IMMERSIVE AR PET GAME WITH HAND MOTION

BY

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ABSTRACT

This project aims to provide an engaging and interactive solution for individuals who desire the experience of owning a pet but cannot do so due to various constraints. The project will leverage Augmented Reality (AR) technology to create a virtual pet-raising game that offers a realistic and immersive experience. The game will incorporate hand-detection technology to enable intuitive interactions with virtual pets. ARCore, Unity and ManoMotion will be the primary game development tools. ARCore is compatible with most mobile devices. It uses the device's camera and internal sensor to detect the position and orientation of the environment, estimates light conditions and compute location changes. With these capabilities, ARCore can seamlessly blend virtual objects with the real world. Unity provides a cross-platform development environment for AR applications that run on different devices with varying capabilities. ManoMotion is a hand-tracking software that uses machine learning algorithms to track and recognise hand movements in real-time. It captures the hand movements using a camera and analyses the data to identify various gestures made by the user's hand. The software provides position coordinates and rotation values in three-dimensional space and distinguishes between left and right hands. ManoMotion provides gesture analysis to interpret users' intentions, allowing developers to create customised experiences catering to different behaviours.

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LIST OF ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
5G	Fifth Generation
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
C#	C-sharp
CNNs	Convolutional Neural Networks
HMD	Head-mounted Display
LiDAR	Light Detection and Ranging
ML	Machine Learning
RGB-D	Red Green Blue-Depth
RNNs	Recurrent Neural Networks
SDK	Software Development Kit
SLAM	Simultaneous Localization and Mapping
UI	User Interface
VIO	Visual Inertial Odometry
VR	Virtual Reality

Chapter 1 Introduction

1.1 Problem Statement and Motivation

The hectic lifestyle of modern times is one of the primary reasons that prevent people from getting a pet. Raising a pet requires significant time and effort, including regular feeding, cleaning and providing medical attention when necessary. Moreover, pets like cats and dogs require regular exercise and playtime to maintain their physical and emotional well-being. It is also essential to clean the house more frequently, so it does not smell. These challenges often make it difficult for people to care for real pets, leading to neglect and other issues.

There is a lack of interactive and engaging mobile applications that utilise augmented reality (AR) technology, particularly in virtual pet games. Existing virtual pet games are often limited to a 2D or 3D digital environment, making them feel disconnected from the real world and limiting the player's ability to interact with their pet. AR virtual pet games currently available in the market can only place their virtual pets in the real world through the camera lens. The interactions with virtual pets are limited to pressing buttons on the screen, causing the player's experience to feel static and less engaging.

To address these problems, this project aims to provide a solution for individuals who cannot own a real pet but still desire the experience of having a pet. By leveraging AR technology, the game can provide an immersive experience of raising virtual pets using AR technology. To increase the realisticness of the game, hand detection is used to interact with virtual pets. By creating virtual pets that can be interacted with realistically and intuitively, pet lovers can experience the joy of caring for a pet without the extra effort required to care for the real one. Additionally, virtual pets do not get sick, eliminating the need for medical attention and medication. This game can provide a more accessible and convenient way for people to experience the joy of owning a pet without the additional responsibilities and challenges of caring for a real one.

1.2 Objectives

Firstly, this project aims to develop a virtual pet mobile game that utilises AR technology to provide users with a more realistic pet-raising experience. Secondly, the game is to improve the immersive experience of pet games by adding the hand detection function, which is not currently available in the market.

In this game:

- AR technology improves realism by placing virtual pets in the real world.
- Users can interact with the virtual pet using hand-detection technology.
- Virtual pets can respond to the player by the detected hand gesture.
- A virtual pet's random responses and actions can mimic the actual pet.

The game is designed to simulate the experience of raising a real pet. Hence hand motion detection plays a vital role in recognising the hand gestures made by users. This feature is essential to create a virtual pet that behaves and responds like a real pet, with the ability to recognise and react to the player's hand gestures and simulate real-life behaviour. Virtual pets in this game can perform a few actions, such as running, walking and eating.

To create a more realistic and dynamic user experience, the virtual pet in this mobile game will not always respond to the player's interactions. Like real pets, the virtual pet may ignore the player's hand gestures. This randomness and unpredictability will make the game more challenging and exciting, as users can keep trying to attract the pet's attention by hoping the pets will respond to them. It will also add an element of surprise to the game, as the virtual pet's responses will not always be predictable.

Furthermore, this feature will help to reinforce the idea that virtual pets require attention and care, just like real pets. By mimicking real-life pet behaviour, users will be encouraged to engage with their virtual pet regularly and be reminded of the responsibilities of pet ownership.

1.3 Project Scope

At the end of this project, a virtual pet mobile game utilising augmented reality (AR) and hand motion detection technology will be developed. The primary goal of this project is to bring the experience of raising a virtual pet closer to the real world with AR technology. The proposed mobile game will offer users a more realistic experience of raising a virtual pet by implementing AR features and hand motion detection that allows users to view the virtual pet in their real-world environment and interact with it in a more immersive way.

In addition, the virtual pets will be able to behave and respond like a real pet, with the ability to recognise and react to the player's hand gestures and simulate real-life pet behaviour. The game will detect the player's hand movement through the mobile device's camera and interpret the gestures as specific actions to which the pet will respond. Some randomness is added to the game to make the virtual pet's action more unpredictable, thus making the game more challenging and interesting. To ensure a smooth and user-friendly experience, the game will feature a clean and intuitive user interface that allows users to navigate and interact with the virtual pet easily.

1.4 Contributions

As mentioned above, many virtual pet games are available nowadays. However, most pet games are in 2D or 3D with a digital environment and background. Even though some virtual pet games provide AR features, the games only project the virtual pet onto the 3D world. The interaction with virtual pets is only based on the buttons on the screen, making the virtual pet less realistic and disconnected from the users. This project supports more realistic interaction by implementing hand motion detection in the game for users to interact with the virtual pet with their hands.

By incorporating randomness and unpredictability into a virtual pet's behaviour, the action of the virtual pet will not be entirely predictable, and the pet may occasionally ignore the player's gestures or exhibit unexpected behaviour. Players must be patient and adapt to the pet's personality rather than being able to control its behaviour fully. Thus, this will reinforce the idea that pets require patience and effort to take good care of them.

The development of an AR pet game utilising hand motion detection technology provides a unique and immersive gaming experience and demonstrates this technology's potential in other fields beyond gaming. For instance, in education, students can visualise and interact with complex models, making learning more engaging and accessible by using AR. Hand motion detection provides a more natural and intuitive interface for students to interact with educational content. In healthcare, this technology can be used for rehabilitation and physical therapy. AR and hand motion detection technology can be used to visualise and simulate complex medical procedures, allowing doctors to practise and refine their skills in a safe and controlled environment. By showcasing the potential of this technology in various fields, this project contributes to the advancement of AR and hand motion detection technology and its potential impact on different industries.

1.5 Report Organization

The report is structured into seven chapters, each focusing on different aspects of the project. In Chapter 1, an introduction to the project is provided, comprising five distinct sections. The initial section addresses the problem statement and motivation, elucidating the driving factors behind creating an augmented reality(AR) aided mobile application for grocery shopping. The second section outlines the project's objectives, detailing the intended accomplishments. The third section delimits the project scope, explicitly defining its boundaries, including inclusions and exclusions. Subsequently, the project's contributions are discussed in the fourth section, highlighting its novel contributions to existing knowledge. Lastly, the fifth section explicates the report's structure, delineating its organisation.

The literature review in Chapter 2 presents an extensive study of current technologies and systems. There are four sections in this chapter. An introduction to current technology is presented in the first section, and a review of AR-based game applications is presented in the second. The preceding work's limitations are compared in the third section, and a summary is given in the fourth.

Chapter 3 presents the system methodology/approach, which contains the methodology used to develop the system, system architecture, use case diagram and description and activity diagram.

The system design in Chapter 4 presents the system flowcharts and system component diagrams. The explanation of functionality of the system is also included in this chapter.

Chapter 5 presents the system implementation, which provides information and procedures to complete the system. This chapter is divided into six sections: hardware setup, software setup, setting and configuration, system operation, implementation issues and challenges and concluding remarks.

The system evaluation and discussion in Chapter 6 presents the assessment process of the complete system, encompassing five sections: system testing and performance metrics, testing setup and results, an examination of project challenges, an evaluation of project objectives, and concluding remarks.

Finally, Chapter 7 provides the conclusion and recommendations for the system. The recommendations section outlines potential works for further system improvement.

Chapter 2 Literature Review

2.1 Review of the Technologies

2.1.1 Augmented Reality (AR)

Augmented Reality (AR) technology has emerged as a groundbreaking innovation that merges the digital and physical worlds, enriching the sensory experience and transforming how people interact with their surroundings.

From entertainment and gaming to healthcare, education, manufacturing, and retail, augmented reality technology has been used in a variety of applications. As demonstrated in well-known smartphone applications like Pokemon Go, augmented reality (AR) improves immersive experiences through interactive overlays in the entertainment sector. By superimposing important information onto a surgeon's field of view, augmented reality (AR) helps surgical procedures in the medical industry, boosting precision and lowering risk. By bringing static content to life, augmented reality (AR) in education makes hard subjects more engaging and encourages interactive learning. With virtual try-on experiences and interactive product presentations, AR is also revolutionising retail.

The capabilities of AR have increased dramatically as a result of recent developments. Accurate real-time tracking of a user's position and environment is made possible by simultaneous localization and mapping (SLAM) algorithms and spatial mapping, leading to fluid AR interactions. The user experience is improved by new hardware, including depth-sensing cameras and a small, powerful processor. Smart glasses are one example of a wearable augmented reality gadget growing increasingly advanced, providing hands-free interaction and smoothly integrating into daily tasks. The expansion of 5G networks will make it easier to include cloud-based augmented reality (AR) applications. The capabilities of 5G enable AR applications to dramatically faster data throughput and lower latency.

2.1.2 Hand Tracking

The ability to recognise and monitor hand movements and gestures in real time has changed human-computer interaction. Hand tracking uses various techniques, from conventional computer vision methods to complex deep-learning strategies. Traditional techniques use colour, borders, and shapes to identify hands in pictures and films. Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) are two examples of modern deep learning algorithms that excel at learning intricate patterns and subtleties from large datasets, producing high accuracy.

The quick development of deep learning technologies has driven recent advances in hand tracking technology. Tracking accuracy in three-dimensional space has improved because of depth-sensing technology like RGB-D cameras and LiDAR. Furthermore, real-time performance has dramatically increased, which has led to smooth interactions.

2.1.3 Augmented Reality (AR) Development Platform

Apple's software development kit (SDK), ARKit, enables programmers to efficiently incorporate augmented reality (AR) into their projects. Visual Inertial Odometry (VIO) can accurately track the surroundings and comprehend the object's movement without extra calibration. Digital objects can be placed on horizontal surfaces in a space that ARKit has identified, such as floors or tables. Additionally, the SDK calculates ambient lighting using the camera sensor. ARKit can monitor user faces using the TrueDepth camera on an iPhone to build a face model to which real-time effects can be applied.

ARCore serves as Google’s platform for creating AR applications. ARCore gives smartphones the ability to perceive their surroundings, comprehend their environment, and interact with information using various APIs. To seamlessly integrate virtual information with the real world, ARCore uses three key capabilities: motion tracking, environmental comprehension, and light estimation. To determine the phone's location, ARCore uses simultaneous localization and mapping (SLAM) [1]. It can compute the location change using these feature points by identifying the visually distinguishable features. As a result, the

virtual object remains where it was left, even if the camera moves around. Light estimation is another ARCore capability. It can determine the camera image's average intensity and colour correction and recognise its surroundings' lighting information. Developers may combine the virtual object with the real environment by leveraging ARCore's understanding of the real world.

Unity AR foundation is a cross-platform framework purposely built for AR development [2]. It supports many features needed for AR development, such as plane tracking, point clouds, anchors, and environment probes. It also supports multiple AR platforms such as ARKit, ARCore and HoloLens, allowing developers to build AR applications that can run on various devices with different capabilities. AR Foundation is designed to simplify the development process for AR applications and provides tools and assets to help developers.

2.1.4 Hand Tracking Framework

Leap Motion is a technology company specialising in hand tracking and motion control. Their hand tracking technology allows users to interact with digital content using natural hand movements and gestures. Leap Motion provides hardware and software solutions for integrating hand tracking into various applications, including VR, AR and desktop systems. The company’s hardware, a small controller that tracks hand movements and translates them into digital interactions, enabling users to manipulate virtual objects, navigate interfaces and more.

MediaPipe is a cross-platform, open-source framework developed by Google that provides various tools and components for developers applying artificial intelligence (AI) and machine learning (ML) techniques to their applications. Hand tracking solution is one of its standout characteristics. Using input sources like pictures or videos, MediaPipe Hand Tracking uses machine learning models to detect and track hands in real time. Developers who want to add hand-tracking capabilities to their applications without having to create tracking algorithms from the start might benefit from this technology. With its support for 2D

and 3D hand tracking, MediaPipe is adaptable for various applications, including augmented reality, virtual reality, and human-computer interaction.

ManoMotion is a hand-tracking software that uses machine learning algorithms to track and recognise hand movements in real time [3]. It uses a camera to capture the hand movements and then analyses the data to identify the various gestures being made by the user's hand. The hand-tracking feature provides the position coordinates in three-dimensional space (x, y, z) and rotation values of individual points or the entire skeleton. The technology also detects the orientation of hand joints and distinguishes between the left and right hand. It also measures the distance from the hand to the camera and thus calculates the relative depth information, which values ranging from 0 to 1. Besides hand tracking, it also has a skeleton tracking feature, which contains the confidence and joint information of the skeleton.

ManoMotion also provides hand gesture analysis to interpret the user's intentions [3]. The technology will collect information from previous and current frames to identify the type of gesture the user performs. The data is categorised into three groups, allowing developers to create customisable experiences that cater to various behaviours and can be mapped into Unity. This means that users can perform hand gestures, including pointing, grabbing and pinching. It can be integrated with various platforms and devices, including smartphones, tablets, AR, and VR headsets. It has been used in various applications, including gaming, education and healthcare.

2.1.5 Summary of Technologies Review

The technological evaluation looked at the most recent advancements in ARKit, ARCore, and Unity AR Foundation, frameworks for augmented reality experiences that allow seamless integration. Additionally, it addressed hand-tracking innovations like Leap Motion, MediaPipe, and ManoMotion, demonstrating how they can recognise and analyse hand gestures for natural interactions. These innovations are revolutionising entire sectors by boosting user experiences, bridging the gap between the digital and physical worlds, and creating new opportunities for creativity and immersive applications.

2.2 Review of Existing Systems/Applications

2.2.1 3D virtual pet game "Moar" with augmented reality to simulate pet raising scenario on mobile device

In the paper proposed by C. Allen et al, the authors have designed a mobile game for users to raise their virtual pet, Monsta in an augmented reality environment [4]. Users are required to feed, clean, and take care of the pet to make sure their pet is in good condition. Other than the pet-raising module, the authors have also added battle modules to increase the fun of the game. Users have to train and enhance the ability of Monsta in order to compete in a battle. The game is designed using Unity 3D and the programming language used is C#. The game consists of both 3D and 2D components. The character Monsta, food, a battle arena, and potions are in 3D while the splash screen, icon, and graphical user interface are in 2D. The game can stimulate pet-raising scenarios as users can feed and clean the pet like in real life. It is simple to play and the battle module added has increased the attractiveness of the game.

Figure 2. 1 White Monsta in Moar from Paper [4]

2.2.2 Collaborative Augmented Reality for Chess Game in Handheld Devices

The implementation of AR is popular in chess games. The paper proposed by C. S. Yusof et al. has designed a 3D virtual AR chess game that can be played on handheld devices [5]. Handheld devices such as smartphones and tablets are more common and cheaper than dedicated devices for AR such as a Head-mounted Display (HMD). The authors have utilised the camera in handheld devices for vision-based tracking, thus extra external hardware can be eliminated in the AR system. The game allows competition between multiple users, hence increasing the interaction between users.

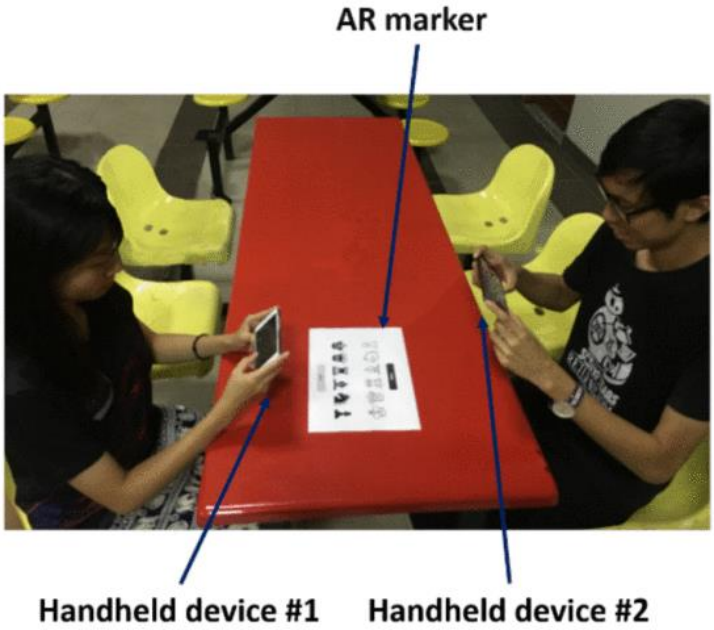

Figure 2. 2 Experiment Setup of Chess Game from Paper [5]

2.2.3 An Interactive Augmented Reality Chess Game Using Bare-Hand Pinch Gestures

Another implementation of AR in chess games from the authors M. Bikos et al. is an interactive AR chess game, in which users can manipulate virtual chess pieces with their bare hands [6]. To display the virtual chess board in the real environment, the authors used fiducial markers and also markerboards provided by the ArUco library. In order to improve the immersive experience for users, the authors have implemented a robust pinch gesture detection system that allows users to interact with virtual chess pieces. Users can grab and move the chess pieces like in real life by using pinch gestures.

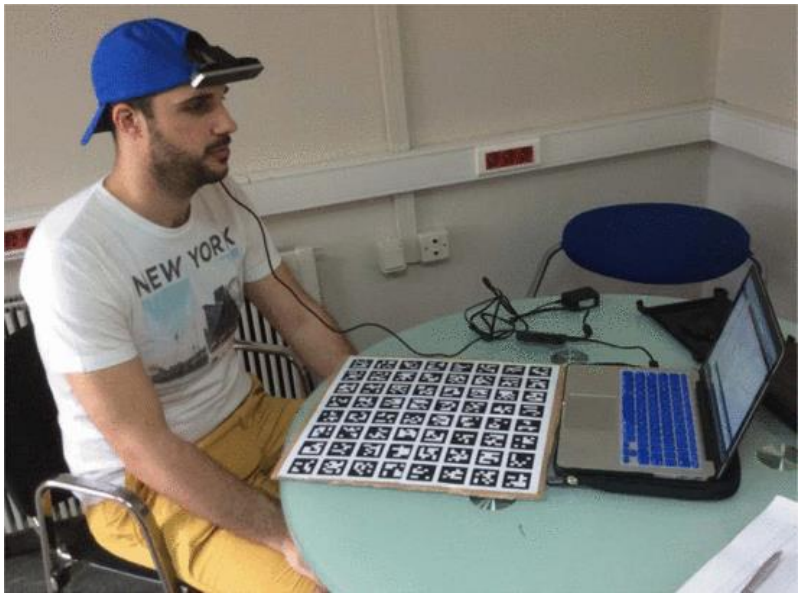

Figure 2. 3 Experiment Setup of Chess Game from Paper [6]

2.2.4 GeoBoids: A mobile AR application for exergaming

Other than the implementation of AR in chess board games, R. W. Lindeman et al. have developed a mobile AR game called GeoBoids [7]. In this game, users are required to move physically. The location of GeoBoids flocks is generated randomly, thus users have to find the flocks that are nearest to them. When users find the GeoBoids flock, the game will switch to arcade mode. Users have to capture the GeoBoids flock within the time limit in order to pass the level. Authors have used motion sensors that allow users to capture the flock by using swipe gestures. Hence increasing the interaction between users and the virtual objects. Besides that, another special feature of the game is the use of whistle sound as an input option. When users whistle to the phone, the GeoBoids will get scared and flock more tightly together, increasing the chances of users capturing them.

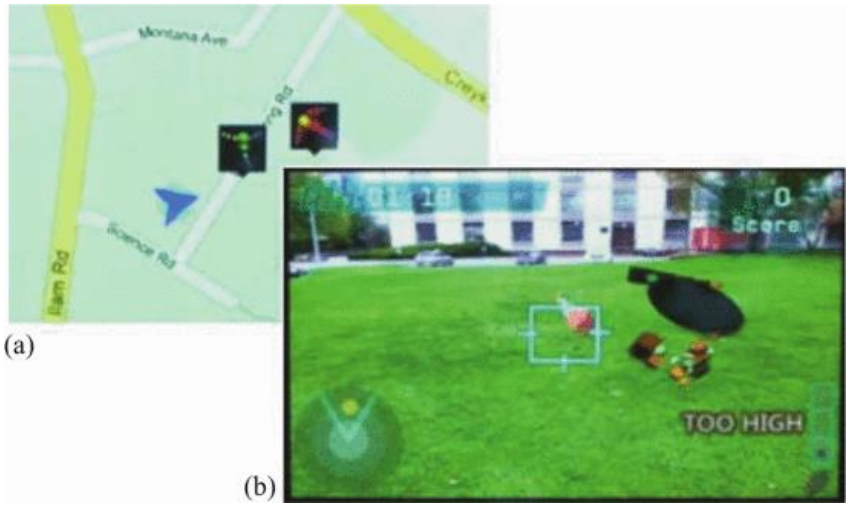

Figure 2. 4 Two Different Mode of Game from Paper [7]

2.2.5 ARZombie: A mobile augmented reality game with multimodal interaction

D. Cordeiro et al. have developed a mobile AR game called ARZombie [8]. In this game, users have to shoot the zombie to earn points and pass the levels. In order to enhance the interaction between users and the real world, authors have used facial recognition systems to detect people in the real world. If the faces are recognized as zombies, the game will display a virtual zombie mask over the face of the detected person. The zombies will become more dangerous as the level goes up. To pass the level, users have to shoot the zombie by firing a gun on the screen. In this paper, the framework proposed by the authors does not have any environmental restrictions and it can be used in other areas of AR such as education and medicine.

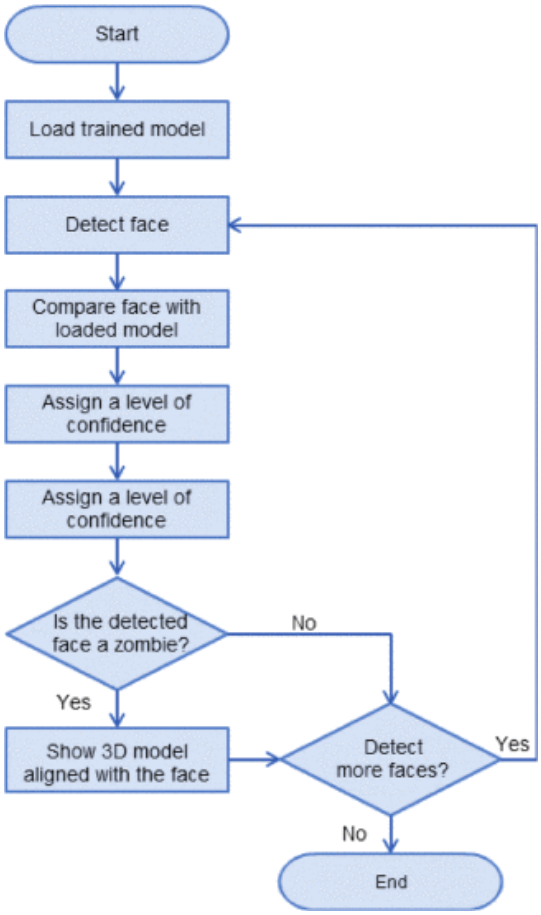

Figure 2. 5 Face Recognition of ARZombie From Paper [8]

2.2.6 Exploring affection-oriented virtual pet game design strategies in VR attachment, motivations, and expectations of users of pet games

In this paper, C. Lin et al. have conducted a study on how people think of virtual pets and what makes people interested to play pet games [9]. The study is divided into 2 parts, which are an online survey and a lab study. In the lab study, users played 3 different VR games, 2 of them are related to animals and the other one is not. The authors found that people play pet games for 2 main reasons, which are people using virtual pets as the replacement for real pets and seeking emotional support. There are some responses stated that although virtual pets can give companionship, they still prefer real pets. Taking care of virtual pets can help people to learn how to take care of and train pets before they actually get the real animal.

2.2.7 Talking Dogs AR

Talking Dogs AR is an AR dog simulator game [10]. The game implements AR technology for placing the dog in a real-world environment. When users enter the game, users are required to scan the surrounding area for a flat surface. After that, a dog will be placed on the detected surface. Users can train, feed, and play with the virtual dog. Users must take care of the virtual dog's condition, such as food level and happiness. If the dog feels hungry and unhappy, it refuses the training activity. So users must take care of the virtual dogs, such as feeding and playing with them. The interaction with the virtual dog is through the button on the screen. There are three main buttons, train, feed and game. The train button trains the virtual dogs to perform some action, for example, jumping through the hoops. The feed button is to feed the virtual dogs such as apples, doughnuts and hotdogs. Other than that, the play button is to play with virtual dogs, like throwing balls and giving bones.

Figure 2. 6 Virtual dog in real-world environment from game [10]

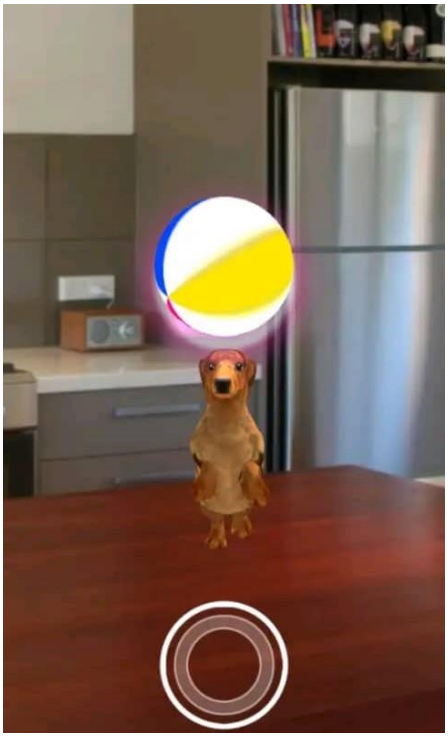

Figure 2. 7 Playing ball with virtual dog from game [10]

2.2.8 Dog Play AR

Dog Play AR is another AR dog simulator game in Google Play Store [11]. In this game, users can place the virtual pet in the real-world environment, resize them and move them around the surroundings. There are several virtual pet options for users, including shepherd, husky, golden retriever and more. Users need to click the show button to see the virtual pet in 3D view. The size of the virtual pets can be changed by scrolling the scale option on the screen's left side. Next, users can move the virtual pets' position with the help of the move option. The virtual pets can perform many animations, such as attack, run, idle, sit, trot, jump, eat and dig. Users can click the animation button and choose the action they want the virtual pet to perform. Users can share their virtual pet by taking a screenshot of their pet and sharing them using the share option.

Figure 2. 8 Game screen from game [11]

2.2.9 Limitation of Previous Works

In previous studies, [4] and [5] have implemented AR in their game, however, the games lack real interaction with the virtual AR environment. Other than the user experience not being immersive enough, [4] needs to have more variants of pets so users can have more variance to choose their pets. While in [6] [7], although the authors have included the hand detection framework, the gesture is only limited to one type. For example, in [6], the hand gesture detection is only for hand pinch in order to move the chess pieces. The users in [6] need to wear a hat on their heads with the sensor attached to the back of it in order to detect the motion of hand gestures. In paper [7], the users claim that the virtual object is less engaging with the users thus reducing the attractiveness of the game. Face detection is implemented in paper [8], but detection mainly depends on the person's eye. Hence users have to be close enough to other people for the games to detect the zombies. In paper [9], the games that the authors selected are not specifically designed for the study. Hence, the feeling of raising the virtual pet might not be as real as playing the games that develop specifically for keeping a pet. Game [10] and game [11] provide limited interaction between users and their virtual pets. In the game [10], users can only interact with their pets through buttons on the screen, which does not provide an immersive experience. With limited interaction, they can only feed, train, and play with their pets. It also does not show the unpredictability and realism of the pet's behaviour. In the game [11], the animation of the pet is played by clicking the action button on the screen, which does not create interaction between users and virtual

pets. At the same time, users can move their pets around by using buttons on the screen, which further detracts from the immersive experience.

2.2.10 Summary of Existing System

The current system demonstrates the potential and integration of hand tracking within the AR environment. However, it only detects only one specific hand gesture, requiring the addition of external sensors. Unfortunately, the existing AR pet game does not incorporate this hand tracking technology, resulting in a less immersive gameplay experience. The existing pet game only allows for on-screen buttons for interaction.

Chapter 3 System Methodology/Approach

3.1 System Design Diagram

3.1.1 Methodology

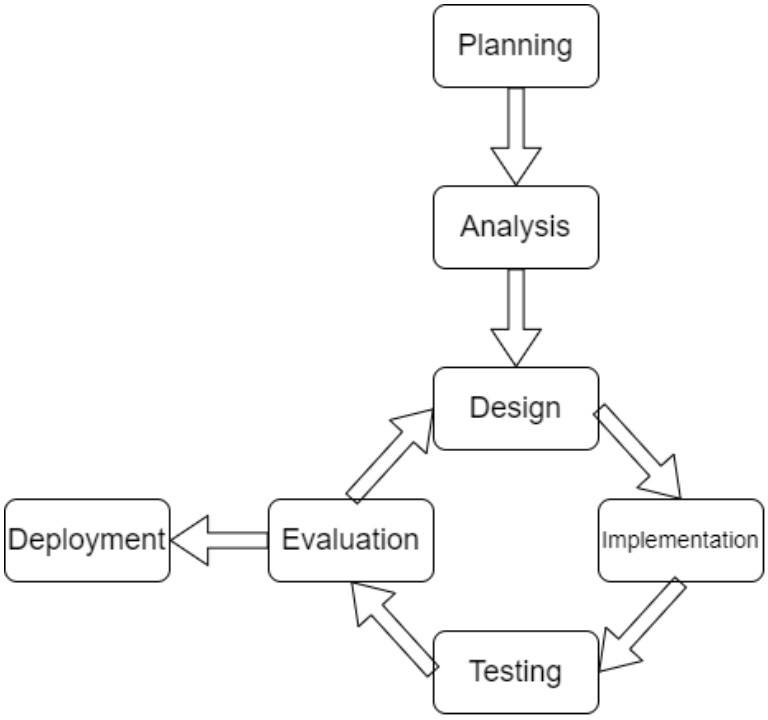

Figure 3. 1 Agile Development Approach

The agile development methodology is used in this project. The design, implementation, testing, and evaluation phases are interleaved. Agile methodology focuses more on working on the code rather than designing and practising minimal documentation. One of the advantages of this approach is that it can embrace the change in requirements. It is more flexible compared to the waterfall methodology. As agile methodology iterates the phases, the quality of the project is improved and helps to create a good quality product.

The project is divided into small, manageable parts. Each cycle usually lasts for 2 to 4 weeks, involving a set of tasks that are identified by the developers. At the end of the cycle, developers review the progress and identify areas of improvement. This allows the development team to adapt to changing requirements and address potential issues.

3.1.2 System Architecture Diagram

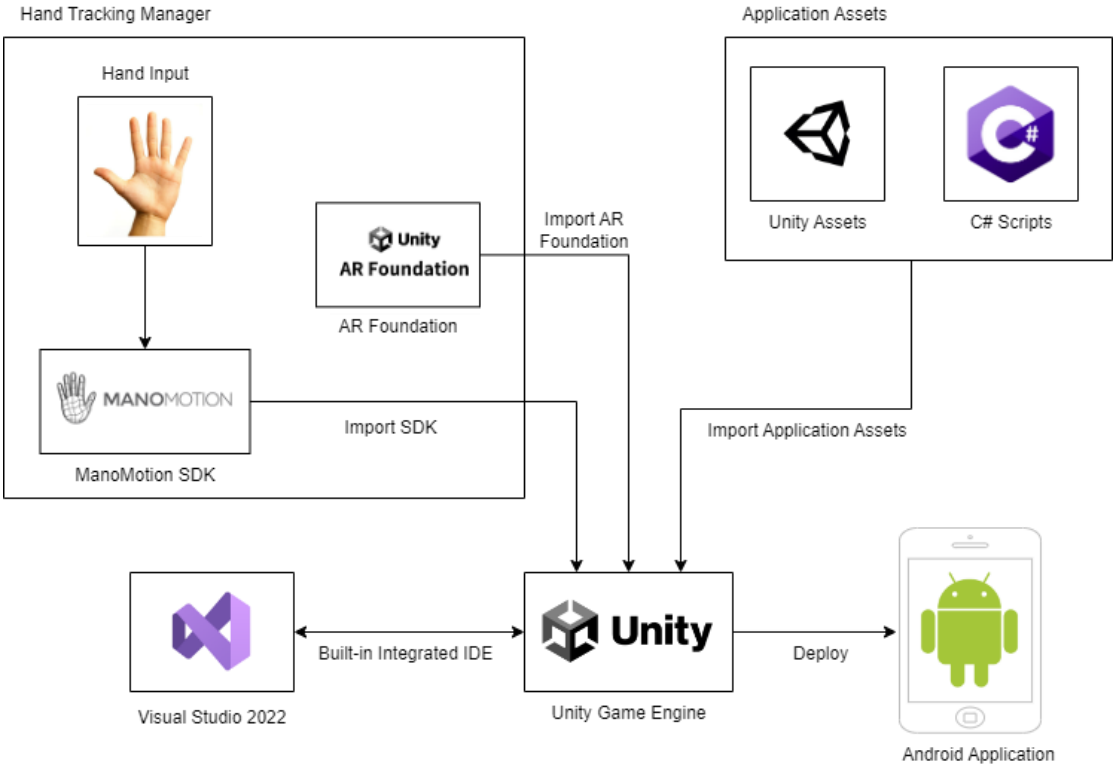

Figure 3. 2 System Architecture Diagram

Figure 3.2 shows the system architecture diagram of the application. The hand's movements are captured by the camera, serving as input data. The Unity game engine acts as the development platform for creating the application. The ManoMotion SDK is integrated into Unity for hand tracking and gesture recognition. The AR Foundation framework facilitates building the augmented reality (AR) environment on mobile devices, which detects the surrounding environment and calculates feature points for placing virtual objects seamlessly in the real world. Unity's Asset Store offers a variety of assets that assist in application development. The core functionality and behaviours of the application are scripted in C#, using Visual Studio 2022 as the integrated development environment. Finally, the application is deployed on the Android platform for mobile users.

3.1.3 Use Case Diagram and Description

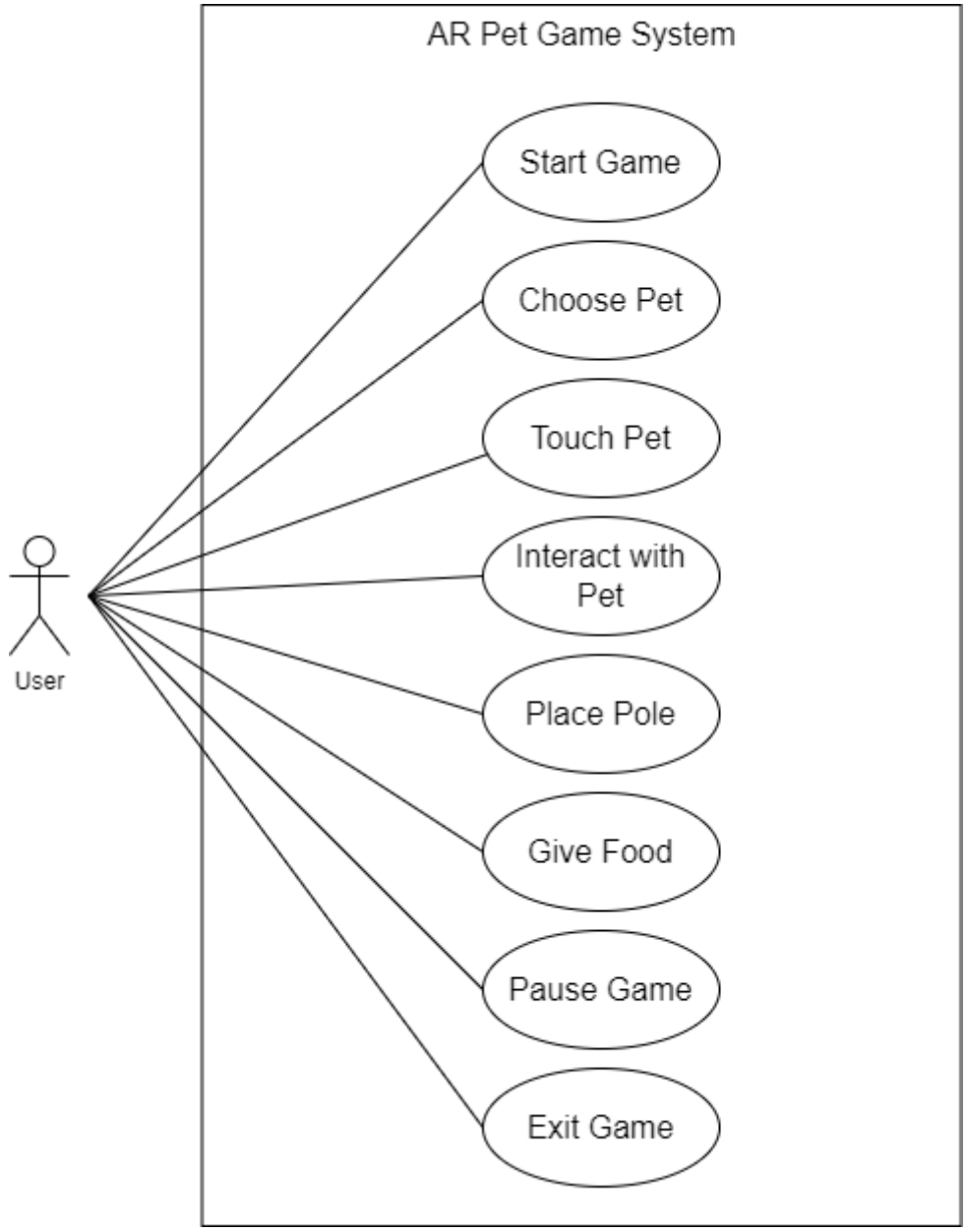

Figure 3. 3 Use Case Diagram

Use Case Description

Table 3. 1 Use Case Description for Start Game

Use Case Name	Start Game		
Use Case ID	UC001	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to start the game.		
Trigger	User opens the game.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User opens the game.	
	2	System displays the main menu.	
	3	Users select “Start Game”.	
	4	System displays the next scene.	
Alternate Flow - Exit Game	3.1	User selects “Quit Game”.	
	3.2	System terminates.	

Table 3. 2 Use Case Description for Choose Pet

Use Case Name	Choose Pet		
Use Case ID	UC002	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to choose the type of pet.		
Trigger	User selects “Start Game”.		

Scenario Name	Step	Action
Main Flow	1	User chooses the skin of the pet by pressing previous and next button.
	2	User views the pet by rotating around the pet.
	3	User presses the “Start” button.
	4	System saves the pet selection.
	5	System display next scene.
Alternate Flow	-	-

Table 3. 3 Use Case Description for Touch Pet

Use Case Name	Touch Pet		
Use Case ID	UC003	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to touch the pet.		
Trigger	User’s hand collides with the pet.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User’s hand collides with the pet.	
	2	Device vibrates.	
	3	System check pet activity status.	
	4	System check pet energy level.	
	5	Pet responds.	

Alternate Flow - Invalid activity status	3.1	Pet activity status invalid.
	3.2	Pet does not respond.
Alternate Flow - Invalid energy level	4.1	Pet energy level invalid.
	4.2	Pet does not respond.

Table 3. 4 Use Case Description for Interact with Pet

Use Case Name	Interact with Pet		
Use Case ID	UC004	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to interact with the virtual pet.		
Trigger	User hand gesture is visible on the screen.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User performs a hand gesture.	
	2	System check pet energy level.	
	3	System check pet activity status.	
	4	System runs the random function.	
	5	System analyses hand gestures.	
	6	Pet respond.	
	7	Decrease pet’s energy.	
Alternate Flow - Invalid energy level	2.1	Pet energy level invalid.	
	2.2	Pet sleep.	

Alternate Flow - Invalid activity status	3.1	Pet activity status invalid.
	3.2	Pet does not respond.
Alternate Flow - Random function false	4.1	Random function returns false.
	4.2	Pet does not respond.
Alternate Flow - Invalid hand gesture	5.1	Hand gestures perform by user is invalid.
	5.2	Pet does not respond.

Table 3. 5 Use Case Description for Place Pole

Use Case Name	Place Pole		
Use Case ID	UC005	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to place pole in an AR environment.		
Trigger	User presses the pole button.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User presses pole button	
	2	System check pet activity status.	
	3	System place pole.	
	4	System check pet energy level.	
	5	System runs the random function.	
	6	Pet respond.	
	7	Decrease pet's energy.	

	8	System destroys the pole.
Alternate Flow - Invalid activity status	2.1	Pet activity status invalid.
	2.2	Pet does not respond.
Alternate Flow - Invalid energy level	4.1	Pet energy level invalid
	4.2	Pet does not respond.
	4.3	System destroys the pole.
Alternate Flow - Random function false	5.1	Random function return false.
	5.2	Pet does not respond.
	5.3	System destroys the pole.

Table 3. 6 Use Case Description for Give Food

Use Case Name	Give Food		
Use Case ID	UC006	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to place food in an AR environment.		
Trigger	User presses the food button.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User presses food button.	
	2	System check pet activity status.	
	3	System place food.	
	4	System check pet energy level.	

	5	Pet respond.
	6	Increase pet's energy.
	7	System destroys food.
Alternate Flow - Invalid activity status	2.1	Pet activity status invalid.
	2.2	Pet does not respond.
Alternate Flow - Invalid energy level	4.1	Energy level of pet maximum.
	4.2	Pet does not respond.
	4.3	System destroys food.

Table 3. 7 Use Case Description for Pause Game

Use Case Name	Pause Game		
Use Case ID	UC007	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to pause the game.		
Trigger	User presses the pause button.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User press pause button.	
	2	System pause the game.	
	3	System display pause menu.	
	4	User press resume button.	
	5	System resumes the game.	

Alternate Flow - Home button	4.1	User presses home button.
	4.2	System display main menu scene.

Table 3. 8 Use Case Description for Exit Game

Use Case Name	Exit Game		
Use Case ID	UC008	**Importance Level**	High
Actor	User	**Use Case Type**	Detail, Essential
Purpose	To allow user to exit the game.		
Trigger	User presses the back or exit button.		
Scenario Name	**Step**	**Action**	
Main Flow	1	User presses the exit/back button.	
	2	System terminates.	
Alternate Flow	-	-	

3.1.4 Activity Diagram

Main Menu Module

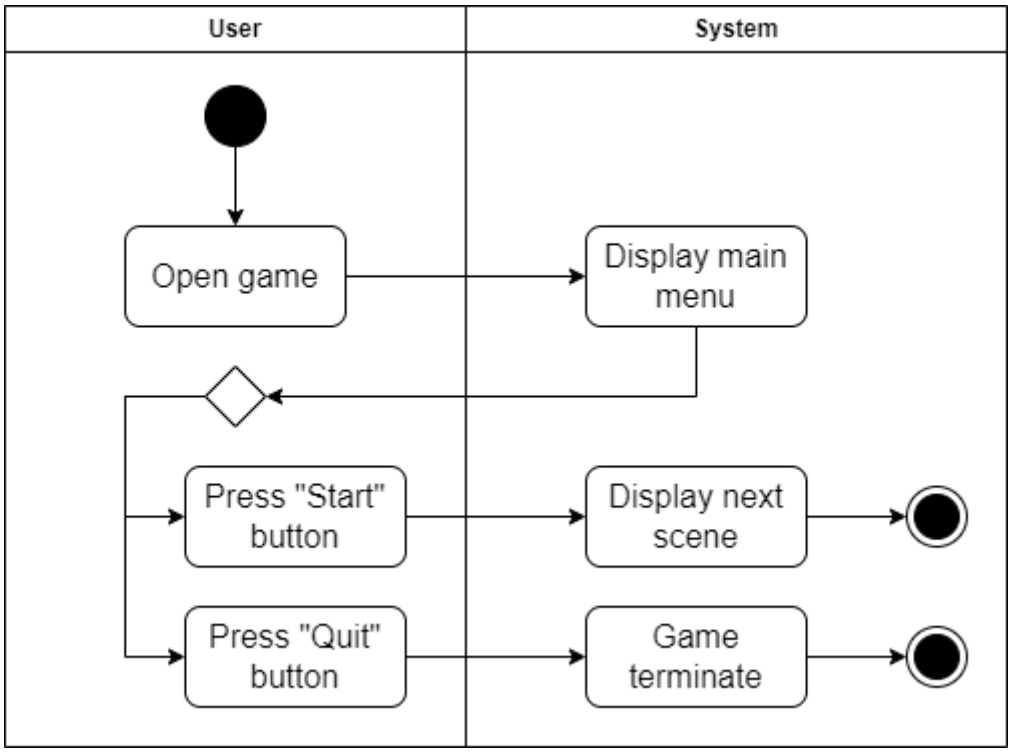

Figure 3. 4 Main Menu Activity Diagram

The activity diagram for the main menu scene starts with the user opening the game. The system displays the main menu, which consists of two buttons, “Start” and “Quit”. If the user presses the “Start” button, the system will display the next scene, the character selection scene. The system will terminate the game if the user presses the “Quit” button.

Character Selection Module

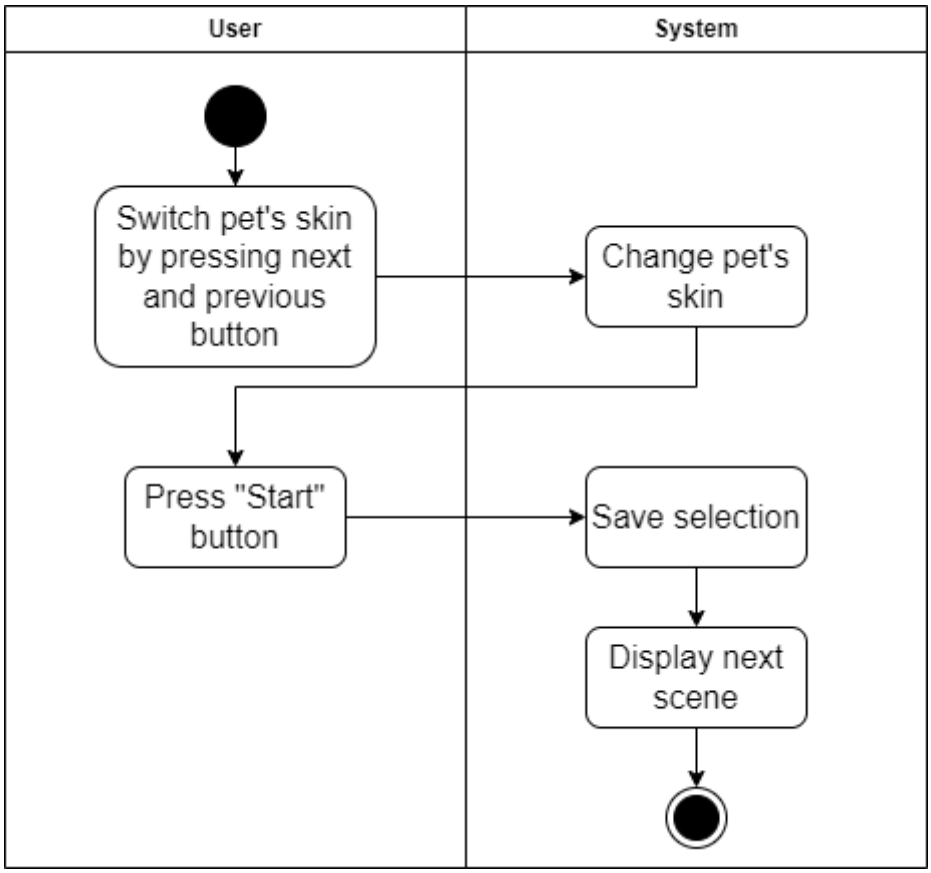

Figure 3. 5 Character Selection Activity Diagram

The character selection module allows the user to select the pet's appearance. A few types of appearance of cats and dogs are available. User can switch between the pet by pressing the next and previous buttons on the screen. User may also rotate the pet around to see the whole body of the pet from other different angles. After the user decides on their favourite pet, the user presses the "Start" button to start the game. The system will save the user's selection and display the next scene, the main game scene.

Touch Pet Module

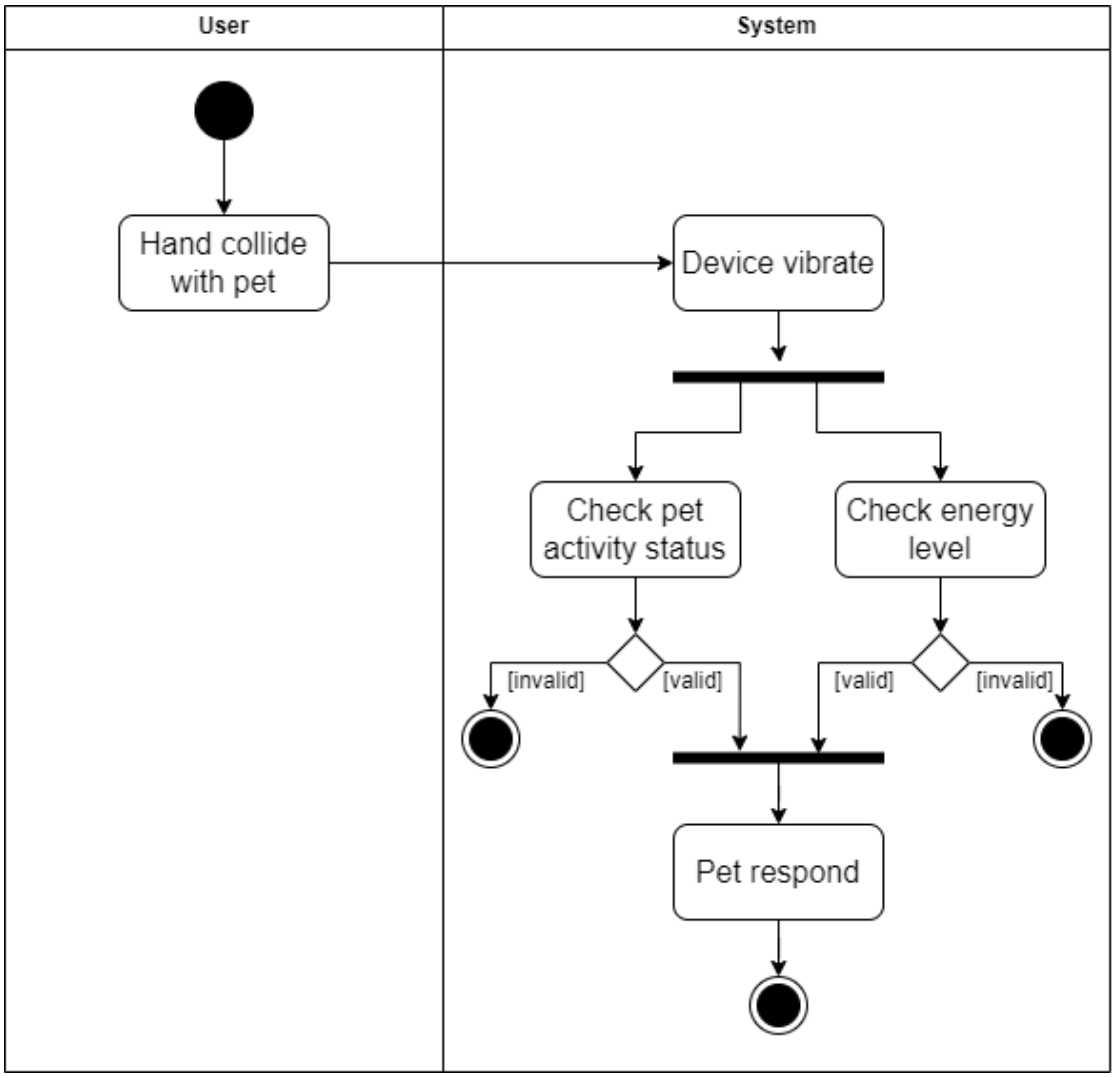

Figure 3. 6 Touch Pet Activity Diagram

Activity diagram 3.6 shows how the touch pet module works. The device will vibrate when the user's hand collides with the pet. Then, the system will check the pet's activity status and energy level. If both activity status and energy level are valid, the pet will respond to the touch from the user. If one of the conditions is invalid, the pet will not respond to it.

Interaction with Pet Module

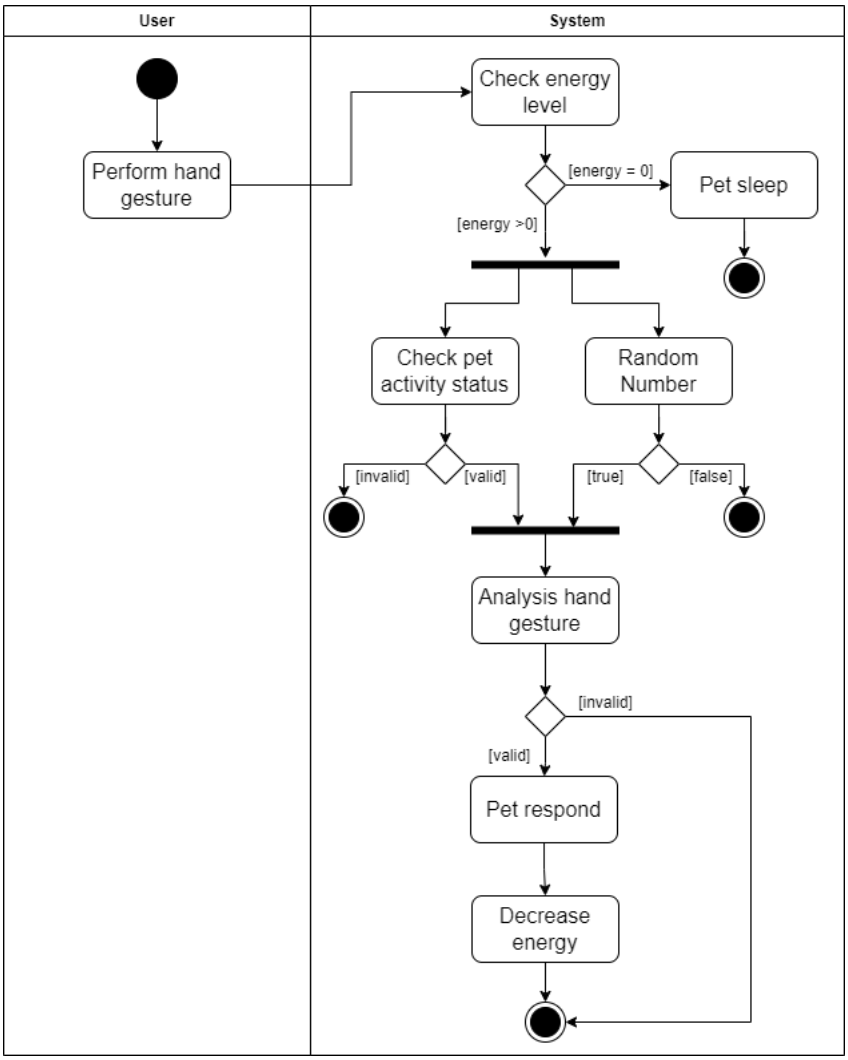

Figure 3. 7 Interaction with Pet Activity Diagram

Figure 3.7 shows the interaction process between the user and the pet. The system will check the pet's energy level when the user performs a hand gesture. If the energy level is 0, the pet will sleep and not respond to the hand gesture. If the energy is larger than 0, then the system will check the pet's activity level and run the random number function. The system will analyse the hand gesture input to determine if both conditions are valid. If one of the conditions is invalid, the pet will not respond. If the hand gesture is valid, the pet will respond according to the type of hand gesture made. After the pet takes action, the energy level will decrease. If the hand gesture is invalid, the pet will not respond to it.

Place Pole Module

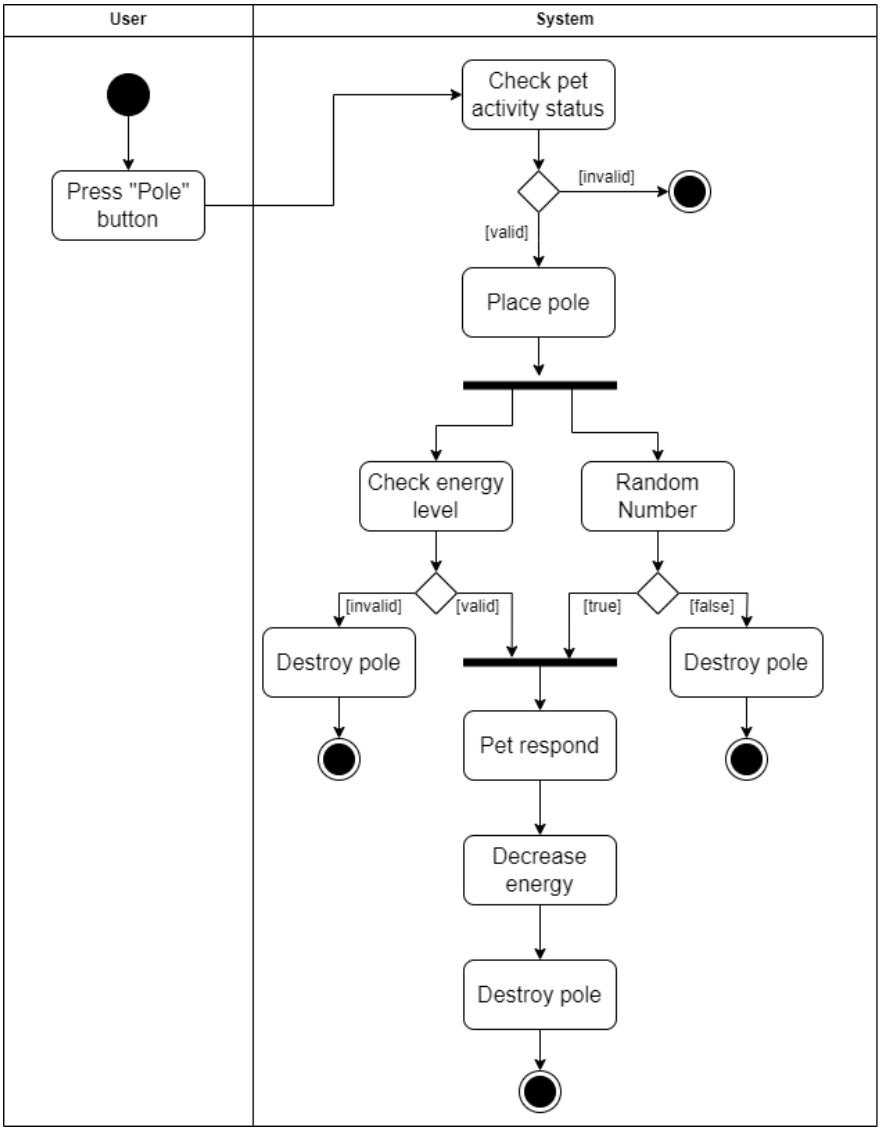

Figure 3. 8 Place Pole Activity Diagram

Figure 3.8 shows the placing pole in the AR environment. When the user presses the "Pole" button on the screen, the system will check the pet activity status. If the activity status is valid, the system will place the pole inside the AR environment. Otherwise, the pole will not be placed. After placing the pole, the system will check the pet's energy level and run the random number function. If both conditions are valid, the pet will respond to the pole and decrease the energy level. After the pet responds to the pole, the pole will be destroyed. If the energy level of the random number function is invalid, the system will directly destroy the pole.

Give Food Module

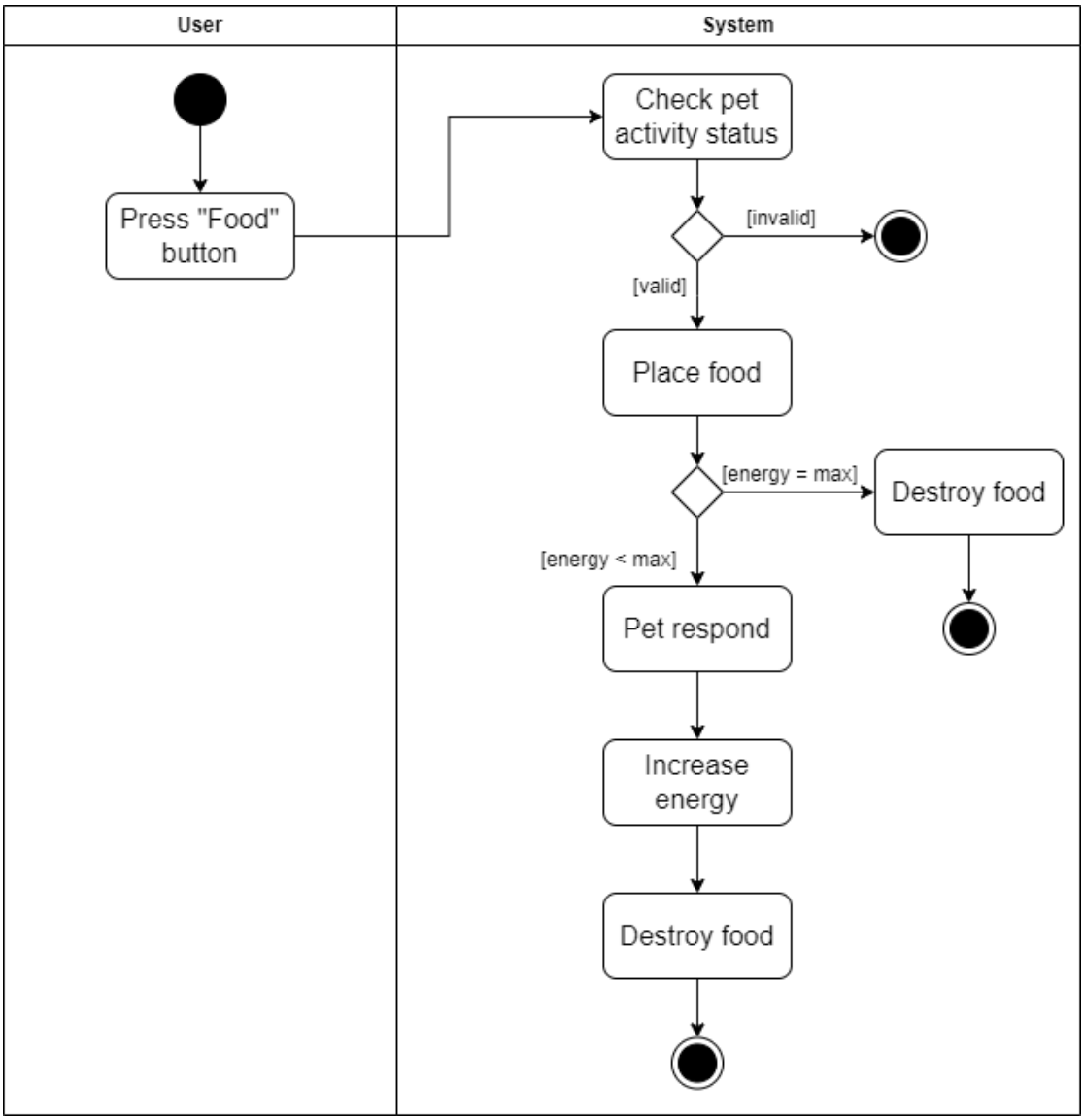

Figure 3. 9 Give Food Activity Diagram

Figure 3.9 shows the activity for giving food to the pet. The system will check the pet's activity status when the user presses the "Food" button. If the activity status is valid, the food will be placed inside the AR environment; otherwise, the food will not be placed. After placing the food, the system will check the pet's energy level. If the pet's energy level reaches maximum, the pet will not eat the food and will be destroyed. However, if the pet's energy level is less than the maximum, the pet will respond by eating the food. Then, the energy level will increase, and the system destroys the food after some time.

Pause Menu Module

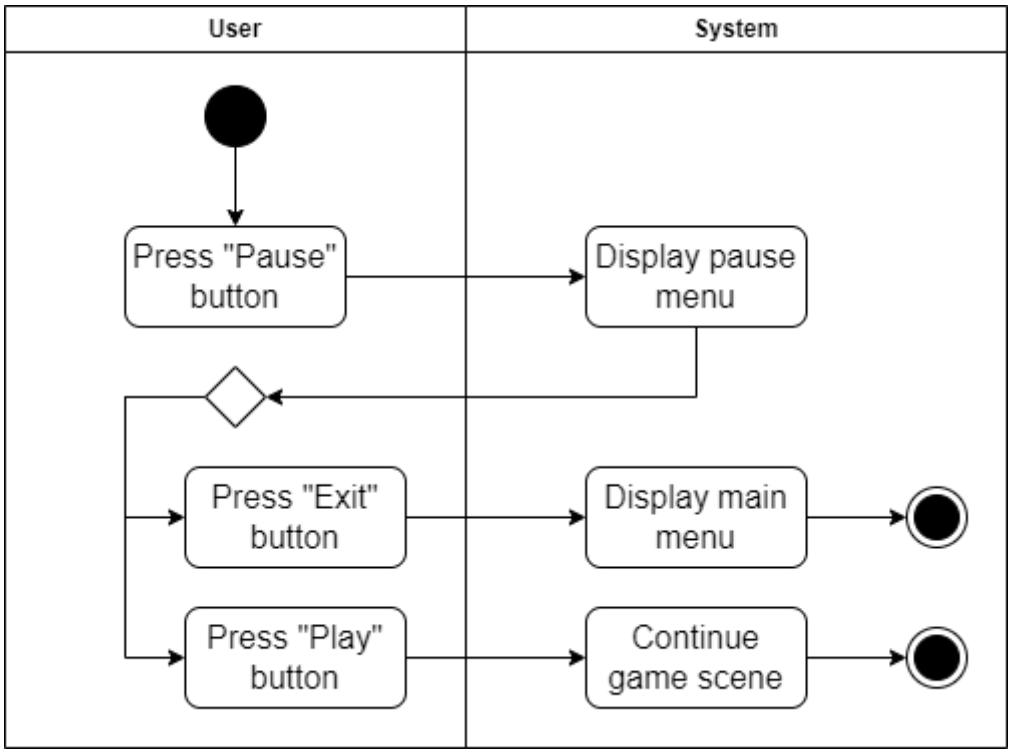

Figure 3. 10 Pause Menu Activity Diagram

The gameplay scene has a pause button for the user to pause the game at any time. When the user presses the pause button, the system will pause the game and display the pause menu. User can either press the play button to resume the game or the exit button to exit to the main menu.

Play Sound Module

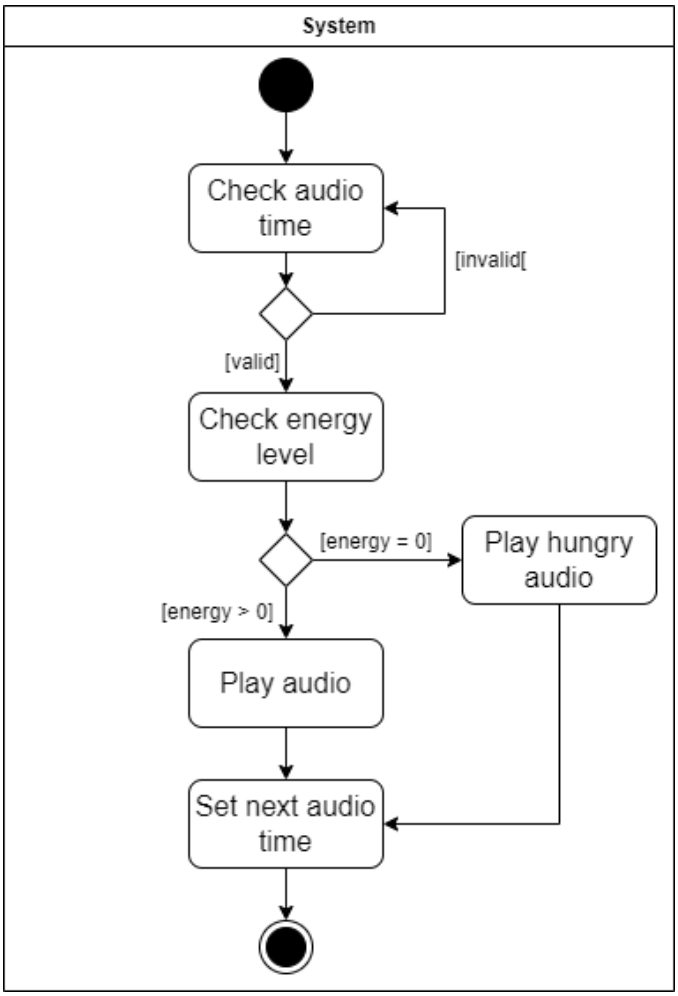

Figure 3. 11 Play Sound Activity Diagram

Figure 3.11 shows the activity flow for the sound module. The system will check the time for playing the audio time. If the condition is met, the system will check the pet's energy level. When the energy level is greater than 0, the system will play normal audio; otherwise, the system will play hungry audio. After the audio is played, the system will set the next audio time by randomly generating a number for the next audio time. The system will generate a smaller number for the pet, making more frequent sounds when hungry.

Exit Game Module

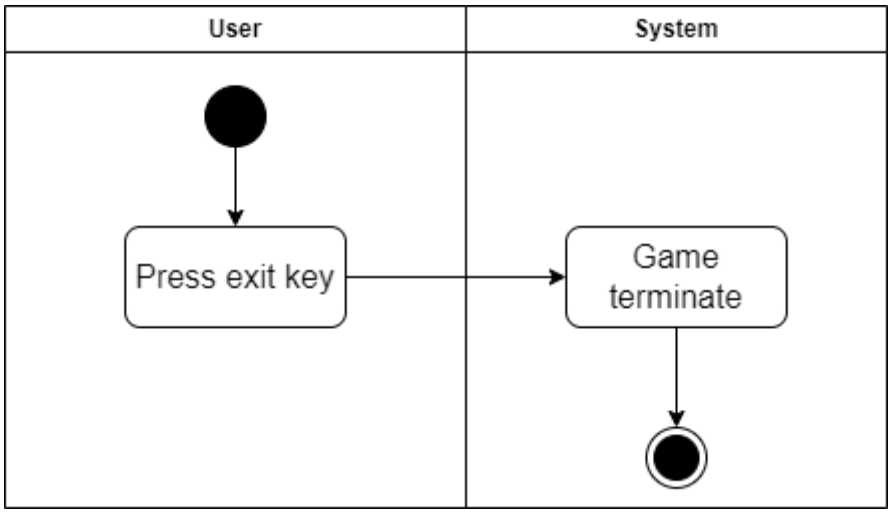

Figure 3. 12 Exit Game Activity Diagram

Figure 3.12 shows the activity for the exit game module. When the user presses the exit key, the system instantly terminates the game.

Chapter 4 System Design

4.1 System Flowchart

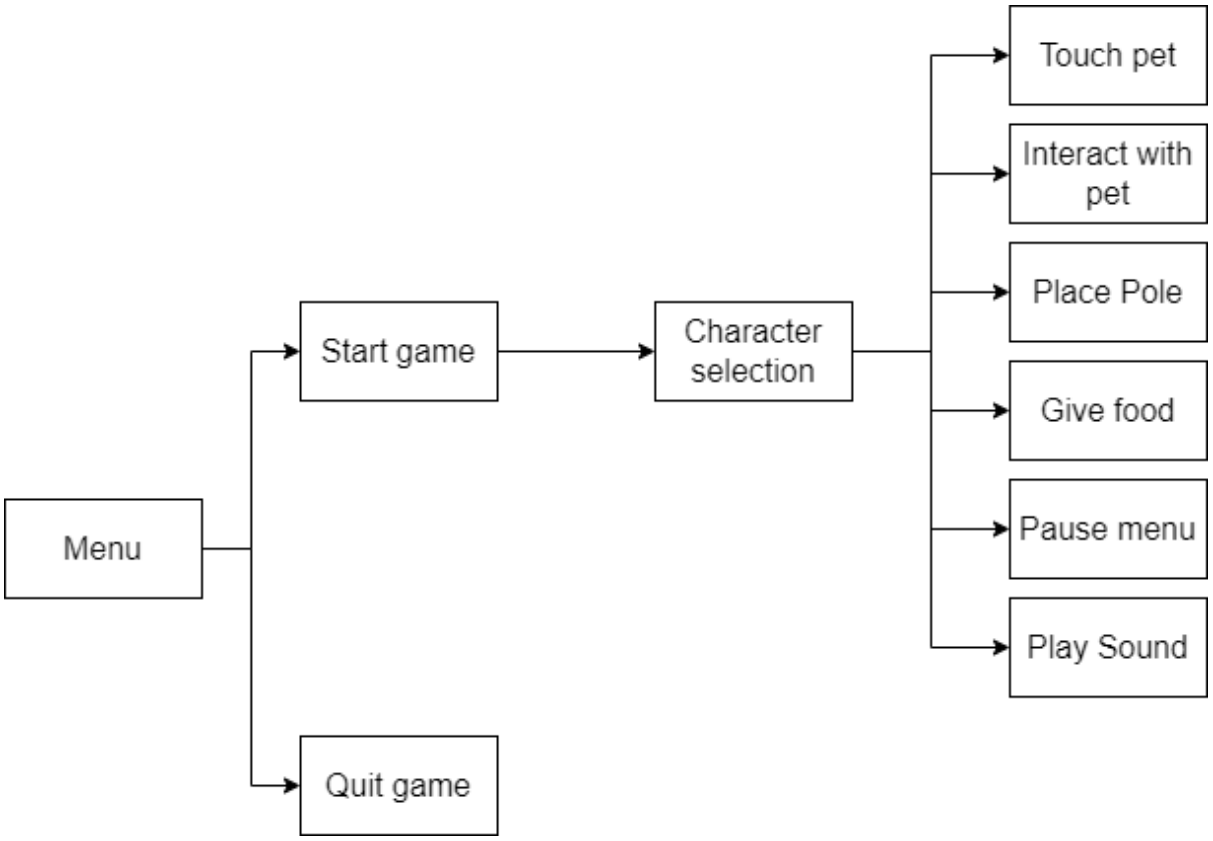

Figure 4. 1 System Flowchart

Main Menu Scene

The system flow of the immersive AR pet game is presented in the figure above. After launching the game, a menu interface is displayed, which provides options for users to either start the game or exit the application.

Character Selection Scene

After clicking the start button, users can view and choose the pet's appearance using the next and previous buttons. Users may also rotate the pet around to view the pet's details. When users are satisfied with the choice, users click the start button to start the game.

Main Game Scene

After selecting the desired pet, users can start playing the game by interacting with it using hand gestures. The pet will respond to the user's hand movement, and users can touch and play with the pet. The device will give vibration feedback to indicate to users that they are touching the pet. Users can also move the virtual pet by performing specific actions, and the pet will move to the position pointed out by users.

Additionally, several buttons are available for users to interact with the pet, such as the food button for feeding the pet and the scratching pole button for the pet to play with. These buttons will trigger specific actions in the virtual pet, providing users with a more engaging and interactive experience.

Moreover, there are two additional features to enhance the game's realism: sound effects and a random function. The pet will make sounds at random intervals, mimicking real-life pet behaviour. The random function will determine whether the pet should respond to user interactions.

Pause Menu

Lastly, a pause button allows users to pause the game anytime. Users can resume the game or quit the game. If the quit button is pressed, the game will lead users to the main menu scene.

4.2 System Components Diagram

Main Menu Scene

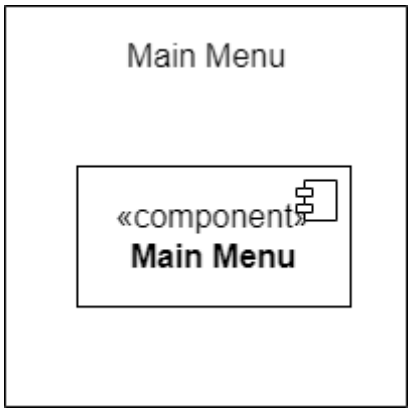

Figure 4. 2 Main Menu Component Diagram

Character Selection Scene

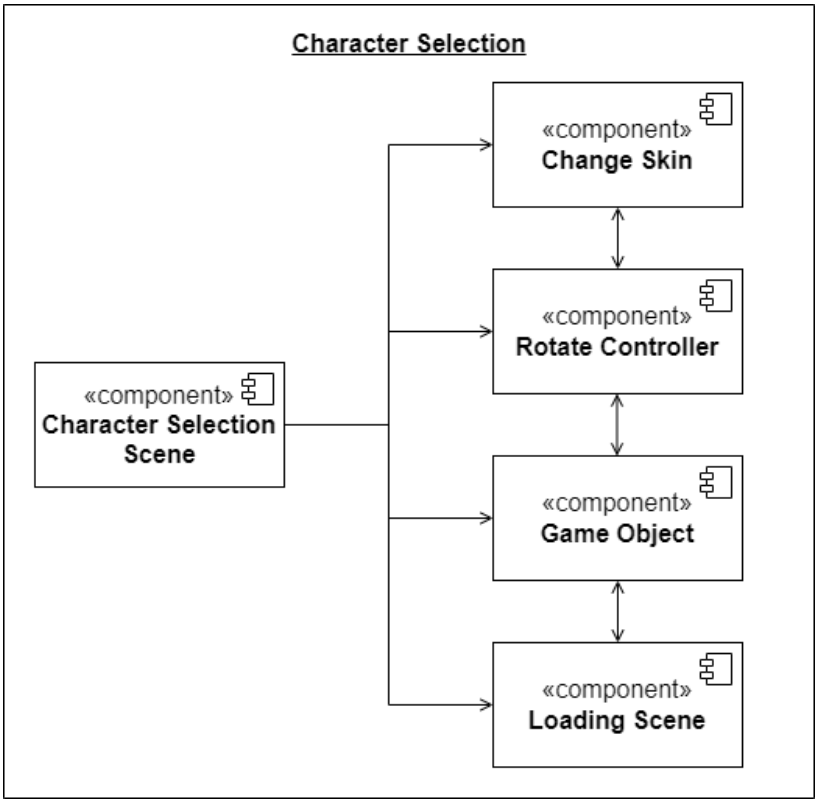

Figure 4. 3 Character Selection Component Diagram

Main Game Scene

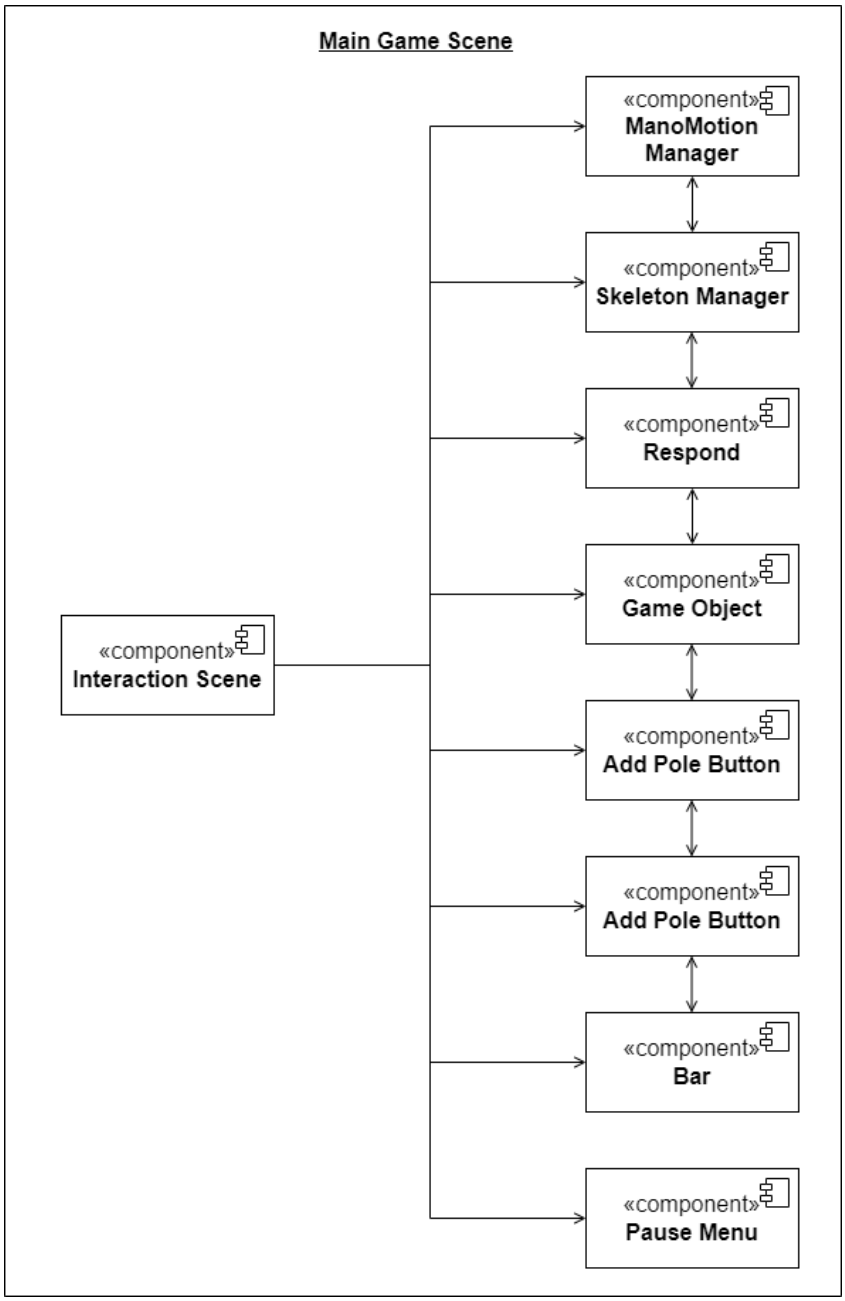

Figure 4. 4 Main Game Scene Component Diagram

Chapter 5 System Implementation

5.1 Hardware Setup

The hardware involved in this project is a laptop and android mobile device. The laptop is used for game development and the mobile device is used for testing the output.

Table 5. 1 Laptop **S**pecification

Description	**Specifications**
Model	Acer Swift SF514-55TA
Processor	11th Gen Intel(R) Core(TM) i5-1135G7
Operating System	Windows 11
Graphic	Iris Xe Graphics, CineCrystal In-plane Switching (IPS) Technology
Memory	8GB
Storage	512GB

Table 5. 2 Mobile Device Specification

Description	**Specification**
Model	XiaoMi Mi 10T
Processor	Octa-core
Operating System	Android 10
Memory	128GB

5.2 Software Setup

Table 5. 3 Software Specification

Software	**Specifications**
Game Engine	Unity 2021.3.11f1
Platform	Android 7.0 ‘Nougat’ (API level 24) or higher
Integrated Development Environment	Visual Studio 2022
Programming Language	C# (C Sharp)
Hand Tracking	ManoMotion SDK Pro 1.4.9 ARFoundation
AR Framework	Unity AR Foundation 4.2.7

5.3 Setting and Configuration

Setting up Unity

1. Open Unity Hub, click New Project to create a new project.

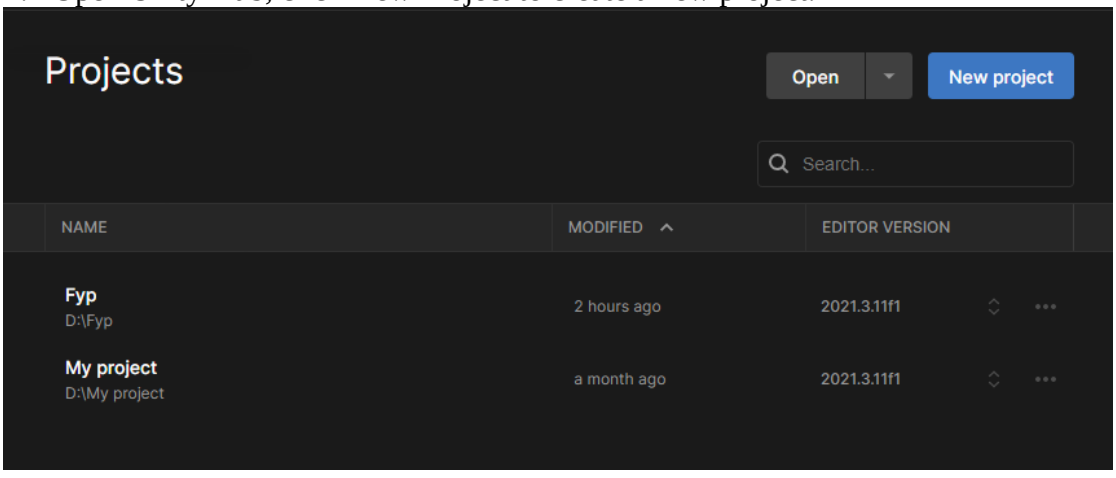

Figure 5. 1 Create New Project in Unity

2. Select the 3D template, rename the project name and choose the desired location. Then click Create Project.

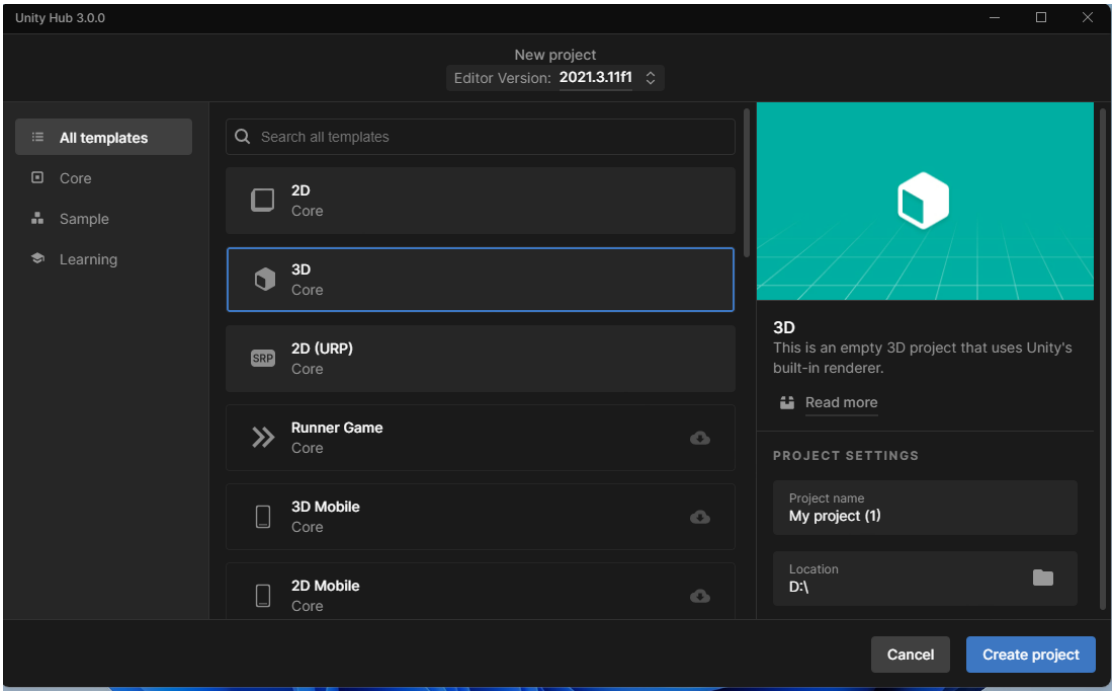

Figure 5. 2 Select 3D Template

3. Set the minimum API level of the project to Android 7.0 ‘Nougat’.

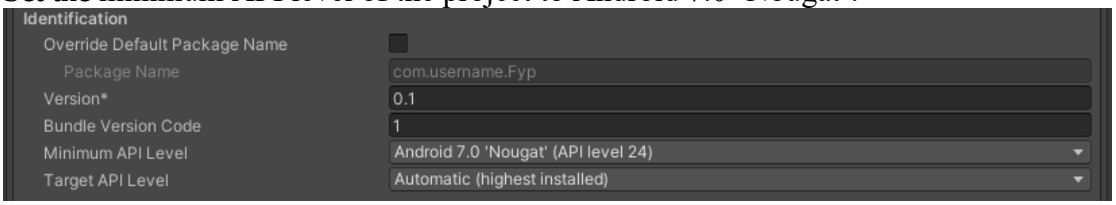

Figure 5. 3 Set Minimum API Level

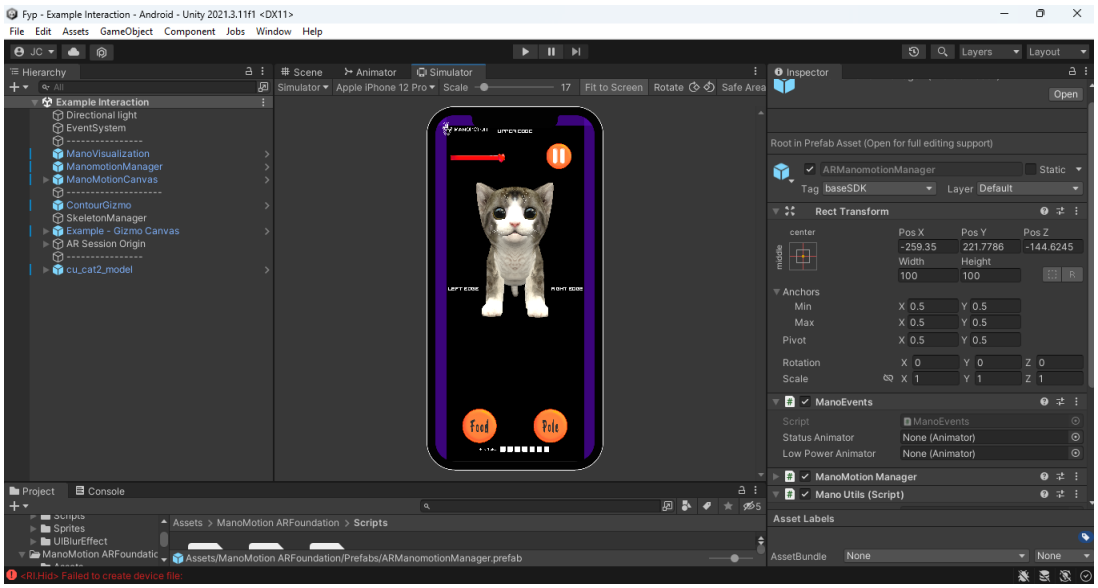

Figure 5. 4 Project Created

Setting up Visual Studio

1. Select Edit on the menu bar, then select Preferences.
2. Find the option External Tools.
3. Choose Microsoft Visual Studio 2022 for the external script editor.

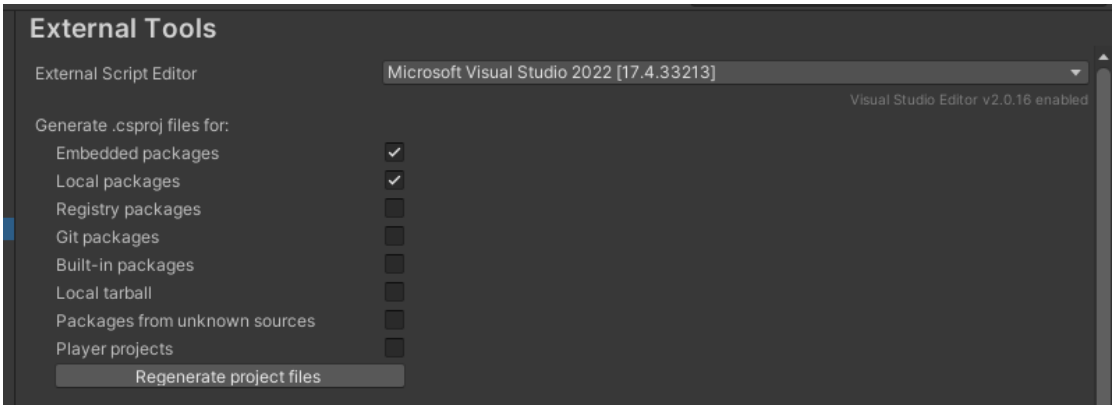

Figure 5. 5 Setup External Tools

Setting up ManoMotion

1. Register an account on the ManoMotion website.
2. Download the SDK file (Pro & AR Foundation).

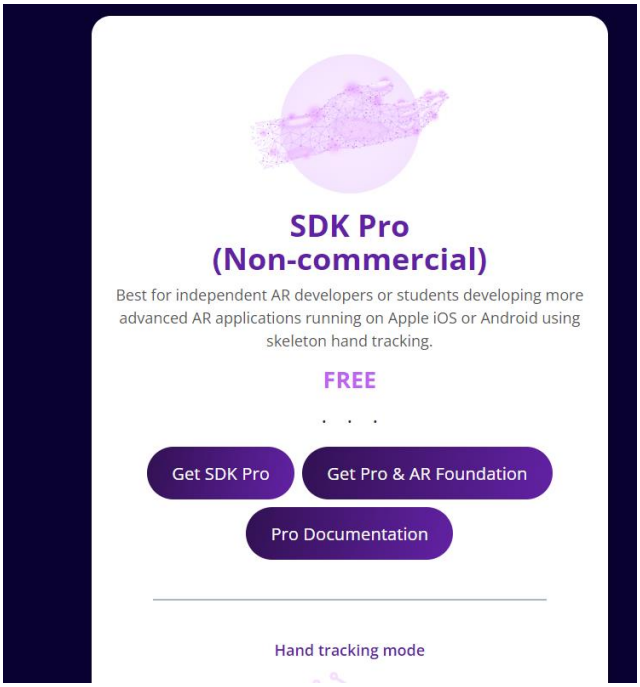

Figure 5. 6 Download ManoMotion SDK

3. Import the ManoMotion package to the Unity project.
4. Generate a licence for the project.

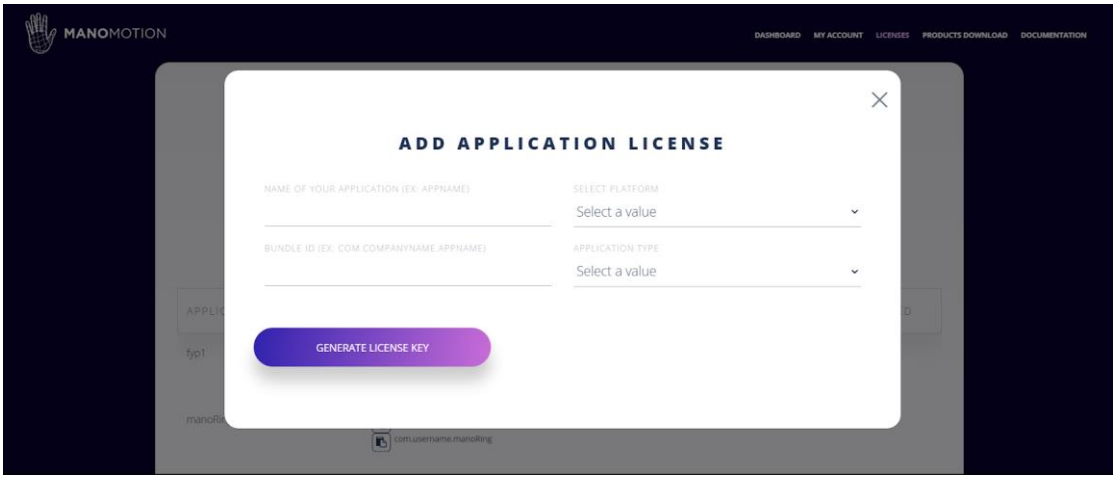

Figure 5. 7 Generate Licence

5. Copy the licence key generated by ManoMotion.

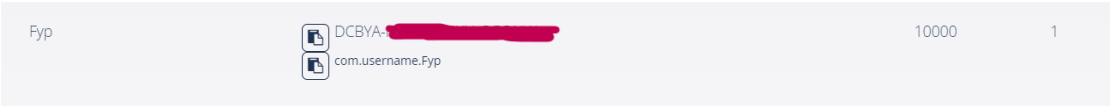

Figure 5. 8 Generated Licence

6. Paste the licence key to the ManoMotion Manager in the inspector window.

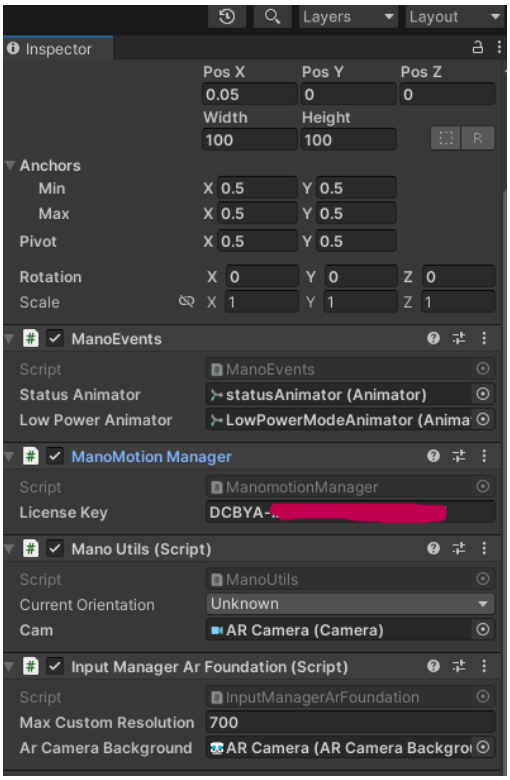

Figure 5. 9 Licence Key in ManoMotion

Setting up assets

Cu Cat 2

1. Download the asset from Unity asset Store.
2. Import the asset from the package manager.

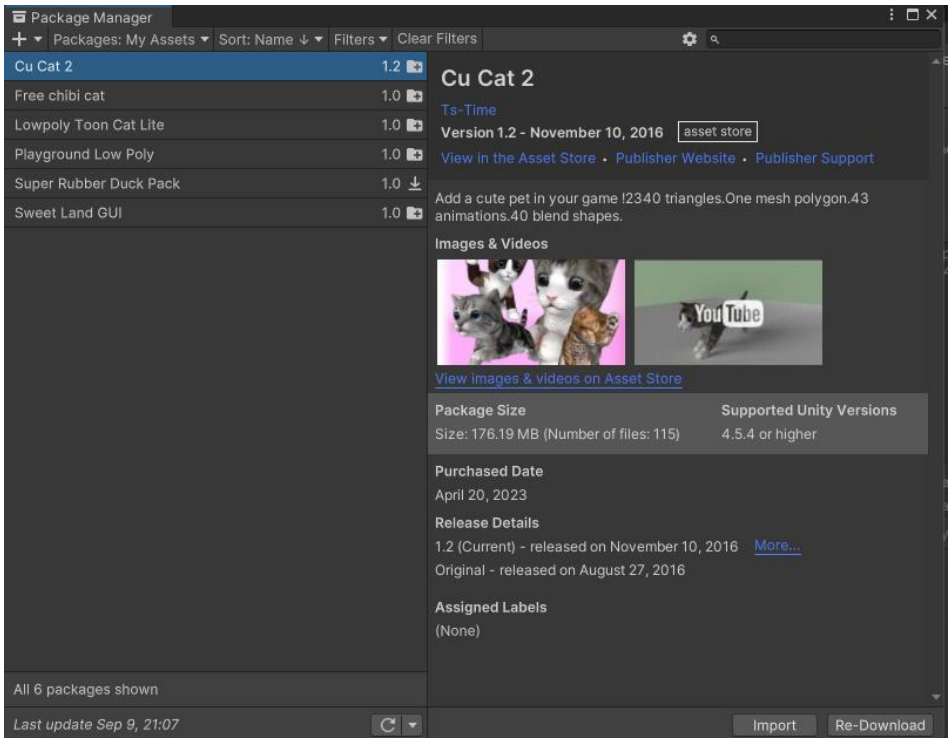

Figure 5. 10 Cu Cat 2 Asset

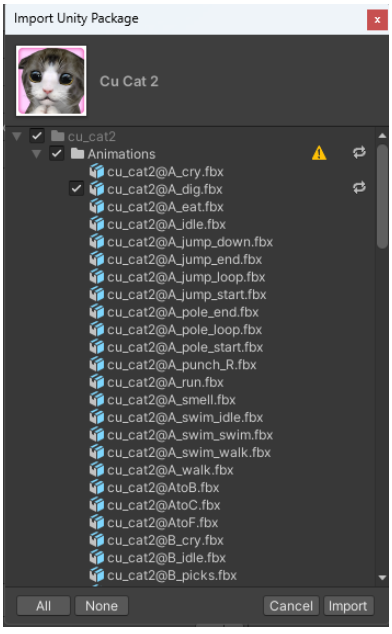

Figure 5. 11 Import Cu Cat 2 Asset

Playground Low Poly

1. Download the asset from Unity Asset Store.
2. Import the asset from the package manager.

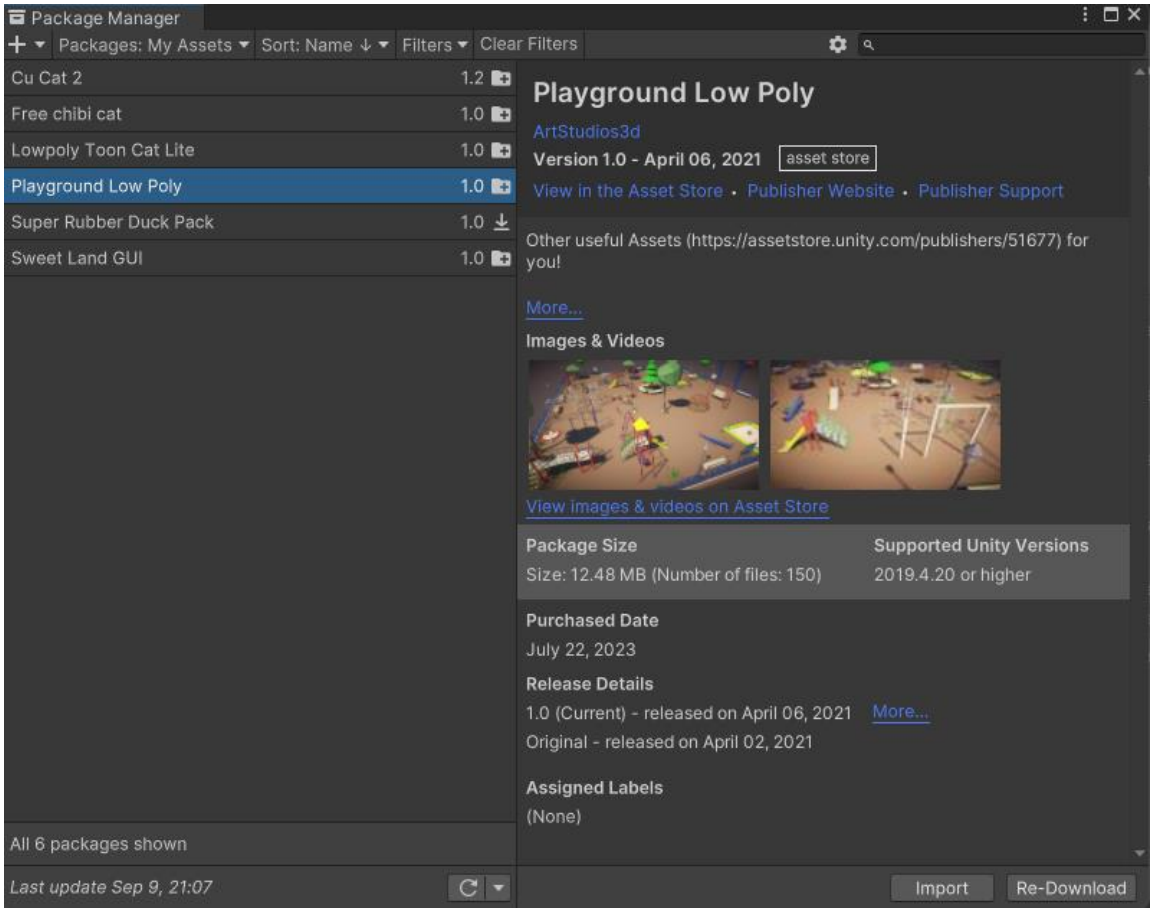

Figure 5. 12 Playground Low Poly Asset

Sweet Land GUI

1. Download the asset from Unity Asset Store.
2. Import the asset from the package manager.

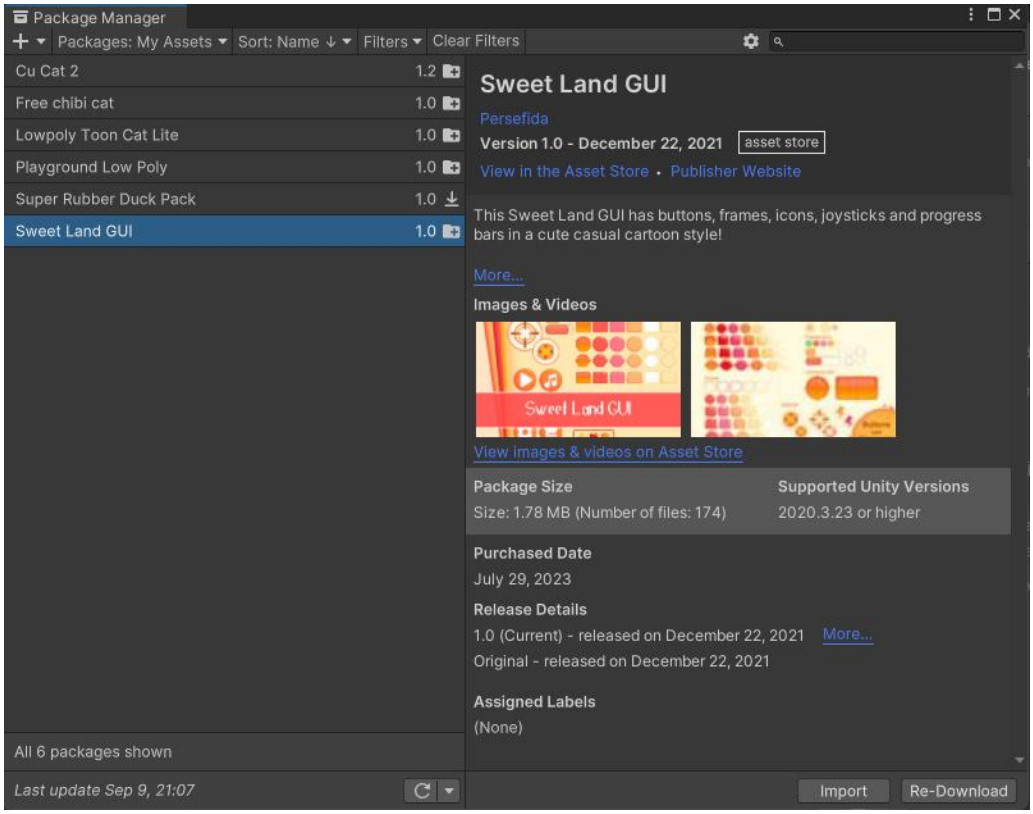

Figure 5. 13 Sweet Land GUI Asset

5.4 System Operation

Main Menu Scene

After the user launches the game, the system will show a main menu scene. A simple UI with two buttons: start and quit. The start button will lead the user to another screen, character selection, while the quit button will terminate the game.

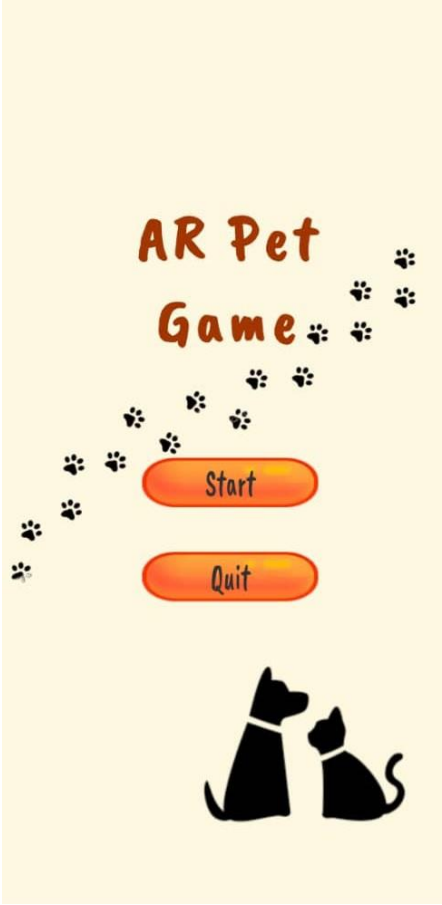

Figure 5. 14 Main Menu UI

Character Selection Scene

User will choose the desired character by pressing the next and previous buttons. In addition, the user can rotate the pet around to view the pet from different angles. If the user has confirmed the selection, the user can start the game by pressing the start button. The system will lead the user to the main game scene.

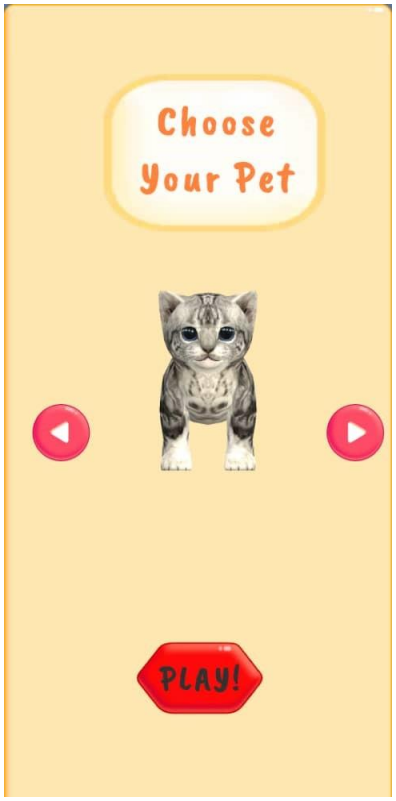

Figure 5. 15 Character Selection Scene 1

Figure 5. 16 Character Selection Scene 2

There are eight types of cat appearances and two types of dog appearances for user to choose from.

Figure 5. 17 Types of Cat Appearance

Figure 5. 18 Types of Dog Appearance

Loading Scene

A loading screen will appear while the system is loading for the main game scene.

Figure 5. 19 Loading Scene

Main Game Scene

The pet will be placed in the AR environment when the game starts. An energy bar is located at the top left corner of the screen to show the pet's energy level. A pause button is on the top right corner of the screen for the user to pause the game.

Figure 5. 20 Main Game Scene

User perform some hand gestures and the pet will respond to the valid hand gesture. Besides, the food button and pole button is for user to place the food and pole in the AR environment.

Types of Valid Hand Gesture and Response of the Pet

Hand Gesture: Grab with backside of hand face to camera.

Response: Pet sit.

Figure 5. 21 Pet Sit

Hand Gesture: Point when the pet is not visible on the screen.

Response: Pet walks to the new position.

Figure 5. 22 Pet Walk

Hand Gesture: Click.

Response: A ball will spawn and roll towards the pet, pet will hit the ball.

Figure 5. 23 Pet Punch

Hand Gesture: Swipe right.

Response: Pet roll.

Figure 5. 24 Pet Roll

Hand Gesture: Grab with palmside of hand face to camera.

Response: Pet walks towards the camera. Pet will nod its head or play catch.

Figure 5. 25 Pet Nod Head

Figure 5. 26 Pet Play Catch

Hand Gesture: Touch.

Response: Device vibrates and the pet relaxes.

Figure 5. 27 Pet Lay

Types of Pet's Response When Button Is Pressed

Button: Food

Response: When the energy level is less than maximum, pet will eat.

Figure 5. 28 Pet Eat

Response: When the energy level is maximum, the pet will lay down.

Figure 5. 29 Pet Lay Down

Button: Pole

Response: Pet will either scratch the board below or the pole above.

Figure 5. 30 Pet Scratch Below

Figure 5. 31 Pet Scratch Pole

Other Response

Condition: When the energy level of the pet decreases until 0, the pet will not respond and sleep.

Figure 5. 32 Pet Sleep

Pause Game Scene

When the user presses the pause button, a pause menu will appear. The pause menu contains two buttons, which are resume and exit. The resume button will let the user continue to play the game. The exit button will lead the user back to the main menu scene.

Figure 5. 33 Pause Menu

5.5 Implementation Issues and Challenges

- Hand tracking and gesture analysis issues

The performance of hand tracking and gesture analysis greatly relies on the speed of the internet, as real-time analysis of hand movements is required. In cases of weak internet connections, delays may occur. Additionally, when the hand moves too swiftly, there can be delays in the skeleton tracking's ability to follow accurately.

Furthermore, the ManoMotion framework is sometimes over-sensitive to some gestures. When the user transitions between gestures, the system may misinterpret these transitions as intentional gestures, leading to unintended responses from the pet, even if the user's original intention did not involve making that specific gesture.

- Virtual pet position in the AR environment

The system must continuously track the user’s device and the real-world objects to which the virtual pet is anchored. Sometimes, the problem arises when tracking is lost, or calibration is not maintained correctly, especially when the background is too plain and has no unique feature points for the system to track the positions.

5.6 Concluding Remark

The project utilises several software and technology platforms throughout its development lifecycle. The game is built using the Unity game engine, with C# scripts used to handle gameplay flow and control the pet's responses. These scripts are written using Visual Studio 2022.

In addition, the ManoMotion framework is important in hand tracking and gesture analysis, allowing user interaction with the virtual pet through specific hand gestures. Hence, the user can instruct the pet to perform various actions, making the game more immersive.

A random number function has been incorporated to add unpredictability to the gameplay. The characteristics of this function differ between pet types. For instance, the probability of the random number function returning 'true' for a dog is higher than for a cat, reflecting the dog's typically more obedient nature.

Furthermore, audio elements, such as dog barking and cat meowing, have been integrated to mimic the behaviour of real pets. These sounds occur at random intervals controlled by a separate function within the script. When the pet is hungry, it increases the frequency of the pet making noise to signal its need for food.

Lastly, the game contains essential components of any gaming experience, including a main menu, loading screen, and pause menu, to provide a comprehensive and user-friendly interface.

Chapter 6 System Evaluation and Discussion

6.1 System Testing and Performance Metrics

Main Menu

Table 6. 1 Testing Component for Main Menu

Testing Component	Description
Start button	Verify the functionality of the button.
Quit button	Verify the functionality of the button.

Character Selection

Table 6. 2 Testing Component for Character Selection

Testing Component	Description
Previous button	Test the functionality of the button.
Next button	Test the functionality of the button.
Rotate pet	Test if the pet can be rotated.
Play button	Test the functionality of the button.
Save user selection	Test if the selection has been saved.

Loading Scene

Table 6. 3 Testing Component for Loading Scene

Testing Component	Description
Loading scene	Test if the scene appears between the main menu scene and main game scene.

Main Game Scene

Table 6. 4 Testing Component for Main Game Scene

Testing Component	**Description**
Pet model	Test if the pet model is placed in the AR environment.
Energy bar - eat	Test if the energy bar increases.
Energy bar - action	Test if the energy bar decreases.
Food button	Test the functionality of the button.
Pole button	Test the functionality of the button.
Food after action	Test if the food is destroyed.
Pole after action	Test if the pole is destroyed.

Pet Response

Table 6. 5 Testing Component for Pet Response

Testing Component	**Description**
Grab gesture with backside of hand face to camera	Test if the pet responds.
Point gesture when pet is not visible inside the screen	Test if the pet responds.
Click gesture	Test if the pet responds.
Swipe right gesture	Test if the pet responds.
Grab gesture with palm	Test if the pet responds.

side of hand face to camera - action a	
Grab gesture with palm side of hand face to camera - action b	Test if the pet responds.
Touch - device vibrates	Test if the device vibrates.
Touch - pet action	Test if the pet responds.
Food (energy bar is not maximum)	Test if the pet responds.
Food (energy bar is maximum)	Test if the pet responds.
Pole - action a	Test if the pet responds.
Poe - action b	Test if the pet responds.
Hungry	Test if the pet responds.
Pet is performing action	Test if the pet responds.
Random number function - true	Test if the pet responds.
Random number function - false	Test if the pet responds.

Sound

Table 6. 6 Testing Component for Sound

Testing Component	**Description**
Cat	Test the sound effect.
Dog	Test the sound effect.
Cat - hungry	Test the sound effect.
Dog - hungry	Test the sound effect.

Pause Menu

Table 6. 7 Testing Component for Sound

Testing Component	**Description**
Pause button	Test the functionality of the button.
Resume button	Test the functionality of the button.
Exit button	Test the functionality of the button.

6.2 Testing Setup and Results

The game is tested for its overall functionality to match the expected results. The table of testing is listed below.

Main Menu

Table 6. 8 Testing Results for Main Menu

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Start button	Change scene to character selection scene.	Change scene to character selection scene	Pass
Quit button	Quit the game.	Quit the game.	Pass

Character Selection

Table 6. 9 Testing Results for Character Selection

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Previous button	Display the previous pet appearance.	Display the previous pet appearance.	Pass
Next button	Display the next pet appearance.	Display the next pet appearance.	Pass
Rotate pet	Pet able to rotate around.	Pet able to rotate around.	Pass
Play button	Change scene to loading scene.	Change scene to loading scene.	Pass
Save user selection	Selected pet appears in the main game scene.	Selected pet appears in the main game scene.	Pass

Loading Scene

Table 6. 10 Testing Results for Loading Scene

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Loading scene	Appear between character selection scene and main game scene.	Appear between character selection scene and main game scene.	Pass

Main Game Scene

Table 6. 11 Testing Results for Main Game Scene

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Pet model	Pet is placed in the AR environment.	Pet is placed in the AR environment.	Pass
Energy bar - eat	Energy bar increases.	Energy bar increases.	Pass
Energy bar - action	Energy bar decreases.	Energy bar decreases.	Pass
Food button	Place food in front of pet.	Place food in front of the pet.	Pass
Pole button	Place pole in the AR environment.	Place pole in the AR environment.	Pass
Food after action	Destroy food.	Destroy food.	Pass
Pole after action	Destroy pole.	Destroy pole.	Pass

Pet Response

Table 6. 12 Testing Results for Pet Response

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Grab gesture with backside of hand face to camera	Pet sit.	Pet sit.	Pass
Point gesture when pet is not visible inside the screen	Pet moves to a new position.	Pet moves to a new position.	Pass
Click gesture	Ball spawn and roll toward the pet. Pet punches the ball.	Ball spawn and roll toward the pet. Pet punches the ball.	Pass
Swipe down gesture	Pet roll.	Pet roll.	Pass
Grab gesture with palmside of hand face to camera - action a	Pet moves forward to the camera and nods head.	Pet moves forward to the camera and nods head.	Pass
Grab gesture with palmside of hand face to camera - action b	Pet moves forward to the camera and plays catch.	Pet moves forward to the camera and plays catch.	Pass
Touch - device vibrates	Device vibrates.	Device vibrates.	Pass
Touch - pet action	Pet lays down and relaxes.	Pet lays down and relaxes.	Pass
Food (energy bar is not maximum)	Pet eats.	Pet eats.	Pass
Food (energy bar is maximum)	Pet lays down.	Pet lays down.	Pass

Pole - action a	Pet scratches the board below.	Pet scratches the board below.	Pass
Poe - action b	Pet scratches the pole above.	Pet scratches the pole above.	Pass
Hungry	Pet sleep.	Pet sleep.	Pass
Pet is performing action	Pet continues to finish the action without being interrupted.	Pet continues to finish the action without being interrupted.	Pass
Random number function - true	Pet responds.	Pet responds.	Pass
Random number function - false	Pet does not respond.	Pet does not respond.	Pass

Sound

Table 6. 13 Testing Results for Sound

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Cat	Meow sound	Meow sound	Pass
Dog	Bark sound	Bark sound	Pass
Cat - hungry	Hungry meow sounds more frequent.	Hungry meow sounds more frequent.	Pass
Dog - hungry	Hungry bark sounds more frequent.	Hungry bark sounds more frequent.	Pass

Pause Menu

Table 6. 14 Testing Results for Pause Menu

Testing Component	**Expected Result**	**Actual Result**	**Pass/Fail**
Pause button	Game pause and pause menu appear.	Game pause and pause menu appear.	Pass
Resume button	Game resume and close pause menu.	Game resume and close pause menu.	Pass
Exit button	Change to the main menu scene.	Change to the main menu scene.	Pass

6.3 Projects Challenges

Several challenges arose during the project's development. One of the issues was the interruption of pet actions due to changing hand gestures. When a specific action started by the pet was not completed, a new hand gesture would instantly trigger another action, resulting in abrupt and unnatural pet behaviour. Hence, a boolean variable is added to monitor and act as a flag to control the pet's movement.

The positioning of the pet introduced another challenge. Extra consideration was necessary when calculating the position in real-world and screen viewpoints. Incorrectly using the wrong point type could result in the pet or virtual objects being placed in incorrect positions within the AR environment, impacting the overall user experience.

The game scene's loading time takes longer than expected, leading to an undesirable delay. Without including a loading screen, the user is confronted with a black screen, which adversely affects their overall experience. Therefore, adding a loading screen became crucial, serving as a useful indicator to inform users that the main game scene is loading and preventing them from mistaking it as a game error.

6.4 Objectives Evaluation

1. AR technology improves realism by placing virtual pets in the real world.
    - Virtual pet is placed inside the real world by using AR technology.
    - The other virtual objects such as food and pole are also placed using AR technology.
    - The virtual pet incorporates smoothly into the real world.

2. Users can interact with the virtual pet using hand-detection technology.
    - Users are able to instruct and interact with pet using hand gestures.
    - Hand gestures such as grab, click and point are examples of hand gestures used in this project.

3. Virtual pets can respond to the player by the detected hand gesture.
    - Valid hand gestures can trigger a pet's response.
    - Pet actions such as sit, play, walk, run and roll are used to respond to the user's hand gestures.

4. A virtual pet’s random responses and actions can mimic the actual pet.
    - Random number function used to increase the uncertainty of the pet to react towards the hand gesture.
    - Certain instructions from the users will result in two different actions from pets to increase the randomness.

6.5 Concluding Remark

The project has achieved its objectives and successfully implemented the necessary functionalities. Using hand tracking and augmented reality technologies has significantly improved users' immersion in their interactions with the virtual pet.

Additionally, the project's successful completion achieved its technical goals and improved the user experience by making it more engaging and pleasant. The AR pet game successfully overcomes the gap between the virtual and real worlds by mixing augmented reality with hand motion controls, offering an engaging setting for users to interact with their virtual pets.

Chapter 7 Conclusion and Recommendation

7.1 Conclusion

Raising a pet requires significant time and effort, including regular feeding, cleaning and providing medical attention when necessary. Thus, people often find it challenging to care for real pets. Besides, there is a lack of interactive and engaging mobile applications that utilise AR technology, particularly in virtual pet games. Existing virtual pet games are often limited to a 2D or 3D digital environment. The interactions with virtual pets are limited to pressing buttons on the screen, causing the player's experience to feel static and less engaging.

To address these problems, this project aims to provide a solution for individuals who cannot own a real pet but still desire the experience of having a pet. The game can provide an immersive and interactive experience of raising virtual pets by leveraging AR technology and hand detection technology.

Hand motion detection and gesture analysis are used to recognise the hand gestures made by users. This feature is essential to create a virtual pet that behaves and responds like a real pet, with the ability to recognise and react to the player's hand gestures and simulate real-life behaviour. Some randomness is added to the game to make the virtual pet's action more unpredictable, thus making the game more challenging and interesting.

The integration of augmented reality (AR) technology and hand tracking in this project improves the AR pet game's immersive experience while also demonstrating the potential uses of these technologies in other industries. Combining hand interactions and augmented reality in innovative applications can improve education, healthcare, training, design, accessibility, and many other aspects of daily life and professional activities. Future AR and hand-tracking applications will likely be even more inventive and significant as technology develops.

7.2 Recommendation

One future improvement recommendation is to enhance the transition between pet actions within the project. The transitions seem abrupt because the pet's posture does not change when performing actions. Consider using transitional movements or postures as a part of the action to achieve a smoother and more natural movement. This could improve the realism and smoothness of the pet's interactions, enhancing the user experience and visual appeal.

To improve realism, consider implementing mouth movement for the pet when it makes sounds. Due to the current model limitations, it is not possible to implement the mouth movement. However, coordinating the pet's mouth movements and vocalisations in future work can significantly improve the appearance of a natural virtual pet.

User experience can be greatly improved by increasing the set of recognised hand motions beyond the scope of the ManoMotion framework. A wider variety of movements that the pet can recognise and respond to is provided, allowing for more dynamic and interactive interactions. The interactions may appear more realistic and responsive by adding more variety of pets' responses to particular motions, mimicking the behaviour of real pets.

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FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2Y3	**Study week no.: 2**
Student Name & ID: Chong Jing Voon 21ACB00519	
Supervisor: Dr Ng Hui Fuang	
Project Title: Immersive AR Pet Game with Hand Motion	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Moving pet in AR environment

2. WORK TO BE DONE

- Fix bugs in the project
- Add hand gesture to trigger pet respond.

3. PROBLEMS ENCOUNTERED

- Having difficulties in coordinate the position of pet in the AR environment

4. SELF EVALUATION OF THE PROGRESS

- Satisfied with the progress.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2Y3	**Study week no.: 4**
Student Name & ID: Chong Jing Voon 21ACB00519	
Supervisor: Dr Ng Hui Fuang	
Project Title: Immersive AR Pet Game with Hand Motion	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Implement more hand gesture to trigger the response from pet.

2. WORK TO BE DONE

- Fix the bugs in the project.
- Add function to the button.

3. PROBLEMS ENCOUNTERED

- Some hand gestures are too sensitive.

4. SELF EVALUATION OF THE PROGRESS

- Satisfied with the progress.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2Y3	**Study week no.: 6**
Student Name & ID: Chong Jing Voon 21ACB00519	
Supervisor: Dr Ng Hui Fuang	
Project Title: Immersive AR Pet Game with Hand Motion	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Add function to button.

2. WORK TO BE DONE

- Fix the bugs in the project.
- Do character selection scene.

3. PROBLEMS ENCOUNTERED

- Pet cannot face the direction of the pole correctly.

4. SELF EVALUATION OF THE PROGRESS

- Satisfied with the progress.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2Y3	**Study week no.: 8**
Student Name & ID: Chong Jing Voon 21ACB00519	
Supervisor: Dr Ng Hui Fuang	
Project Title: Immersive AR Pet Game with Hand Motion	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Done character selection scene.
- Control the pet respond.

2. WORK TO BE DONE

- Fix the bugs in the project.
- Add random function and sound module.

3. PROBLEMS ENCOUNTERED

- The action of pet get interrupt when hand gesture changed.
- The skin selection for dog is limited.

4. SELF EVALUATION OF THE PROGRESS

- Satisfied with the progress.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2Y3	**Study week no.: 10**
Student Name & ID: Chong Jing Voon 21ACB00519	
Supervisor: Dr Ng Hui Fuang	
Project Title: Immersive AR Pet Game with Hand Motion	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Done random function and sound module.
- Display energy bar of pet.
- Control the energy of pet.

2. WORK TO BE DONE

- Enhanced UI.
- Add pause menu.

3. PROBLEMS ENCOUNTERED

- Difficulties in setting up random sound interval.

4. SELF EVALUATION OF THE PROGRESS

- Satisfied with the progress.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T2Y3	**Study week no.: 12**
Student Name & ID: Chong Jing Voon 21ACB00519	
Supervisor: Dr Ng Hui Fuang	
Project Title: Immersive AR Pet Game with Hand Motion	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Enhanced UI.
- Complete all the features.
- Add pause menu.

2. WORK TO BE DONE

- Write report and prepare presentation.

3. PROBLEMS ENCOUNTERED

- Pause button does not work after quitting to main menu and enter to the main game scene again**.**

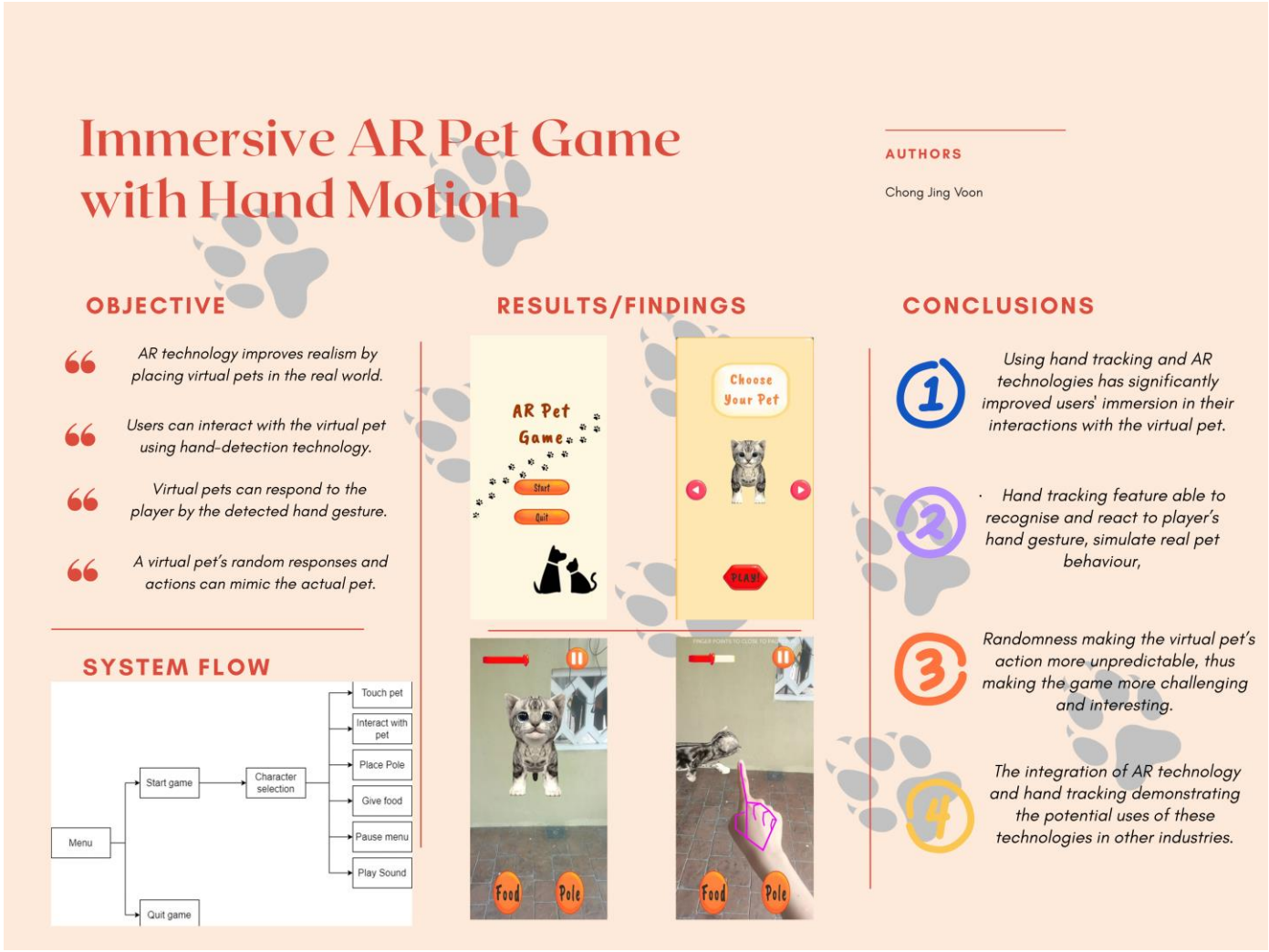
4. SELF EVALUATION OF THE PROGRESS

- Satisfied with the progress.

Supervisor's signature

Student's signature

POSTER


Immersive AR Pet Game with Hand Motion
AUTHORS
Chong Jing Voon
OBJECTIVE
AR technology improves realism by placing virtual pets in the real world.
Users can interact with the virtual pet using hand-detection technology.
Virtual pets can respond to the player by the detected hand gesture.
A virtual pet's random responses and actions can mimic the actual pet.
SYSTEM FLOW
Menu
Start game
Character selection
Quit game
Touch pet
Interact with pet
Place Pole
Give food
Pause menu
Play Sound
RESULTS/FINDINGS
AR Pet Game
Start
Quit
Choose Your Pet
PLAY!
Food
Pole
Food
Pole
CONCLUSIONS
1
Using hand tracking and AR technologies has significantly improved users' immersion in their interactions with the virtual pet.
2
Hand tracking feature able to recognise and react to player's hand gesture, simulate real pet behaviour,
3
Randomness making the virtual pet's action more unpredictable, thus making the game more challenging and interesting.
4
The integration of AR technology and hand tracking demonstrating the potential uses of these technologies in other industries.

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Title of Final Year Project	IMMERSIVE AR PET GAME WITH HAND MOTION

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Based on the above results, I hereby declare that I am satisfied with the originality of the Final Year Project Report submitted by my student(s) as named above.

Signature of Supervisor

Name: Dr. Ng Hui Fuang

Date: 14/09/2023

Signature of Co-Supervisor

Name: _____

Date: _____

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I, the author, have checked and confirmed all the items listed in the table are included in my report.

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