

Bachelor thesis

Raising Environmental Protection Awareness through Interactive Virtual Experiences

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Task description:

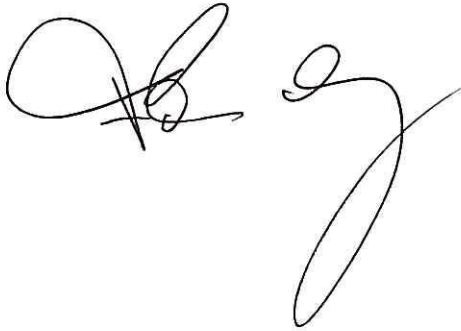
This thesis is concerns itself with the details of developing interactive virtual experiences that attempt to raise awareness for environmental protection.

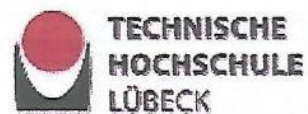
By means of developing a serious game prototype that features a collection of mini-games, the inter-connectedness of various areas of life on earth is to be portrayed.”

Tasks:

- Research environmental protection issues
- Document interactive application development using Unreal Engine 4 and its Blueprint system - Evaluate the applicability of common game mechanics in serious games
- Design mini-games that help to educate about the cycle of life

Herr B.Sc. F. Anthony

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Statement on the bachelor thesis

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Zusammenfassung der Arbeit

Abstract of Thesis

Fachbereich: **Electrical Engineering and Computer Science**

Department:

Studiengang: **Information Technology**

University course:

Thema: **Raising Environmental Protection Awareness through**

Subject: **Interactive Virtual Experiences**

Zusammenfassung:

Abstract :

The quality of human life has improved rapidly, and games have become an indispensable entertainment for many people. Meanwhile, the rapid expansion of humanity has caused increasingly serious environmental problems. Therefore, it makes sense to develop a game that encourages people to raise environmental protection awareness through virtual experience. First, this thesis investigates and explains environmental issues. Then, the thesis focuses on developing this game, including analyzing and designing game elements, developing game content in detail by Unreal Engine 4, and testing the game. Then, the game test results, and user experience feedback are compared with the traditional serious game mode. The results show that the game runs smoothly and performs well. Besides, this game mechanism is more likely to immerse players, and the game has a positive impact on users in raising environmental protection awareness.

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Table of Contents

Task Description.....	ii
Statement on the Bachelor Thesis	iii
Abstract of Thesis.....	iv
Table of Contents	v
1 Introduction.....	1
1.1 Motivation	1
1.2 Target	1
1.2.1 Target Platform and Equipment	1
1.2.2 Target People	2
1.3 Organization	2
2 Related Technology Overview	3
2.1 Unreal Engine.....	3
2.1.1 Unreal History	3
2.1.2 Unreal Engine 4.....	3
2.1.3 Blueprints Visual Scripting	4
2.2 Version Control Systems.....	6
2.2.1 GitHub.....	6
2.2.2 GitKraken.....	6
3 Environmental Issues	8
3.1 Global Environment Overview.....	8
3.2 Environmental Problems	9
3.3 Municipal Solid Waste	10
3.3.1 Basic Information.....	10

3.3.2	Management and Effectiveness.....	10
3.4	Deforestation	12
4	Game Design.....	14
4.1	Game Mode.....	14
4.1.1	Proposal 1: A Running Game like Temple Run.....	14
4.1.2	Proposal 2: A collection of mini-games	15
4.1.3	Comparison and Selection.....	15
4.2	Game World View.....	15
4.2.1	Related Games	15
4.2.2	Background Story.....	17
4.2.3	Town Map	18
4.3	Game Designed Missions	18
4.3.1	Mission 1: Cleaning Up the Rubbishes	19
4.3.2	Mission 2: Controlling Water Pollution	20
4.3.3	Mission 3: Planting Trees.....	22
4.4	Game Operation Guide.....	23
5	Game Implementation.....	24
5.1	Construction of Town Map	24
5.1.1	Sky Atmosphere System	25
5.1.1	Architecture Style.....	26
5.1.2	Functionality of Buildings.....	26
5.2	Improvement on Player Character	27
5.3	Shopkeeper System	28
5.3.1	Set up Shopkeeper.....	28
5.3.2	Shopkeeper UI.....	29

5.3.3	Player Inventory UI.....	31
5.4	Mission System	31
5.4.1	Mission NPC	31
5.4.2	Mission Template.....	33
5.4.3	Mission List.....	34
5.4.4	Mission Journal	35
5.5	Startup Animation	35
6	Game Evaluation	37
6.1	Game Test	37
6.1.1	Test Environment	37
6.1.2	Functional Test.....	38
6.1.3	Performance Test	39
6.1.4	Result	40
6.2	Usability Test	40
6.2.1	Methodology	40
6.2.2	Result	40
7	Conclusion and Outlook.....	45
7.1	Review.....	45
7.2	Limitation	45
7.3	Outlook.....	46
	Acknowledgments.....	47
	Appendix A - List of figures	48
	Appendix B - List of tables	49
	Appendix C - User Questionnaire.....	50
	Bibliography	52

1 Introduction

1.1 Motivation

The quality of people's life has developed and improved rapidly in recent years, as well as the people's pursuit of virtual life. Therefore, the electronic entertainment industry becomes more and more important. In 2019, the global games market generates revenues of \$120.1 billion, which was up 4% from \$115.5 billion in 2018 [1].

Games have become a significant part of the Internet industry, so the development capabilities based on game engines are essential. Unreal Engine 4 is currently one of the most used game engines in the game industry and is the choice of most medium and large game companies. UE4's powerful graphics performance and outstanding picture expression have conquered game lovers and game developers. For example, Fortnite, developed by Unreal Engine 4, clinched the top spot for the second year in a row, generating \$1.8 billion in 2019 [1].

At the same time, with the speedy expansion of human civilization, it inevitably has an impact on the earth's environment. Environment protection becomes a hot issue all around world. People are very familiar with terms such as "PM2.5", "sea-level rise", and "desertification", but the vast majority of people who are protected in the city circle and live in their comfort circles do not pay much attention to environmental protection.

Therefore, developing a 3D game with the theme of environmental protection is meaningful. When people are immersed in the game world and have completed different missions, environmental protection is more vividly and concretely displayed in their minds. They will gradually realize the importance of being environmentally friendly and awaken the awareness of protecting the environment in real life.

1.2 Target

This thesis will be based on a 3D game development built by Unreal Engine 4 with the theme of environmental protection. The thesis focuses on both parts of theoretical design and practical development. In this section, the target platform and the operating equipment will be defined. Then the target people of this game will be analyzed.

1.2.1 Target Platform and Equipment

The target platform of this game is the PC-side windows platform. The chief operating equipment is the keyboard and mouse.

1.2.2 Target People

The target audience of this game is mainly young people who like to play single-player role-playing 3D games. They need to have a reading foundation in English and be able to use the computer without barriers. At the same time, this game encourages those who like to complete tasks to get bonus, who are adventurous, willing to explore new maps, or interested in environmental protection to try to play.

1.3 Organization

The rest of the thesis is organized as follows. In chapter 2, some background information about Unreal Engine, version control system is given. They play a significant role in the development of the game. In chapter 3 this thesis will search for environmental protection issues and discuss in detail the parts that inspire the game missions. Chapter 4 introduces the concept design of this 3D game. Designing missions to enable players to raise environmental awareness in a virtual game experience is the main factors taken into consideration. These missions play a role as mini-games, which help players to educate about the cycle of life. In Chapter 5, the implementation of the game explains. The entire game will be divided into several parts and the important details of each part will be presented. In Chapter 6, the developed game is evaluated through tests, include the tests of game itself and the questionnaires from the target group. The process of how to evaluate the game and the feedback from the tests are also analyzed and demonstrated. Finally, the thesis is concluded by reviewing the achievements, explaining the limitation, and listing the improvement in the future.

2 Related Technology Overview

This chapter focuses on the tools used for game development. Unreal Engine 4 and version control systems which are useful for game development will be introduced.

2.1 Unreal Engine

Unreal Engine, as a game engine, is one of the core works of developer Epic Games. As the most open and advanced real-time 3D creation tool in the world [2], it has conquered countless players with its excellent expressiveness and powerful functions. It is not only used for game development, but also provides the freedom and control to creators with cutting-edge content, interactive experiences, and immersive virtual worlds.

2.1.1 Unreal History

Unreal Engine has gradually developed and improved over the past 20 years, providing a complete set of engines and development tools.

The first game was developed by Unreal Engine in June 1998 [3]. Because of its exquisite graph, it was one of the best-selling games released during the same period and it was widely praised in the PC player circle. Meanwhile, its development has also laid the foundation of the Unreal engine. The modular design of the engine allows other person who have authorized licensees to easily customize different parts of the engine without rewriting the entire program.

In 2001, the website of the Unreal Developer Network (The Unreal Developer Network, UDN) was put into use, which provided a communication platform for game developers all around the world.

In September 2002, the game *Unreal Championship* was released. The success of the game also brought some new compelling engine features. For example, the Static Mesh concept appeared, and it remains an important part of the development of Unreal Engine games.

Unreal Engine 3 was launched in 2009, which provides core technology array and content editing tools. The relatively simple code structure is convenient for developers from different countries to program.

In 2012, Epic launched Unreal engine 4, which has been widely used so far.

2.1.2 Unreal Engine 4

The biggest difference between Unreal Engine 4 (UE4) and previous generations of engines is its open source. Anyone can download UE4 from the official website and can freely access to

the complete C++ source code. Meanwhile, People can study, customize, extend, and debug the entire Unreal Engine, and complete the projects without obstruction as well.

Moreover, UE4 inherited the powerful functions from Unreal Engine 3 and innovated. It adds a lot of features related to image quality based on Unreal Engine 3. For example, the later version of UE4 uses PBR texture, which is much more realistic and convenient than the material split map method in the Unreal Engine 3. Also, UE4 supports more development platforms. In this fast-paced era, mobile phones have become an indispensable part of human lives. UE4 supports deliver content on mobile platforms including IOS and Android mobile devices, laying a solid foundation for the future game market.

Because of UE4's superiority in 3D game development, this game was developed with the latest version of UE4: version 4.24.

2.1.3 Blueprints Visual Scripting

“The Blueprints Visual Scripting system in Unreal Engine is a complete gameplay scripting system based on the concept of using a node-based interface to create gameplay elements from within Unreal Editor” [4]. The system is extremely flexible and powerful. After creating the nodes, developers only need to arrange the links with the mouse to realize the programming. It visualizes the programming process and is quite friendly to UE4 beginners and developers who are not proficient in the C++ language [5]. Besides, the C++ programming of UE4 also provides syntax marks for blueprints. Developers can easily create a basic system and expand the system on the blueprint system [6].

The most common Blueprints are Level Blueprint and Blueprint Class (always called Blueprint) [7]. Level Blueprint is used to control the global event graph [8]. It can interact with the actors in the level to realize the functions. For example, Level Blueprint is needed when making the sky's change according to the time. Blueprint Class is another form of Blueprints. It can be freely created by developers as a new class or type of actor [9]. Like other actors, they can also be included in the map as instances. Blueprint is suitable for making interactive resources, such as turning on or off the light and collecting things. For instance, there is a light created as Blueprint in the scene, and the player can switch the light on and off or change the color of the light.

The Blueprint Class which contains only the code, variables, and components inherited from its parent named Data-Only Blueprint [10]. It is unallowed to add any nodes, but its inherited elements can be modified.

A Blueprint Interface is a collection of one or more functions [11]. It likes the abstract base class in C++, which can be named only instead of implemented. Blueprint Interfaces can be added to other blueprints for implementation. The blueprint with a Blueprint Interface will

have the function of this Blueprint Interface, which is essentially the same as the interface in general programming. Blueprint Interfaces allow different types of Blueprint Classes to directly access and share data information.

As for the Blueprint Macro Library, it likes a container, holding a collection of Macros or self-contained graphs that can be placed as nodes in other Blueprints [12]. The advantage of using it is saving time since they can store commonly used sequences of nodes, including the input and output for both execution and data transfer. Blueprint Macro Libraries do not need to be compiled, which is similar to the macro in C++.

Another thing important in Blueprints Visual Scripting is the Unreal Motion Graphics Designer (UMG). It is a visual UI authoring tool which often used to create UI elements, such as in-game HUDs [13]. The core of the UMG is Widget. Table 2.1 shows some common widgets used in UMG.

Table 2.1 Common Widgets

Common Widgets	Instructions
Canvas Panel	A designer friendly panel which allows widgets to be laid out at arbitrary locations, anchored and z-ordered with other children of the canvas.
Button	A click-able primitive widget to enable basic interaction.
Text	A simple static text widget.
Image	Allows developers to display a Slate Brush, or texture or material in UI.
Scroll Box	An arbitrary scrollable collection of widgets.
Horizontal/Vertical Box	Allows widgets to be laid out in a flow horizontally/vertically.

The Blueprints System consumes more CPU performance and is more complicated to maintain than C++. As a kind of visual programming, it is very easy to get started and more convenient to develop. In this case, as a newbie to UE4, choosing to use Blueprints Visual Scripting programming in developing this game is a wise choice.

2.2 Version Control Systems

Git is a distributed version control system which does a significant role in coordinating work among programmers [14]. The source of Git is free and open. It is designed to handle projects with speed and efficiency. Also, it is powerful, flexible, and easy to learn. In this section, GitHub and GitKraken will be introduced.

GitHub is chosen to update the bachelor thesis and game development progress. GitKraken is used to edit the files and schedule the project timing. These two tools make version control and communication easier.

2.2.1 GitHub

GitHub is a kind of code hosting service built based on the Git version control system [15]. Users can easily create a new repository to start sharing their projects. The security feature of a repository can be set up as public or private. The public can be seen by anyone. However, if users just want to share the codes with certain persons, choosing “private” and inviting contributors can protect achievements well. Besides, every time uploading a new file or changing an old file, a commit will be added to the GitHub. Both the owner and the contributors of the repository can view the commit to check information. Also, the history version of the file can be easily viewed with annotated changes, so users can feel free to modify the codes on the GitHub.

Another function often used is the “Issues” function. All contributors can open or close labels. A project can be divided into several specific sub-goals which are recorded in different labels with the implementors' name and sometimes the deadline. The one who participated in this project can define his responsibility clearly and complete sub-goals efficiently. Meanwhile, it is a kind of communication ways for contributors.

2.2.2 GitKraken

GitKraken is a Git GUI client for Windows, Mac, and Linux [16]. Users can connect their repositories between GitHub and GitKraken, so pull or push files between each other is convenient. The built-in code editor in GitKraken allows users to add new files and folders and edit them directly. For example, the user can use GitKraken to pull the latest version of a coding file from GitHub and edit it in the GitKraken. After the coding finished, the user can push the file to GitHub so that all contributors can view the file. These two tools can complement each other, greatly simplifying the process of sharing codes and files.

In addition, as Figure 2.1 shows, GitKraken has a function named GitKraken Glo Boards. Its function is like the “Issues” function in GitHub but more organized and visual. Users can create cards that do the same functions as issues. Adding subtasks, writing comments,

choosing the assignees, giving the deadlines and many other functions are available on the cards. Besides, users can sort the cards to manage the project flow, such as “To do”, “In Progress” and “Done”. Certainly, Glo Boards can be linked with GitHub Issues.

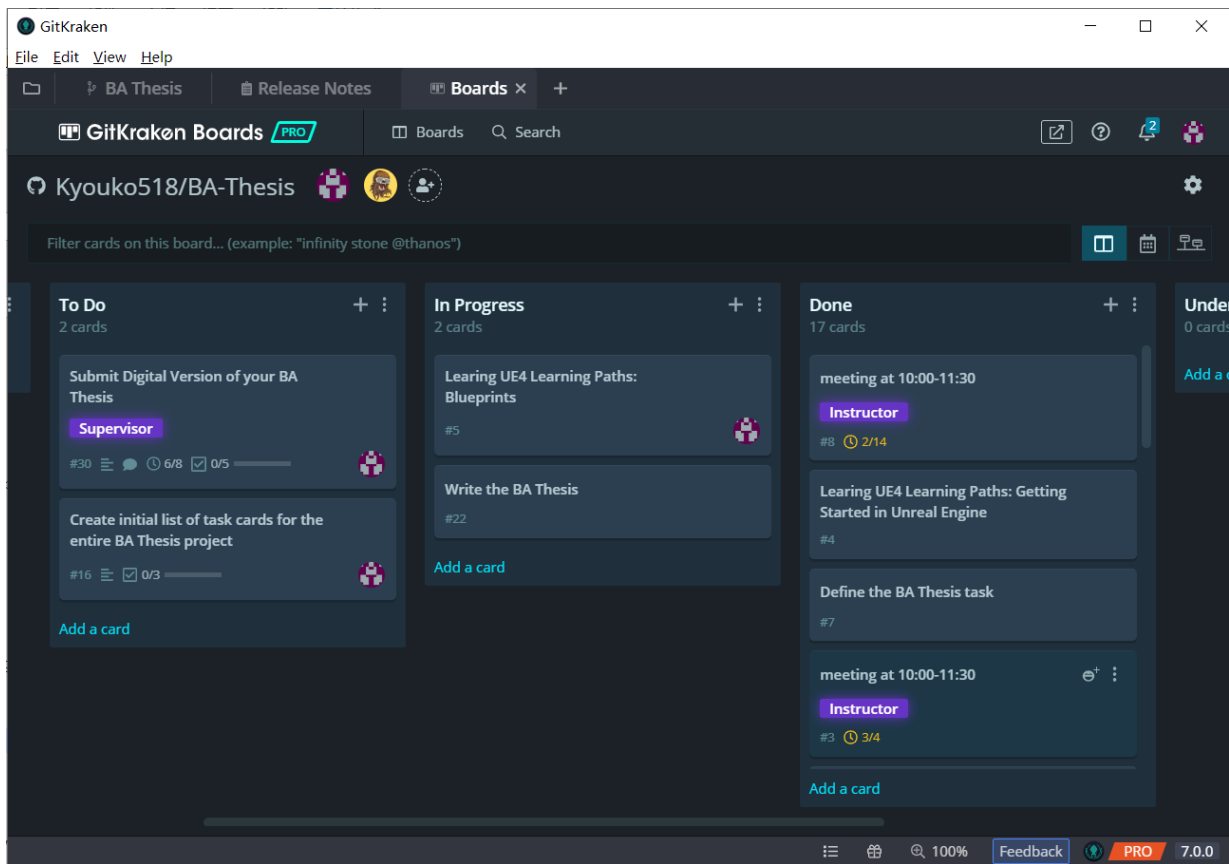


Figure 2.1 GitKraken Boards

3 Environmental Issues

This chapter describes the overview of the world's environmental issues and analyzes two specific problems.

3.1 Global Environment Overview

The global environment includes the atmosphere, hydrosphere, lithosphere, and biosphere [17]. This range is the place where humans and creatures live, provides various resources to human beings. Also, it is a space that constantly being transformed and impacted by human beings.

- **Atmosphere**

The atmosphere is a layer of mixed gas surrounding the earth due to gravity. The main components of the earth's atmosphere are nitrogen, oxygen, argon, carbon dioxide, and trace gases less than 0.04%, which are essential for the growth and development of humans and organisms [17].

- **Hydrosphere**

The Hydrosphere contains all the solid, liquid, and gaseous water of the earth. The hydrosphere's main body is the oceans, and its area accounts for about 71% of the global area. Besides, lakes, rivers, swamps, glaciers, and even the water in minerals are all parts of the hydrosphere. Also, water is the most important material on the surface and plays an essential role in the energy conversion of the geographical environment [18].

- **Lithosphere**

The lithosphere contains all cold and hard solid land and is about 60 to 120 kilometers thick. Its surface is not flat. The lithosphere has a variety of minerals, which are a significant source for human production and living materials [18].

- **Biosphere**

All creatures on the earth, including microorganisms, plants, and animals, live in the biosphere. It is the largest ecosystem on earth and space where humans are born and survive [17].

As Figure 3.1 shows, these four systems have their individual identities, but also affect each other. Events caused by a sphere will have a bidirectional impact on other spheres. Meanwhile, the interaction can also occur between the sphere and the sphere [18]. For example, the lithosphere's activity can cause a volcanic eruption. The erupting dust enters the atmosphere and the hydrosphere and makes an impression on them. Pollution of water sources indirectly poses a threat to the survival of creatures in the biosphere. Thus, the global environment is an interconnected whole.

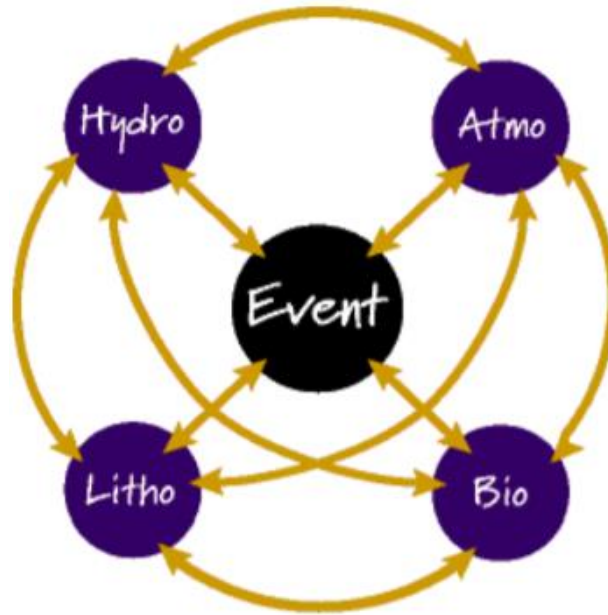


Figure 3.1 Interactions between the 4 Spheres [18]

3.2 Environmental Problems

As discussed in section 3.1, the global environment is an interconnected whole. Human activities inevitably cause various problems for the environment. Some environmental issues need to be resolved urgently [19].

- **Waste Disposal**

Waste disposal is the treatment and management method of solid, liquid, or gas waste. It aims to reduce the adverse effects of waste on human health and the environment [19]. Municipal Solid Waste is an important part in waste disposal, which will be introduced in section 3.3.

- **Deforestation**

Deforestation is one of the important issues of climate change and soil degradation. The need for agricultural land, increased demand for wood, and growing industrialization and urbanization result in large-scale felling of trees [19]. This environmental issue will be analyzed in section 3.4.

- **Greenhouse Effect and Global Warming**

The greenhouse effect is a phenomenon that caused by the emission of the greenhouse gases like methane, water vapor and carbon dioxide. After releasing these gases excessively, the greenhouse effect will be more severe, and the temperature will get

higher. This is known as global warming. It will have a series consequence like the rising of sea levels, the melt of glacier and the city near sea being flooded [19].

- **Ozone Depletion**

Ozone is distributed in the stratosphere of the atmosphere, about 20km to 30 km above the ground. The ozone layer, which is about three millimeters thick, weakens the sun's ultraviolet radiation to protect the earth. However, due to chemical pollutants emitted by industry, especially chlorofluorocarbons (CFCs), the ozone layer gradually thins in recent years. Increased ultraviolet rays from the sun can cause an increased risk of cancer, eye damage, or the death of animals, plants, and marine life [19].

- **Loss of Biodiversity**

The biodiversity means the total species involves plants, animals and microorganisms and the whole system. Due to the lack of the ecosystem, species start becoming extinct and cause the loss of biodiversity. The main reasons for the loss of biodiversity involve following three points: the loss of the habitat, the overuse of the resources and the pollution of overuse fertilizers, pesticides and oil [19].

3.3 Municipal Solid Waste

In recent years, with the increasing threat to human health caused by pollution, pollution problems have begun to attract more and more attention. In this chapter, a kind of pollution named Municipal Solid Waste will be mentioned, and the situation will be analyzed.

3.3.1 Basic Information

Municipal Solid Waste (MSW) consists of daily items that people use and throw away, which are more commonly known as trash or garbage [20]. MSW has multiple sources, mainly produced by residential, commercial, and institutional areas, involving schools, businesses, and hospitals. MSW includes many kinds of usual rubbishes, such as packaging, clothing, bottles and cans, food, newspapers, electronics, and batteries. However, according to the Environmental Protection Agency's (EPA) definition, industrial, hazardous, or construction and demolition (C&D) waste does not belong to MSW.

3.3.2 Management and Effectiveness

The MSW has several conventional methods to manage. First, people should get awareness of reducing trashes from the source. Then, recycling, composting, disposal, and waste-to-energy are all helpful in processing [21].



Figure 3.2 Waste Management Hierarchy [21]

Next, the situation of MSW treatment in the United States in 2017 will be analyzed. The data from the U.S. Environmental Protection Agency (EPA) indicates that in 2017, the United States generated approximately 268 million tons (U.S. short tons) of MSW. On average, each person produces about 4.51 pounds per day, which is a decrease from 4.53 pounds in 2016. Sixty-seven million tons of MSW were recycled, and 27 million tons were composted. The recycling and composting rate accounted for 35.2 percent of the total waste, compared with 10 percent in 1980, which was much improved. More than 34 million tons of MSW were combustion energy recovery, which accounted for 12.7 of the totals. The remaining 139 million tons (52.1 percent) of garbage were landfilled. The landfill rate per capita is 2.5 pounds per day, much lower than the 3.2 pounds per day in 1990 [22].

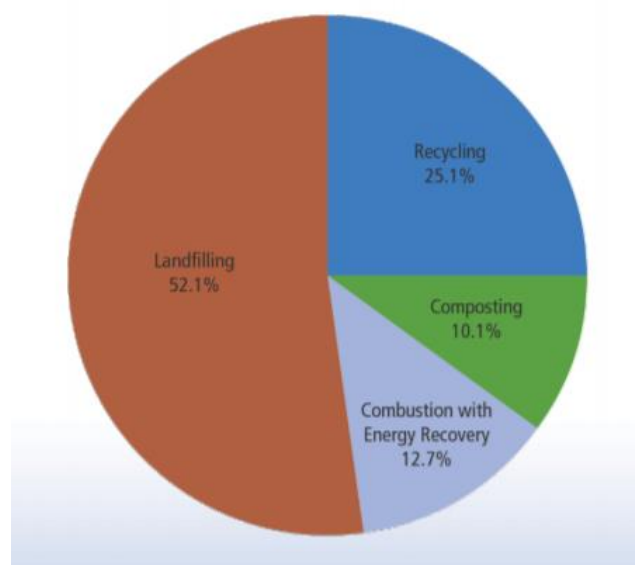


Figure 3.3 Management of MSW in the United States, 2017 [22]

In the past few years, people's awareness of environmental protection has gradually increased. It is essential for reducing waste generation and improving waste utilization. Compared with 2017 and 2016, although the waste produced by each person per day was only reduced by 0.2 pounds, the cumulative difference in one year reached 0.01 billion tons, which is enormous. Meanwhile, the increasing materials are recycled and reused, reducing the emission of harmful substances. It not only has a substantial beneficial impact on environmental protection but also creates employment opportunities and excellent economic value. In a word, raising people's awareness of environmental protection has a positive effect on the environment and economy.

3.4 Deforestation

The forest covers about 30% of the earth's surface. However, with natural wildfires, illegal logging, and large amounts of wood being used for commercial purposes, the forests on earth are decreasing at an alarming rate. Forests play a crucial role in maintaining the balance of oxygen and carbon on the earth. Thus, in addition to reducing oxygen supply, deforestation also causes about 15% of greenhouse gas emissions [19].

As Figure 3.4 shows, trees have great power. In the United States, forests remove 1438.2 million tons of carbon dioxide annually, which is equivalent to offsetting 10%-20% of the country's greenhouse gas emissions. At the same time, trees help avoid harmful climate impacts like floods and prevent soil erosion. Besides, trees have a significant influence on water and air quality. they can help collect and filter drinking water. Tree leaves can absorb more than 35,000 million pounds of air pollutants a year [23]. There is no doubt that trees are beneficial for the health of the earth and human.

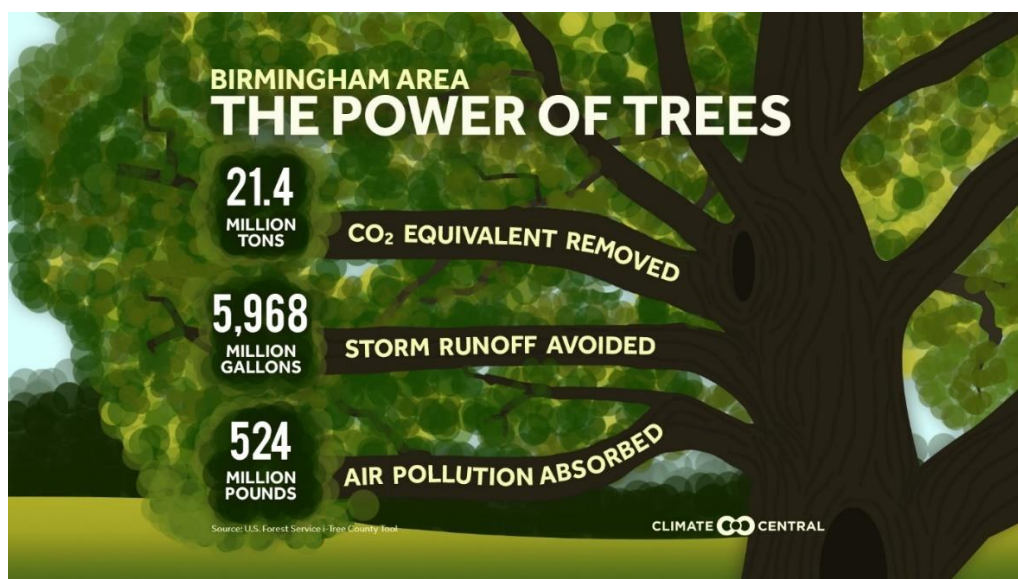


Figure 3.4 the Power of Trees [23]

In a word, trees are not only closely related to human life as wood, but also an integral part of the ecosystem. It is necessary to rebuild and restore degraded forest land while reducing the deforestation of existing forests to solve the problem of deforestation. At the same time, people also need to raise awareness of environmental protection and take care of plants and trees around them.

4 Game Design

In this chapter, the detailed concepts of designing the game are given, including the decision of game mode, the worldview of the game and three missions. Then, the basic operation guide of the game will be indicated.

4.1 Game Mode

Two different game modes are proposed. After careful consideration and analysis of the advantages and disadvantages, the game's core is finally determined to be a collection of mini games.

4.1.1 Proposal 1: A Running Game like *Temple Run*

The game is designed as a running adventure game, like the famous mobile game *Temple Run*.

In this game, the city where the game character is born has been polluted. One day, a boy accidentally discovers the escape route from the city, so he embarks on a journey. However, garbage blocks his way. The landforms caused by the harmful environment, such as rising seawater and desertification, also makes his escape more difficult. Meanwhile, since successfully escaping the city will reduce the benefits of the city leaders, the leaders ask killers to chase the boy.

The game is expected to be divided into three levels: City, River, and Desert. In City level, there will be a variety of garbage thrown everywhere, and ubiquitous vehicles hinder players from going forward. At the same time, players may lose sight due to excessive carbon dioxide emissions. In River level, players need to obtain boats and avoid the aggressive creatures that are polluted in the river. In Desert level, the loss of physical strength encourages players to get every reward.

In the game, the game character will run automatically and can be manipulated to jump, run left and right, and slide the shovel to avoid obstacles. The player needs prevent the character being killed by the killer in the rear or dying due to the map element. Besides, there will be random rewards in the game, such as garbage bags which can automatically collect garbage and boats used on rivers.

Every time a level is completed, the city's pollution rate will decrease. When all levels are successfully passed, the city's environmental conditions will become excellent again, thus triggering people to think about environmental protection.

4.1.2 Proposal 2: A collection of mini-games

In this proposal, the game is designed as a role-playing game.

The player-controlled character arrives in a polluted town on the island. In this town, garbage is everywhere, and the ocean is also polluted.

There are many buildings and non-player characters (NPCs) in the town, and the player can freely explore the town or the offshore. Furthermore, the player can accept missions related to protecting the environment from NPCs in the town. These tasks are regarded as mini-games. Every time a mission is completed, the pollution rate of the town will drop. When the pollution rate is reduced to 0, the town's environment will be wonderful.

The further information of this game mode will be introduced in the next sections.

4.1.3 Comparison and Selection

The proposals of both modes are based on the fact that the city or town is polluted. The essential result is hoping players to reduce the pollution rate and save the environment through the game, and ultimately arouse the players' awareness of environmental protection.

Of course, these two game modes have their advantages and disadvantages. The former is relatively more enjoyable and easier to attract players for repeatedly challenging to win. Nevertheless, the first game mode focuses more on adventuring. Players may immerse in how to complete the level and ignore environmental protection. The second game mode is clearer in purpose. It guides the player to protect the environment through the instructions of the mini-games, and it is better to arouse the player's awareness of environmental protection. Meanwhile, the player has a higher degree of freedom in the game and can independently explore the map. However, because the mission of environmental protection is comparatively serious, people's interest may be low.

Based on the above, the second game mode: a collection of mini-games was finally chosen as the core.

4.2 Game World View

This section supplements a complete world view, including background information and game map design for the game. Also, many games are analyzed and referenced for designing the world view of this game.

4.2.1 Related Games

This game's worldview design mainly refers to three games: *Fallout*, *Monster Hunter: World*, and *Sim City*.

The first game, named *Fallout* is a computer role-playing game developed by Interplay. *Fallout* is a series of games, and the introduction here is *Fallout 1*. The background story takes place in the wasteland after the nuclear war [24]. The protagonist is kicked out by Refuge No. 13. He needs to go to the wasteland to find water quality chips for survival. In the process, he needs to explore the map and collect items. Its story background is very similar to the upcoming game. They both happen in environments that need to be rebuilt, and the player characters both need to collect items to complete tasks to promote the game process. Therefore, *Fallout* is indispensable in the design of maps and mission mechanisms.



Figure 4.1 World View of *Fallout 1*

The bulletin board in the center of the town is inspired by *Monster Hunter: World*. In the setting of *Monster Hunter: World*, players need to receive tasks from the bulletin board each time they want to hunt monsters. Otherwise, they cannot start. At the same time, the bulletin board can be used as a medium for communication or team formation with friends. As an essential part of the game, the bulletin board guides players to arrange their games better. While the designing game is a stand-alone game, the temporary function of the bulletin board is to view the task details. Players can view the details of current, completed, or failed tasks near the bulletin board, and accept or cancel the missions. This bulletin board is essential for players to plan or manage their missions.



Figure 4.2 Bulletin Board in *Monster Hunter: World*

As a city-building simulation game, *Sim City* provides a lot of inspiration in the mission design part. Because it is unreasonable to let players build buildings according to the actual situation, transitions between starting and ending building factories or planting trees become a big problem. *Sim City* gives an excellent answer. According to *Sim City*, after the player selects a location and reaches the construction or growth conditions, a period of animation is used to show the construction or growth process. Then the complete factory or the grown tree is displayed. Players can participate in the process without waiting too long.

Also, some other role-playing games have an influence on this game, such as *Overwatch*. All in all, the development of this game is inseparable from the impact of various excellent games.

4.2.2 Background Story

There is a historic town on an island. It used to be very prosperous, but due to economic development and population growth, the environment is worsening. Rubbishes is everywhere. The trees gradually withered. The polluted seawater has reduced the fish resources on which the townspeople depend. Fewer and fewer people live on the island. People on the island gradually realized the importance of environmental protection, but they cannot solve the problem of the town.

The player character will be born at the gate of the town. The player can control the character to walk, run, jump, and interact with other objects. After knowing the necessary information, the player can freely explore the island, such as talking with NPCs and checking missions on the bulletin board.

When talking to NPCs in the town, the player may receive the missions given by the NPCs. Every mission plays the role as a mini-game. Follow the mission instructions to complete the mission will get rewards, such as golds, specific items, and reducing the pollution rate of the town. The initial pollution rate of the town is 100. When the town's pollution rate reduces to 0, the town's environment will be significantly improved.

The game also has the alternation of day and night. One day in the game is equivalent to twenty minutes in reality.

4.2.3 Town Map

Different areas are set in the town. The town gate is in the east, which is the only entrance except for entering the town from the sea. After entering the town, the bulletin boards are built in the middle of the town. The town hall is in the northeast corner of the town, and the town leader is always there. The south of the town hall is the residential area. A commercial area with multiple shops is in the southwest corner of the town. The west of the town is the dock, connecting the town and the sea.

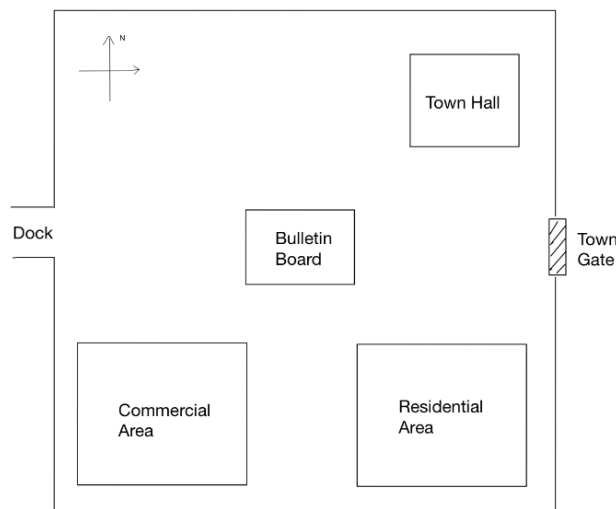


Figure 4.3 Town Map

4.3 Game Designed Missions

In this section, three designed missions will be introduced. These missions do the same function as mini-games. The details and the flow charts of the missions will be shown.

4.3.1 Mission 1: Cleaning Up the Rubbishes

Cleaning up the rubbishes is the first mandatory mission of the game, or it can be called the novice mission.

The process of this mission is simple. The player will receive this mission when he enters the town and talks with the town leader for the first time. To complete the mission, the player needs to find rubbishes scattered on the ground in the town (including on the beach) and pick them up. When the target rubbish count is reached, the mission list will update automatically. Then the player needs to return to talk with the town leader to submit the mission. At this point, the mission of “cleaning up the rubbishes” has been accomplished and the pollution rate will reduce to 90.

The purpose of this mission is to raise the players' awareness of not throwing away rubbishes and picking up the existing rubbishes on the ground in the real-life. Besides, a simple mission also allows players to get familiar with the operations of the game while doing the mission.



Figure 4.4 Flow Chart of Mission "Cleaning Up the Rubbishes"

4.3.2 Mission 2: Controlling Water Pollution

Controlling water pollution is a relatively complex and vital mission in the game. The player needs to start with the easiest subgoal to clean up the solid waste discharged into the water from the town and follow the instructions in the mission list to complete a series of missions. Finally, the environmental problem of water pollution will be solved from the source.

After completing the first mission of “cleaning up the rubbishes”, the player can learn about the current pollution condition of the town through multiple conversations with the town leader. Then, the town leader will give the player the mission of “controlling water pollution” and the props needed in completing the task, including a small boat and 100 golds. This mission is mainly composed of five sub-missions.

First, the player needs to use the boat to clean up the rubbishes near the sea and the beach. If recyclables or seafood are collected, the player can sell them at the shopkeeper. The player can also purchase the required items at the shopkeeper, such as larger boats and fishing nets. When rubbishes are cleaned up, the player needs to return to the town leader to deliver the mission and get the next task of finding the reason for the rubbishes.

In the new mission phase, the player needs to complete two sub-missions: going to the beach and interviewing the residents of the town. When the player comes to the beach again, a new scene is triggered. Townspeople complain about the storage of rubbish bins in the town and on the beach. Then they just throw the rubbishes into the sea. When the player goes back to the town to interview the townspeople, he will find that there is no factory in the town specializing in recycling and disposing of rubbishes. The lack of rubbish bins to collect rubbishes and the inability to dispose of rubbishes are the main reasons for the town's water pollution.

After finding the cause, the player needs to inform the town leader of the reason. The town leader will give the player sponsorship, and the next phase of the mission starts. The player first needs to go to the shopkeeper to buy rubbish bins and allocate them reasonably in the town and on the beach. When a certain amount of rubbish is collected, the player starts a new sub-mission. He needs to choose a spare space in the town to build a rubbish disposal factory. The functional layout of the factory requires the player to know the relevant knowledge before making decisions.

So far, the environment inside the town has been immensely improved. The town leader will commend the player, and the townspeople will also appreciate him. The player needs to complete the last sub-mission: to hold environmental protection-related lectures in the town to raise the town residents' environmental protection awareness, such as lectures with the theme of rubbish classification or recycling.

When this whole mission is completed, the pollution rate of the town will be significantly reduced. Through this mission, the player can learn better about solid waste based on essential environmental awareness, including waste sorting, recycling, landfill, and incineration. At the same time, as the core task of the game, the player can get the sense of fun and accomplishment while completing the mission.

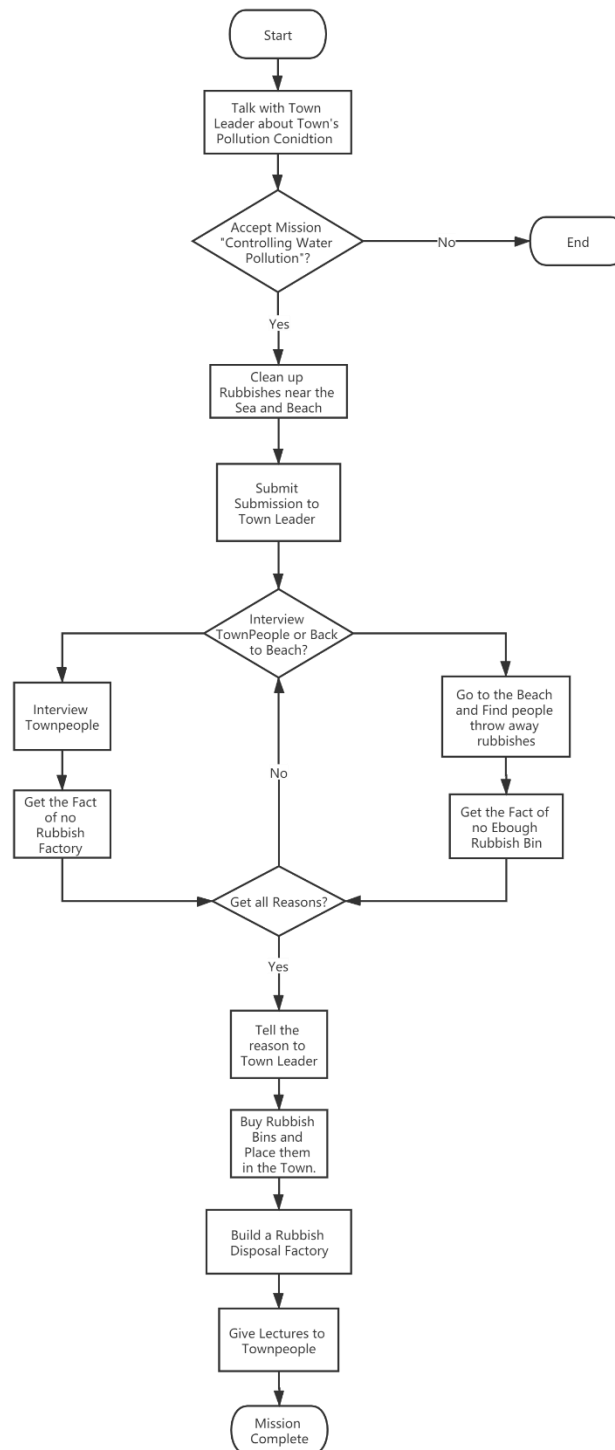


Figure 4.5 Flow Chart of Mission "Controlling Water Pollution"

4.3.3 Mission 3: Planting Trees

Planting Trees is a daily task in this game, which can be triggered by different NPCs at regular intervals. The reward is fixed as ten golds and reducing the pollution rate by 2 points. This mission can be repeated.

The mission flow is simple. After receiving the mission, the player needs to buy tree seeds or flower seedlings and watering pots from the shopkeeper. Then he needs to find an arable land and plant the seeds. The player can use a watering pot to draw water from the coast to water the seeds. After waiting for half a minute for animation, the seeds will gradually grow and beautify the environment. Finally, the player needs to go back to the mission bulletin board to confirm the mission completed.

This mission can be done multiple times. Although there are few rewards each time, the numerous completions of the task are of considerable significance to the change of the environment. Moreover, this mission is to warn players that protecting the environment is not an impulse. It requires perseverance to be effective.

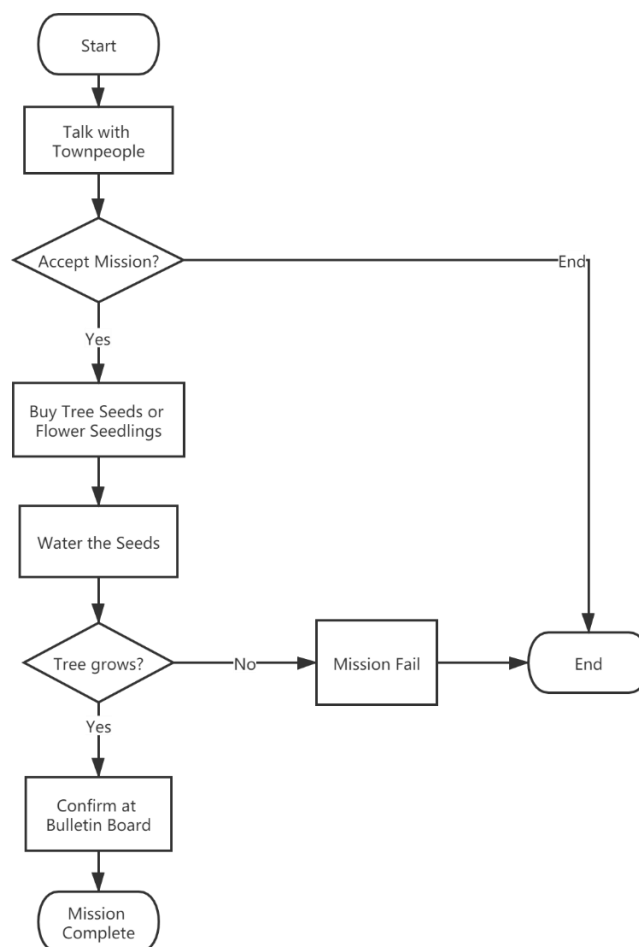


Figure 4.6 Flow Chart of Mission "Planting Trees"

4.4 Game Operation Guide

The operation of this game is similar to most third-person role-playing 3D video game, and the following is the basic operations.

1. The player can press [W], [A], [S] and [D] on the keyboard to control the player character to move forward, left, backward and right.
2. Pressing [Space] on the keyboard allows the character to jump.
3. The player can use mouse to rotate the view.
4. Pressing [E] allows the character to interact with nearby objects, including NPCs and items. And for mission journal, the player can interact with the bulletin boards to open or close it. But if the player is far away with the boards, pressing [ESC] can also close the mission journal when it is visual.
5. Pressing [Left Alt] can call or hide the cursor.
6. The player can press [Tab] to open package and check items.
7. Pressing [B] allows to slide in or out the mission list.

5 Game Implementation

In this chapter, the important parts of the entire game development process will be explained. The whole game can be divided into five parts: the construction of the map, the improvement on player character, shopkeeper system, mission system and background introduction at the beginning of the game.

5.1 Construction of Town Map

Constructing the game map is the first step in developing the game. Since the background information of this game takes place on a small island, the component resolution of the landscape is 16*16. This size not only includes all the elements needed for the game but also allows players to walk around the entire map easily. Besides, the map is small and clear, so the mini map is not necessary.

The layout of the buildings in the town is built based on the design in section 4.2.3 and improved. Due to the large number of buildings in the commercial area and residential area, the locations of the residential area and the town hall have been swapped for the beauty and balance of the map. Meanwhile, the layout of the dock in the middle of the west of the town was not reasonable, so it was transferred to the northwest corner, where is no construction arrangement.

The start point of the player is set outside the town gate. The player needs to open the town gate to enter the town. The town gate is an actor blueprint composed of four components. As Figure 5.1 shows, when the player is near the town gate, the Box Collision is triggered. At this time, if the player presses E to interact, the iron gate will slowly rise to a passable height. When the player leaves the range, the iron gate will automatically close.

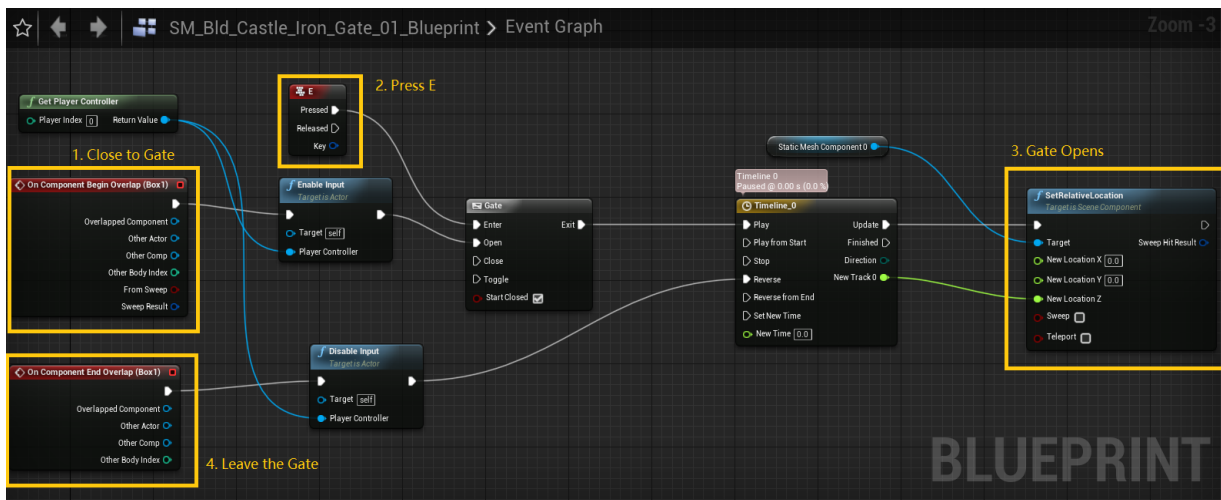


Figure 5.1 Town Gate's Blueprint

In the rest process of building the map, the atmosphere, architecture style, and functions of the map are considered repeatedly.

5.1.1 Sky Atmosphere System

When creating a new level, the initial thing to consider is the Sky Atmosphere System. Since the new level has no light source and is completely dark, creating a suitable sky atmosphere system is very important. The version 4.24 of UE4 has a default sky atmosphere system that can be used directly. However, to fit the actual situation of the game better, the sky atmosphere system in this game is created separately.

This system is mainly composed of three actors: AtmosphericFog, BP_Sky_Sphere, and DirectionLight, all of which come from UE4. The attribute “Direction Light Actor” of BP_Sky_Sphere is associated with the created DirectionLight so that the atmosphere’s color shows as the different points in the day by rotating the DirectionLight.

Besides, the DirectionLight should change automatically over time so the game can be more realistic. Level blueprint is used for this purpose. As Figure 5.2 displays, Event Tick represents that the DirectionLight will rotate 0.3 degrees in the Y direction per second, which means it will rotate 360 degrees every 20 minutes. So, in this game, 20 minutes is equivalent to a day and night in real life. This ratio not only allows players to be more immersive in the game but also prevents the feeling of boredom caused by the slow time flow rate.

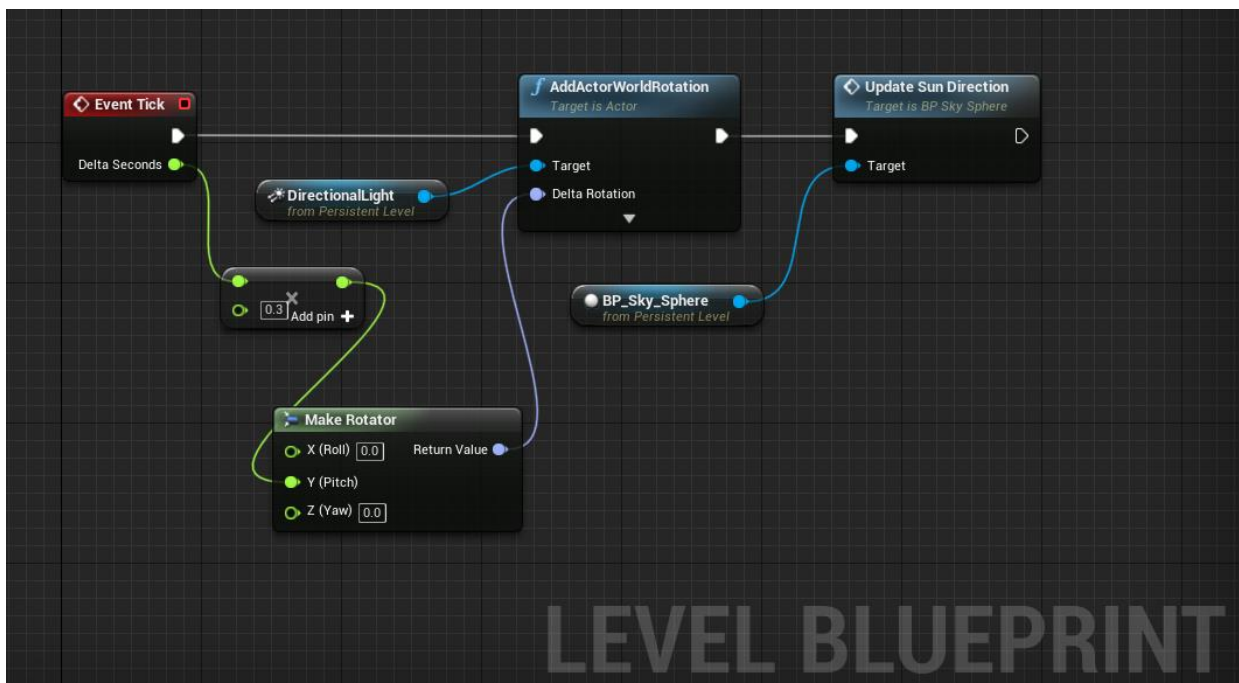


Figure 5.2 Level Blueprint _ Event Tick

5.1.1 Architecture Style

As for architectural style, because the background of this game is contemporary society, the architectural style was initially selected as a modern style. However, in the process of construction, the modern style does not match the isolated island. The town was closed for a long time, and it should be more backward than recently. Therefore, the medieval style began to be considered. In the medieval style, a low poly style is popular and widely used. After trying, this style is suitable for this town and was adopted. Figure 5.3 shows a sample of the low poly style.



Figure 5.3 Low Poly Style [25]

5.1.2 Functionality of Buildings

When constructing a specific building, how to express its functionality becomes a problem. According to common sense, characters can enter and exit the buildings through the door in general games and interact with indoor objects, such as turning on or off lights. Furthermore, there will be NPC in the building if it is a store, allowing players to purchase items. Completing such an architecture requires lots of details useless for the functionality but is effective for improving the sense of playing and much time-consuming.

Since this game is more focused on awakening the player's awareness of environmental protection rather than the fun, and the development time and developers are limited, a more concise construction plan is adopted after careful consideration. The buildings in the town will be constructed as entities. Players can distinguish different areas of the town through different appearances, but no buildings can be entered or interacted. Besides, buildings in the same area have different signs on the exterior. For example, in the commercial area, there will be a boat placing around the fish shop, and the blacksmith shop will have a special sign. For buildings with unique functions, the affiliated NPCs, will provide services outside the building. For instance, the shopkeeper and the town leader will wait players outside the shops and the town hall.



Figure 5.4 Detail signs for Fish Shop and Blacksmith Shop

This construction saves a lot of time to concentrate on the function of the game rather than the appearance. At the same time, it is also clear enough to allow players to find their destination.

5.2 Improvement on Player Character

The player character of this game mainly adopts the default third person character in UE4 and has been improved.

As Figure 5.5 indicates, both the mesh and the animations of the player character have been replaced with Paragon: Gideon, the resource in the UE4 marketplace. Gideon looks like a traveler wearing a robe, which is fit in this game. The material of the flying disc, which is behind him and used to release the attack, was transparentized, making the character more suitable for the game's background settings. Besides, Gideon's skeletons have been adjusted to prevent uncoordinated walking or running postures.



Figure 5.5 Player Character

5.3 Shopkeeper System

In this section, constructing the shopkeeper system will be introduced, including interacting with the shopkeeper, buying and selling items, and viewing the player's belongings.

5.3.1 Set up Shopkeeper

To complete the shopkeeper system, it is necessary to build a shopkeeper NPC.

First, create a character blueprint. Since there is no professional artist, various resources in the UE4 marketplace are useful. After choosing the right mesh, the animation of shaking slightly while standing is added to make NPC more real.

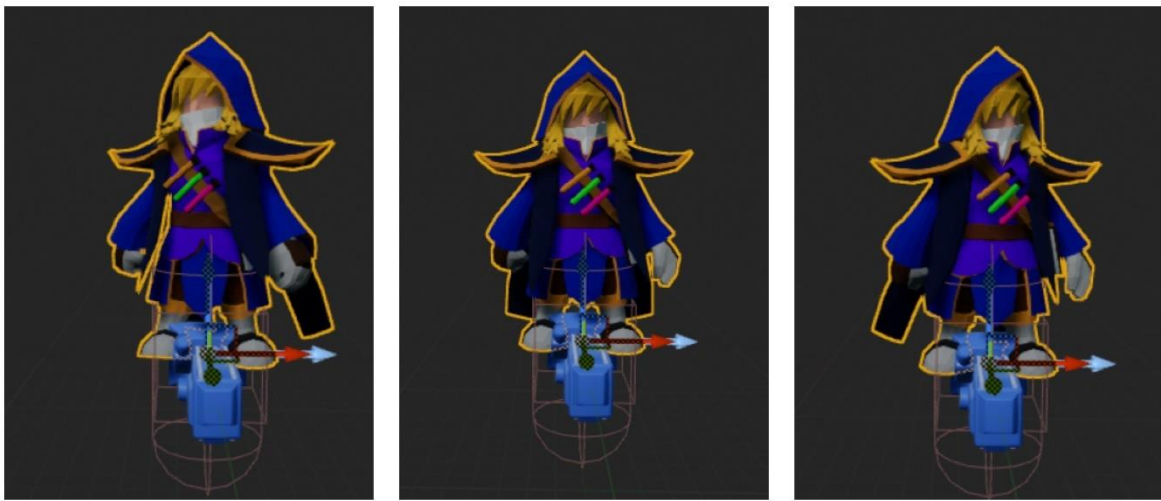


Figure 5.6 Shopkeeper's Viewport (Shakes Slightly while Standing)

Secondly, to realize the interaction between the player and the NPC, a new component needs to be added for detecting the distance. Like the blueprint town gate mentioned in section 5.1, a Box Collision is added here. However, the reason why the player close to this NPC is always he wants to buy goods. Therefore, when the player enters the Box's detection range, the purchase interface with the product list will be opened in default without pressing. Meanwhile, the cursor will be visual for the further operation.

Third, when the product list opens, no matter which direction the player approaches the NPC, the NPC should always show the front face to the player like the actual purchase experience. Thus, a camera component is added to the blueprint. This component fixedly shoots the front of the NPC. When the product list shows, the game perspective will automatically switch to this camera's perspective.

5.3.2 Shopkeeper UI

The user interface (UI) of the shopkeeper consists of two widget blueprints. One blueprint is used to construct single product information, including product name, price, image, description, and purchase button. Another blueprint is used to build the overall user interaction interface, including the necessary instructions, product list, the buy and sell conversion button and exit button. The product list consists of multiple former blueprints.

A structure blueprint named `ItemStructure` and a data table miscellaneous called `ItemDataTable` were constructed for storing item information. The former defines the structure of items in the shop as name, price, thumbnail, and description. Each product can be distinguished by these four labels. The latter is similar to the table in the database. It uses `ItemStructure` as the row structure. Developers can add specific product information in the table. For instance, `ItemDataTable` has a product named Small Boat. Its price is 50 gold. Its thumbnail is a 2D texture from the local folder. Its description is, "Just a small boat.". Based on these two assets, developers can add information about any item to use.

After defining the object's structure, the list of goods on the purchase interface needs to be built. The total number of items cannot be fixed due to the variety types of items. Thus, each time the player enters the shop purchase interface, the item information stored in the data table will be circulated, arranged in a row of four different types. At the same time, other information on the UI interface will be filled according to the settings. After multiple adjustments to the widgets on the UI interface, the complete purchase interface is shown in Figure 5.7.

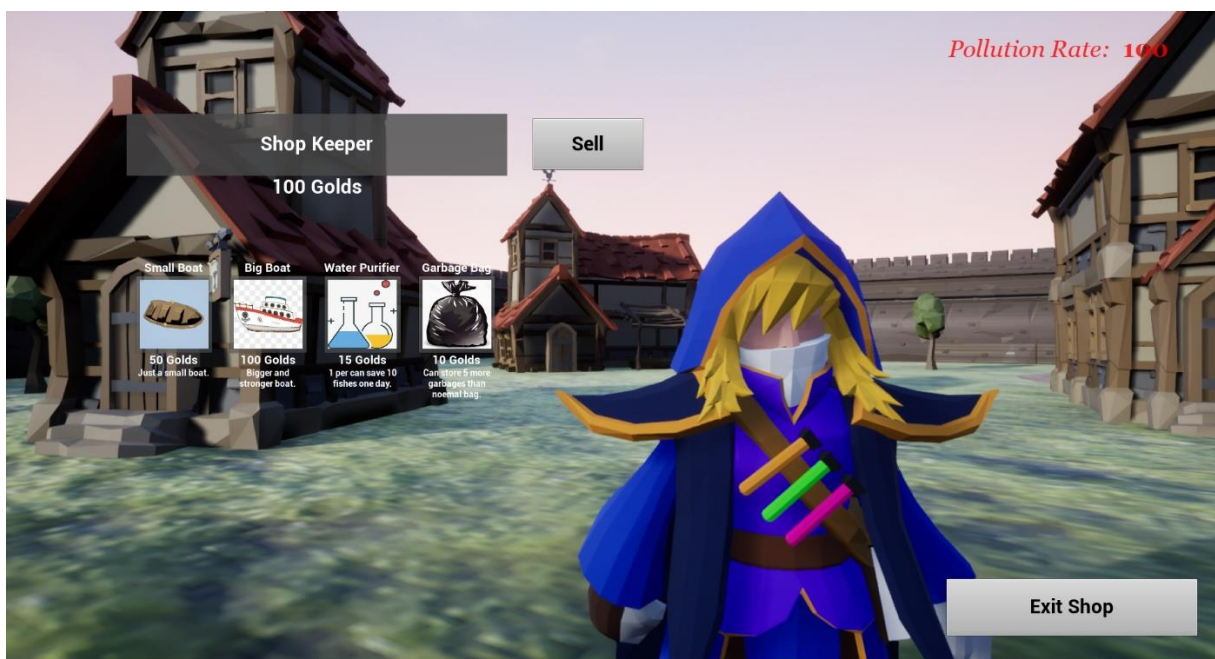


Figure 5.7 Shopkeeper Purchase Interface

Players can purchase items by clicking on the thumbnails of the items. Meanwhile, the golds will reduce. When the golds are not enough to buy items, the number of possessions cannot be increased even if the player clicks to buy. A new function named `AddToInventory` is created to store the purchased item information. Moreover, each item has a unique `ItemId` to distinguish and a variable `Quantities` to store the number to prevent duplicate items. Whenever a player buys a product, it will be automatically numbered as the `ItemId` and added to the player's inventory, and the variable `Quantities` will be increased by one.

When the player needs to switch to the sale interface, press the "Sell" button. As Figure 5.8 indicates, the sale interface is similar to the purchase interface. The difference is that the number of things the player holds is limited. Therefore, the list of items for sale will be displayed with the specific number of each item. Indeed, the possessions' necessary information will also be presented to facilitate the player to view. Similar to buying items, the player can sell items by clicking on the items' thumbnails. The number of possessions will be reduced by one. The data stored in inventory will also decrease synchronously. Also, the player will get 0.8 times the original price of the golds. When a kind of possessions is sold out, it will disappear in the sale interface. If the player wants to switch to the purchase interface again, press the "Buy" button.

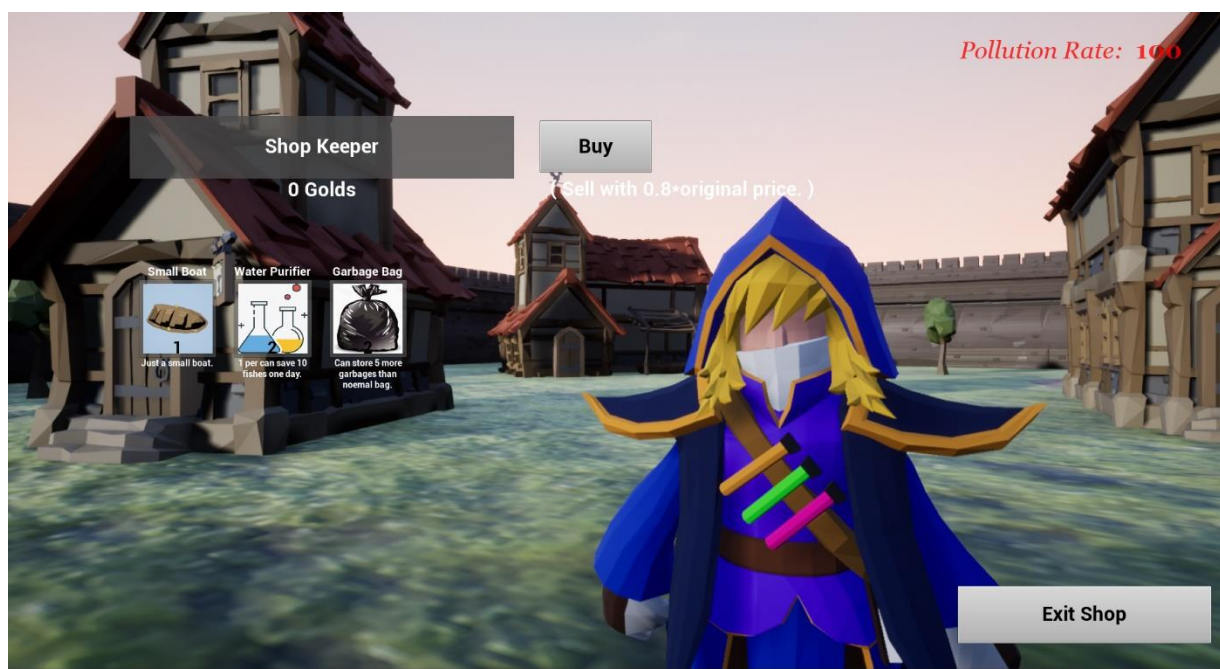


Figure 5.8 Shopkeeper Sale Interface

Press the "Exit Shop" button in the lower right corner to return to the game mode. The player can use the mouse and keyboard to control the character again, and the cursor disappears.

5.3.3 Player Inventory UI

The player can press Tab to open the Player Inventory UI interface to view the backpack. As Figure 5.9 shows, this interface is approximately the same as the shopkeeper sale UI interface. It will display the player's golds, the number and description of possessions, and the exit button, but there is no switch button to change the mode of "Buy" and "Sell". Meanwhile, because the On Clicked function of the item icon is not set, clicking the item on the backpack interface is invalid.

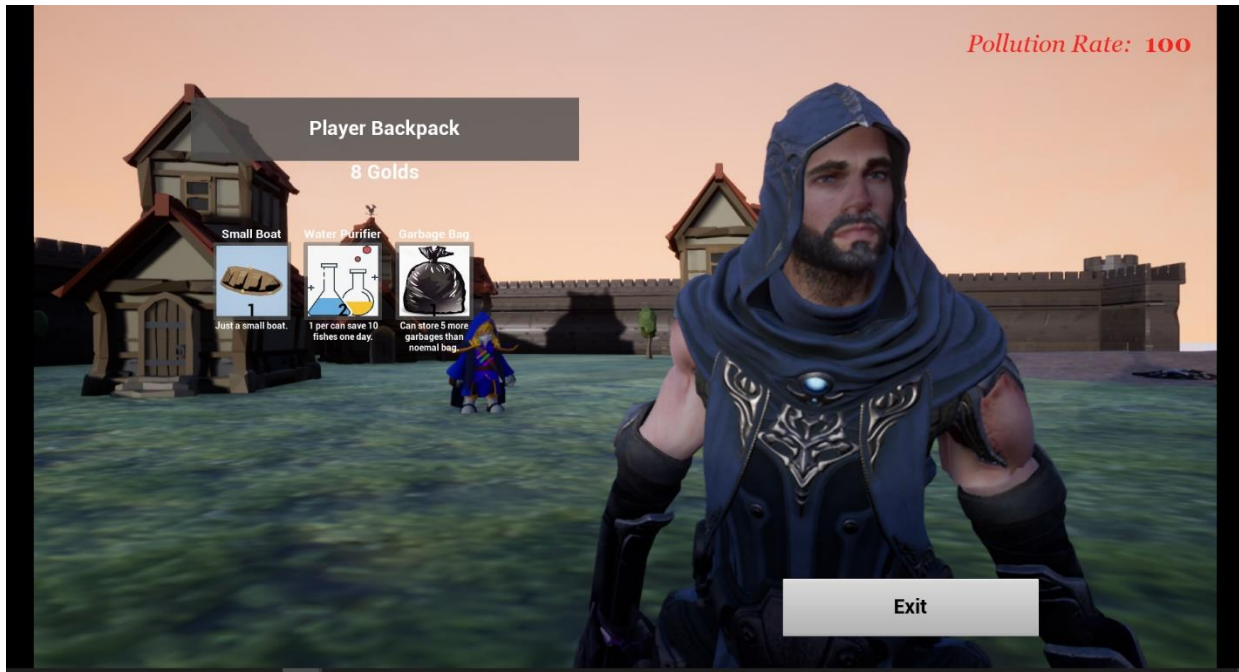


Figure 5.9 Player Inventory Interface

5.4 Mission System

In this section, the first mandatory mission “Cleaning Up the Rubbishes” will be introduced in detail. Meanwhile, this mission system constructs some templates to pave the way for further mission development.

5.4.1 Mission NPC

Although only one NPC, the town leader, is involved in this mission, virtually all NPCs are almost the same. Therefore, a character blueprint called `Master_Npc` is created as a template. Due to limited resources, the character's mesh and animation are the same as the shopkeeper. Only the appearance color is changed as a distinction. At the same time, for better interaction, two widget components are added directly above the NPC head. One of them is called `InteractionWidget`, which is used to display NPC's name and the tips of "press E to interact".

The other is called `MessageComponent`, used to show what the NPC says to promote the progress of the mission.

In section 5.3.1, the first condition for the interaction between the player and the NPC is to trigger the collision box. However, in this mission, the player needs to interact with many objects, including the town leader, rubbishes, and bulletin boards. Therefore, it is troublesome to set the collision of each actor one by one. Then, a new interface blueprint named `i_Intertable` is created, which can be added to other blueprints as a multi-functional collection. This interface blueprint has three functions. Function `OnEnterPlayerRadius` and `OnLeavePlayerRadius` are used to determine whether the player enters the interaction range or not, and function `OnInteractWith` is to interact with the player.

The next step is starting to write the blueprint `Master_Npc` events. First, when the game begins to play, the information in `InteractionWidget` and `MessageComponent` is loaded. The functions `OnEnterPlayerRadius` and `OnLeavePlayerRadius` inherited from `i_Intertable` detect whether the player is near the NPC to determine whether to display the contents of the two widget components. When the player presses E within the interaction range to interact, the NPC will judge whether he has an acceptable mission. If so, the player will get the mission, and the mission list will automatically appear. If not, depending on whether the player is performing the task given by the NPC, the `MessageComponent` will display different messages, as shown in Figure 5.10.



Figure 5.10 Message Shown from Town Leader

So far, `Master_Npc` is built entirely. However, a `Master_Npc` can only set two talk templates, one is the default message when the mission is accepted but not completed, and the other is the message when no task can be distributed. Thus, the child blueprint of `Master_Npc` is built

for realizing more message functions. It adds a new branch for logical judgment based on Master_Npc, which can give the correct message when the player needs to dialogue with it.

5.4.2 Mission Template

The first step to create the mission template is to define attributes. Among the structure blueprints established, the significant ones are s_MissionInfo and s_GoalInfo. The former includes the mission's name, type, description, rewards, sub-missions, and the mission NPC's id and name. The latter is a sub-task structure of a complete mission, which contains the goal type, description, sequence number of the next sub-mission. And some elements used to create a mission template are also involved in this structure, such as AdditionalName, AmountToCollect, GoalClass, and GoalId. Besides, there are some simple data structures, such as s_MissionReward that stores mission reward information, and s_CompletedGoal, which stores completed sub-mission information.

Two task templates have been created in this game, namely the collection mission template and the talk mission template. The talk template is relatively more uncomplicated. An AdditionalName variable is used as the NPC's name to be chatted when the task is displayed. The template for collecting items requires AdditionalName as the name of the collection and AmountToCollect as the number to be collected. GoalClass and GoalId will be detected according to the different mission objects in the process of completing the mission. For example, there are two sub-missions in the mission of cleaning up rubbishes. The collection of 6 rubbishes uses the collection template and the dialogue with the town leader using the talk template. Therefore, when the player interacts with the rubbish, the system detects whether the class of this object is rubbish to prevent picking up the wrong types of items. When the player talks to the NPC, not only the actor's class but also the id are detected to confirm it is the specified NPC.

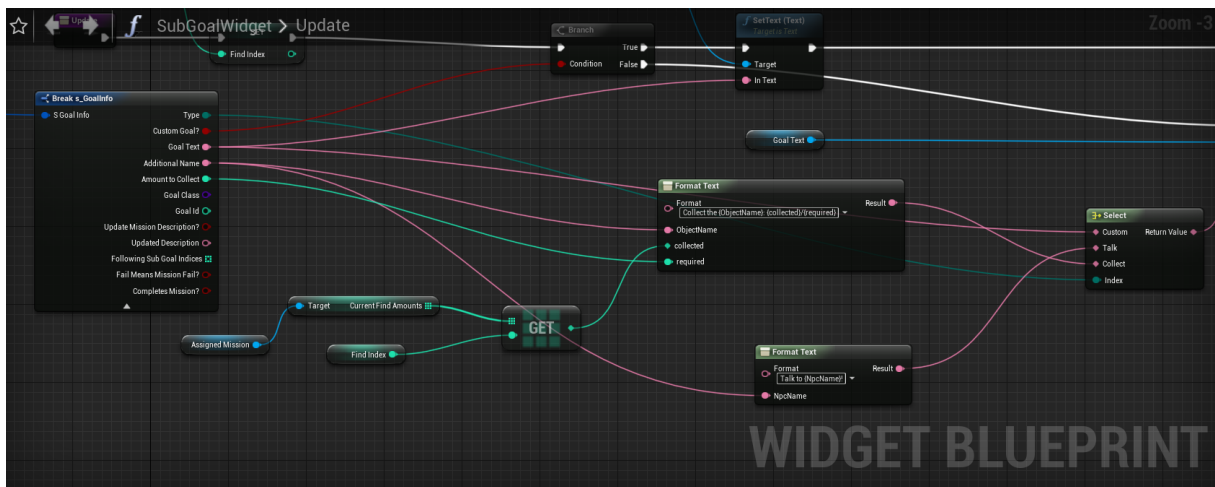


Figure 5.11 Mission Template

In the collect template, object actors such as rubbishes also have InteractionWidget as a reminder like NPC actors. It includes the name of the object and the tip of "Press E to interact".

The town's pollution rate is indicated in red in the upper right corner of the screen. The initial pollution rate is 100. Whenever the player completes a mission related to environmental protection, the pollution rate will decrease by different values according to the difficulty of the task. For example, when the player completes the mission of "clean up the rubbishes", the pollution rate will drop to 90, as shown in the Figure 5.12. When the pollution rate successfully drops to 0, the town is no longer polluted.

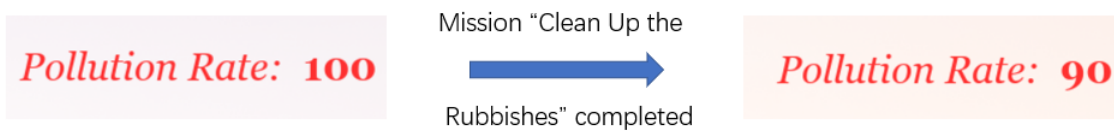


Figure 5.12 Pollution Rate

The establishment of such mission templates not only standardizes the display of task descriptions but also reduces the development efforts of similar tasks.

5.4.3 Mission List

The mission list is designed to facilitate players to view the currently ongoing missions. When the player receives the task, the mission list will appear on the right side of the screen, as shown in Figure 5.13. The player can press the Left Alt to call the mouse to select the task. And pressing B can hide or re-extract the mission list.



Figure 5.13 Mission List

Whenever a sub-mission is completed, the mission list will be automatically updated to the next sub-mission to guide the player to complete the entire mission. When the whole mission is completed, the mission list of this mission will disappear.

Besides, in the

5.4.4 Mission Journal

As Figure 5.14 indicates, the mission journal records all details of missions, including current, completed, and failed missions. Meanwhile, some specific mission information which are not in the mission list, such as tips given by the mission publisher and specific mission rewards, will be published in the mission journal. The player can view the mission journal by pressing E next to the bulletin board in the town center.



Figure 5.14 Mission Journal

5.5 Startup Animation

The content of this section was added to the game after the test from target group. It is principally about the introduction of the background and operation at the beginning of the game, increasing the player's usability.

Startup movies can be added in the project part of project settings. Multiple movies can be added, and they will be played one by one automatically. Also, two options about playing can be chosen: Wait for Movies to Complete and Movies Are Skippable. The former forces the player to watch the entire movie before starting the game, while the latter allows the player to press any button to skip the startup movie. According to different development needs, the developer can choose the suitable mode.

In this startup movie, it briefly introduces the player's condition and sets the goal of reducing the town's pollution rate to prevent the player from being overwhelmed when entering the

game. At the same time, the essential operation of the game will be displayed. The player can browse the operation and remember.

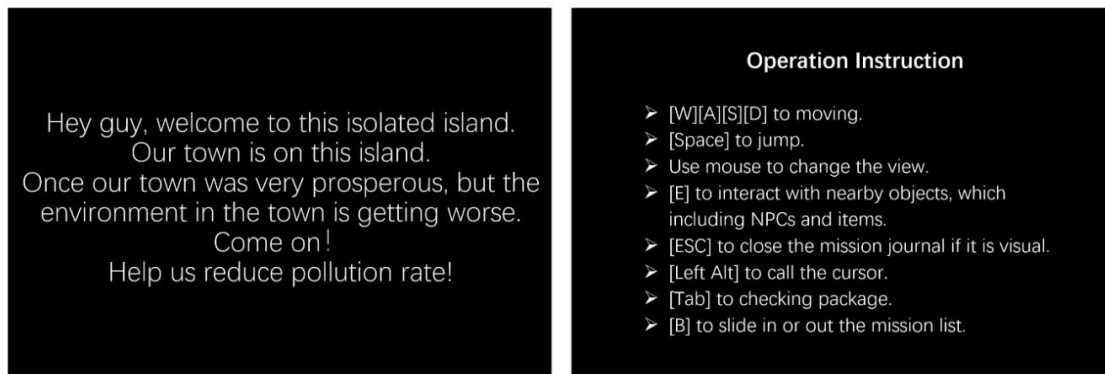


Figure 5.15 Startup Movie

Besides, every time the game starts, the player character is born from the sky, which is thoroughly unreasonable. So, after the startup movie ended, a unique scene conversion is added to make the game starting more natural.

First, a camera needs to be created in the level. Adjust its position to the desired startup scene. Then as the level blueprint showed in Figure 5.16, the function Set View Target with Blend is used, and the newly created camera replaces the player character's camera. Constructing an identical function again, but this time, the new view target is from the player character's camera. Set a delay before testing. In the test, a simple view conversion is completed.

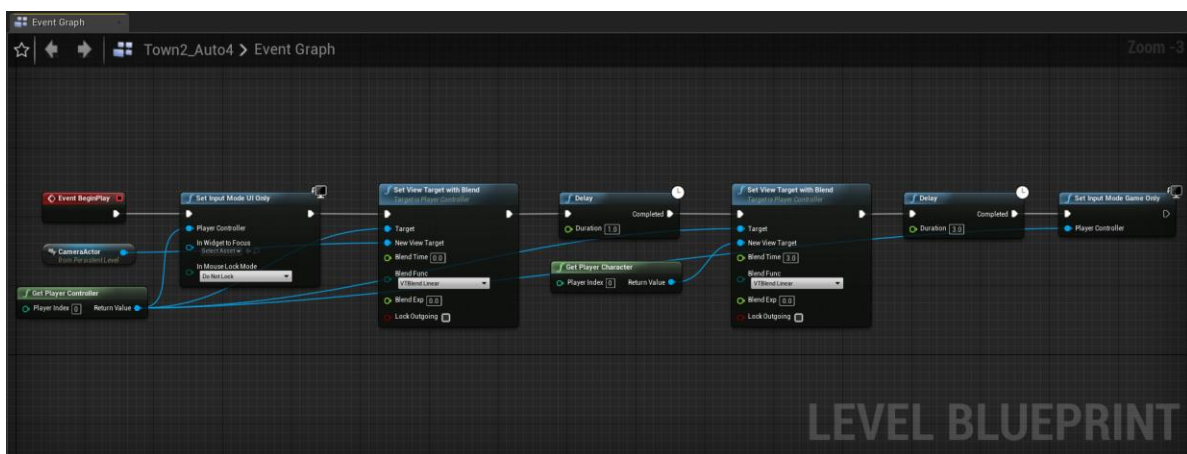


Figure 5.16 Level Blueprint: View Conversion

However, there is a small bug. If the player controls the player character during the view conversion, even if there is no player character in his sight, the character can still be manipulated. Then the conversion between the UI mode and the game mode was introduced to prevent accidental touches. Till now, the startup animation is complete.

6 Game Evaluation

This chapter describes the evaluation of this game, including test part and conclusion. In the test part, game's functional test and performance test are carried out. Besides, the questionnaire survey and feedbacks are given after the target group experiences the game.

Game testing is similar to software testing. Both are aimed at discovering vulnerabilities in software. They require relevant personnel to conduct tests according to product behavior descriptions, such as documentation or program code. They need a real or simulated real test environment and need to have the test results from the testers, which point out what problems exist.

However, due to the characteristics of the game itself, there are some differences between game testing and software testing. These differences include the different emphasis on performance, interaction and security. Game testing is essential in game development, and it is an integral part of ensuring game quality.

6.1 Game Test

Game testing is mainly divided into two aspects, one is functional testing, and the other is performance testing. The functional test is primarily to check whether each function is implemented as expected, while the performance test is to check the resources consumed by the game.

6.1.1 Test Environment

The test environment of this game is mainly personal computers. The computer configuration and test tools are shown in Table 6.1. Profiler is a performance test tool for UE4 to analyze game resource consumption, detect CPU and GPU occupancy, and frame generation delay.

Table 6.1 Test Platform and Tools

CPU	I7-9570H
GPU	GeForce RTX 2070
RAM	16 GB
Operating System	Windows (64 bits)
Performance Test Tool	UE4 Profiler

6.1.2 Functional Test

Game functional testing is mainly aimed at game implementation. It primarily consists of two parts. First, test the use cases of the shop system. The test results are shown in Table 6.2.

Table 6.2 Shop System Cases Test

Case Name	Operating Steps and Expected Results	Result
Enter the shop purchase interface	After approaching the shopkeeper, the player will automatically enter the shop purchase interface and can view the goods and golds.	Pass
Purchase goods	Click on the item thumbnail to purchase the specified item.	Pass
Enter the shop sale interface	Click the Sell button to enter the shop sales interface, the player can view the belongings and golds.	Pass
Sell property	Click the belonging thumbnail to sell the item.	Pass
Return to the shop purchase interface	Click the Buy button to enter the shop purchase interface.	Pass
Exit the store	Click the Exit button to launch the shop and return to game mode.	Pass
View backpack	Press Tab to open the backpack interface, the player can view the belongings and golds.	Pass
Exit backpack	Press Tab again to exit the backpack interface and return to game mode.	Pass

Then, test the use cases of the mission system. The test results are indicated in Table 6.3.

Table 6.3 Mission System Cases Test

Case Name	Operating Steps and Expected Results	Result
Accept the mission: Clean up the rubbishes	Approach the town leader and press E to interact with him. After successfully accepting the mission, the mission list with the first sub-mission appears on the right side of the screen.	Pass
Hide / Recall mission list	Press B to hide or call up the mission list.	Pass

Complete sub-mission: collect rubbishes	Look for rubbishes scattered on the map and press E to collect. The collected rubbishes will disappear. After collecting 6 rubbishes, the mission list will be automatically updated to a new sub-mission: talk to the town leader.	Pass
Complete the sub-mission: talk to the town leader	When this sub-mission appears in the mission list, talk to the town leader. He will praise and thank the player. The entire mission completed.	Pass
Return to the shop purchase interface	Click the Buy button to enter the shop purchase interface.	Pass
View mission journal	Go to the bulletin board and press E, the mission journal will appear.	Pass
View mission details	In the mission journal interface, view the mission details by click the selected mission according to the mission status.	Pass
Cancel mission	Click the Cancel button on the detail interface to cancel the mission. The mission also disappears in the mission list.	Pass
Exit mission journal	Press E again near the bulletin board or press ESC to exit the mission journal.	Pass

6.1.3 Performance Test

The performance of the game tests the occupancy of CPU, GPU, and memory. Table 6.4 states the statistical data of performance occupancy as the testing result.

Table 6.4 Performance Test Result

Average CPU Occupancy (%)	Average GPU Occupancy (%)	average Memory Usage (MB)	Maximum Memory Usage (MB)	Average Frames (frames/second)
28.7	65.0	203.5	210.1	59.57

As can be seen from the above results, the CPU consumption of this project is low. Due to the large number of map resources, GPU has a high occupancy rate, but it has not reached the upper limit of PC performance. Memory usage is low and relatively stable. In terms of the frames number, the upper limit of PC performance is not used at all, only reaching the maximum value of exporting settings, which is approximately 60 frames per second.

6.1.4 Result

From the result of the functional test, the game's various functional use cases passed the test correctly, and no individual function causes game bugs. All operations of the player can respond ideally, and every function realization is carried out as expected.

In the performance test, this project does not use the game graphics which consume high PC performance and can run smoothly on the PC.

6.2 Usability Test

6.2.1 Methodology

The prototype is evaluated mainly based on the user experience. Each user participating in the test needs to read the Readme file before playing the game. This document first introduces the game background and operations to prevent players from getting confused after entering the game. Besides, this file lists three functions that players need to evaluate. After reading the Readme file, players can experience the game and try the functions that need to be tested. After that, they will be provided with an online questionnaire and asked to fill it out truthfully. Finally, the data from the questionnaire will be collected and analyzed.

The questionnaire can be divided into two parts. The first part is about the game itself, including game difficulty and game playability. The second part is about environmental protection awareness. The collected data are mainly analyzed through graphs.

The target group of the game test is young people with an English ability. All tests were conducted online.

6.2.2 Result

There are 10 people participating in the evaluation of this game. Seven of them have rich experience in 3D video games, and the other three have less exposure to the game.

The first question in the questionnaire is about the difficulty of the game's operation. As shown in Figure 6.1, 90% of people think that the game is easy to operate. Only one person feels that it is a little challenging in operating, but not painful. Thus, the operation of this game is in line with most video games, and even people who are not familiar with games can quickly master it.

Is this game easy to operate?
10 responses

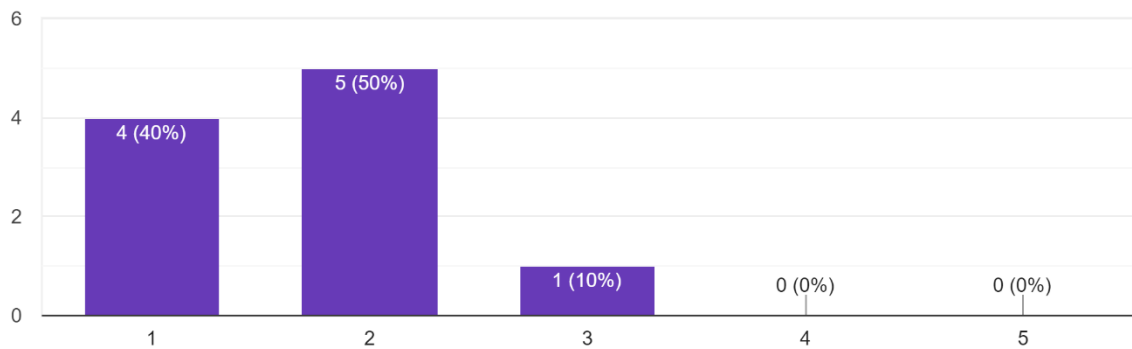


Figure 6.1 Operation Difficulty

As for the difficulty of finding game missions, unlike the difficulty of operation, more people think it is easy to find. As Figure 6.2 shows, it accounts for 60% of the total number. Meanwhile, there is also a person who thinks it difficult to find the mission. After analysis, there are two main reasons for the two-level differentiation of this answer. First, the mission NPC of "cleaning up the rubbishes" stands on the left-hand side of the town gate, which is very conspicuous. Therefore, even the player does not know the NPC's function, he will talk to him and get the mission, as the reason why most people think it is easy. Second, since this game does not build a mini-map system or an arrow pointing system, if the player is away from the NPC, he will miss the task and hard to find again.

Can you find the mission of the game?
10 responses

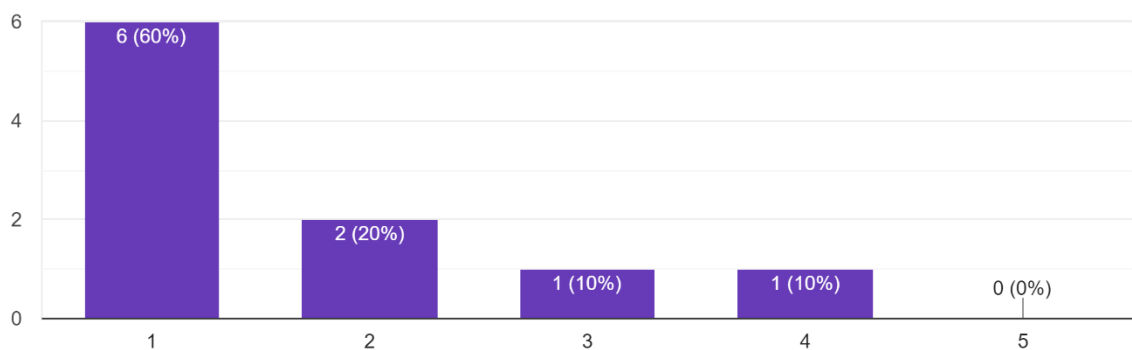


Figure 6.2 Difficulty of Finding Missions

The next question is about transition animations, such as startup movies or some action transitions. Everyone chose yes, which means more animations to improve the game experience are necessary. Section 5.5 is set up based on this question's result.

Does this game need more animations, such as introducing background information at the beginning?

10 responses

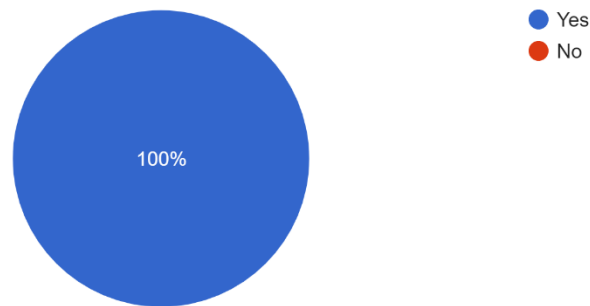


Figure 6.3 Transition Animations

The interesting level of the game has always been a problem in this game development. Besides, the maps and tasks that the player can explore are limited due to time and technical limitations. In this case, 70% of people chose level 3, which means that the game is not boring but also not fun. This game has a lot of space for improvement in the fun aspect.

Is this game interesting?

10 responses

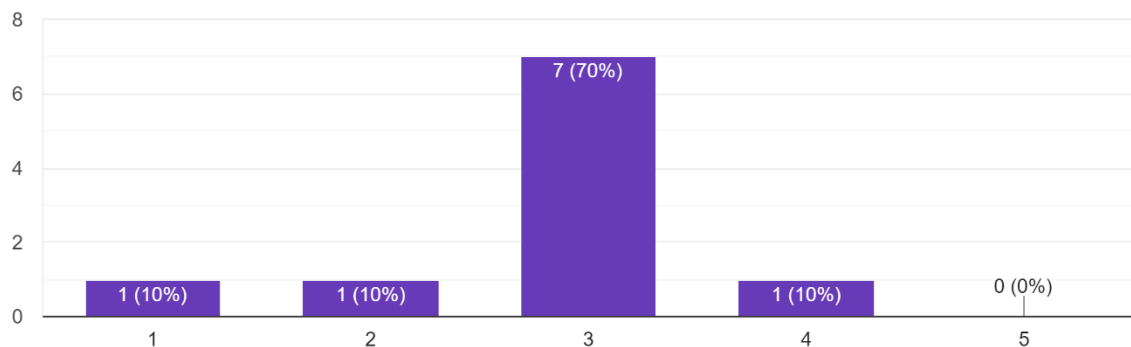


Figure 6.4 Interesting Level

Awakening up people's awareness of environmental protection is most critical parts of this game development. It can be seen from Figure 6.5 that 70% of people think that they have

inspired a bit of their environmental awareness. It is a good beginning, and when the follow-up missions are developed, more people will raise their environmental protection after playing this game.

Can you inspire awareness about environmental protection?

10 responses

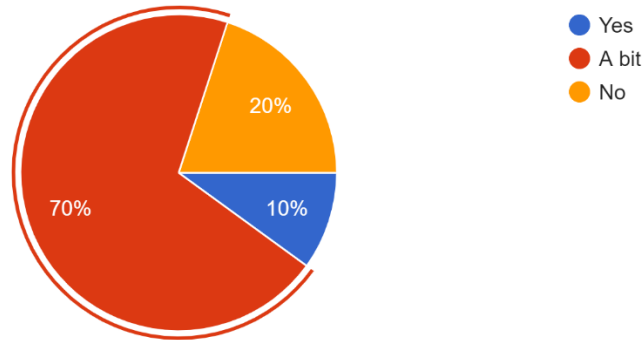


Figure 6.5 Environmental Protection Awareness

The sixth question is about game mechanics. This role-playing 3D video game mechanic is different from the traditional serious game mechanics, so how effective this attempt is essential. As shown in Figure 6.6, 80% of the testers answered “Yes” to the question of whether this type of game mechanism can raise environmental awareness among players. Therefore, this game mechanism has a lot of application space in the serious game mode. Players can bring themselves into the player character while playing the game and be immersive. Then players can better understand and remember relevant environmental protection knowledge and improve their environmental protection awareness.

Does this type of game mechanic (RPG 3D video game) give you a sense of substitution in terms of raising environmental awareness?

10 responses

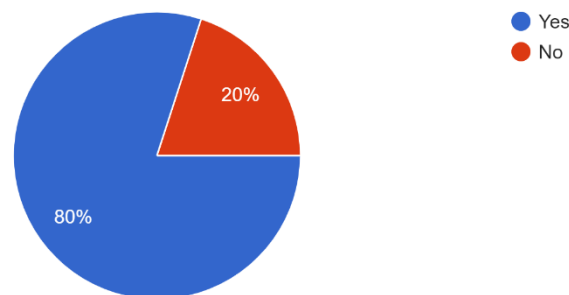


Figure 6.6 Question about Game Machanic

Furthermore, testers also gave a lot of suggestions for the game. These suggestions can be mainly divided into three categories. The first category is about some bugs during the game as follows:

1. The character running out of the map will fall forever and cannot restart the game.
2. Lights and shadows in the town are too dark, affecting the game experience.
3. If the player far away with the bulletin board when the mission journal is on, pressing E cannot close the mission journal.
4. Town leader's name is always shown in screen after the first time interacting with him.

These bugs have already fixed in the subsequent development. The second category is recommendations for existing game resources. There are three main points:

1. The sensitivity of the mouse is too high. It should be adjustable.
2. The texture of the player character and items needs to be more visual, so that the player can feel more engaged.
3. The interaction of the operation interface needs to be optimized. For example, after opening the backpack, close the backpack with ESC will be more in line with the game habits.

Some of these suggestions have already achieved, such as the second point. The rest will be implemented in the future development. The third category is for the content development in the future. Testers recommend some related games or movies which can be used as references, such as *Environmental Sword* and *Forest*. These games are complete and interesting, which can attract players to play. Besides, testers also hope to add more missions to enrich the game to implement the theme of raising environmental awareness.

Overall, this game runs smoothly and performs well. Its operation is relatively simple. Both experienced gamers and people who are new to the game can quickly master it. Players can complete the game content under the guidance of the game. They can feel fun in the virtual experience and realize the importance of protecting the environment. Meanwhile, this game also needs improvement, which will be detailed in the limitation section of the next chapter.

7 Conclusion and Outlook

This chapter gives the review, limitation, and outlook.

7.1 Review

This thesis first introduces the development tools of this game and the issues related to environmental protection. Then, it analyzes the design and concept of this game in detail, including the game's mode, the world view of the game, and the design of each mission in the game. The second part of the thesis starts with the implementation of this game. Based on the concept design, the realization of game maps, shop systems, and the mission of "cleaning up the rubbishes" is principally valued. Finally, the game was tested in three aspects: functional test, performance test, and usability test.

Regarding game development, it is an iterative and tortuous process. Even if a complete and detailed design is set in the early stages of game development, various problems will appear in practice. Developers need to make repeated attempts to determine the most suitable solution. Simultaneously, a small mistake in the development process may cause the entire game to fail. It is crucial to master the debugging technology.

This thesis has researched environmental protection issues and made an essential analysis of MSW and deforestation. Mini-games are designed as several missions. These missions help to educate players about the environment's cycle of life. The final test results of this game are excellent. The game runs smoothly and the functions are completed. Players can quickly grasp how to operate the player character and complete the novice mission. Meanwhile, the role-playing 3D video game mechanism performs well in serious games. Players can wake up and raise their environmental protection awareness through playing games.

As the above contents show, the goal of this thesis is achieved.

7.2 Limitation

The limitations of this thesis are mainly listed in the following three aspects:

Limitations in **research phase**:

1. UE4 has many great features waiting to be learned.
2. Research on environmental protection issues need to be strengthened. For example, the hotly discussed environmental topic Sea Level Rise can be studied and applied to this game.

Limitations in **implementation phase**:

1. Due to the limitation of personnel, the game art is mainly obtained from the UE4 Marketplace and needs to be improved.
2. Due to the limitation of development time, the mission of "cleaning up the rubbishes" is principally concentrated. More and more interesting environmental protection related mini-games can be added.
3. The blueprint system has certain limitations, and C ++ is required for expansion and optimization.

Limitations in **evaluation phase**:

1. The samples for game performance test are too few.
2. Usability test samples are a little less.
3. Usability test can be improved by testing face to face, recording the test environment and testers' performance.

7.3 Outlook

In the future, some improvements could be taken into consideration. Developers can search more in environmental protection issues and apply them in this game. And developers can improve the artistic aspects of the game to make the style more uniform. At the same time, developers should continue to learn the relevant knowledge of Unreal Engine, including the c ++ programming language, which helps to develop games better. The focus of the next phase should be to improve and complete the designed missions to make the game more game-oriented, as well as the theme more apparent.

Acknowledgments

My sincere thanks go to my supervisor Anthony Fabio for supporting and guiding me on this thesis. I am a relatively unconfident person, and Mr. Anthony is a very cheerful and talkative person. What I got from him was not only many constructive advices, but also confidence and expression.

I would also like to offer my thanks to for students in environment major. The discussion with them inspired me on the theme of this thesis. I hope more and more people can value and protect the environment in the future.

Moreover, I am grateful to testers who are willing to experience my game and give suggestions. Their valuable suggestions are indispensable for my game's improvement.

In addition, I would also like to thank the predecessors who have mastered the UE4 technology and shared their experiences. Under the guidance of their books and videos, I can gradually complete this game

Special thanks go to my beloved parents, Hongwei Wu and Guohong Yu, as well as my little sister Qinyuan Wu. Thank them for supporting me and encouraging me during this hard time. Their love made me not alone during the isolation of the coronavirus at home.

This bachelor thesis, as my first "academic article", really tortures me a lot these days. In the process of struggling with it, I gradually got used to thinking from an academic perspective. I wish I would keep thinking and do better research in my favorite field.

Thank you all from the bottom of my heart.

Appendix A - List of figures

Figure 2.1 GitKraken Boards	7
Figure 3.1 Interactions between the 4 Spheres [18]	9
Figure 3.2 Waste Management Hierarchy [21]	11
Figure 3.3 Management of MSW in the United States, 2017 [22]	11
Figure 3.4 the Power of Trees [23].....	12
Figure 4.1 World View of <i>Fallout 1</i>	16
Figure 4.2 Bulletin Board in <i>Monster Hunter: World</i>	17
Figure 4.3 Town Map.....	18
Figure 4.4 Flow Chart of Mission "Cleaning Up the Rubbishes"	19
Figure 4.5 Flow Chart of Mission "Controlling Water Pollution"	21
Figure 4.6 Flow Chart of Mission "Planting Trees".....	22
Figure 5.1 Town Gate's Blueprint	24
Figure 5.2 Level Blueprint _ Event Tick.....	25
Figure 5.3 Low Poly Style [25]	26
Figure 5.4 Detail signs for Fish Shop and Blacksmith Shop.....	27
Figure 5.5 Player Character.....	27
Figure 5.6 Shopkeeper's Viewport (Shakes Slightly while Standing).....	28
Figure 5.7 Shopkeeper Purchase Interface	29
Figure 5.8 Shopkeeper Sale Interface.....	30
Figure 5.9 Player Inventory Interface.....	31
Figure 5.10 Message Shown from Town Leader	32
Figure 5.11 Mission Template.....	33
Figure 5.12 Pollution Rate.....	34
Figure 5.13 Mission List	34

Figure 5.14 Mission Journal	35
Figure 5.15 Startup Movie.....	36
Figure 5.16 Level Blueprint: View Conversion	36
Figure 6.1 Operation Difficulty	41
Figure 6.2 Difficulty of Finding Missions.....	41
Figure 6.3 Transition Animations	42
Figure 6.4 Interesting Level	42
Figure 6.5 Environmental Protection Awareness	43
Figure 6.6 Question about Game Machanic	43

Appendix B - List of tables

Table 2.1 Common Widgets.....	5
Table 6.1 Test Platform and Tools	37
Table 6.2 Shop System Cases Test.....	38
Table 6.3 Mission System Cases Test	38
Table 6.4 Performance Test Result	39

Appendix C - User Questionnaire

Kyouko's Game

**Required*

1. Is this game easy to operate? *

Mark only one oval.

	1	2	3	4	5	
Easy to operate without reading instructions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Even if I read the instructions, I do n't know how to operate.

2. Can you find the mission of the game? *

Mark only one oval.

	1	2	3	4	5	
Easy to find what to do	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	I don't know what I can do

3. Does this game need more animations, such as introducing background information at the beginning? *

Mark only one oval.

☐ Yes

☐ No

4. Is this game interesting? *

Mark only one oval.

	1	2	3	4	5	
Attracting me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Really boring

5. Can you inspire awareness about environmental protection? *

Mark only one oval.

☐ Yes

☐ A bit

☐ No

6. Does this type of game mechanic (RPG 3D video game) give you a sense of substitution in terms of raising environmental awareness? *

Mark only one oval.

☐ Yes

☐ No

7. Are there any suggestions that can be used in environmental protection games? For example, what can be an interesting mission? *

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