Serious Game for Fire Safety Evacuation Training

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Abstract

This dissertation thesis presents research aimed at the process of creating a fire safety evacuation training serious game, containing serious (learning) and entertainment game mechanics with a methodology for achieving a balance between the two components. The proposed methodology was applied through a reinforcement machine learning algorithm implemented on artificial intelligence characters within the game and dynamically modifiable difficulty adjusting according to the player's performance. By utilising this approach, players were placed in different parts of the building, and were able to follow the actions of the AI, in this way learning evacuation procedures more effectively and choosing the optimal path faster. Due to the time constraint and development complexity, some features were not fully implemented and, in the future, it is recommended that they be added as an improvement. Additional functionality can be also added to the prototype as requested by the target audience and maintenance can be carried out regularly to ensure bugs do not appear and the system is kept up to date with the fire evacuation procedures. The methodology and project management taken resulted in the successful completion of the report, with the main aim of creating a serious game for fire evacuation training achieved, and recommendations prior to future work made for the prototype's release. The project and the report have been finalized and the research questions have been addressed. In conclusion, the prototype supports the University of West of England community by fulfilling its main aim of providing a fire evacuation training game in the library.

Video Demonstration - https://youtu.be/Z_Hp7SIDw08

Table of Contents

List of Tables

List of Figures

Acknowledgements

I would like to thank all the people who supported me while writing this master's project - my supervisor Nikolaos Ersotelos for their time, guidance and assistance with the development of the project and my family members and friends for their encouragement to continue working on this project until the end.

Chapter 1

Introduction

1.1 Problem Overview

In most countries it is mandatory to have emergency evacuation plans and drills for public buildings. When it comes to safeguarding safety and protection in times of crisis, their importance cannot be overstated. However, it is difficult to have the time and financial resources required to perform a drill and train participants. In this case, serious games can be used as a tool for training, planning and evaluating emergency plans.

The University of West of England is composed of three campuses, where fire drills are carried out regularly. While students and staff members are not required to participate in emergency drills, this may result in difficulties if an emergency occurs in the future. This project aims to provide a solution for training fire evacuation behaviour by analysing data from multiple sources, choosing a suitable methodology, showing the process of designing and implementing an artefact and critically evaluating all aspects of the project's outcome.

Since time is a serious constraint, for this dissertation thesis, the University of the West of England's library will be considered. The chosen building is large, with multiple exits and staircases which must be examined thoroughly to put together a training case for the player. Based on the evacuation difficulties seen in the

University of the West of England and several universities, the project has been created in a generic way to help in training the user's evacuation skills. The floor plan and assets applied in the game are similar, as the building's architecture is common across universities.

1.2 Learning Objectives

First, it is mandatory to define the learning objectives of the project prior to the development of the game mechanics. The learning goal of this project is to train the evacuation skills of participants in a fire event at the University of the West of England Library by:

- Adopting fire evacuation behaviour by teaching players to follow the fire evacuation signs.
- Activating the fire alarm
- Avoiding fire
- Using the fire doors when evacuating, practicing closing them to contain the fire inside the same room.
- Using the stairs when evacuating, not using the lift
- Leaving the building immediately, without collecting any belongings
- Asking the staff for assistance – for players with mobility issues.

The before-mentioned learning objectives will be achieved by applying game mechanics accordingly and teaching the player how to utilise them.

1.3 Project Questions

Overall Research Question

How existing serious game development methodologies can enhance the learning experience of the staff and students to evacuate the library building in case of fire by following the indicated instructions?

Sub-research Questions

- What serious game mechanics, found in background research can be used for a fire safety evacuation training game?
- How did previous work gamify learning features of a serious game so that the player is engaged and finds the game entertaining?
- In existing research, how do projects achieve a balance between serious and entertainment parts in a serious game?

1.4 Aims and Objectives

The aim of this dissertation is to create a serious game for fire evacuation training.

The project objectives are:

- Choose topic and submit dissertation proposal
- Literature review write-up
    - Research relevant literature
    - Analyse existing game development methodologies for improving student and staff learning experience in fire evacuation training scenario
    - Describe the main research themes, with their advantages and limitations
    - Identify game mechanics related to the project methodology
- Prototype Development Process
    - Identify the requirements from the literature
    - Choose a prioritization approach and classify the requirements
    - Describe the game and system architecture

    - Produce design documentation (game flow, use case diagrams, graphical user interface style, user interface mock-ups)
    - Describe each requirement's implementation
    - Provide instructions for the prototype's deployment
    - Include screenshots of the prototype
- Evaluate all aspects of the project development against:
    - Aims and objectives
    - Learning objectives of the prototype
    - Functional and non-functional requirements
    - Development tools
    - Methodology and project plan
- Conclude the project
    - Give an overview of the project's outcome
    - Restate the aims and objectives, how they were achieved, and how well they were satisfied.
    - Make recommendations prior to future work
    - Personal evaluation

1.5 Target audience

This project is targeted towards University of the West of England students and staff members who visit the library and are interested in training their evacuation skills in case of a fire event.

1.6 Privacy, ethical, social and professional issues

The prototype will not require any human participation unless a decision is made in the future to evaluate the game, using a questionnaire or user testing. If personal data is involved in the game, it will be stored in a database and an Ethical

Review Application Form will be re-submitted. The data will be handled with care and respect to the legal guidelines in the EU General Data Protection Regulation (Goddard, 2017). Therefore, currently, the project will not raise any privacy, ethical, social, or professional issues.

1.7 Structure Overview

- Chapter 1 - Gives an overview of the problem, the overall and sub-research questions, aims and objectives, target audience, ethical, social and professional issues and a brief summary of the report structure.
- Chapter 2 - Literature Review - Literature related to methodologies for improving student and staff learning experience for fire evacuation training is researched. The main themes of the research are indicated, with their advantages and limitations and a critical analysis of published research papers/books is made with a comparison to new research contributions. Additionally, game mechanics associated with the chosen methodology are investigated and critically evaluated.
- Chapter 3 - Prototype Development Process - Determines the requirements elicited from the literature review and groups them based on a prioritization technique. Specifies the game and system architecture and explains how the research questions were addressed. Presents the design documentation from the aims and objectives section and describes the development process of the prototype from beginning to end, with deployment instructions and prototype screenshots.
- Chapter 4 - Evaluation - Evaluates the prototype against the aims and objectives of the project, learning objectives, the requirements, methodology and the project plan. The utilisation of the development tools applied for the system is analysed.
- Chapter 5 - Conclusion - Gives an overview of the project's outcome. Reflects on how the project's aims and objectives have been achieved including limitations, proposes recommendations prior to future work, and

provides a personal evaluation.

1.8 Chapter Summary

This chapter has introduced the problem, learning objectives including the research questions, the project's aims and objectives and other important aspects to the development of the prototype such as the target audience and the privacy, ethical, social, and professional issues. To inform the reader of the dissertation thesis's structure, a brief description was given of each chapter.

Chapter 2

Literature Review

This section will investigate the advantages and limitations derived from the existing literature related to methodologies for improving student and staff learning experience for fire evacuation training. For this dissertation, popular databases in the game development field were searched, such as IEEE Xplore, ACM Digital Library, and Google Scholar. The initial search comprised the keywords serious games, evacuation, and training displaying 16,300 results from which the most relevant ones to the development of the prototype were selected. To determine a methodology for this dissertation thesis, the terms artificial intelligence and reinforcement learning were added to the keyword ”evacuation”, and papers were filtered based on their advantages, limitations, and publication date.

The content was grouped into multiple sections, starting with an introduction to serious games and a brief overview of their benefits in a fire evacuation training scenario. The second paragraph outlines the methodology used for the prototype’s creation - the combination of the serious and entertainment parts, vital for the creation of a serious game. The next two sections describe the respective partitions in detail, and how balance will be realised through the implementation of a machine learning algorithm and game difficulty modification. Common topics among papers were focused on decision-making under stress and the use of artificial intelligence machine learning algorithms.

2.1 Serious Games

According to Perez et al. (2023), games have existed in all human societies and many other animal species. Whilst the oldest board games, such as Go, Backgammon, or Checkers, are still played nowadays, video games have become one of the most popular forms of entertainment. However, games have also had intentions and benefits beyond entertainment such as learning new skills, conveying values, or awareness-raising.

Serious Games are currently heavily used for military, emergency services, and corporate training as gamification of risk communication and particularly decisions related to natural hazards is an effective way to communicate the issues and motivate learners (Hawthorn et al., 2021). As an example, serious games have been successfully used for conveying risks and training behaviour in case of earthquakes. In this instance, Feng et al. (2020) worked on developing an immersive virtual reality serious game for earthquake emergency training, aiming to help players acquire skills that align with best practises for immediate earthquake response and post-earthquake evacuation. Another example is De Carvalho et al.'s work (2022) presenting a serious game related to fire evacuation in public schools, which improved students' knowledge on how to behave in case of fire and contributed towards a positive fire safety culture in schools.

The research undertaken shows that a serious game for training evacuation skills is a viable solution. However, the main challenge in developing a serious game is to strike a balance between entertainment and skills or such that neither ends dominating (Dorrigiv, 2021).

2.2 Serious Game Components

Barbosa et al. (2014) state that the player has to feel that he is playing a game where the learning is only a consequence of the playing actions. Otherwise, the game is not viewed as an engaging activity. High-quality serious games must achieve both aspects: they must systematically support players to reach the characterising goal ("serious" part), and they must elicit and maintain the player experience ("game" part). Furthermore, both parts should be perfectly matched and integrated rather than be addressed in isolation (Murti et al., 2019). In the next sections, the quality criteria for serious games are discussed, considering both aspects of the serious and the entertainment parts and the balance between them.

Educational Part (Learning Mechanics)

According to Caserman et al. (2020), there are several elements that the game developer should consider during the design process of a serious game. The first element of the serious part is to characterise the goal of the learning objectives by making it the focus of the game. The second one involves adopting appropriate methods for achieving the goal by presenting learning content in a meaningful way, using appropriate interaction technology (visual display, speakers, and controllers), ensuring the game is responsive by avoiding critical errors causing a crash, remaining neutral on political and social issues, providing feedback on user progress, and giving rewards. Other important aspects are intuitive game mechanics, natural mapping of keys, and learning/training process that is not simplified due to technical features. The last element is ensuring the quality of the serious game developed by showing the goal is achievable and that the learning effects are sustainable. In addition to the learning objectives of the serious game, it is essential to identify all the goals that may be obtained (e.g., raising awareness, supporting motivation, learning new skills) (Catalano et al., 2014).

Entertainment Part (Game Mechanics)

Good game design not only includes attractive graphics and great sound effects but should also ensure player experience and complete game flow containing a game won/lost state. To improve player experience and immersion, development teams need to pay special attention to aesthetic features, gameplay, core mechanics, and level design (Rahimabad and Rezvani, 2020). Possible game features include player performance assessments and challenges.

Williams-Bell et al.'s (2015) studies and reviews suggest that game-based learning is effective for motivating and achieving learning goals. With the advent of recent technological advancements, it is possible to extend and improve assessment by keeping track of players' in-game performance. In-game assessment is valuable given that it is integrated into the game logic without breaking the player's game experience and provides immediate feedback and implementation of adaptability.

Setting up clear goals, followed by techniques to collect player data can be done to assess the player's performance in the game (Bellotti et al., 2013). In Capuano et al.'s (2015) virtual reality game any action is evaluated by the system and player feedback is provided by performing action-based assessment. Additionally, the value of each action done by the player is estimated depending on the time spent to complete the evacuation, and the player is checked whether they successfully evacuated within the time limit.

At the heart of each game is a hidden reward system that establishes communication with the player and gives rewards to persuade them to continue playing (Borna et al., 2018). In Ribeiro's work (2013) challenges were evident to be efficient in training the player's evacuation behaviour. They can be added to the game, with a scoring system showing the time taken to evacuate from the building. Authors Barbosa et al. (2014) who developed a serious game with challenges show that the audience liked to play the game and considered it addictive.

2.3 Balancing Tools (Mechanics)

Artificial Intelligence Methodologies

Computer games have been associated with artificial intelligence since the creation of the first programme designed to play chess by Shannon (1993). Nowadays, the development of new generation serious games still requires the exploitation of this type of advanced technology as its widely used across serious games. Modi et al.'s study explores more than 100 journal articles and web articles related to the use of artificial intelligence-based gamification. An applicable example of adding artificial intelligence to this scenario is found in De Fino et al.'s work (2023), where the AI characters are programmed to move to a specific location for the purpose of evacuation. However, further development in machine learning algorithms is required to understand human behaviour in case of emergency as few existing works focus on the evacuation of a small number of agents (Liu et al., 2023).

Machine learning techniques, particularly reinforcement learning, are an excellent learning approach for studying evacuation. The algorithm can produce anticipatory behaviours, which are useful in crowd simulation, intelligent control, analysis, and prediction. These behaviours help address sequential decision-making problems (Bahamid et al., 2022). Another efficient method is deep reinforcement learning, which enables modeling an evacuation scene, gathering real-time data like crowd distribution and disaster location, using a path-planning algorithm to determine the best escape path, instigating movement through dynamic guidance signs, and enhancing evacuation efficiency (Gu et al., 2023). However, this technique will not be considered for the implementation of the AI characters as it is used for large-scale evacuation drills, whereas the prototype is not planned to include a large number of AI characters due to the time constraint, which makes reinforcement learning the preferred approach.

In Ünal et al.'s learning model (2022) it is shown that reinforcement learning is applied to a pre-defined environment and the agents are set as the evacuees, who have evacuation directions as actions. An algorithm that can be utilised in this scenario is the Q learning algorithm, which has a tabular structure consisting of states and actions and is widely used in the path planning of agent evacuation (Gu et al., 2023). For this project, by combining spatial and reinforcement learning variables, realistic evacuation will be simulated during an emergency, and the player will be supported in making the right judgment in case of panic, to be able to choose the optimal path when an emergency event such as a fire occurs.

Modifiable Difficulty

Since human nature and individual differences are complex, an objective and systematic assessment of learner behaviour and performance in serious games remains difficult. To have an impact, serious games must extend to cover a larger field than traditional games by tailoring the game experience depending on the player's performance. Ruffino et al.'s (2018) simulation and serious game for fire evacuation training presents four different levels of difficulties. Through their implementation, users were trained in the position of fire exit stairs and firefighting equipment. Additionally, they identified alternative evacuation paths effectively and managed their emotions during the scary situation.

Daylamani-Zad et al.'s paper (2022) states that decision-making is greatly affected when the player is under the influence of a high level of stress. Williams-Bell et al.'s work (2015) also verifies this claim by stating that stress can have a negative impact on situations of vigilance such as natural disasters, which can be life-threatening, as they require a person to make decisions in quick succession to avoid catastrophic consequences. Therefore, it is apparent that making decisions under stress can and often leads to undesirable results like increased distraction and prolonged reaction time due to hurried decision-making. Consequently, making decisions under stress can be trained on by the scoring and the difficulty modification system in the game, which will encourage the player to perform better and evacuate faster.

2.4 Chapter Summary

In conclusion, building on the benefits reported in the research, this work presents a serious game that is aimed at creating a balance between the game and the simulation with a scenario that represents the real world and provides player performance assessment, in-game challenges, artificial intelligence characters implemented with the Q learning algorithm and different difficulty levels, set with a threshold that will adjust according to the player performance. By considering the challenges to the development prior to the prototype creation, the game would allow for more accurate simulation features and player assessment, resulting in the player gaining deeper insight into fire safety evacuation training.

Chapter 3

Development Process

3.1 Organisation and Prioritisation of the requirements

As all requirements in this project are not of the same importance, and their complexity varies, there is a need to prioritize them so that the developer can find out which requirements have high priority and need to be implemented in the current version. For this project, the MoSCoW prioritization technique which is widely used by analysts and stakeholders, will be applied to classify the requirements. Jahan et al. (2019) states that in the MoSCoW mechanism, the list of requirements can be classified into four priority categories, found in Table 3.1.

Requirement	Description
M: Must have	The most important requirements that must be implemented in the release.
S: Should have	Requirements that are high priority but can be implemented in the next release.
C: Could have	Desirable requirement, but not necessary. Can be implemented in the next release.
W: Will not have	A requirement that will not be implemented in the current release but could be considered in the future.

Table 3.1: MoSCoW prioritization technique

The functional and non-functional requirements identified from the literature research are described in Table 3.2 and 3.3, with their purpose and priority based on the chosen prioritization technique. The features that were mandatory for the project's success or required to be implemented first were set as a "Must have" priority, while the ones that could be implemented in the next version were appointed as "Should have" and "Could have" priority.

Feature Number	Feature	Purpose	Priority	Citation
F-1	Core Mechanics	Defines the basics of the gameplay and the interaction technology (visual display, speakers, controllers).	Must have	Caserman et al.'s work (2020), Rahimabad and Rezvani (2020)
F-2	Game won/lost state	The game can be won/lost by achieving a goal. The goal of the learning objectives is well-defined and contributes towards the serious part. The game flow will be complete, and the player's performance is evaluated when the game is won/lost.	Must have	Rahimabad and Rezvani (2020)
F-3	Player's performance assessment	With the help of a scoring system, the player's performance is assessed when the game is won/lost based on the player's data, and immediate feedback is provided. Decision-making under stress will be improved.	Must have	Williams-Bell et al. (2015), Bellotti et al. (2013), Capuano et al.'s (2015)

F-4	Dynamically modifiable difficulty	Dynamically modifiable difficulty, set with a threshold, placing the player at various parts of the building during the evacuation. Each level will have a different difficulty, which will help in training their decision-making skills under pressure. Additionally, the users will be trained in the position of fire exit stairs and firefighting equipment, which will enhance their decision-making under stress.	Must have	Ruffino et al. (2018)
F-5	Artificial Intelligence Characters	AI characters that will move across the level on a pre-designed space. They will support the player in choosing the optimal path in case of panic through the implementation of the Q learning machine algorithm, and will show more realistic behaviour for AI.	Must have	De Fino et al. (2023), Ünal et al. (2022), Gu et al. (2023)
F-6	Challenges	Helps in training the player's evacuation behaviour. After completion of a challenge, the player is rewarded. In this way, communication is established, and they are persuaded to continue playing.	Should have	Ribeiro et al. (2013), Borna et al. (2018), Barbosa et al. (2014)

F-7	Sound effects	The sound effects will make the game more realistic and will improve the player's experience and enjoyment.	Should have	Rahimabad and Rezvani (2020)
F-8	Level Design	To improve game design, additional 3D models, and other assets such as visual effects will be added.	Could have	

Table 3.2: Functional Requirements

Feature Number	**Feature**	**Purpose**	**Priority**	**Citation**
NF-1	Learning is only a consequence of the playing actions.	To achieve a balance between entertainment and learning.	Must have	Barbosa et al. (2014)
NF-2	Learning content is meaningful and well-presented.	The player understands the game's goals and the learning process is effective.	Must have	Caseman et al. (2020)
NF-3	Responsiveness	The game is responsive to any user input, and there are no critical errors causing a crash.	Must have	
NF-4	Avoidance of political and social issues	To remain neutral on the political and social issues the game can raise.	Must have	
NF-5	Intuitive game mechanics and natural mapping of keys.	The learning process is prioritized over the technical features related to the gameplay.	Should have	

Table 3.3: Non-Functional Requirements

3.2 Development Tools

The choice of a game engine is significant to the project, as it can affect the development of the game entirely. The most popular game engines are Unity, Unreal Engine, CryEngine, Shiva and Game maker (Singh et al., 2022). According to Vohera et al. (2021), regarding platform deployment, Unity and Unreal engine are the best choice, but when it comes to visuals and animation, Unreal and CryEngine are superior. As the developer is more experienced with Unity and Unreal Engine, they were further considered, and Unreal Engine was picked out for the ease of implementation of new features and the advantage it has over Unity in visuals and animation.

For greater participation in the fire evacuation training serious game, web-based serious games can be developed, thus eliminating the process of downloading, and installing, which is beneficial for popularisation (Yang et al., 2021). However, due to the time constraint and the unfamiliarity with the technology it was decided to consider other options. Results from Murti et al.'s paper (2019) show that the PC game platform is the most popular platform compared to the mobile or console game platforms, making it most fitting for this project.

Another factor that needs to be considered to ensure player immersion is to determine the dimension of the game. Abd-Alrazaq et al.'s (2022) found that 3D serious games were slightly more common than 2D serious games. As claimed by the author, this can be explained by the fact that 3D games are more immersive and attractive to players. Since this project aims to reach a wide audience, a 3D serious game will be developed.

3.3 Game Architecture

As seen in Figure 3.3.1, a modular design was chosen for the prototype, meaning that the overall functionality of the game was separated into smaller, separate tasks. They are handled by five major components - a game engine, game interface, asset manager, state, and AI component. The game engine is crucial to the game since it is responsible for the rendering of the graphics, level action and transition, game logic containing nodes, the sound subsystem containing the sound effects, and the input/output of the devices used for the game - a mouse, keyboard, speaker, monitor, etc. Additionally, it also controls the presentation of audio and visual elements, the position of the character, user input from the UI buttons, and scene/level updates.

The game interface is represented by the level UI, main menu, the game won/lost, tutorial, and credits UI. The third major component - the game state contains data about the current state the player and the AI are in and interacting with the game engine, the AI, and the asset manager components as they are dependent on it. The organization and distribution of all game-related assets are taken on by the asset manager (Figure 3.3.1). The metadata descriptions define the context of use and the nature of the assets and are compulsory in the design as they will make the environment more realistic. Lastly, the artificial intelligence component comprises a mesh, animation, movement, and decision-making based on the Q learning algorithm, handled by the execution manager. The flow of data among the components is indicated by arrows in Figure 3.3.1, and by applying a modular design, improvements of the component features can be easily accommodated in future changes of the project.

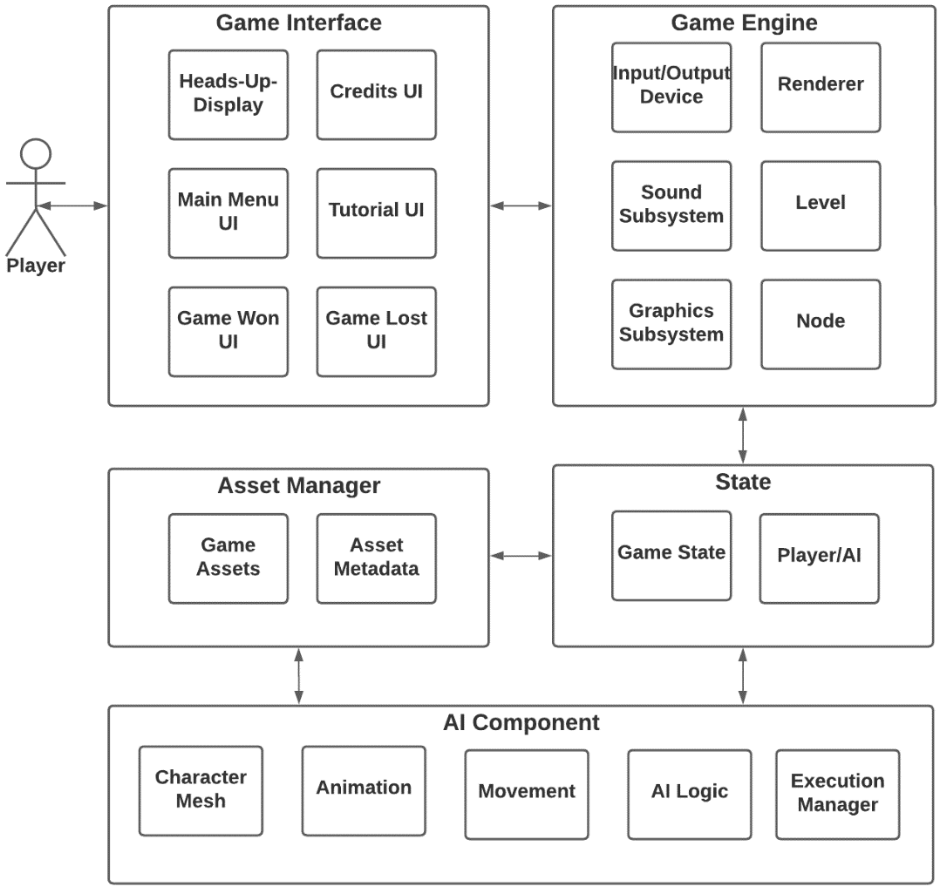

Figure 3.3.1: Game Architecture

3.4 System Architecture

Figure 3.4.1 gives an overview of how the main research question and sub-research questions were addressed in the implementation of the prototype.

Learning Part/Objectives

The learning part/objectives consist of six components – teaching players to follow the fire evacuation signs (consists of assets), activating the fire alarm (includes fire alarm actor, asset and sound effect), avoiding fire (fire visual effect with a background sound effect of the entire building burning and an additional one of when the player is set on fire will be added, resulting to the player losing health), opening/closing fire doors to contain the fire (comprises of a fire door actor and asset), using the lift (lift actor that gives the player the choice of using the lift or the stairs), collecting personal items (rucksack, laptop, and phone which will deduct the player's health on collection as a penalty as they should leave as quickly as possible) and asking a member of staff for assistance (in case the user has mobility issues).

Serious Part

The serious part includes four main components – the core game mechanics (defining the gameplay and the peripheral devices), a game won/lost state (user interface, displaying the evacuation time and giving the options of going back to the main menu, playing again, or exiting the game), a tutorial (includes multiple user interface screens), and a Heads-Up-Display (shows the player's health, timer, challenge, goal, and wins/deaths).

Entertainment

The entertainment part comprises five components - sound effects (related to a burning building, player set on fire, collected coin/personal item, triggered fire alarm), visual effects (fire), assets (2D and 3D models, character meshes), animation (for character movement) and challenges (opening/closing fire doors and triggering the fire alarm which will give a coin as a reward). Coins will contain an actor with a mesh and logic which will enable them to increase the evacuation time.

Game Balance

The game balance involves two components – modifiable difficulty, placing the player at different parts of the building depending on their wins and death count, and animated AI characters, with movement logic implemented with the Q learning algorithm for the purpose of training the player.

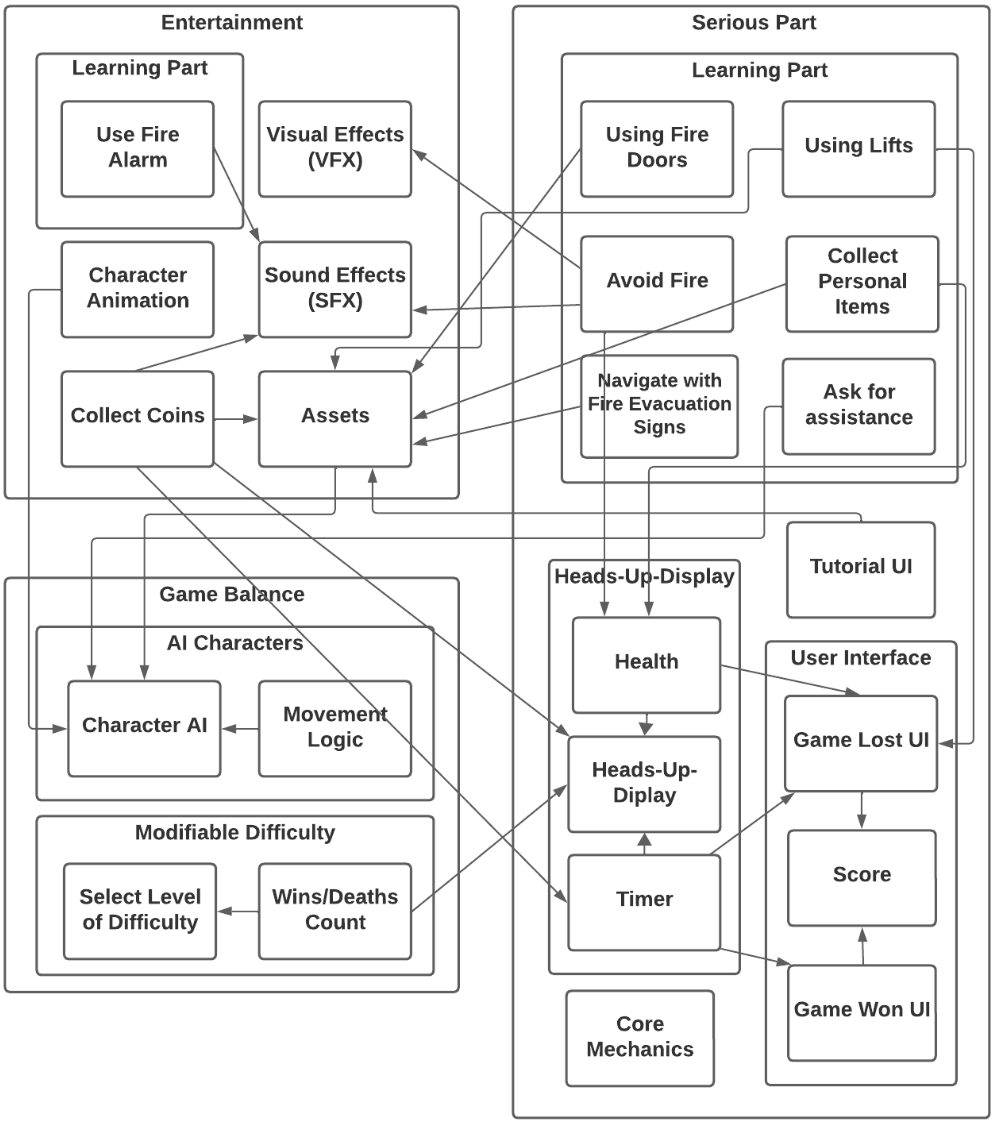

Figure 3.4.1 System Architecture

3.5 Design

The design of the system meeting the stated requirements will be described in this section, including a game flow chart, use case diagram, graphical user interface style, user interface mock-ups and prototype screenshots.

Game Flow

Figure 3.5.1 is a flowchart showing the overall flow of the game from start to finish. The game starts with the Main Menu, from which the player has the option to play the game, go to the tutorial where they can see in detail how to play the game and start the game, or they can view the credits/quit the game. For each of the user interfaces (tutorial, credits) there is an option to go back. When the user starts the game, they are set on level 2. While they are playing, the system checks whether the time has run out, if they have entered a fire, have reached a fire exit, or requested assistance.

If the player loses the game, they are displayed with the game lost user interface, and can choose from the options to play again, go to the main menu, and quit the game. In case the player reaches the fire exit, they are shown the game-won user interface, where they can select from the same options. Presuming that they decide to play again, the system checks the number of wins/deaths and places them at a level of fitting difficulty. The AI will support the player in decision-making during the evacuation and finding the shortest path to win the game.

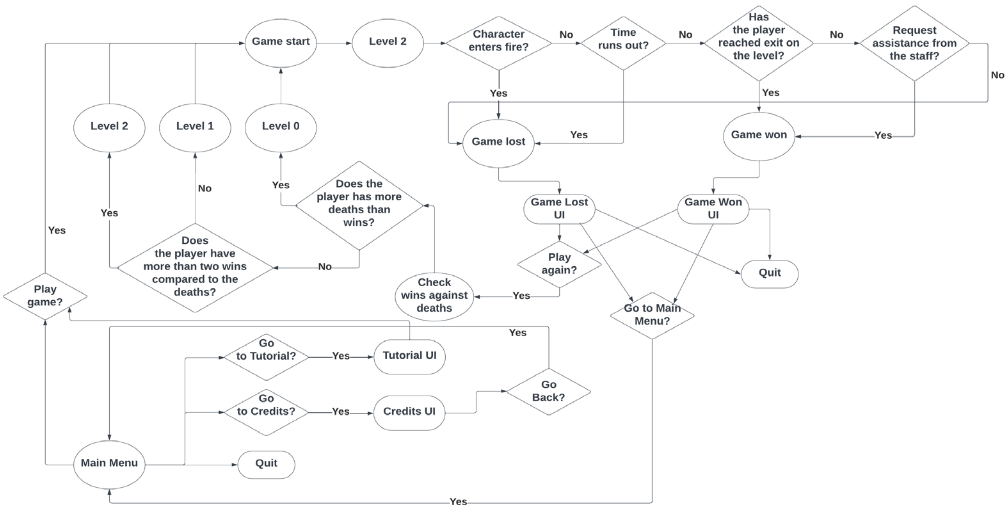

Figure 3.5.1: Game Flow Diagram

Use Case Diagram

Figure 3.5.2 displays use case diagram showing various use cases and the different types of users the system has.

The use case describes a combination of the following elements:

- The player who is the primary actor, initiating an interaction with the system to achieve the goal of evacuating through the building.
- The AI character/s is an actor that performs the behaviour of moving to a specific location, in this case, doors on levels 1 and 2. They are going to be trained using the Q learning algorithm in triggering the fire alarm and recognizing the fire door, through which they will escape.
- Preconditions to the start of the game are the main menu containing the functionality described in the game flow diagram.

When triggering the start game button, the player can access the game mechanics from the System Architecture Diagram (Figure 3.4.1). When finishing a game, if the player chooses to play again, a level is generated based on their performance (wins/deaths).

Figure 3.5.2: Game Use Case Diagram

Graphical User Interface (GUI) Style

When designing the graphical user interface, human psychology and physiology must be always considered as the colour and shape dictate the success of the game (Burke, 2021). The author claims that colour choice should be based on colour psychology theory to give the user a certain feeling when interacting with each area of the user interface. The colour selection for the buttons and the background was based on Crane's article on the psychology of using colours in games – in the UI red represents danger, green points the way to play, orange provokes the player, and blue/yellow guides them (2023). Bright colours were used to create a sense of urgency for the buttons while muted tones were applied for the user interface background to create a more relaxed atmosphere.

Font Style

While many game developers choose stylized fonts to match their game's theme, most of these types of fonts are difficult to read by players with normal vision, which prevents vision-impaired players from reading. According to Khaliq et al. (2019), a low-vision gamer will benefit from the option of switching more complicated fonts with some more basic and simplistic fonts. Consequently, for this game, a widely used font was applied - Roboto Bold, described as having a clean, geometric design (O'Brien, 2018).

The inclusion of larger font sizes in games is also recommended for users with low vision. Di Gregorio (2022) recommends that having a readable standard font size is a good starting point, with 18 pt. being advised to be used for dyslexic users. This leads to the conclusion that the most common standard font size for individuals without visual impairments is 18 points. Consequently, for the user interface mock-ups, a font size larger than the one outlined in the literature was chosen, with the smallest one being 25 points in the tutorial UI, making the prototype suitable for both dyslexic users and individuals without visual impairments.

User Interface Mock-ups

Figure 3.5.3: Main Menu

Figure 3.5.4 is an example of the primary “game won screen”. A second screen was implemented, which is shown as an output for when the player asks a member of staff for assistance with evacuation due to mobility conditions (Figure 3.5.5).

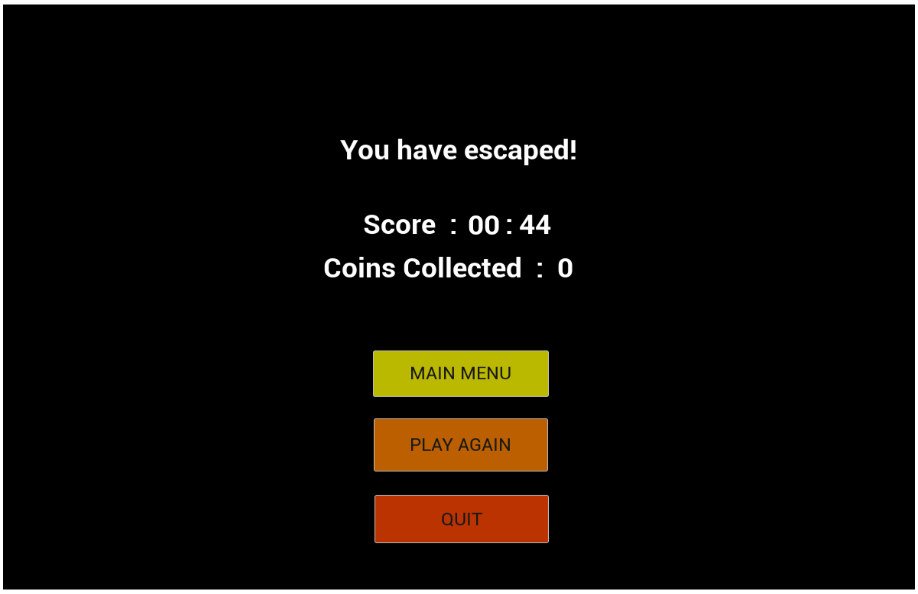

Figure 3.5.4: Game won UI

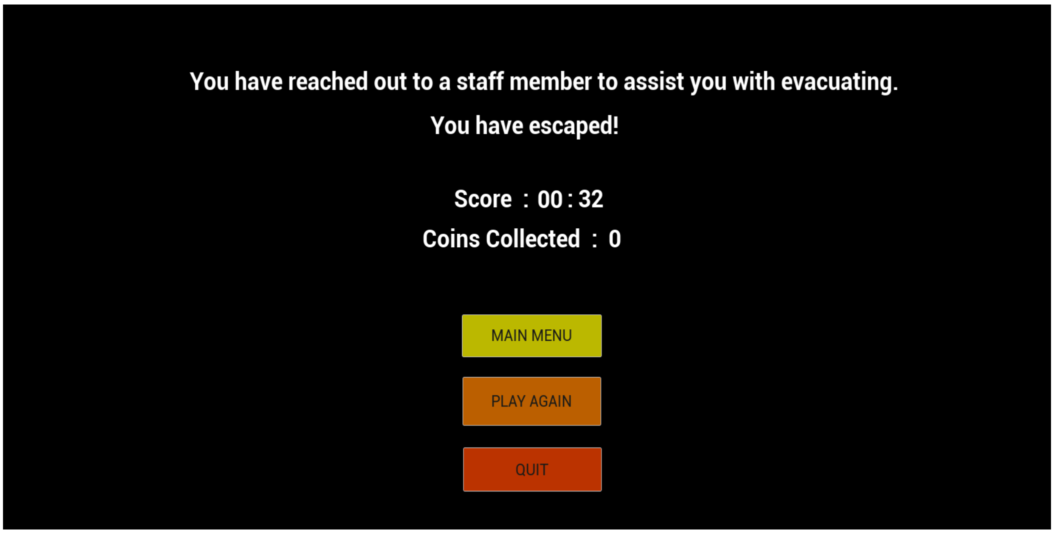

Figure 3.5.5: Game Won UI with staff assistance

Figure 3.5.6 is an example of one of the game lost UI screens, shown when the time runs out. For player set on fire and lift used, a different message was shown, giving the player information according to the learning outcome.

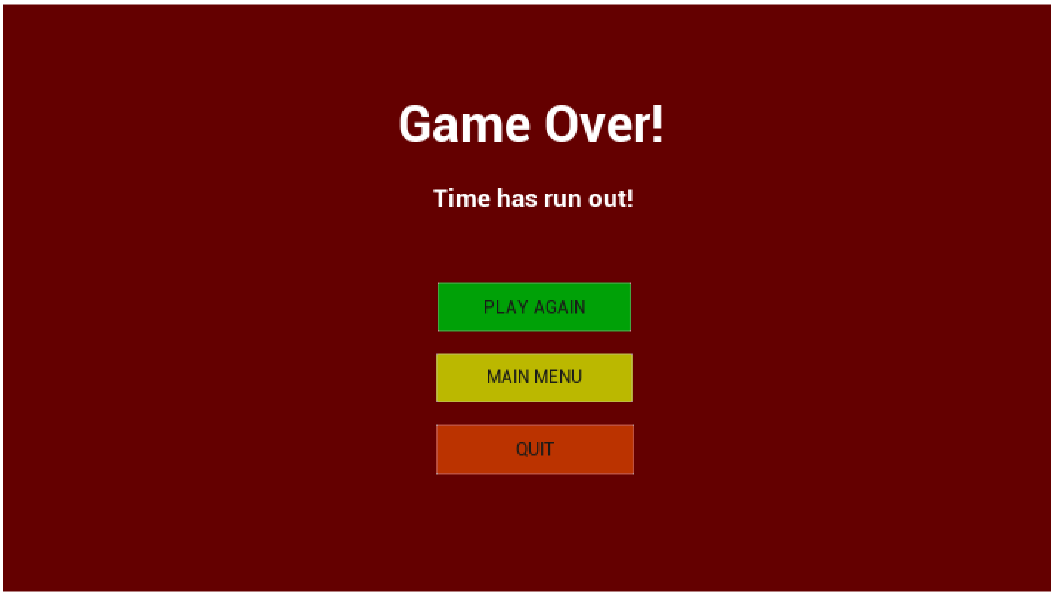

Figure 3.5.6: Example of game lost UI for time run out

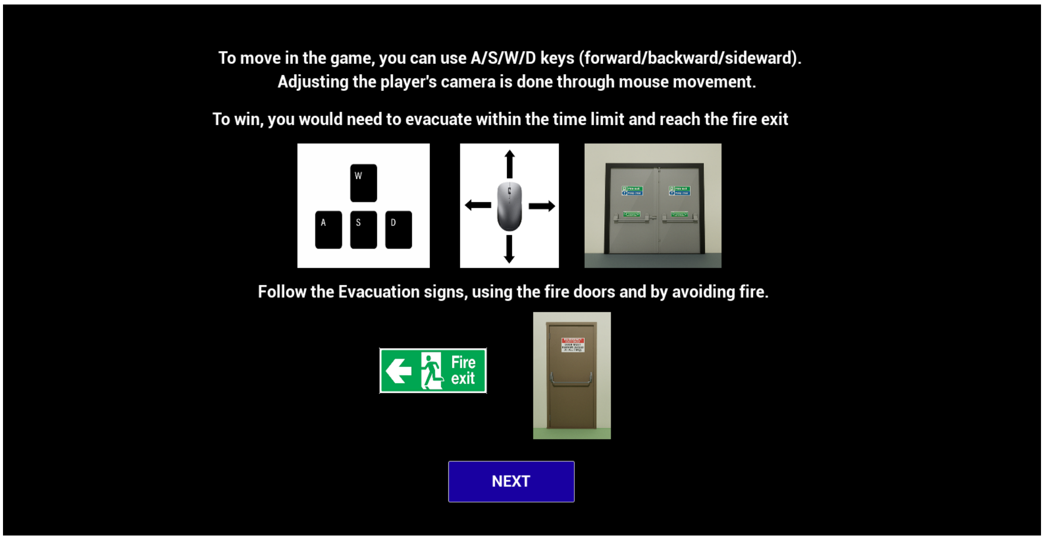

Figure 3.5.7: Tutorial UI Screenshot

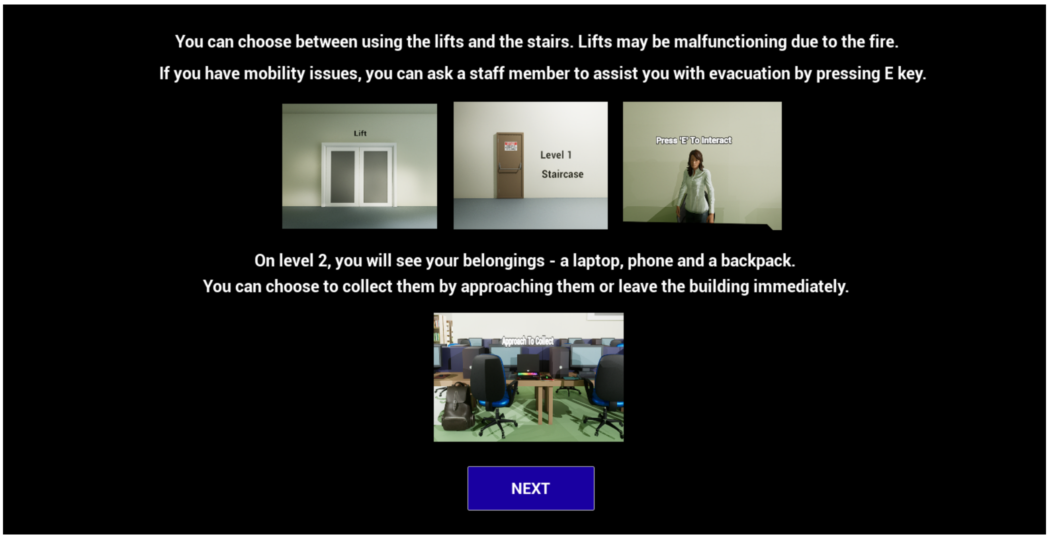

Figure 3.5.8: Tutorial UI Screenshot 2

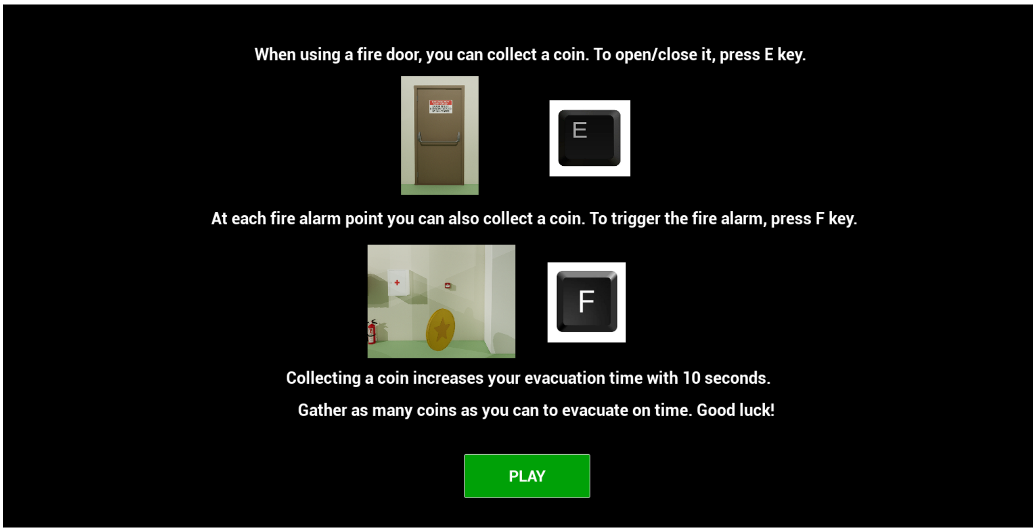

Figure 3.5.9: Tutorial UI Screenshot 3

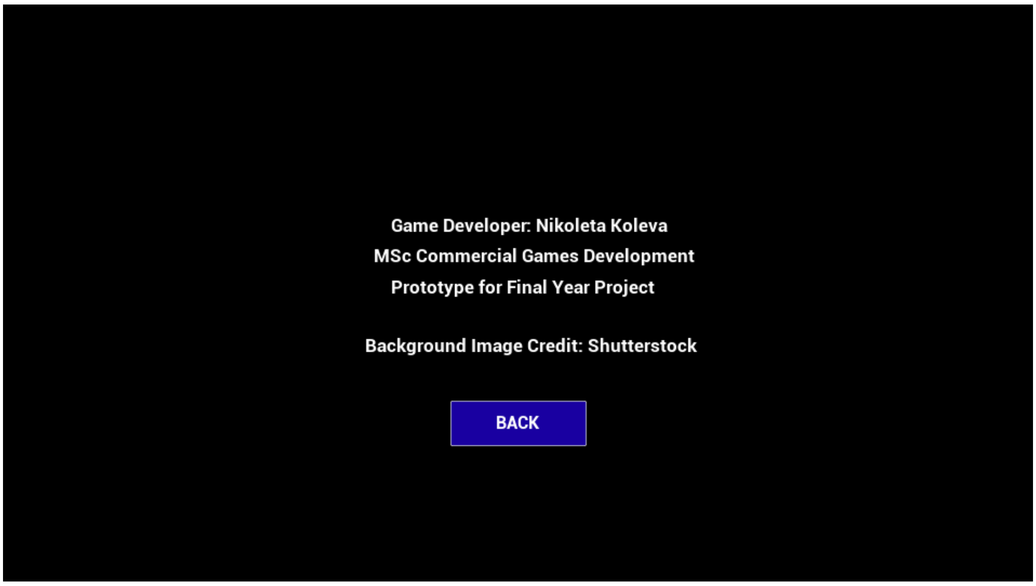

Figure 3.5.10: Credits UI

3.6 Implementation

This section documents the creation of the system meeting the stated requirements. Each of the functional/non-functional requirements was developed according to its priority from Tables 3.2 and 3.3, while also considering the learning objectives.

The project was started with an empty Unreal engine build from which all game features were developed. Firstly, the level design was created, with static meshes for the walls and floor/ceiling. To apply the floor and wall materials, it was chosen to use the materials from the Unreal Engine's starter pack (Unreal Engine 4.26 Documentation., n.d.), which can be imported for free.

Choosing suitable lighting for the environment is mandatory as it can be utilised to articulate a mood in the game. In Unreal Engine, lighting is composed of positioning directional lights, skylights, spotlights, point lights, and rect lights, out of which point lights were found the best choice (Figure 3.6.1). They emit light in all directions from a single point in space (Unreal Engine 4.27 Documentation., n.d), whereas the rest did not apply to this requirement.

Figure 3.6.1: Lighting in the project

Core Mechanics

A character class (player) was created, which includes a camera, operating in first-person view and a collider. Next, a game mode class was made, selecting the character class so that the player can spawn in the level. The basic gameplay mechanics, comprising of the keyboard and camera movement were added afterward. For greater efficiency and simplicity, the axis mappings in the project settings were used (Figure 3.6.2) since it would allow for the easy change of both mechanics in case a decision was made to switch to a different platform such as Xbox, Android, etc. As stated in the System Architecture section, the camera movement was implemented successfully using the mouse, and the character movement (forwards/backward/sideways) was mapped to the A/W/S/D keyboard keys, used widely as a standard for character movement on keyboard.

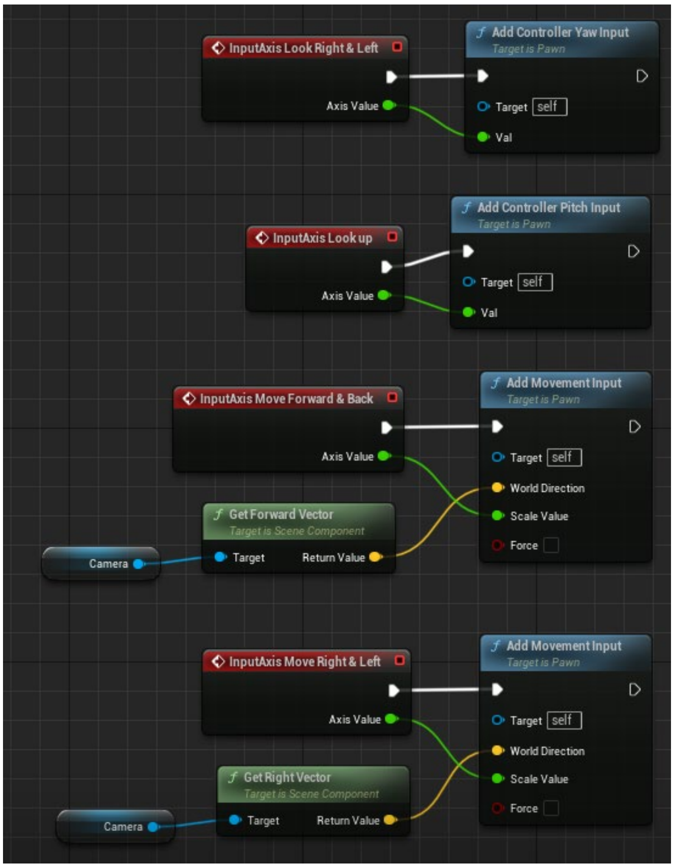

Figure 3.6.2: Character and mouse movement

Accordant to the building's architecture, on level 2 the fire exit is directly accessible through the staircase. However, level 1 has both a fire exit and a staircase leading to the ground floor. It is therefore necessary to consider level transitions when implementing the game mechanics. To implement the level transition, it is required to have a game instance class storing the variables, like the coins, wins and deaths (Figure 3.6.3).

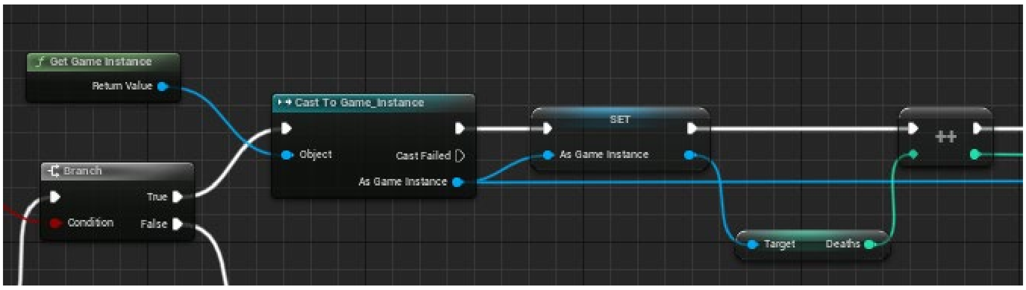

Figure 3.6.3: Setting a variable through the game instance

Game won/lost state

The game states are dependent on the timer and the fire features. The timer can be set from the character class and can be adjusted to be over a minute or less than a minute. To test the game, it was set to 2 minutes and 30 seconds.

Figure 3.6.4 shows the implementation of the timer, first checking if the number of seconds is zero, if it is not, it is decreased by 1. Then the other condition (branch) is checked, if the minutes are zero, the game increases the number of deaths by 1, displaying the game over user interface and setting the game to paused as seen in Figure 3.6.5. If this condition is not satisfied, it will set the seconds to 59 and remove 1 from the minutes, continuing until the condition is fulfilled.

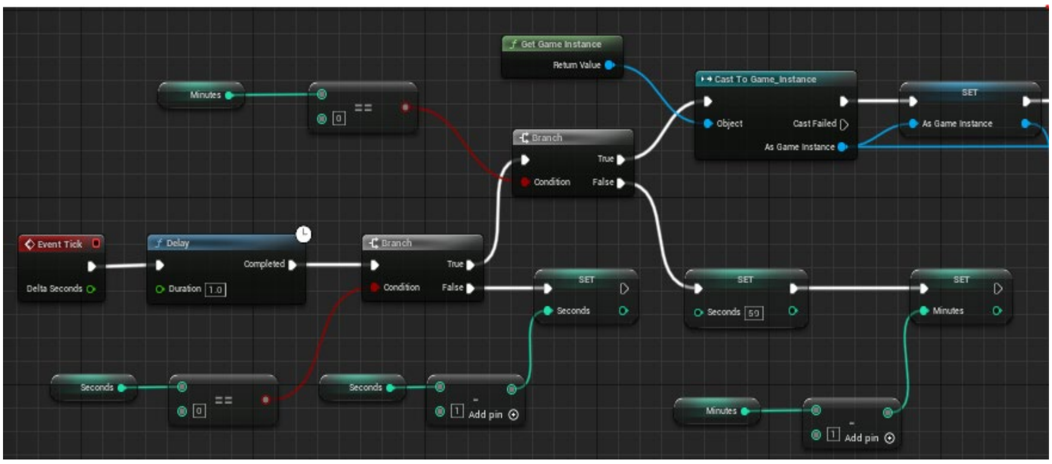

Figure 3.6.4: Timer implementation

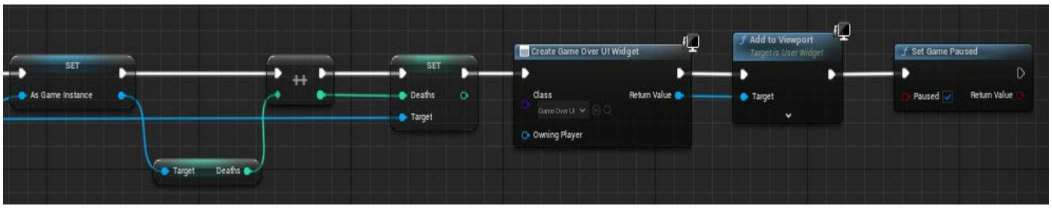

Figure 3.6.5: Setting the number of deaths after the time has run out

To have a ”set on fire” effect functionality, a custom for loop macro was developed (Figure 3. 6. 6), that enabled the player to have their health reduced by 10 with a delay of a second until it reached zero (Figure 3.6.7). Then the player is presented with the game over screen, the number of deaths is increased, and the game is paused (Figure 3.6.8).

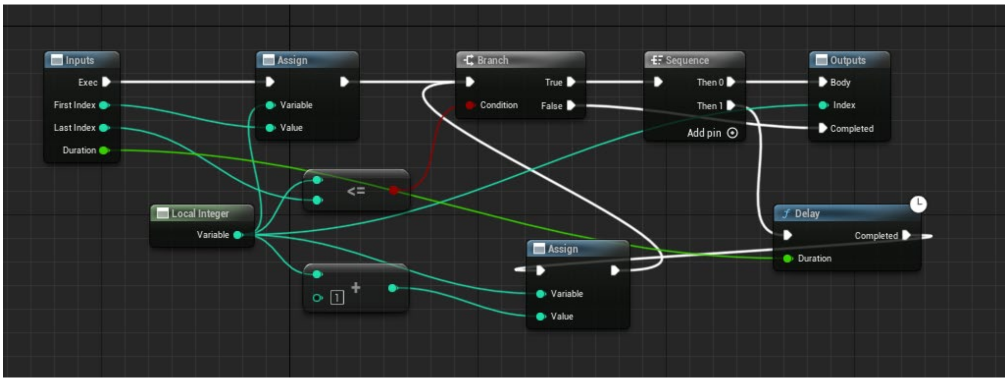

Figure 3.6.6: Custom for loop macro

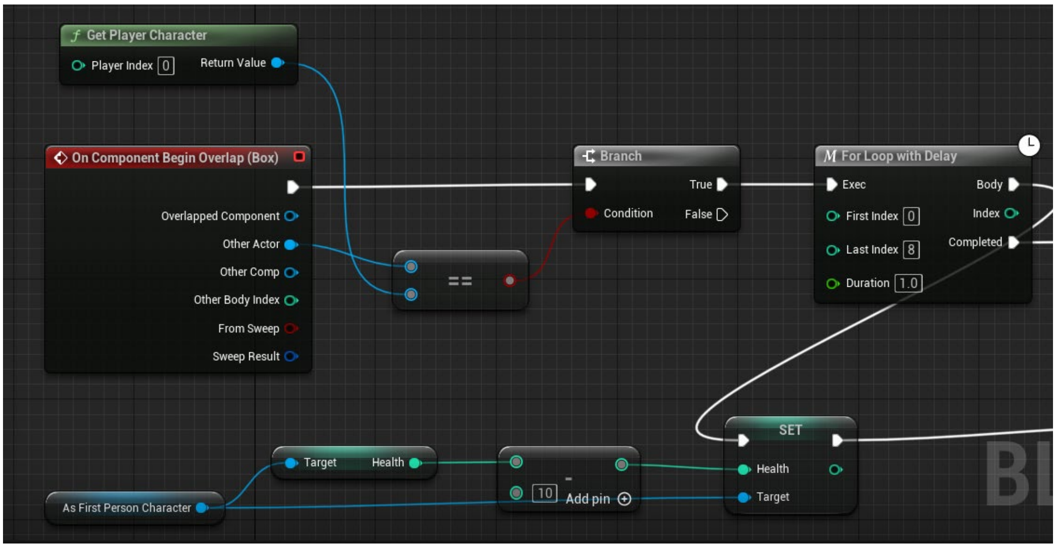

Figure 3.6.7: Burning effect implementation

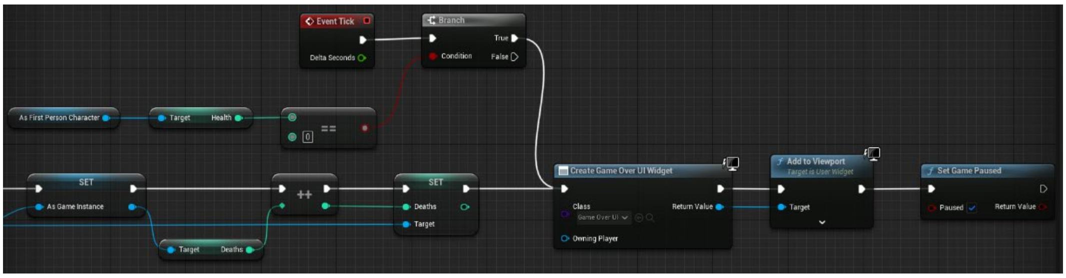

Figure 3.6.8: Player's health has reached zero check

The fire visual effect (Figure 3.6.9) was created in Unreal engine using the Niagara System and 6x6 sprite textures for the flames, 8x8 sprite texture for the smoke, and a texture for the heat distortion from the Starter Content. The effects were chosen specifically to target the CPU, since with the GPU usage the performance of the game was compromised and the recommended device on which the prototype will be played on may not have a dedicated graphics card.

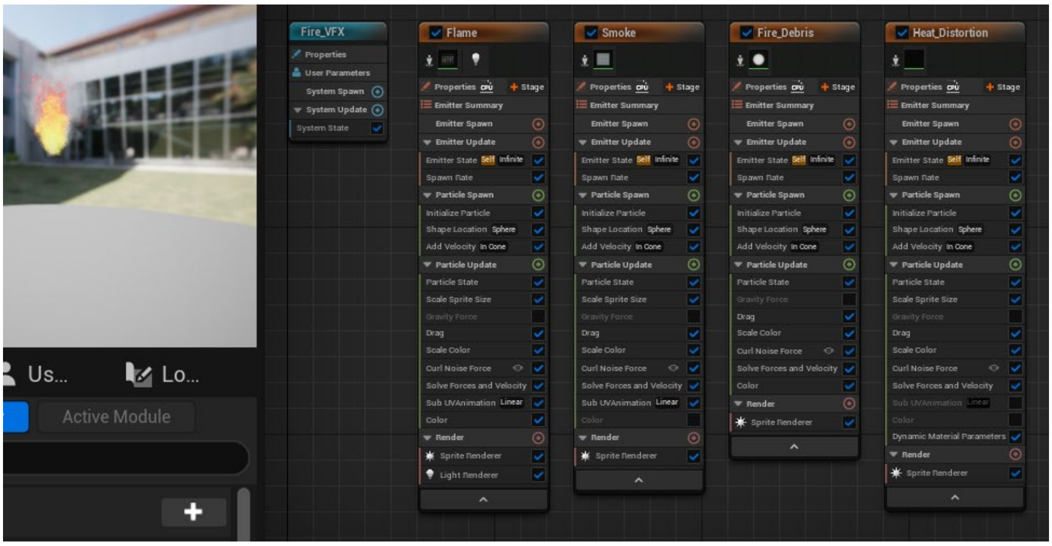

Figure 3.6.9: Fire VFX created with Niagara System

Similarly to the game lost state, the game won state increases the wins and shows the game won user interface screen (Figure 3.6.10).

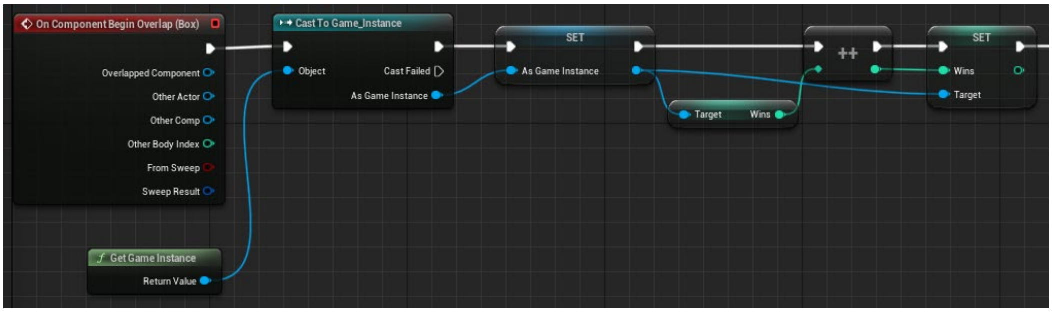

Figure 3.6.10: Game won state

Player's performance assessment

Through the timer, wins, and deaths of the player, their performance was analysed. When the user wins or loses a game, they will be able to view their score on the game won screen (Figure 3.5.4). The player's stats are displayed on the Heads-Up-Display (Figure 3.6.11).

Figure 3.6.11: Game Level Heads-Up-Display (HUD)

Dynamically Modifiable Difficulty

As described in the game flow diagram (Figure 3.5.1), a threshold was set to load a level of according difficulty after the player wins/loses the game and chooses to play again. In Figures 3.6.12 and 3.6.13 branching was used first to check if the number of deaths is higher than the number of wins, and if the condition was true, the ground floor level was selected, as it was of the lowest difficulty. Otherwise, if the condition was false, it was checked if the number of wins was higher with more than one, placing the player at level 2 if true, or at level 1 if false.

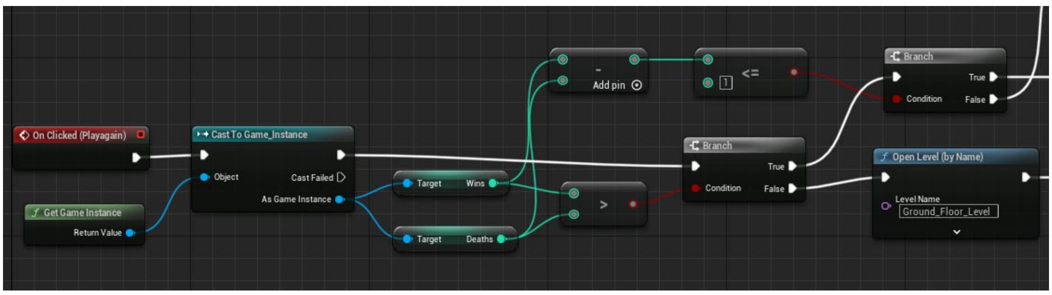

Figure 3.6.12: Dynamic difficulty development

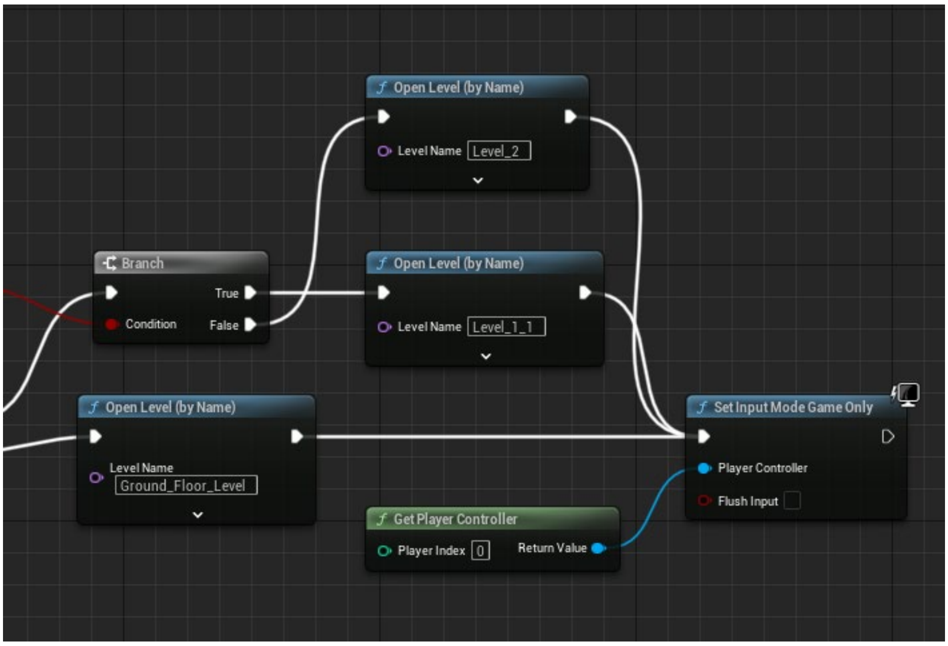

Figure 3.6.13: Setting the level depending on the wins and loses

AI Characters

To train the player in triggering the fire alarm and recognizing the fire door, the AI characters are going to be trained and implemented using the Q learning algorithm. Additionally, they will represent a more realistic behaviour in the fire evacuation case, appropriate for this scenario. The chosen algorithm consists of two phases: training (exploration) and exploitation phase. While in training, the agent populates a Q table according to the rewards it receives. It uses the table to predict the actions that will lead to rewards and the ones that will not, which becomes the basis for how the agent chooses to make decisions in the exploitation phase (Lee and Chen, 2023). The setup for this task is one fire exit door, one alarm, and two doors, represented as four states/locations (0 – fire exit door, 1 – fire alarm, 2,3 - doors), to which the AI travels randomly travels to.

To train the AI in triggering the fire alarm and recognizing the fire door, a Q and Reward table were applied as a 2-dimensional array. The reward table (Table 3.4) contains all the reward information the AI can encounter in the environment – the states where the AI reached a door that is not a fire exit were not rewarded (0 points), while the state in which the AI goes from the fire alarm to the fire door was rewarded with 1 point R(0,0).

	Action				
State		**0**	**1**	**2**	**3**
	0	1	0	0	0
	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0

Table 3.4: Values for Rewards Table

The Q table is initially set empty (Table 3.5), and as the algorithm progresses, it gets populated with the reward information discovered by the agent during the training phase.

	Action				
State		**0**	**1**	**2**	**3**
	0	0	0	0	0
	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0

Table 3.5: Values for Q Table

In Figure 3.6.14, the Q learning equation is shown, where the state and action pair refer to a coordinate in the Q and Rewards table, and gamma is a predetermined discount rate between 0 and 1.

Q (state, action) = R (state, action) + Gamma * Max [Q(next state, all actions)]

Figure 3.6.14: Q Learning Equation

If the AI is trained successfully, the agent should display intentional behaviour of first going to the fire alarm and then going to the fire exit door, when the exploitation phase starts.

Firstly, the implementation of the 2-dimensional arrays was done, as they were the basis of the algorithm. This type of array is not supported natively in Unreal Engine blueprints, therefore, to work around this issue, a custom struct array was created, whose elements are arrays (Figure 3.6.15). In this way, the 4 by 4 2-dimensional array for the Q and the Rewards table was applied.

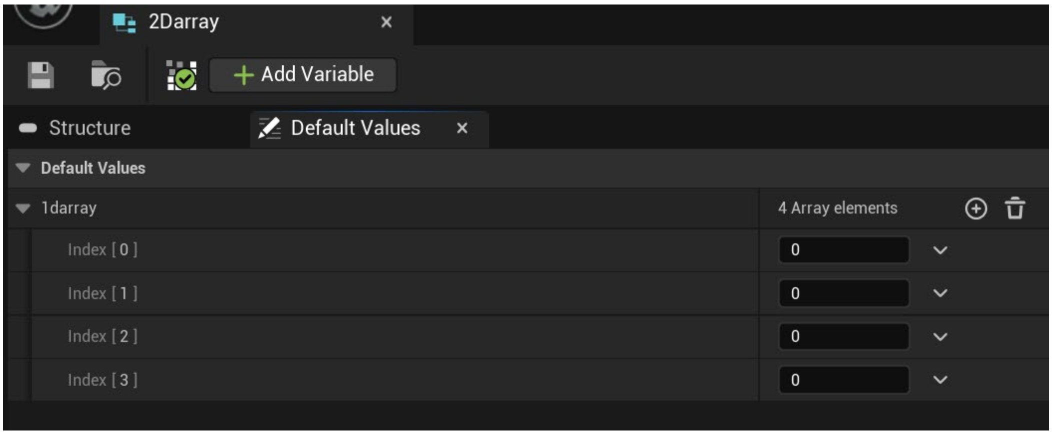

Figure 3.6.15: Custom Array Struct

Next, the AI character blueprint was added, with 4 variables, each representing the destination the AI will go to (Figure 3.6.16). The target destinations were placed on level 1 and 2, and the variables of the character component were assigned to its respective object within the level blueprint.

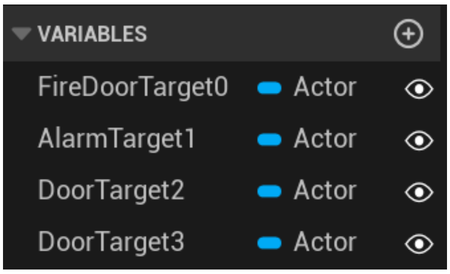

Figure 3.6.16: AI Character Blueprint variables

A low-poly mesh for the characters was obtained for free while the bones were created in Blender (Figures 3.6.17, 3.6.18, 3.6.19). To attach the bones to the skeleton, automatic weights were assigned. During the animation process, there was an issue with the female characters, and it was necessary to do weight painting to have the bones match the mesh to solve the problem. Since the mesh was composed of multiple layers that were not visible, this proved to be a time-consuming process. Upon adding it to the AI Blackboard, an issue occurred with the running/idle animation. As a solution, the Unreal engine running animation was set and, in the future, it is recommended to add idle animation for each character.

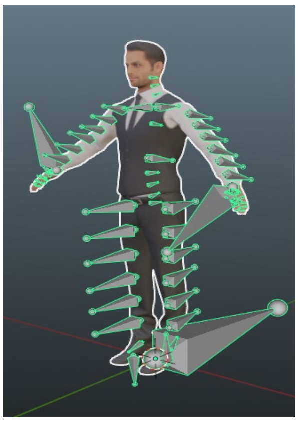

Figure 3.6.17: Rigged male AI character

Figure 3.6.18: Rigged female AI character

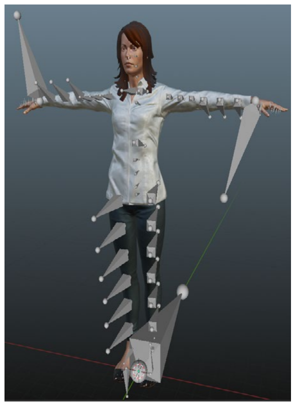

Figure 3.6.19: Second rigged female AI character

A navmesh was added to each level where AI characters are included (Figure 3.6.20). It was designed and programmed to restrict the character's movement to certain preset areas (in green), and not to allow him to enter the fire.

Figure 3.6.20: Navmesh Implementation

Following that, the AI Blackboard and behaviour tree (Figure 3.6.21) are introduced, which control the character's movement logic. The AI Blackboard's includes two variables - wander and target that represent the destinations which will be explored and exploited by the characters in each phase.

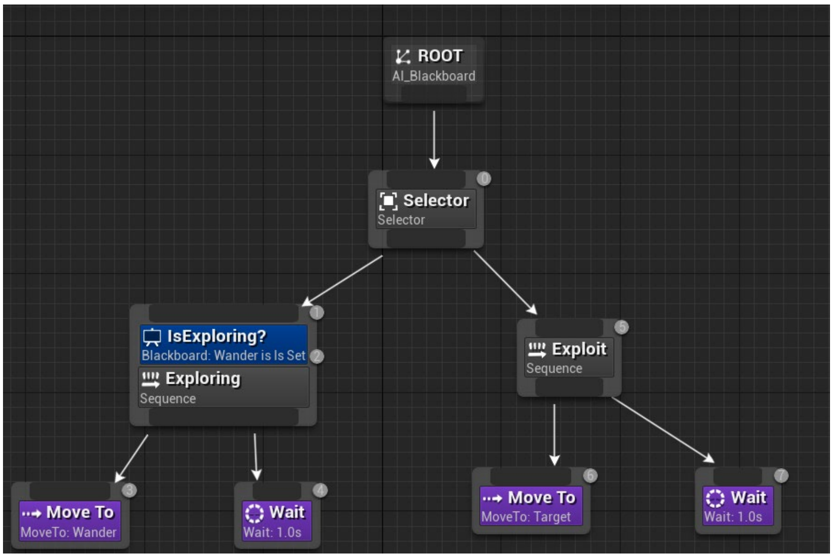

Figure 3.6.21: AI Behaviour Tree

Figure 3.6.22 illustrates the logic that will determine the balance between exploration and exploitation. The number of times exploring were set to 20, while the exploitation count was set to 5, as the player is to evacuate promptly. To transition to exploitation, the wander key is cleared as seen in the figure.

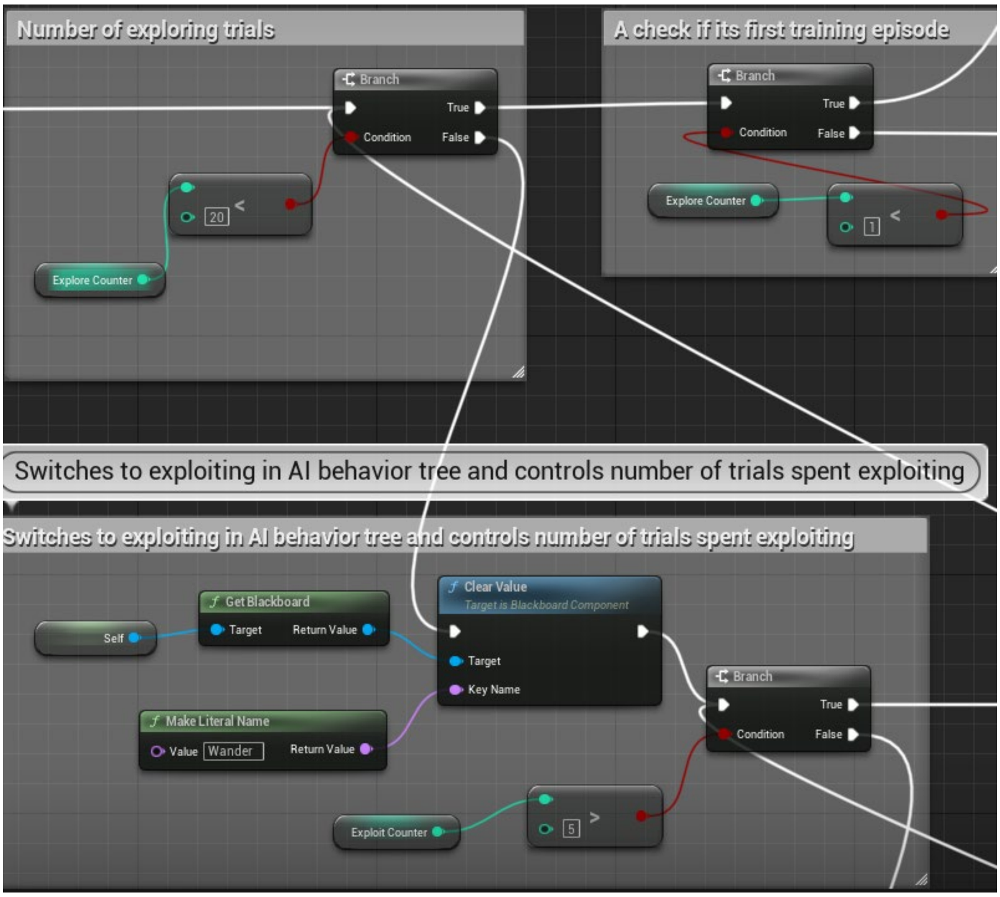

Figure 3.6.22: Exploration to exploitation transition

The main logic for exploring the environment is shown in figure 3.6.23, starting with a counter, which keeps track of how many iterations the agent has completed, as well as choosing a random location each time iterations begin, which corresponds to the environment's target points.

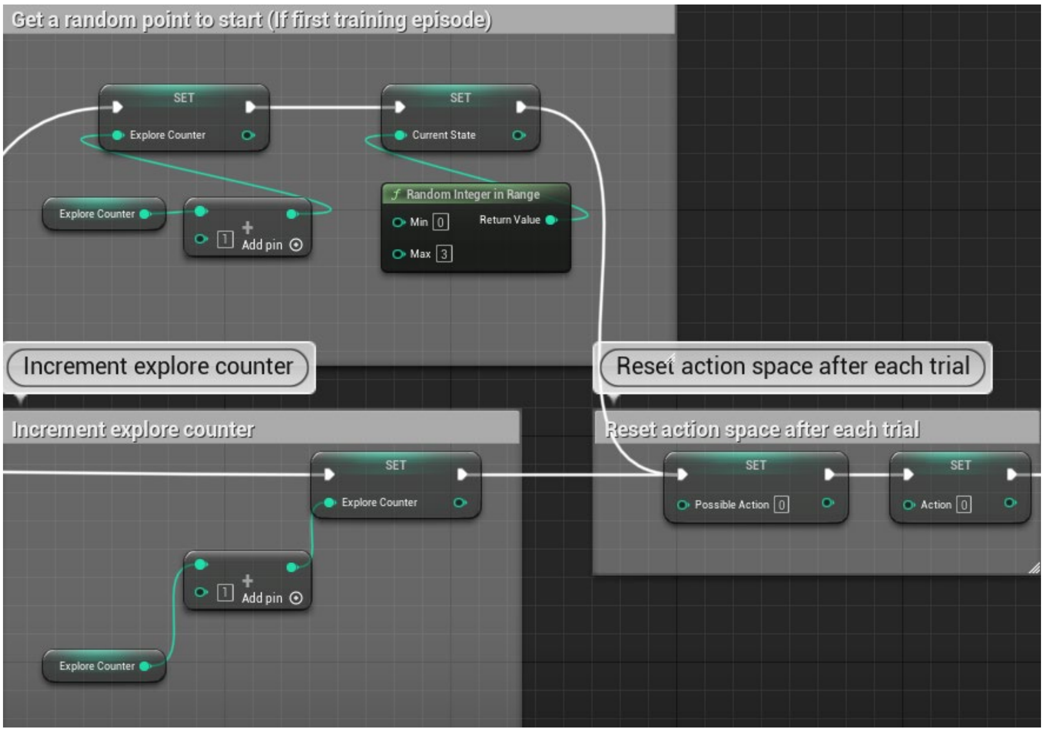

Figure 3.6.23: Start the exploration phase at a random point

The agent also requires logic to choose a random action in each iteration, since this is the entire premise of exploration. To achieve this, each of the various destinations the agent could visit for a reward were given a number between 0 and 3, which considered all possible state action pairings of 4 by 4 (Figure 3.6.24).

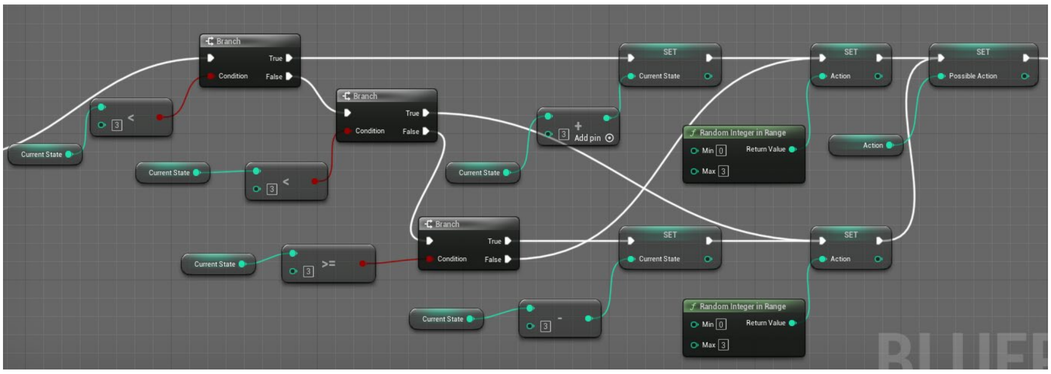

Figure 3.6.24: Choosing a random location at each iteration

Next, to visualize the agent moving between states while undergoing training, it was required to cast the logic to the AI character blueprint (Figure 3.6.25) and add a delay (Figure 3.6.26).

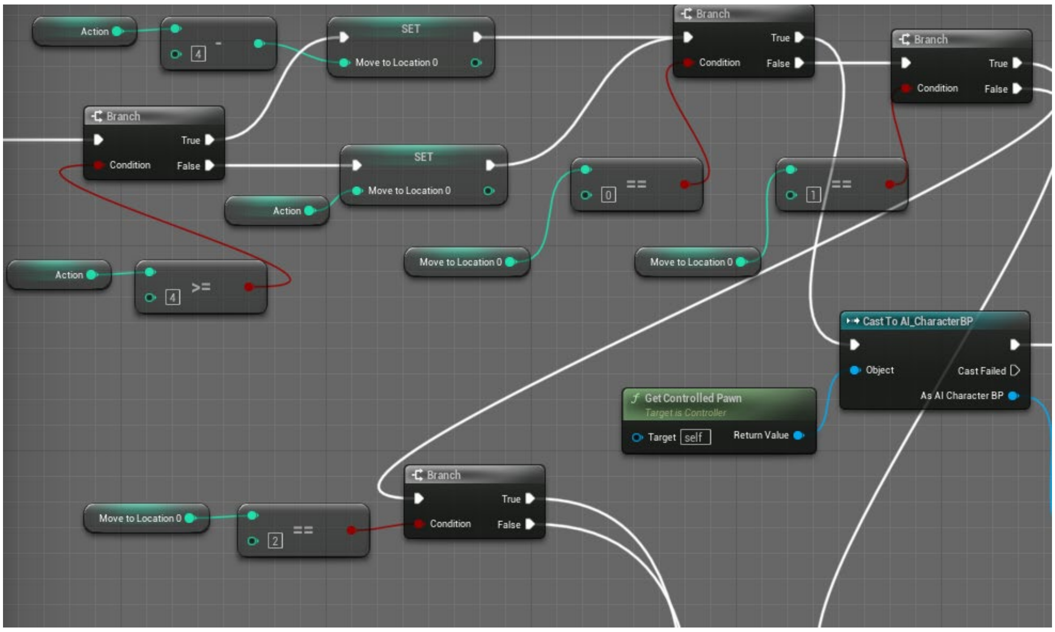

Figure 3.6.25: Visualizing the movement logic through the character blueprint

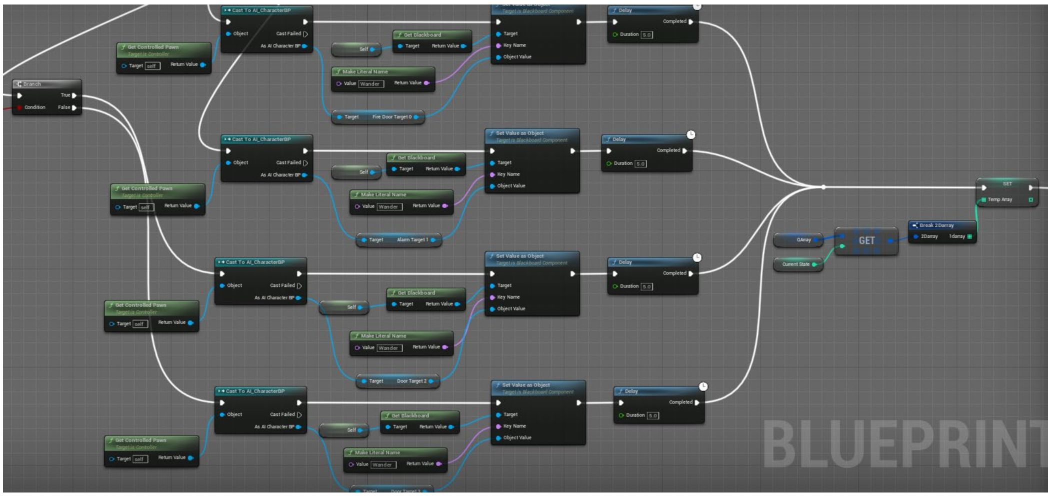

Figure 3.6.26: Movement logic

Since updating multi-dimensional arrays is not supported by Unreal Engine, a workaround must be employed to continue with the Q learning update equation. To solve this, a temporary one-dimensional array is created, existing values are copied to it from the Q table, and the values are updated before they are copied back to the Q table. After the creation of the temporary array, it is imperative to perform a bellman update (Lee and Chen, 2023), which is represented by Max[Q(next state, all actions)]. In this case, the agent evaluates the current state action pair one step ahead to see what the best action would be. This involves iteratively scanning the Q table to determine the agent's highest possible following action, storing it in a variable, and using that variable as input into the Q learning equation. Figure 3.6.27 depicts the logic for determining Max[Q(next state, all actions)].

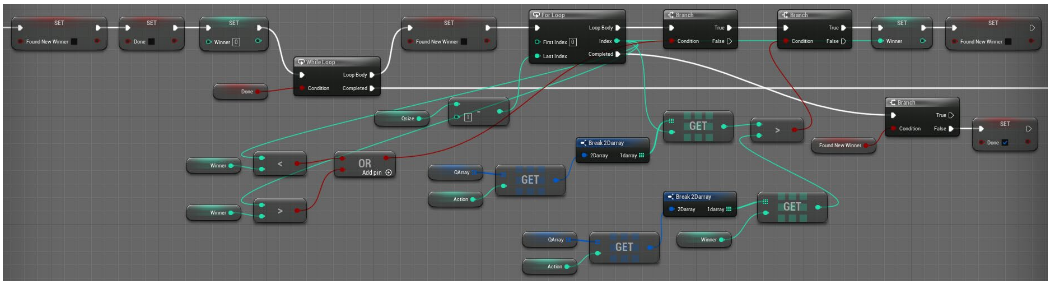

Figure 3.6.27: Determining Max[Q(next state, all actions)] – Bellman update

Once Max[Q(next state, all actions)] has been determined the remainder of the terms in the Q learning equation are going to be considered next, namely multiplying Max[Q(next state, all actions)] by gamma (the discount factor) and adding that to any reward obtained from undertaking the present action, that is R(state, action).

Next, Max[Q(next state, all actions)] was multiplied by gamma (the discount factor), which was set to 0.8 (Figure 3.6.28). Having identified all the values to add to the Q equation, the values were inserted, the calculation was performed, and the Q table was updated with the results from the temporary array (Figure 3.6.29). Additionally, the current state is set to the action from the previous one, which enhances the exploration. The exploration process is repeated anew until the AI learns the correct state for solving the task, in this case, the value of R(0, 0) in the Rewards table which is set to 1.

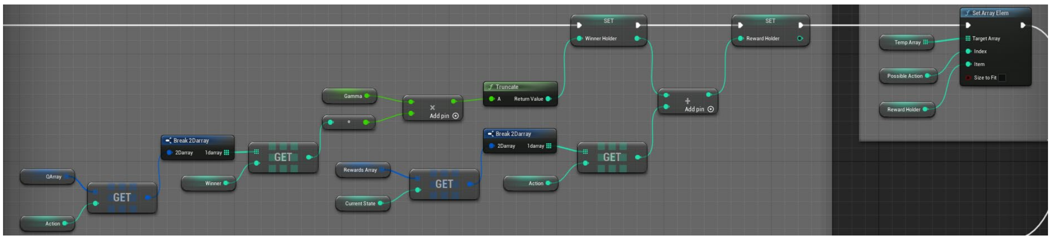

Figure 3.6.28: Multiplying Max[Q(next state, all actions)] by gamma (the discount factor)

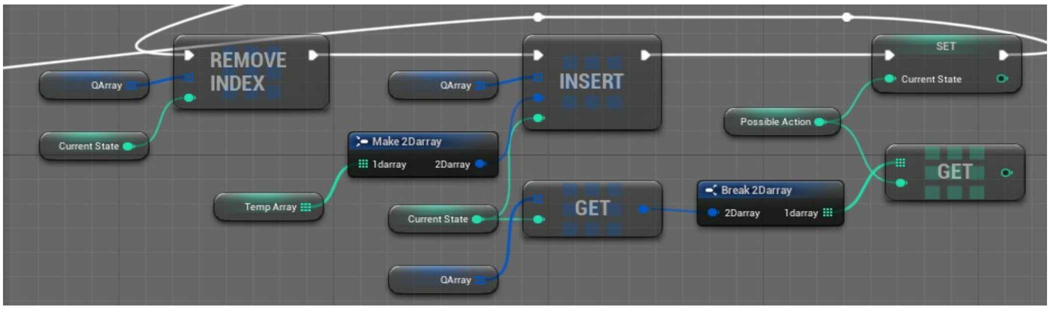

Figure 3.6.29: Replacing the Q table with the temporary array

The last step is the implementation of the exploitation phase, where the AI demonstrates the gained behaviours through training. Instead of executing the Q updates, it solely retrieves the values accumulated in the Q table to ascertain the optimal course of action to undertake at any particular location. Higher value table locations correspond to better actions. Once the best action has been identified (Figure 3.6.30), we change our action variable to show the new winner and check to see if the agent has received a reward as a result (Figure 3.6.31).

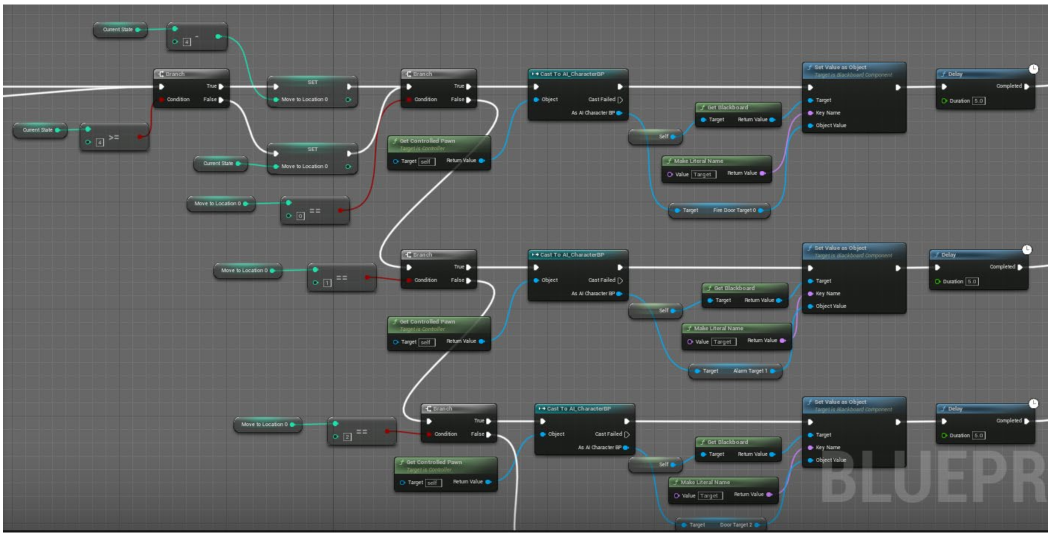

Figure 3.6.30: Choosing the advantageous action in the Q table

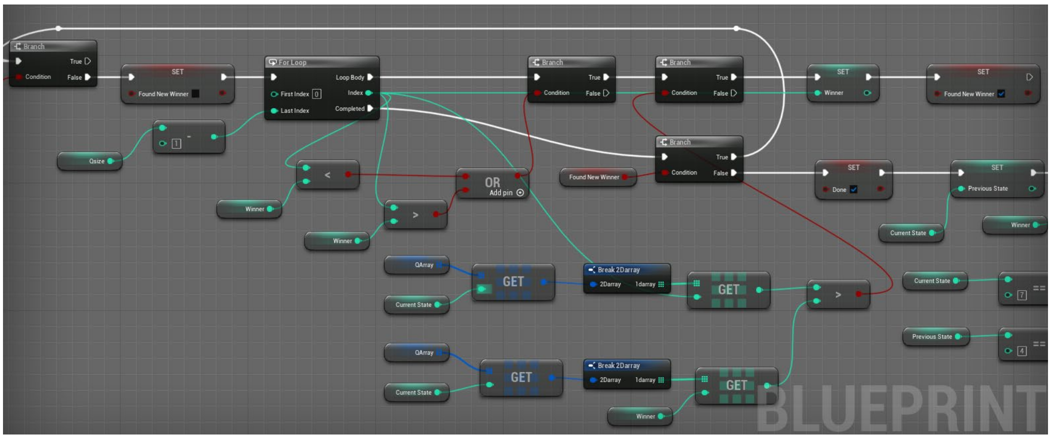

Figure 3.6.31: Decision-making in the exploitation phase

Upon completion, the AI characters showed behaviour of approaching the fire alarm first and arriving at the fire exit door when the exploitation phase had begun. Since the game is played for a short time, the number of exploration (20) and exploitation (5) trials is low and can be increased in the future for greater accuracy. Additionally, the AI can't currently trigger the fire alarm due to the development complexity, and it is recommended to implement this feature as an improvement.

Challenges

Adopting fire evacuation behaviour

The main challenge/goal of the game is to follow the fire evacuation sign toward the fire exit. The 3D assets were acquired for free and further modified in Blender to have a specific set of models for the project (Figure 3.6.32). They have been added to each level of the game near the ceiling, indicating the way to the exit.

Figure 3.6.32: Fire Evacuation Signs Modelling in Blender

Fire alarm

The fire alarm implementation can be seen in Figure 3.6.33. A check is performed first with a line trace, to see if the player is close to the fire alarm, then triggering the sound when the F key is pressed.

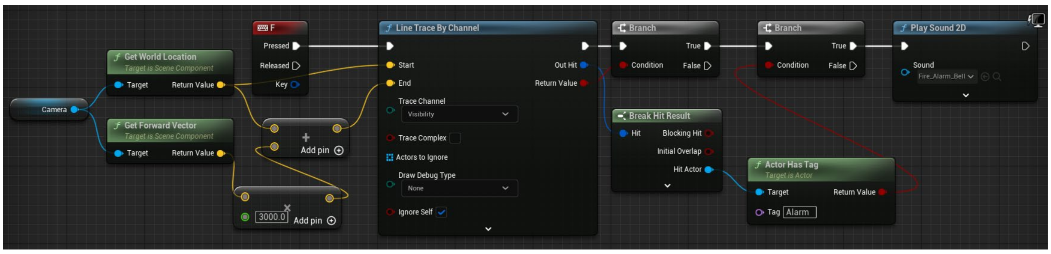

Figure 3.6.33: Fire Alarm Implementation

Fire Doors

Fire door assets were added, one for fire exit to a different part of the building

(Figure 3.6.34), and another for exiting the building (Figure 3.6.35).

Figure 3.6.34: Fire Door

Figure 3.6.35: Second Floor Fire Exit Door

Opening and closing a fire door was done through a flip-flop function, enabling a smooth animation of the door opening with a timeline (Figure 3.6.36). Similarly, to the fire alarm, a line trace was applied to check when the player is near the door and trigger it with the “E” key.

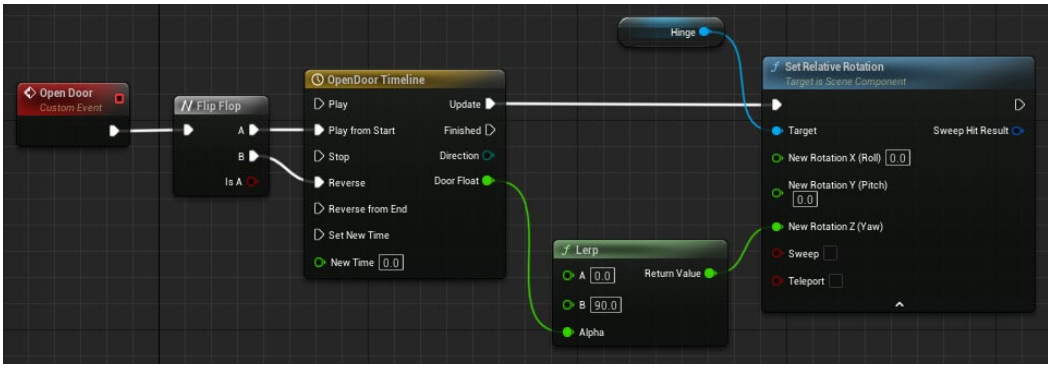

Figure 3.6.36: Opening/Closing Fire Door Implementation

Staircases and Lifts

The player will have a choice of using the lift or taking the staircase (Figure 3.6.37). By using the staircase, they are led to another level or a fire door, from which they win the game, however, if they decide to use the elevator, they are shown the game lost UI, as a penalty since lifts should not be used in this scenario.

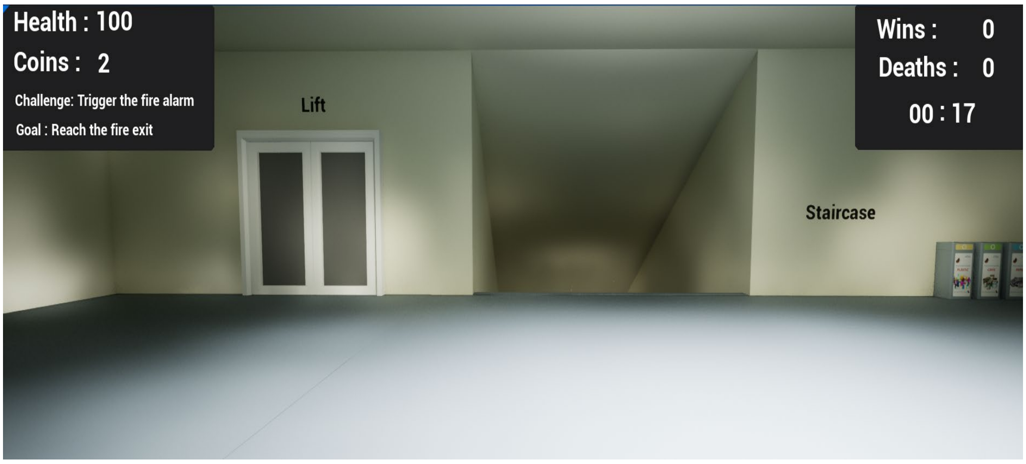

Figure 3.6.37: Staircase and lift

Personal belongings

Collecting a personal belonging decreases your life by 20 points (Figure 3.6.38) due to the fatigue from carrying while breathing in smoke. The items consist of a rucksack, a laptop, and a phone (Figure 3.6.39) and can be gathered when approaching them.

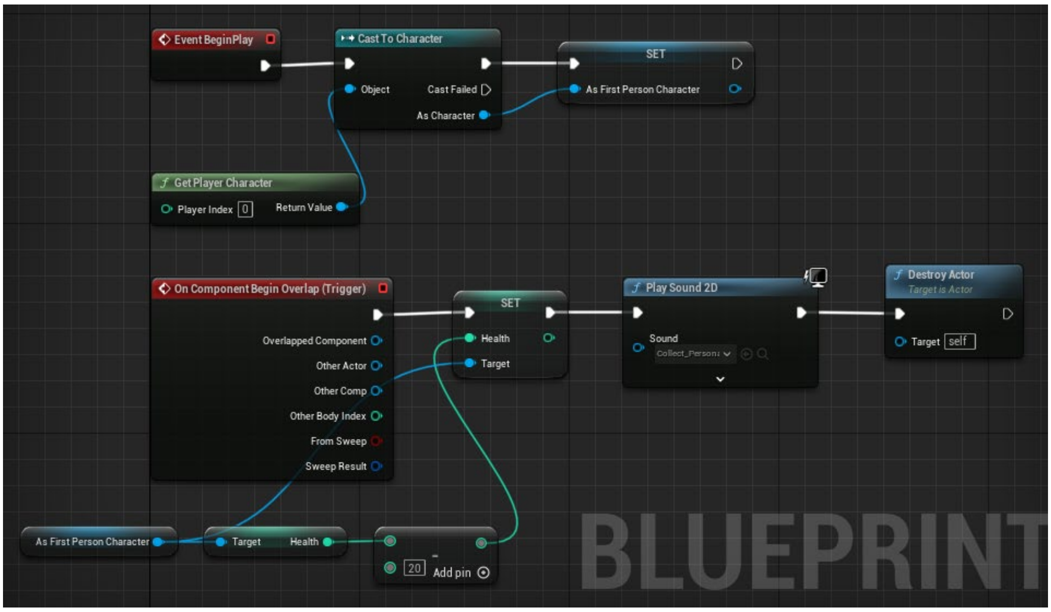

Figure 3.6.38: Personal belongings Implementation

Figure 3.6.39: Personal collectibles screenshot

Rewards (Coins)

To collect a coin, the player must approach a fire alarm point or use a fire door. Each coin includes a mesh and spinning animation. When collected, they increase the evacuation time by 10 seconds, increasing the number of coins in the game instance, playing a sound effect, and removing the coin from the level (Figure 3.6.40).

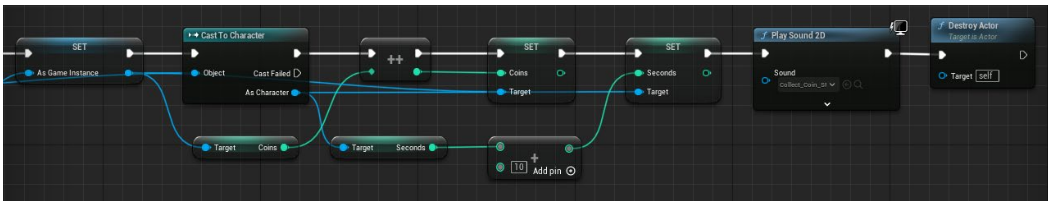

Figure 3.6.40: Collectable coins

Asking the staff for assistance (Players with mobility condition)

Staff can be approached at help desks on level 1 and 2 and asked for assistance with evacuation by triggering the “E” key due to mobility issues (Figure 3.6.41). As a result, the “game won” screen is shown as seen in the user interface mock-ups section (Figure 3.5.5). Line tracing was used to check if the player was close to the actor and trigger the "game won" interface with "E".

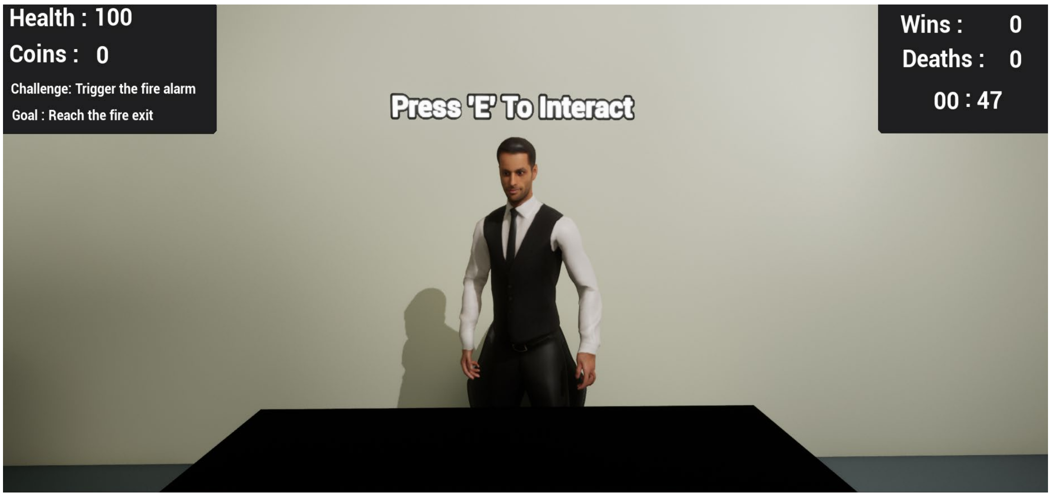

Figure 3.6.41: Interacting with staff for assistance

Sound Effects

Sound effects were downloaded from the Epidemic Sound website (Epidemic Sound, 2023) with a license. The game includes sound effects based on a burning building, a collected coin, a triggered fire alarm, collected personal belongings and fire sound effects for when the player is set ablaze. They were interconnected as 2D sounds (Figure 3.6.42), some played on a loop such as the fire alarm sound, while the others were played just once (sounds for collectibles).

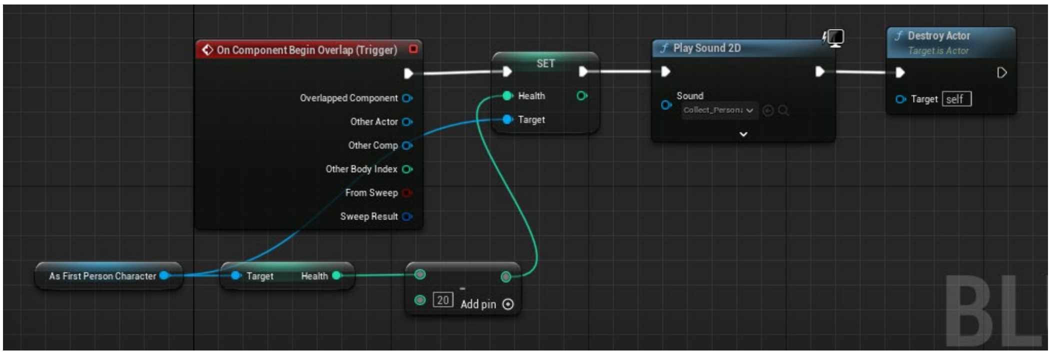

Figure 3.6.42: Application of the sound effects

Level Design

The main menu (Figure 3.5.3), tutorial user interfaces (Figure 3.5.7, 3.5.8, 3.5.9), and credits (Figure 3.5.10) were applied in a widget switcher (Figure 3.6.43).

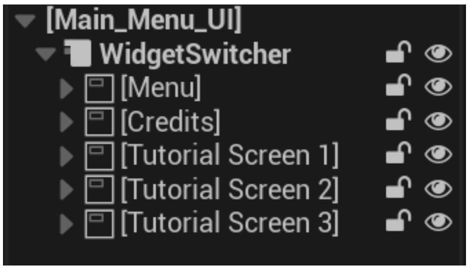

Figure 3.6.43: Widget Switcher

This allowed for easier switching between user interfaces when the buttons were clicked (Figure 3.6.44).

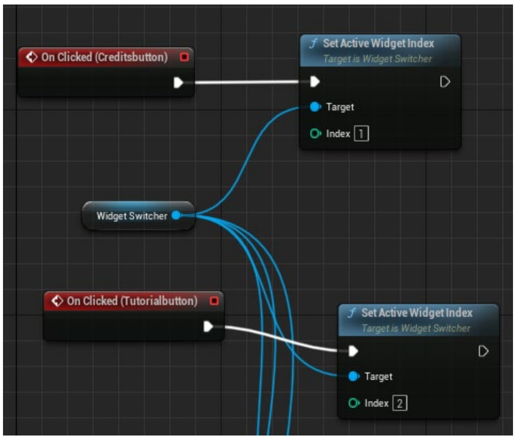

Figure 3.6.44: Implementation of UI assets

The prototype includes a number of assets acquired for free, including 3D models for the interior of the building (Figure 3.6.45), character assets (player and AI) (Figure 3.6.46), and 2D sprites (3.6.47).

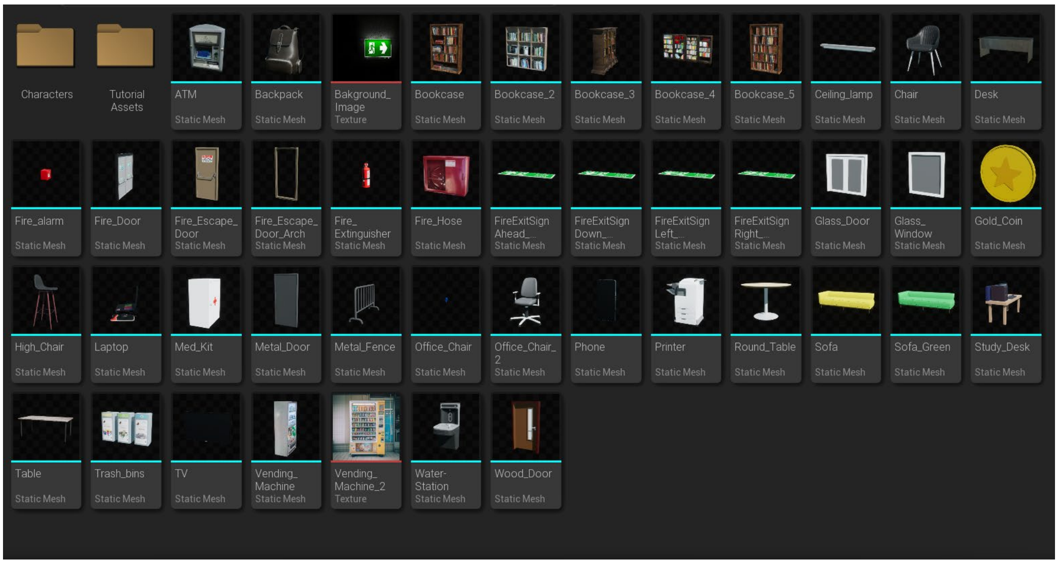

Figure 3.6.45: 3D models

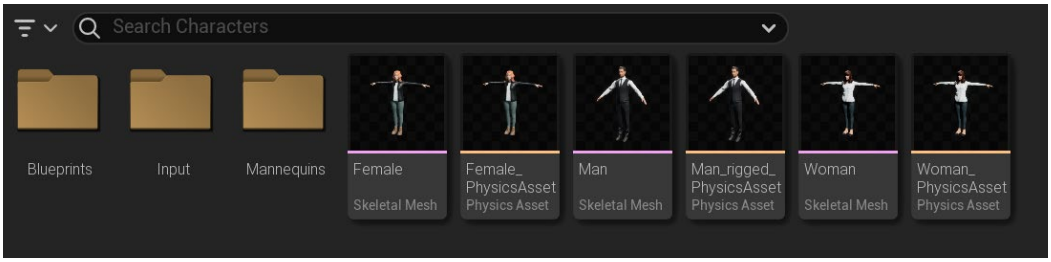

Figure 3.6.46: Character physics assets and skeleton

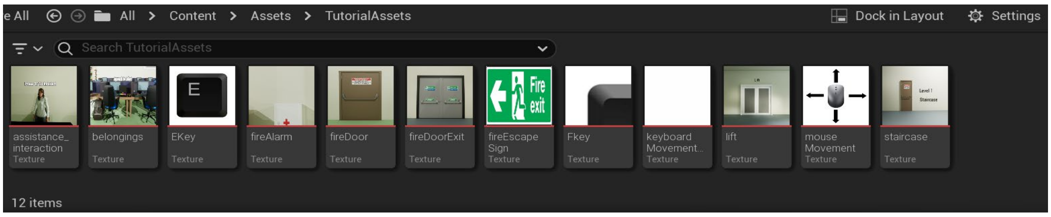

Figure 3.6.47: 2D sprites

The 3D models for this project have been modified in Blender where necessary - the primary objective was to have realistic models, which are able to reproduce the interior of the library as closely as possible (Figure 3.6.48).

Figure 3.6.48: Level 2 Library

Additionally, a smoke visual effect from the Unreal Engine starter pack (Unreal Engine 4.26 Documentation, n.d.) was added, making the game more challenging due to the reduced in-game visibility. For example, level 1 has two fire exits, however, the player may choose to take the longer one with the stairs since they may not be able to see the fire exit door (Figure 3.6.49).

Figure 3.6.49: Fire Exit Door on level 1

3.7 Deployment

Delivery platform

The game was built for a Windows device with 1080x1920 display resolution.

Hardware requirements

A Windows device is required to run the game. Although the game can be run on most devices, it is recommended that the chosen device have a dedicated graphics card for optimal game performance.

Software requirements

The project is built in Unreal Engine 5.1 as this was the most recent version of the engine at the time the project was started. For future development, it would be beneficial to use the latest version so that improvements and new features can be added as needed.

3.8 Prototype Screenshots

Figure 3.8.1: Ground Floor Screenshot

Figure 3.8.2: Level 1 Interior

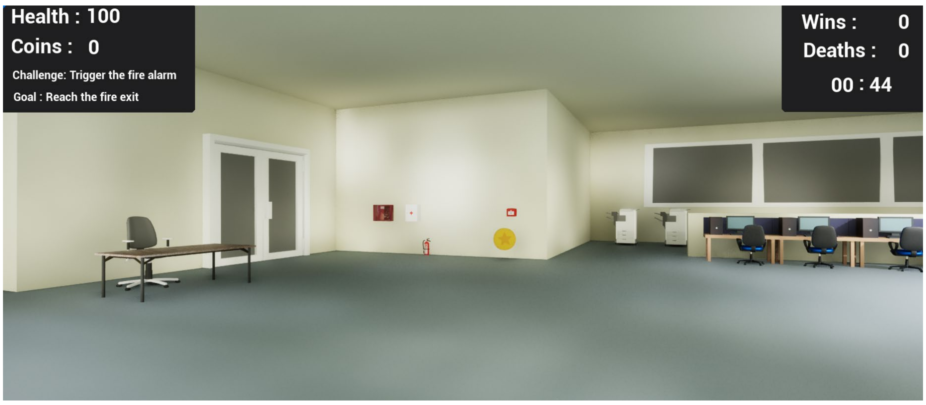

Figure 3.8.3: Level 1 Fire alarm point

Figure 3.8.4: Level 2 AI Characters

3.9 Chapter Summary

This chapter determined and grouped the requirements gathered from the literature review into functional, non-functional, ethical, and legal requirements. To allow for the development of the requirements in a timely manner within the time frame, the requirements were assigned a priority using the MoSCoW technique. The project’s design was shown in this chapter, followed by the implementation of each requirement and the deployment specifics of the project.

Chapter 4

Evaluation

4.1 Evaluation against the Aims and Objectives

The requirements-gathering process, performed through literature proved to be valuable, as the elicited criteria gave the opportunity to build upon existing methodologies and serious games research, and design and implement the prototype. Developing the requirements with the MoSCoW technique allowed for the timely implementation of each requirement based on its priority. The design process including the game, system architecture, and the documentation applied to the game design provided a deeper insight into the planning and design process while the prototype's development was described in the prototype development process chapter, showing the reader the implementation in detail.

4.2 Evaluation against the Learning objectives

Tables 4.1, 4.2 and 4.3 critically evaluate the implementation outcome of the learning, functional, and non-functional requirements from the prototype's development process with each working feature marked as ”satisfied” or ”partly satisfied”.

Requirement Number	**Requirement**	**Satisfied?**	**Testing**
L-1	Teaching players to follow the fire evacuation signs	SATISFIED	Fire evacuation signs were added as assets to the game. The player can follow them to the fire exit and learn this behaviour.
L-2	Activating the fire alarm	PARTLY SATISFIED	The player can activate the fire alarm with F key and a sound is emitted on activation. However, a reward (coin) is received only when they reach a fire evacuation point and not when triggering the alarm.
L-3	Avoiding fire	SATISFIED	The fire asset and sound effect was added to the game. When the user goes inside the fire, they are set on fire and lose health resulting in the game's lost screen being displayed.
L-4	Using the fire doors when evacuating, practicing closing them to contain the fire inside the same room.	PARTLY SATISFIED	The user can open and close fire doors with the “E” key. They receive a reward (coin) for using a fire door, but in the current release don't receive any for closing it to contain the fire inside the room.
L-5	Using the stairs when evacuating, not using the lift.	SATISFIED	The player can use the stairs and the lift. Using the lift results in the game being lost, whereas the stairs lead to a fire exit.

L-6	Not collecting any belongings and leaving the building immediately	SATISFIED	Personal items can be collected on level 2. The player loses health when collecting any as a penalty.
L-7	Asking the staff for assistance (for users with mobility issues)	PARTLY SATISFIED	Players can ask the staff to help them evacuate by approaching them and pressing “E” key. The game is won when this is done. Can be further improved by adding additional interactions with the AI.

Table 4.1: Learning Objectives Evaluation

4.3 Evaluation against Requirements

The research performed in the Literature review chapter to extract the requirements was beneficial as it was directly related to fire evacuation training serious games and their development, meaning the requirements were more specific for the type of prototype that was created. There is a possibility that the requirements-gathering process would have been more effective if a questionnaire or face-to-face interviews aimed at the target audience were done to determine some of the requirements like their most used device (platform), the operating system, whether they prefer an installable game or a web one and the features they think such game should have.

Requirement Number	Requirement	Satisfied?	Testing
F-1	Core Mechanics	SATISFIED	The player can move the camera with a mouse freely and is able to move through the game with A/S/W/D keys (forwards, backward, sideways).
F-2	Game won/lost state	SATISFIED	The player loses the game after the evacuation time has run out or if he is set on fire. The game can be won when the exit is reached.
F-3	Player's performance assessment	PARTLY SATISFIED	The game shows the evacuation time of each level after the player wins the game. Can be enhanced by considering that the fire alarm was triggered, and the fire doors were closed.
F-4	Dynamically Modifiable Difficulty	SATISFIED	Three difficulty levels were implemented, each setting the player at a different part of the building. The number of wins is checked against the number of deaths to
F-5	Artificial Intelligence Characters	PARTLY SATISFIED	The AI character was implemented with a mesh and animation. Moves on pre-designed space at a random location. They can identify the fire exit door and before heading to it, they pass by the fire alarm point. However, they are currently not able to trigger the fire alarm and there is no idle animation, which can be added in the future.
F-6	Challenges	PARTLY SATISFIED	The game has a challenge to trigger the fire alarm and a goal of reaching the fire exit. This can be further improved by adding the challenge of closing the fire doors.

F-7	Sound effects	SATISFIED	Sound effects were implemented related to burning when a player is set on fire, a burning building, collecting a coin, personal collectibles and triggering the fire alarm.
F-8	Level Design	SATISFIED	A large number of assets were added to the prototype, including AI character meshes, fire and smoke VFX, different types of bookcases/couches/chairs, a desk, table, ceiling lamp, glass door/window, fire door/fire exit door, metal/wood door, ATM, metal fence, printer, trash bin, TV, vending machine, water station, different fire exit signs, fire hose, extinguisher, alarm, med kit, coin,

Table 4.2: Functional Requirements Evaluation

Requirement	Requirement	Satisfied?	Testing
NF-1	Learning is only a consequence of the playing actions.	PARTLY SATISFIED	The game provided a reward for reaching a fire alarm point and using a fire door. Different message is displayed on game won/lost screens, providing feedback on the player's actions. This can be further improved by adding a coin for triggering an alarm and closing a fire door.
NF-2	Learning content is meaningful and well-presented.	PARTLY SATISFIED	The game contains a tutorial that guides the user in playing the game. Can be further improved by adding a video of how each of the game's features is used.
NF-3	Responsiveness	SATISFIED	While testing the game, there were no critical errors causing the game to crash. The game takes only the user input required for the player's actions.
NF-4	Avoidance of political and social issues	SATISFIED	No political or social issues were included in any way in the game.
NF-5	Intuitive game mechanics and natural mapping of keys.	SATISFIED	The game mechanics applied were generic (camera movement with the mouse), character movement with W/A/S/D keys, triggering an alarm with F key, and opening/closing a door with E key.

Table 4.3: Non-Functional Requirements Evaluation

4.4 Evaluation against Development Tools

The choice of game engine affected the development of the game in terms of the application of the machine learning algorithm. As Unreal Engine didn't support a way to initialize a 2-dimensional array, a workaround was required which could have been avoided if a different engine was used. Another aspect that affected the game was the decision to create a 3D game. Despite the additional development difficulty in recreating a 3D environment, the scenarios were successfully made and represented a model similar in architecture to the UWE library building.

The chosen platform currently restricts the game to be playable only on PC, however, as the core mechanics of the game were created with axis mappings in the project settings, they can be easily changed to a different platform. Another factor affecting the project's outcome was the choice of animation tools. A challenge was faced when animating the characters as the mesh was not fully animated in Blender due to issues with assigning automatic weights. Consequently, weight painting was required which took longer time than originally predicted. If this project were to be done again, it is recommended that the developer plan more time for the artificial intelligence implementation.

4.5 Methodology and Project Plan Evaluation

As for the applied methodology, the implementation of dynamically modifiable difficulty and an artificial intelligence character resulted in more efficient training of the player in finding the fire alarm, managing their emotions under stress and navigating inside the building. Additionally, the chosen algorithm proved efficient as the AI showed the desired behaviour once trained and the evacuation environment appeared more realistic due to their actions.

The time management throughout this project could have been improved by splitting tasks from the artefact into smaller subtasks and assigning them a specific time frame earlier on in the project development. Since the amount of time the project was developed was short and there were complications to the technical implementation of some requirements, this resulted in them not being fully implemented and recommended for future work. However, as the project's milestones were set earlier on in the project's development, the base requirements of the artefact were met, and deviations were made for the successful completion of the project.

4.6 Chapter Summary

To sum up, the project's aims and objectives were fulfilled and proved beneficial to both the project's development and future work in case prototype documentation is necessary. The elicited requirements were specific due to the literature research, however, in the future, extra methods could be utilized for their gathering. Some of the criteria related to the learning objectives, serious, entertainment, and balance part of the serious game were partly satisfied due to complications with the implementation and requiring a longer period to be applied. Although the development tools initially selected for the project implementation were of assistance, the animation development program can be changed based on project criteria in the future. The methodology appeared to be effective for the user's training as the AI was successfully trained, resulting in the users gaining a deeper insight into the fire evacuation training. Additionally, the project plan could be improved by adding extra time for deviations due to complications with the project development.

Chapter 5

Conclusion

5.1 Project Overview

The project aims and objectives in the Introduction chapter were met, and the report was finalized. The overall research question of investigating serious game methodologies to enhance the learning experience of staff and students to evacuate within the building in case of fire was achieved in the Literature review chapter and the Development process chapter by critically analysing literature sources and outlining a methodology. The sub-research questions were successfully addressed by applying the methodology for the technical implementation of the artefact.

5.2 Recommendations prior to Future work

Further work recommended to be done on the prototype includes finishing the requirements that were not fully satisfied in the duration of this paper due to the time restrictions and complexity. A further development recommendation is to add a small pop-up window on the in-game UI screen with a map of the floor showing the player’s location, which would help the user become familiarised with the library environment. Additionally, mechanics for measuring and managing the users’ distress and panic emotions can be included.

In future releases, if bugs arise, they could be fixed by the development team and maintenance could be carried out on a regular basis to make sure the game meets the target audience's needs. As more functionality is expected to be requested by the users, further requirement-gathering methods can be applied such as a questionnaire to improve the prototype depending on the target audience's needs.

5.3 Personal Evaluation

At the beginning of the project, the project progress was affected by unforeseen circumstances, not mentioned in the Project Initiation Document, such as the deadlines of multiple coursework due at the same time for other modules in the course. As this factor had not been a risk, therefore there was no plan in place to mitigate any issues that would come of it. Consequently, to avoid this, preparations could have been made earlier on to finish the assigned project work before the deadline.

Furthermore, considerable time was spent on the research summary chapter as it was challenging to settle the approach and development tools that will be utilized for the artefact. If this project were to be done again, it is recommended to start the implementation of the prototype earlier on in the project development and to familiarize oneself with the development tools in advance before the implementation stage.

5.4 Chapter Summary

The project and the report have been finalized and the research questions have been addressed. The project was developed during the academic year, for a short amount of time with unforeseen circumstances affecting its development. As a result of the difficulties met, it is advised for the partially satisfied requirements to be implemented in future work to polish the prototype and publish it online. In conclusion, this project supports the University of West of England community by fulfilling its main aim of providing a fire evacuation training game in the library.

Chapter 6

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Appendix A

Dissertation Proposal (Final)

Creative Technology Dissertation Proposal

Serious Game for Fire Safety Evacuation Training

Student name: Nikoleta Koleva

Student number: 22040611

Module code: UFCFLK-60-M

Module name: Creative Technology Dissertation

Course name: MSc Commercial Games Development

Assessment 1 - Dissertation Proposal (Final)

1 Dissertation Title

The title chosen for the Creative Technology Dissertation is Serious Game for Fire Safety Evacuation Training.

2 Introduction

The University of West of England is composed of three campuses, where fire drills are conducted on a regular basis. However, students and staff members don't participate in the training which may lead to difficulties if a crisis happens in the future. Nowadays serious games have been widely used to train evacuation skills and have proven to be a successful method of teaching (Blasko-Drabik, 2013). Consequently, this project aims to provide one for training fire evacuation behavior by creating a prototype and producing a report.

3 Background

Emergency evacuation plans and drills are compulsory in public buildings in many countries. Their importance is significant when it comes to guaranteeing safety and protection during a crisis. Gamification of risk communication and particularly decisions related to natural hazards is thought to be an effective way to communicate the issues to motivate learners. As an example, serious games have been successfully used for conveying risks and training behavior in case of earthquakes (Feng et al., 2020), fire (Oliveira et al., 2015) and tsunami evacuation (Hawthorn, 2021). Ribeiro's paper supports this statement by examining results showing that users who played the serious game in his work learned evacuation procedures and evacuated faster (2012). In conclusion, developing a serious game is a viable and adequate solution to training evacuation skills in case of an emergency.

4 Aims and objectives

The goal of this project is to create a serious game for fire safety evacuation training by researching relevant literature on the topic. Considering the time constraints, for this dissertation Frenchay campus will be considered (Figure 1.1) with the most used block (D - Library) and a minimum of one scenario.

Figure 1.1: Frenchay Campus Map

The library is a big building, with multiple exits and staircases which must be considered fully to recreate a specific case for training the player. To get a hold of the building's architecture, a map of the floors used for the scenarios will be obtained and the evacuation instructions will be studied. To recreate the environment, Oliveira et al. (2015) and Ribeiro et al.'s (2012) approach will be used where the environment was designed virtually in a game engine.

The project objectives are:

- Choose topic and submit dissertation proposal
- Literature review write-up
  - Research the corresponding development tools and programming languages for the development of the game by reading relevant literature
  - Test and review similar serious games. List key features, evaluate their design and performance

Methodology and Project management evidence
  - Compare alternative development models
  - Choose development model and describe the project plan

Requirements elicitation
  - Identify functional and non-functional requirements for the project
  - Organize and prioritize requirements by the MoSCoW prioritization technique (ProjectSmart, 2022)
  - Group requirements into featureSets

Design documentation
  - Produce design documentation (System architecture, Graphical User Interface Style, UML diagram, UI mockups)

Create prototype
  - Develop server-side
  - Develop client-side

Game testing
  - Identify test plans
  - System tests
  - Evaluate test results

Project evaluation
  - Evaluate the prototype against the Aims and Objectives, the Requirements and the project methodology
  - Personal evaluation

Summarize the project's outcome and give recommendations prior to future work

Provide regular weekly reports to track progress

Finalize the report

Conduct the final demonstration

5 Methodology

The research I will do will be in the form of a literature review, identifying the key topics related to the development of a fire safety training evacuation game. The relevant academic literature will be researched, with the corresponding theories, methods, and gaps in ongoing research investigated.

Existent applications online or ones produced in research papers will be reviewed along with the suitable development tools and programming languages. Their features in common will be listed, with their advantages and disadvantages, and their design. Where it is feasible, their overall performance will be evaluated by testing the game.

The research from the literature review will allow for requirements to be elicitated and considered along with accessibility, security, ethical, legal requirements, which will be then grouped into featureSets using the MoSCoW method. The featureSets will be analyzed throughout the Design chapter and will provide order for the development of the serious game in the Prototype and Testing chapters.

6 Research Questions

Overall Research Question

- How to develop a fire safety evacuation training serious game?

Sub-research questions

1. What are already existent applications/serious games?
    - Subject area to be researched - examine games which can be downloaded/played online. Research papers which have produced a serious game
    - How this contributes to the overall research question - the prototype will be built based on the requirements elicited from the literature review
    - Appropriate research methods for achieving this - list key features, development tools used, game engines and programming languages
    - What I am hoping to achieve - gather requirements from the prototype for the literature review and examine tools/game engines to use for development
2. What serious game approaches can be used for a fire safety evacuation training game?
    - Subject area to be researched - games containing features such as single-player/multiplayer, quiz
    - What I am hoping to achieve - examine different approaches to developing the prototype
    - How this contributes to the overall research question - the prototype will be based on one approach or might combine a few to improve its efficiency
    - Appropriate research methods for achieving this - reading different research papers
3. How to gamify the learning features so that the player is engaged?
    - Subject area to be researched - gamified techniques and elements in other games

- What I am hoping to achieve - encourage information retention regarding best practices to follow in a fire emergency
- How this contributes to the overall research question - gamified methods and elements will be considered for the prototype
- Appropriate research methods for achieving this - read various valid sources, with achievable methods in the project's time frame

7 Deliverables

The deliverables for this project are a prototype (a serious game) and a report which will give details of the development and research strategies. Documentation supporting the report will be:

- Creative Technology Dissertation Proposal
- Ethics certificate
- Literature review
- Methodology and Project Management evidence
- Requirements specification
- Design specification
- Test strategies
- Project evaluation
- Summary

8 Evaluation

To evaluate the project's outcome, the prototype will be appraised to how well the Aims and Objectives initially set were met. Additionally, the implementation outcome of the functional and the non-functional requirements with each working feature's purpose, advantages and disadvantages will be outlined. The chosen project development model and methodology will be critically assessed against the success of the prototype and the completion of the requirements, and a personal evaluation will be drawn.

9 Ethical, social and professional issues

The prototype won't require any human participation unless a decision is made in the future to test and evaluate the game. If personal data is involved, it will be stored in a database and an Ethical Review Application Form will be submitted. The data will be handled with care and respect to the legal guidelines in the EU General Data Protection Regulation (Goddard, 2017). Requirements related to the regulation include:

- Any personally identifiable information collected will have purpose for the prototype
- Personally identifiable information will not be stored
- Data should be as accurate as possible

10 Limitations

A significant constraint is that the application may require experience with programming languages which I have no preceding experience with. Online courses and tutorials will help in gaining a better understanding and completing the project within the time constraint.

Another limitation is the accessibility to building structure such as the maps needed to create the virtual environment. It may be difficult to get a hold of this information as it is stored in the university's system. It is possible to find a way around this by making a test fire evacuation scenario in person in the building.

As mentioned in the Aims and Objectives section, since time is a major constraint, for this dissertation Frenchay campus will be considered with the most used block (D - Library) and a minimum of one scenario. Respectively, the requirements will be prioritized so that the most essential features are developed within the time constraints.

11 Hardware/Software needed

The computers required for this project will be both university ones and my personal computer. I will use them as required for accessing apps such as Visual Studio, GitHub or game design applications such as Blender or Substance Painter/Designer. As literature is researched, it will be decided on the game engine which will be used. The ones which will be considered will be Unity and Unreal Engine as they have a lot of documentation provided, receive regular updates and I have previous experience using them.

12 Log of risks

Description	Impact	Likelihood	Mitigation	First indicator
Covid lockdown	High	Likely	Entering the university buildings while I can gather the necessary information needed for the project in	A warning is given by the government
Software Failure	High	Likely	Keep a backup of the prototype	Software can't be used or crashes
Hardware Failure	High	Likely	Keep a backup of the prototype	Hardware issues
Project Deadline	High	Likely	Follow the project plan, provide weekly reports to the supervisor and prioritize tasks	The project deadline nears and there are too many requirements to fulfil until the deadline
Becoming ill	High	Unlikely	N/A	N/A

Indicative Reading List

[1] First Question

1. National Fire Protection Association (2021) https://www.sparky.org/
2. Fire Safety Matching Game, https://www.twinkl.co.uk/resource/us-a-172-fire-safety-bingo
3. Ruppel, U., & Schatz, K. (2011). Designing a BIM-based serious game for fire safety evacuation simulations. Advanced engineering informatics, 25(4), 600-611.

4. Daylamani-Zad, D., Spyridonis, F., & Al-Khafaaji, K. (2022). A framework and serious game for decision making in stressful situations; a fire evacuation scenario. *International Journal of HumanComputer Studies*, *162*, 102790.
5. Capuano, N., & King, R. (2015, September). Adaptive serious games for emergency evacuation training. In 2015 International Conference on Intelligent Networking and Collaborative Systems (pp. 308-313). IEEE.
6. Chittaro, L., & Ranon, R. (2009, March). Serious games for training occupants of a building in personal fire safety skills. In 2009 Conference in games and virtual worlds for serious applications (pp. 76-83). IEEE.
7. Ruffino, P. A., Permadi, D., Mahadzir, M. B., Osello, A., & Aris, A. B. (2018, June). Simulation and serious game for fire evacuation training. In Proceedings of the 17th International Conference on Computing in Civil and Building Engineering, Tampere, Finland (pp. 5-7).
8. Sacfung, A., Sookhanaphibarn, K., & Choensawat, W. (2014). Serious game for fire safety evacuation plan. In Advanced Materials Research (Vol. 931, pp. 583-587). Trans Tech Publications Ltd.
9. Yang, Y., Xu, Z., Wu, Y., Wei, W., & Song, R. (2021). Virtual fire evacuation drills through a webbased serious game. Applied Sciences, 11(23), 11284.

[2] Second Question

1. Jacob, G., Jayakrishnan, R., & Bijlani, K. (2018). Smart fire safety: Serious game for fire safety awareness. In Information and Decision Sciences: Proceedings of the 6th International Conference on FICTA (pp. 39-47). Springer Singapore.
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3. de Carvalho, P. V. R., Ranauro, D. O., de Abreu Mol, A. C., Jatoba, A., & de Siqueira, A. P. L. (2022). Using Serious Game in Public Schools for Training Fire Evacuation Procedures. International Journal of Serious Games, 9(3), 125-139.
4. Rodrigues de Carvalho, P. V., Ranauro, D. O., Abreu Mol, G., Jatoba, A., Legey de Siqueira, A. P., & de Abreu Mol, A. C. (2022). Using a Serious Game in public schools for training fire evacuation procedures. Mathematics Teacher Education & Development, 24(1).
5. Zhang, K., Suo, J., Chen, J., Liu, X., & Gao, L. (2017, September). Design and implementation of fire safety education system on campus based on virtual reality technology. In 2017 Federated Conference on Computer Science and Information Systems (FedCSIS) (pp. 1297-1300). IEEE.
6. He, Q., Hong, X., Zhao, G., & Huang, X. (2014, September). An immersive fire training system using kinect. In Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication (pp. 231-234).
7. Landrum, L. L. (2008). Creating accessible websites: Developing a fire safety website for teenagers who are deaf or hard of hearing. Oklahoma State University.
8. Smith, S., & Ericson, E. (2009). Using immersive game-based virtual reality to teach fire-safety skills to children. Virtual reality, 13, 87-99.

[3] Third Question

1. Silva, J. F., Almeida, J. E., Rossetti, R. J., & Coelho, A. L. (2013, June). Gamifying evacuation drills. In 2013 8th Iberian Conference on Information Systems and Technologies (CISTI) (pp. 1-6). IEEE.
2. J. Ribeiro, J. E. Almeida, R. J. F. Rossetti, A. Coelho and A. L. Coelho, "Using serious games to train evacuation behaviour," 7th Iberian Conference on Information Systems and Technologies (CISTI 2012), Madrid, Spain, 2012, pp. 1-6.
3. Ribeiro, J., Almeida, J. E., Rossetti, R. J., Coelho, A., & Coelho, A. L. (2013). Towards a serious games evacuation simulator. arXiv preprint arXiv:1303.3827.
4. I. P. Stroe, A. Ciupe, S. N. Meza and B. Orza, "FireEscape: a Gamified Coordinative Aproach to Multiplayer Fire-Safety Training," 2019 IEEE Global Engineering Education Conference (EDUCON), Dubai, United Arab Emirates, 2019, pp. 1316-1323, doi: 10.1109/EDUCON.2019.8725148.
5. Mystakidis, S., Besharat, J., Papantzikos, G., Christopoulos, A., Stylios, C., Agorgianitis, S., & Tselentis, D. (2022). Design, development, and evaluation of a virtual reality serious game for school fire preparedness training. *Education Sciences*, *12*(4), 281.
6. Almeida, J. E., Rossetti, R. J., Jacob, J. T. P. N., Faria, B. M., & Lega Coelho, A. (2017). Serious games for the human behaviour analysis in emergency evacuation scenarios. Cluster Computing, 20, 707720.
7. Radianti, J., Lazreg, M. B., & Granmo, O. C. (2015). Fire simulation-based adaptation of SmartRescue App for serious game: Design, setup and user experience. Engineering Applications of Artificial Intelligence, 46, 312-325.

8. Quiroz-Palma, P., Penades, M. C., & Nunez, A. G. (2022). Improving Emergency Management Training Within Organizations: TiER-Tool-A Serious Game. In Handbook of Research on Promoting Economic and Social Development Through Serious Games (pp. 164-190). IGI Global.

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[1] J. Ribeiro, J. E. Almeida, R. J. F. Rossetti, A. Coelho and A. L. Coelho, "Using serious games to train evacuation behaviour," 7th Iberian Conference on Information Systems and Technologies (CISTI 2012), Madrid, Spain, 2012, pp. 1-6.

[2] Oliveira, M., Pereira, N., Oliveira, E., Almeida, J. E., & Rossetti, R. J. (2015). A multi-player approach in serious games: testing pedestrian fire evacuation scenarios. Oporto, DSIE15, January.

[3] Goddard, M. (2017). The EU General Data Protection Regulation (GDPR): European regulation that has a global impact. International Journal of Market Research, 59(6), 703-705.

[4] Feng, Z., Gonzalez, V. A., Mutch, C., Amor, R., Rahouti, A., Baghouz, A., ... & Cabrera-Guerrero, G. (2020). Towards a customizable immersive virtual reality serious game for earthquake emergency training. Advanced Engineering Informatics, 46, 101134.

[5] Hawthorn, S., Jesus, R., & Baptista, M. A. (2021). A review of digital serious games for tsunami risk communication. International Journal of Serious Games, 8(2), 21-47.

[6] Blasko-Drabik, H., Blasko, D. G., Lum, H. C., Erdem, B., & Ohashi, M. (2013, September). Investigating the impact of self-efficacy in learning disaster strategies in an on-line serious game. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 57, No. 1, pp. 1455-1459). Sage CA: Los Angeles, CA: SAGE Publications.

[7] ProjectSmart (2022) MoSCoW Method. https://www.projectsmart.co.uk/tools/moscow-method.php

Dissertation Plan

	2023																														
Milestone / Week #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Choose topic and submit dissertation proposal	21 Feb - 7 March																														
Research relevant literature											8 May - 28 May																				
Describe Methodology													21 May - 4 June																		
Requirements elicitation														29 - 11 June																	
Design																12 - 25 June															
Prototype creation											8 May - 30 July																				
Application testing																					23 July - 13 Aug										
Project Evaluation																								14 - 27 Aug							
Report Write-up											8 May - 7 Sept																				

University of the West of England
BRISTOL

Faculty of Environment & Technology
Faculty Research Ethics Committee (FREC)

Ethical Review Checklist for Undergraduate and Postgraduate Modules

Please provide project details and complete the checklist below.

Project Details:

Module name	**Creative Technology Dissertation**
Module code	**UFCFLK-60-M**
Module leader	
Project Supervisor	
Proposed project title	**Serious Game for Fire Safety Evacuation Training**

Applicant Details:

Name of Student	Nikoleta Koleva
Student Number	22040611
Student's email address	nikoleta2.koleva@live.uwe.ac.uk nikoleta819@gmail.com

	CHECKLIST QUESTIONS	Yes/No	Explanation
1.	Does the proposed project involve **human tissue, human participants, animals, environmental damage, the NHS, or data collected outside the UK**?	No	*If the answer to this is 'No' then no further checks in the list need to be considered.*
2.	Will participants be clearly asked to give consent to take part in the research and informed about how data collected in the research will be used?		
3.	If they choose, can a participant withdraw at any time (prior to a point of "no return" in the use of their data)? Are they told this?		
4.	Are measures in place to provide confidentiality for participants and ensure secure management and disposal of data collected from them?		

CHECKLIST QUESTIONS		Yes/No	Explanation
5.	Does the study involve people who are particularly vulnerable or unable to give informed consent (eg, children or people with learning difficulties)?		
6.	Could your research cause stress, physical or psychological harm to humans or animals, or environmental damage?		
7.	Could any aspects of the research lead to unethical behaviour by participants or researchers (eg, invasion of privacy, deceit, coercion, fraud, abuse)?		
8.	Does the research involve the NHS or collection or storage of human tissue (includes anything containing human cells, such as saliva and urine)?		
9.	Will the research require any UWE staff or students to collect primary data from outside the UK?		

Your explanations should indicate briefly for Qs 2-4 how these requirements will be met, and for Qs 5-9 what the pertinent concerns are.

- **Minimal Risk:** If **Q 1 is answered 'No'**, then no ethics approval is needed.
- **Low Risk:** If **Qs 2-4 are answered 'Yes'** and **Qs 5-9 are answered 'No'**, then no approval is needed from the *Faculty Research Ethics Committee* (FREC). However, your supervisor must approve (a) your information and consent forms (Qs 2 & 3) and (b) your measures for participant confidentiality and secure data management (Q4).
- **High Risk:** If **any of Qs 5-9 are answered 'Yes'**, then you must submit an application for full ethics approval *before* the project can start. This can take up to 6 weeks. Consult your supervisor about how to apply for full ethics approval.

Your supervisor must check your responses above *before* you submit this form.

Submit this completed form via the *Assignments* area in Blackboard (or elsewhere if so directed by the module leader or your supervisor).

After you have uploaded this form, your supervisor will confirm it has been correctly completed by "marking" it as *Passed*/100% via the *My Grades* link on the Blackboard.

Further research ethics guidance is available at http://www1.uwe.ac.uk/research/researchethics