Augmented Reality Treasure Hunt Game

By

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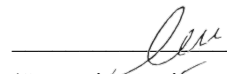

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ABSTRACT

The title of this project is called “Augmented Reality Treasure Hunt Game”. The growing trend of mobile AR Treasure Hunt games encourages players to explore their environment and interact with augmented reality elements, all facilitated by the use of Mapbox API for location-based experiences. These games offer both entertainment and educational opportunities, though the current market lacks high-quality AR outdoor treasure hunts that integrate Mapbox effectively. Additionally, fostering interpersonal skills is paramount, necessitating multiplayer functionality to promote cooperation and communication. Regular updates are crucial for player engagement. This project adopts an Agile methodology with an iterative plan to address these challenges, encompassing five key modules: the Interface Module, AR Module, Game Logic Module, Location Services and Tracking Module, and the Database Module. Educational missions promote learning, while a cooperation module enhances player interaction and collaboration. Developed in Unity using C# and Mapbox API, the game allows players to work together, utilizing real-world maps to find virtual points and interact with AR elements while on a quest for treasure. Furthermore, the application permits users to create and join custom game flows, offering flexibility and extending the game's appeal. In short, this project target to forge a new platform that offers an exciting and engaging learning experience for players.

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LIST OF ABBREVIATIONS

AR	Augmented Reality
UI	User Interface
3D	Three Dimensional
API	Application Programming Interface

CHAPTER 1
Introduction

1.1 Project Inspiration

In this technological age, most traditional games like chess are developed as digital games. Treasure hunt is also one of them. In conventional, the host of the treasure hunt game has to hide their items physically, give clues to other players, and ask them to find the hidden items. Nowadays, this game mode has been transformed and developed into a mobile application. In a treasure hunt mobile application, the treasure can be a virtual item, and the player can solve the missions to find the hidden treasure. Some treasure hunt games provide multiplayer mode so that they can be played together by a group of people. If augmented reality (AR) is applied in the treasure hunt game, it is called an AR treasure hunt game.

Augmented reality allows for the real-time integration of digital data with the environment around the user [1]. The digital elements can be added at a specific location in our real world and can be viewed using the device's camera. AR can be applied to different fields, such as retail, education, and entertainment, to improve the user experience. AR retail applications allow users to interact with a product by creating virtual simulations. By using AR, classroom education and self-learning applications can be designed to be extraordinary and more interactive [2]. Besides, AR game applications such as Pokemon Go [3] are one of the trends in mobile entertainment applications. AR gaming applications bring freshness to the players because AR is new to most people and brings a different gaming experience compared to traditional gaming applications.

AR treasure hunt games add digital elements to the game and make the game to be more exciting and able to attract more players. This project will focus on developing a versatile and fun location-based AR treasure hunt mobile application.

1.2 Problem Statement

In the mobile app store, there are many treasure hunt mobile games designed to provide fun for players. However, many of these games lack well-designed mission structures, player interactions, and custom gameplay, which can lead to a less-than-satisfying gaming experience. Creating a successful treasure hunt requires going beyond standard gameplay to include additional elements like AR and customizable treasure hunt sessions. These enhancements can significantly improve the overall gaming experience and ensure player fun and engagement.

1.2.1 Lack of customization game flow and immersive AR experience of a treasure hunt mobile game

Based on the review of existing treasure hunt mobile applications, it has been observed that the majority of these games follow a predefined flow set by the system, limiting players' ability to modify the gameplay. Players of these games usually only allowed to follow certain instructions or completing the system-defined missions to obtain the predefine clues. So, if the player knows the routine of finding hidden treasure, it is easy for the player to feel bored and unchallenged. Besides, there are limited treasure hunt mobile game combined with AR to provide players with a different gaming experience. Therefore, treasure hunt mobile games that lack frequent updates with new features and treasure hunt maps will be eliminated from the market because players will lose interest and uninstall it.

1.2.2 Lack of additional knowledge acquired through the treasure hunt game

A success treasure hunt game does more than provide fun to the players. Learning through gaming helps players to gain additional knowledge, no matter what field it is about. Treasure hunt missions that ask player to solve certain knowledge-based questions are important because it provides the player with an opportunity to learn. Furthermore, the process of using the clues obtained to find hidden treasures becomes an engaging brainstorming journey that enhances the overall gaming experience. However, most of the reviewed system do not contains learning-worthy missions. For example, in mobile game named ARrrrrgh [4], no mission is set up, and the player finds the hidden treasure only by distance hint. Besides, the mission in Mystery Coast [5] asks the player to swipe the screen to clean the key in order to find the hidden treasure. (see Figure 1.1). Most players play treasure hunt games not just for

the achievement and enjoyment of solving challenging and interesting missions, they are also trying to explore and learn new things. Through missions with learning value, players can gain additional knowledge while playing treasure hunting mobile games.

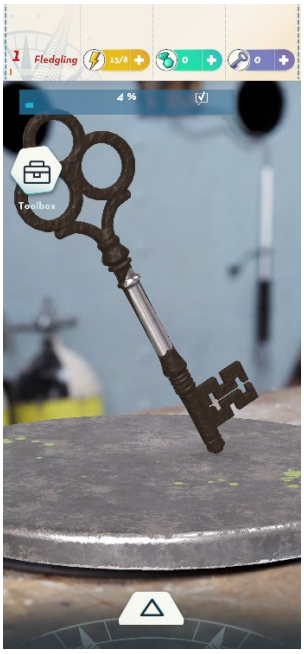


Figure 1.1 : Mission in the Mystery Coast

1.2.3 Lack of interactivity between players

The player is the most important part of a treasure hunt game. The success of a game application depends on the player's gaming experience. Due to the ability of multiplayer video games to foster positive social interactions between players of all ages helps players from different generations maintain their relationships and improve their overall well-being [6]. For multiplayer AR treasure hunt games, the players can group as a team to start their treasure hunt journey. Team missions will be set up to increase the interaction between team members. However, most systems do not support players playing as a team but individually. For example, Scavengar [7] allows players to create a game and set up the missions. The players can play the same game that has been created at the same time individually, so there will be no interaction between those players.

1.3 Project Objectives

Project objectives are set in this project and aim to be accomplished after the project. There are two objectives in this project which will be discussed below.

1.3.1 To develop a location-based treasure hunt game that allow players to explore the outside world with friends through interactive and learning-worthy treasure hunt missions

The main objective of this project is to develop an interactive treasure hunt game that encourages players to explore the outside world while engaging in exciting missions. Nowadays, many teenagers are addicted to playing games that do not bring useful value to their life and it is a waste of time. The proposed system can provide teenagers with a new entertainment and education platform through its interactive game sessions. Players can obtain the clues through mission solving and use these clues to find the hidden treasure. Besides, the team missions will be designed to guide the player to cooperate with team members. Furthermore, the proposed system has a text chat function that will be used as a communication channel between team members. This can increase the interaction between players. In short, this project aims to provide a platform that allows players to explore new things, obtain knowledge and make friends by playing treasure hunt games and solving learning valuable missions.

1.3.2 To create an immersive AR experience by implementing AR techniques into outdoor treasure hunt mobile game that offers players an immersive and interactive experience by blending the virtual and real worlds with customizable game flow

Blending the virtual and real worlds by adding an AR element to the treasure hunt and creating an immersive AR experience was the second goal of the project. Players can discover and capture their surroundings while treasure hunting, looking for AR elements added to the checkpoints. Once the AR camera is enabled and a checkpoint is reached, AR elements are displayed on the device's screen. Players need to interact with these AR elements to enable checkpoints and attempt missions. Additionally, hidden treasure takes the form of AR elements that, once discovered, can be seen on the player's device. Besides, creator mode allows to set the flow of the game as they want by placing missions, clues and AR elements in the map. This helps improve playability for players as they won't easily get bored with the game. In short,

this project aims to provide players with a new AR experiential outdoor treasure hunt experience, and at the same time can customize the treasure hunt map they want.

1.4 Project Scopes

This project serves the map of UTAR Kampar Campus as foundation and develop an outdoor location-based AR treasure hunt mobile game named “Secrets of the Greenwood”. In this project, the target users are UTAR Kampar students. So, the game design including game mission and game flow are designed to increase the interaction between students and give students more opportunities to explore the beauty of UTAR Kampar campus. In short, the users of this mobile game will not only get fun but additional knowledge while playing the game.

Besides, there is total five main modules in this project which are **interface module**, **AR module**, **game logic module**, **location services and tracking module** and **database module**. **Interface module** consists of attractive UI elements to show the instruction and handle the simple interactions between application and users. The UI design is related to forest theme, inspired by our campus' forest-like surroundings. The UI is mobile responsive which able to render the content according to the resolution of mobile device. Due to the limitation of the mobile phone screen size, panel will be used to group the UI elements which will be show on the same time so that it helps to separate UI to different layer and increase the usability.

Furthermore, **AR module** is responsible to handles the AR functionality including camera integration and rendering 3D virtual objects in the correct position and orientation which is known as virtual point. A variety of 3D objects can be selected and placed on virtual points specified by the user. When the user reaches the virtual point and captures it with the mobile device's camera, the virtual object will come alive and interact with the user.

In addition, treasure hunt game consists of complex game logic and storyline to construct an attractive game. The **game logic module** is used to control the flow of the game and ensure the integrity of storyline. Not only that, the user may perform some

invalid operations, and the game logic module are responsible for responding to these operations to prevent issues that will affect the gaming experience.

Location services and tracking module includes GPS services and position tracking services. In this outdoor location-based treasure hunt mobile game, the tracking of the user current position in the map is important as this affects the flow of the game. Therefore, users need to enable the location services permission of this application while playing this game. The distance between the user and the virtual point will be calculate and update to ensure the user only able to capture the virtual objects that close to them.

Database module is one of the modules in this project. Firebase will be used in this project to store the data such as user details, game progress and game session information such as missions and virtual points. The primary purpose of using a cloud database is to centralize and synchronize the data that generated by multiple users. Besides, applications can manage user identities and access restrictions securely with the help of Firebase's user authentication service. Since it is an online database, the user devices must connect to network while playing this mobile game.

By utilizing the functionalities of these modules, location-based AR Treasure hunt game able to be developed and provide users with a good gaming experience. This game provides flexibility to users, as they can become a creator and create a new game session or act as a player and join on other players' game sessions. Creator are allowed to define and set up his game session including the allocation of virtual points, missions and clues. The creator can select their desired position to initialize the virtual points by clicking the map. There are four types of missions available in this game, which are multi-choice question missions, short answer missions, puzzle missions and image recognition mission. For multi-choice question missions and short answer missions, the creator needs to provide the questions and answers. Puzzle mission which is word search puzzles will be implemented. Image recognition missions require the player to identify the name of the picture to complete the mission. In multiplayer game mode, missions can be designated as cooperative missions, requiring players in the same team to reach the same virtual points on the map in order to attempt them. The mission

information will be stored to cloud database after the virtual point is initialized by creator.

For players, they can join the initialized game session and start their treasure hunt journey. The game session's virtual points information will be retrieved from cloud database after the game is started. Players need to find virtual points by the clues provided. Once they reach the virtual point and switch to AR camera view, they will be able to capture the AR virtual object and interact with it. The mission information will be provided after the interaction and clue can be collected if the mission is complete. If the mission failed due to incorrect answers or response time is exceed, the virtual point will be temporarily disabled for 5 minutes. The game finished when the treasure is found by the player through the help of clues and the game information such as time taken to finish the game, total mission completed will be displayed to player.

1.5 Project Impact and Contribution

Location-based AR treasure hunt game will bring players a new gaming experience and funs. It will become the main trend in mobile entertainment applications if the contents and functionalities are well-designed and developed. The main motivation for developing the location-based AR treasure hunt game is to provide a platform for the players to explore the surrounding, kill time, and learn through gaming. Players with an adventurous spirit would like to play treasure hunt games with interesting and challenging missions. Besides, the proposed AR treasure hunt game requires players to go outdoors and find the treasure. So, by playing the treasure hunt game, players can know more about their surroundings and not only stay at their homes. The missions might consist of knowledge questions so that the player will obtain some additional knowledge through gaming. Playing a multiplayer AR treasure hunt game for an icebreaking session in an event will be a good choice because they have to be teamwork to find the hidden treasure. In short, the main contribution of this project is to develop a location-based AR treasure hunt game application that consists of useful functionalities and is suitable for teenagers to play. The proposed system will provide

fun to the players, and the players can learn some extra knowledge while playing this game.

1.6 Chapter Summary

The report for this UTAR Kampar location-based AR treasure hunt mobile game project consists of four chapters. In Chapter 1: Introduction, project background of the AR treasure hunt game, the motivation behind its development, project statements, the specific project objectives and the project scope will be discussed. Chapter 2: Literature Review will focus on the conducting research about the existing AR techniques, treasure hunt applications and the relevant techniques in a location-based AR treasure hunt mobile application. Chapter 3: System Methodology will discuss the overall project development, outlining the system's functionalities for players, specifying the necessary hardware and software requirements for implementing the game. In Chapter 4: Design of System, a comprehensive and detailed design of the AR treasure hunt game will be presented. This will include detailed explanations of the data storage design and the system architecture. In Chapter 5: System Testing, test cases and a project verification plan, including a user study, are conducted to perform testing and validate the project objectives. Chapter 6: Discussion discussed project outcomes, system limitation, and future enhancement, providing insights for future development and research. In the final chapter, Chapter 7, the project will be concluded. The report's overall goal is to give readers a comprehensive understanding of the AR treasure hunt game project by providing information on development background, development process, and system design.

CHAPTER 2

Literature Review

In this chapter, the literature review regarding the different kinds of AR techniques, existing location-based applications, existing treasure hunt games and the types of missions in a treasure hunt game will be conducted. By doing this, the most suitable AR technique can be identified and implemented in this project. Furthermore, reviewing the applications related to location-based or treasure hunt games provides a clear direction to develop the application by identifying those application pros and cons. In short, this chapter reviews the techniques and applications that are related to this project and intend to provide idea to develop a location-based AR treasure hunt game that combines the pros of the reviewed systems and eliminate the cons that are identified.

2.1 Review of AR technique

Mainly there are three types of AR techniques: Marker-based AR, Markerless AR, and Location-based AR. These techniques can augment the surroundings by adding digital elements to a live view [8].

2.1.1 Marker-based AR

Marker-based AR activates the AR experience using a designated marker [9] (see Figure 2.1). The markers can be an AR QR code, images, or other distinct objects. After the marker is captured by using the device's camera and if the marker is recognized, the data will be retrieved from the database. Then the corresponding digital element will be shown in the device. Marker-based AR is the easiest to implement because the user only needs to prepare a marker and save the AR content into the database. It does not have to consider environmental factors such as the need for a flat surface to place an AR object. The marker can be placed anywhere as long as a camera can detect it. In addition, marker-based AR content is stable for tracking if the marker image is prepared properly. Suppose the camera fails to focus on the marker after some time. In that case, the AR content will disappear, and detection is needed again to load the corresponding digital elements.

Normally, marker-based AR is used by personnel to create their marker with their favorite 3D contents. Some industries use marker-based AR to integrate with their business operation. Launching an AR food menu in a restaurant will help to improve customer satisfaction because, with the visual representation of food, it is easier for the customer to choose their desired food [10]. The customer can scan the markers provided on the menu to view the food model (see Figure 2.2).

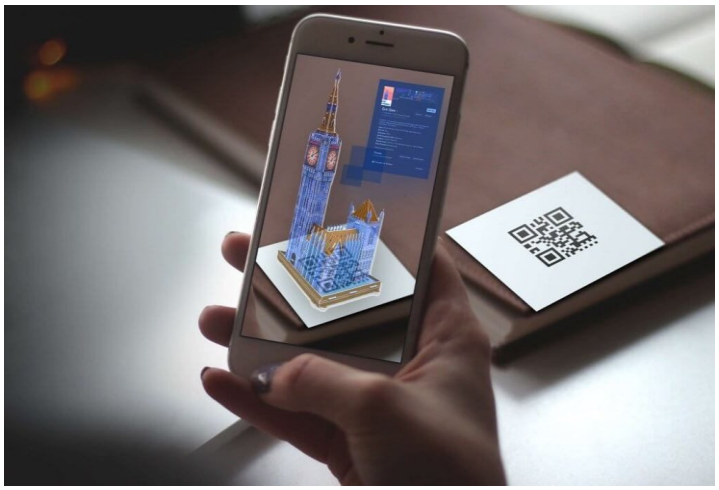


Figure 2.1 : Example of the Marker-based AR

Figure 2.2 : AR Food Menu

2.1.2 Markerless AR

Markerless AR can activate the AR experience without the need for a marker. It employs computer vision to identify objects in the physical world and display relevant information on them rather than using images or QR codes to add digital content to the real world [11]. The digital elements can be placed on a recognizable feature, such as a flat surface, after scanning the real environment [9]. It utilizes a concept called Simultaneous Location and Mapping (SLAM) to place the AR overlay [12]. By simultaneously mapping the area during the Instant Tracking AR experience, SLAM locates the user precisely within an uncharted environment [13]. After the virtual object is placed in a certain location, even if the player moves the camera away, the virtual object will still show on the screen when the camera is moved back to the location of the virtual object.

Most industries are using markerless AR in their applications. This is because markerless AR is more flexible than marker-based AR. Retail company IKEA has introduced an AR app named IKEA Place, allowing consumers to shop online using markerless AR. When a surface is identified, the user can choose an item of furniture and place it in the space (see Figure 2.3). This function can help customers buy the most suitable furniture for them, which greatly improves customer satisfaction. Besides, there are many AR games that apply markerless AR. Angry Birds AR: Isle of Pigs is an AR game developed by Rovio Entertainment Corporation [14]. Figure 2.4 shows the game contents of AR Angry Birds. Adding these digital elements into the user's environment will make the game more attractive and fun.

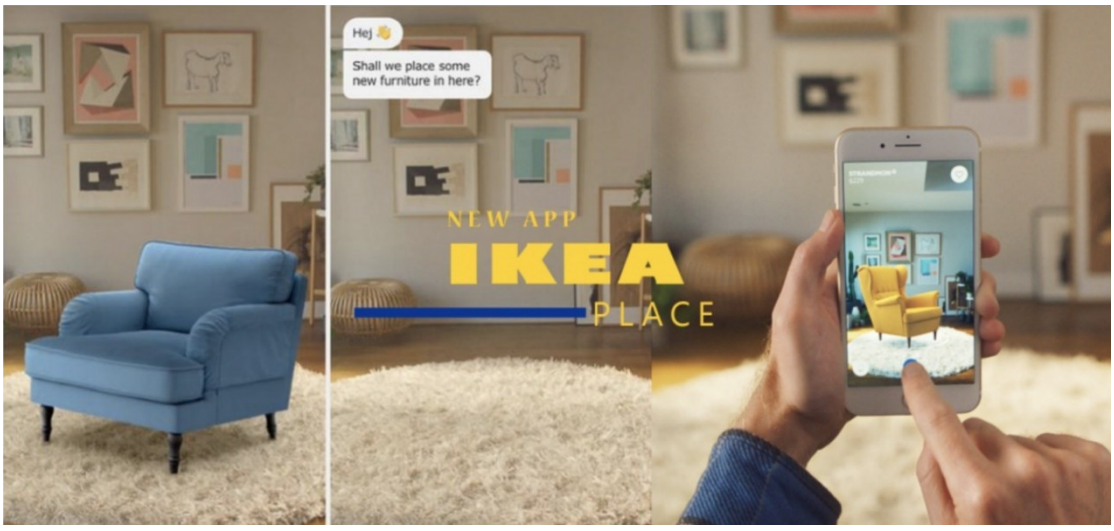


Figure 2.3 : Markerless AR IKEA Place

Figure 2.4 : AR Angry Birds find a flat surface and place contents

2.1.3 Location-based AR

Location-based AR is similar to markerless AR as it does not require any physical marker to activate the AR experience. It heavily relies on GPS and an accelerometer to accurately identify a device's location and position [15]. Real-time location systems (RTLS) are important in location-based AR because it helps to identify the present location of the users by getting the information from the sensors. After obtaining the data about the user's current location, by connecting the received information with points of interest (POI), the application determines augmented reality geolocation and how and where to add digital elements to the real world [16].When the user is near enough to the location, the AR contents will appear on the screen when scanning with the device's camera.

In 2018, Google announced that developers can now use Google Maps API as a foundation to create their games [17]. So, many developers have started integrating Google Maps' API in their location-based applications. In the tourism industry, using location-based AR applications can become a great way of improving the travelling experience. Figure 2.5 shows that location-based AR tourism applications can detect the nearest shops and display relevant information virtually on the screen. Other than that, Pokemon Go [3] also use location-based AR. Sometimes, some rare Pokemon will be released at specific locations and times. After the players go to the location and turn on the camera, the Pokemon will show on the screen, and the players can try to catch it.

Figure 2.5 : Location-based AR application for tourism industry

2.1.4 Comparison between types of AR

Table 2.1 shows the comparison of different types of AR based on characteristics. The three types of AR work differently, relying on markers, SLAM or GPS services. The performance of different kinds of AR, including stability, may be affected by environmental factors.

Table 2.1 : Comparison of characteristics between different types of AR

	Marker-based AR	**Markerless AR**	**Location-based AR**
Marker	Marker-based AR needs to generate a marker and capture it to activate AR experiences	Markerless AR does not need a marker to activate AR experiences	Location-based AR does not need a marker to activate AR experiences
GPS	Marker-based AR does not have to turn on GPS services to activate AR experiences	Markerless AR does not have to turn on GPS services to activate AR experiences	Location-based AR have to turn on GPS services to activate AR experiences
Stability	Marker-based AR contents are stable if the marker is placed and captured properly	Markerless AR contents are stable	Location-based AR contents are stable if device's GPS signal is good
Environmental Factor	Marker-based AR might have issues such as marker might not be detected in the dark	Markerless AR need to find a suitable and recognizable surface before placing an AR object	Location-based AR might have issues such as weak GPS signal, and it will affect the AR experience

2.1.5 Limitation of AR Techniques

From previously reviewed AR types, some limitations exist in each of the AR types. The limitation of marker-based AR is that it requires an additional step for the user to experience AR because the marker must be printed out and placed somewhere. For an outdoor AR treasure hunt game, placing all the markers physically at the treasure hunt checkpoints is troublesome. Besides, most markers are easy to be broken and get damaged. If other players destroy the markers, it will affect others' gaming experience on their treasure hunt trip.

For markerless AR, it has overcome the problem of having a marker in marker-based AR. However, it needs to recognize a suitable surface before placing AR content. The surface must have a texture so that it helps computer vision to recognize it is a flat surface. By using markerless AR, the user's environment will need to be considered. Some AR treasure hunt games implement markerless AR, such as ARrrrrgh [4], but it is not suitable to implement if it is an outdoor treasure hunt game because the AR contents for treasure hunt missions are needed in a wide range of areas.

The location-based AR using GPS will only be suitable for outdoor activities because the collection of indoor activity data is inaccurate using GPS. The limitation of location-based AR is the accuracy of the user’s position. In some cases, that cause GPS inaccurate such as satellite signal blockage will also affect the AR experience [18].

2.2 Review of Types of Map API

Nowadays, many applications have the demand to track the user’s location in order to provide them with a better user experience. To achieve it, the application must have the capability to access both map data and GPS data. Various map APIs have been introduced for developers to integrate it in the application. With the help of Map API, it brings convenience for the developers to use location-based services such as geocoding and mapping. There are two kinds of Map API being reviewed in this project which are Google Map API and Mapbox API

2.2.1 Google Map API

The Google Map API was launched in 2005. When it was first released, it only contained limited functionalities such as displaying a map of the earth and allowing users to get directions from point to point [19]. After that, developers started embedding it into their web applications for mapping purposes. Through the evolution of Google Map API, it added many functions, such as offline maps, real-time traffic information, and Mobile SDK for developers. Nowadays, developers can build mobile applications with embedded Google Maps functions easily using those SDKs.

2.2.2 Mapbox API

The Mapbox API is provided by the Mapbox company and was first introduced in 2010. Its original purpose was to provide customers with customizable maps. Even though they have evolved to provide features such as geocoding and navigation, their original purpose has not changed. Mapbox aims to provide its customers with flexibility and customization capabilities regarding the type of map they require including the map appearance. Many famous applications are using Mapbox API such as Facebook, and Pinterest. [20]

2.2.3 Comparison of Map API

Table 2.2 shows the comparison of characteristic and performance on different Map API. The two Map APIs differ in price, functionality, and performance, and the choice of Map API may be influenced by these criteria.

Table 2.2 : Comparison of characteristic and performance on different Map API

	Google Map API	**Mapbox API**
Price	- First $200 usage each month is free	- Free for up to 25,000 mobile users and 50,000 web loads
Map Customaization	- Extensive customization require additional tools or extensions	- Flexible customization and developers have more control over map design
Accuracy	- Lower error rate	- Higher error rate

2.3 Review of Location-Based AR Application

2.3.1 Jurassic World Alive

Jurassic World Alive (JW Alive) [21] is a mobile game developed by Ludia company with implement AR technique and location-based services. The application collects the user's surrounding data and some of the significant places on the map will be marked as checkpoints and shown on the map. The dinosaur will be generated and shown on the map when the user reaches a certain position. By interacting with the dinosaurs on the map by screen touch, the virtual dinosaur will be rendered and displayed on the screen captured by the device camera (see Figure 2.6). Location-based services allow developers to create interactive games that utilize user location data while AR enables more creative application content.

Figure 2.6 : AR Dinosaur in Jurassic World Alive

2.3.2 Pokémon GO

Pokémon GO is the most popular location-based game that attracts players because of its special playstyle and its rich elements such as AR virtual elements. It was developed by Niantic and released in 2016. Location-based services are the main part of Pokémon GO to support its unique and engaging gameplay. The GPS services of the

player's device are used to track their position and movements. When the player's real-world position is close to a certain location, the Pokémon will be displayed on the map and the player can interact with it (see Figure 2.7). The location of PokéStops and Gyms are set according to the real-world position and the player can walk into the area to activate it. This game's success relies on its ability to use geolocation technology to bridge the virtual and real worlds.

Figure 2.7 : AR Pokémon in Pokémon Go

2.3.3 AR City

AR City is a location-based AR application developed by Blippar and it is currently in beta testing [22]. It attracts users with its new and interesting way of navigating the city. There are three main layers of information will be available through this app including basic AR-based navigation, improved map contents, and positioning of urban visuals. Around 300 cities worldwide can be navigated and explored using AR and computer vision through this application. It utilizes GPS functionalities to track the user's location in order to provide additional information about the places including names of streets and buildings and local points of interest (see Figure 2.8). It will only show points of interest within the user's visible view, rather than, for instance, those hidden by a building, in order to enhance the visual experience. In short, location-based services and AR elements are used by ARCity for city navigation.

Figure 2.8 : Navigation view in AR City

2.3.4 Google Maps AR

Augmented reality (AR) is integrated into Google Maps AR developed by Google to give users a dynamic and simple wayfinding experience. It introduces the "Live View" feature, which enhances real-time navigation guidance by combining augmented reality (AR) overlays on the smartphone camera view. Google Maps Live View will show the road names and distances in AR and major turns to keep you on track [23] (see Figure 2.9). The app will also make an effort to identify your surroundings by analyzing what your camera captures and comparing it to Street View imagery to ensure that you are travelling in the right direction.

Figure 2.9 : Google Maps AR Live View

2.3.5 WallaMe

WallaMe is an innovative augmented reality (AR) social messaging application that has gained popularity for its unique approach to location-based communication. It was developed by WallaMe Ltd. which was established as a startup in London in 2015. WallaMe enables users to create "WallaTags" which include virtual messages, custom drawings, and multimedia content and place it in specific real-world locations. Users have to take a picture of a wall in their surroundings and add the created "WallaTags" to the wall virtually. After that, when there are people who pass by and capture the wall using WallaMe will be able to see the AR elements (see Figure 2.10). The fun and interactive nature of WallaMe where users can leave hidden surprises for friends or strangers, creates a novel form of social interaction.

Figure 2.10 : AR contents shows on wall in WallaMe

2.4 Review of Treasure Hunt Mobile Game

Treasure hunt is a game in which the players have to find the hidden treasure by using the obtained hints to guess the position of the hidden treasure. There are many treasure hunt applications in the application store. However, the contents of these applications are mostly different. Some of the treasure hunt games have implemented AR to make the game more interesting to the players, but some did not. Besides, the treasure hunt game also can be classified as an indoor treasure hunt game or an outdoor treasure hunt game. Outdoor treasure hunt game requires players to go outside and move around to find the clues of the hidden treasure.

2.4.1 ARrrrrgh

ARrrrrgh [4] (see Figure 2.11) is a simple AR treasure hunt game suitable for a small group of players. As long as the area of the place is large enough to hide the treasure and it has a flat surface that can be recognized by computer vision, the game can be played. There are only two steps to conducting a treasure hunt game. The first player has to find a suitable location to hide an AR treasure, while the second player will have to dig for the hidden treasure to win. First, the device camera must be turned on, and the player will start scanning the environment. When a flat surface is recognized, the system will notify the player that it is an available space to hide the treasure. After the first player has decided to hide the treasure, he can click the hide button, and the treasure will be hidden under the ground virtually. After that, the first player must pass the device to the second player because players are using the same device to conduct this treasure hunt game. The application will hint to the second player at the location of the hidden treasure by providing information about the distance from the hidden treasure. The second player can press the dig button when the location is confirmed. If the location of the hidden treasure is found correctly, an AR treasure will show, and the game ends.

Playing a treasure hunt game using ARrrrrgh is easy because the game can start and finish in just a few clicks. The game logic implementation is simple and suitable for families to play. Other than that, the only hardware requires to play ARrrrrgh is a mobile device with a camera.

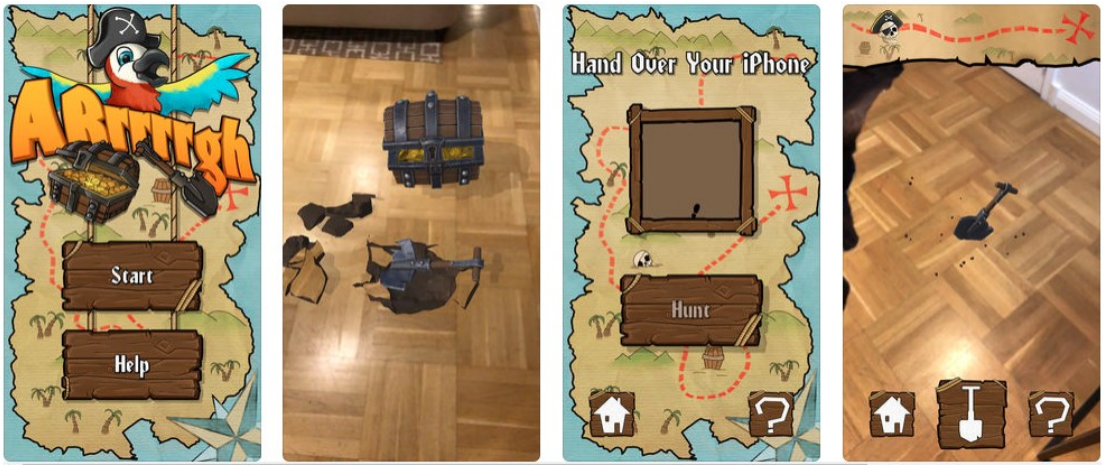


Figure 2.11 : ARrrrrgh treasure hunt game design and implementation

2.4.2 Scavengar

Scavengar [7] is an outdoor AR application. The user can create a showroom or a story-driven experience and place the AR content. This application supports location-based and space-bound placing digital elements. The GPS service must be turned on to create a location-based AR experience. After that, the map containing information about your current surroundings will be shown on the screen. The user can move the map and set the start point location of the game. The AR contents can be placed on any map location by clicking the add item button. Digital elements such as 3D items, coins, and crystals can be placed on the map. After a game is set up properly by the owner of the game, the other players can start their trip to collect those items (see Figure 2.12). It is similar to a treasure hunt game, but a treasure hunt game requires players to find out the hidden item, while a scavenger hunt game requires players to collect those available items in their surroundings. The missions are placed at the checkpoint and the players have to go to the checkpoint to solve the mission. The player wins by obtaining the highest points and finishing the checkpoints.

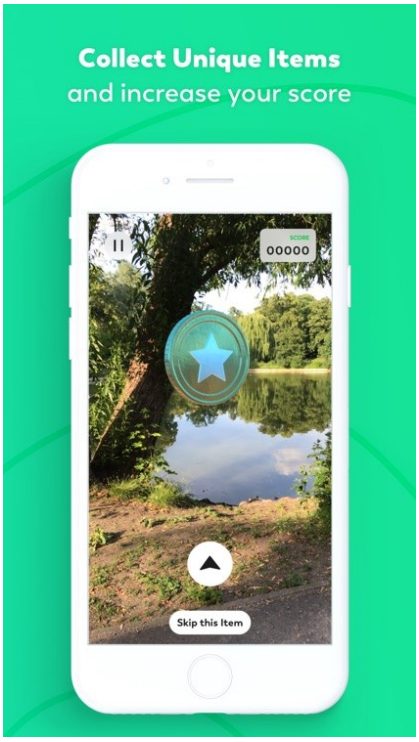


Figure 2.12 : Collecting AR item in Scavengar game

2.4.3 Geocaching Application

Geocaching application (see Figure 2.13) is one of the best outdoor treasure hunt applications. The lover of a treasure hunt uses it to identify where are the caches. A cache is a hidden treasure that might contain low-cost trinkets or geocoin. For geocaching participants who like to hide the caches, they need to prepare a waterproof container and a logbook to list the people who visit the cache and the item they want to put inside it. After that, they have to hide objects somewhere physically and upload the clues to the application. The other players will find the object according to the map in the Geocaching application. GPS services must be enabled if players want to play a treasure hunt using Geocaching. Besides, this application provides a platform that allows players to send messages to others in the geocaching community. With this platform, the players can discuss what they have found or share the story about their treasure hunt trip. The profile function will help keep track of what the user has found and hidden previously. This application provides a platform for those who love to play outdoor treasure hunts.

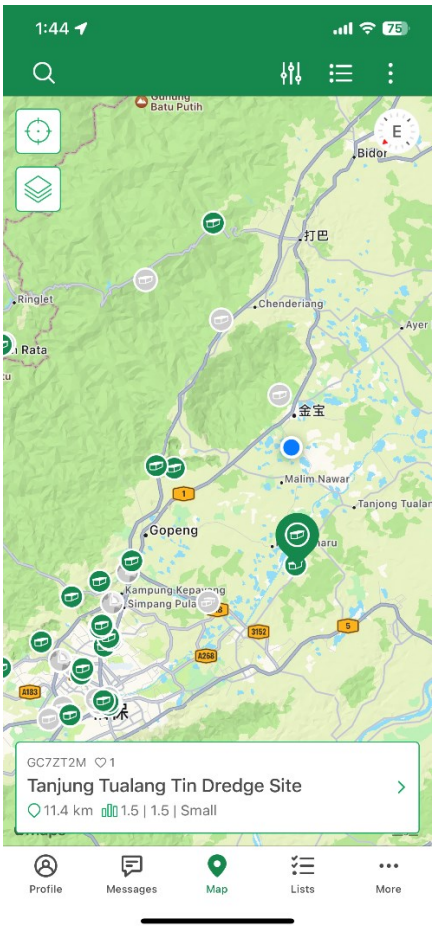


Figure 2.13 : Geocaching Application Map View

2.4.4 Comparison between Existing Treasure Hunt Applications

Table 2.3 shows the comparison of different treasure hunt applications based on characteristics and functionalities. The comparison helps to identify strengths and weaknesses of treasure hunting apps present in the app marketplace.

Table 2.3 : Comparison of characteristics and functionalities between existing treasure hunt applications

	ARrrrrgh	**Scavengar**	**Geocaching**
Type of AR	ARrrrrgh use Markerless AR to place the AR contents	Scavengar use location-based AR to place the AR contents	Geocaching do not use AR
Number of players in a game	Normally 2 to 4 persons	The game does not limit the number of players, but each player playing the game individually	Not limited
Interaction between players	Players of ARrrrgh will have physical interaction because they are sharing the same device	There is no interaction between players	The players of Geocaching can use text chat to interact with each other's
Cost to create a new game	ARrrrrgh is free to create a new game	Scavengar is free to create a game with normal AR items A subscription is needed if you want to create a game with custom 3D items	Find a cache is free but hiding a cache requires subscription to the premium plan

2.4.5 Limitations of Existing Treasure Hunt Applications

There are limitations that exist in the reviewed treasure hunt applications. In ARrrrrgh application, only a limited AR element, such as an AR treasure, will be shown to the player. Besides, the game session is conducted on a single device, so it is not suitable for large groups of players. As mentioned in the previous chapter, missions are an important element of treasure hunt games. However, there is no interesting mission in this application that will provide clues for the player to find the hidden treasure but only distance hints. So, the application can become a bit boring after several successes.

The limitation of Scavengar is that it does not support team-mode treasure hunt games. Team mode treasure hunt will be more fun than solo treasure hunt as the players will feel that they are part of the team and will be more willing to help the team to win. Besides, normal users can only place some AR elements, such as coins and crystals. A premium account is also needed if the player wants to place a custom 3D item.

Geocaching application is used for an outdoor treasure hunt. It has some limitations, such as not supporting AR and no treasure missions in the application. All the caches on the map are physically in that location, and the players can go to the location to look for it. AR contents cannot be placed on the location, and the hint of the hidden caches will be given by the hider but not from solving the mission.

2.5 Review of Mission Types in Conventional Treasure Hunt and Mobile Treasure Hunt

2.5.1 Quiz

Quiz missions including multi-choice questions and short answer questions are available in both conventional treasure hunts and mobile treasure hunts. The primary purpose of such missions is to encourage the player to study and use this knowledge to attempt the quiz. Usually, the questions are thoughtfully designed to evaluate the knowledge and skills that players have acquired both in the classroom and throughout their lives, in addition to providing entertainment.

2.5.2 Puzzle Solving

Puzzle-solving in a treasure hunt offers players an opportunity to cleverly figure out a solution to a puzzle. The types of puzzle solving including ciphers, logic puzzles and word puzzles are available in both types of treasure hunts. Having this kind of mission makes the treasure hunt game become interesting and challenging because players are willing to challenge and test their own abilities.

2.5.3 Team-Based Challenges

Some treasure hunt games group players as a team and victory belongs to the team when the hidden treasure is found. For a conventional treasure hunt game, members of the group might need to follow specific instructions provided by the owner of the checkpoint in order to obtain the clues. For examples, player A need to understand the player B's body language to guess a word. To complete the mission, the team members must work together effectively. Team-based challenge missions can also be implemented in a multiplayer treasure hunt mobile game, and it requires the cooperation of the team to complete the virtual missions.

2.5.4 Physical Observation Challenges

The player's observation of the environment is the challenging part of the treasure hunt. In the conventional treasure hunt game, players need to observe their surroundings to identify what is happening and analyze the situation. Players with good observation skills will be able to find more clues related to hidden treasures. Once the checkpoint location has been determined from information gathered through observation, they may need to travel to the actual location to find new clues. For a treasure hunt mobile game, the creator of the game can have physical observation missions if they are interested in placing the clues physically on the checkpoint location for the players to search.

CHAPTER 3

System Methodology

3.1 Project Development

This project will implement agile development. Iterative development embraces change, which allows game development to change requirements as better ideas emerge. In addition, incremental development helps in prototyping the system to ensure that the initial idea is feasible in later stages of implementation. Agile development divides the phases in the Software Development Life Cycle (SDLC) into distinct cycles known as iterations. An iterative project plan (see Figure 3.1 and Figure 3.2) has been developed and will be executed according to the timeline. In this project plan, eight iterations of SDLC phases will be employed and the duration of each iteration is set to 4 weeks and is aimed at achieving certain goals.

During the first iteration, the initial planning and requirements gathering for this project take place. The overall design of a location-based AR treasure hunt game is analyzed and designed through a literature review. A simple application that aligns with the chosen technique and interface design will be built during the implementation. The goal of this iteration is not only to use the foundational application to validate the feasibility of the approach but also to test and refine the core functionalities of this project.

While the second iteration, the project's primary emphasis will be on advancing the location service and tracking module, as well as the augmented reality (AR) module. Finding and evaluating a suitable Map API for integration and choosing the best AR technique to use within the project are the main goals of this iteration. Testing and evaluation will be performed to assess the accuracy and functionality of both the chosen Map API and the basic AR implementation.

In the third iteration, the focus will turn to the game logic module and the database module. The early stages of planning, analysis, and design will play a key role in determining the choice of a cloud database, shaping the database structure, and developing game logic, including the storyline. Thereafter, the implementation phase seamlessly incorporates these modules into the existing application framework. Testing

will be conducted to ensure smooth game flow and reliable operation of database functions.

During the fourth iteration, this project will focus on identifying additional requirements to enhance the playability of the AR treasure hunt. The process will involve an analysis and design phase, where an improved solution will be conceptualized and subsequently implemented during the implementation phase. Test cases will be carefully designed to align with the flow of the game. At the same time, the entire system will be comprehensively developed based on the collected requirements. A thorough evaluation will take place as this project move into beta. This involves performing test cases and user studies to fully evaluate the overall performance of the project.

In the fifth iteration, the project will mainly focus on turning the prototypes into functional modules. This involves analyzing and designing the data structures, followed by implementing the functions into the system. Subsequently, testing will be performed to evaluate the newly implemented functionalities and ensure they meet the requirements. Moving on to the sixth iteration, the project will shift its focus to developing the multiplayer game mode. Photon server functionalities will be identified and analyzed for use in multiplayer connections. After integrating the Photon server into the system, the performance of the Photon server will be evaluated.

In the seventh iteration, the game logic for multiplayer game mode, such as collaboration missions, chat functions, and game synchronization, will be planned and implemented into the system. The system will then be tested to evaluate whether the multiplayer game functions as expected. In the last iteration, the project will concentrate on updating project documentation and conducting detailed user studies. This involves recruiting participants, collecting data, and analyzing the data collected. The findings from the user study will be used to evaluate the success of the project and make enhancements based on user feedback.

PHASE	TASK DESCRIPTION	START DATE	END DATE
ITERATION 1		**20-May-23**	**15-Jun-23**
Planning & Requirements	Identify the requirements of AR Treasure Hunt Game	20-May	24-May
Analysis & Design	Conduct literature review about technique and application related to AR Treasure Hunt Game for analysis and design purpose	25-May	2-Jun
Implementation	Implement simple application integrated with selected technique and interface for application	3-Jun	12-Jun
Testing	Test whether requirements can be satisfied	13-Jun	14-Jun
Evaluation & Review	Evaluate performance of the simple AR application builded and review for possible improvement	15-Jun	15-Jun
ITERATION 2		**16-Jun-23**	**13-Jul-23**
Planning & Requirements	Focus on planning and requirements gathering on location service and tracking module and AR module	16-Jun	21-Jun
Analysis & Design	Analysis the market available Map API and types of AR	22-Jun	25-Jun
Implementation	Implement the Map Function in AR Treasure Hunt Game with simple game logic	26-Jun	10-Jul
Testing	Test the accuracy and functionalities of Map API and the AR view	11-Jul	12-Jul
Evaluation & Review	Evaluate the performance of Map API and determine the final selection	13-Jul	13-Jul
ITERATION 3		**14-Jul-23**	**10-Aug-23**
Planning & Requirements	Focus on database and game logic planning	14-Jul	17-Jul
Analysis & Design	Identify the pros and cons of cloud database and conduct database design and game logic design	18-Jul	20-Jul
Implementation	Integrate database into AR Treasure Hunt and implement game logic for the game flow	21-Jul	5-Aug
Testing	Test the game flow and database functionalities	6-Aug	8-Aug
Evaluation & Review	Evaluate the game flow and database performance and review for improvement	9-Aug	10-Aug
ITERATION 4		**11-Aug-23**	**7-Sep-23**
Planning & Requirements	Plan to identify the additional requirements that helps to improve the playability	11-Aug	14-Aug
Analysis & Design	Analysis the further technique and game flow and design better solution	15-Aug	18-Aug
Implementation	Improve and complete the AR treasure hunt game	19-Aug	30-Aug
Testing	Test the application with the defined test cases	1-Sep	4-Sep
Evaluation & Review	Conduct user study to evaluate the project	5-Sep	7-Sep

Figure 3.1: Iterative Project Plan (FYP1) of Location-based AR Treasure Hunt Game

PHASE	TASK DESCRIPTION	START DATE	END DATE
ITERATION 5		**15 - January - 24**	**4 - February - 24**
Planning & Requirements	Identify the prototypes that require real functionalities to be implemented in the system	15 - Jan	17 - Jan
Analysis & Design	Design the necessary functions to transform the prototypes into a functional system	18 - Jan	21 - Jan
Implementation	Implement the designed functions into the system to make the prototypes functional	22 - Jan	28 - Jan
Testing	Conduct thorough testing of the implemented system to ensure functionality and identify any issues or bugs	29 - Jan	1 - Feb
Evaluation & Review	Assess the system to ensure that it meets the planned requirements and review it for further improvements or adjustments	2 - Feb	4 - Feb
ITERATION 6		**5 - February - 24**	**3 - March - 24**
Planning & Requirements	Identify the functionalities required from the Photon Server	5 - Feb	7 - Feb
Analysis & Design	Design the integration of the Photon Server for the multiplayer game mode, including how it will interact with the existing system	8 - Feb	11 - Feb
Implementation	Integrate the Photon Server into the project to establish connections for multiplayer server purposes	12 - Feb	25 - Feb
Testing	Test the integrated Photon Server functionalities and ensure compatibility with the existing system through comprehensive testing	26 - Feb	29 - Feb
Evaluation & Review	Evaluate the performance of the Photon Server to ensure it meets the requirements and review its effectiveness in enhancing the multiplayer game experience	1 - Mar	3 - Mar
ITERATION 7		**4 - March - 24**	**31 - March - 24**
Planning & Requirements	Integrate additional functions such as multiplayer missions, chat functions, and game synchronization for multiplayer.	4 - Mar	6 - Mar
Analysis & Design	Analyze the current system architecture and design the integration of multiplayer missions, chat functions, and game synchronization.	7 - Mar	9 - Mar
Implementation	Implement the planned features	10 - Mar	21 - Mar
Testing	Conduct rigorous testing of the implemented features to ensure they function as intended	22 - Mar	29 - Mar
Evaluation & Review	Evaluate the performance and effectiveness of the integrated functions	30 - Mar	31 - Mar
ITERATION 8		**1 - April - 24**	**18 - April - 24**
Planning & Requirements	Plan how to conduct user studies, update project documentation and reports accordingly	1 - Apr	3 - Apr
Analysis & Design	Design procedures for the user study, including selecting methods for data collection, defining participant criteria, and creating study materials	4 - Apr	7 - Apr
Implementation	Execute the planned user study, distribute materials, recruit participants, and conduct data collection according to the designed procedures	8 - Apr	11- Apr
Testing	Gather feedback and insights from participants during user testing, analyzing data to identify strengths, weaknesses, and areas for improvement	12 – Apr	15 – Apr
Evaluation & Review	Assess findings from the user study, review project objectives, and determine any necessary revisions or enhancements based on user feedback	16 – Apr	18 – Apr

Figure 3.2: Iterative Project Plan (FYP2) of Location-based AR Treasure Hunt Game

3.2 System Functionalities

The figure 3.3 shows the use case diagram of the AR Treasure Hunt Mobile Game. There are two types of users in this game which are creators and players. The users need to register and login to their account before they are allowed to play the game. They can view and edit their personal profile which consists of information such as their nickname, inventory and game history. Users also can view the leaderboard showing top players. If the user wants to create a new game session, they will act as a creator and they need to set the virtual points including the placement of missions, clues and AR virtual objects. Creators are allowed to delete the game that created by them. For a user who wants to play the treasure hunt game, they can join the available game session and start to play. Player needs to find the hidden treasure to win the game and they can get clue by completing the mission available on their surroundings.

Figure 3.3: System Functionalities for the AR Treasure Hunt Mobile Game

3.2.1 Design of Account Registration Procedure

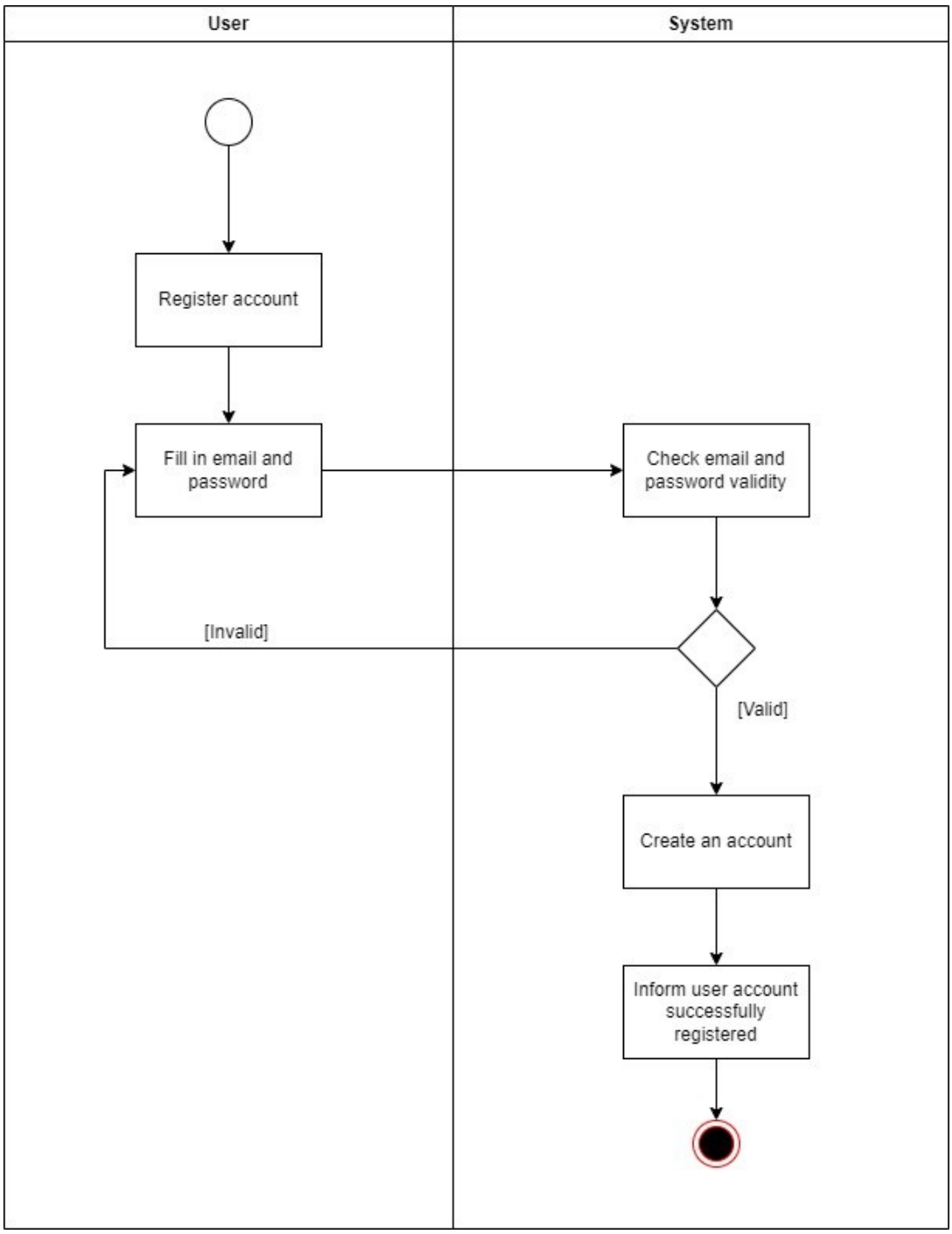


Figure 3.4: Register Account Activity Diagram

Figure 3.4 illustrates the account registration process. Users can submit the registration request after entering their email account and password. These submitted credentials are then carefully checked for validity. This requires verifying that the email

address is unique and has not been registered before. In addition, the system ensures that the password provided is the same as the confirmed password. If all checks are valid, an account will be created based on the information submitted by the user. Otherwise, users will be requested to refill the credentials and resubmit the registration request. Once the account is successfully created, the system will display a message to inform the user that the account registration is successful.

3.2.2 Design of Account Login Procedure

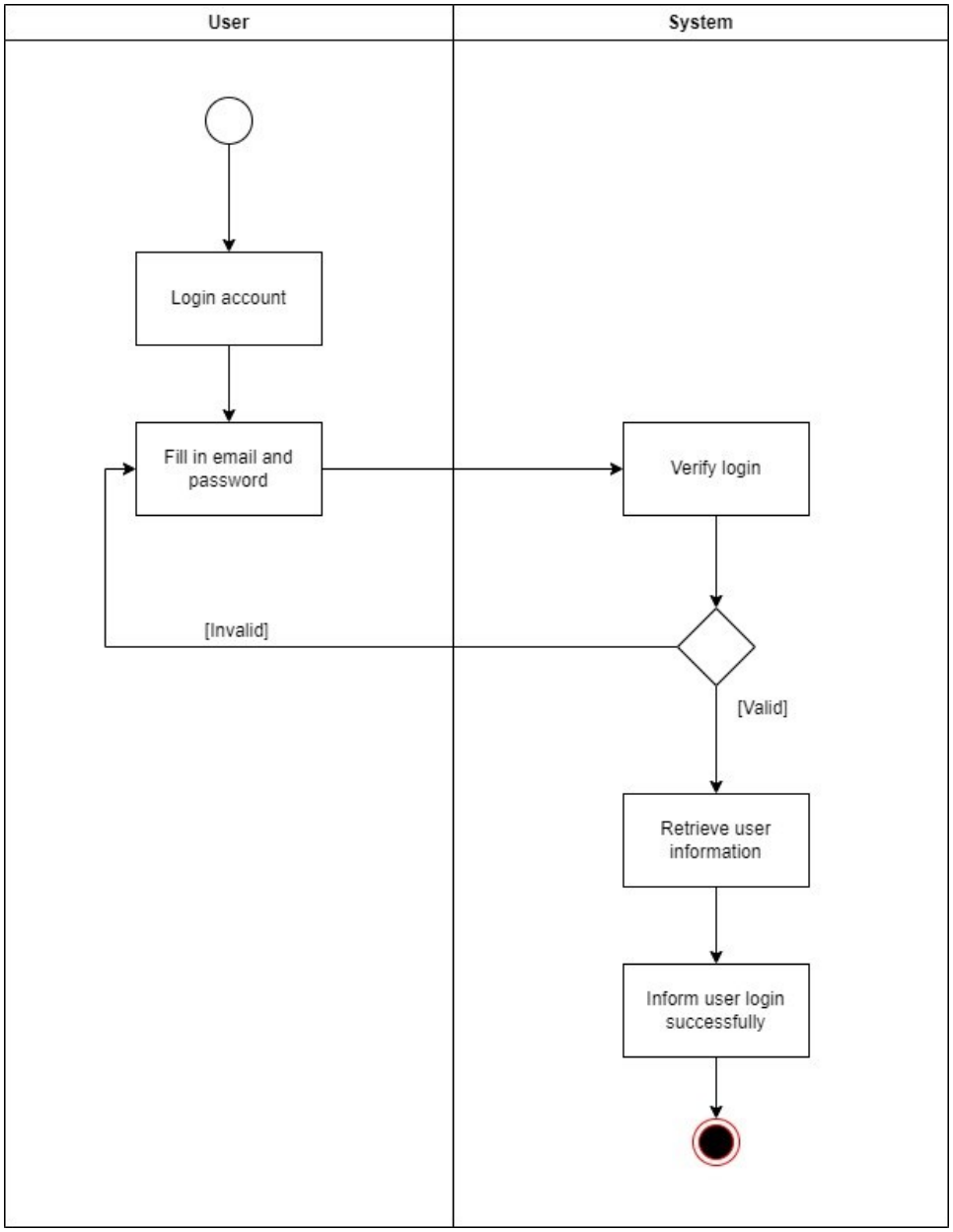


Figure 3.5: Login Account Activity Diagram

Figure 3.5 illustrates the process of account login. Users need to fill in their email account and password and then click the login button. The system will verify whether the account exists and whether the login credentials are correct. If the account login verification is successful, the system will display a message to inform the user login is successful and the user information will be retrieved and loaded into the game.

3.2.3 Design of User Profile Viewing and Editing Procedure

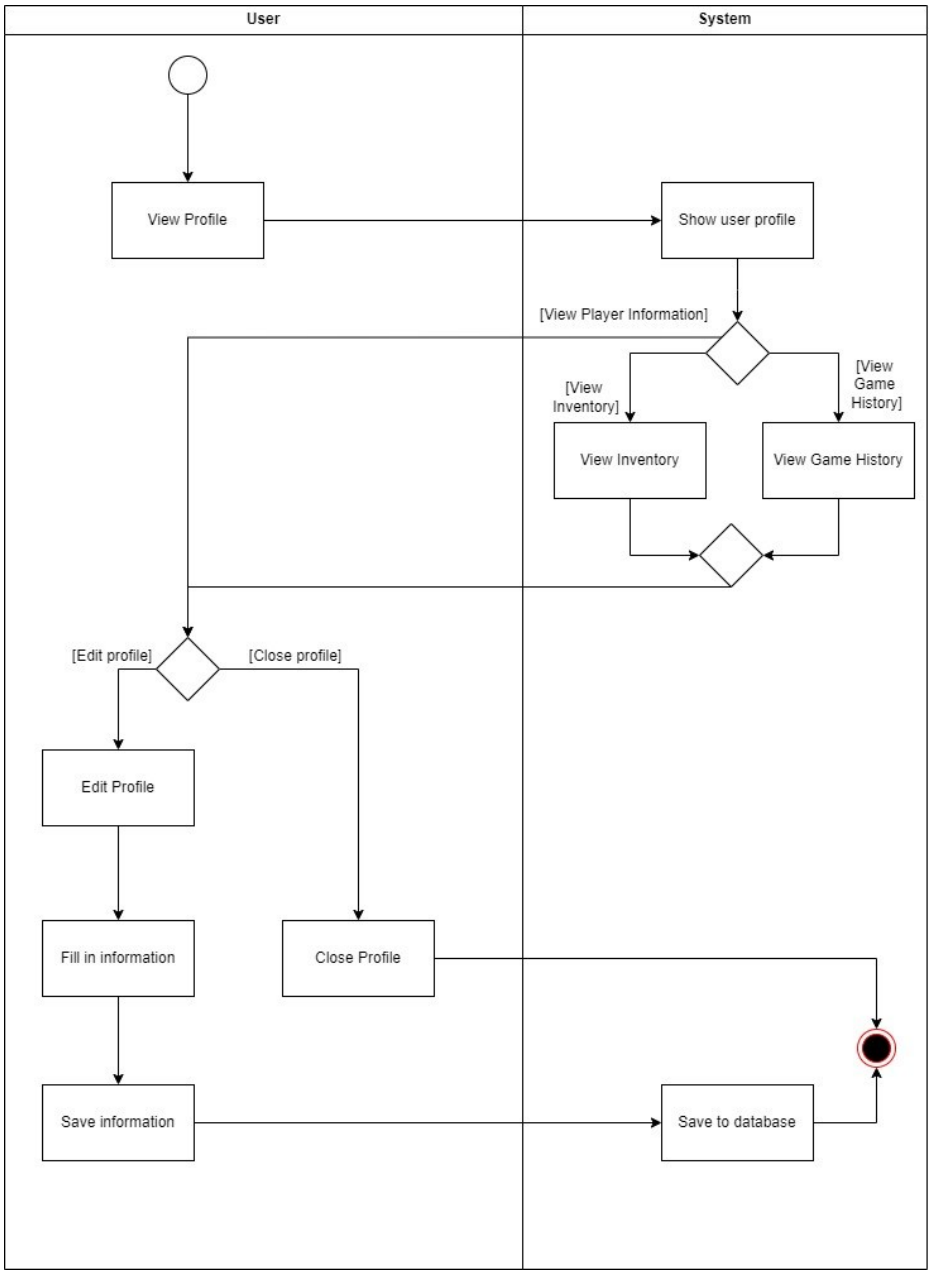


Figure 3.6: View and Edit Profile Activity Diagram

Figure 3.6 illustrates the process of viewing and editing the profile. Users can click on the “View Profile” button and the system will show the user profile. User can choose to view inventory and game history. If users want to edit their profile, they can fill in the new information and save it. The system will save the edited user profile to the database. Otherwise, they can click the “Close Profile” button and end the activity.

3.2.4 Design of Leaderboard Viewing Procedure

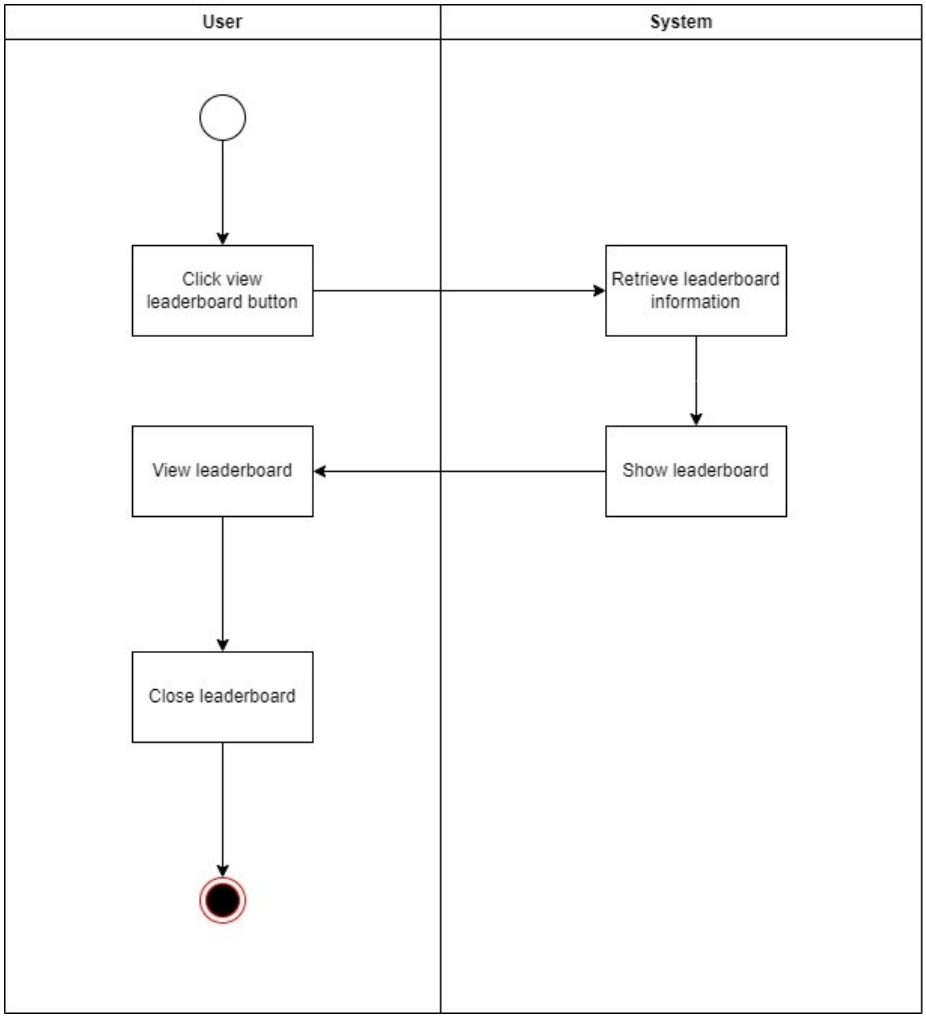


Figure 3.7: View Leaderboard Activity Diagram

Figure 3.7 illustrates the process of viewing the leaderboard of the treasure hunt game. Users can click the “Leaderboard” button to view the leaderboard. The system will retrieve the latest leaderboard information and display it to the user. After viewing the leaderboard, users can close the leaderboard and continue with other operations.

3.2.5 Design of Player Play Treasure Hunt Game Procedure

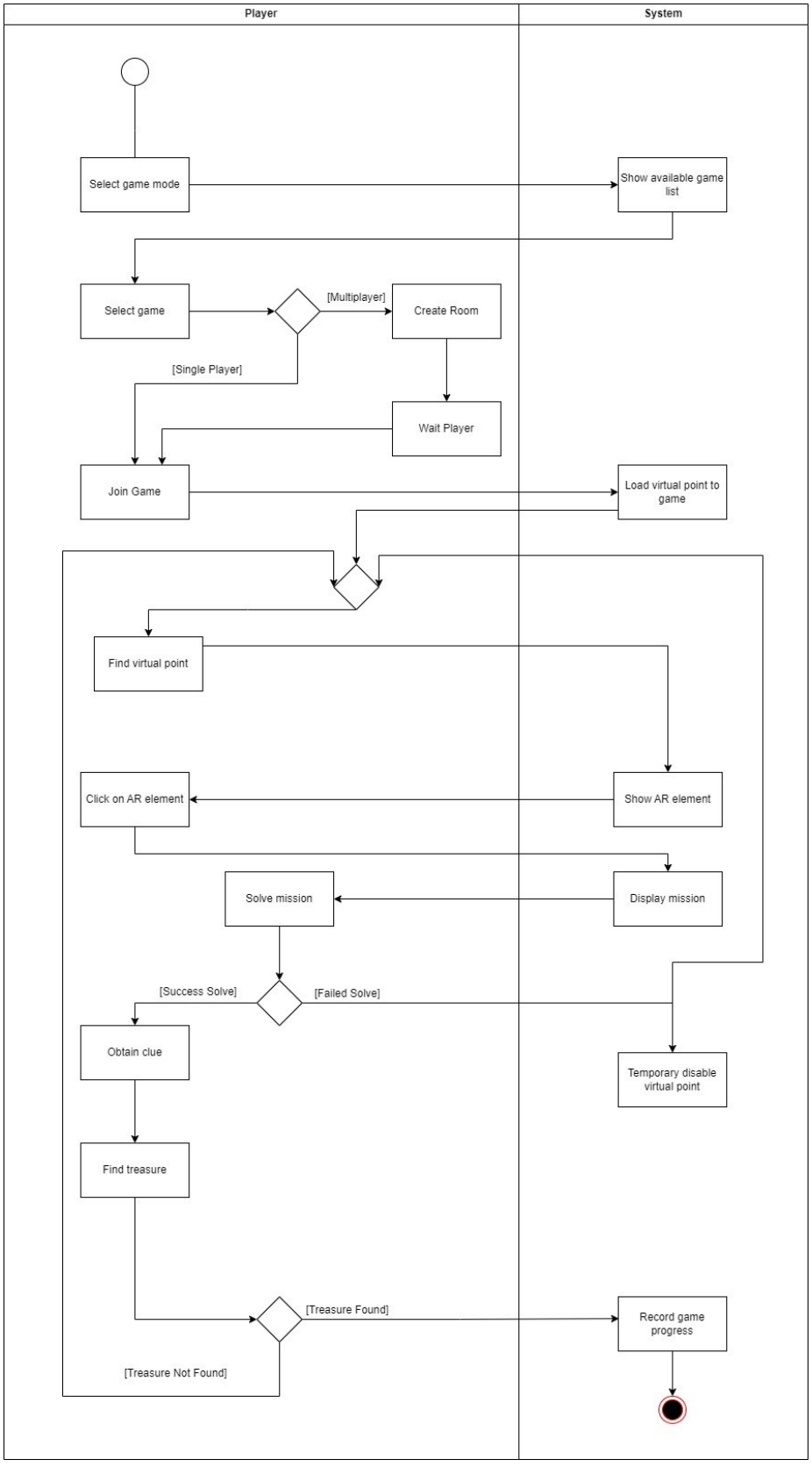


Figure 3.8: Play Treasure Hunt Game Activity Diagram

Figure 3.8 illustrates the process of playing a treasure hunt game. Users can select to play single-player or multiplayer games. After selecting the game mode, the available games will be shown on the game list. Users can select the game to play and join the game. The virtual points will be loaded into the game session and users need to find the virtual points physically. When the virtual point is found, the AR elements will show on the screen. By clicking on the AR element, the system will display the mission. By solving the mission, a clue will be obtained, and it is used to find the treasure. If the mission fails, the virtual point will be disabled for 5 minutes, and the player can look for any other virtual points. If the players are unable to use the obtained clue to find the treasure, they can find other virtual points to obtain more clues. When the treasure is found by the player, the game session is ended, and the game process and information will be recorded in the database.

3.2.6 Design of Creator Create Treasure Hunt Game Procedure

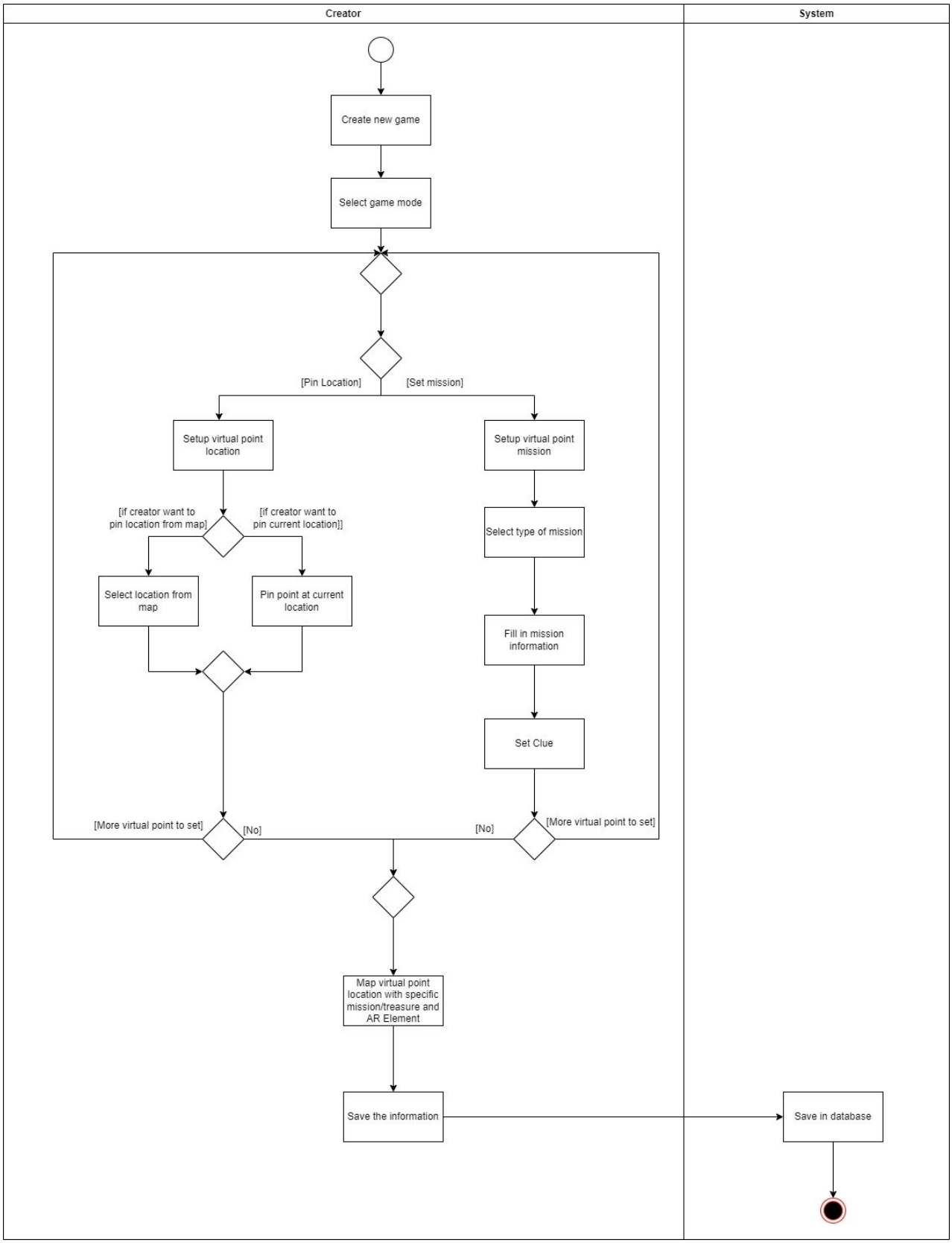


Figure 3.9: Create New Treasure Hunt Game Session Activity Diagram

Figure 3.9 illustrates the process of creating a new treasure hunt game session. Creators can select to create single-player or multiplayer games. Creators can set up the virtual point location with two options. They can either pin it by selecting the location from the map or pin their current location as a virtual point location. Creators also need to set up the mission for virtual points. They can select the type of mission and fill in the mission information. After that, they need to set clues for the creating mission. If the creators want to set more than one virtual point, they just need to repeat the step. When there is no more virtual point to set, the creator needs to map the virtual point location with a specific mission or treasure and an AR element. After mapping, the creator needs to save the information and the system will proceed with the saving to the database.

3.2.7 Design of Creator Delete Treasure Hunt Game Procedure

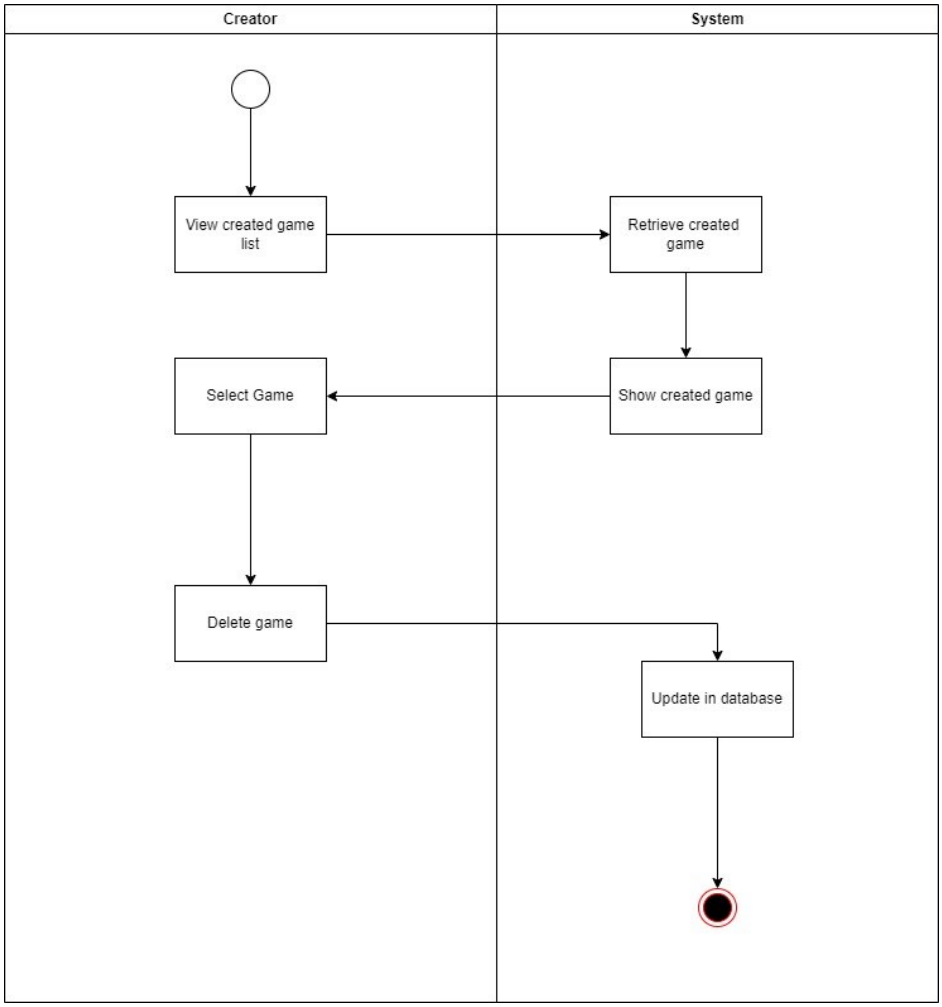


Figure 3.10: Delete Existing Treasure Hunt Game Session Activity Diagram

Figure 3.10 illustrates the process of deleting an existing treasure hunt game created by the respective creator. Creators can view their list of created games, select the one they want to delete, and proceed with its removal. Subsequently, the update will be sent to the cloud database.

3.2.8 Design of User View Tutorial as Creator and Player Procedure

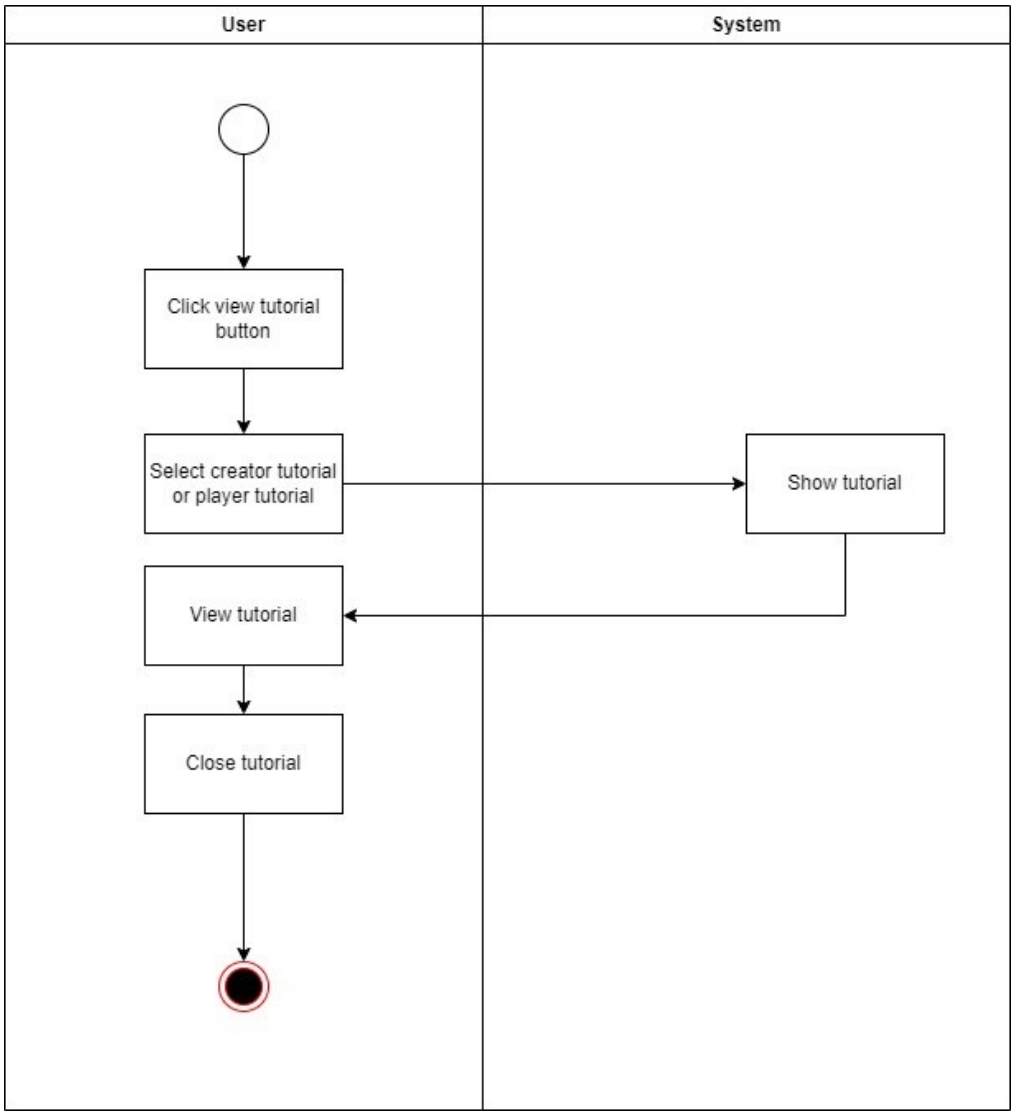


Figure 3.11: View Tutorial Activity Diagram

Figure 3.11 illustrates the process of viewing a tutorial, demonstrating how a creator can create a treasure hunt game session, and how a player can join a treasure hunt game and complete it.

3.3 Hardware and Software Architecture

3.3.1 Hardware

The hardware involved in this project is a custom desktop computer and mobile device with android operating system. A Desktop computer is used to develop the AR treasure hunt game using Unity platform. A mobile device is used to test the functionalities and performance of the proposed system. Table 3.1 shows the specifications of the desktop computer while Table 3.2 shows the specifications of the mobile device that was used in this project.

Table 3.1 : Specifications of desktop computer

Description	Specifications
Model	Custom Desktop
Processor	AMD Ryzen 5 3600
Operating System	Windows 10
Graphic	NVIDIA GeForce RTX2060 6GB
Memory	16GB DDR4 RAM
Storage	1TB HDD 512GB SSD

Table 3.2 : Specifications of mobile device

Description	Specifications
Model	Xiaomi Redmi 9T
Processor	Octa-core Max2.2GHZ
Operating System	Android 11RKQ1.200826.002
Memory	6GB
Storage	64GB

3.3.2 Software

In this project, the software that will be used to construct the AR treasure hunt game is Unity, ARCore, Mapbox SDK and FirebaseSDK.

Unity

Unity is a real-time 3D development platform, which include powerful packages such as ARFoundation and its help to build the AR treasure hunt mobile application. Besides, it can integrate with ARCore, Mapbox SDK and Firebase SDK to provide extra functionalities. The programming language that used to write game logic scripts in Unity is C#.

ARCore

ARCore is developed by Google and it provides the capability for android devices to experience AR. It is responsible to track the environment and motion to enable a stable, realistic and interactive AR interactions. ARCore only supports android device with operating system above Android 8.1.

Mapbox SDK

Mapbox SDK can be integrated in Unity, and it allows developers to integrate interactive and customizable maps into the applications. Rather than mapping, it also provides the Geocoding functionality and helps to build an interesting location-based AR treasure hunt mobile application.

Firebase SDK

Firebase SDK provides a great help in user authentication and data storing. It can be integrated in Unity and used in the application development. Firebase provides cloud database services which will be used in this application for storing most of the game data.

CHAPTER 4

Design of System

4.1 Graphical User Interface Design

In this project, a forest-themed graphical user interface is designed and applied to the application. Figure 4.1 shows the homepage UI of the location-based AR treasure hunt game. The theme of the game is “Secrets of the Greenwood".

Figure 4.1 : UI Design of Home Page

Figure 4.2 shows the UI design of the user profile, which contains information such as username, level, experience bar, and total number of treasures found.

Figure 4.2 : UI Design of User Profile

Figure 4.3 shows the UI design of the avatar changing panel. This panel displays the available avatar selections.

Figure 4.3 : UI Design of Avatar Changing Panel

The UI design of the password modification panel is shown in Figure 4.4. User can modify their password by entering old password and their desired new password.

Figure 4.4: UI Design of Password Modification Panel

Figure 4.5 presents the UI design of the inventory, which displays the gems collected by the player through mission completion.

Figure 4.5 : UI Design of Inventory

Figure 4.6 showcases the UI design of the game history, providing details about the games played by the player, including relevant information about each game.

Figure 4.6 : UI Design of Game History Panel

Figure 4.7 shows the UI design of the leaderboard. The leaderboard contains the usernames of the top 10 players.

Figure 4.7 : UI Design of Leaderboard

Figure 4.8 shows the UI design of the create or join game page for Location-based AR Treasure Hunt Game and tutorial button.

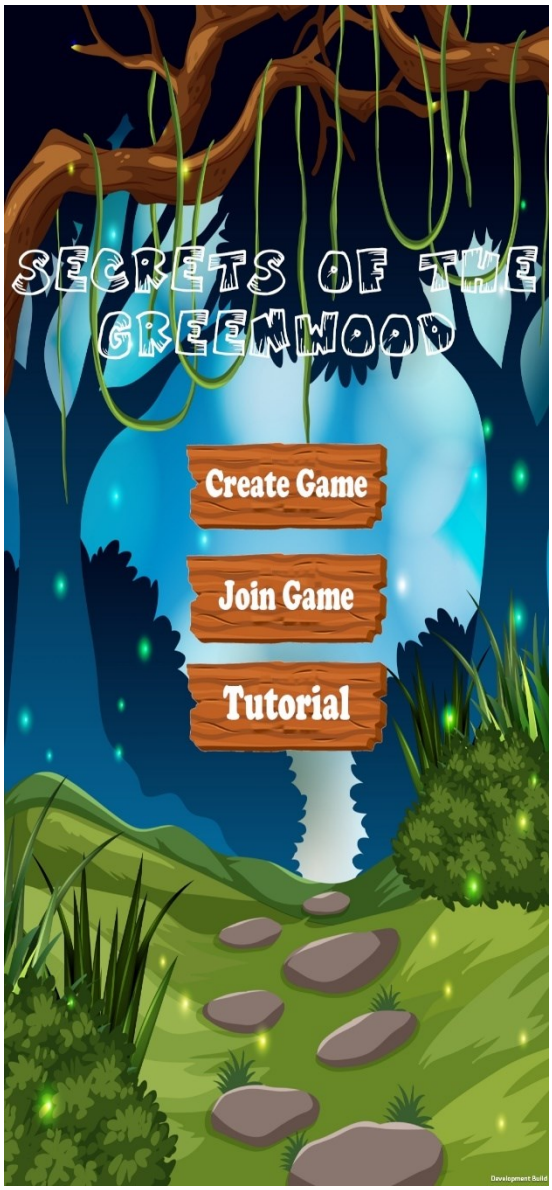


Figure 4.8 : UI Design of Create Game and Join Game Page

Figure 4.9 displays the UI design of the tutorial, guiding users on how to create a new game or play an existing one.

Figure 4.9 : UI Design of Tutorial Panel

The UI design of the created game list is shown in Figure 4.10. Creators can edit and create games here.

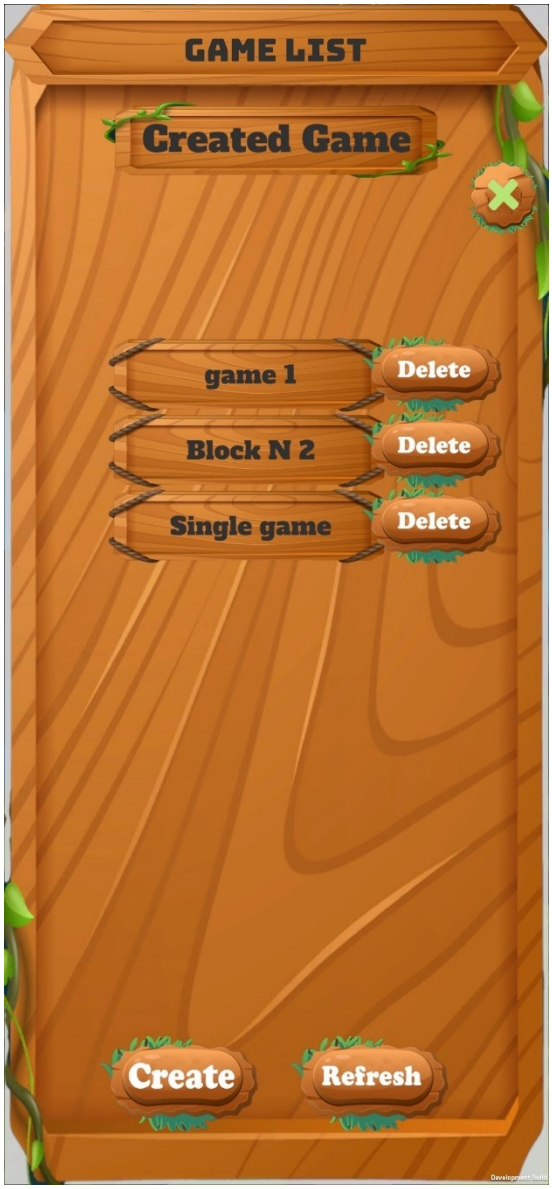


Figure 4.10 : UI Design of Created Game List

Figure 4.11 shows the UI design of the player mode selection panel. Creators can choose to create single-player or multiplayer games.

Figure 4.11 : UI Design of Player Mode Selection Panel

Figure 4.12 shows the UI design of the creator pinpoint on the map. Creators can scroll and zoom in on the map to find preferred locations for placing virtual points.

Figure 4.12 : UI Design of Creator Pinpoints on Map

Figure 4.13 shows the UI design of virtual point list. Creators can delete the existing virtual point.

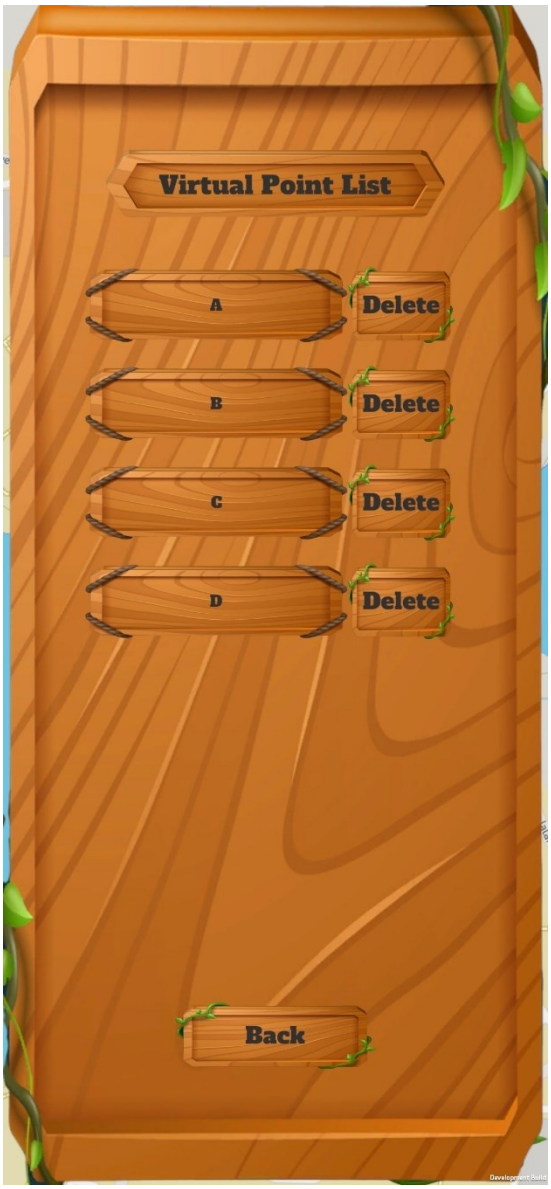


Figure 4.13 : UI Design of Virtual Point List

Figure 4.14 shows the UI design of creator creating a mission. The creator needs to enter the mission information and save it.

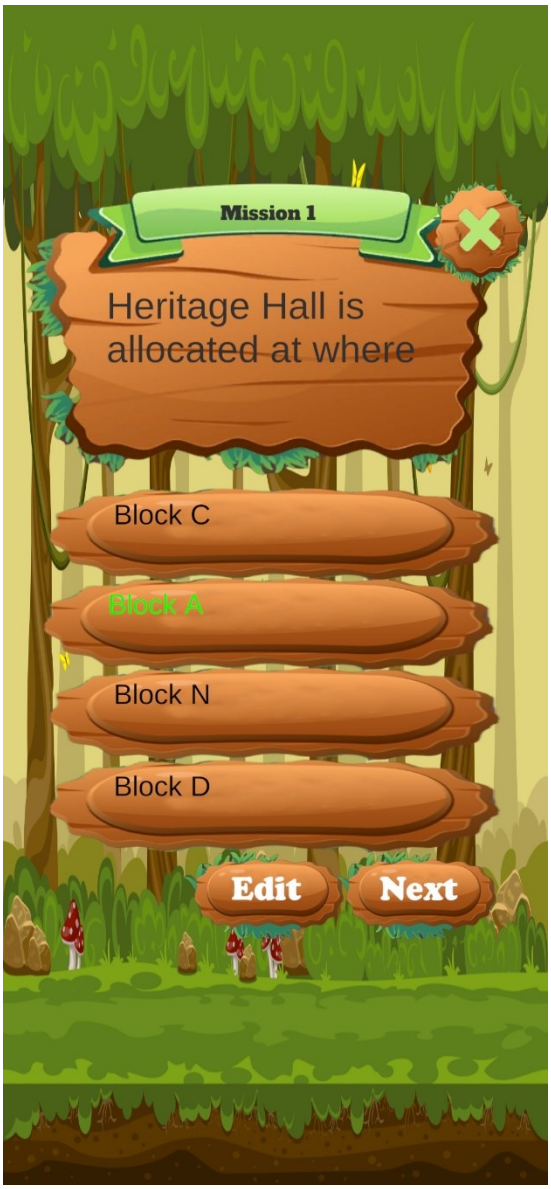


Figure 4.14 : UI Design of Creator Creating Mission

Figure 4.15 shows the UI design of creator creating clue for a mission. After the creator creates a task, he or she needs to set up a clue for the mission.

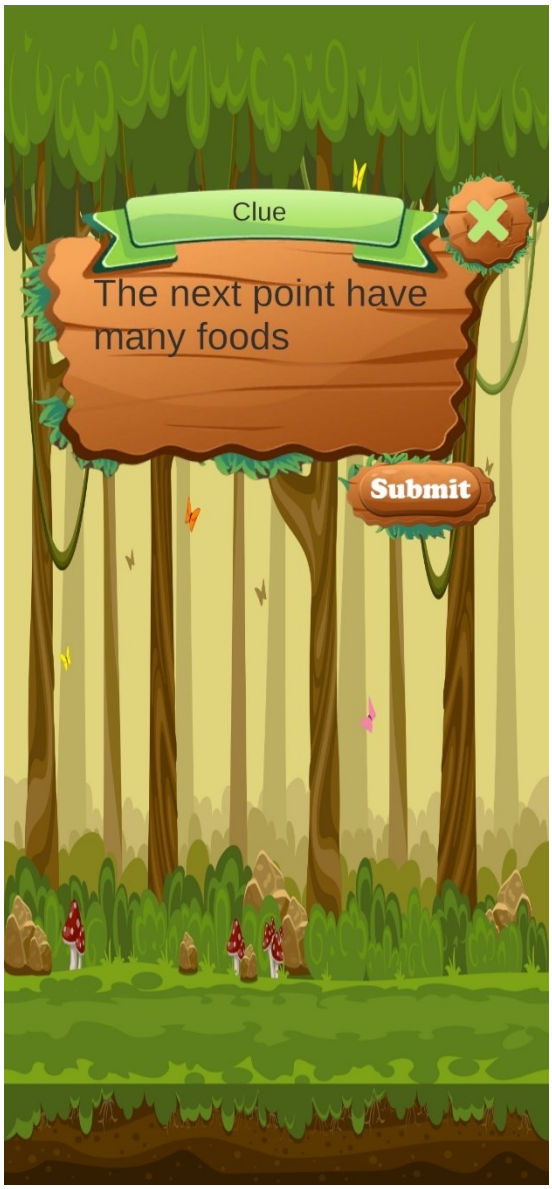


Figure 4.15 : UI Design of Creator Creating Clue

Figure 4.16 shows the UI design of mission list created by the creator. It allows creator to delete certain mission.

Figure 4.16 : UI Design of Mission List Created by Creator

Figure 4.17 shows the UI design of mission mapping panel. It allows creator to map the virtual points with missions and specific AR elements

.

Figure 4.17 : UI Design of Mission Mapping Panel

Figure 4.18 shows the UI design of game setup info panel. It allows creator to enter a game session name and information about the game being created.

Figure 4.18 : UI Design of Game Setup Info Panel

Figure 4.19 shows the design of the game creation success notification, which indicates that the data has been stored in the database.

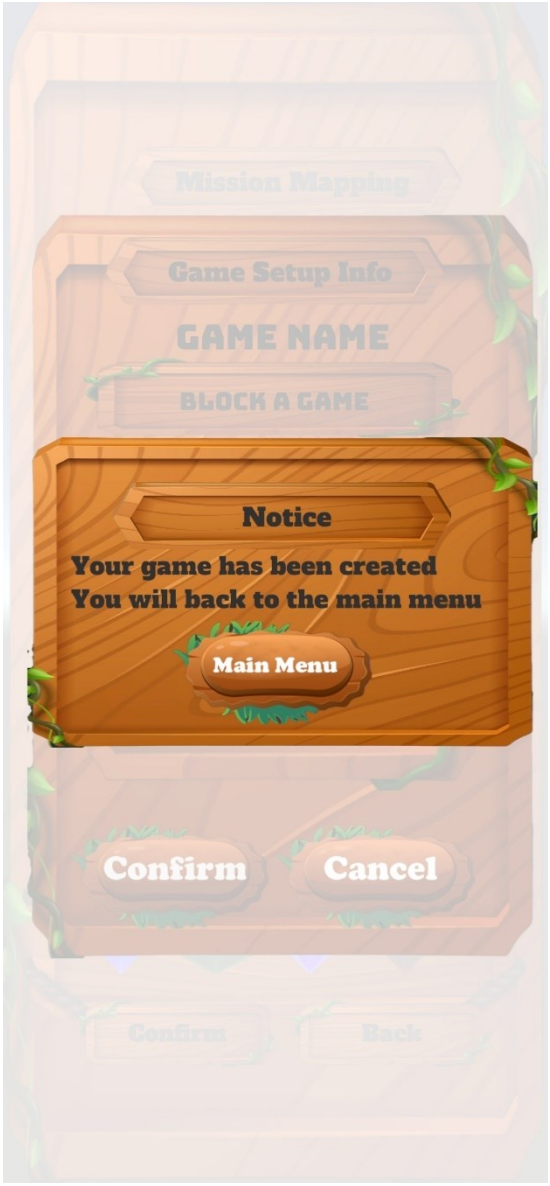


Figure 4.19 : UI Design of Game Created Notification

Figure 4.20 shows the UI design for the list of available games for players to join. Players can choose to play single player game or multiplayer game.

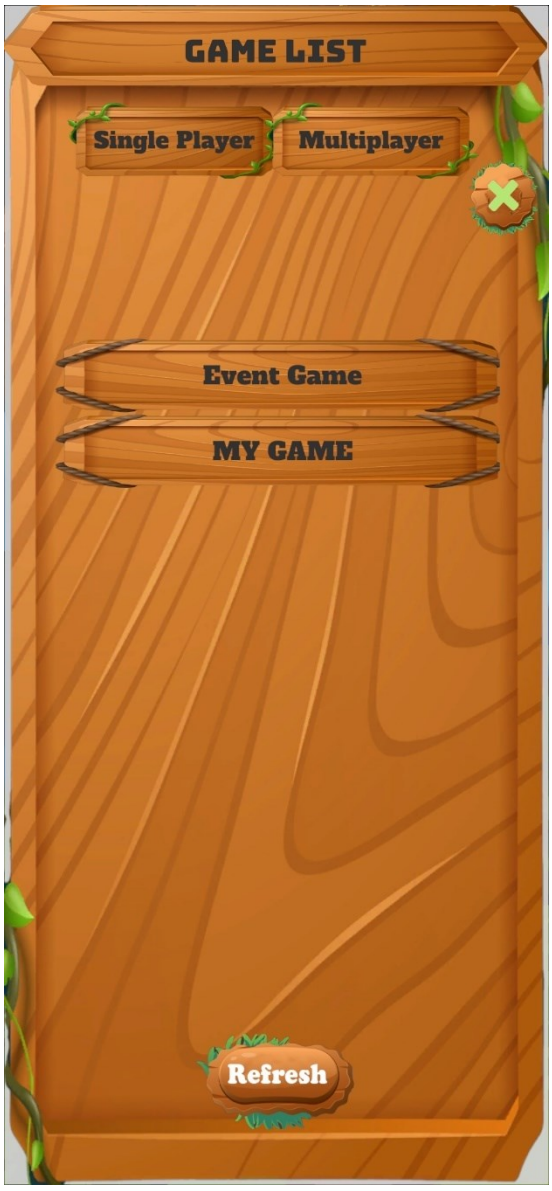


Figure 4.20 : UI Design of List of Available Games

Figure 4.21 shows the UI design of the game information panel. Players can know some information about their chosen game before playing it.

Figure 4.21 : UI Design of Game Information Panel

Figure 4.22 illustrates the UI design of the multiplayer online room list, allowing players to join. It displays the number of players currently inside each room.

Figure 4.22 : UI Design of Multiplayer Room List

Figure 4.23 depicts the UI design of the multiplayer game's “Create New Room” panel. Players are required to name the room when opening a new room for a multiplayer game session.

Figure 4.23 : UI Design of Create New Room Panel

Figure 4.24 illustrates the UI design of the multiplayer room. Players will join the room before the game starts, initiated by the room owner.

Figure 4.24 : UI Design of Multiplayer Room

Figure 4.25 depicts the UI design of the chat function within the multiplayer game interface. Players can communicate with each other using the chat box feature.

Figure 4.25 : UI Design of Multiplayer Chat Box

Figure 4.26 shows the UI design of virtual point with AR element. When the player reaches the virtual point, they can interact with the AR element.

Figure 4.26 : UI Design of Virtual Point with AR Element

Figure 4.27 shows the UI design of the mission attempt confirmation panel, which is used to inform players about the confirmation of the mission attempt.

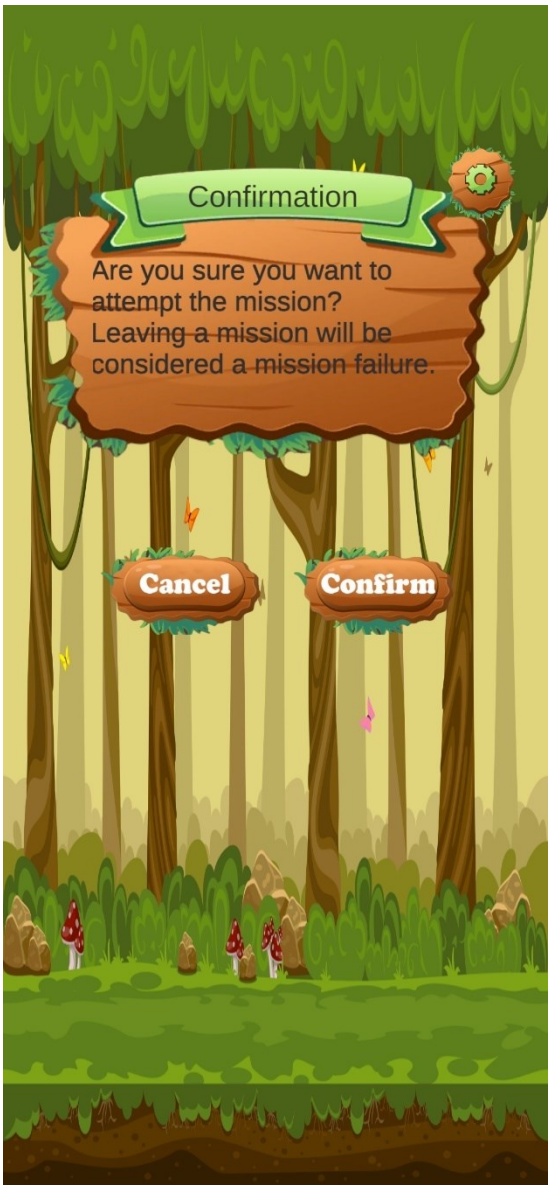


Figure 4.27 : UI Design of Confirmation Panel for Attempting Mission

Figure 4.28 illustrates the UI design of the multiplayer game interface during a collaborative mission attempt. Players are only able to attempt the mission when the distance between two players is less than 50 units.

Figure 4.28 : UI Design of Collaborative Mission Attempt Panel

Figure 4.29 shows the UI design of player attempting a mission. Player can attempt mission by interacting with the panel.

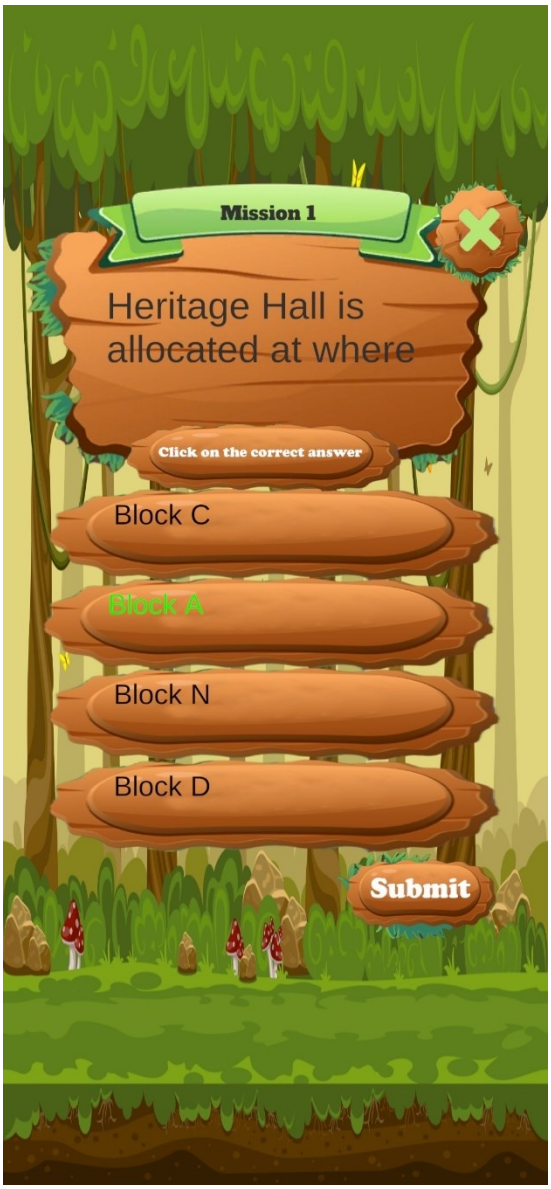


Figure 4.29 : UI Design of Mission Attempt Panel

The UI design of the pause menu is shown in Figure 4.30. Players can stop the game, return to the main menu, or exit the game.

Figure 4.30 : UI Design of Pause Menu Panel

Figure 4.31 shows the UI design for players to discover treasures. When the player clicks on the treasure, the treasure will change from closed mode to open mode.

Figure 4.31 : UI Design of Treasure Found by Player

Figure 4.32 shows the UI design for the treasure hunt end panel. The panel displays player information and information related to the game being played.

Figure 4.32 : UI Design of Treasure Hunt Game End

Figure 4.33 depicts the UI design for the treasure hunt game ranking panel, showcasing the player rankings for the current game in play.

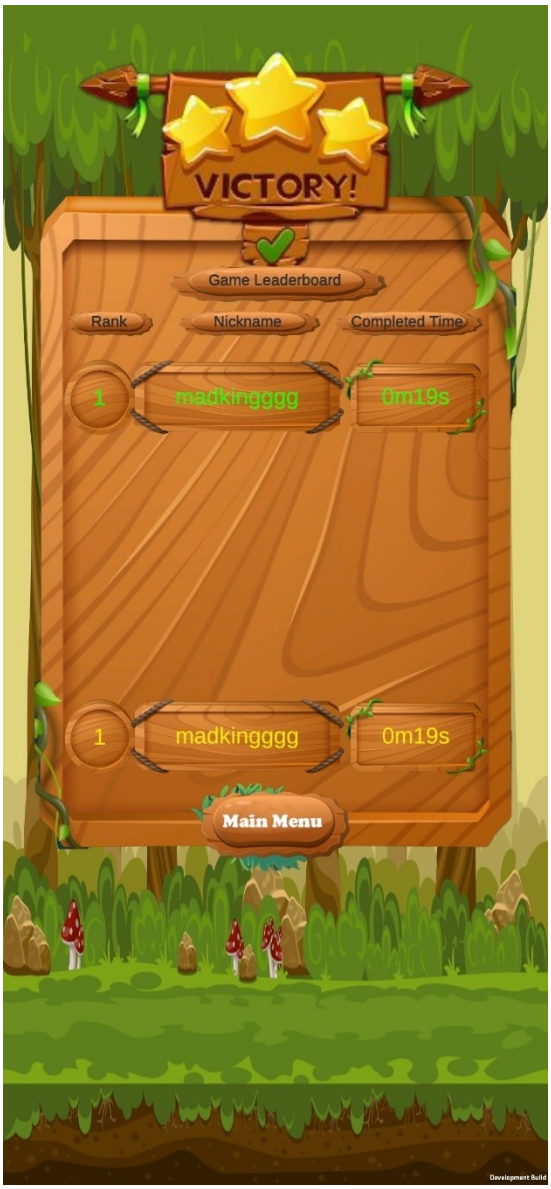


Figure 4.33 : UI Design of Treasure Hunt Game End Ranking Panel

4.2 Data Storage Design

Figures 4.34 is the class diagram for location-based AR Treasure Hunt Game. It shows the structure and relationships between classes employed in building a mobile application using the C# programming language. There are total of 11 classes being used in this application which are “User”, “GameSession”, “GameSessionRecord”, “MultiplayerGameSession”, “VirtualPoint”, “VirtualPointLocation”, “Mission”, “SelectionMission”, “ShortAnswerMission”, “WordPuzzleMission” and “ImageIdentifyMission”. This project uses real-time firebase to store the information needed in this application to support the game operation. Firebase serve as NoSQL Database, and it used collections and documents to store records. The C# objects in this application will be converted to JSON format and a request is sent to the firebase server to store the records.

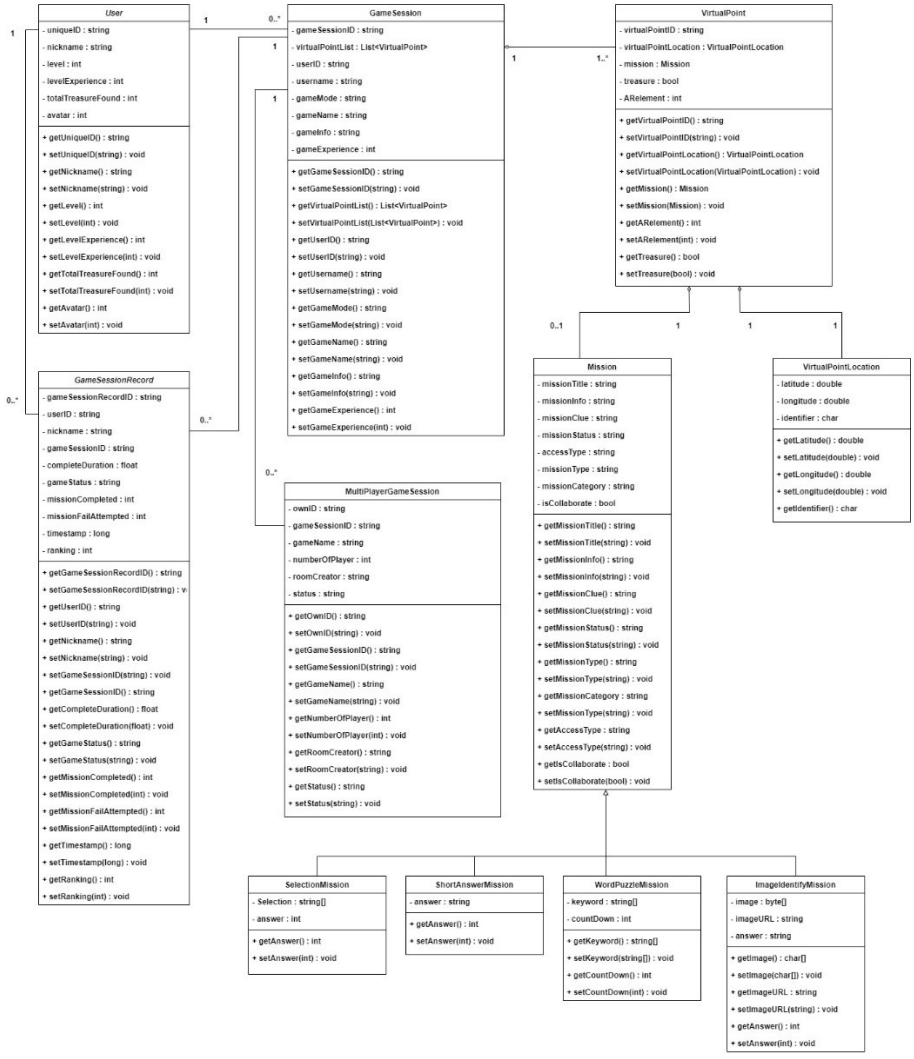


Figure 4.34: Location-based AR Treasure Hunt Game Class Diagram

4.3 System Architecture Design

Figure 4.35 illustrates the interaction between the clients and the server for the location-based AR treasure hunt mobile application. Since this project is only aimed at developing a treasure hunt for the Android platform, the final product is an Android application. Users need to be connected to the internet to play or create treasure hunts, as all data is stored in the Firebase Realtime Database that can be accessed through Firebase SDK. Besides, GPS needs to be enabled, as the Mapbox SDK is completely dependent on GPS to provide functionalities such as mapping and geocoding. With this system architecture design, the data is centralized in the database and can be retrieved simultaneously by multiple users.

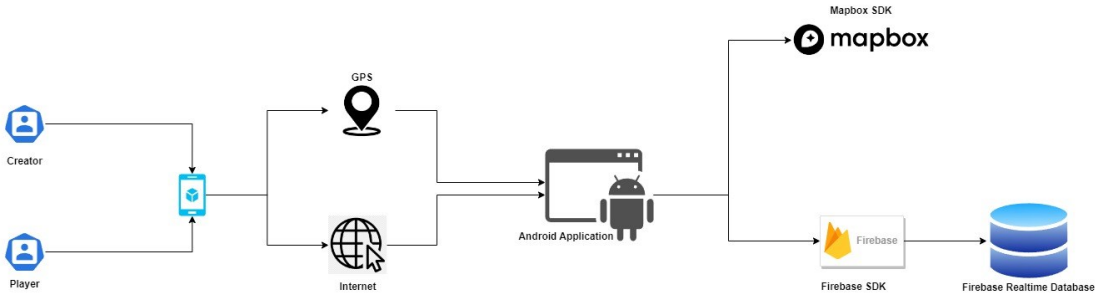


Figure 4.35: Location-based AR Treasure Hunt Game Architecture Diagram

CHAPTER 5

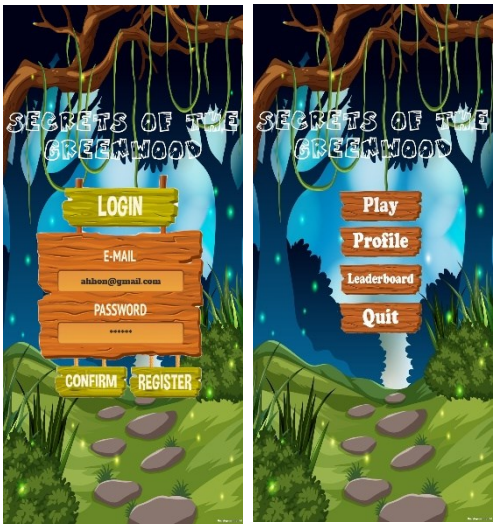
System Testing

This project's objectives are to develop a location-based treasure hunt game that allows players to explore the outside world with friends through interactive and learning-worthy treasure hunt missions, and to create an immersive AR experience by implementing AR techniques into the game. The test cases are designed to prove the achievement of these objectives.

5.1 Test Cases

5.1.1 User

5.1.1.1 Login

Cases	Expected Output and Output
Login	
Input correct email and correct password	Expected output: User can successfully log in to their account and the game menu will be shown. System output: After inputting correct credentials, the user is logged in to their account, and the game menu panel is displayed.  (Matched with expected output ☑)

Input correct email and wrong password	Expected output: A message will show indicating incorrect credentials. System output: A message displaying “Wrong Password” appears on the user’s device.  (Matched with expected output ☑)
Input wrong email and correct password	Expected output: A message will show indicating incorrect credentials. System output: A message displaying “Account does not exist” appears on the user’s device.  (Matched with expected output ☑)

Input wrong email and wrong password	Expected output: A message will show indicating incorrect credentials. System output: A message displaying “Account does not exist” appears on the user’s device.  (Matched with expected output ☑)

5.1.1.2 Register

Cases	Expected Output and Output
Register	
Register using a non-existing email in the database	Expected output: The account will be registered successfully, and the user will be taken to the login scene. System output: The account is created successfully, and the user is brought to the login page to log in.  (Matched with expected output ☑)

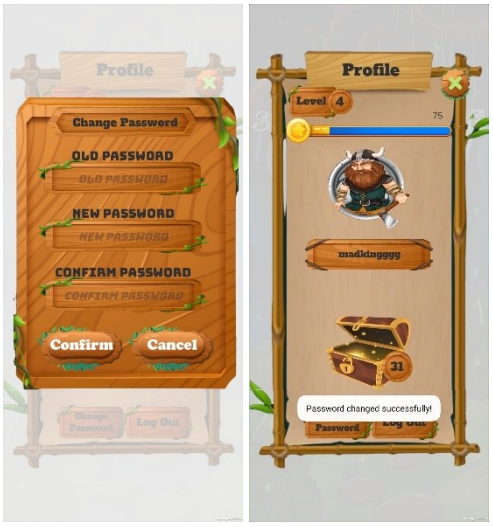
Register using a duplicate email in the database	Expected output: A message will show indicating that the email was registered previously. System output: A message displaying “Email Already In Use” appears on the user’s device.  (Matched with expected output ☑)
Register using a duplicate username with other users	Expected output: A message will show indicating that the username is taken. System output: A message displaying “Username already exists. Please choose a different one” appears on the user’s device.  (Matched with expected output ☑)

Register using different passwords for password and confirm password fields	Expected output: A message will show indicating that the inputted passwords do not match. System output: A message displaying "Password Does Not Match!" appears on the user's device.  (Matched with expected output ☑)

5.1.1.3 View Profile and Edit Profile

Cases	Expected Output and Output
View Profile	
View user's username, level, experience, total treasure found, and avatar	Expected output: Users can view their username, level, experience, total treasure found, and their avatar by clicking the "Profile" button. System output: After clicking the "Profile" button, a panel displaying all the user's information is shown.  (Matched with expected output ☑)

View user's gem inventory	Expected output: Users can view the total gems collected through mission completion. System output: After clicking the treasure logo button in the profile panel and then clicking the "Inventory" button, the number of different gems collected by that user will be displayed.  (Matched with expected output ☑)
View user's game history	Expected output: Users can view the game history and information about the games played previously. System output: After clicking the "Game History" button, users can view the list of game histories and their respective dates. By clicking on a game, the information about that game will be displayed on another panel.  (Matched with expected output ☑)

Edit Profile	
Edit user password by inputting the correct old password and new password	Expected output: Users are allowed to edit their account password by inputting the correct old password and new passwords. System output: By inputting the correct old password and two matched new passwords, the user's password is updated in the database.  (Matched with expected output ☑)
Edit user password by inputting the wrong old password	Expected output: If the user enters the wrong old password when changing passwords, the password will not be updated, and a message will show that the old password is incorrect. System output: When the user inputs the wrong old password while changing passwords, the update is not performed in the database, and a message is shown to indicate to the user that the old password is incorrect.  (Matched with expected output ☑)

Edit user avatar	Expected output: Users can select the avatar, and the update will be performed in the database. System output: When a user clicks on their avatar and then selects another avatar from the avatar selection panel, after clicking the "Confirm" button, their profile avatar is changed.  (Matched with expected output ☑)

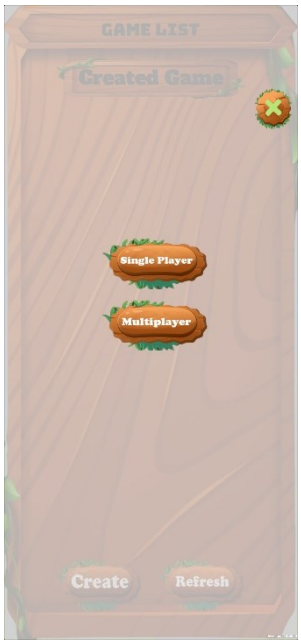
5.1.1.4 View Leaderboard and View Tutorial

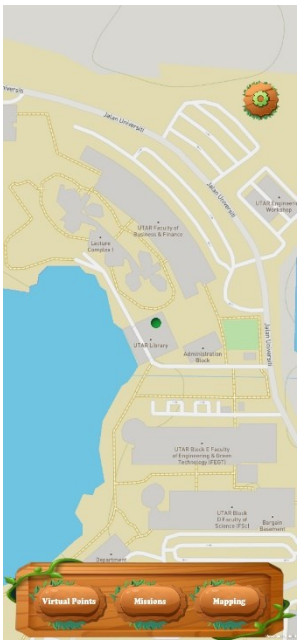
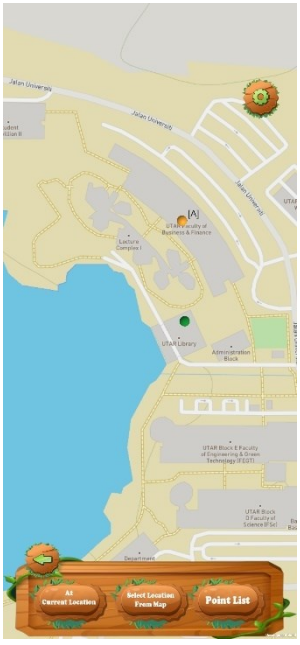
Cases	Expected Output and Output
View Leaderboard	
View leaderboard ranking users based on level	Expected output: When a user clicks the "Leaderboard" button on the game menu panel, it shows the ranking of users based on their level. System output: After clicking the "Leaderboard" button, the system retrieves the top 10 users of the game based on their level and shows them to the user.  (Matched with expected output ☑)

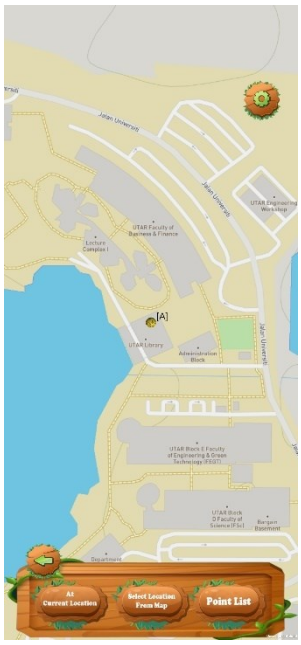
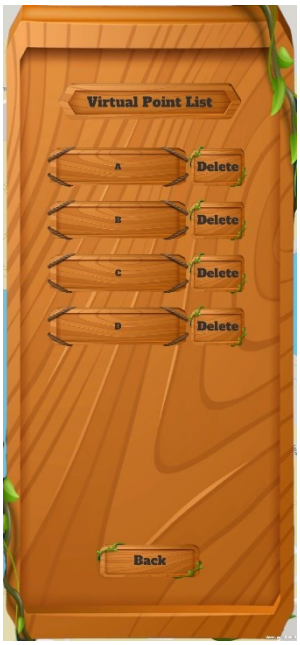
View Tutorial	
View tutorial steps for creators to create a new game	Expected output: Users can view the tutorial about creating a new game as a creator page by page by swiping after clicking the "Creator" button on the tutorial page. System output: After clicking the "Tutorial" button and selecting the "Creator" button, the tutorial for creating a new game is shown, and the user is allowed to swipe left and right for other pages.  (Matched with expected output ☑)
View tutorial steps for players to play a game	Expected output: Users can view the tutorial about playing the game as a player page by page by swiping after clicking the "Player" button on the tutorial page. System output: After clicking the "Tutorial" button and selecting the "Player" button, the tutorial for playing a game is shown, and the user is allowed to swipe left and right for other pages.  (Matched with expected output ☑)

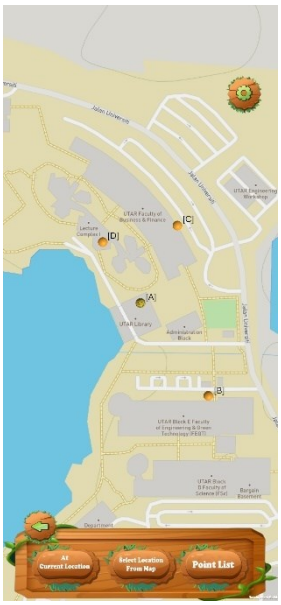
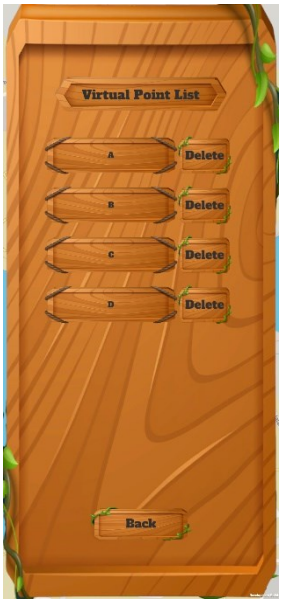
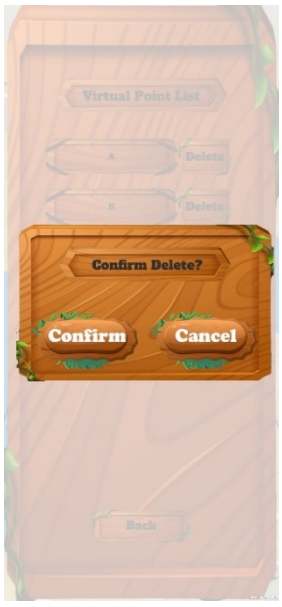
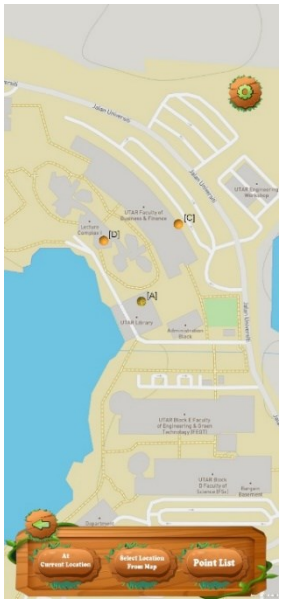
5.1.2 Creator

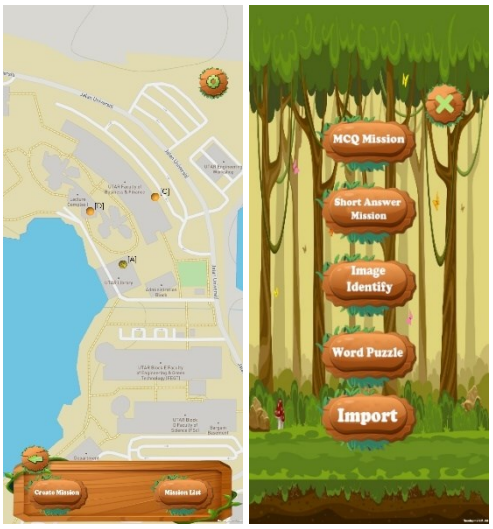
5.1.2.1 Creating a Game

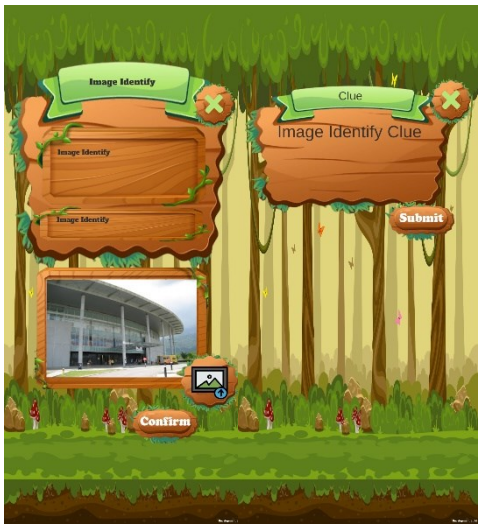
Cases	Expected Output and Output
Start Create Game	
Select the game mode to create	Expected output : Show two button for creator to select the game mode while creating game. System output: Upon clicking the "Create" button, the system displays "Single Player" and "Multiplayer" buttons for the creator to select.  (Matched with expected output ☑)

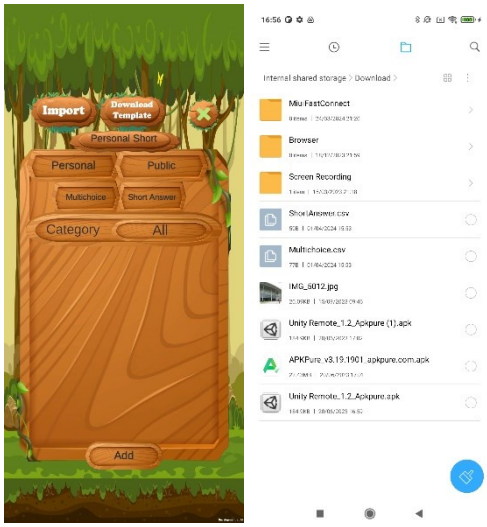
Enter new scene and view the map of UTAR Campus with an indicator showing own current location	Expected output: After selecting the game mode, the scene will change, allowing the user to view the map and other tools to create a game. System output : The system switches to a new scene and loads the UTAR Kampar map, showing a green pin at the creator's current location.  (Matched with expected output ☑)
Setup Virtual Pinpoint	
Place pinpoint on the map	Expected output : Clicking the "Select Location From Map" button and then clicking on the map spawns a yellow pinpoint. System output : After clicking the "Select Location From Map" and then clicking on the map, a yellow pinpoint labeled with A is spawned on the map.  (Matched with expected output ☑)

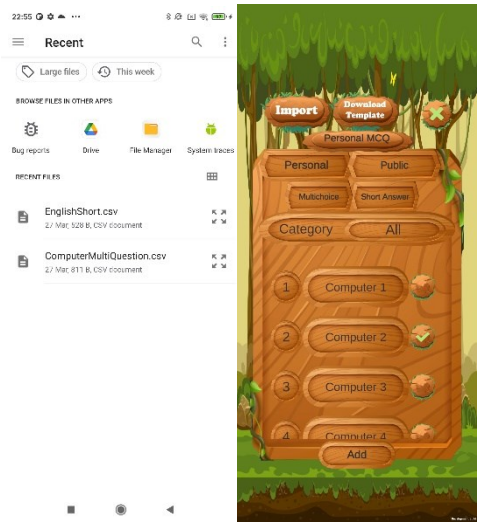
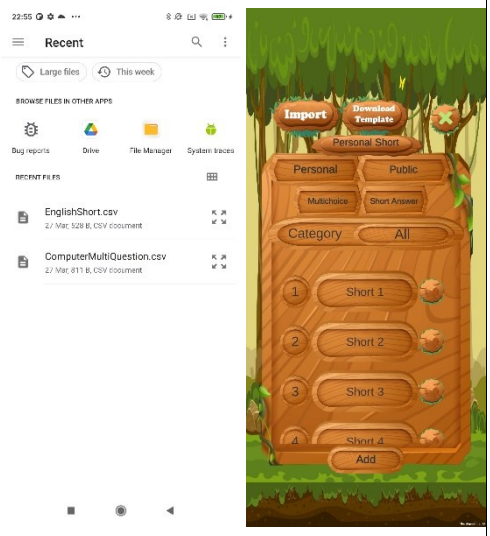
Place pinpoint on current location	Expected output : Clicking the "At Current Location" button spawns a yellow pinpoint at Creator's current location. System output : After clicking the "At Current Location" button, a yellow pinpoint labeled with A is spawned on the map, adjacent to the green pinpoint indicating the Creator's current location.  (Matched with expected output ☑)
View pinpoint list	Expected output : After clicking the "Point List" button, a list of pinned points will appear on the panel. System output : After clicking the "Point List" button, it displays the names of pinned points along with a delete button for each.  (Matched with expected output ☑)

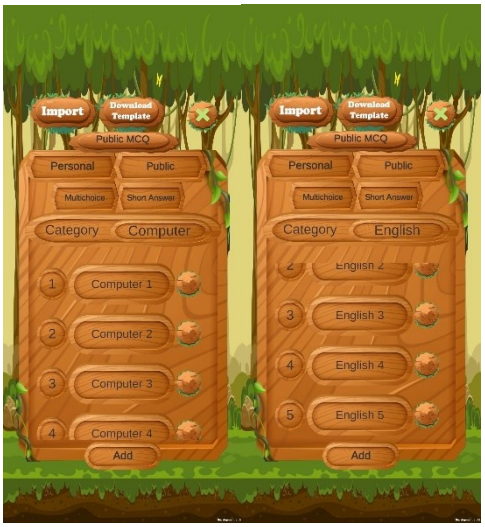
Delete pinpoint	Expected output : After clicking the "Delete" button (Delete point B) and confirm the delete action, the corresponding virtual pinpoint will be removed from the list and the map. System output : After clicking the "Delete" button of point B, a confirmation panel will appear. After confirming in the panel, point B is removed from both the map and the list.      (Matched with expected output ☑)

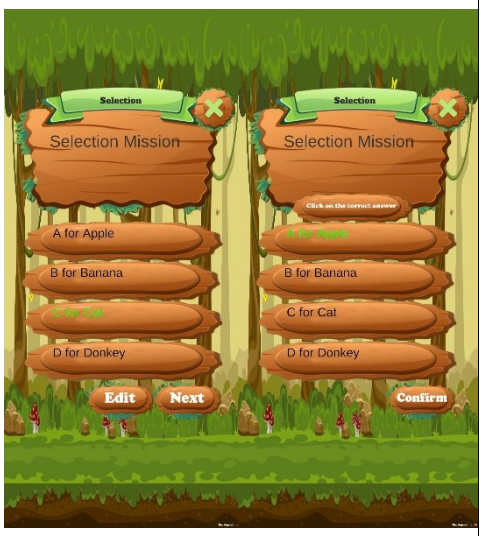
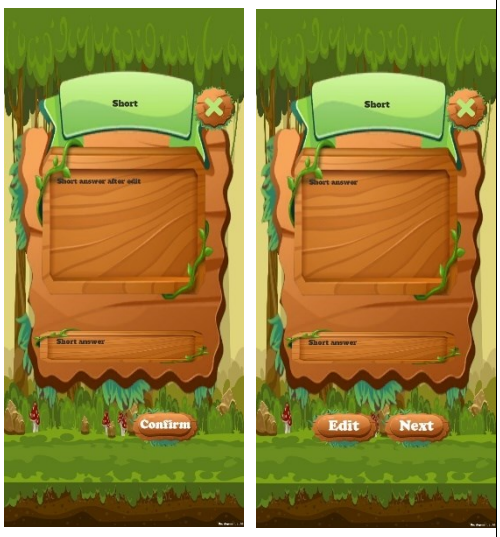
Setup Mission	
Select mission type	Expected output : Clicking the "Create Mission" button displays several options of mission types, from which the creator can select one. System output : After clicking the "Create Mission" button, five types of missions are listed, and they can be selected by clicking on them.  (Matched with expected output ☑)
Setup selection mission	Expected output : Clicking the "MCQ Mission" button from the mission type panel should enable the user to input a title, question, selection answers, and clue for the mission. System output : After clicking the "MCQ Mission" button, the creator is allowed to input mission information, select the correct answer for the question, and input a clue for that specific mission.  (Matched with expected output ☑)

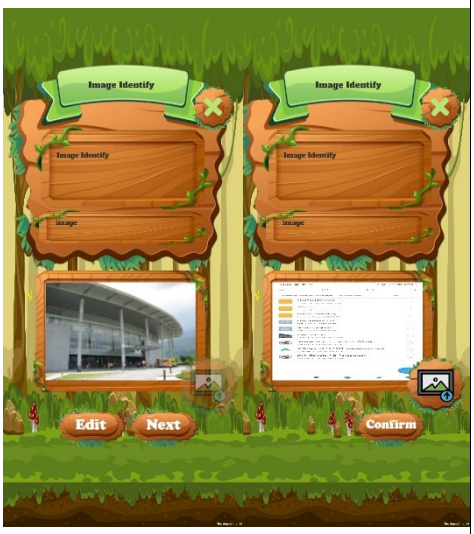
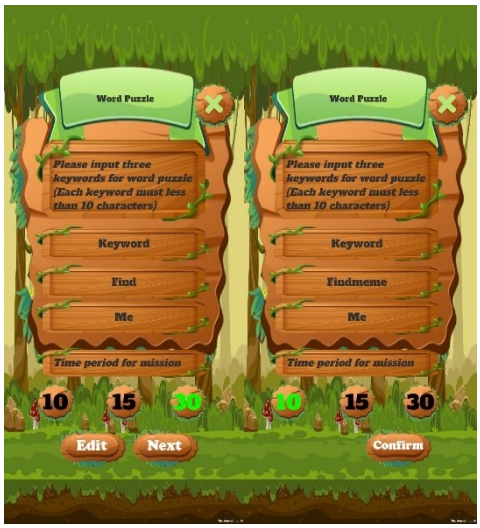
Setup short answer mission	Expected output : Clicking the "Short Answer Mission" button from the mission type panel should enable the user to input a title, question, short answer, and clue for the mission. System output : After clicking the "Short Answer Mission" button, the creator is allowed to input mission information, include question and correct answer, and input a clue for that specific mission.  (Matched with expected output ☑)
Setup image identify mission	Expected output : Clicking the "Image Identify" button from the mission type panel should enable the user to input a title, question, answer, clue for the mission and upload an image. System output : After clicking the "Image Identify" button, the creator is allowed to input mission title, question, answer, upload an image, and clue for the mission.  (Matched with expected output ☑)

Setup word puzzle mission	Expected output : Clicking the "Word Puzzle" button from the mission type panel should enable the user to input a title, three keywords, select the countdown time for that mission, and then enter the clue for that mission. System output : After clicking the "Word Puzzle" button, the creator is allowed to input mission title, three keywords, select one countdown time from three options, and then enter the clue.  (Matched with expected output ☑)
Import Mission	
Download the CSV file template for inputting mission data	Expected output : Clicking the "Download Template" button will download two CSV file template named "ShortAnswer.csv" and "Multichoice.csv" for the creator to import mission externally. System output : After clicking the "Download Template" button, two CSV file templates are downloaded into the device's "Download" folder.  (Matched with expected output ☑)

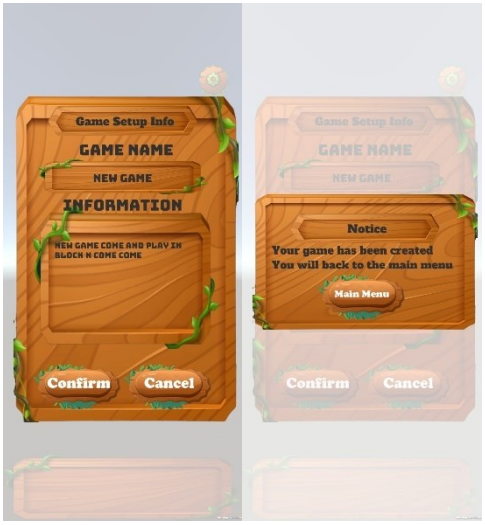
Import selection mission from CSV file	Expected output : Clicking the "Import" button allows the creator to select a CSV file from the device. Then, selecting the multichoice CSV file enables the importation of selection missions into the game. System output : After clicking the "Import" button, it brings up the file selection page, allowing the user to choose a CSV file. Upon selecting the "ComputerMultiQuestion.csv" file, the selection missions are imported.  (Matched with expected output ☑)
Import short mission from CSV file	Expected output : Clicking the "Import" button allows the creator to select a CSV file from the device. Then, selecting the short answer CSV file enables the importation of short answer missions into the game. System output : After clicking the "Import" button, it brings up the file selection page, allowing the user to choose a CSV file. Upon selecting the "EnglishShort.csv" file, the short answer missions are imported.  (Matched with expected output ☑)

Filter imported missions according to their category	Expected output : Selecting the category dropdown enables the creator to filter the imported missions. System output : After clicking on the "Computer" category, only computer category questions are displayed, and when changed to "English", only English questions are shown.  (Matched with expected output ☑)
Add the imported mission to the list of missions available for setting up the game.	Expected output : By toggling the switch and clicking the "Add" button, the mission can then be used for mission setup in that game. Since the imported questions do not have clues, in the mission list, the imported questions will be marked as invalid and will need to be edited. System output : After ticking the "Computer 1" question and clicking the "Add" button, it gets removed from the list, a toast message appears, and it shows in the mission list, allowing the creator to use it in the mission setup.  (Matched with expected output ☑)

Edit Mission	
Edit selection mission	Expected output : The creator is allowed to edit the created "Selection Mission", such as changing the question, selection answers, correct answer, and mission clue. System output : After selecting the "Selection Mission" from the mission list, the creator can click on the "Edit" button to begin editing the question, selection answers, correct answer, and mission clue, and then save the changes.  (Matched with expected output ☑)
Edit short answer mission	Expected output : The creator is allowed to edit the created "Short Answer Mission", including changing the title, question, answer, and clue for that mission. System output : After selecting the "Short Answer Mission" from the mission list, the creator can click on the "Edit" button to begin editing the title, question, answer and mission clue, and then save the changes.  (Matched with expected output ☑)

Edit image identify mission	Expected output : The creator can edit the created "Image Identify Mission," including changing the title, question, answer, uploading another image, and adding a clue for that mission. System output : After selecting the “Image Identify Mission” from the mission list, the creator can click on the “Edit” button to begin editing the title, question, answer, mission clue, or reupload an image by clicking the “Image” button, and then save the changes.  (Matched with expected output ☑)
Edit word puzzle mission	Expected output : The creator can edit the created "Word Puzzle Mission," including changing the title, three keywords, and countdown time. System output : After selecting the “Word Puzzle Mission” from the mission list, the creator can click on the “Edit” button to begin editing the title, three keywords, and select the countdown time.  (Matched with expected output ☑)

Mapping Mission and Virtual Point	
Drag mission, virtual point, and AR element to correct columns	Expected output : If the mapping is completed, which includes a virtual point, mission, and AR element, or a virtual point with treasure, after clicking the "Confirm" button, another panel will appear for the creator to input the game name and information. System output : After dragging the elements to their corresponding positions and clicking on the "Confirm" button, a panel appears where the creator can input the game name and information about the game.  (Matched with expected output ☑)
Drag mission, virtual point, and AR element to incorrect columns	Expected output: If the mapping is incomplete, after clicking the "Confirm" button, a toast message will appear to inform the creator that the mapping is incomplete. System output: When leaving one blank in the mapping column and clicking "Confirm", it displays a message indicating that the mapping is not complete.  (Matched with expected output ☑)

Save to database	
Enter game name and game info and save to database	Expected output: After the mapping process, the creator needs to input the game name and game information, then click on the "Confirm" button. A notice will appear indicating if the newly created game data was successfully saved in the database. System output: When the creator inputs the game name and game information, then clicks on the "Confirm" button, the newly created game data is successfully saved to the database.  (Matched with expected output ☑)

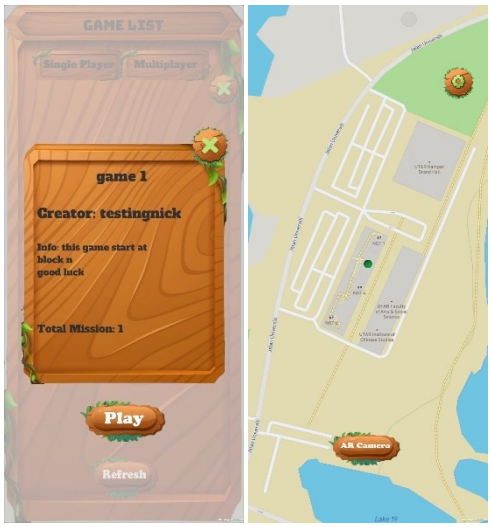
5.1.2.2 Deleting a Game

Cases	Expected Output and Output
Delete Created Game	
View created game list	Expected output: The creator can view the games they have previously created. System output: System retrieved the game created by that creator and show on the list. (Matched with expected output ☑) 
Delete created game	Expected output: The creator can click the "Delete" button beside the game name, then perform delete action to the created game. System output: After clicking on the "Delete" button, a confirmation panel will appear. When creator clicks "Yes", the game is deleted from the database as well as from the list. (Matched with expected output ☑) 

5.1.3 Player

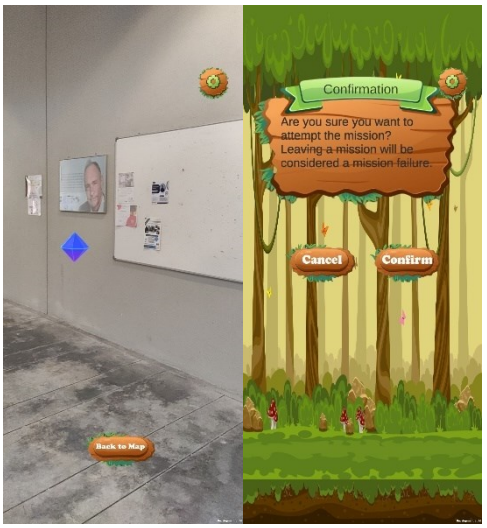
5.1.3.1 Playing a Game

Cases	Expected Output and Output
View Game List	
View available single player game list	Expected output: Players can view the single-player game list by clicking the "Single Player" button. System output: After clicking the "Single Player" button, the available single-player game list is retrieved and shown in the panel.  (Matched with expected output ☑)
View available multiplayer game list	Expected output: Players can view the multiplayer game list by clicking the "Multiplayer" button. System output: After clicking the "Multiplayer" button, the available multiplayer game list is retrieved and shown in the panel.  (Matched with expected output ☑)

Select Game	
Select single player game and play	Expected output: Players can select one of the single-player games by clicking on it. A join panel will appear, and by clicking join, the player will enter the game. System output: After selecting the single-player game and clicking the join button, it brings the player to another scene, and the game starts.  (Matched with expected output ☑)
Select multiplayer game and create room	Expected output: Players can select one of the multiplayer games by clicking on it. A panel with "Create" and "Join" buttons will show. By clicking the "Create" button, players can create a new room for the selected game. System output: After selecting the multiplayer game and clicking the "Create" button, players can enter the game name. After clicking another "Create" button, players can create a new room and join it.  (Matched with expected output ☑)

Select multiplayer game and join existing room	Expected output: Players can select one of the multiplayer games by clicking on it. A panel with "Create" and "Join" buttons will show. By clicking the "Join" button, players can view the available room list for that game and join one. System output: After selecting the multiplayer game and clicking the "Join" button, the available room list for that game will be shown, and players can join a room.  (Matched with expected output ☑)
Change team in multiplayer game room	Expected output: In a multiplayer room, players can switch their team before the game starts. System output: By clicking the "Team Number" button, players in the room can switch to another team.  (Matched with expected output ☑)

Start game when team member is not complete	Expected output: In a multiplayer room, each team must have either no players or two players. If this requirement is not fulfilled, the game cannot be started by the room owner. System output: When team 1 and team 2 both have only 1 player, the game cannot be started, and a message shows that each team must have 2 players.  (Matched with expected output ☑)
Play Single Player Game	
View map with player current location	Expected output: After the single-player game is started, a map of UTAR Kampar is loaded into the game, and a green pin shows the current location of the player. System output: After loading into the single-player game scene, the map of UTAR Kampar is shown on the screen, and a green pin indicates the player's current location.  (Matched with expected output ☑)

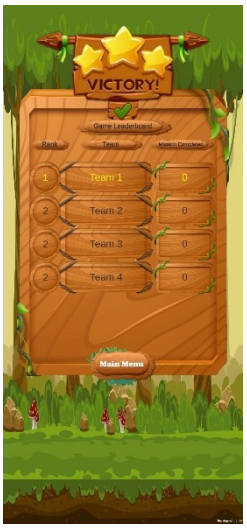
Locate the AR element and attempt the mission	Expected output: Capturing an AR element using the AR camera and touching the AR element on the screen will show an attempt panel, allowing the player to attempt the mission. System output: The AR element is captured when the player is near the virtual point set up by the creator of the game. By clicking on the AR element on the screen, the player can attempt the mission.  (Matched with expected output ☑)
Locate the AR element and get information about buildings	Expected output: Capturing an AR element in UTAR buildings using the AR camera and touching the AR element on the screen will show a panel containing information about the buildings. System output: The AR element is captured when the player is near the buildings that contain virtual points. By clicking on the AR element on the screen, the player can see information about the buildings.  (Matched with expected output ☑)

Attempting the mission and providing the correct answer	Expected output: After attempting the mission and entering the correct answer for the question, a clue will be provided. System output: By entering the correct answer set by the creator of the game when attempting the mission, a clue is given to find the treasure.   (Matched with expected output ☑)
Attempting the mission and providing the wrong answer	Expected output: After attempting the mission and providing the wrong answer, the virtual point will be disabled for 5 minutes. System output: By entering an answer that does not match the answer set by the creator of the game when attempting the mission, the mission is considered failed and can be reattempted after 5 minutes.  (Matched with expected output ☑)

Find treasure and end game	Expected output: When reaching the virtual point set by the creator to hide the treasure, the AR camera can capture the AR treasure. By clicking on the treasure, the treasure will be opened, and the game will end. System output: When the player walks to the virtual point and uses the AR camera to capture the surroundings, a treasure appears. By clicking on it, the treasure opens, and a game-ending panel appears.  (Matched with expected output ☑)
Award experience points and enable leveling up after the game ends	Expected output: When the game ends, the player can gain experience points and level up if their experience is sufficient. System output: The ending panel shows the current experience and level of the player, and it increases the experience after the game ends.  (Matched with expected output ☑)

View the ranking of players who have played the game	Expected output: In the game ending panel, the leaderboard will display the ranking of players who have played the game and the current ranking of the player. System output: After clicking "Next" button on the first page of the game ending panel, the leaderboard shows the current ranking of the player in this game and other players' rankings.  (Matched with expected output ☑)
Play Multiplayer Game	
View the map with player current location and teammate's current location	Expected output: In a multiplayer game, after loading into the game, a UTAR Map will be displayed. A green pin indicates the player's current location, and orange pin indicate teammate' current locations. System output: After loading into the multiplayer game scene, the map of UTAR Kampar is shown on the screen. A green pin indicates the player's current location, and orange pin show the location of teammate in the same team.  (Matched with expected output ☑)

Locate the AR element associated with a collaborative mission	Expected output: After reaching a virtual point set up with a collaborative mission and capturing the AR element, the mission can only be attempted when two players in the same team are near each other. Otherwise, the attempt button will be disabled. System output: When clicking on the AR element, an attempt panel is displayed showing the distance between the two players. The attempt button will only be activated when the distance between the two players is less than 50.  (Matched with expected output ☑)
Players can utilize the chat function to message their teammates.	Expected output: In a multiplayer game, teammates are allowed to communicate using text through the chat box. System output: By clicking the "Chat" button, the chat box is opened, allowing players to send messages to their teammate and receive messages from them.  (Matched with expected output ☑)

When one player finds the treasure, the other players will be synchronized to the game end scene	Expected output: In a multiplayer game, when one player successfully finds the treasure, all players will be synchronized to the game end scene. System output: When team 1 and team 2 were playing the multiplayer treasure hunt game, and team 1 found the treasure, players from team 2 transitioned to the game end scene.  (Matched with expected output ☑)
View the ranking of the multiplayer game	Expected output: When the multiplayer game ends, the player can view the team ranking of that game sorted by the winner and total missions solved. System output: When team 2 won the game, the leaderboard after the game end showed that team 2 was ranked 1st, and it displayed the total missions solved by each team.  (Matched with expected output ☑)

5.2 Project Verification Plan

5.2.1 User Study

User Study: Location-Based AR Treasure Hunt Game on Kampar Campus

Objective :

This user study's goal is to assess the location-based augmented reality (AR) treasure hunt game's usability, user experience, player interactions and AR experience on the Kampar Campus.

Participants :

2 students from the UTAR Kampar campus representing varying levels of familiarity with mobile applications and the campus environment will be recruited.

Methodology :

User study will be conducted at UTAR Kampar Campus. Participants will be given a mobile device with a location-based AR treasure hunt mobile game called "Secrets of the Greenwood" installed.

Orientation :

Participants will learn about game concepts, objectives, and basic game logic. They will learn how to use AR features and navigate around campus.

Task Scenarios :

Participants will play the roles of creators or players. They will be asked to join the game or create a new treasure hunt session. Players need to find virtual points, interact with AR objects and complete quests to get clues to find treasure. Creators can set new games to their liking. They can place virtual points and set tasks for others to play.

Observation and Data Collection :

Observers are responsible for observing the behaviour of participants when they interact with the mobile game. Data will be collected through video recordings, screenshots and participant comments.

Usability Metrics :

Usability will be determined by task completion time, correctness and user experience score.

Feedback :

After completing the tasks provided, participants will be asked to provide their overall gaming experience, the challenges they faced, and suggestions for improving the Treasure Hunt mobile app.

Data Analysis :

The data collected will be used for analytical purposes, to understand user preferences and to evaluate the effectiveness of the game and user satisfaction.

Expected Outcomes :

This user study aims to collect the following information:

- How the user feels about the AR experience of the mobile game.

- The efficiency of learning from treasure hunt games.

- Engagement levels of participants during the treasure hunt.

- Participants' difficulties and possible areas for improvement.

Benefits :

The location-based AR treasure hunt game will be improved considering the results of this user study, ensuring that it provides users with a fun and engaging experience as they explore the Kampar Campus.

Ethics and Consent :

Participants will be made aware of the study's objectives, methods, and legal rights. Their participation will be completely optional, and their information will be kept private and anonymous.

Conclusion :

This user study's goal is to contribute to the development of a more interesting and interactive campus exploration tool by offering insightful information on how to improve the user experience of the Location-Based AR Treasure Hunt Game on Kampar Campus.

5.2.2 User Study Questions and Results

1. Could you please share your overall experience with playing this game?

Result : Participants consider their overall experience with the game to be positive, viewing it as a novel and enjoyable new gaming experience.

2. What are your thoughts on the treasure hunt aspect of the game, particularly with the addition of augmented reality? Did you find it enjoyable?

Result : Participants find the addition of augmented reality to the treasure hunt aspect of the game to be enjoyable, as it enhances exploration in the real world, making the game more engaging.

3. How do you feel about the customization options available for the game flow? Do you think they contribute to different playstyles?

Result : Participants believe that the customization options available for the game flow allow for diverse playstyles, enabling users to create and play unique game sessions tailored to their preferences. They also find the mission setup to be easily customizable, enhancing versatility.

4. In your opinion, do you believe this application could be beneficial for university events in guiding newcomers?

Result : Participants affirm that the application could be beneficial for university events in guiding newcomers, citing its integration of university exploration within the gameplay and provision of faculty information as players progress through the game.

5. Do you think players can gain educational value through solving missions to uncover treasures?

Result : Participants recognize the educational value embedded within the game, viewing it as a gamified learning experience where completing missions enhances player knowledge.

6. Were there any challenges or difficulties you encountered while using the mobile application?

Result : Participants encountered challenges primarily related to the user interface of the mobile application, suggesting that improvements could enhance usability.

[Multiplayer]

7. Regarding the multiplayer mode, do you believe the chat function enhances player interaction?

Result : Participants acknowledge that the chat function enhances player interaction in multiplayer mode, particularly when team members are separated at different locations while seeking clues.

8. For the multiplayer game mode, do you think that small groups of players can have an enjoyable experience?

Result : Participants believe that small groups of players can indeed have an enjoyable experience in the multiplayer treasure hunt game, as it allows simultaneous participation and collaboration among team members.

5.2.3 User Study Data Collection and Analysis

A user study was conducted with the aim of gathering the necessary information to validate the project objectives. Two participants were invited to play the treasure hunt game developed as part of this project on the UTAR Kampar Campus. They independently explored the functionalities and features of the game, utilizing the application as creators to design their own treasure hunt game session. Furthermore, both participants joined a multiplayer game set up for testing purposes and played together.

Following the test session, where they assumed roles as both creators and players in the treasure hunt mobile game, individual interviews were conducted to gather their feedback. Both participants believe that integrating AR techniques into the treasure hunt mobile game adds additional fun and provides players with an opportunity to experience AR. Besides, they think that the allowing creators to define a new treasure hunt game session extend the playability of the game. This allows players to engage in fresh experiences by participating in games with diverse treasure hunt routes created by other users.

Moreover, the participants in the user study believe that the developed application could be utilized beneficially for university events, particularly in guiding newcomers. It can assist them in navigating the various faculties of UTAR Kampar Campus and discovering the university's beauty. They believe that by incorporating learning-worthy missions into a treasure hunt game session, players can derive educational value from solving these missions. Since trying out the multiplayer game mode of the treasure hunt game, they believe that small groups of players playing together will have an enjoyable experience. They also think that the chat functions provide convenience for team members to communicate and offer a platform for player interaction. Participants mentioned that there are some improvements that can be made, particularly in increasing the user-friendliness of the user interface.

In summary, a user study with an interview session was conducted to gather feedback from users who were using the application developed in this project for the first time. This feedback not only helped validate certain aspects of the project objectives but also identified opportunities for future enhancements to the application.

CHAPTER 6
Discussion

6.1 Objective Achievement

This project has two objectives: to develop a location-based treasure hunt game that allows players to explore the outside world with friends through interactive and learnable treasure hunt tasks; and to create an immersive treasure hunt by applying AR technology to outdoor treasure hunts.

In order to measure whether the project objectives were achieved, system testing was conducted and recorded in Chapter 5. According to testing, all functions work well and produce the expected output in the order of the game flow. This proves that the project has developed a location-based AR treasure hunt game that allows players to explore the outside world with friends.

In addition, to prove that the developed AR treasure hunt game brings fun and provides players with a way to learn by solving learning-worthy missions, this project conducted a user study to collect players' opinions and user experience. Based on collected data and analysis, it was found that users believe that enabling creators to define and set learning-worthy missions during the creation of a new treasure hunt game session allows players to learn while engaging in the game.

In summary, through system testing, including functional testing and user study, it is proven that the project objectives have been achieved and the developed applications have brought value to users.

6.2 System Limitation

Limitations exist in the system developed in this project due to integrated services and technical constraints. Position tracking accuracy is a major concern in location-based applications, as low accuracy can degrade user experience and affect game flow. The accuracy of GPS location tracking is affected by many factors, including user device's GPS signal and the Map API used in the project. Unfortunately, this problem cannot be fixed directly, only to minimize the possible error rate to ensure that the application still performs close to intended.

Besides, this project also uses Firebase to store all the data, and there are limitations for the free version, such as the number of connections to the database at the same time and data storage limits. Furthermore, this system heavily depends on GPS and network services to operate, as data such as location and other game logic operations need to interact with Firebase to obtain the latest data. The system may face difficulties and lower the performance of playing the treasure hunt game when the device experiences GPS or network service issues.

Additionally, this project is specifically tailored for players to engage in a treasure hunt using the UTAR Kampar map, limiting gameplay to this area. Players outside of this region may not be able to participate in the game, restricting its accessibility.

6.3 Future Enhancement

While the system is quite complete and all game flows run smoothly, there are still opportunities for future improvements to enhance availability and overall experience. In addition to leveraging better location and map service providers and online database services to improve the gaming experience, the AR treasure hunt game could benefit from frequent updates to bring more excitement to players.

In the future, the AR treasure hunt game could incorporate events to attract more players to participate simultaneously. This would increase player interactions and provide opportunities for players to get to know each other while exploring UTAR Kampar Campus through the game. Additionally, introducing new types of missions would make the game more diverse and engaging for players.

Furthermore, while the game is currently only available for play in UTAR Kampar, future iterations of the application could expand its reach to allow gameplay at any location. This could involve implementing custom map areas and enabling players near specific locations to join the game and participate in treasure hunts.

In summary, future enhancements to the system could involve leveraging better service providers, introducing new game logic through frequent updates, and expanding the game's accessibility to players in other locations.

CHAPTER 7
Conclusion

AR Treasure Hunt game is one of the trends of the mobile game application. It encourages people to go outside and discover their surroundings. By allowing players to interact with augmented reality elements using their device's camera, this game not only promotes relaxation but also offers the chance for players to learn new things.

However, judging from the research on existing treasure hunt games, there aren't many high-quality AR outdoor treasure hunt games available on the market right now, and those that do tend to lack educational value. Besides, effective interpersonal and communication skills are essential in today's society, and an outdoor treasure hunt game with multiple players can be crucial in developing these abilities. It promotes player interaction and improves their capacity for cooperation and effective communication.

The main goal of this project is to develop a location-based AR treasure hunt game that takes these novel requirements into account and addresses the problems that currently exist in the treasure hunt gaming market. Along with educational missions to aid players in learning, the proposed application also has a cooperation module to promote player interaction and cooperation. In this multiplayer game, players work with their teammates to complete missions as they search for the treasure by locating virtual points and interacting with AR elements. Additionally, users of the application can join and take part in games created by others as well as create their own custom game flows. The playability of the game is greatly improved by this level of flexibility.

To ensure proper development of the treasure hunt mobile game for this project, a literature review on the development of treasure hunt games was conducted. Additionally, all analyses and designs generated during the project development process were meticulously documented. Following the development of the application, system testing was performed to assess the achievement of project objectives, and it proved to be successful.

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APPENDIX

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 1**
Student Name & ID: Tan Kean Hon 21ACB02568	
Supervisor: Ts Dr Ku Chin Soon	
Project Title: Augmented Reality Treasure Hunt Game	

1. WORK DONE

Changed the design prototype into a workable function.

2. WORK TO BE DONE

Implement the Multiplayer Game Mode.

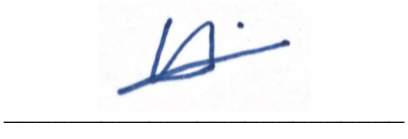
3. PROBLEMS ENCOUNTERED

Faced time constraints while learning new techniques such as Photon Server.

4. SELF EVALUATION OF THE PROGRESS

Good. All tasks are currently in progress.

Supervisor's signature



Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 5**
Student Name & ID: Tan Kean Hon 21ACB02568	
Supervisor: Ts Dr Ku Chin Soon	
Project Title: Augmented Reality Treasure Hunt Game	

1. WORK DONE

Allow players to generate rooms and connect to server as part of the multiplayer game mode.

2. WORK TO BE DONE

Implement the core logic for the multiplayer game.

3. PROBLEMS ENCOUNTERED

Challenged by the lack of two mobile devices for multiplayer testing.

4. SELF EVALUATION OF THE PROGRESS

Need improvement but all tasks remain in progress.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 7**
Student Name & ID: Tan Kean Hon 21ACB02568	
Supervisor: Ts Dr Ku Chin Soon	
Project Title: Augmented Reality Treasure Hunt Game	

1. WORK DONE

Completed most of the multiplayer game logic.

2. WORK TO BE DONE

Need to add an extra feature: text-to-speech functionality.

3. PROBLEMS ENCOUNTERED

None

4. SELF EVALUATION OF THE PROGRESS

Good. All aspects are functioning well, and progress is on track.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 9**
Student Name & ID: Tan Kean Hon 21ACB02568	
Supervisor: Ts Dr Ku Chin Soon	
Project Title: Augmented Reality Treasure Hunt Game	

1. WORK DONE

Added text-to-speech function, completed whole system.

2. WORK TO BE DONE

Perform testing and fix discovered issues.

3. PROBLEMS ENCOUNTERED

None

4. SELF EVALUATION OF THE PROGRESS

All is going well, just need to stay focused on finishing the remaining work.

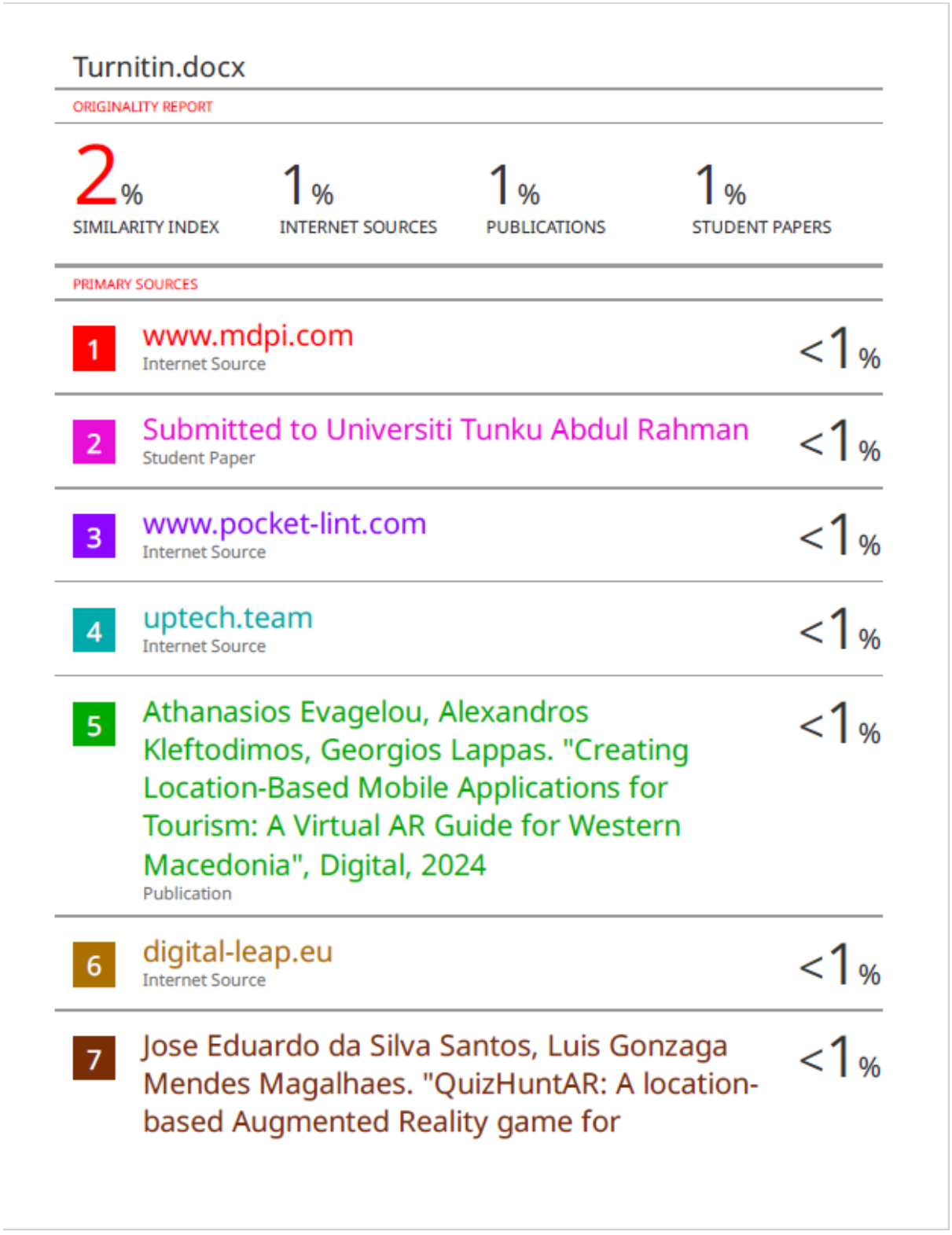
Supervisor's signature

Student's signature

POSTER


UNIVERSITY TUNKU ABDUL RAHMAN
FACULTY OF INFORMATION COMMUNICATION TECHNOLOGY
FINAL YEAR PROJECT
Developed by : Tan Kean Hon
Supervised by : Dr. Ku Chin Soon
AR Treasure Hunt Game
Introduction
This project integrates Augmented Reality (AR) into a Treasure Hunt Mobile Game enhancing the immersive experience of real-life adventure
Project Objective
- To develop a location-based treasure hunt game that allow players to explore the outside world with friends through interactive and learning-worthy treasure hunt missions
- To create an immersive AR experience by implementing AR techniques into outdoor treasure hunt mobile game that offers players an immersive and interactive experience by blending the virtual and real worlds with customizable game flow
Project Scope
~In the treasure hunt mobile game, UTAR Kampar students can embark on an immersive treasure hunt adventure.
~Players use the app to explore the campus, solving missions, and capturing virtual objects through augmented reality.
~There are various mission types, such as multi-choice questions, puzzles, and cooperative challenges for multiplayer mode.
~Players retrieve clues and interact with AR objects to find the hidden treasure
~Creators have the power to design game sessions, placing virtual points, missions, and clues on the map
Techniques
Software
Unity 3D
Mapbox SDK
Firebase SDK
Programming Language
Play
Profile
Quit

PLAGIARISM CHECK RESULT



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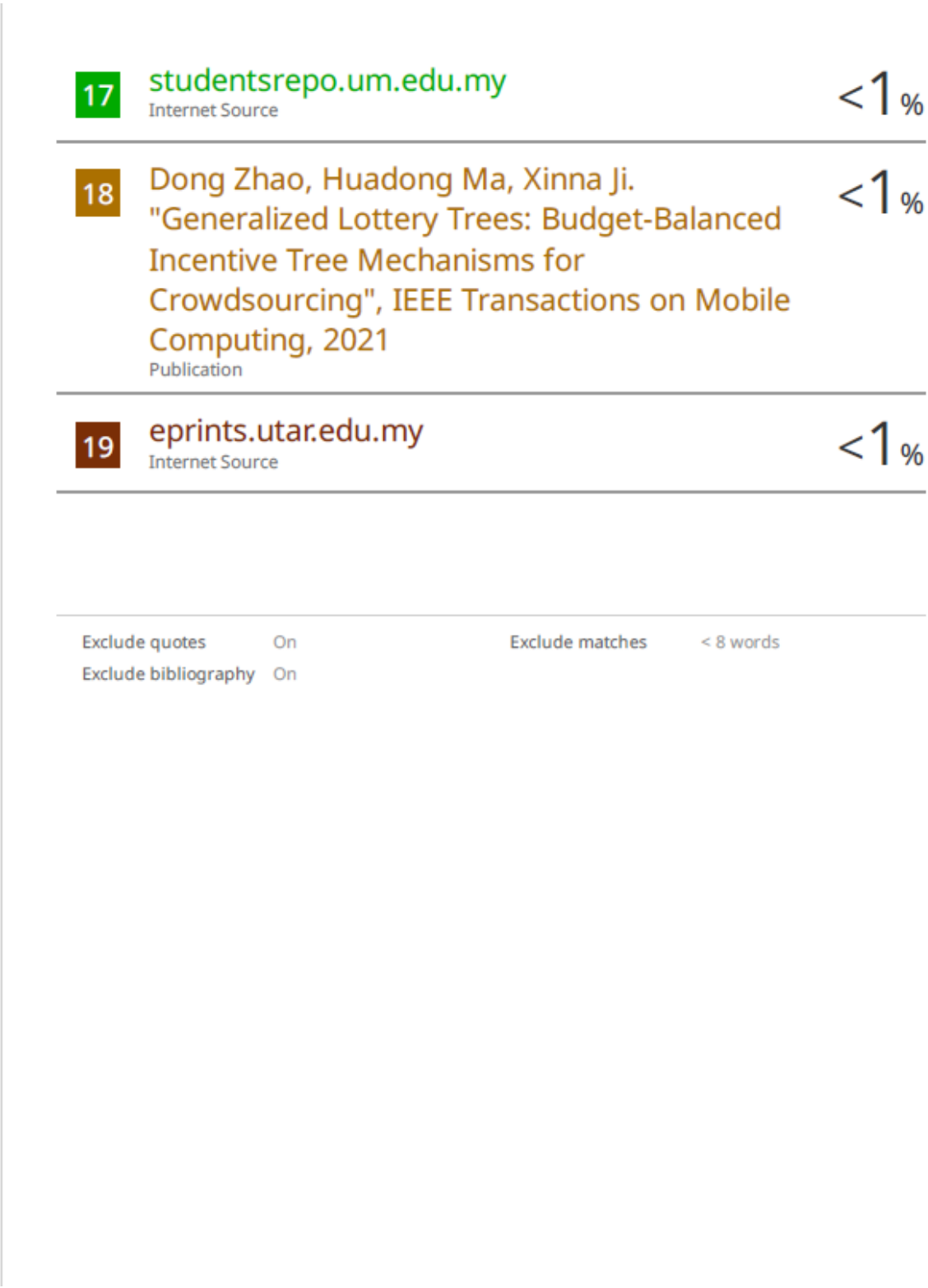
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Full Name(s) of Candidate(s)	TAN KEAN HON
ID Number(s)	21ACB02568
Programme / Course	BACHELOR INFORMATION SYSTEMS (HONOURS) INFORMATION SYSTEMS ENGINEERING
Title of Final Year Project	Augmented Reality Treasure Hunt Game

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Signature of Supervisor

Name: Ku Chin Soon

Date: 23/04/2024

Signature of Co-Supervisor

Name: _____

Date: _____

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY (KAMPAR CAMPUS)

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Student Name	TAN KEAN HON
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