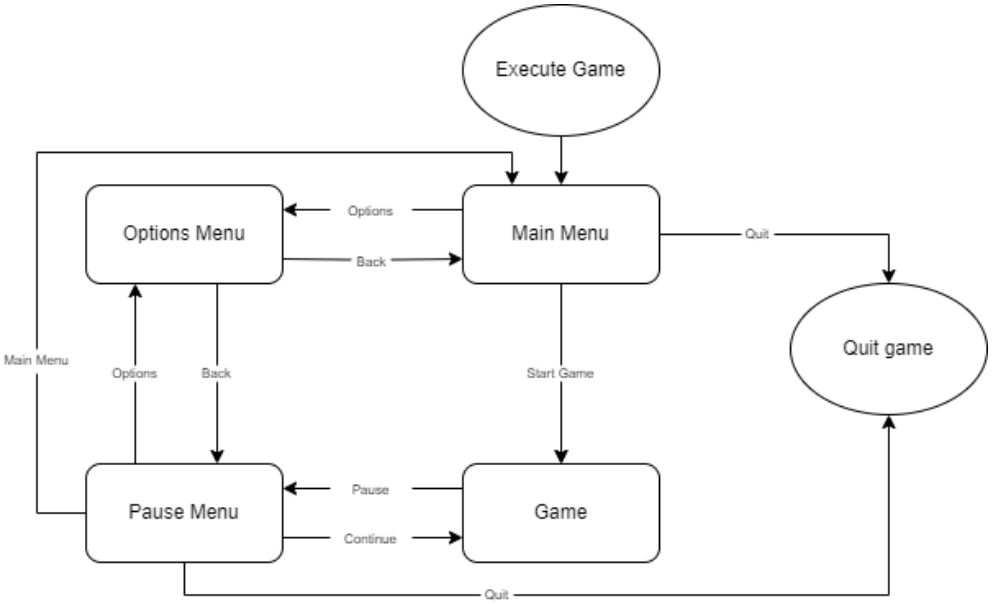


Figure 4.1: Flow Diagram.

4.2 Movement and physics

4.2.1 Interaction between elements.

Blooming Emotions takes place on an XY plane in which the world will be based. However, the character is able to move along the walls or the ceiling thanks to certain ramps that will be on the stage. However, there may be times when these ramps are not there and the walls are an obstacle for the player, so it will need its wits to overcome the tests. In short, the collisions that will occur: Character - Character / Character - Scenario

4.2.2 Controls.

The necessary controls will be displayed to be able to interact and move around the environment (Figure 4.2).

- W,A,S,D: These controls make up the player's movement, to go left it is needed to press "A", to move right it is "D", to move forward it would be "W" and to go backward it is "S".
- Mouse Movement: Mouse control is directly related to camera control.
- E: The "E" key is used as an interaction button, used to open doors, activate mechanisms, pick up cubes or drop them.
- SHIFT: Pressing the "SHIFT" key allows the player to move faster.

- SPACE: Pressing SPACE allows the character to jump to elevated platforms.
- ESC: The "ESC" key can be pressed to pause the game and return to the start menu.

Figure 4.2: Keyboard controls.

Chapter 5

Analysis and design of systems

This chapter introduces the requirements analysis, the design, the architecture of the proposed work, and the design of its interface.

5.1 Requirements analysis

Both types of requirements, functional and non-functional, will be discussed in this section.

5.1.1 Functional requirements.

The functions that this system will develop are mainly three.

- First of all the movement of the playable character. The inputs to this function are the WASD keys, which will respectively cause the output to move the character forward, left, backward, and right. Combined with this fact, the character can move through ramps placed on different surfaces (walls, ceilings, floors...). To achieve this behavior, a premise was started: it is necessary to move the axes of the character to the next axes positioned in its next step. To achieve this purpose, lines were first drawn from the character's point of view to the surface to which he had to move, which led to the conclusion of making a base change and obtaining the direction vectors of the next surface. However, in this case, the character was not working properly.

  Finally, it was concluded that it was only necessary to modify the local axes of the character through a cross product, to obtain the base sought. This was achieved by first obtaining the normal of the surface on which the character is , and together

with the vector Y (right vector in *Unreal Blueprints*) that in both bases will be the same. With these two parameters obtained, through a cross product the axis perpendicular to both is obtained and the base change can be made.

- Second, the player can interact with cubes in order to solve puzzles with them, either using them as props to climb other structures or putting them on pedestals to open doors. The input for this function is the E key, and it has two possible outputs. In case the player does not have a cube taken, it would take it. Otherwise, the character would drop the cube.

- Third, the player will be able to access a pause menu to exit the game. The input for this function would be the ESC key, which would cause the exit of the pause menu through which the application could be exited.

- To finish, the player will also be able to open doors by pressing a button. The input for this function would be the E key, which would cause the button to do a press animation and the door would go down, as an output.

5.1.2 Non-functional requirements.

The non-functional requirements in this project would be mainly:

- The performance must be optimal, it is expected that a minimum of 60 frames per second is necessary, for a clear and fluid result. For this, it is estimated that an average team will be needed, which will be detailed in section 5.3.

- Quality is also a very important point to deal with. The video game must be visually attractive for the player, therefore good artistic references must be sought and innovated through them, in turn creating different assets and scenarios that can be visually interesting.

- Finally, compatibility. The game will be compatible for most computers, so that it can be played with both humbler equipment and more expensive equipment.

5.2 System design.

This section will be shown through use case diagrams.

- The use case diagrams that will be shown in figures 5.1 and 5.2, will describe the actions to be performed by the player, both in the menu scene and in the game scene.

Figure 5.1: Use case diagram in game scene.

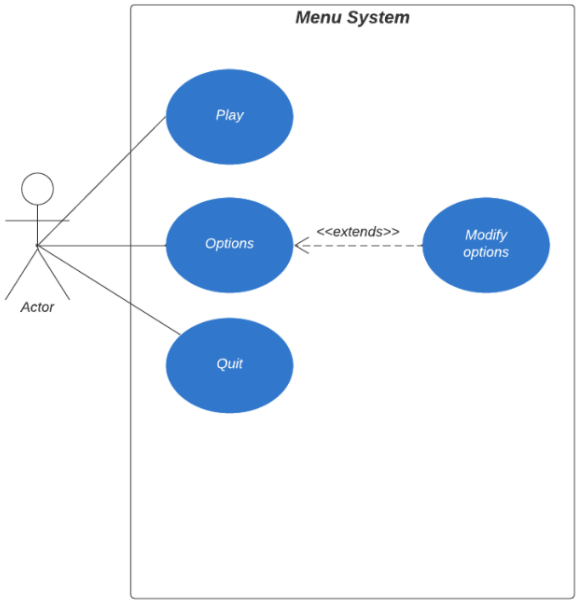


Figure 5.2: Use case diagram in menu scene.

5.3 System Architecture

For optimal and stable performance, it will be necessary to have an average computer, made up of graphics cards such as *NVIDIA GeForce GTX 1060*, 16GB RAM, and a processor between 2.3 Ghz and 2.69 Ghz.

5.4 Interface design.

The desired interfaces for this project will be shown below in the following figures.

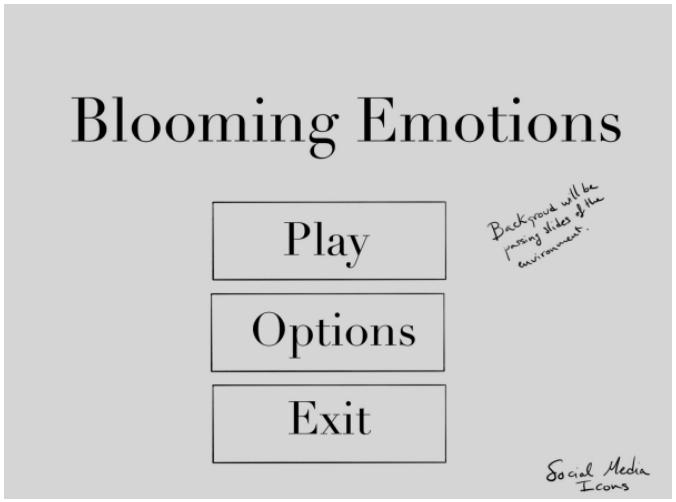


Figure 5.3: Interface for menu scene, work in progress version.

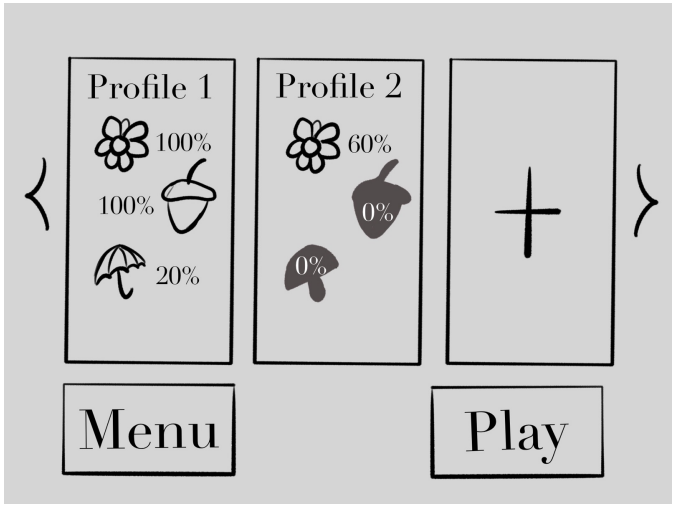


Figure 5.4: Interface for profile selection scene, work in progress version.

Chapter 6

Technical Art

Contents

6.1 Import Assets to Unreal

The import of assets to *Unreal Engine 4* was complicated due to different circumstances.

The first one would be the number of meshes and polygons that the entire stage had. This caused performance failures, so the problem of optimization was seen in the early stages of development. Due to this, simpler designs and structures were chosen, as well as a retopology of the entire stage, which was an optimal remodeling.This resulted in having to postpone or eliminate other phases of development or ideas that were wanted to be shown from the outset.

The second circumstance would be the amount of materials that this whole scenario needed. To achieve this goal, the option of working with the *Bridge* software was considered. This software was in turn a challenge due to the number of errors and problems it generated.The *Unreal Engine* version (4.27.2) used to develop this project used to give errors when importing and downloading the plugin that served as a link between the engine and the application. Due to this problem, different options were considered. It was possible to use another, more up-to-date version of *Unreal Engine* (5.0), but the *Ninja Character* plugin was not supported in later versions. Likewise, it was decided to work through *Blender* (3.1.2), but its version, in turn, was not accessible from *Bridge*.

Finally, it was decided to work with a lower version in *Blender* (2.93.1) for the correct import of materials, having previously modelled in the updated version.

The third circumstance is due to the lack of experience with *Unreal Engine* since no work had been done on this program until the date of creation of this project. In this situation, completely unknown software had to be documented and learned from scratch. For the creation of own materials there was no link between *Blender* and *Unreal*, because the *Blender* owned nodes through which the materials are created, *Unreal Engine* could not transcribe them to its own node system. Because of this issue, it was an option to bake the textures and this led to another issue, *Blender*'s bake of materials can only be done through its own *Cycles* render engine, and certain nodes of the materials made only worked in its other *Evee* render engine (Figure 5.1 and Figure 5.2).However, although no solution was found to this problem, new ideas emerged to achieve the same goal, which will be discussed in the next section.

Figure 6.1: Bushes with Studio Ghibli aesthetics.

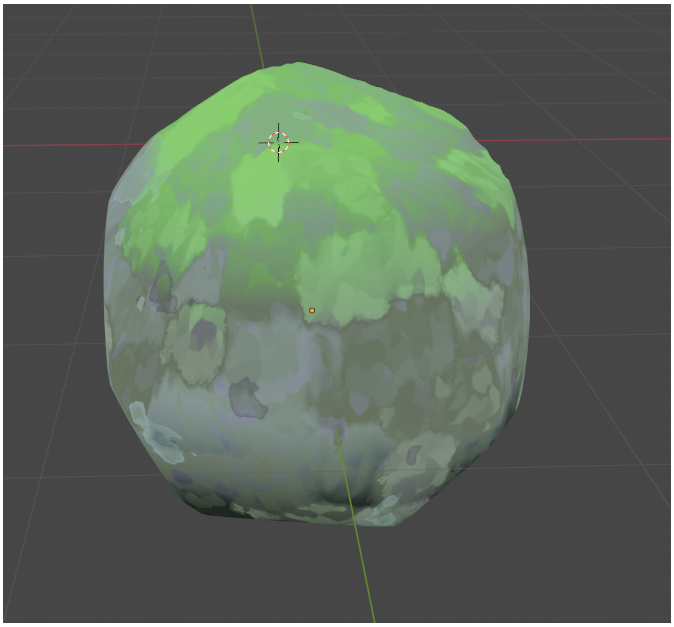


Figure 6.2: Rock with Studio Ghibli aesthetics.

6.2 Creation of Shaders.

The process of creating a shader as a final answer to the problem encountered in the creation of the materials was very satisfactory. An attempt was made to compose a shader inspired by cell shading games [14] like The Borderlands Saga or The Wolf Among Us (Figure 5.3).

(a) The Wolf Among Us

(b) Borderlands 3

Figure 6.3: References for cell shader aesthetics

For the creation of this shader [13], the need to achieve two results is sought. In the first place, it was sought to compose a line that bordered the models to give it a more cartoonish or comic style. Next, the need was found to structure how the light

was reflected on the object, so it was sought to compose a shadow that was much more segmented and not as blurry as the default.

For the first objective, a sobel operation was required, which compares the depth and normals between neighbouring pixels. If both pixels have a significant difference between them, a line would be placed that would make up the desired outline. In the image below it can be seen how it would be done to obtain the difference between the central pixel and the one on its left. To compose the whole idea, it must be done for all remaining pixels (top, bottom and right) for both depth and normals(Figure 5.4).

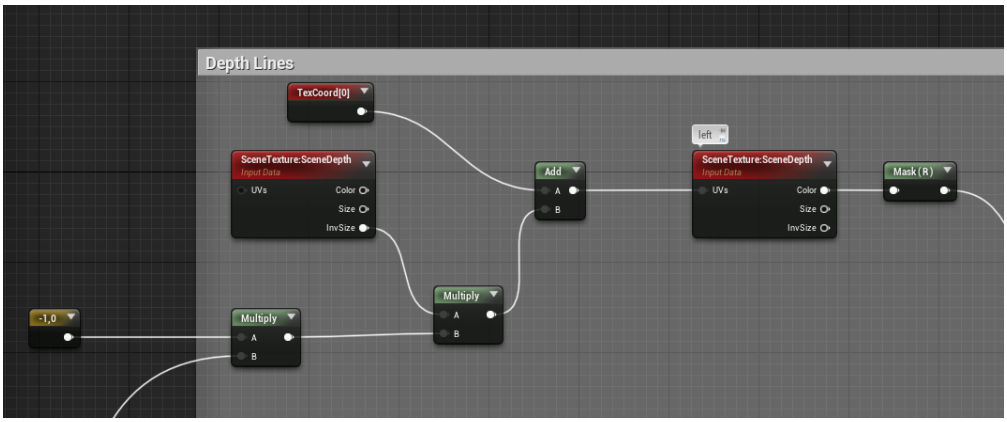


Figure 6.4: A piece of code of the idea of cell shader.

Doing all of the above, it would give the result shown in Figure 5.5.

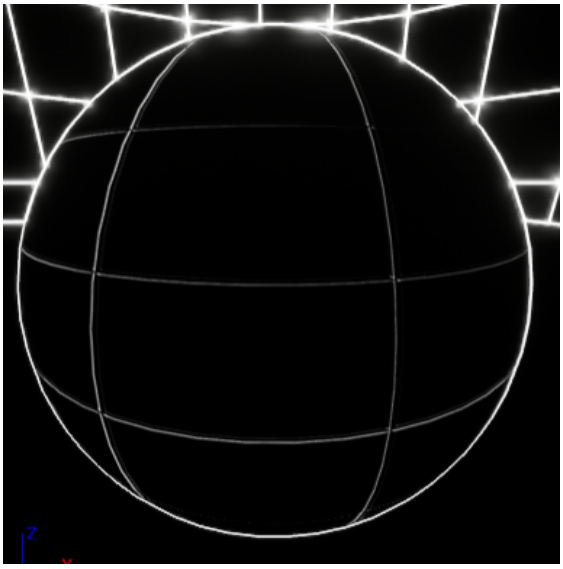


Figure 6.5: Previsualization of the outline shader.

For the second objective, it is needed to add the diffuse colour of the scene itself and

modify its values so that they appear more segmented. In addition, it was sought to give a specific tint to the shader since it gave a more vivid touch (Figure 5.6). The following image shows how through the number of color parameters different looks are obtained by adding or removing steps (Figure 5.7).

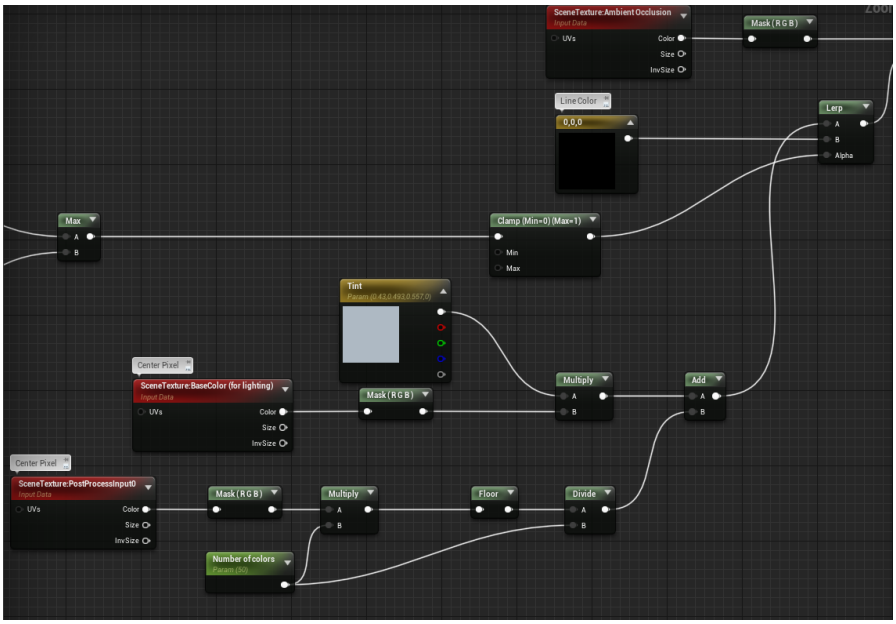
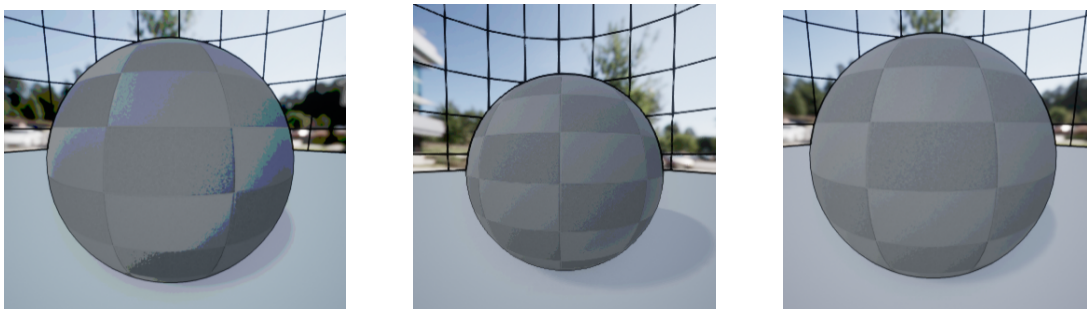


Figure 6.6: A part of code to get colours segmentation.



(a) 25 (b) 50. (c) 100.

Figure 6.7: Different numbers as colours parameter

6.3 Creation of PBR materials.

Using Bridge's material libraries (Figure 5.8) saved a very complicated and tedious part of 3D art projects: texturing. The textures that these materials brought with them were impeccable and were specifically designed 3D modeled with realistic finishes, which gave them a complete quality. Another large part of the 3D art consisted of the modeling of the 3D scenarios and specific assets symbol of the technical demo that was sought to be created, with which, there was a large part of texturing and asset modeling work.

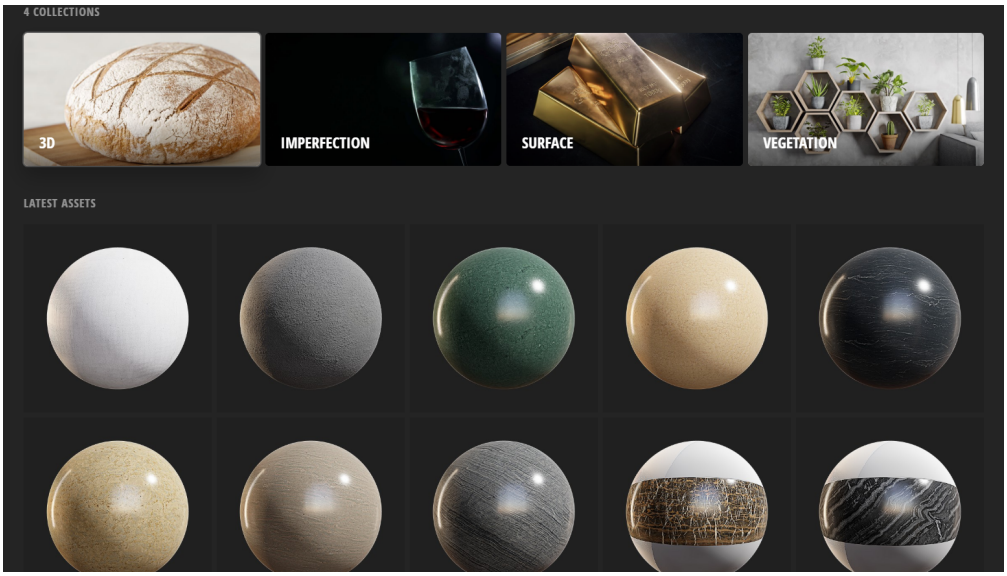


Figure 6.8: Bridge material libraries

It has been worked with the Blender modeling software and with their respective Evee rendering engines mainly, and Cycles when it was necessary to bake these materials. The materials that have been used are Physically Based Rendering (PBR). Next, it will be explained in detail what these types of materials are and why it is the best work tool.

What does PBR stand for and why is it so important? PBR materials are a rendering method based on the physical properties of light and how it interacts with surfaces. For this reason, they are so widely used, since they reflect reality as accurately as possible. However, when it is necessary to recreate the world in three dimensions through video games, a series of parameters have to be configured in the materials. Lacking a guide for the realization of the materials, the number of parameters in the materials will cause hundreds of errors to be made when recreating these materials and surely the result will not be entirely correct.

PBR consists precisely in establishing these limits for a simulation of optimal reality, and for this, it is necessary to study how light works and how it reacts when it comes into contact with an object, in order to establish a system based on those physical

properties and power. Add those real material properties, to a material created in a 3D environment. Although there are multiple parameters, they could be summarized in some specific and minimum ones for a good finish, which can show an acceptable result to reproduce reality.

In addition, PBR materials work under any lighting and environment, being optimal and it is not necessary to retouch their properties at any time. At the moment of creating them, they have the ability to be used in any situation and for this reason, they are so widely used in the video game or computer graphics industry.

Using these types of physically correct materials made it easy to switch between the Blender modeling software and the Unreal Engine, since as their physically correct properties do not change, the finish in both environments is similar. The stage, its lighting, its materials and its textures had to be consistent for each platform. The use of these materials ensured the ability to pass the scenarios and assets without any type of modification since they serve a reality-based operation.

To conclude, knowledge about the creation of these PBR materials is crucial and essential within the video game industry, since it is usually the most used standard in most companies. For this reason, it is so necessary and beneficial to have learned all this knowledge, since it allows you to enter the world of work with a much higher level.

6.3.1 Physical Properties of PBR Materials.

To understand how PBR materials work, it is necessary to understand their physical properties with respect to reality. This way we make sure that they are correctly created.

When the eye decodes a specific colour, it is because the wave frequencies that reach that object are being absorbed mostly for the entire range of colours, with the exception of the wave frequencies associated with that colour that we see, since that these, bounce outwards, which allows us to understand and distinguish the different colours(Figure 5.9). This leads us to think that the colours are not physical or inherent to the material, but that it is the frequency waves that this material bounces that give it this characteristic. The frequencies absorbed by the object are transformed into heat and therefore into energy.

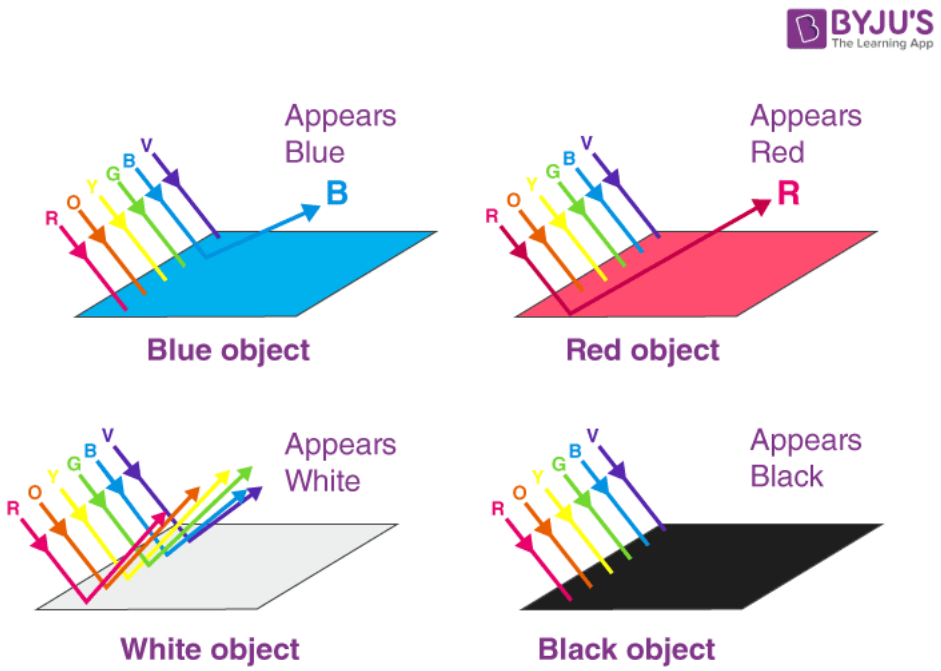


Figure 6.9: Physics of colours

When light travels through the environment and bounces off a wooden surface, for example, what happens is that a part of the reflected light will always exist on that surface. This part of the light, as it is happening on the surface of the wood, is really affected by the imperfections that may be on the surface. In case of looking for a polished material, varnished wooden object without many imperfections, the reflection will be higher and more mirror-like, resulting in very sharp reflections. In the opposite case, of looking for a matt material, this reflection will have different characteristics, it will be less due to a very rough surface and with imperfections, which will result in an almost imperceptible reflection.

With this explanation, the terms diffuse reflection and specular reflection can be defined. Specular reflection is one that is always reflected by the surface of objects(Figure 5.10), and which can be sharper or less depending on the roughness of the material surface. When a light does not reflect enough, it is transmitted to the new medium, penetrates our piece of wood and bounces within it, because when the medium changes, the light rays take different directions. This concept is called refraction. Actually, the color that we perceive from a wooden object is due to what happens inside the object. So that the light that is transmitted inside the object is perceived as visible wave frequencies, as a result of multiple bounces inside the object and ends up bouncing outwards, which generates a type of reflection known as diffuse reflection(Figure 5.10),

which is responsible for the base color of the object. In certain circumstances, it is also necessary to reproduce these behaviors in a 3D environment.

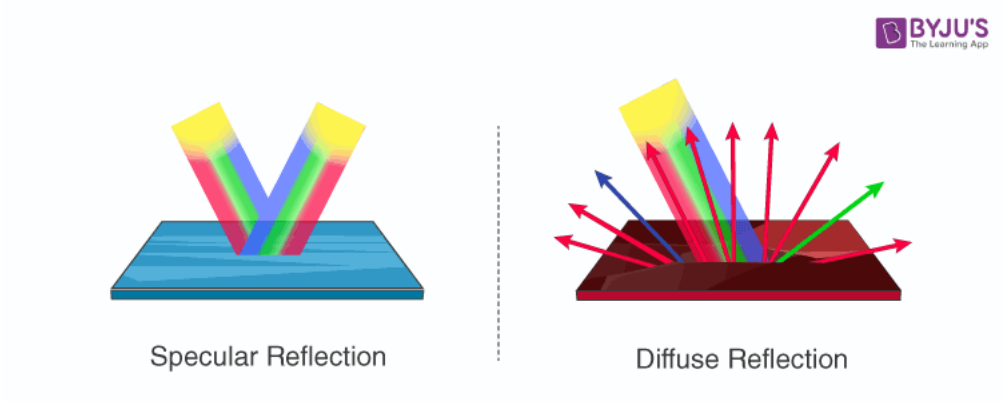


Figure 6.10: Types of reflexions.

The first physical law that PBR materials must comply with is that the light that falls on an object is equal to the sum of the refraction, diffuse reflection and specular reflection, which are the qualities that in a 3D environment it is necessary to control for its composition. For this reason, it's not allowed to add or generate more energy than enters the object, and it has to be consistent with the values that are granted.

Main types of materials

With this basic knowledge of how light works, it is indispensable to create a classification or categories of how light affects different types of materials, a series of classes that have some very notable differences. Materials can be segmented into two types:

- Dielectric or non-conductive, such as plastics.
- Conductors, for example metals.

Light does not affect both types of materials in a similar way, so the differences they have will be explained in order to distinguish them.

The most important difference found is in the reflectivity. Based on dielectric materials we can find that it is quite low, close to 2%-5%, while in conductive materials the reflectivity reaches 60%-90%. The light bounced off dielectric materials, as mentioned, determines its color, while conductive materials do not have color per se since it is absorbed.

In the specular reflection of dielectric materials, all their wave frequencies are reflected equally, which causes to see the colors as they are, that is, these materials do not have their color per se, but diffuse lighting, by not reflecting by equal all the wave frequencies the waves bounce and the concrete color is perceived. In the render engine it can be specified through two parameters, the diffuse reflection parameter (inside the

object) and the specular reflection parameter (on the surface of the object). The parameter for specular reflection in these materials must have a white color and the diffuse reflection parameter must have the color to be represented.

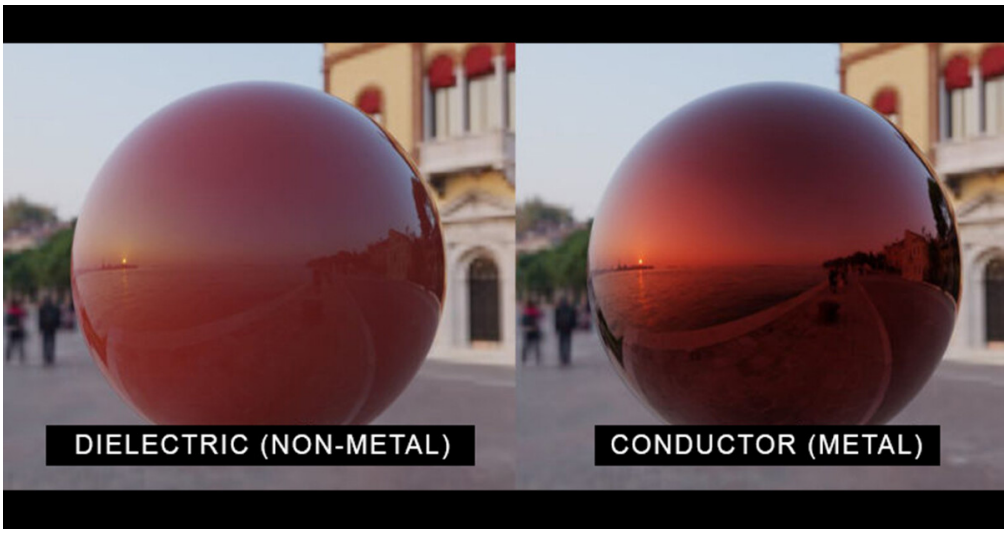


Figure 6.11: Types of materials.

However, when it is wanted to represent a conductive material, the opposite happens. On the surface of metals, not all wave frequencies are reflected equally, and the light that crosses the surface cannot return to the outside, so these wave frequencies are absorbed. To create a conductive material, the diffuse parameter (inside the material) must have a black color and the specular reflection parameter (surface of the material) must have the color to be reflected. As seen in figure 5.11, both materials work in a totally opposite way.

Materials PBR variables.

To develop PBR materials, it must be taken into account what maps are needed and their respective functions.

For the image (Figure 5.12), different types of maps have been chosen, which will be explained in detail later.

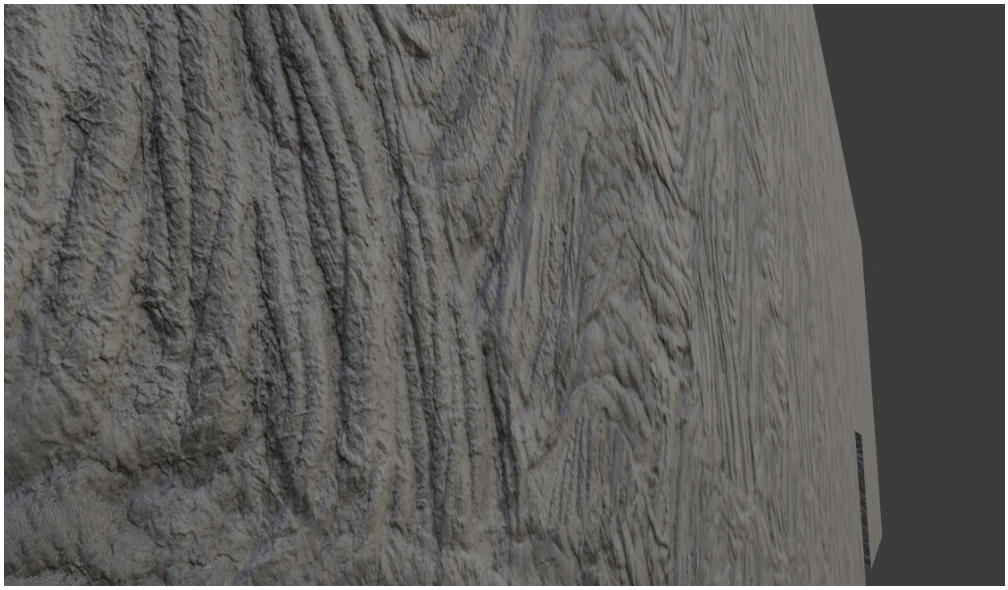


Figure 6.12: Created material on a surface.

For the creation of this material, different maps have been needed to give it realism and compose it as PBR. These maps are:

- Diffuse map : This is the map of the base color that the material will have. It can also have other names such as albedo or base color (Figure 5.13).

Figure 6.13: Albedo Map.

- Ambient Occlusion: this is a map that gives more depth to the material, giving it more realism by adding more shadow to the spaces near the edges or more hidden. This principle makes sense in reality, because light accesses more easily on smooth and protruding surfaces and as it approaches edges or hidden parts, light rays have a harder time accessing and therefore are darker (Figure 5.14).

Figure 6.14: Ambient Occlusion Map.

- Roughness: This map has the function of giving roughness or polish to a material, so there will be parts that will show more reflection and other imperfections that will not emit such a pure reflection (Figure 5.15).

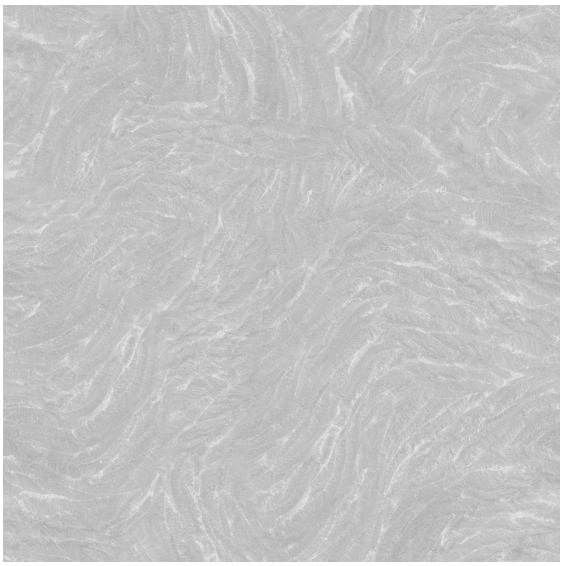


Figure 6.15: Roughness map.

- Normal map: A special type of texture that allows to add surface details such as bumps/lumps/bumps, grooves, scratches to a model that catches the light as if it were represented by real geometry (Figure 5.16).

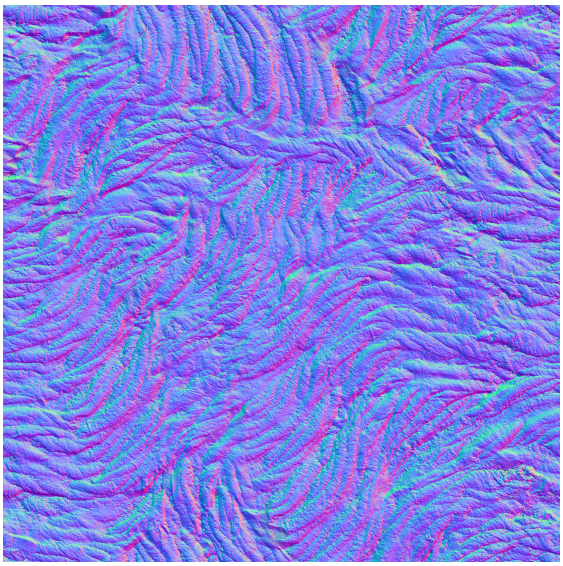


Figure 6.16: Normal map.

Chapter 7

Narrative Design

Contents

7.1 Characters.

This section will proceed to list and describe all the characters in Blooming Emotions as well as their abilities and behavior.

7.1.1 Protagonist.

The main character is the protagonist of Blooming Emotions. He doesn't really know how he has appeared in the white room. He just got to thinking. He seeks to get out of his mind to be able to realize life and all the dimensions that his person encompasses. He will deal with his vulnerabilities thanks to the characters he helps during the game. He will gain abilities as he passes zones.

7.1.2 Amara.

Amara (Figure 6.1) is a garden squirrel who lives on a small farm in the heart of Campo Grande. She is very perfectionist and careful with details. The character meets her at the end of her level. It is the perfectionist part of the player and the one that helps the player to continue forward.

Figure 7.1: Conceptualization of Amara.

7.1.3 Tippy.

Tippy (Figure 6.2) is a marquis beaver who hides in the south of Campo Grande. He leads the territory with his force. However, appearing weak is one of his greatest vulnerabilities. He is the strongest part of the player and at the end of his chapter he shows the player that it is okay to be sad and cry, which is part of the healing process and it is necessary to lean on others and not a sign of weakness.

Figure 7.2: Conceptualization of Tippy.

7.1.4 Breeze.

Breeze (Figure 6.3) is a painter chameleon that lives on the northeast coast of Campo Grande. She tries to compose nature paintings, always going to the woods or hillsides to develop her work. It is said that she suffered from a curse from a very young age, because his emotions caused the time to change. For this reason, on many occasions she will be seen nervous and emotionally unstable, trying to be a chameleon always happy. She and the player will share vulnerabilities and her cinematic will work to identify emotions and accept negative emotions as part of the healing process.

Figure 7.3: Conceptualization of Breeze.

Chapter 8

Results and future work

Contents

8.1 Results obtained.

The results of the project have been satisfactory and have far exceeded expectations. This is mainly due to the fact that all the proposed objectives have been met. Finally, a project of such magnitudes requires unexpected requirements and problems not initially considered, extend the development time, which leads to changing the orientation of the project. The organization of the project was impeccable due to the predisposition to carry out this project and the results that were obtained based on the study that was carried out.

A series of images will be shown to contemplate the results obtained (Figures 7.1 to 7.11), in addition to sharing the project link in Git,it can be accessed from the link at the appendix.

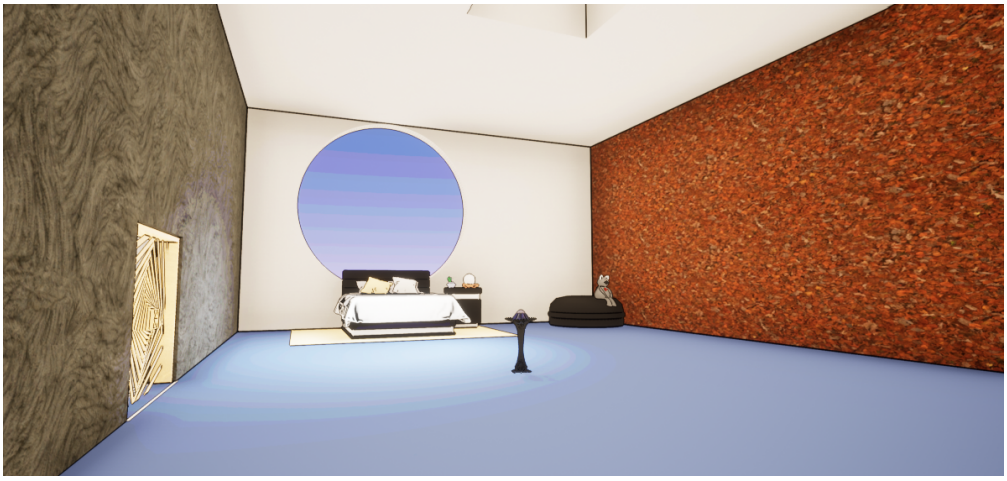


Figure 8.1: Stage 1, Work in progress version.

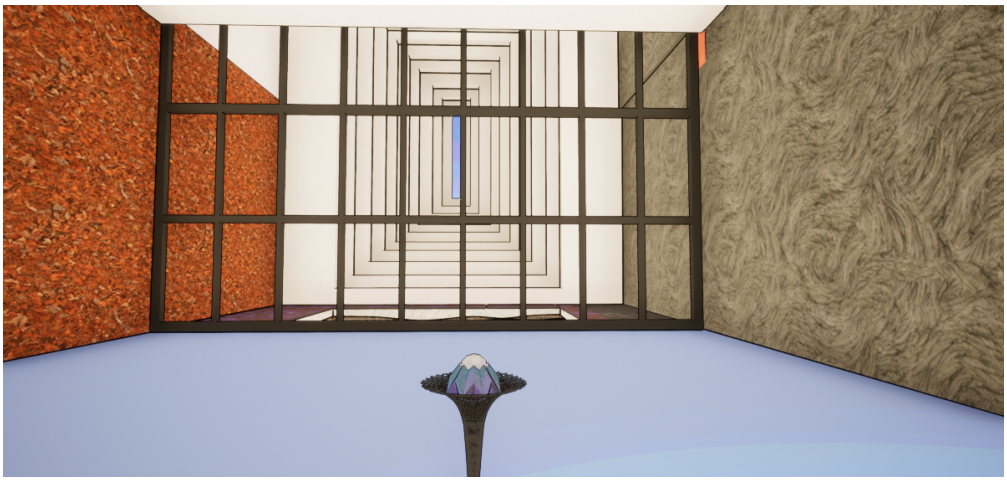


Figure 8.2: Stage 1, Work in progress version.

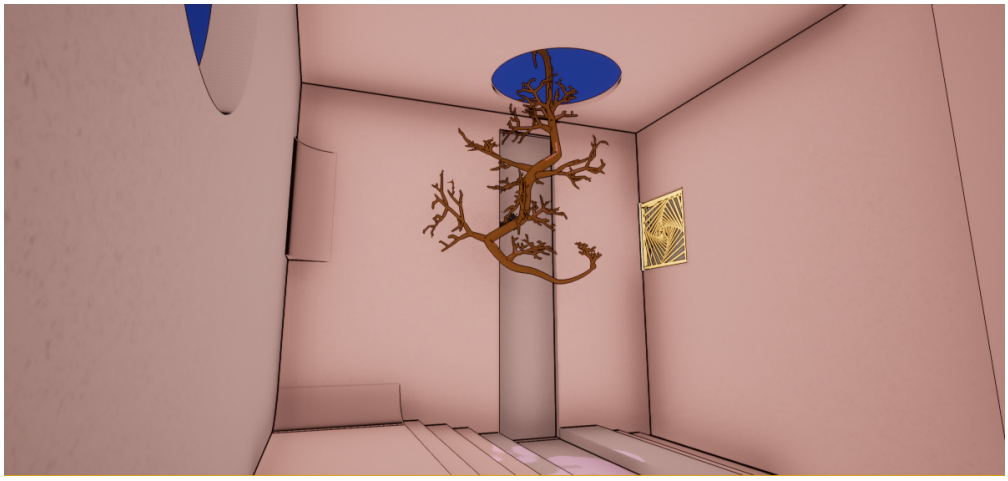


Figure 8.3: Stage 2, Work in progress version.

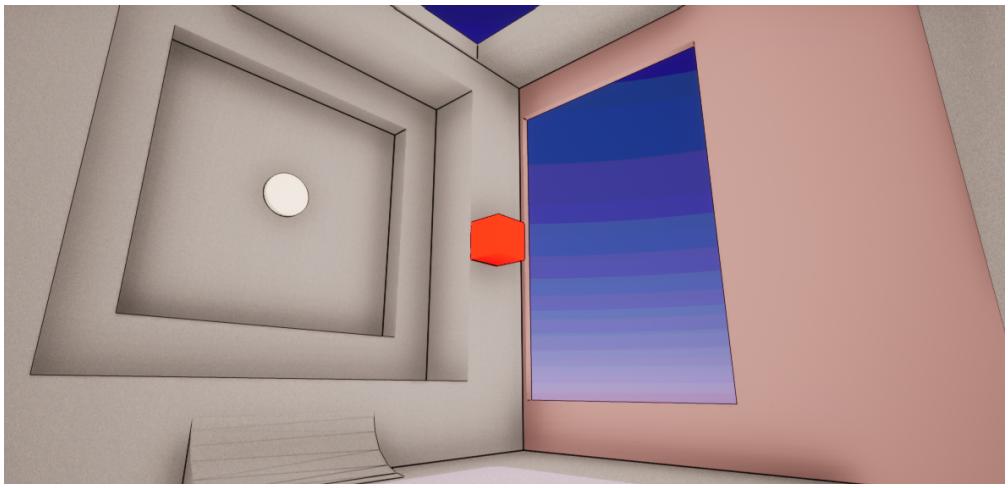


Figure 8.4: Stage 3, Work in progress version.

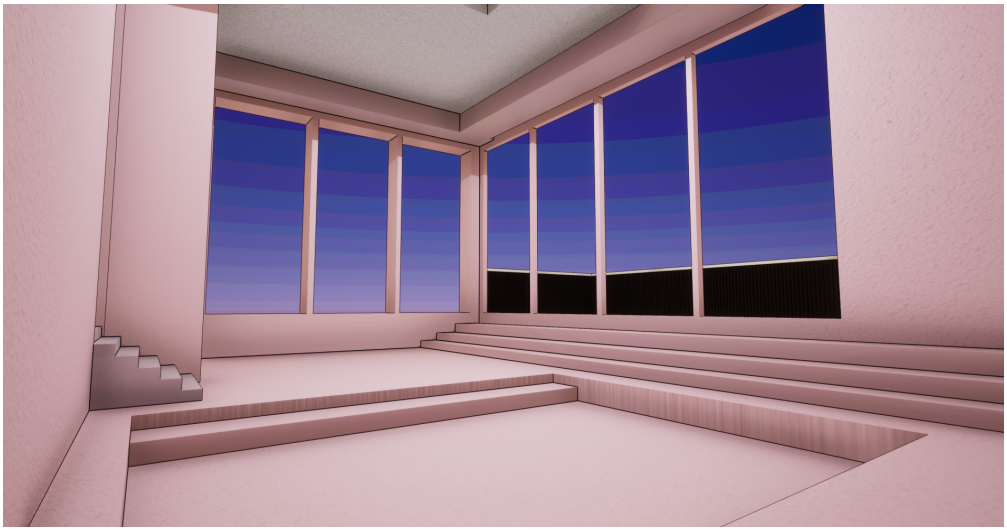


Figure 8.5: Stage 4, Work in progress version.

Figure 8.6: Corridor, Work in progress version.

Figure 8.7: Stage 5, Work in progress version.

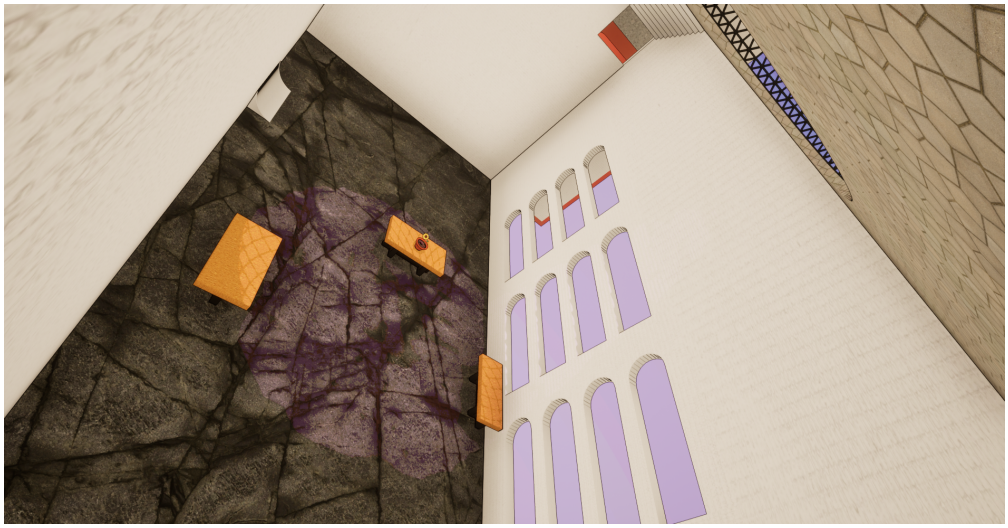


Figure 8.8: Stage 6, Work in progress version.

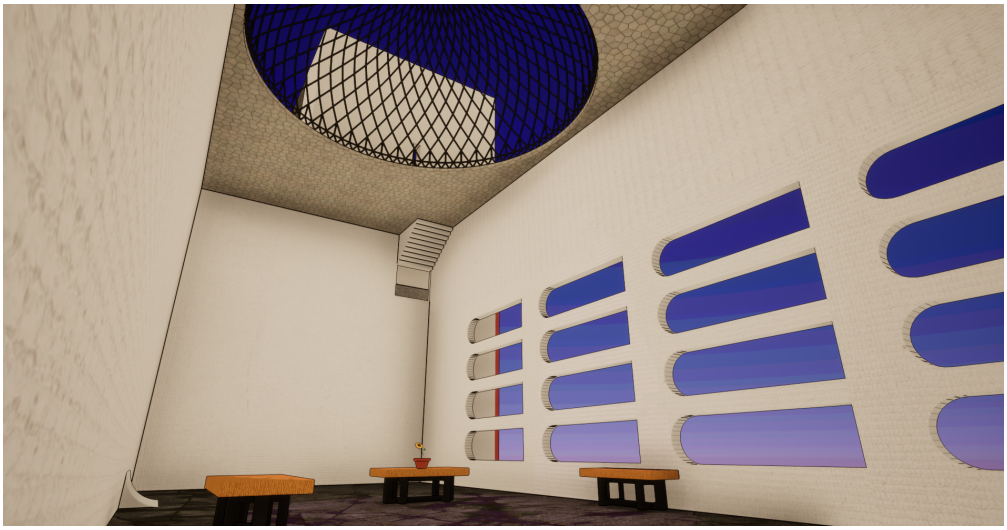


Figure 8.9: Stage 6, Work in progress version.

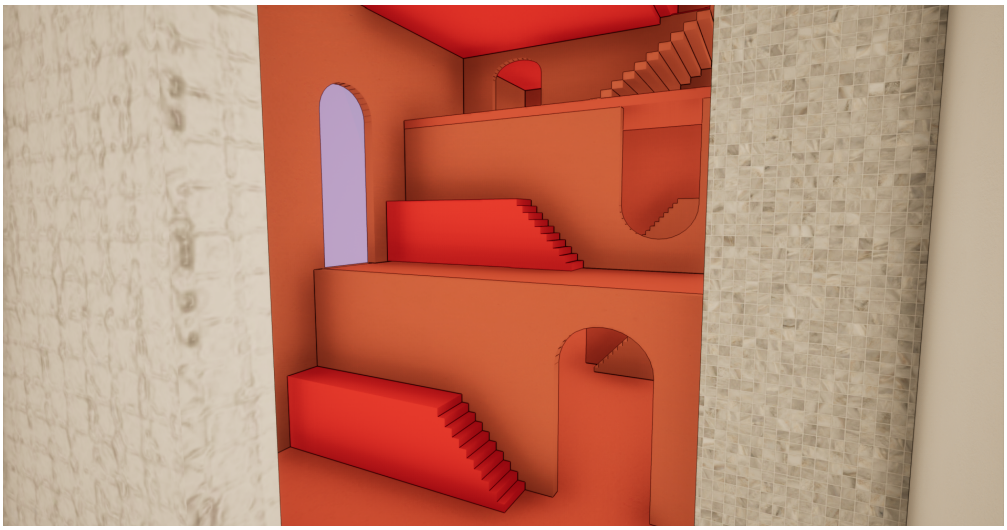


Figure 8.10: Stage 7, Work in progress version.

Figure 8.11: Final stage, Work in progress version.

The planning process had certain delays in different parts of the development so certain design ideas had to be postponed or eliminated. However, the result remained satisfactory. The entire project was divided into three different parts, pre-production, production and post-production.

The pre-production was carried out over a month/two months, with processes of documentation and conceptualization of the initial idea from which it started. In this process, different areas such as neuroarchitecture, cognitive behavioral psychology, color psychology, biophilia and the importance of design in space were investigated. The conceptualization was carried out after this documentation. In this section, two different Pinterest boards were created to show the references against the spaces that were sought and how the video game space was wanted to be composed with the combination of these photographs.

In the production, different phases of development were carried out. It began with the programming of the movement and the mechanics since it was expected to be a complicated and difficult part to complete. Subsequently, the modeling of the scenarios began, composing them with the help of the references found and displayed on the Pinterest board. When this process concurred, the materialization and creation of assets that would serve to enrich the scene began. This process will be explained in detail in chapter 3.

Finally, in the post-production process, the lighting adjustments and the final touches were made for a more professional vision of the technical demo. In turn, the interfaces and menu were added to give the final finish. At last, documents such as this memory and the script for the presentation had to be drafted.

At last, it should be noted that it has been a hard and difficult project and I was not always sure of being able to be proud of the work done. But, with the estimated time for its realization, composing a scenario that was faithful to what was studied and

documented, I consider that the result is satisfactory. I am glad to have been able to carry out a project as exciting as this, and develop a functional technical demo on which to work in the coming months and polish over time.

8.2 Future Work.

Not only is the monitoring of the project proposed due to the need to deepen and finish many sections to which it has not been possible to dedicate the expected time, but it is also proposed to further develop the scenes and the story, composing a game that has different areas with more characters with whom you have to meet again, making each area have different mechanics and are consistent with the new scenarios.

As an addition, it is proposed to pass the project to Unreal Engine 5, to maximize the user experience and having the option of using the *Niagara Effects* particle systems[16], which is Unreal's own particle and fluid physics system and which gives a much more professional finish. In addition, with this version of the engine, thanks to *Nanite*[15] technology, which is Unreal Engine 5's new virtualized geometry system that uses a new internal mesh format and rendering technology to render pixel-scale detail and a large number of objects, so scenes will be much richer in detail and with more realistic geometries displayed without the need to optimize them, due to how this technology helps to load the environment without a loss substantial frames per second.

APPENDIX A

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[16] Niagara visual effects. (s/f). Unrealengine.Com. Recuperado el 20 de mayo de 2022, de https://docs.unrealengine.com/4.27/en-US/RenderingAndGraphics/Niagara/
[17]¿Cuánto Cobra un Programador de Videojuegos? (Sueldo 2022). (s/f). Jobted.es. Recuperado el 23 de mayo de 2022, de https://www.jobted.es/salario/programador-videojuegos

A.2 Links

Drive repository: https://drive.google.com/drive/folders/16d2i0j7CjYWWhRob4d82pJF8YY-35Bpq?usp=sharing

Pinterest boards:

- https://www.pinterest.es/al376536/mundo-interno/
- https://www.pinterest.es/al376536/mundo-externo/