AR DISPLAY CONTENT IN FRIDGE

BY

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ABSTRACT

As the technology of today has benefited mankind, it is important that it should be leveraged in a wide range of applications that are connected to everyday life. This project is regarding the game-changing technology trend – Augmented Reality (AR). AR is an immersive technology that involves the overlay of digital information, including text, audios, and images, onto the physical world using compatible devices such as smart glasses, smartphones, or tablets. There are four types of AR technology, which are marker-based, markerless, projection-based, and superimposition-based. In this project, marker-based AR will be integrated in the development in relation to the content of the fridge to ensure maximum functionality and usability. It is a known fact that the fridge is one of the most essential pieces of home appliances in human daily. Thus, in this project, the fridge content that will be focusing is the fruits item. The development of this project was encouraged by the need for effective assistance in educating children in basic food information learning. There are three major problems will be the focus to be solved on this project - the lack of integration of AR with fridge-related applications in pre-school education, the inability of a real-time interaction with 3D models, and the limitation of fruit's information retrieval module. Some literature reviews and in-depth studies are carried out regarding the mentioned problems. The reviews of existing applications including Empty My Fridge, Frigloo, KitchenPal, Fridge, ARBreakfast, and HCLearn Nutrition are written in the literature review section of this report. The solution of this project is to develop a marker-based AR application that scans the fruit packaging and displays the AR virtual content. It will not only assist children in learning about the names of fruits and basic information but will indeed also replace the inefficient and uninspiring traditional textbook-based approach to education in pre-schools education. The availability of 3D models can enhance students' enthusiasm and motivation in learning. The expected final product of this project is the combination of marker-based AR technology, Unity as Integrated Development Environment (IDE), and Vuforia Engine as Software Development Kit (SDK) in an Android mobile application with the ability to display AR virtual content based on AR image markers when scanning the food packaging of fridge-related items, thus enabling a rapid retrieval module for fruit information and 3D models.

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LIST OF ABBREVIATIONS

AR	Augmented Reality
2D	Two dimensional
3D	Three dimensional
API	Application Programming Interface
CPU	Central Processing Unit
CRUD	Create, Read, Update, and Delete
CSS	Cascading Style Sheets
ECE	Early Childhood Education
fps	frames per second
GB	Gigabyte
GC	Garbage Collection
GCP	Google Cloud Platform
GPU	Graphics Processing Unit
GUI	Graphical User Interface
HLAPI	Multiplayer Networking High-Level API
HTML	Hypertext Markup Language
IDE	Integrated Development Environment
IOS	iPhone Operating System
KB	Kilobyte
LOD	Level of Detail
MR	Mixed Reality
OS	Operating System
PC	Personal Computer
RDA	Recommended Dietary Allowance
ROI	Return On Investment
SDK	Software Development Kit
UGUI	Unity Graphics Processing Unit
UI	User Interface
VR	Virtual Reality
XR	Extended Reality

Chapter 1
Introduction

1.1 Background Information

Immersive technologies, such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and Extended Reality (XR), have emerged as a potential solution to address the limitation of traditional learning methods. Augmented reality (AR) is the simultaneous integration of virtual reinforcement in verified communication by means of narratives, images, animations, and other actual entities [1]. Among these technologies, AR has gained considerable popularity due to its ability to overlay digital information onto the real world. AR applications employ the lens to add virtual content on top of the actual world. An example of this is the Pokémon GO game, which was all the rage in 2016 [28]. AR can be classified into different types based on its implementation, including marker-based, markerless, projection-based, and superimposition-based AR. In this report, the major technology to be focused and applied is the marker-based AR technology. This technology uses targeted image or object as predefined markers to trigger the display of digital content.

Figure 1.1.1 Pokémon GO [28]

In addition, augmented reality technology is very suitable in aiding workplace tasks, daily works, and educational learnings. Indeed, it has already provided a huge contribution in the fields of education and medical. The capacity of augmented reality technology to make connections and deliver a more concrete perspective to academic achievement has made it popular in the academic area [2]. As an illustration, in the realm of medical education, AR is applied in anatomy instruction by creating a 4D structure of human organs for medical students to optimise their instructional objectives [3]. The combination of digital and actual interaction enhances classroom events. Undeniable the fact that current demand for augmented reality and virtual reality technologies are estimated to reach US$215 billion in the year 2021.

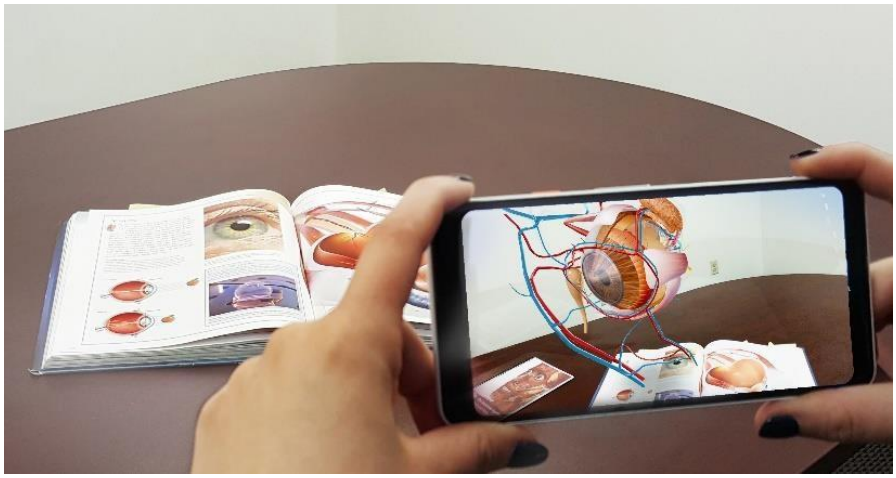


Figure 1.1.2 AR medical education [7]

Traditionally, early childhood education textbooks have relied on 2D illustrations to teach children about various topics, including fruits and their nutritional benefits. However, these textbooks have faced criticism for their lack of engagement and interactivity, which can lead to a tedious learning experience. This approach can be particularly problematic when trying to introduce new concepts to children as it can be difficult to re-motivate and maintain their interest in learning. Therefore, there is a need for an alternative approach to teaching children about fruit and its nutritional benefits that can address these issues.

Augmented reality (AR) technology has emerged as a potential solution to this problem. By incorporating AR technology into early childhood education, it is possible to enhance the quality and effectiveness of knowledge transfer during the teaching and learning process. AR education is a modern educational method that utilises AR technology to provide a more interactive and engaging learning experience for children. This approach can help to make learning about fruits and nutrition more interesting and memorable for children, leading to a greater likelihood of knowledge retention and application in the long term.

Fruits are perishable items that are consumed all around the world due to their nutritional value and health benefits. However, they have a limited shelf life due to their high moisture content and delicate structure, making them susceptible to spoilage, and therefore, they require special attention when it comes to storage and consumption. The best consumption period for fruits varies depending on the type of fruit, storage conditions, and its ripening stage. Understanding the optimal time for consumption helps to maintain the nutritional value, flavour, and texture of the fruit. Proper storage is also crucial in maintaining the quality of fruits. For example, some fruits require refrigeration to slow down the ripening process, while others can be stored at room temperature. Therefore, understanding the best consumption period and proper storage methods is necessary for anyone who wishes to enjoy the full benefits of fruits.

The fridge is one of the most essential home appliances for storing and preserving food items, including fruits. Fruits are among the most perishable food items, and the fridge provides an optimal environment to keep them fresh for a longer time. The fridge also plays a crucial role in regulating the temperature, humidity, and airflow necessary for the preservation of fruits. As times progressed, so did the development of fridges. Various well-known brands have even started to develop refrigerators with smart features. These smart features deploy advanced technology to make the products more advantageous and novel in the market. For example, the Korea brand LG has adopted a new technology in the development of its refrigerators, ThinQ (Wi-Fi), which is an application developed by LG to control all LG's smart appliances [6]. The application allows the user to control all the functions of the fridge such as ice-making, food storage and temperature setting on the mobile phone. The application also allows users to access the current condition of the fridge such as accidental fridge door opening or

power failure. Amongst the LG products that have this technology is the GC-Q22FTQKL.

Figure 1.1.3 My fridge

Figure 1.1.4 GC-Q22FTQKL [5]

Figure 1.1.5 LG logo [4]

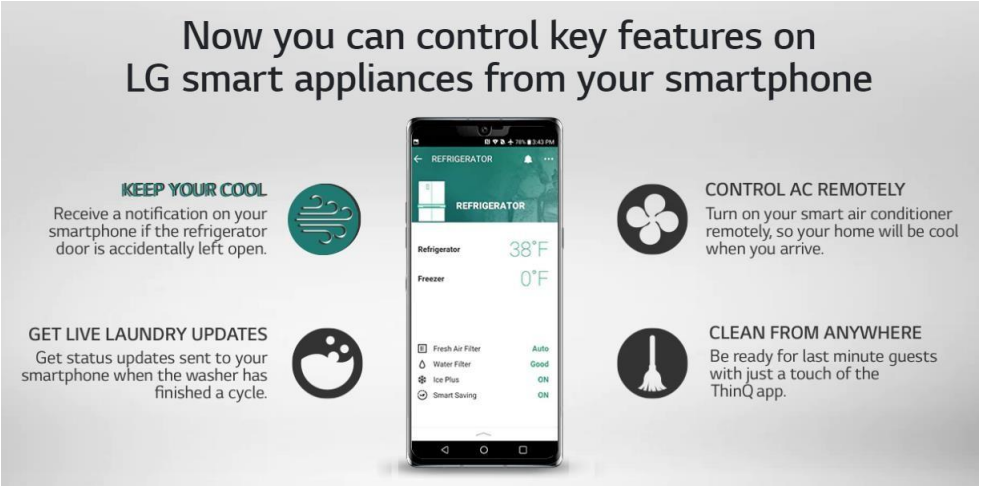


Figure 1.1.6 LG ThinQ [6]

In today's society, food packaging plays an important role in the protection and preservation of food. It provides an effective barrier against harmful external elements and ensures that food can be consumed safely. It also provides vital information about the food product, such as the name of the product, the manufacturing company, recipe and ingredients, net weight, and expiry date. In relation to fruits, packaging is essential in ensuring the fruit remains fresh and prevents spoilage. The packaging as well must include the necessary information, such as the name of the fruit, its origin, and the best consumption period.

Food packaging plays a crucial role in the purchasing process as it provides consumers with a visual impression of the product. The packaging design and visual appeal can attract consumers and influence their purchasing decisions. Therefore, it is essential that the packaging design not only protects and preserves the food but also provides the necessary information required for the consumer to make an informed decision. However, there is no avoiding the fact that the font on the food packaging is too small, making it difficult to read. This is also due to the incompatibility of the size of the food packaging with the necessary information. The dense inscriptions can lead to the most valuable and important information not being read easily by the consumers, thus creating a redundant burden for them.

Figure 1.1.7 Dense inscriptions on food packaging

In conclusion, the deliverable product of this project is an AR mobile application that scans the fruit packaging and displays AR virtual content related to fruits. The application will replace the traditional textbook-based approach to early childhood education and provide a more engaging and interactive learning experience for children.

1.2 Problem Statement and Motivation

1.2.1 Problem Statement

i. The nonexistence of a marker-based augmented reality application that scans and displays the contents of food packaging for fridge-related items.

The lack of suitable augmented reality applications for assistive devices has resulted in a significant loss in the market for these applications, which have the potential to be beneficial in both everyday life and the education sector. While some AR applications have been developed for the kitchen or food-related purposes, most of them are designed for gaming or recipe applications. Although there are a few fridge-related applications available, they are limited to basic scanning, such as scanning barcodes, rather than scanning food packaging. When individuals have difficulty identifying food items in their fridge, they have to describe and search the internet to obtain accurate answers, which can be both cumbersome and time-consuming. Furthermore, some users may struggle to identify objects or may not be able to read and write, leading to incorrect identification of food. One reason for this is that there are currently no augmented reality applications that scans food packaging and displays AR virtual content is able to be downloaded and installed from the Internet. These issues of identifying and recognising the contents of a fridge, although not frequently encountered by adults, can be a significant problem for younger users, particularly children.

ii. The inability of performing a real-time interaction between the scanned food's packaging 3D model and the user.

The current state of augmented reality technology in the food industry is still in its early stages. While there are a few AR applications available that allow users to virtually display 3D models of food objects, the number of such applications is still limited. Additionally, only a few food packaging models can be scanned and interacted with, using functions such as drag, scale in, scale out, and rotate. These applications are mostly found in games or storybook applications, rather than in educational materials. This presents a challenge in creating an engaging and immersive food learning environment, particularly for children. The lack of interactive learning opportunities and engaging materials can result in a low-quality learning experience, which may fail to spark the interest of children in learning about food and its related topics.

iii. Limitation of rapid scanning and retrieving the retrieval module of virtual content.

Measuring the use of AR technology in an educational context has proven to be a promising method for improving the quality and effectiveness of transferring know-how in the pedagogical process. However, it is important to note that the current AR applications for food learning have some limitations. Despite having a retrieval module for AR virtual content, the virtual content included in these applications is often limited and insufficient. This is mainly because most of the applications provide only general virtual content, such as a 2D image of the food item that is mapped on the device screen, or they rely on scanning and retrieving the same information from the food package. These limited functionalities only offer duplicate information to the user, which can result in a lacklustre learning experience. As a consequence, these applications may not be effective as educational aids for early childhood education, as they lack the necessary interactive and informative features that can encourage children's curiosity and engagement in the learning process.

1.2.2 Motivation

The rise of augmented reality technology has led to the development of numerous AR applications, but most of them are primarily designed for entertainment purposes such as gaming or storybook content. However, there is still a significant gap in AR applications that can be utilised for daily household appliances such as fridges. While regular fridge applications exist, there is a lack of AR applications that can help users organise and manage their fridge content effectively while also providing educational information to children. This has created an opportunity for the development of AR applications that can enhance everyday life, specifically in the area of fridge organisation and education. The implementation of AR technology in fridge applications can be incredibly beneficial in helping users identify and understand the contents of their fridge, including various food items such as fruits, vegetables, meat, dairy products, snacks, and more. However, many individuals may still struggle with identifying the name of a food item, its nutritional value, and the optimal consumption period. Therefore, the development of an AR application that can address these challenges is crucial to improving the overall user experience and promoting healthy habits.

Children's learning styles and environments are crucial in their development and using an augmented reality (AR) application to scan food packaging can help them learn about the contents of the fridge. By allowing children to interact with 3D models of the food items in real-time, through features such as drag, scale in, scale out, and rotate, the AR application can increase their engagement and enjoyment of learning new things from an early age. Additionally, the AR application will assist users in identifying fruits by simply scanning the food packaging, providing information on the fruit's name, nutritional value, and best consumption period. Studies have shown that approximately 80% of students are more interested in participating and learning in a class that uses AR technologies. AR technology allows for the integration of virtual content and physical objects in an application, creating a unique learning experience that is both engaging and interactive. When designing an AR-based learning environment, six main factors should be considered: courses, consistency of intervention, self-educating competencies, parental engagement, pupil's background,

and platform [9]. By considering these factors, the AR application can be optimised to provide an effective and engaging learning experience for children.

Moreover, the lack of knowledge regarding the best consumption period for fruits can lead to significant consequences, such as an increase in the percentage of food waste and a decrease in fridge hygiene. People who are not aware of the best consumption period may continue to consume fruits that have already expired, leading to food poisoning, vomiting, or even life-threatening situations. Therefore, it is critical to educate people about the best consumption period for different fruits to avoid such issues. Even though the promotion of the best consumption period for fruits is relatively easy, some people still disregard it and do not give it the attention it deserves. This emphasises the need for an application that can provide comprehensive information about the best consumption period of fruits to assist people in avoiding such risks.

Consuming enough nutrients is vital for maintaining good health, and fruits are an important part of a healthy diet. However, not everyone may be aware of the nutritional value of the fruits they consume, leading to an imbalance in dietary intake and unhealthy eating behaviour. This can even lead to diseases such as diabetes [8] because of the high amount of glucose consumed. Therefore, it is crucial to educate people about the nutritional content of different fruits. Children, in particular, need to be educated about nutrition, as they are still in the learning process and may not be able to identify the basic nutritional values contained in each fruit. For example, a child may not be able to tell whether the basic nutritional value of an apple is vitamin A or B. Even adults can get confused about the nutritional content of different fruits. Therefore, an AR application that displays the fruit's nutritional information and introduction can be helpful in educating people about the nutritional value of different fruits. By providing information on the nutritional value of different fruits, the AR application can help people make informed decisions about their diet and ensure that they consume enough nutrients on a daily basis. This can also help prevent diseases and promote healthy eating habits.

Furthermore, the proposed AR application also presents a significant opportunity for food and fruit brand companies to enhance their marketing strategies and contribute to society at the same time. By joining forces or collaborating, food and fruit brand companies can create a database and repository of AR virtual content of their products that can be displayed to consumers when they scan the food packaging with the application. This collaboration will enable the maximisation of a significant positive return on investment (ROI) and feedback from customers, thus adding value in all aspects. The AR technology will provide an innovative and engaging way to showcase the nutritional values and benefits of each product, which can increase customer loyalty and awareness. It is a promising future prospect to enhance early childhood education through the implementation of advanced technology and also promoting healthy eating habits.

In conclusion, the implementation of AR technology in a fridge organising application provides a unique and innovative way to improve everyday life by promoting healthy eating habits and providing useful information about food products. The proposed application has the potential to make a significant impact on society by reducing food waste, promoting healthy eating, and enhancing early childhood education. By collaborating with food and fruit brand companies, the application can also enhance marketing strategies, add value, and increase competitiveness in the market.

1.3 Objectives

i. **To implement marker-based augmented reality to the AR display content in fridge application that specifically uses the scanned food packaging as markers.**

The main part of the food packaging for a specific fruit item can be scanned by an AR-enabled mobile application, which will be used as a marker to activate the augmented reality features and environment on the device screen. To achieve this, it will be ensured that the camera meets the compatibility requirements of the equipment used, making it compatible with the lens conditions of the AR camera. Once the camera is aligned with the food packaging, the image targets are then processed to identify feature points, which are used to render the AR virtual content around them. The virtual content will be overlaid on top of the real-life image targets and displayed to the user. The entire set of virtual content objects will be displayed on the screen of the user's device, allowing them to interact with the AR environment and learn more about the fruit item, such as its nutritional value and best consumption period.

ii. To develop a 3D model with scanned food packaging marker which allows real-time interaction with the user.

The marker-based AR featured camera will capture the pre-defined food packaging as a marker, which will then be used to render the respective virtual 3D model of the scanned food packaging on the device screen. When the user scans the food packaging, the AR-enabled camera will recognise the marker and attach the related 3D model on to it. The user will then be able to see a stereoscopic food model with realistic textures in the virtual world, which will enhance the realism and engagement in the learning environment created by the digital application. By providing a 3D model of the fruit, the user can see the fruit in more detail, and this will be particularly useful for younger user groups. The 3D model can be manipulated through interactive functions such as drag, scale in, scale out, and rotate, which will allow the user to explore the fruit in a more engaging way. This will ultimately assist in fostering the desire to learn, which will be a great aid to early childhood education. In addition, children are difficult to control in the learning process, and their curiosity makes old-fashioned rules and systematic approaches to education no longer work for them. Therefore, this AR application will become a greater need for convenient, dynamic, and unusual educational support tool. By providing a more engaging and interactive learning experience, children will be more likely to stay interested and motivated in learning about food and nutrition.

iii. To develop a rapid retrieval module to retrieve information about fruit by scanning food packaging.

The marker-based AR technology that is implemented serves the food packaging as image markers. This will allow the user to easily retrieve the virtual content of a specific fruit item by simply scanning the marker with an AR-enabled camera. This will trigger the fruit's information retrieval module, which will display the virtual content of the fruit, including its name, characteristics introduction, nutritional information, best consumption period, and more. The virtual content that is displayed to the user will be enlarged to allow for easy viewing, even for users with visual difficulties. There are three patterns of educating methods that can be achieved within this retrieval module. Firstly, the audio learning method allows the user to listen to the characteristic's introduction and nutritional information of the specific fruit item through the information panel. The user can perform play, pause, and stop actions on the displayed information panel, making it convenient for them to learn at their own pace. Secondly, the YouTube icon displayed within the retrieval module will redirect the user to a related YouTube video once clicked on it. This achieves the video educating method, which allows the user to gain a more in-depth understanding of the fruit item. Thirdly, the interactive functions are the most ideal and engaging educating approach that aims to achieve. This educating method allows the user to interact with the 3D models of specific fruit and view their texture and appearance in detail. Moreover, the user can also learn about the best consumption period of different fruits, which is especially convenient and greatly reduces the risk of food poisoning due to accidental consumption of expired or obsolete food.

1.4 Project Scope

In this project, the main architecture of the proposed AR mobile application is based on the marker-based augmented reality technology, which involves using pre-defined image markers to trigger AR content. The application has two main features: scanning the fruit's packaging as an image marker to retrieve AR virtual content and rendering the scanned fruit's 3D model, which allows for interactive functions between the fruit and the user. To detect and recognise the pre-defined image marker as a target, a software development kit (SDK) is required. Vuforia Engine is implemented as the database for the markers. The images of the fruit's packaging will be stored in the target manager of Vuforia to serve as markers. Vuforia offers marker-based tracking, which involves using specific images as markers to trigger AR content. It uses computer vision technology to recognise and track images in real-time, allowing developers to overlay digital content on top of real-world objects. Unity3D, an integrated development environment (IDE), will also be utilised in this proposed AR application. Unity3D is a cross-platform game engine that allows developers to create interactive 3D and 2D content. By using Vuforia and Unity3D together, the engaging AR experiences that are easy to use can be developed to provide the users with a seamless experience.

Throughout this project, the focus is on fruits as the main food item target for the AR mobile application. This means that the virtual content and 3D model will be related to different types of fruit. For the retrieval module, the content will be presented in different forms including text, audio, and video. The text-form content will provide a brief introduction to the fruit, including information on texture, colour, and nutrition. The audio-form content will be accessed by clicking on an information 'i' button and will provide additional information about the fruit. The information panel will then be displayed to the user and allow the user to play, pause, and stop the audio to listen to the information which enabling customisable learning. The video-form content will be accessed through a YouTube icon button that will be displayed together with other virtual content. When clicked, the user will be redirected to the YouTube platform where they can watch videos related to the specific fruit item. This will provide a more engaging and interactive way for users to learn about fruits and their nutritional benefits. Overall, this approach will make learning about healthy eating habits more accessible and enjoyable for users.

In addition, the implementation of 3D models of fruits is an important aspect of this project. To acquire these models, Sketchfab.com is utilised as the main resource. Sketchfab.com is an online platform that hosts a vast collection of free and paid 3D models from various categories. This resource has been chosen after thorough research and evaluation of its capabilities. For this project, the .obj format is decided to be used for all the 3D models. The decision to use this format is based on the fact that it can provide a more realistic appearance and intricate details on the textures of the fruit's model. Additionally, this format ensures the optimal performance of the application by allowing smooth loading and rendering of the 3D models. Overall, utilising Sketchfab.com and the .obj format will enhance the visual experience and provide users with an interactive and realistic understanding of the fruits' appearance and characteristics.

Moreover, to enhance the user experience and interactivity with the 3D models of fruits, an extension called LeanTouch will be implemented in the AR application. LeanTouch is a touch-screen input library that is compatible with Unity3D and allows for easy implementation of touch-based interaction features in the application. By implementing LeanTouch, users will be able to interact with the 3D models of fruits in a more intuitive way. For example, they can drag the fruit around the screen to view it from different angles or scale in and out to zoom in and out of the model. These interactive functions will make the application more engaging and help users to understand the characteristics and features of fruits more easily. Therefore, the addition of LeanTouch will greatly enhance the user experience and increase the usability of the proposed AR application.

Lastly, the proposed AR application will be developed to operate on the Android platform as the operating system. Android has become a popular choice for game and application development as it offers access to a large user base and is an easy-to-use development tool. Android devices are available at various price points, making them more affordable for a wider range of consumers. Also, many Android devices come with powerful hardware specifications that permit the development of high-quality applications. This makes it easier for developers to create advanced and innovative features that can enhance user experience. Another advantage of the Android platform is the availability of the Google Play Store, which is one of the largest app stores globally. By publishing the AR application on the Google Play Store, it will be accessible to millions of Android users around the world. This allows for easier distribution and promotion of the application to a wider consumer base.

1.5 Contributions

The development of this AR display content in fridge application offers a significant societal contribution as it combines two important aspects of education – fridge content and food nutrition, to create an adjunct for early childhood education. The application offers an innovative and interactive way for children to learn and understand the various fruit items. By providing a lively and dynamic educational context, it can effectively stimulate children's interest and curiosity in fruit items. The application's educational benefits go beyond fruit items as it provides a platform for educating children about basic nutritional information. With the 3D models of the fruit items, children can have a detailed view and study of the items in relation to fridge content. This can enhance children's understanding of the importance of healthy eating habits and encourage them to make informed choices when it comes to their diet. Overall, the AR display content in fridge application can have a positive impact on early childhood education and nutrition, making it a valuable tool for parents and educators alike.

The AR display content in the fridge is a unique and innovative solution that distinguishes itself from other fridge-related applications. The use of marker-based AR technology provides an enhanced user-device interaction, allowing real-time interaction and engagement with the 3D models of specific fruit objects. This technology, coupled with the virtual content retrieval module, which provides best consumption period information, contributes to the improvement of the application's performance, offering enhanced services to users. The inclusion of the best consumption period information is significant in addressing global concerns such as food waste, food poisoning, and accidental consumption of expired or no freshness food. By providing a simple rendering and displaying of this information, the application makes it easier for users to keep track of their food's freshness, leading to more efficient and convenient use of fridge contents. The application's all-in-one concept incorporates all necessary functions into a sophisticated application that offers the community a convenient and efficient way to discover the contents of their fridge. Moreover, this application is a great contribution to early childhood education, as it offers children an enjoyable, immersive, and user-friendly approach to learn about fruit items and basic nutritional information.

1.6 Report Organisation

The details of this report are shown in the following chapters.

Chapter 1: Introduction

In this chapter, the background information is presented which helps the reader to understand the underlying reasons and inspiration for proposing this project. The problem statement and motivation are also included with the explanation of the challenges that the project aims to address. The objectives are clearly stated, as well as the project scope which outlines the direction of the development and resources being used. Lastly, the potential societal benefits that this project may contribute are explained.

Chapter 2: Literature Review

In this chapter, a thorough analysis, review, and study of existing similar applications or systems are presented. The aim is to gather information about the shortcomings of these existing applications and compare them in order to identify useful features that can be considered within the proposed application. The proposed solutions are presented and explained in order to avoid the shortcomings identified in existing applications.

Chapter 3: System Methodology/Approach

In this chapter, the system methodology is described which involves the presentation of the system design diagrams. These diagrams are intended to provide a clear understanding of the architecture design of the proposed application. The included diagrams are System Architecture Diagram, System Use Case Diagram, System Activity Diagram, and System Flowchart Diagram.

Chapter 4: System Design

In this chapter, the system design is discussed in detail. The content included are System Block Diagram, UI Design Diagram, 3D Model Diagrams, application logo design, and scripts design explanations that focuses on the programming code that will be used to implement various features and functionalities within the application.

Chapter 5: System Implementation

In this chapter, the hardware and software setup required to run the proposed application are detailed. The configuration and settings of each platform used to develop and run the application are also described. Following by the presentation of the system operation of the proposed application, which provides a step-by-step guide on how the application is used by the end-users. Finally, the chapter concludes with a discussion on the implementation issues and challenges faced during the development of the application.

Chapter 6: System Evaluation and Discussion

In this chapter, the focus is on testing and evaluating the performance of the proposed system. The results obtained from the testing are presented, along with explanations of the different performance metrics used to evaluate the system's performance. The testing setup and results are illustrated by showing the console responding. This provides visual evidence of the system's performance and helps the reader understand how the system operates. Finally, the chapter concludes by evaluating the project's objectives and discussing how well they were met by the proposed system.

Chapter 7: Conclusion and Recommendation

In the final chapter of the report, the overall conclusion of the project is presented, providing a clear and concise summary of the project, its achievements, limitations, and potential for further development and improvement. Recommendations are also included for future work and improvements that can be made to enhance the performance and effectiveness of the application.

Chapter 2
Literature Review

2.1 Review of the Existing Applications

2.1.1 Empty My Fridge

Brief Introduction

The main usage of Empty My Fridge application is to assist users in managing their food inventory and reduce food waste. By keeping track of the expiry dates of food materials, users can avoid consuming expired or spoiled food and save money by reducing food waste. The additional feature of exploring recipes using existing food items in the pantry, cupboards, and freezer allows users to utilise the food items they have before they expire or go to waste. This application is available in both IOS and Android platforms. Additionally, the application can be installed and used on various hardware platforms, such as smartphones, tablets, and websites. Lastly, it is utilising cloud database for data storage [10].

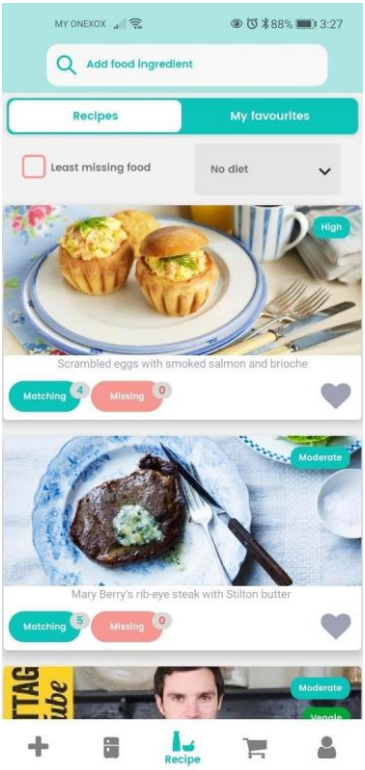


Figure 2.1.1.1 Recipe page

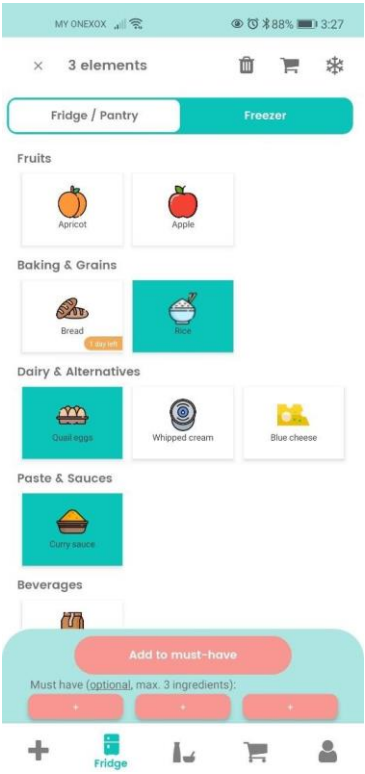


Figure 2.1.1.2 Adding to inventory page

Strengths

1. The AI adding functionality:
    - With the use of artificial intelligence (AI) to identify and add food or ingredients to the virtual fridge. This is done by scanning receipts or shopping lists, which makes it easier and more convenient for the user to input their food items into the app. This is an innovative feature that can save users a lot of time and effort when it comes to tracking their food items and expiration dates.

2. The AI searching algorithm:
    - This functionality allows the user to search for ingredients based on priority levels. This means that the app can suggest recipes or meals based on the ingredients that the user has on hand and can also provide suggestions for which ingredients to use first based on their expiration dates.

Weaknesses

1. Poor UI design:
    - This is specifically for the website version of this application, where the UI design is not attractive enough to capture the user's attention, which may result in lower user engagement and retention.

2. Only 2D outputs are provided:
    - The 2D output of the retrieved content makes the application even more inferior when compared to other applications that provide more interesting and visually appealing outputs. This may also result in a lack of user engagement and interest in the application.

3. Insufficient details on food items:
    - It only provides a minimal food-related information. While it provides the name and category attributes of food products, it does not provide any nutritional information. This could be a significant disadvantage for users who are trying to maintain a specific diet or control their eating habits.

4. Only user-friendly to adult users:
    - Although the application provides necessary information, the way it presents the information is not visually or audibly appealing, which may not attract children's attention. This may limit the application's user base to only adult users.

2.1.2 Frigloo

Brief Introduction

The main usage of Frigloo application is to helps users organise the contents of their fridge. One of its core features available on the market is fridge sharing. Users can manage their food storage space remotely and conveniently with all their family members. Also, it supports multilingual in terms of language settings. This application is available in Android platform only. Additionally, the application can be installed and used on various hardware platforms, such as smartphones and tablets. Lastly, it is utilising local database for data storage [11].

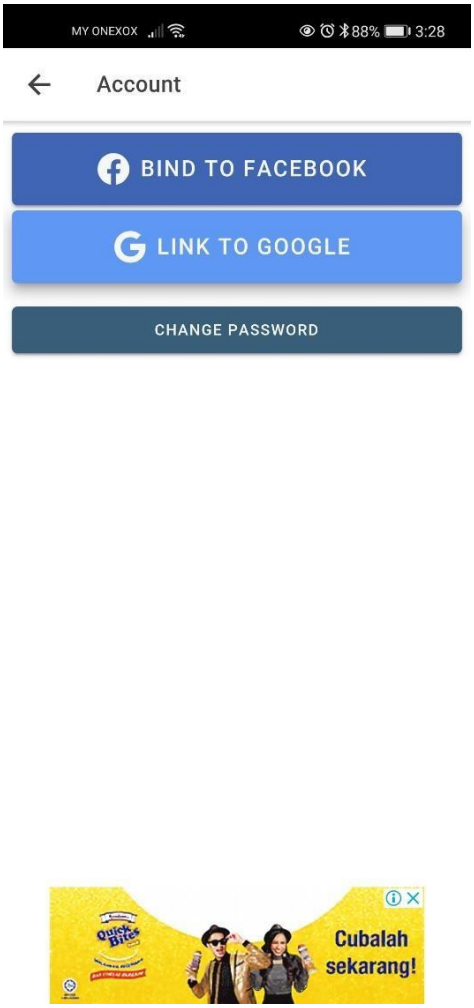


Figure 2.1.2.1 Link to social medias

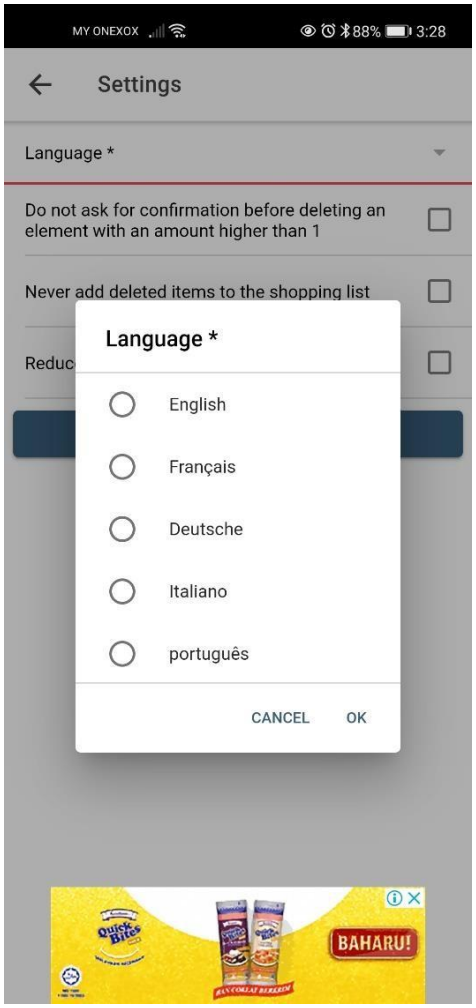


Figure 2.1.2.2 Multilingual

Strengths

1. Enhanced social media integration:
    - Frigloo offers seamless integration with other social media platforms such as Facebook, providing users with more comprehensive information about the application.

2. Advanced search and filter functions:
    - Its search functionality is accompanied by advanced filtering features that allow users to search for food items by category, name, and, most importantly, expiry date. Users can easily search for food products by selecting an expiry date before a specific date.

3. Collaborative fridge management:
    - Frigloo's fridge sharing feature enables users to manage their food storage space remotely and conveniently, promoting seamless collaboration with all members of their family.

Weaknesses

1. Inclusion of in-app advertisements:
    - The presence of in-app advertisements can pose a risk to the security of the application as it can lead to the user being directed to malicious websites or applications through unsolicited advertisements. This can result in cyberattacks and put the user's personal information at risk.

2. Requires in-app purchases:
    - The requirement of in-app purchases to access additional functions or features may make the application less appealing to users who are not willing to spend money. This may limit the user base of the application and result in lower user engagement.

3. Only 2D outputs are provided:
    - The lack of visually appealing outputs, especially in the 2D format, can make the application less attractive to users who are looking for a more immersive experience. This can result in lower user engagement and retention.

4. Insufficient details on food items:
    - The application's lack of nutritional information for food items can be a disadvantage for users who are trying to maintain a specific diet or control their eating habits. This can result in users seeking out alternative applications that provide more comprehensive information.

5. Poor UI design:
    - The unattractive and unappealing design of the application's graphical user interface (GUI) can make it less engaging and less user-friendly. This can result in lower user engagement and retention, limiting the success of the application.

2.1.3 KitchenPal

Brief Introduction

The main usage of KitchenPal application is to manage the fridge contents and recipe recommendations based on added ingredients. Its user interface is attractively designed and neatly ordered. This application is available in both IOS and Android platforms. Additionally, the application can be installed and used on various hardware platforms, such as smartphones and tablets. Lastly, it is utilising local database for data storage [12].

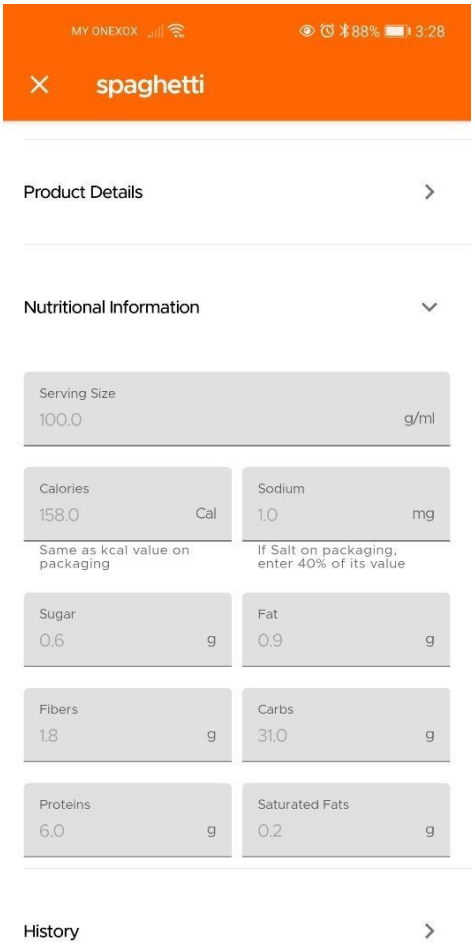


Figure 2.1.3.1 Nutrition information page

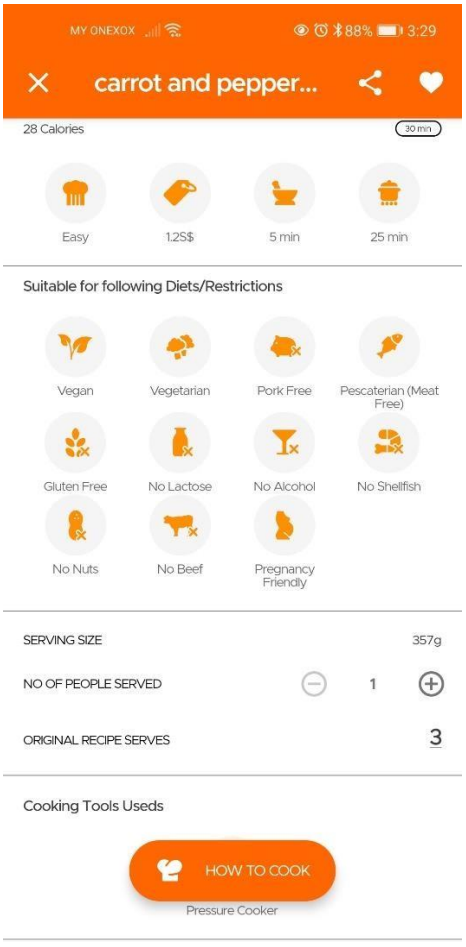


Figure 2.1.3.2 Recipe page

Strengths

1. Google Cloud Platform (GCP): Google Assistant and Google Dialogflow functionality:
   - This allows users to perform certain actions on the app through voice commands, such as adding or searching for food items. This feature is made possible by the integration of Google Assistant and Dialogflow, which are Google's AI-powered conversational interfaces. By using voice commands, users can add or search for food items hands-free, making the app more convenient to use.

2. The nutritional information section:
   - This section provides users with detailed nutritional values of specific foods. This section displays not only basic nutritional information, but also more detailed values, such as calories, sodium, sugar, fat, and so on. The nutritional values are calculated based on the recommended dietary allowance (RDA), which takes into account the user's personal details, such as height, weight, and portion size. This feature is beneficial for users who are trying to maintain a specific diet or control their eating habits. It provides them with the necessary information to make informed decisions about what they eat and can help them achieve their health goals.

Weaknesses

1. Requires in-app purchases:
    - KitchenPal offers in-app purchases for users who want access to the latest features. However, not all users may be willing to make purchases for additional features. Some users may prefer a free application that provides them with helpful assistance rather than having to spend money on it. This may limit the potential user base of the application.

2. Only 2D outputs are provided:
    - The lack of advanced technology is also reflected in the application's limited visual outputs. The application needs to implement more advanced technology to enhance its virtual content and provide a more engaging user experience. Simply displaying 2D outputs such as text and images may not be enough to attract and retain users in the long run.

2.1.4 Fridge

Brief Introduction

The main usage of Fridge application is to prevent food waste and is based on the concept of recommending recipes to users considering the food available to the user. It needs to be used with access to the internet and it is then feasible to add different categories of food to the fridge content list and commence a search for suitable recipes. This application is available in Android platform only. Additionally, the application can be installed and used on various hardware platforms, such as smartphones and tablets. Lastly, it is utilising local database for data storage [13].

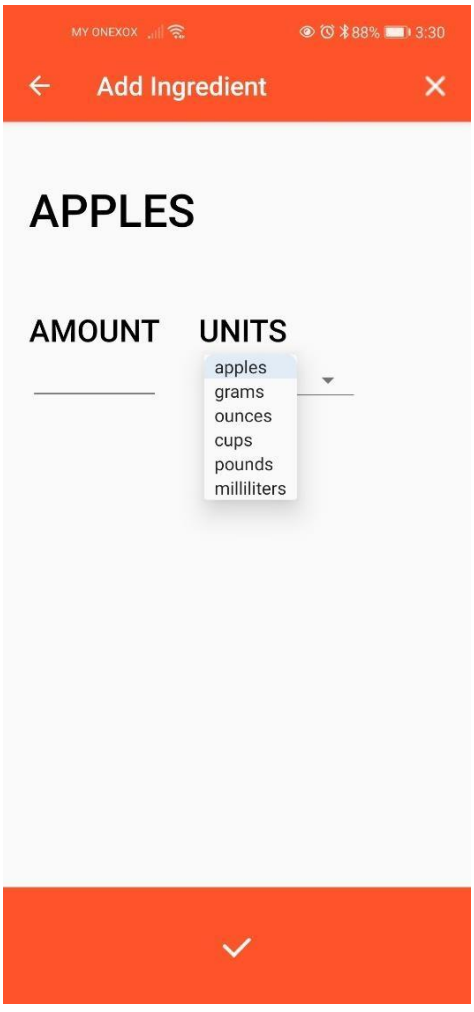


Figure 2.1.4.1 Adding ingredient

Strengths

1. Advanced recipe recommendation feature:
    - It allows users to make the most of the ingredients they already have in their kitchen. By selecting the ingredients, they have on hand and specifying the amount of each, the application can then search for and recommend suitable recipes. The feature includes units of measurement for various food items to make it easier for users to specify the amount of food they wish to include in the recipe. For instance, they can specify the quantity in grams, ounces, pounds, and millimetres. This makes it convenient for users to tailor the recipe to their needs and preferences.
    - Once the user enters the necessary information, the application filters and selects the matching recipe from its database. The recipe is then displayed on the user's screen along with the list of ingredients and step-by-step instructions to cook the recipe. This feature is especially useful for those who have a limited amount of ingredients and want to avoid food waste by making use of what they already have. Additionally, this feature saves time and effort by recommending recipes that can be made quickly and easily with the ingredients on hand.

Weaknesses

1. Poor UI design:
    - Similar to the previous applications being reviewed, the application does not have user interface pages designed in an aesthetically appealing manner. It has been designed to a very simplistic layout and there is not much information about the application to be censored.

2. Insufficient details on food items:
    - The application does not provide any nutritional information about food items. This can be a significant disadvantage for users who are trying to maintain a specific diet or control their eating habits. Nutritional information is important for users to make informed decisions about what they eat and to monitor their calorie intake.

3. Only 2D outputs are provided:
    - This application, again, do not provide any 3D form of outputs to the user, which means that users can only see text and images of the food items they add or search for. There is no 3D form of output to provide users with a more immersive experience. Additionally, the application does not provide any extra information or virtual educational context to be retrieved and displayed, which could limit users' interest in the app.

2.1.5 ARBreakfast

Brief Introduction

The main usage of ARBreakfast application is to help children between the ages of 5 and 12 to understand the proper amount of carbohydrates they can consume at each meal. In terms of the user base, most of the users are children with diabetes. It has therefore been developed to help them learn about food nutrition. This application is available in Android platform only. Additionally, the application can be installed and used on various hardware platforms, such as smartphones and tablets. Lastly, it is utilising local database for data storage [14].

Figure 2.1.5.1 Food nutrition game

Strengths

1. Marker-based AR technology:
    - The marker-based AR technology used in this application is a specific type of augmented reality (AR) technology that uses an object marker, in this case a plate, as a reference point for tracking and displaying virtual content.

2. 3D model retrieval module:
    - The module allows the application to retrieve and display 3D food models on a physical plate using the camera lens scan. This feature can be useful for educational purposes and helping users to better understand the nutritional content of different foods.

3. Game interaction with user:
    - By implementing fun games, this application aims to engage its targeted user base of children and help them to acquire new knowledge in the field of food nutrition. This can be especially helpful for diabetic patients, who may need to closely monitor their diet and nutrition.

4. Nice UI design
    - The nice UI design of this application is an important aspect that can attract users, particularly its target audience of children. An aesthetically appealing and user-friendly interface can make the application to be more engaging and easier to use, leading to a better overall user experience.

Weaknesses

1. Limitation of interactive functions:
    - The nonexistence of interactive functions in an application is a major drawback. Without interactive functions, users may not be able to engage with the application effectively. In the case of an AR-based application that uses 3D models, interactive functions are essential to ensure that users can experience the full benefits of the technology. In this context, interactive functions refer to the ability of the user to interact with the 3D models that are displayed on the screen. Also, in the context of a nutrition and food education application, interactive functions are especially important for engaging users in the learning process.

2.1.6 HCLearn Nutrition

Brief Introduction

The main usage of HCLearn Nutrition application is to allow the user to learn to interpret the nutritional information on labels of real packaged foods. It is an augmented reality application that displays nutritional information about food products by scanning labels on real packaging. The application implements AR technology to identify multiple targets and cylindrical targets for further interpretation of nutritional information. It claims to help users in learning about food nutrition and maintaining the habit of consuming healthy food. This application is available in Android platform only. Additionally, the application can be installed and used on various hardware platforms, such as smartphones and tablets. Lastly, it is utilising local database for data storage [15].

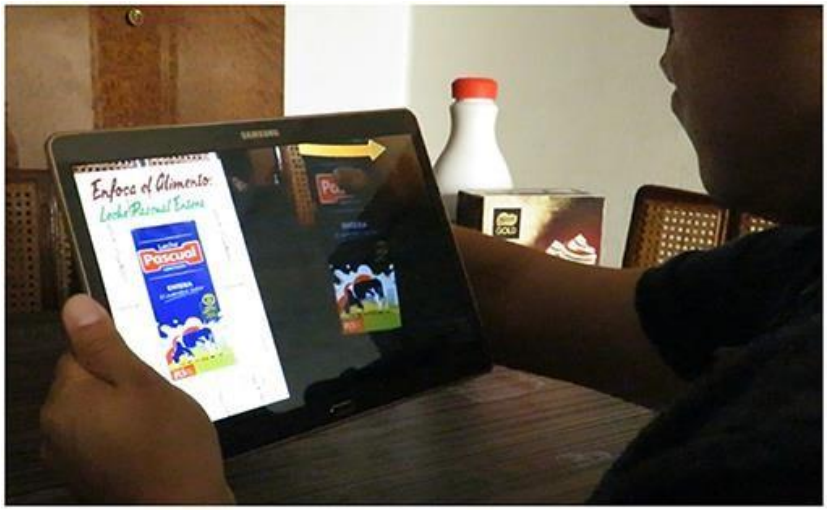


Figure 2.1.6.1 Scanning food packaging

Strengths

1. Marker-based AR technology:
    - In the case of this application, the marker-based AR technology uses the food packaging as an image marker for detection targeting. This means that the application can recognise and detect the packaging of a food product by scanning it through the device camera, and then display the corresponding image of the packaging digitally on the screen. This is a useful feature as it allows the user to quickly and easily identify the food product that they are interested in.

2. AR image recognition:
    - It enables the application to retrieve the nutritional information of food products. When the application scans the packaging of the food product, the AR technology captures the label or text on the packaging and converts it into digitalised context. The application then displays the captured and converted text of the nutritional information of the food product on the left side of the device screen. This is a valuable feature as it provides the user with detailed and accurate information about the nutritional content of the food that they are interested in.

Weaknesses

1. Only 2D outputs are provided:
    - In this case, only 2D outputs are provided when user scans on the food packaging. This means that the retrieved virtual content only includes food packaging image and the texts. However, there are no 3D models being retrieved and displayed to ensure a more enhanced visually appealing context to the user.

2. Limitation of interactive functions:
    - Still, this application is also not equipped with the fun interactive functions that allows real-time interaction between the retrieved AR virtual content and the user. Without interactive functions, users may lose interest quickly or find the application less helpful than expected. Thus, causing a poorer application performance in terms of the user experience.

3. Limited content of nutritional information:
    - Due to the main contribution of this application, there is particularly no additional information and features beyond the scanning of nutritional information. When a food product is scanned, the only result is the nutritional information on its label. This may become a critical disadvantage for users who are looking for more in-depth information about the food they are consuming.

2.2 Critical Remarks

Table 2.2.1 Critical remarks

	Empty My Fridge	Frigloo	KitchenPal	Fridge	ARBreakfast	HCLearn Nutrition	Proposed Application
Operating System							
Android	/	/	/	/	/	/	/
IOS	/		/				
Hardware Platform							
Smartphone	/	/	/	/	/	/	/
Tablet/Ipad	/	/	/	/	/	/	/
Website	/						
Database Management							
Cloud Database	/						
Local Database		/	/	/	/	/	/
Technology Applied							
Artificial Intelligence (AI)	/						
Augmented Reality (AR)							
- Marker-based					/	/	/
- Markerless							
- Location-based							
- Superimposition-based							
- Image Recognition (text converting)						/	
Basic CRUD Functions	/	/	/	/			
Google Assistant - Google DialogFlow			/				
Features							
Adding food item to repository	/	/	/	/			
Interactive actions/Gaming interaction							
- Between users and virtual contents					/	/	/
- Between users and 3D model							/
Recommending recipes	/		/	/			
Retrieval of 3D models as output					/		/
Retrieval of nutritional information			/		/	/	/
Retrieval of game objects (virtual contents)					/	/	/
Priority-based searching	/	/					
Tracking expiry dates	/	/	/				
Social Impact Contributions							
Assisting with fridge content management	/	/	/	/			
Avoiding food poisoning situations	/	/	/				/
Encouraging healthy daily intake					/	/	/
Promoting AR Education					/		/
Reducing food waste situations	/	/	/	/			/
Stimulating fun learning and teaching methods					/		/
Target Audience							
Adults (> 17 years old)	/	/	/	/		/	/
Children (<= 17 years old)					/	/	/

After exhaustive analysis and screening, a table of critical reviews of existing applications has resulted. These critiques were analysed in relation to several important factors in the architecture and development of the application. These included Operating System, Hardware Platform, Database Management, Technology Applied, Core Features, Social Impact Contributions, and Target Audience. These factors play a critical role in the subsequent development of the proposed application, the scope of functionality, and the architectural design decisions. Therefore, after critiquing the existing application, a column for the proposed application was added to provide a basis for the identification and consideration of its intended application development targets and requirements. Overall, the critical review process provides valuable insights and information that can be used to develop a successful application.

2.3 Summary of the Existing Applications

To summarise, several limitations were identified from the reviewed food-related applications. These limitations vary across different applications and include the absence of AR technology, limited interactive functions, lack of nutritional information, poor UI design, in-app purchases, in-app advertisements, and a focus on adult users rather than children. Additionally, some applications only provide 2D outputs, which may result in a lack of user engagement.

The non-implementation of AR technology is a limitation that is found in several reviewed food-related applications, including Empty My Fridge, Frigloo, KitchenPal, and Fridge. Nevertheless, the ARBreakfast and HCLearn Nutrition applications can be excluded because they do implement immersive technology. In this case, the applications would be diminished in intelligibility and would not provide the user with extraordinary technology. Many of the advanced features or functions that have emerged as the world has moved towards high technology would not be available for these applications. In fact, they may become obsolete in the future due to the lack of adoption of advanced technologies. The lack of immersive technology involved in most of these applications also results in their inability to offer enhanced functionality and accessibility beyond that of AR applications. These shortcomings will not allow them to take a dominant position in the market but will instead be eliminated by new applications that embrace the use of high technology one after another.

The limitation of only 2D outputs is a common issue faced by several reviewed applications, including Empty My Fridge, Frigloo, KitchenPal, Fridge, and HCLearn Nutrition. As a result, the user is unable to interact with the particular food product in real time. This may raise the issue of the application being unsuitable for educational purposes. The 2D appearance of the food does not provide the user with a new experience or incentive to explore further. Furthermore, the static 2D presentation not only precludes users from experiencing immersive education but also impedes them from engaging in an advanced education system in dual mode, with both physical and virtual modes. None of the fridge-related and ECE-related applications reviewed have so far been able to satisfy the need to present the user with a 3D model of the desired

food. Therefore, this limitation is a missed opportunity to contribute to society, especially to the population of children.

The limitation of interactive functions is presented in both ARBreakfast and HCLearn Nutrition applications, and most of the reviewed applications are lacking in implementing interactive functions. These applications are only equipped with basic CRUD (Create, Read, Update, and Delete) functions, which only allow basic user request-respond with the virtual contents but not interacting with the virtual content in real-time. Although ARBreakfast fulfils the requirement of retrieving 3D models, it still lacks the most engaging interactive functions. This limitation affects the user experience, as it reduces the level of engagement with the application and limits the capability of the application to provide a more immersive experience to the user.

The limitation of being only user-friendly to adult users is presented in the reviewed applications, namely Empty My Fridge, Frigloo, KitchenPal, and Fridge. These applications are designed and laid out in a way that may not attract the attention of the children consumer base. Factors such as font volume, wording, graphics, and distribution of content are less likely to engage children. However, the applications may be more appealing to adult users. This is an important limitation to address, as children may also benefit from the use of food-related applications, especially those that promote healthy eating habits.

The limitation of insufficient details on food items information is a common issue found in several reviewed applications, namely Empty My Fridge, Frigloo, Fridge, and HCLearn Nutrition. However, the reviewed applications either provided too much detail on the nutritional value of food or did not provide any at all. When over-detailed information is provided, it is difficult for the child user group to acquire a great deal of new knowledge. This in turn pressurises them, which makes them resistant to learning. Children must be educated with patience and guidance. It is therefore essential that the application is only available and provides the most appropriate teaching scope for the child user group, who can benefit from the most basic nutritional values of food presented in a simple and uncomplicated way. If they receive the right amount of learning content, the purpose of the application can be maximised. In short, overly detailed, and complicated content can lead to user fatigue and boredom.

A poor UI design refers to the way that the graphical user interface (GUI) of an application or website is structured and designed, which can affect the user experience. In this case, the limitation of a poor UI design is present in the website versions of the Empty My Fridge, Frigloo, and Fridge applications. The design of the user interface for each scene is considered to be too basic, lacking in creativity and attractiveness to leave a lasting impression on the user. This can make it difficult for users to navigate and use the application effectively, as well as making it less engaging and potentially leading to lower user retention rates. Overall, a well-designed user interface is essential for the success of an application, as it can impact the user's perception of the application and their overall experience.

Lastly, in-app purchases limitation refers to the fact that users are required to pay for additional features within an application in order to unlock or fully use them. The KitchenPal and Frigloo applications were both identified as having this limitation. The problem with in-app purchases is that they can be frustrating for users, particularly if they feel that they are being charged for features that should have been included in the app in the first place. In-app purchases can also make the user experience feel less seamless, as users may be constantly prompted to pay for additional features or content, interrupting their use of the app. In some cases, users may even feel like they are being taken advantage of if they are constantly being asked to pay for things that they feel should be included as part of the basic app experience.

Finally, the presence of in-app advertisements in the Frigloo application can be a serious concern for users. In-app advertisements can be intrusive and negatively impact the user experience. Users may find the ads distracting or annoying, and some ads may even be malicious and lead to security risks. For example, clicking on a malicious ad may lead the user to a phishing site or result in the installation of malware on their device. Thus, the presence of in-app advertisements may raise concerns about the safety and reliability of the information being provided.

2.4 Proposed Solutions

Based on the reviewed existing applications, the final product will be implemented with the following solutions. Firstly, the implementation of marker-based AR technology to the proposed application. This application will be using the food packaging as image marker to be targeted when user is using the application. With this technology is applied as one of the solutions, thus ensuring that the advanced features can be utilised while retrieving the pre-defined AR virtual contents.

Secondly, the decision of employing the concept of 3D models as a means of solving the problem of tedious 2D images or food icons. This is vital in enhancing the application performance in terms of virtual content retrieving. Having a virtual view of a 2D flat object is relatively difficult to provide surprising and distinctive benefits. Therefore, by implementing the concept of creating a 3D model for a specific food product, the 3D model will then be retrieved only on the basis of the feature points marked by the image being detected and tracked.

Thirdly, the solution of developing and prototyping of the interactive functions such as drag, scale in, scale out, and rotate. For accomplishing this solution, two approaches can be performed, which are utilising the touch-screen input extensions from Unity3d and setting up visual buttons. At this point, the touch-screen functionality will be developed to allow dragging, scaling in and scaling out of the retrieved 3D model. The implication of this is that when the user presses the equivalent button on the device screen, the corresponding function will be triggered on the 3D model game object. As for visual buttons that derive from the image markers, they will also be developed with the ability to interact with the 3D model. When the user hovers over the specific area where the virtual button is located, the corresponding interactive function will then be invoked.

Fourthly, the solution of the proposed application design makes it accessible to both adult and juvenile users. Armed with this solution, the application can be more readily and easily adopted by a wider range of users. As well as providing assistance in any condition or situation. This increases the pool of users. At the same time, the presence of a large customer base will guarantee a more favourable market position for the application.

Fifthly, the retrieval module for obtaining information on food items also needs to be intervened to achieve optimisation in order to address the lack of detail and information on food items. Based on the concentration of the project, more fruit item-related information could be considered, such as names, information on characteristics, basic nutritional information, and best consumption period. Consideration of the best consumption period for fruit would support the avoidance of food poisoning and food waste. Therefore, it is imperative that this element is accounted for. By including the information mentioned above, the content exhibited to the user will be more coherent and meaningful.

Finally, an attractive user interface design will also be executed to help in grasping the attentiveness of users, especially children. The colours, fonts, and graphics used in this regard need to be amusing and vivacious to ensuring that the application conveys a captivating impression to the user. These are all elements that are of utmost significance to the task of enthralling the user and are among the most essential of the engineering aspects of developing the application.

Chapter 3
System Methodology/Approach

3.1 System Design Diagram

3.1.1 System Architecture Diagram

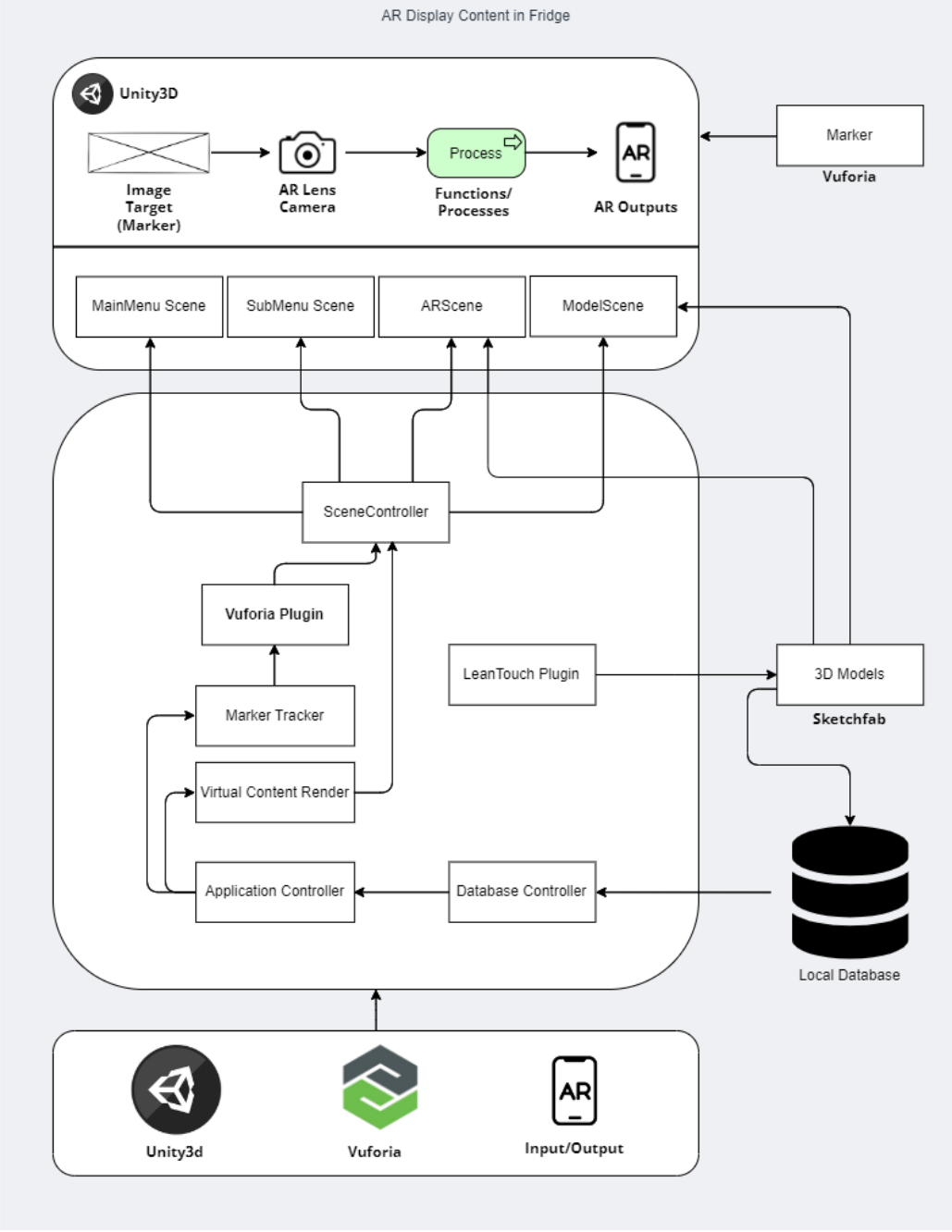


Figure 3.1.1 System architecture diagram

3.1.2 System Use Case Diagram

MainMenu Scene

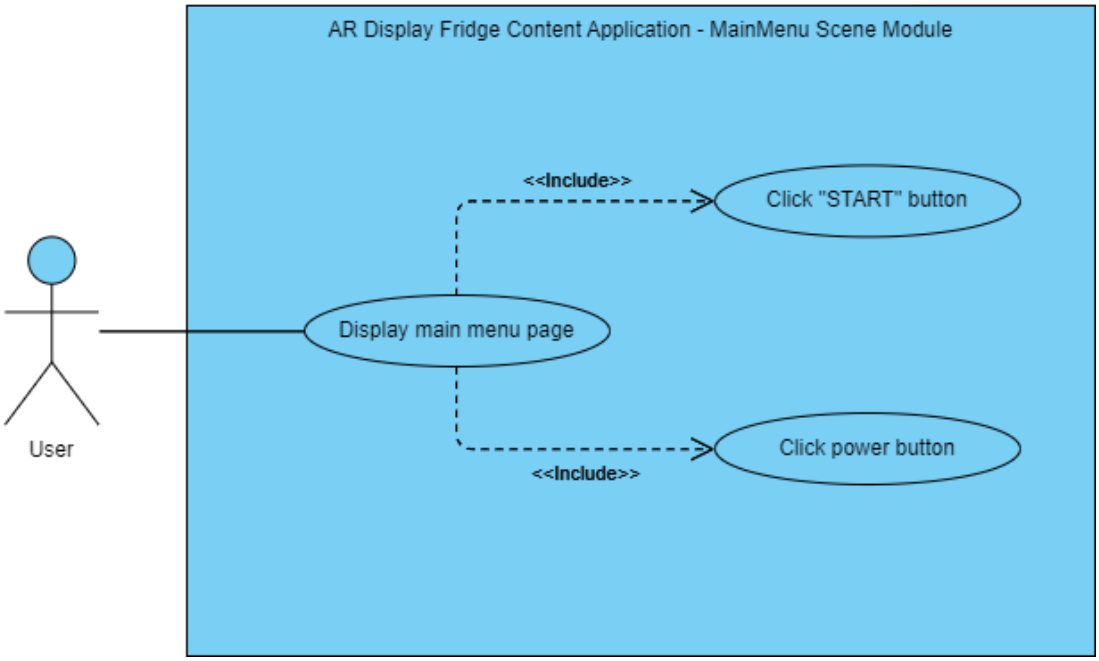


Figure 3.1.2.1 MainMenu scene use case diagram

SubMenu Scene

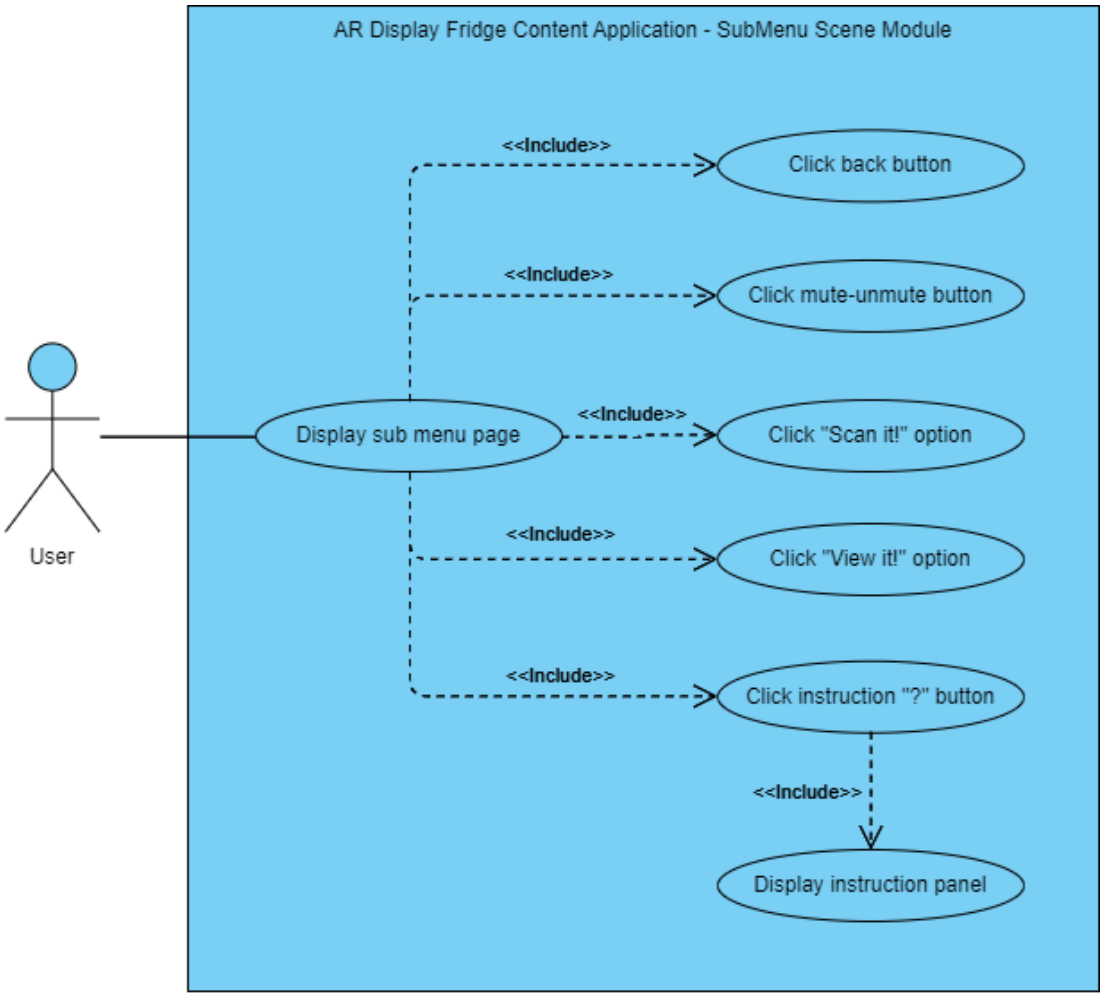


Figure 3.1.2.2 SubMenu scene use case diagram

AR Scene

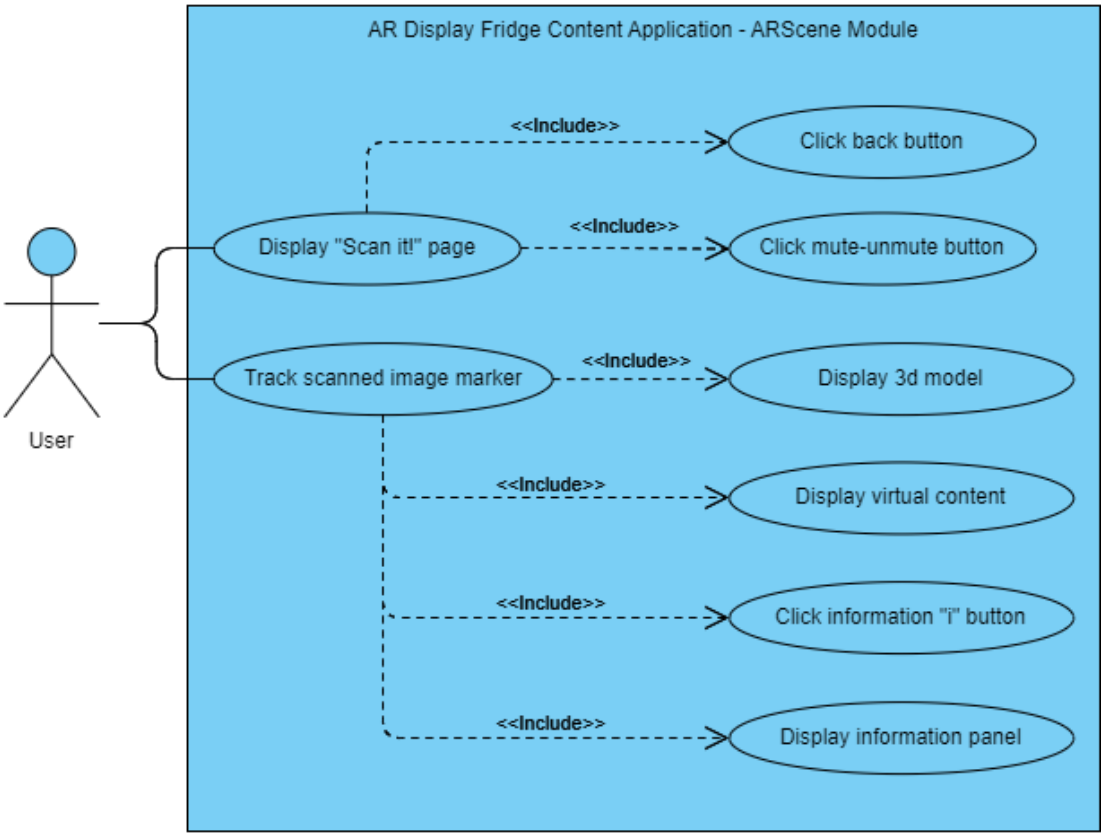


Figure 3.1.2.3 ARScene use case diagram

Model Scene

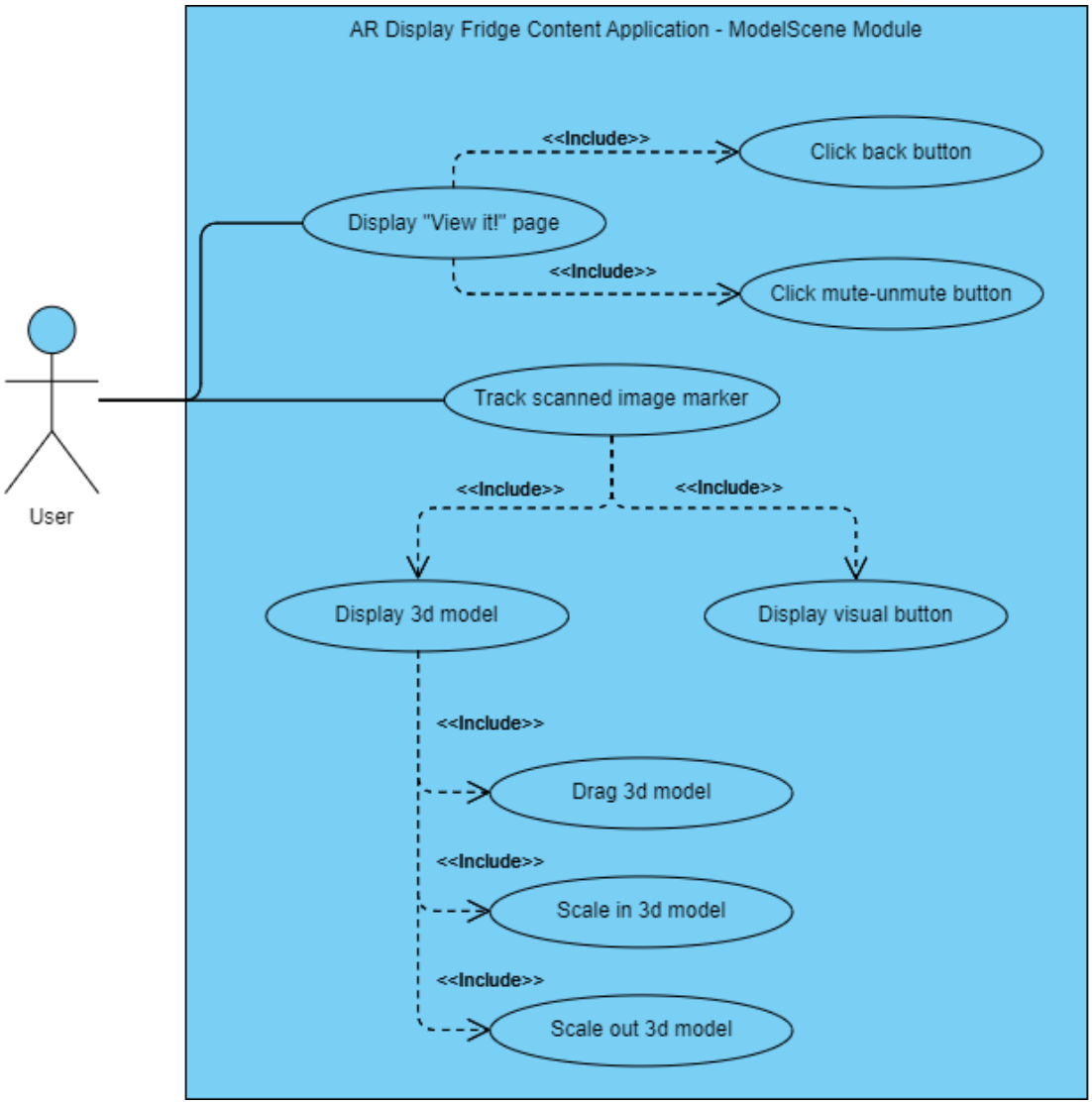


Figure 3.1.2.4 ModelScene use case diagram

3.1.3 System Activity Diagram

MainMenu Scene

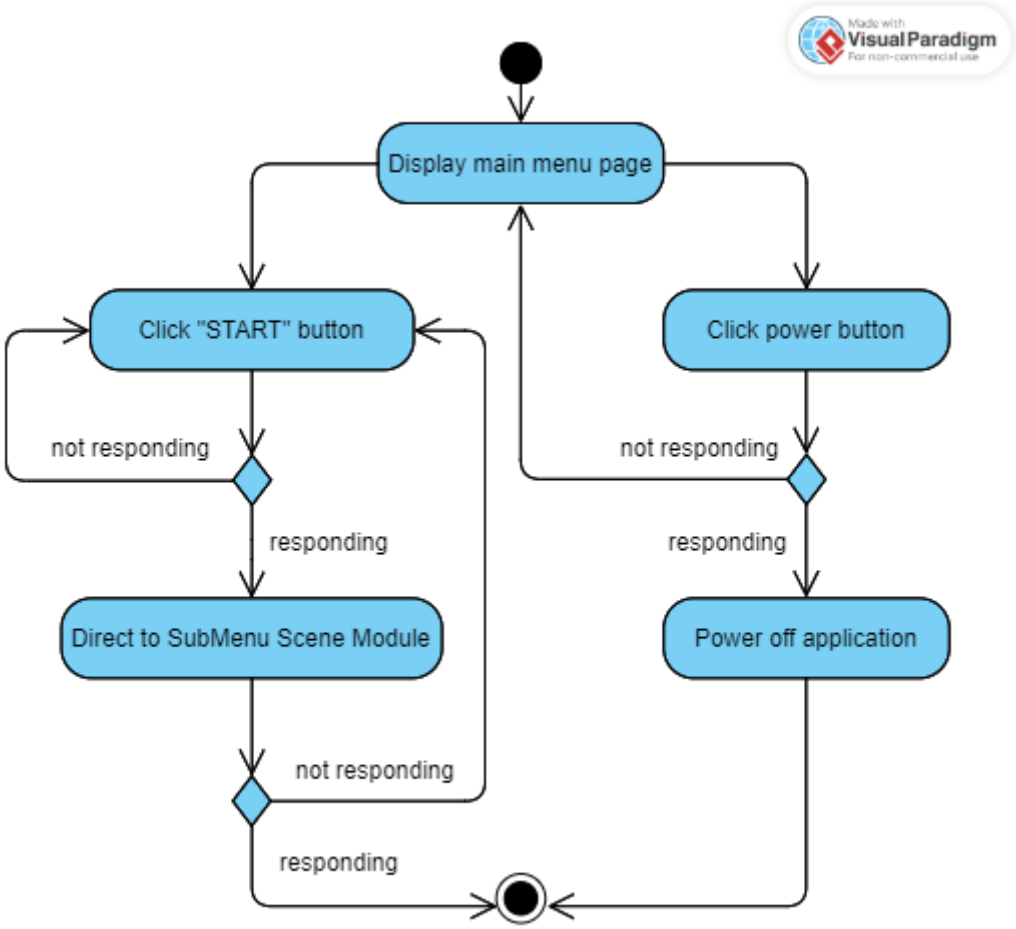


Figure 3.1.3.1 MainMenu scene activity diagram

SubMenu Scene

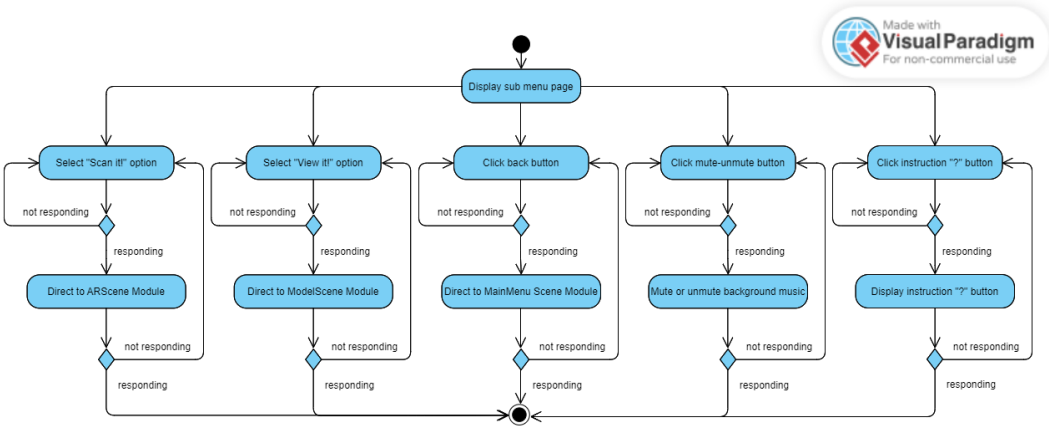


Figure 3.1.3.2 SubMenu scene activity diagram

AR Scene

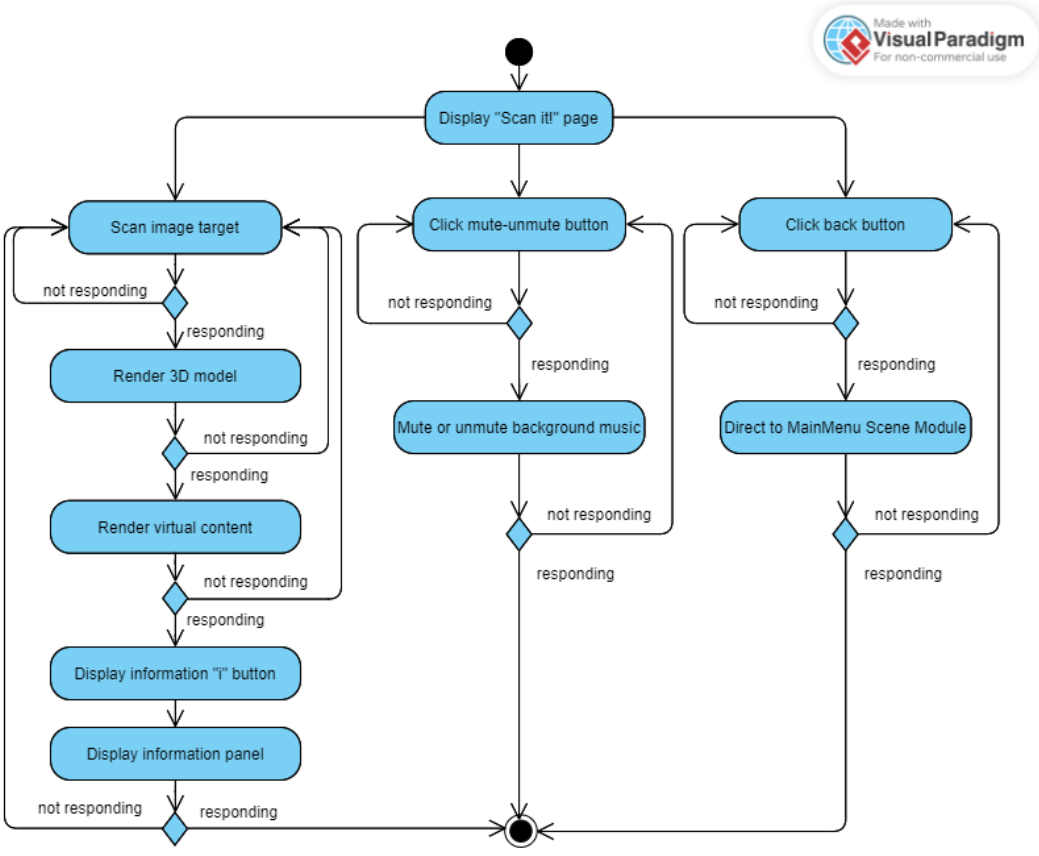


Figure 3.1.3.3 ARScene activity diagram

Model Scene

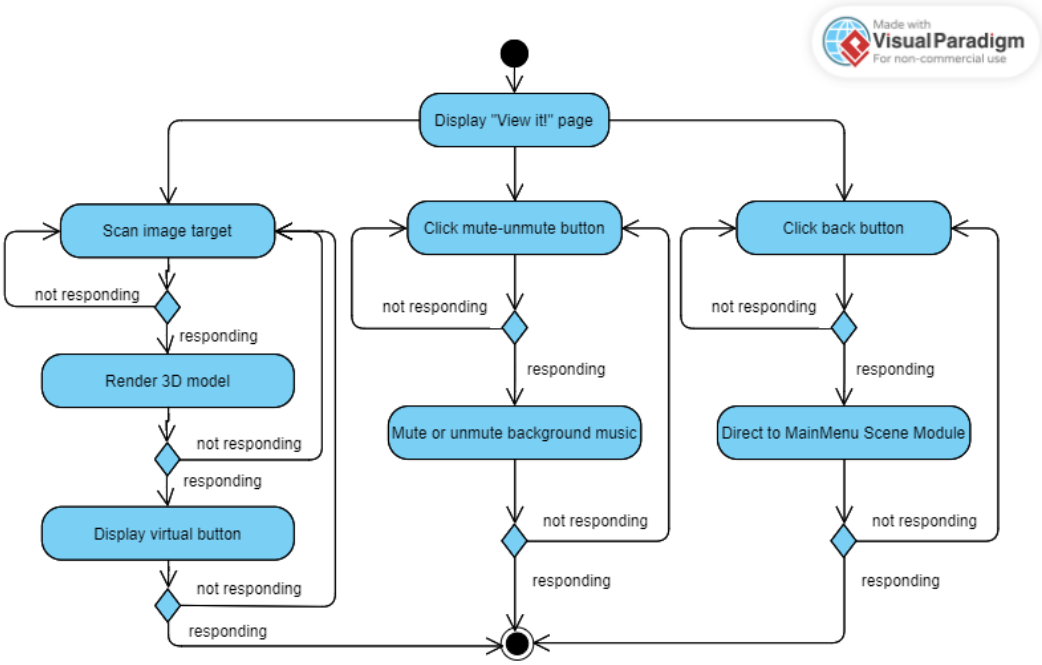


Figure 3.1.3.4 ModelScene activity diagram

3.1.4 System Flowchart

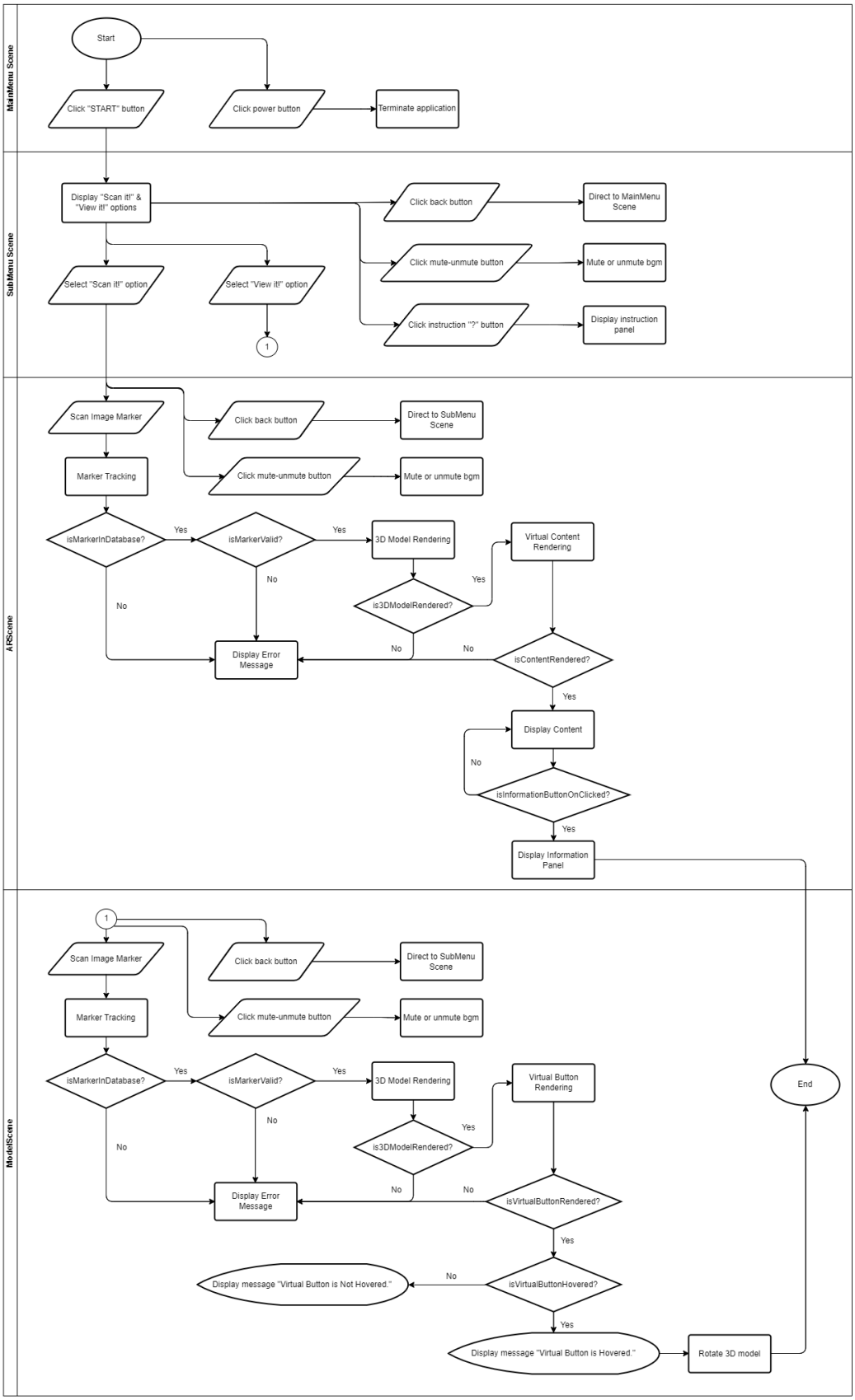


Figure 3.1.4 System flowchart

Chapter 4
System Design

4.1 System Block Diagram

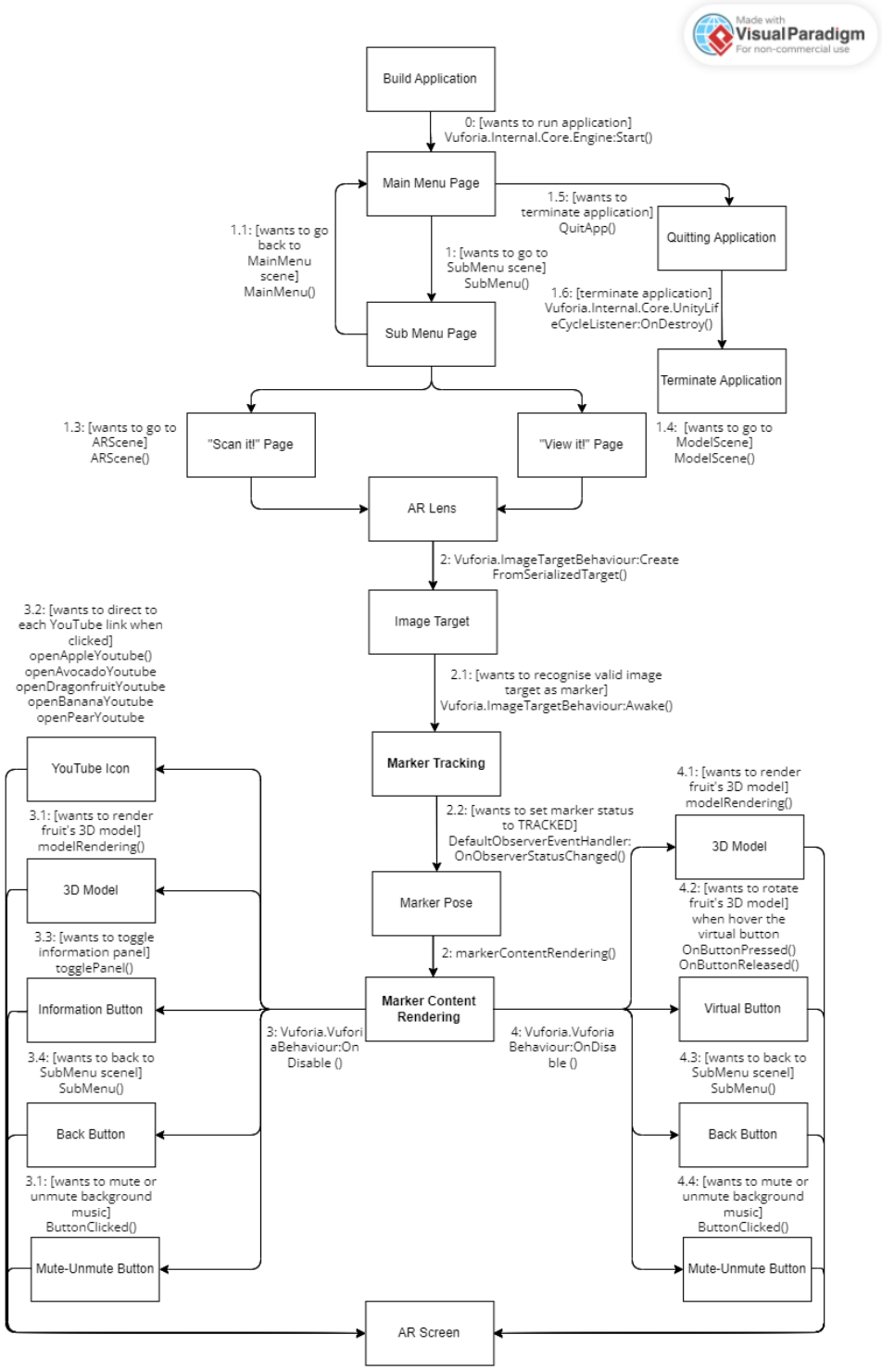


Figure 4.1 System block diagram

4.2 UI Wireframe Design

Main Menu

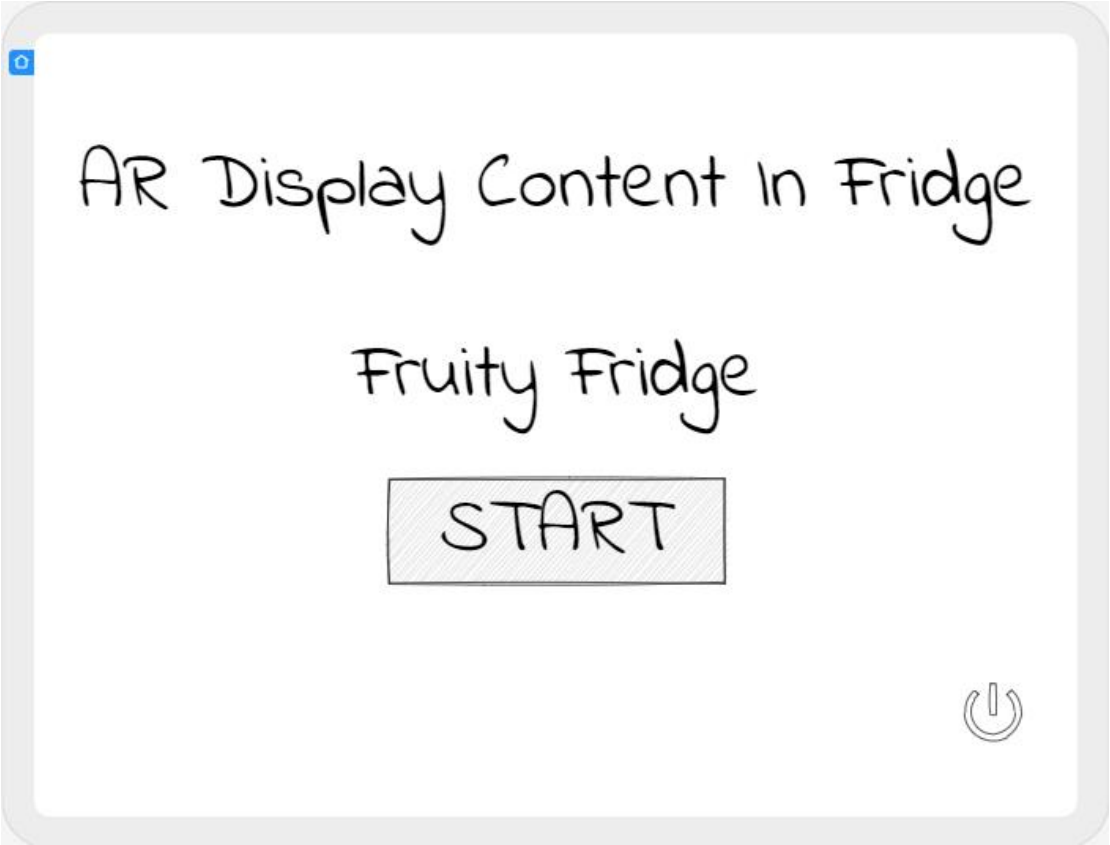


Figure 4.2.1 MainMenu UI wireframe design

Sub Menu

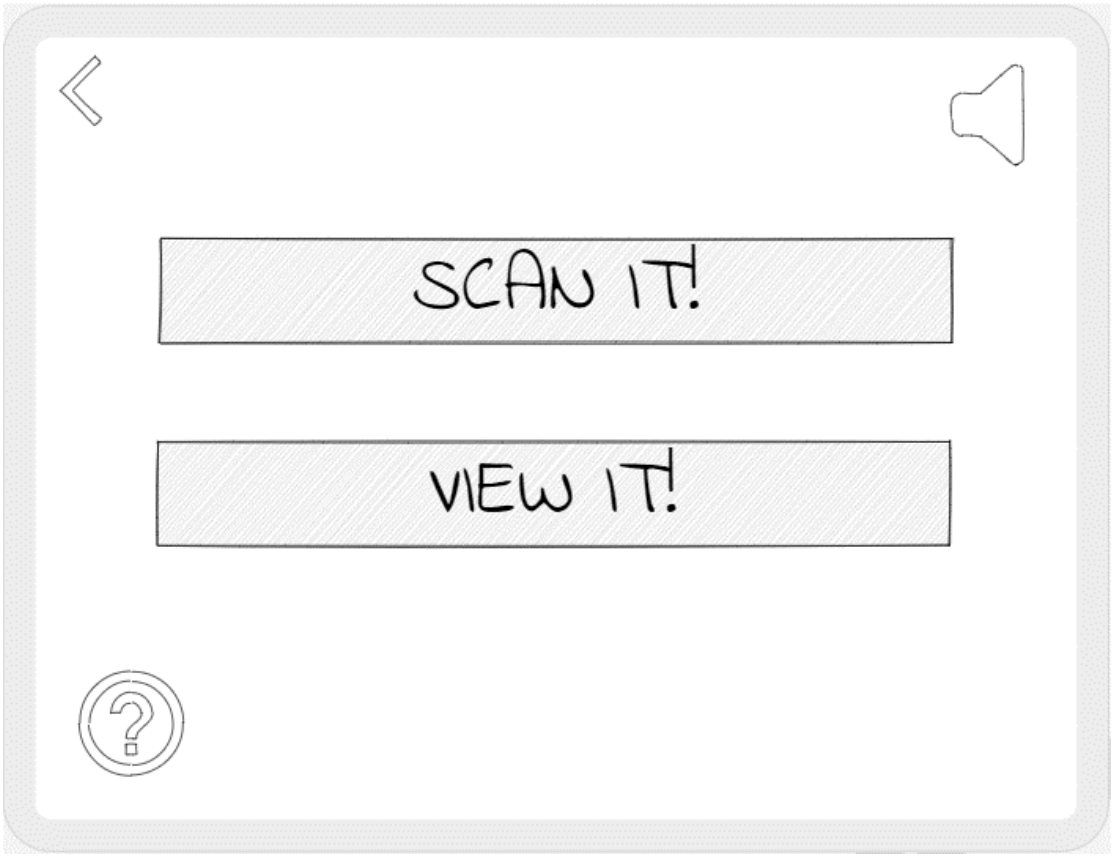


Figure 4.2.2 SubMenu UI wireframe design

Sub Menu – Instruction Panel

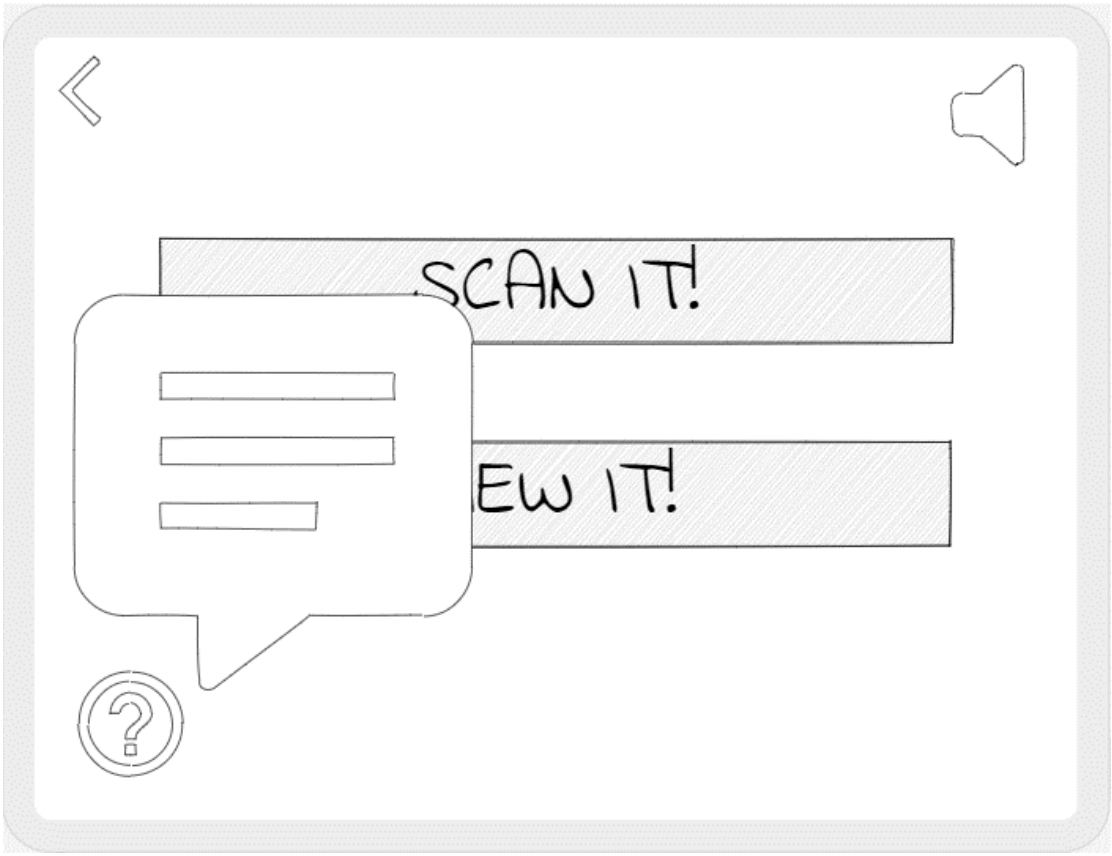


Figure 4.2.3 SubMenu instruction panel UI wireframe design

ARScene

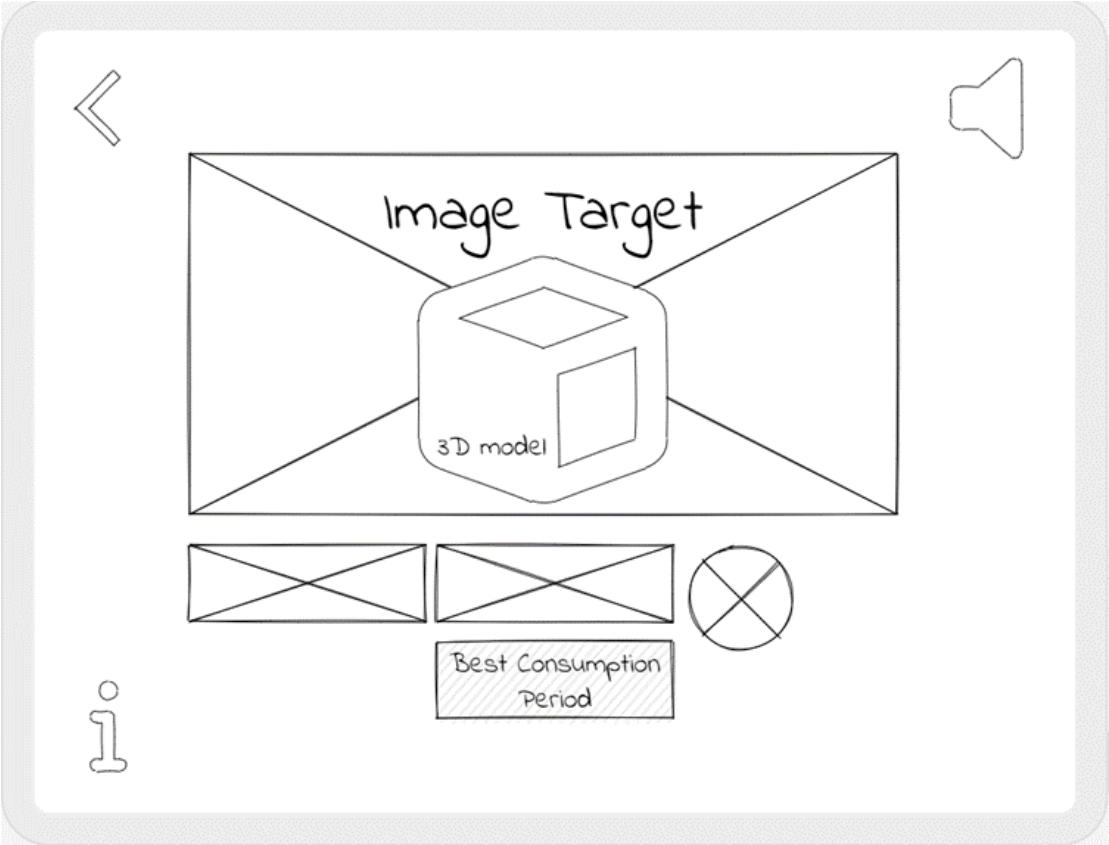


Figure 4.2.4 ARScene UI wireframe design

ARScene – Information Panel

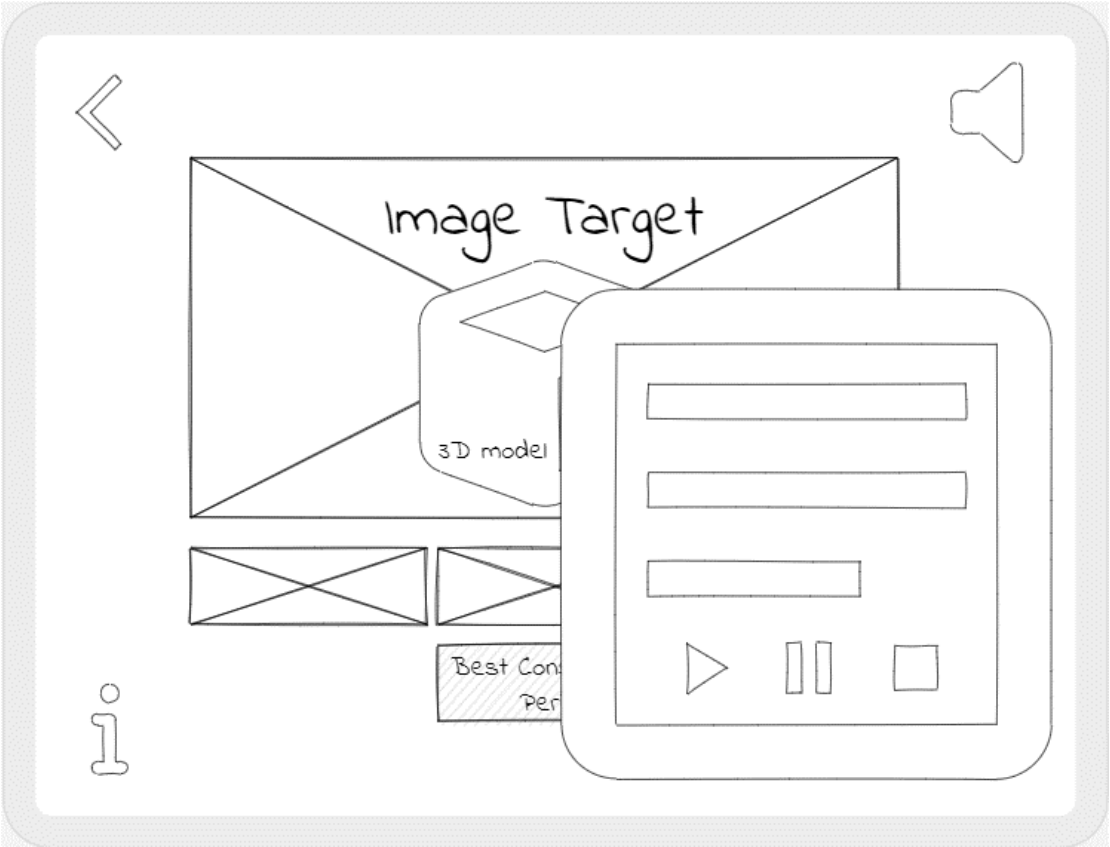


Figure 4.2.5 ARScene information panel UI wireframe design

ModelScene

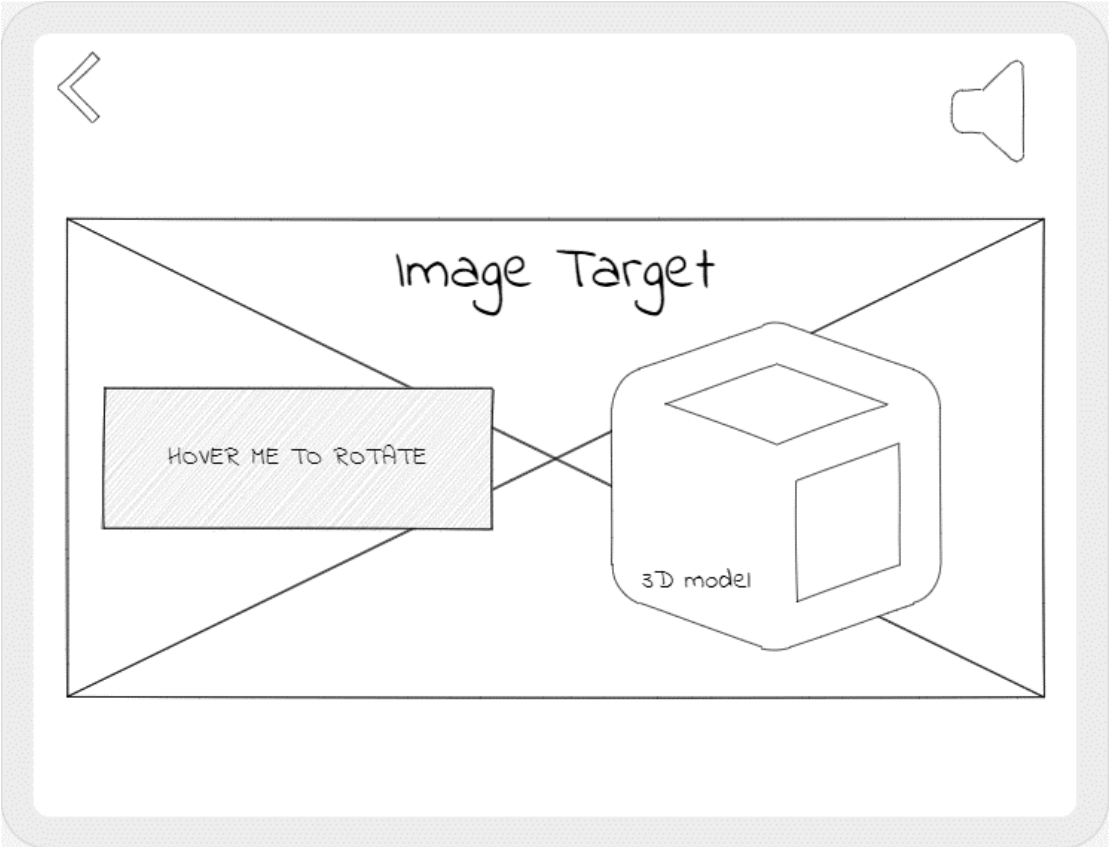


Figure 4.2.6 ModelScene UI wireframe design

4.3 3D Model Design

Apple 3D Model

Figure 4.3.1 Apple 3D model design diagram

- Website link: https://sketchfab.com/3d-models/apple-50ffb91434ea4d978eaefe03220d36fe#download
- Credits: "Apple" (https://skfb.ly/V9ry) by linfredriksson is licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/).

Avocado 3D Model

Figure 4.3.2 Avocado 3D model design diagram

- Website link: https://sketchfab.com/3d-models/avocado-4aa6b5d822204151805c3d2a423782a6#download
- Credits: "Avocado" (https://skfb.ly/6YJCH) by Qlone is licensed under Creative Commons Attribution-NoDerivs (http://creativecommons.org/licenses/by-nd/4.0/).

Banana 3D Model

Figure 4.3.3 Banana 3D model design diagram

- Website link: https://sketchfab.com/3d-models/peeled-banana-22-cad5da0a14ae43759cd9221dd6099bb9#download
- Credits: "Peeled Banana 22" (https://skfb.ly/6RpV7) by deep3dstudio is licensed under Creative Commons Attribution-NonCommercial (http://creativecommons.org/licenses/by-nc/4.0/).

Dragonfruit 3D Model

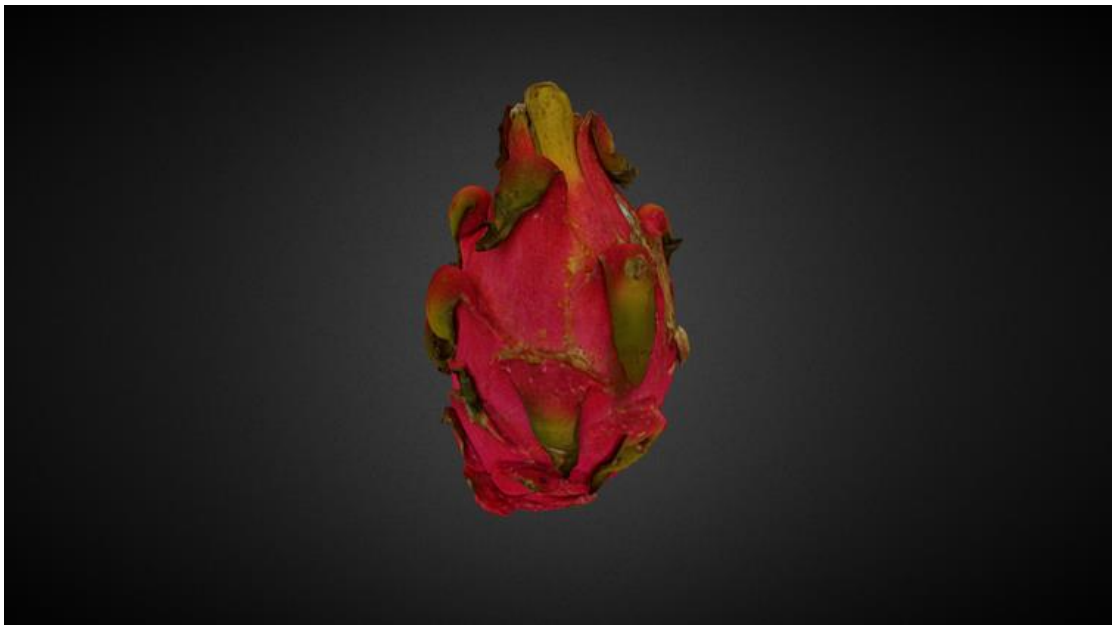


Figure 4.3.4 Dragonfruit 3D model design diagram

- Website link: https://sketchfab.com/3d-models/dragonfruitred-474f15d95dda403cac37f86f3e3d96d8#download
- Credits: "DragonFruit (Red)" (https://skfb.ly/ozJpS) by NAMAHAGE 120% is licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/).

Pear 3D Model

Figure 4.3.5 Pear 3D model design diagram

- Website link: https://sketchfab.com/3d-models/pear-fbecd3d497594041a5170e24d2d6bf40#download
- Credits: "Pear" (https://skfb.ly/V98o) by linfredriksson is licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/).

4.4 Scripts Architecture Breakdown

LinkManager.cs

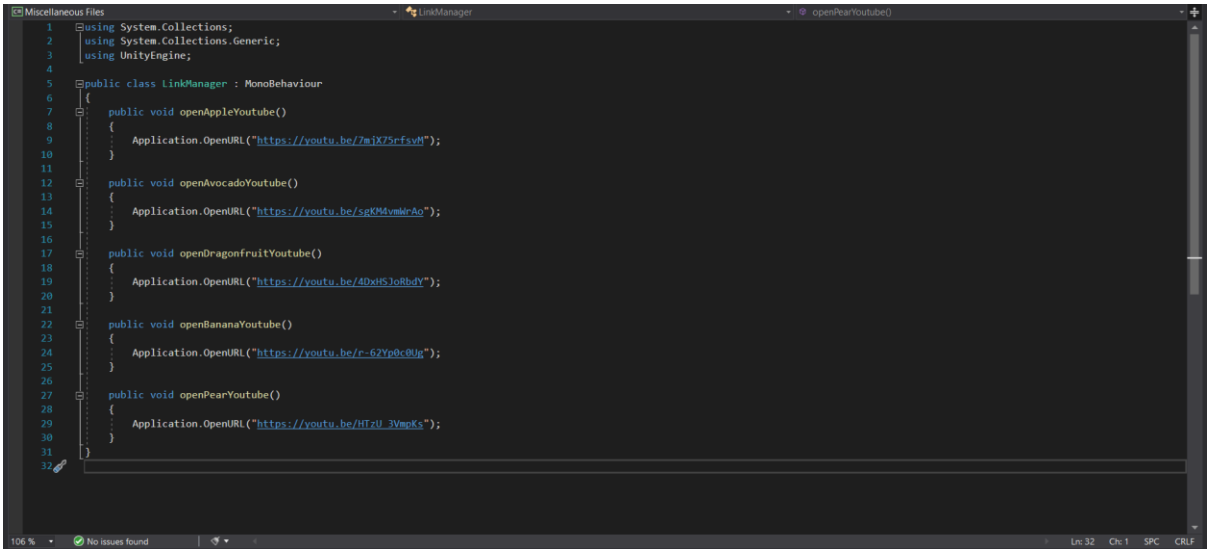


Figure 4.4.1 LinkManager.cs code design

- This script is built into each YouTube icon button to direct the user to the specified YouTube video. When the user clicks the button, the script then starts to execute its function to trigger the events.
- In C#, **Application.OpenURL("");** is a method that is used to open a specified URL in the default web browser of the system [20].

BGMController.cs

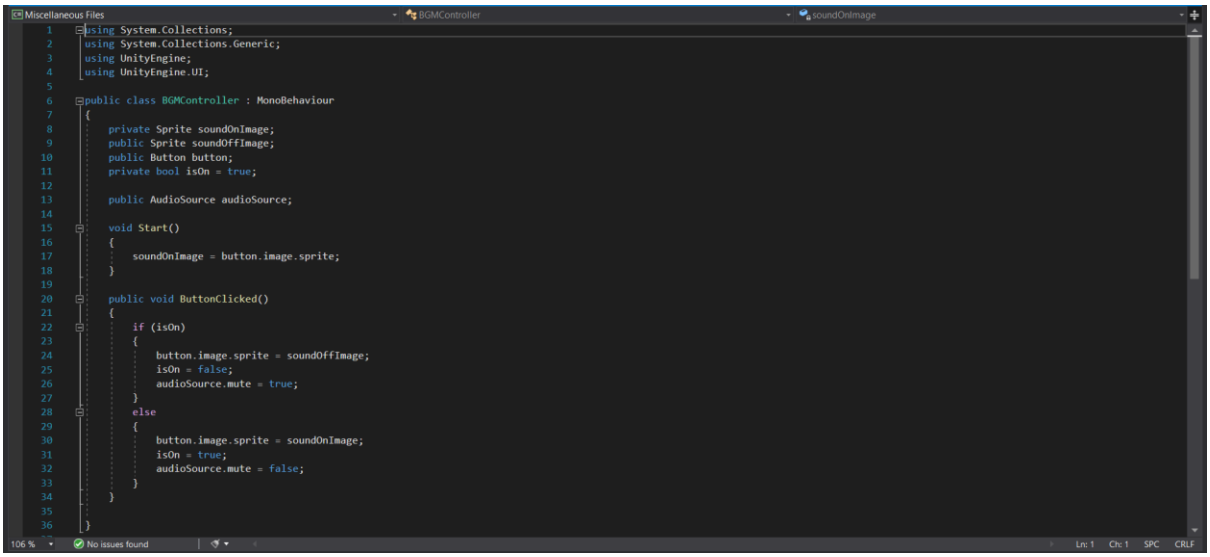


Figure 4.4.2 BGMController.cs code design

- This script is designed to display a 'sound off' image when the user clicks the mute-unmute button while muting the BGM. When the user clicks the mute-unmute button again, this script will execute again which will then display a "sound on" image replacing the image on the mute-unmute button.
- The namespace **UnityEngine.UI** scripting API is used in this script. It contains classes that are used to create and manipulate user interface elements in Unity applications, such as buttons, text fields, images, and sliders [21].
- The **button.image.sprite** property is also used to set the image displayed on a button component [22].

SubMenuController.cs

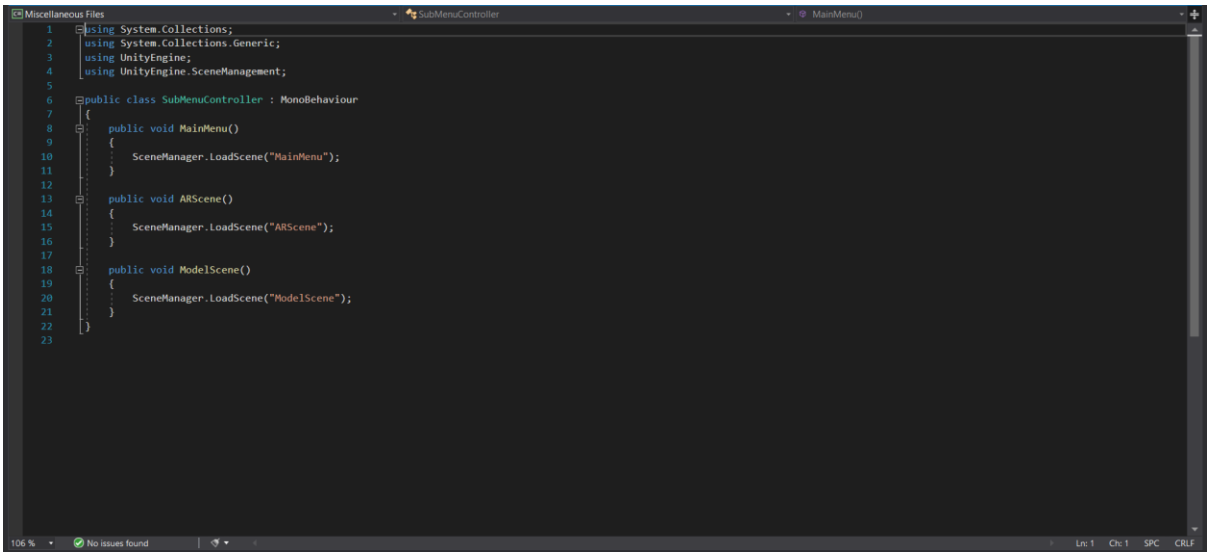


Figure 4.4.3 SubMenuController.cs code design

- This script is basically coded for SubMenu Scene for scene controlling.
- The namespace **UnityEngine.SceneManagement** scripting API is used in this script. It contains classes and methods for working with scenes in Unity, which are the individual levels or environments that make up a Unity application [23].
- **SceneManager.LoadScene(sceneName)** is called to load the specified scene. When this method is called, Unity will unload the current scene and load the new scene, effectively transitioning the player to a new environment [24].

SceneController.cs

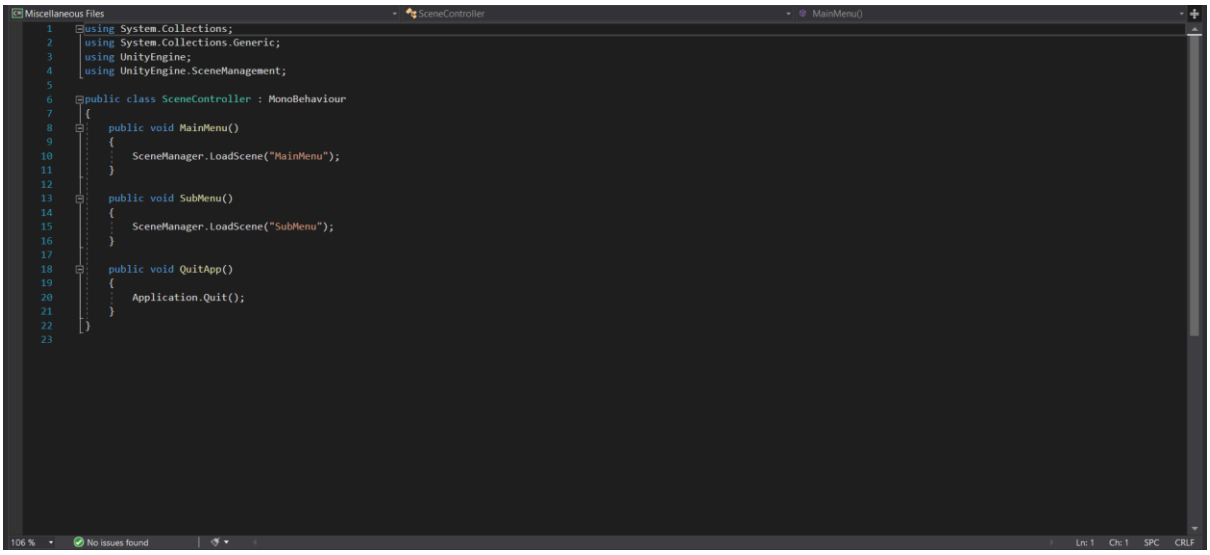


Figure 4.4.4 SceneController.cs code design

- This script is basically coded for MainMenu Scene for scene controlling.
- **Application.Quit()** is a method that can be called to quit the running application or game. In this case, it is used in a "Power" button that allows the user to exit the application [25].

VBRotate1.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Vuforia;

public class VBRotate1 : MonoBehaviour
{
    public GameObject vbBtnObject;
    public Animator modelAni;

    // Start is called before the first frame update
    void Start()
    {
        vbBtnObject = GameObject.Find("RotateVB1");
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonPressed(OnButtonPressed);
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonReleased(OnButtonReleased);

        modelAni.GetComponent<Animator>();
    }

    public void OnButtonPressed(VirtualButtonBehaviour vb)
    {
        modelAni.Play("Rotate2Anims");
        Debug.Log("Virtual button is HOVERED");
    }

    public void OnButtonReleased(VirtualButtonBehaviour vb)
    {
        modelAni.Play("none");
        Debug.Log("Virtual button is NOT HOVERED");
    }
}
```

Figure 4.4.5 VBRotate1.cs code design

- This script is specifically designed for the rotation function of dragonfruit's 3D model.

VBRotateNEW.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Vuforia;

public class VBRotateNEW : MonoBehaviour
{
    public GameObject vbBtnObject;
    public Animator modelAni;

    // Start is called before the first frame update
    void Start()
    {
        vbBtnObject = GameObject.Find("RotateVBNew");
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonPressed(OnButtonPressed);
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonReleased(OnButtonReleased);

        modelAni.GetComponent<Animator>();
    }

    public void OnButtonPressed(VirtualButtonBehaviour vb)
    {
        modelAni.Play("RotateNewAnims");
        Debug.Log("Virtual button is HOVERED");
    }

    public void OnButtonReleased(VirtualButtonBehaviour vb)
    {
        modelAni.Play("none");
        Debug.Log("Virtual button is NOT HOVERED");
    }
}
```

Figure 4.4.6 VBRotateNEW.cs code design

- This script is specifically designed for the rotation function of apple's 3D model.

VBRotateAvo.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Vuforia;

public class VBRotateAvo : MonoBehaviour
{
    public GameObject vbBtnObject;
    public Animator modelAni;

    // Start is called before the first frame update
    void Start()
    {
        vbBtnObject = GameObject.Find("RotateVBAvo");
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonPressed(OnButtonPressed);
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonReleased(OnButtonReleased);

        modelAni.GetComponent<Animator>();
    }

    public void OnButtonPressed(VirtualButtonBehaviour vb)
    {
        modelAni.Play("RotateNewAnims");
        Debug.Log("Virtual button is HOVERED");
    }

    public void OnButtonReleased(VirtualButtonBehaviour vb)
    {
        modelAni.Play("none");
        Debug.Log("Virtual button is NOT HOVERED");
    }
}
```

Figure 4.4.7 VBRotateAvo.cs code design

- This script is specifically designed for the rotation function of avocado's 3D model.

VBRotateBan.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Vuforia;

public class VBRotateBan : MonoBehaviour
{
    public GameObject vbBtnObject;
    public Animator modelAni;

    // Start is called before the first frame update
    void Start()
    {
        vbBtnObject = GameObject.Find("RotateVBBan");
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonPressed(OnButtonPressed);
        vbBtnObject.GetComponent<VirtualButtonBehaviour>().RegisterOnButtonReleased(OnButtonReleased);

        modelAni.GetComponent<Animator>();
    }

    public void OnButtonPressed(VirtualButtonBehaviour vb)
    {
        modelAni.Play("RotateBanAnims");
        Debug.Log("Virtual button is HOVERED");
    }

    public void OnButtonReleased(VirtualButtonBehaviour vb)
    {
        modelAni.Play("none");
        Debug.Log("Virtual button is NOT HOVERED");
    }
}
```

Figure 4.4.8 VBRotateBan.cs code design

- This script is specifically designed for the rotation function of banana's 3D model.

VBRotatePear.cs

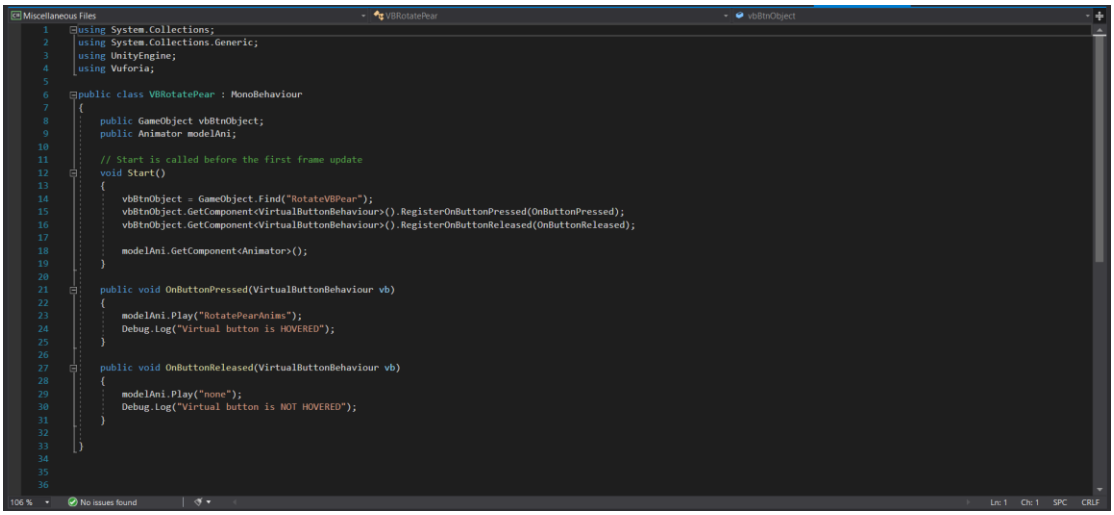
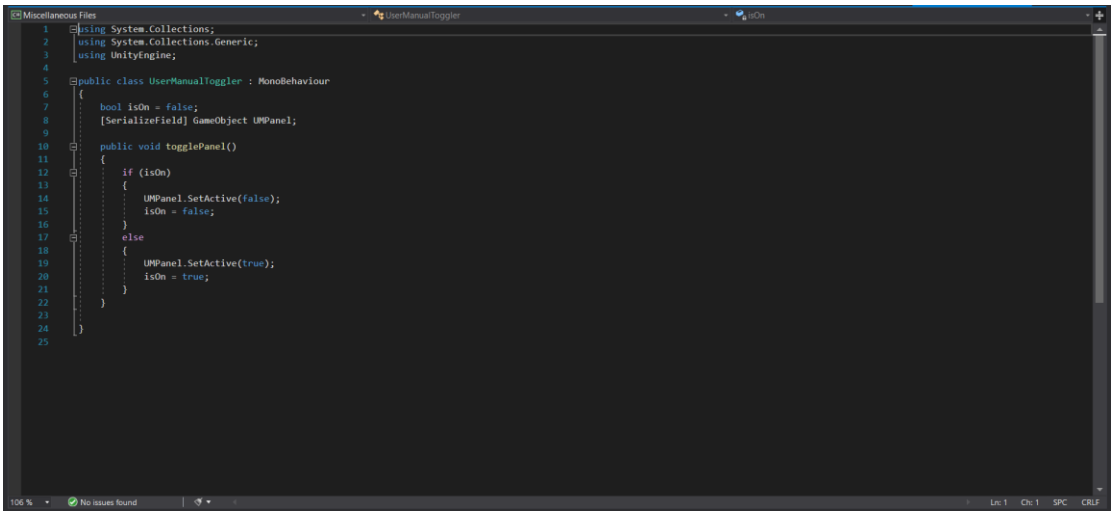


Figure 4.4.9 VBRotatePear.cs code design

- This script is specifically designed for the rotation function of pear's 3D model.
- The five "VBRotate" series scripts above are designed to rotate their respective 3D models when the user hovers over the visual buttons.
- The **Vuforia** namespace is used in the above scripts, it is a namespace that provides access to the Vuforia Engine, which is a software platform that enables developers to create augmented reality (AR) applications for mobile devices and digital eyewear [26].

UserManualToggler.cs

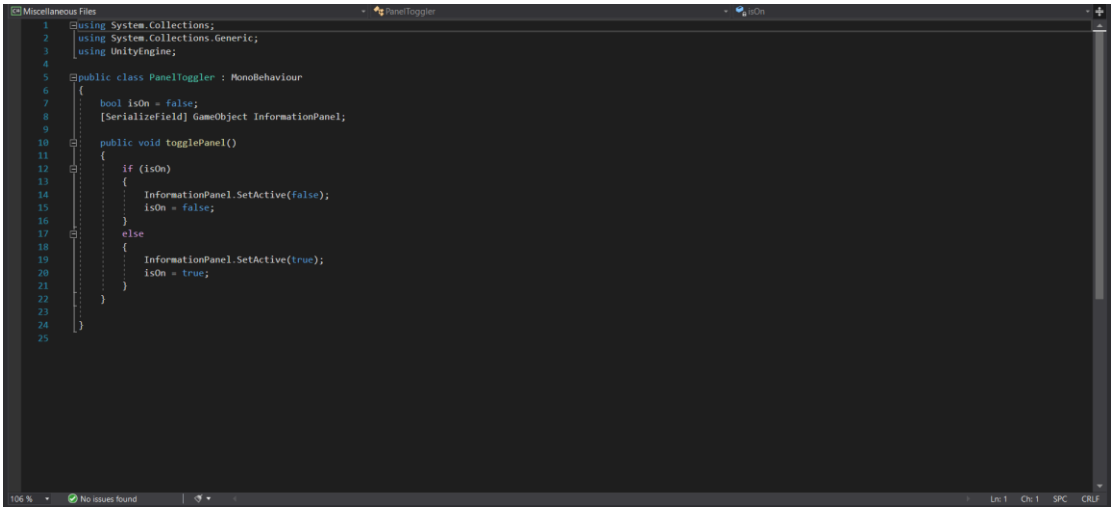


```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class UserManualToggler : MonoBehaviour
{
    bool isOn = false;
    [SerializeField] GameObject UMPanel;

    public void togglePanel()
    {
        if (isOn)
        {
            UMPanel.SetActive(false);
            isOn = false;
        }
        else
        {
            UMPanel.SetActive(true);
            isOn = true;
        }
    }
}
```

Figure 4.4.10 UserManualToggler.cs code design

- This script is specifically designed for the toggling function of the User Manual panel in the SubMenu scene. The field being marked is a **GameObject** named **UMPanel**.

PanelToggler.cs



```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class PanelToggler : MonoBehaviour
{
    bool isOn = false;
    [SerializeField] GameObject InformationPanel;

    public void togglePanel()
    {
        if (isOn)
        {
            InformationPanel.SetActive(false);
            isOn = false;
        }
        else
        {
            InformationPanel.SetActive(true);
            isOn = true;
        }
    }
}
```

Figure 4.4.11 PanelToggler.cs code design

- This script is specifically designed for the toggling function of the Information panel in the ARScene. The field being marked is a **GameObject** named **InformationPanel**.
- **[SerializeField]** is used in the scripts, it is an attribute that can be applied to a field or property to indicate that it should be serialised by Unity's serialisation system [27].

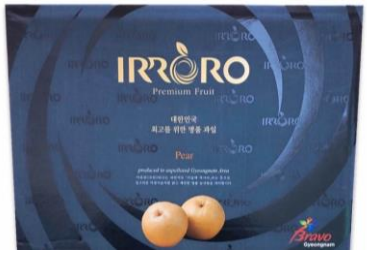
4.5 Application Logo Design

Figure 4.5 ADCIF logo

- It is designed by using Canva.com, while Canva.com is an online platform that provides users with tools to design various visual content like presentations, logos, posters, social media graphics and other graphic designs.
- ADCIF represents “AR Display Content in Fridge”.
- The name Fruity Fridge is a combination of two words: "fruity" which means relating to or resembling fruit, and "fridge" which refers to a refrigerator. The name also reflects the fun and playful nature of the application, which is intended to engage children while also being informative for adults.
- In terms of the colour that are adopted in this logo design, the colour code #FCD8C9 “Pastel Orange” is chosen for the text and colour code #FFFBE2 “Pale Canary” is picked up for the backdrop.

4.6 Data Set

Table 4.6 Data set used in application

Food Packaging Image	Description
	Brand: China Red Fuji **Item Name:** Apple **Resource:** https://yayapapaya.com.sg/shop/Fuji-Red-Apple-Carton-China
	Brand: Westfalia Fruit **Item Name:** Avocado **Resource:** https://www.andnowuknow.com/buyside-news/westfalia-fruit-launches-new-sustainable-packaging-france-johnathan-sutton/chandler-james/77945
	Brand: Del Monte **Item Name:** Banana **Resource:** https://www.delmonte-asia.com.sg/new-products
	Brand: Bai Tong **Item Name:** Dragonfruit **Resource:** https://bahamas.desertcart.com/products/35182421-2-packs-of-dragon-fruit-preserved-pitaya-125-g-pack-premium-snack-from-thailand
	**Brand:** IRRORO **Item Name:** Pear **Resource:** https://momobud.sg/product/premium-irroro-korean-singo-pear-gift-set/

Chapter 5
System Implementation

5.1 Hardware Setup

The hardware involved in this project is a laptop and an Android device. A laptop is issued for the backend workloads such as programming of codes, and to obtain the 3D model objects, then it is also used for applying the AR technology on the 3D models. While an Android mobile phone device is issued for the testing and deploying of this proposed AR application.

Table 5.1.1 Specifications of laptop

Description	Specifications
Manufacturer	Hp
Model	Victus 16-d0xxx
Processor	11th Gen Intel Core i5-11400H
Operating System	Windows 11 Home Single Language
Graphic	NVIDIA GeForce RTX 3050 Ti
Memory	8GB SODIMM RAM
System Type	64-bit operating system, x64-based processor

Table 5.1.2 Specifications of Android device

Description	Specifications
Manufacturer	Huawei
Model	Huawei Nova 7i
Software version	Android 10, EMUI 10, no GMS
RAM and storage	128GB 8GB RAM
CPU	Octa-core (2x2.27 GHz Cortex-A76 & 6x1.88 GHz Cortex-A55)
GPU	Mali- G52 MP6
Sensors	Fingerprint (side-mounted), accelerometer, proximity, compass

5.2 Software Setup

Before commencing the development of the AR Display Content in Fridge Application, the two most important and relevant pieces of software need to be installed and thereafter to be utilised in the specified laptop and browser:

1. Unity Hub 2.4.5 [16]

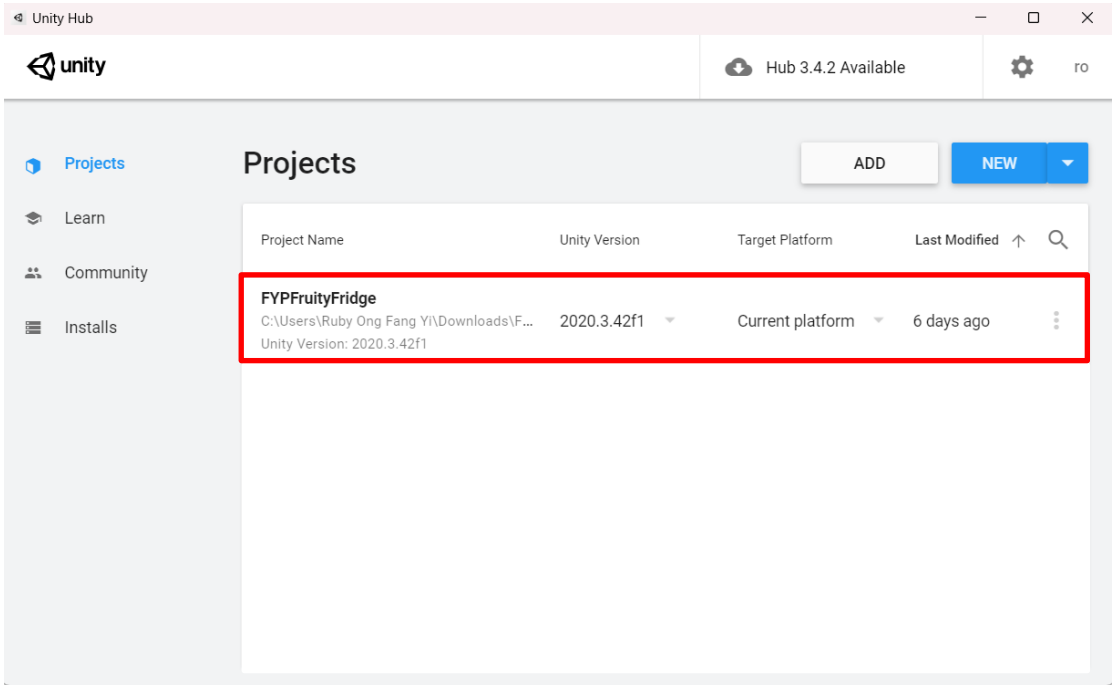


Figure 5.2.1 Unity hub installed

2. Vuforia Engine (SDK, website version) [17]

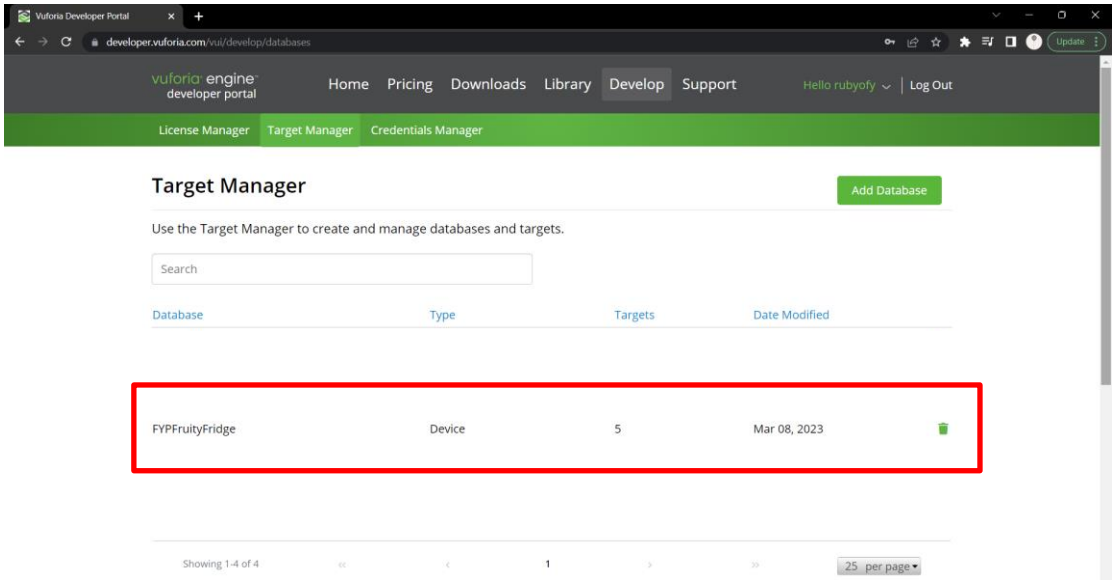


Figure 5.2.2 Vuforia website version

5.3 Setting and Configuration

Unity Version: Unity 2020.3.42f1 [32]

- Unity 2020.3.42f1 is a Long Term Service (LTS) version and it is installed from the Unity Hub 2.4.5.
- Due to the stability and reliability of this application is prioritised. Thus, in terms of stability, Unity 2020.3.42f1 has been available for a longer time and has had more time to be tested and stabilised, which means it is less likely to have bugs or compatibility issues.

Unity Extension: LeanTouch [31]

- LeanTouch is a free touch-screen input library that can be found in the Unity3D asset store.
- It allows game developers to easily implement touch controls for their games on mobile devices. LeanTouch provides a range of touch input functions, including tapping, swiping, pinching, and rotating. It also includes advanced touch input features such as multi-touch, inertia, and velocity.
- LeanTouch as an Unity3D extension is designed to be lightweight and fast, making it ideal for mobile game development. It also supports both 2D and 3D games and includes a range of demos and examples to help developers get started.

3D Model Resource: Sketchfab.com [30]

- Sketchfab.com is a platform that allows users to discover, share, and publish 3D content online. It provides a 3D model viewer that can be embedded on websites, and users can upload their 3D models and showcase them in real-time 3D on the web.
- Sketchfab.com also supports a wide range of 3D file formats and provides tools for editing, optimising, and annotating 3D models. It is used by a variety of industries, including gaming, architecture, education, and e-commerce, to highlight, and share 3D content.

3D Model File Format: .obj [29]

- OBJ (or .obj) is a file format used for storing 3D models.
- It is able to store information about the 3D geometry of a model, including its vertices, edges, faces, and texture coordinates. As well as including the information about the materials used in the model, such as textures and colours.
- It is adopted in this project for storing and sharing 3D models due to its wide compatibility, simplicity, and support for texture mapping.

Vuforia Engine Licensing:

- ARSPacr/////AAABmb6u/kiS70IQtaf13+ytA5KKJln4XxS6rSSwX6igO8rGXJQxz/CdzRC/G/+qGbU2XglAB7dRxaJGOAdBa8+htpuaTFhH7BL5d1hnZguXZ07zb6gkUhZIx1yqWfeel8E88P6xtMuxObaBeW/Ry548Vm5/993AhEh1r/JsHF6Mg8Z1Fe2CSt/Cgp7l9x4lXoGZDoG1bICw7No0+ndIGv8+SQmnfGgcT3JFXpu/hltPZ10s/QRQ892wvrnxQb0aschM7XlDQouXFlk9typnPJhQyZrQADBcvHGyTYP40yxYcNBb5OzMOC0ff4BjiWeVReW9nD1FlfJXj6zyuEwtH+7DXw8XYdMvstMFBPh9lrEMyjax

5.4 System Operation

The following is the step-by-step details of using the AR Display Content in Fridge application:

1. Pressing the logo of ADCIF application.

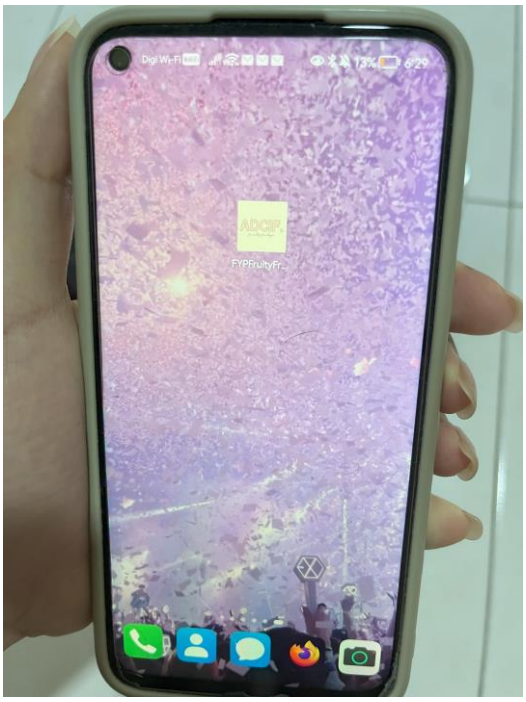


Figure 5.4.1 Launching ADCIF application

2. Loading the application.

Figure 5.4.2 ADCIF loading page

3. Directed to the main menu page.

Figure 5.4.3 ADCIF main menu page

4. Pressing the ‘START’ button.

Figure 5.4.4 ADCIF start button

5. Directed to sub menu page.

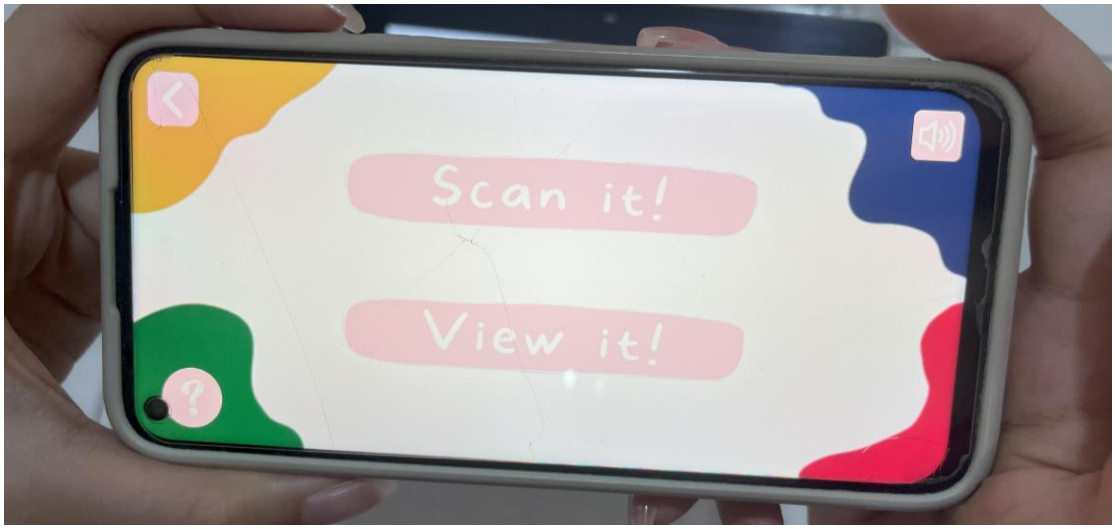


Figure 5.4.5 ADCIF sub menu page

6. Pressing the instruction '?' button.

Figure 5.4.6 ADCIF instruction button

7. Pressing the mute-unmute button.

Figure 5.4.7 ADCIF mute-unmute button

8. Choosing the ‘Scan it!’ feature.

Figure 5.4.8 ADCIF ‘Scan it!’ button

9. Scanning the apple food packaging and being displayed by the virtual content.

Figure 5.4.9 ADCIF ‘Scan it!’ feature

10. Pressing the information ‘i’ button and retrieving of the information panel with Play, Pause, and Stop buttons on it.

Figure 5.4.10 ADCIF information panel

11. Pressing the displayed YouTube icon button.

Figure 5.4.11 ADCIF YouTube icon button

12. Being directed to a YouTube page.

Figure 5.4.12 ADCIF redirects to YouTube platform

13. Pressing the back button.

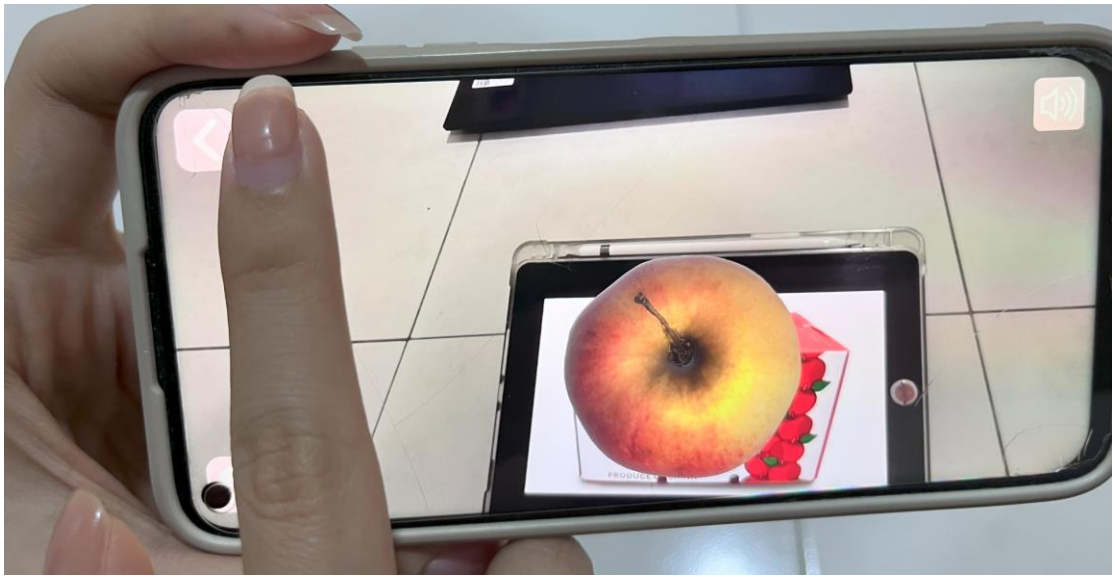


Figure 5.4.13 ADCIF back button

14. Choosing the ‘View it!’ feature.

Figure 5.4.14 ADCIF ‘View it!’ button

15. Scanning the apple food packaging and being displayed by the virtual content.

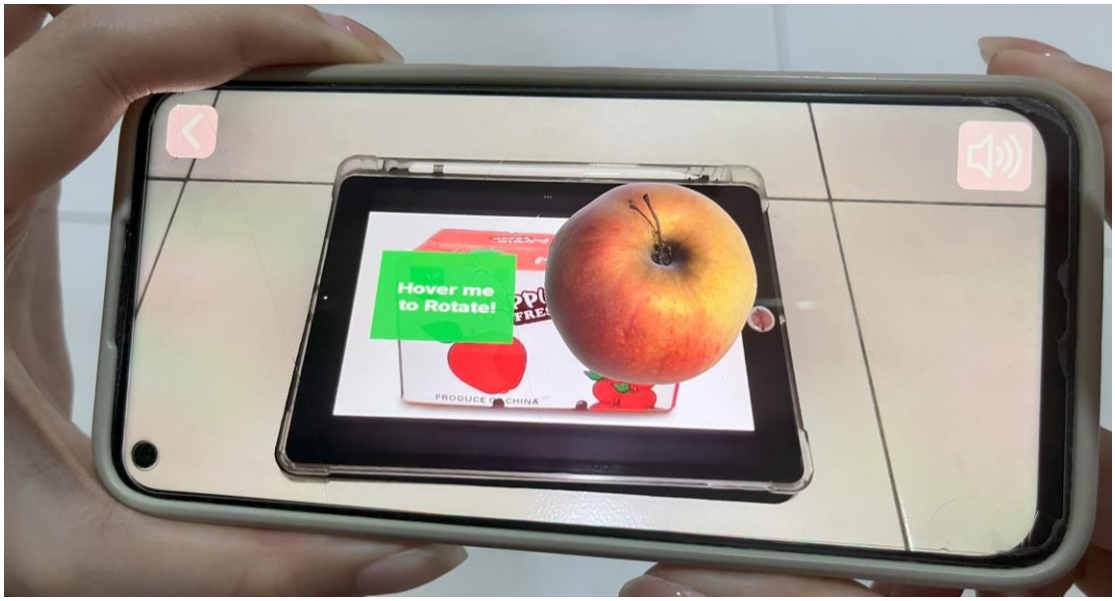


Figure 5.4.15 ADCIF ‘View it!’ feature

16. Hovering the virtual button and triggered the event to rotate the 3D model.

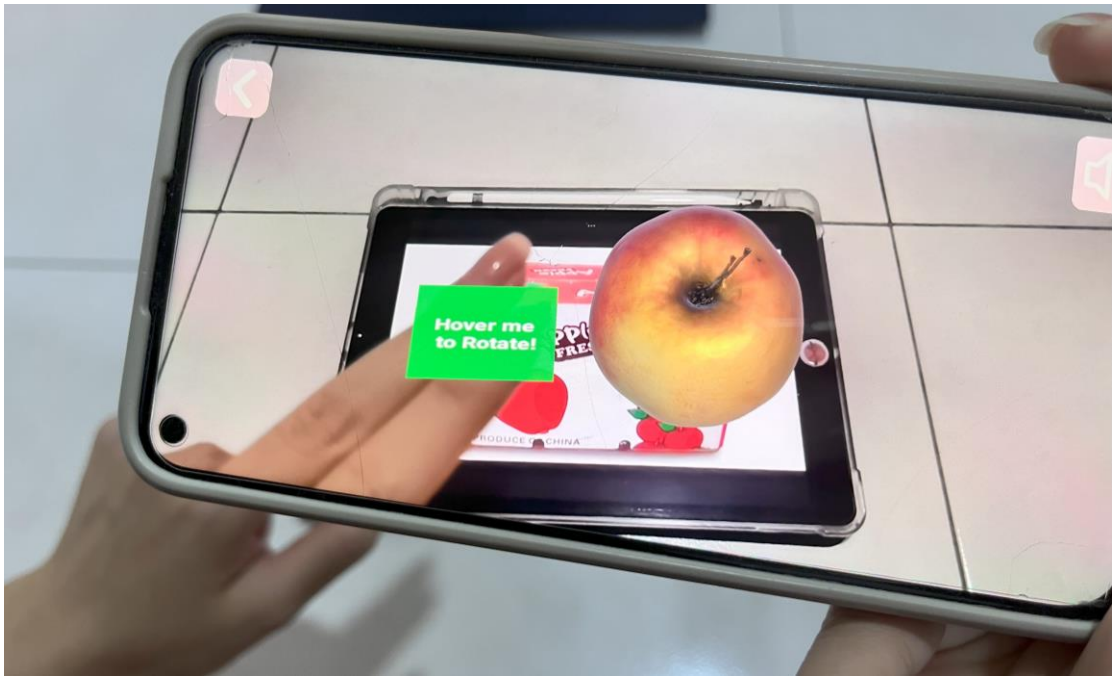


Figure 5.4.16 ADCIF hovering virtual button

17. Dragging the 3D model.

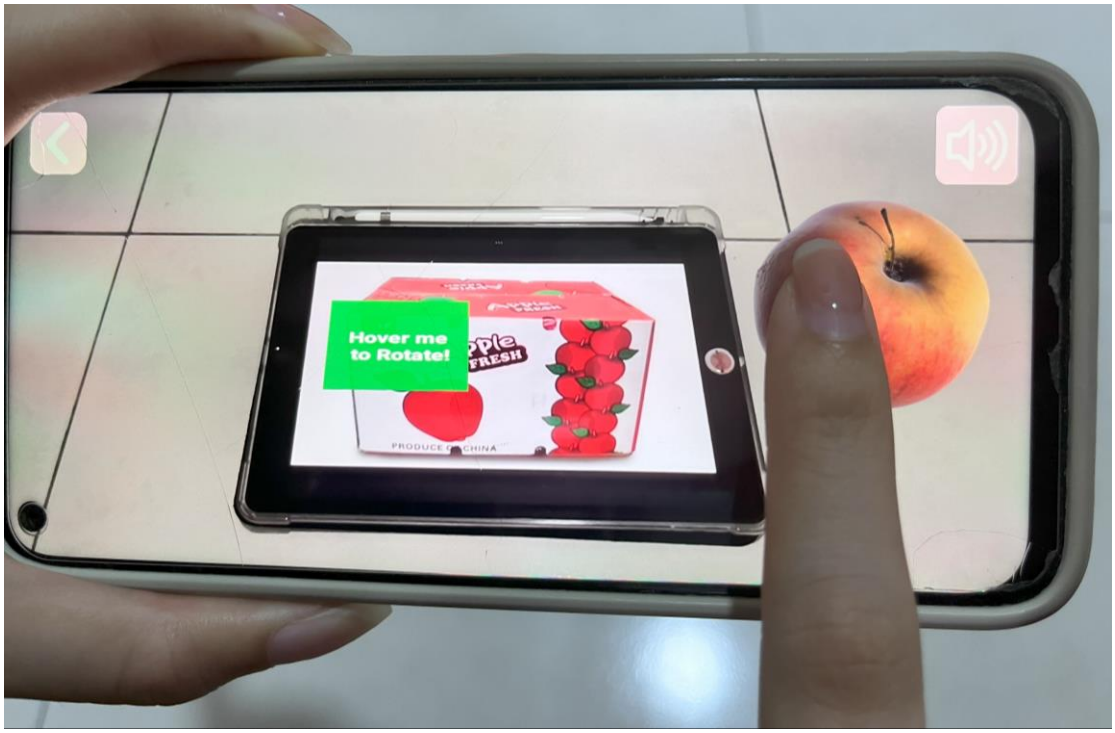


Figure 5.4.17 ADCIF drag interactive function

18. Scaling in 3D model.

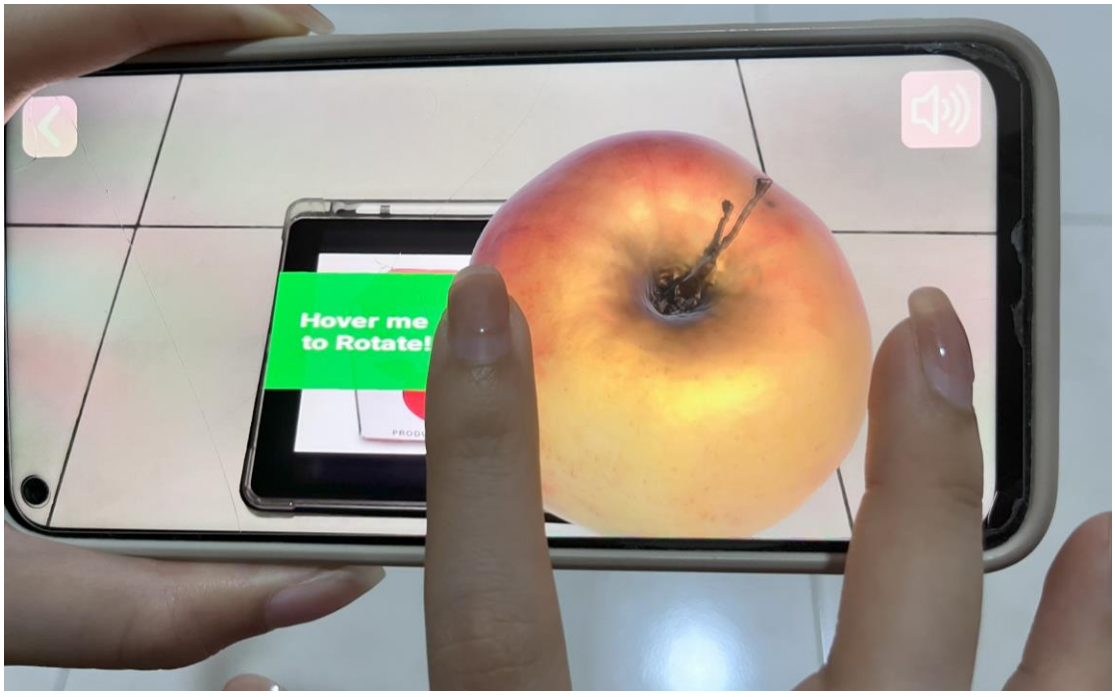


Figure 5.4.18 ADCIF scale in interactive function

19. Scaling out the 3D model.

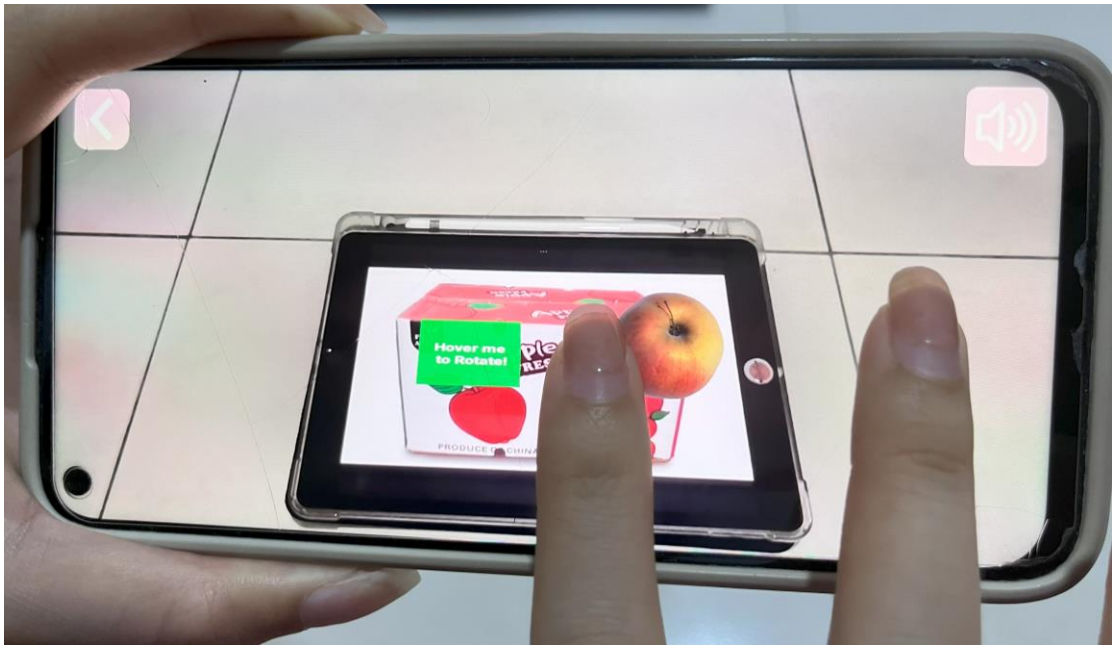


Figure 5.4.19 ADCIF scale out interactive function

20. Pressing the power button.

Figure 5.4.20 ADCIF power button

5.5 Implementation Issues and Challenges

The difficulty pinpointing the accurate placement of the virtual button is one of the implementation challenges experienced, as it needs to be situated in the specific area of the image target that Vuforia is using to identify and track. The sensitivity of the event triggered when the user hovers over the virtual button will be negligible if it is not placed in the correct area. In order to overcome this problem, the 'Show Features' in the Vuforia Target Manager is used to visualise and examine the feature points detected by Vuforia on the target image. This can help in optimising image target detection and tracking performance. By applying this feature, it can then be targeted accurately to the highest feature point set areas on the image. Therefore, the placement of the virtual button in that area ensures that the sensitivity of the virtual button is as high as possible.

It is also challenging to control the dimensions and complexity of 3D models. As some 3D models from online sources present unavoidable risks and potential problems in terms of scale, texture, appearance, and colour. For example, modelling errors, out of scale, unknown authorship and provenance, etc. In addition, as not all resources are reliable and trustworthy, some 3D models from online sources can be a malicious threat. When a faulty 3D model is implemented, errors may occur when the application is called into action to render the 3D model. This can lead to application build failures and can also lead to corrupted back-end operations. To address this challenge, the decision to leverage a credible and stable 3D model library was pursued after exploration. By downloading and using 3D models from Sketchfab.com, the sustainability and integrity of the 3D models can be ensured. It is worth noting that Sketchfab.com is a free online community that offers pre-built 3D models and textures. The LOD (Level of Detail) technology can be applied in the future in order to optimise the real-time rendering of 3D models and to dynamically adjust the LOD according to the distance to the camera [38].

Next, the difficulty in AR content creation. Since it is difficult and time-consuming in creating high-quality AR content, thus Unity built-in support is used to simplify the process of creating AR content. For example, LeanTouch extension is installed to allow the availability of touch-screen features in the proposed application. However, this is not enough to upgrade the application's features. Thus, more plugins and techniques such as TensorFlow and multiplayer networking. TensorFlow is is an algorithm of machine learning and AI that helps to optimise the accuracy of object recognition and tracking. With this algorithm, an object recognition feature can be developed and applied in the near future. Next, Multiplayer Networking High-Level API (HLAPI) is a built-in support of Unity3D [39]. This extension can help to create multiplayer AR experience, thus a gaming feature that is integrated by real-time multiplayer networking can be developed as well.

Lastly, the performance of the proposed application should be optimised as AR application will always need high performance and low latency to ensure seamless experience of user. This is particularly challenging on mobile devices with limited processing power and memory. Therefore, Vuforia's Augmented Reality Cloud can be utilised to overcome the memory side issues. By reducing the number of draw calls can also be helpful in addressing such issue.

5.6 Concluding Remark

In conclusion, this chapter provides a discussion of the key components of implementing a successful AR application, which include hardware setup, software setup, setting and configuration, as well as system operation. The importance of each component in ensuring optimal application performance and functionality is highlighted and explained. Crucially anyway, several challenges remain in developing an augmented reality application, including the difficulty of placing virtual buttons, managing the size and complexity of 3D models, and creating high quality AR content.

To overcome these challenges, the " Show Features " tool in Vuforia Target Manager can be used to optimise image target detection, a reliable and stable 3D model library like Sketchfab.com can be used to ensure security and reliability, and built-in support like the LeanTouch extension can be installed to simplify the AR content creation process. In addition, the performance of the proposed application can be optimised by utilising Vuforia's Augmented Reality Cloud and reducing the number of draw calls. By implementing these solutions, the proposed AR application can provide a seamless and premium user experience.

Chapter 6
System Evaluation and Discussion

6.1 System Testing and Performance Metrics

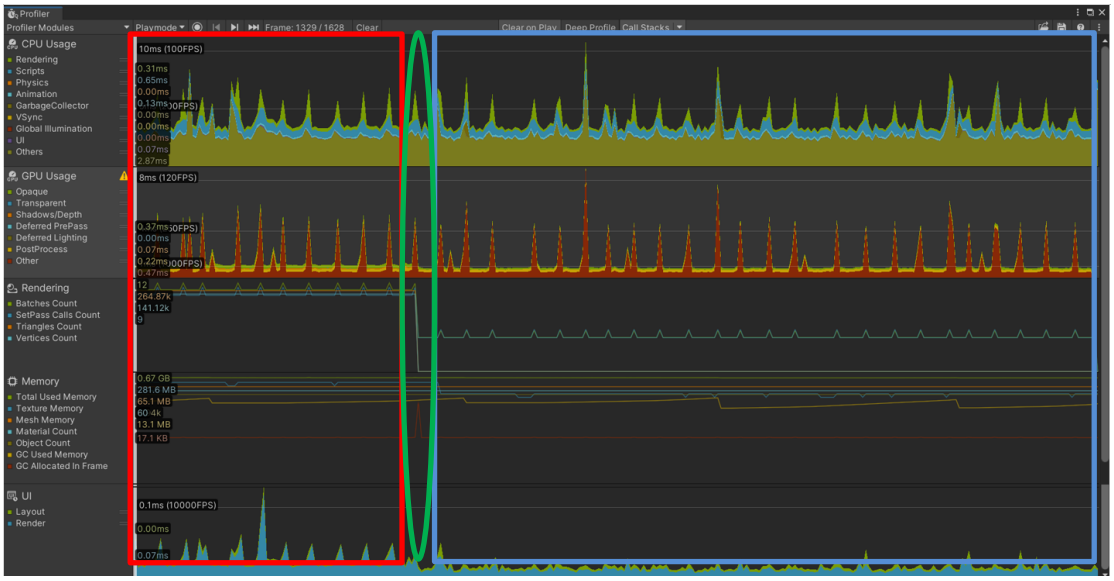


Figure 6.1.1 Full profiler result

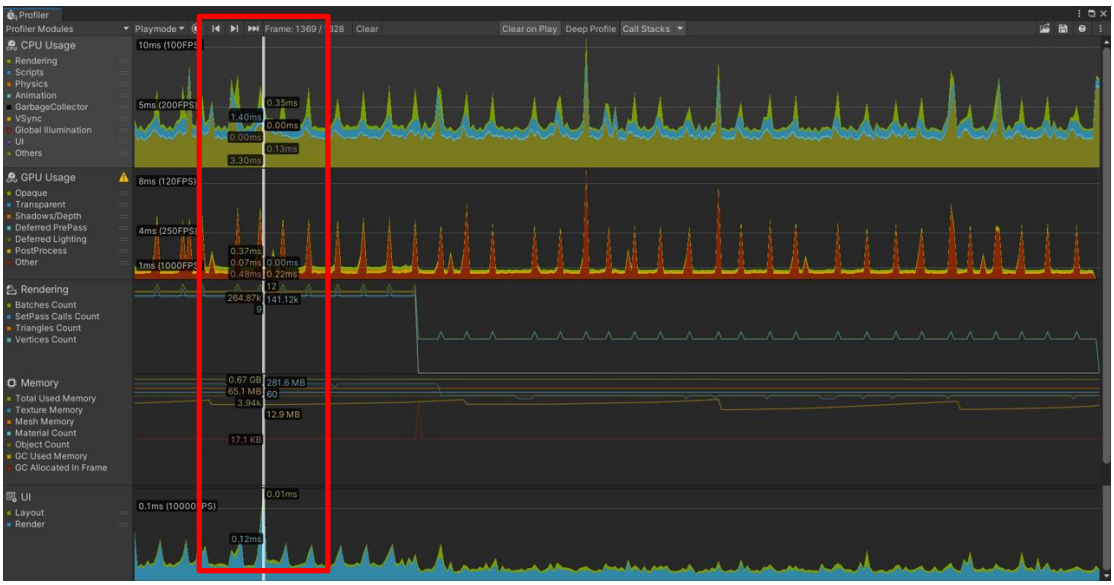


Figure 6.1.2 Profiler result when showing image marker

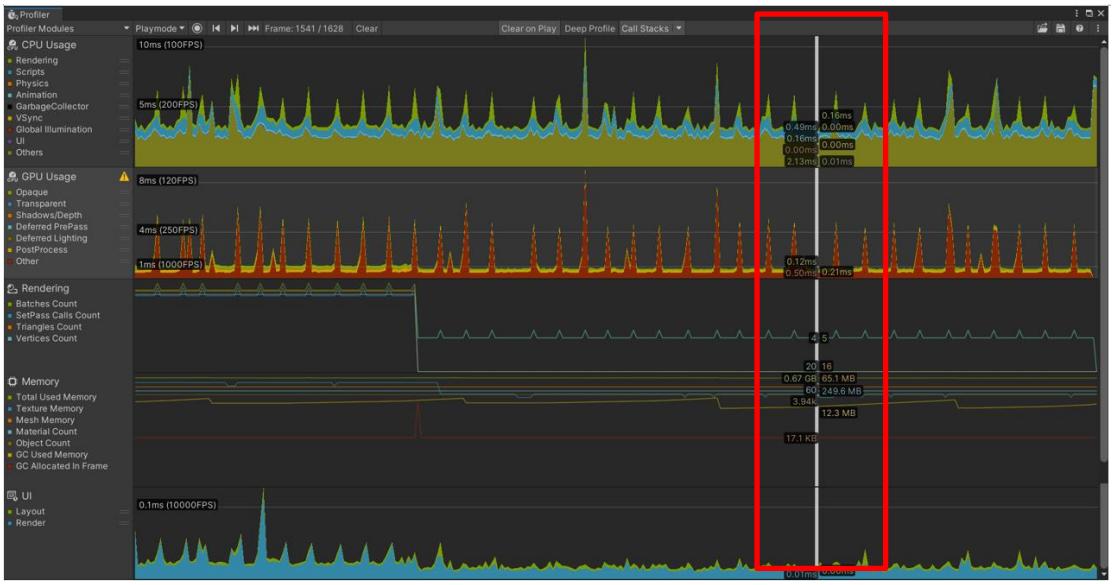


Figure 6.1.3 Full profiler result when not showing image marker

In this project, Unity3D's in-app Profiler is utilised, it is a performance metrics tool that can be helpful in performing a thorough and accurate system testing. The profiler modules that are considered in this performance checking is the CPU usage, GPU usage, Rendering, Memory, and UI. The performance data about this AR application is therefore being tested, recorded, and then gathered to generate an analysis report to examine the performance information.

The CPU Usage Module is one of the most important performance metrics that reflects the overall performance of all CPU-processed tasks in the game. Areas such as PlayerLoop, Update.ScriptRunBehaviourUpdate, BehaviourUpdate, etc. can all affect the CPU utilisation [34]. Following by the GPU Usage Module that is used for measuring the performance of the graphics processing unit (GPU) during the rendering of Unity projects. It provides information on various GPU-related metrics, including rendering time, memory usage, shader complexity, and draw calls [35].

Next, The Rendering Module shows the amount of time expended on rendering the game graphics, including the number of draw calls, the number of triangles, and the duration spent on the CPU and GPU [36]. Additionally, the Memory Module delivers insights into the game's memory usage, including the size of the heap, the number of objects being instantiated, and the memory usage of individual assets and scripts [37]. Besides that, the UI Module reveals a breakdown of hours spent on interpreting the

game's user interface, including the quantity of layout computations and the timing of updating and rendering UI elements [33].

In the case of this profiler result, the 1369th time frame in 1628 refers to one of the time points that is framed when the image marker is scanned by the application, while the 1541st time frame in 1628 refers to one of the time points that is framed when the image marker is moved away from the scanning of the AR lens.

In Figure 6.1.1, there are three areas zoned by different colours. The area in red is the time frames when the image marker is being scanned, while the area in blue is when the image marker is no longer being scanned. The green area is the moment when the image marker is removed from the device's camera, which is the moment when the modules attain a rapid and extreme shift.

CPU Usage Module

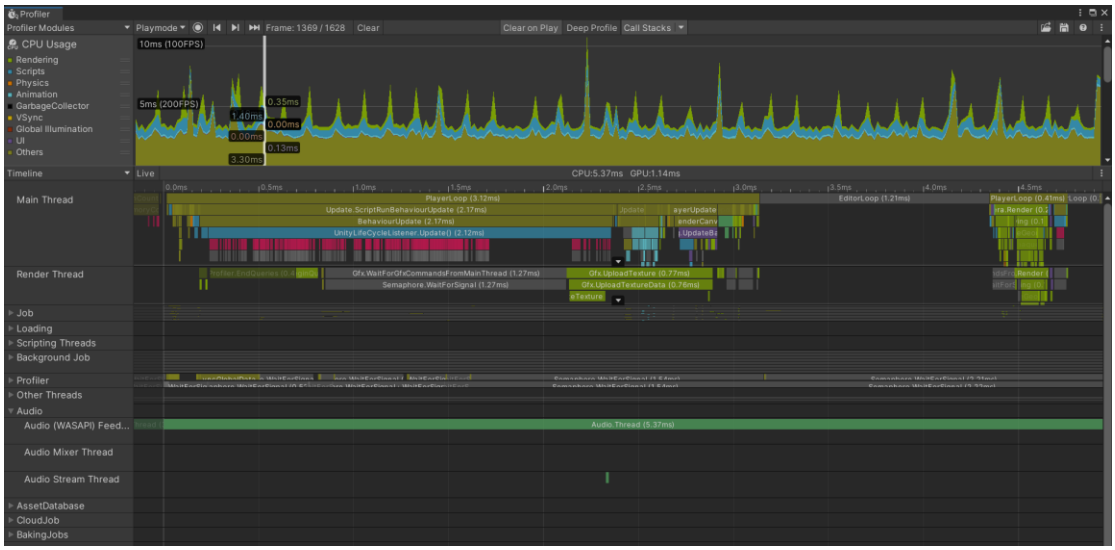


Figure 6.1.4 CPU usage at time frame 1369

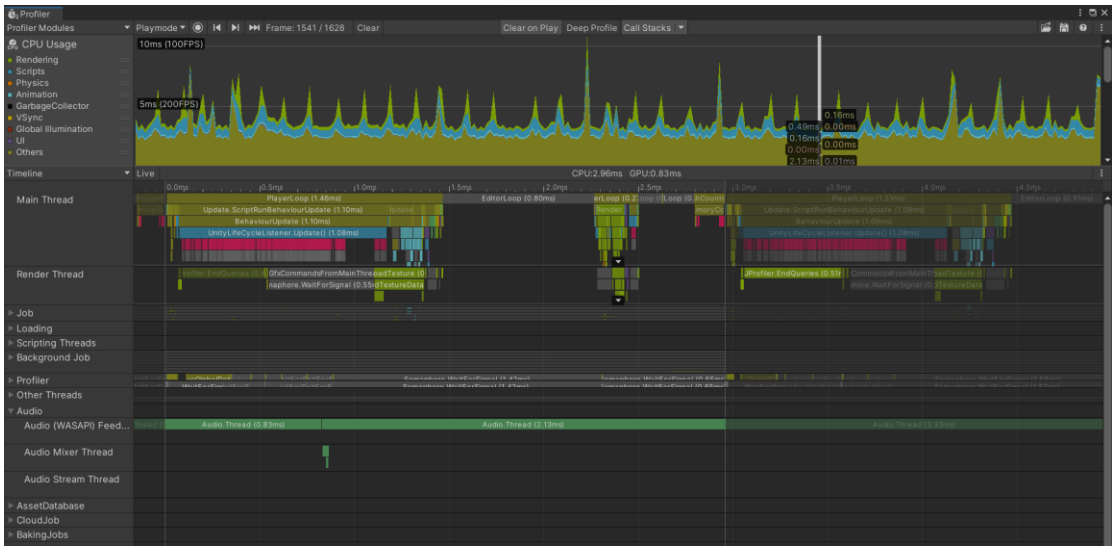


Figure 6.1.5 CPU usage at time frame 1541

In this section, an analysis is performed based on the profiler results in terms of the CPU usage. There are three scripts that are vital in assessing the CPU usage performance information. There are three scripts that are essential for evaluating CPU usage performance information. For example, the PlayerLoop script, the Update.ScriptRunBehaviourUpdate script and the BehaviourUpdate script.

The PlayerLoop script is the main loop in the Unity engine that runs at each game frame. It is responsible for performing various tasks such as updating animations, physics simulation and script execution. In Update.ScriptRunBehaviourUpdate script, it captures all Update function calls for running script behaviours. Update is one of the main functions available to scripts on each game object and it is executed once per frame. While BehaviourUpdate script captures all Update function calls for the running MonoBehaviour, one of the base classes for Unity scripts, which allows the user to customise the behaviour of the game object.

The data captured in Figure 6.1.4 at time frame 1369 are as follows:

- CPU usage: 5.37ms
- PlayerLoop: 3.12ms
- Update.ScriptRunBehaviourUpdate: 2.17ms
- BehaviourUpdate: 2.17ms

The data captured in Figure 6.1.5 at time frame 1541 are as follows:

- CPU usage: 2.96ms
- PlayerLoop: 1.45ms
- Update.ScriptRunBehaviourUpdate: 1.10ms
- BehaviourUpdate: 1.10ms

In conclusion, PlayerLoop uses greater CPU usage when scanning the image marker rather than not scanning the image marker. Thus, to optimise the application, it is necessary to reduce its usage. While on the other hand, it is also considered a reasonable usage, as the CPU runs more tasks during the scanning of image marker, such as updating animations, physics simulation, and script execution.

GPU Usage Module

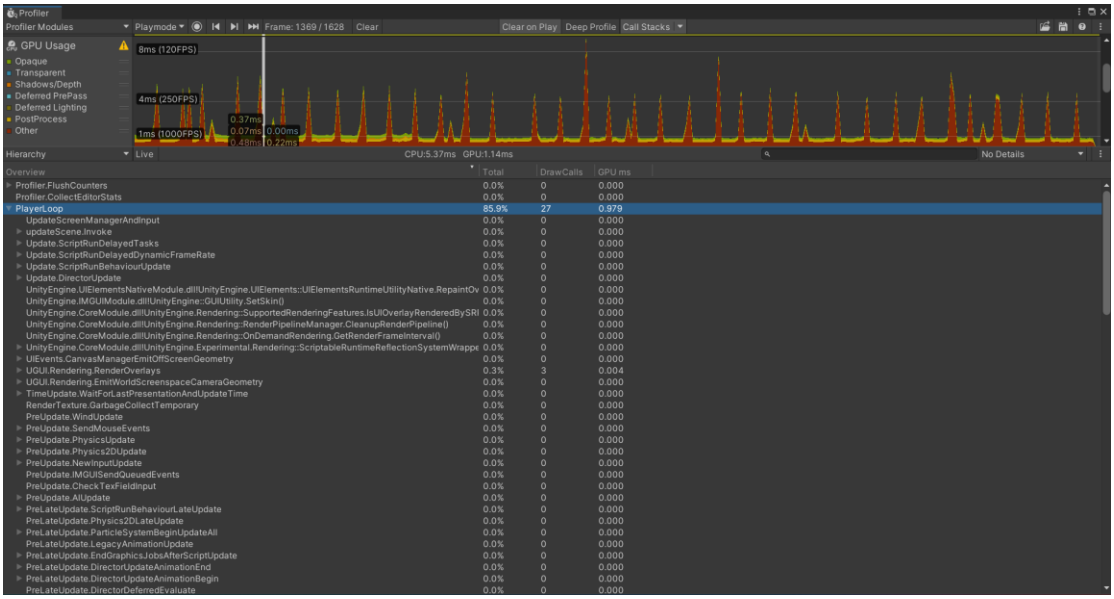


Figure 6.1.6 GPU usage at time frame 1369

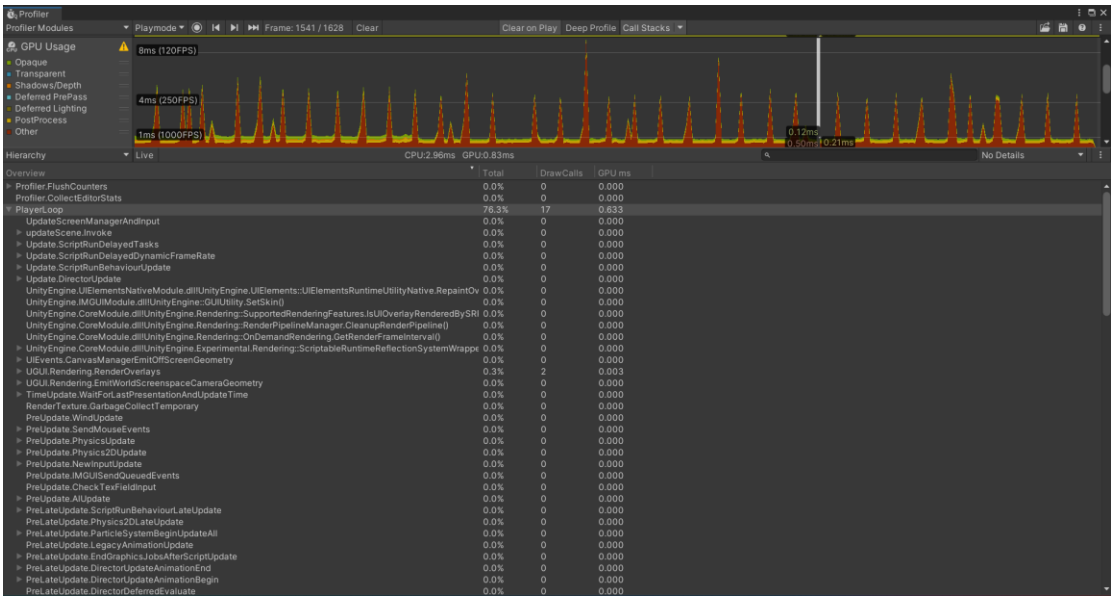


Figure 6.1.7 GPU usage at time frame 1541

In this section, the results of profiling the GPU usage module are analysed to assess performance information for applications in this sector. Similar to the previous section, there are also three most important areas are involved in this GPU usage analysis section. For instance, the PlayerLoop area, the UGUI.Rendering.RenderOverlays area, and the Camera.Render area.

The UGUI.Rendering.RenderOverlays area represents the time for the rendering part of the UGUI, in particular the Overlay Canvas. Also, the Camera.Render area indicates the rendering time of the camera, including various effects and post-processing effects.

In conclusion, the GPU usage for the time frame at 1369 (scanning image marker) was 1.14ms, while the GPU usage for the time frame at 1541 (not scanning image marker) was 0.83ms. It is worth to be notified that when scanning image marker, the area that utilises more resources in the GPU usage is PlayerLoop area. UGUI.Rendering.RenderOverlays and Camera.Render are both area that both occupied 0.3% and 75.2% of the PlayerLoop area.

Rendering Module

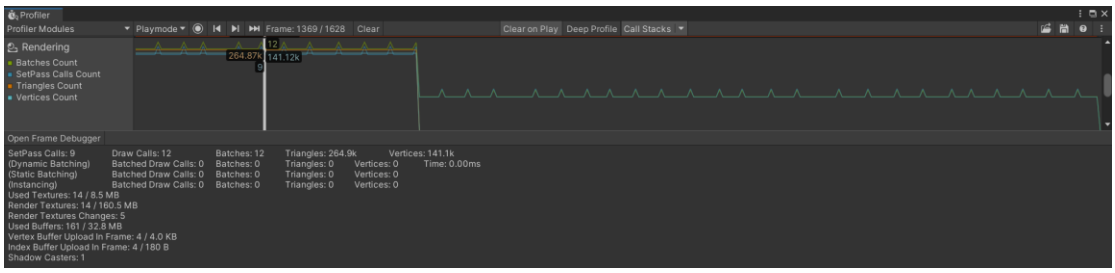


Figure 6.1.8 Rendering module at time frame 1369

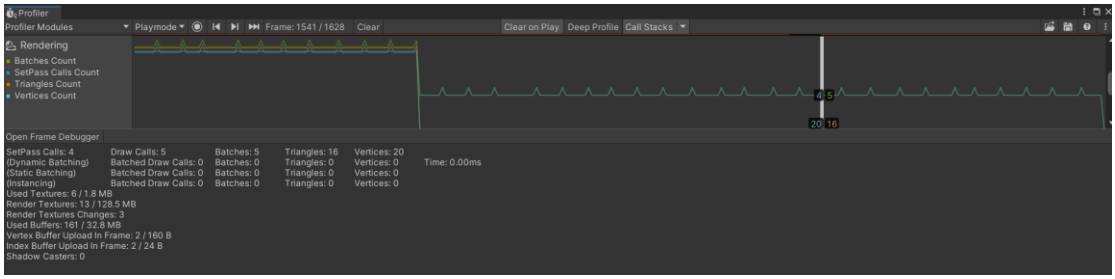


Figure 6.1.9 Rendering module at time frame 1541

In this section, the profiler result of Rendering Module is analysed. In Unity3D's Profiler, the Rendering Module documents rendering-related performance metrics, of which SetPass Calls and Draw Calls are two key measures.

To illustrate, SetPass Calls are the number of times the Unity engine calls the SetPass function in a frame, which is a function used to toggle the rendering state, such as changing the material, changing the blend mode, etc. Each time the SetPass function is called, a state call is made. Each call to the SetPass function requires state switching and data transfer, which consumes CPU and GPU resources [36].

Besides, Draw Calls are the number of times the Unity engine calls the Draw function in a frame, which is used to draw geometry to the screen and each time the Draw function is called, vertex data is transferred to the GPU and drawn. Draw Calls are therefore a metric that reflects the load on the GPU [36].

In the data provided, at the time of showing marker (time frame 1369), the SetPass Calls are 9, meaning that the Unity engine called the SetPass function nine times during the frame, and the Draw Calls are 12, meaning that the Unity engine called the Draw function 12 times during the frame.

In the case of not showing marker (time frame 1541), SetPass Calls are 4 which means that four render states are set in this frame, while Draw Calls are 5, this means that five render operations are performed in this frame. In other words, five objects or UI elements were drawn in this frame, and four different render states (shader, texture, etc.) were used. These two metrics usually appear together, as the render state needs to be set before each render operation is performed.

In conclusion, generally speaking, the lower the number of SetPass Calls and Draw Calls, the better the game performance, as they increase the load on the CPU and GPU. Therefore, considering optimising the textures, rendering order and so on. In this way, the number of SetPass Calls and Draw Calls can be reduced to improve the game performance.

Memory Module

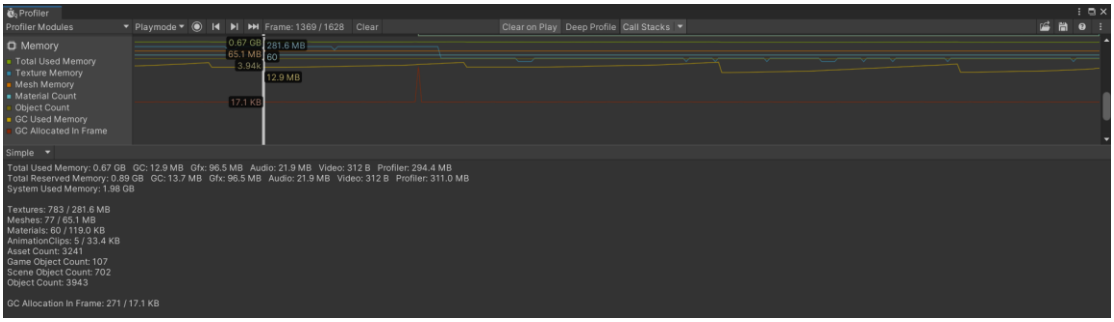


Figure 6.1.10 Memory module at time frame 1369 and 1541

In this section, the Memory Module is being analysed. As well as three significant elements are included. For example, total used memory, GC (Garbage Collection), and GC allocation in frame.

Total used memory is the total amount of memory currently used, which is the total amount of memory currently occupied by the Unity engine and application. GC is the amount of memory recovered by the rubbish collector. This is a very important metric as it helps us to assess the memory usage of the application; more frequent GC means that the application is using more memory. Lastly, GC allocation in frame is the amount of rubbish collection allocation that occurred in this frame. This metric can be used to identify memory allocation problems in a program, especially if it is very high, indicating that a large number of objects are being allocated and freed frequently and may need to be optimised.

According to the data provided, the conclusion remains so. Total used memory is 0.67 GB, total reserved memory is 0.89 GB and system used memory is 1.98 GB. In this case, the difference between used and reserved memory may indicate unused memory, but in this case this difference is small and may not be a major problem.

In the memory module, most of the resource usage looks reasonable, with textures and meshes being used more, and further checks are needed to see if their size and usage is reasonable. The number of materials and animation clips is low, but in practice these may vary depending on the particular scene or function.

In terms of object counts, the number of scene objects is high, but in practice this depends on the size and complexity of the scene. The number of game objects is 107, which seems low, but it increases as the game content increases.

The memory usage of GC allocations in frames may be less than ideal and needs further examination and optimisation. The memory usage allocated in a single frame exceeds 17KB, which may cause performance issues. In addition, the use of object pooling techniques can be implemented to address such issues.

In summary, further examination and optimisation of memory usage and GC allocation is required. Overall, these figures suggest that the application is in a fair state, but that some optimisations could be made to improve performance.

UI Module

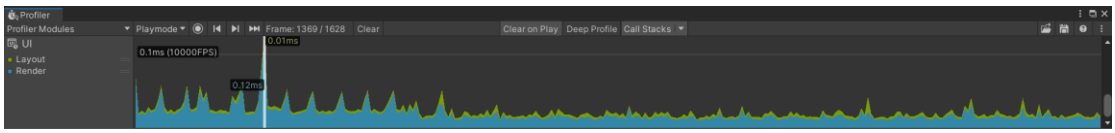


Figure 6.1.11 UI module at time frame 1369

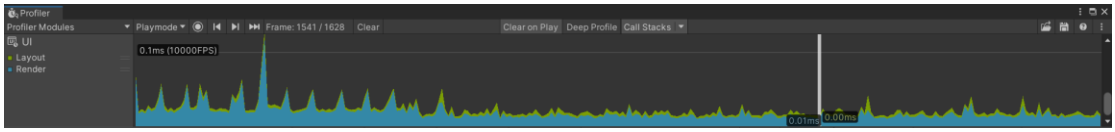


Figure 6.1.12 UI module at time frame 1541

In this section, UI Module is analysed in detail as well. Layout refers to the calculation time of the UI layout, which is the time spent in this frame to calculate the position and size of the UI elements. Render is the time taken to draw the UI elements, which is the smaller the value of these two metrics, the better the performance.

The data captured in Figure 6.1.11 at time frame 1369 are as follows:

- Layout: 0.01ms
- Render: 0.12ms

The data captured in Figure 6.1.12 at time frame 1541 are as follows:

- Layout: 0.00ms
- Render: 0.01ms

In conclusion, for the data obtained with a time frame of 1369 when showing marker, the time spent by Layout is 0.01ms and the time spent by Render is 0.12ms, which means that in this frame the UI layout is computed in a very short time, taking only a small amount of time, while drawing the UI elements takes a little longer, but is still within acceptable limits.

As a general rule of thumb, if the Layout takes longer than 16.67ms/60fps (that is 16.67ms per frame), then the UI layout is computing too long and may need to be optimised. For Render, on the other hand, there is no fixed standard, but it is usually evaluated and optimised on a case-by-case basis.

Based on the data provided, the time taken for both Layout and Render are short enough that they can be considered reasonable and do not require optimisation. However, it is also pertinent to note and observe that these figures only represent a single frame, and in the case that the application suffers from prolonged lag or frame drops, a more comprehensive performance analysis and optimisation is required.

Overview of Profiler Result

Before concluding the entire analysis of the application profiling findings, the correlation analysis in terms of the CPU usage module and the GPU usage module is presented.

The CPU-GPU interplay data obtained for a time frame of 1369 at the time of showing marker is as follows:

1. CPU usage
   [(0ms + 5ms) / (CPU usage: 5.37ms)] = **2.79%**

2. GPU usage
   [(8ms + 4ms + 1ms) / (GPU usage: 1.14ms)] = **11.4%**

In conclusion, optimising the performance of the application is a comprehensive process that requires an analysis of the entire performance profile of the application, taking into account CPU and GPU usage as well as frame rate percentages. In this case, 2.79% for CPU usage and 11.4% for GPU usage.

As the application is not primarily CPU-intensive, such as heavy physics calculations, AI calculations, and so on. Therefore, it is less important to pay attention to the frame rate percentage of CPU usage.

On the other hand, as the application is dominantly GPU-intensive, such as heavy rendering and complex graphics effects. Hence, there is a need to monitor the frame rate percentage of GPU usage. If the frame rate percentage of GPU usage is high, the GPU will probably cause a bottleneck and will need to be optimised for performance.

Overall, the data obtained does not suggest any major optimisation is required as this is a reasonable occurrence. This is because the application uses a lot of rendering and graphics effects such as 3D models, image targets as markers, animations, etc. Consequently, it appears logical that the GPU usage is higher in terms of frame rate, GPU > CPU.

Finally, if optimisation features have to be implemented, then GPU usage is the only area that can be dealt with. For example, reducing overdrawing, reducing texture and material usage as well as reducing screen post-processing effects.

6.2 Testing Setup and Result

6.2.1 Testing Setup

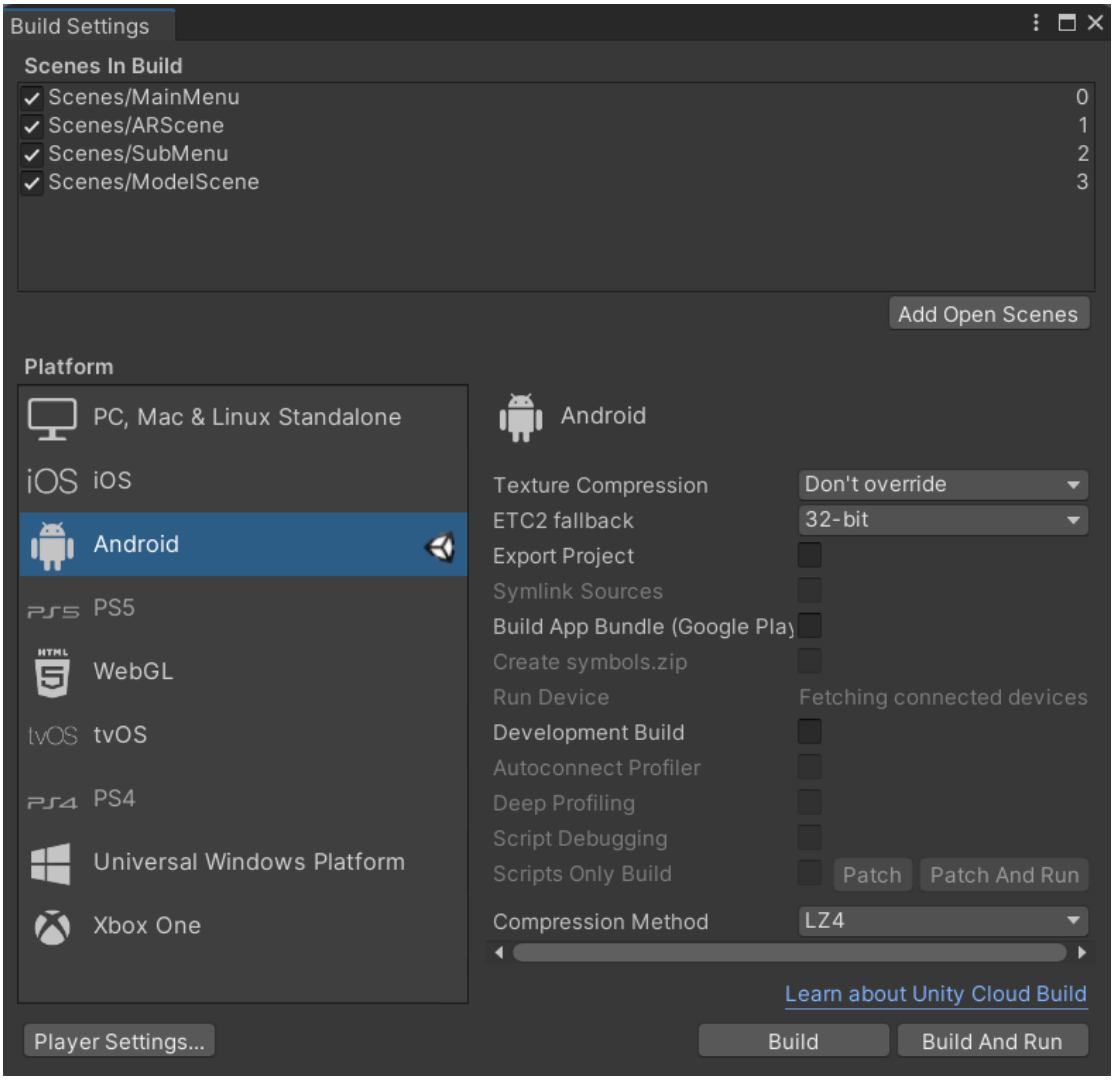


Figure 6.2.1.1 Build settings in Unity3D

- In the ‘Scenes In Build’ section, there are a total of four scenes being added in the build setting. For example, MainMenu, ARScene, SubMenu, and ModelScene.
- In the platform section, Android is installed and be set as the operating system of the application.

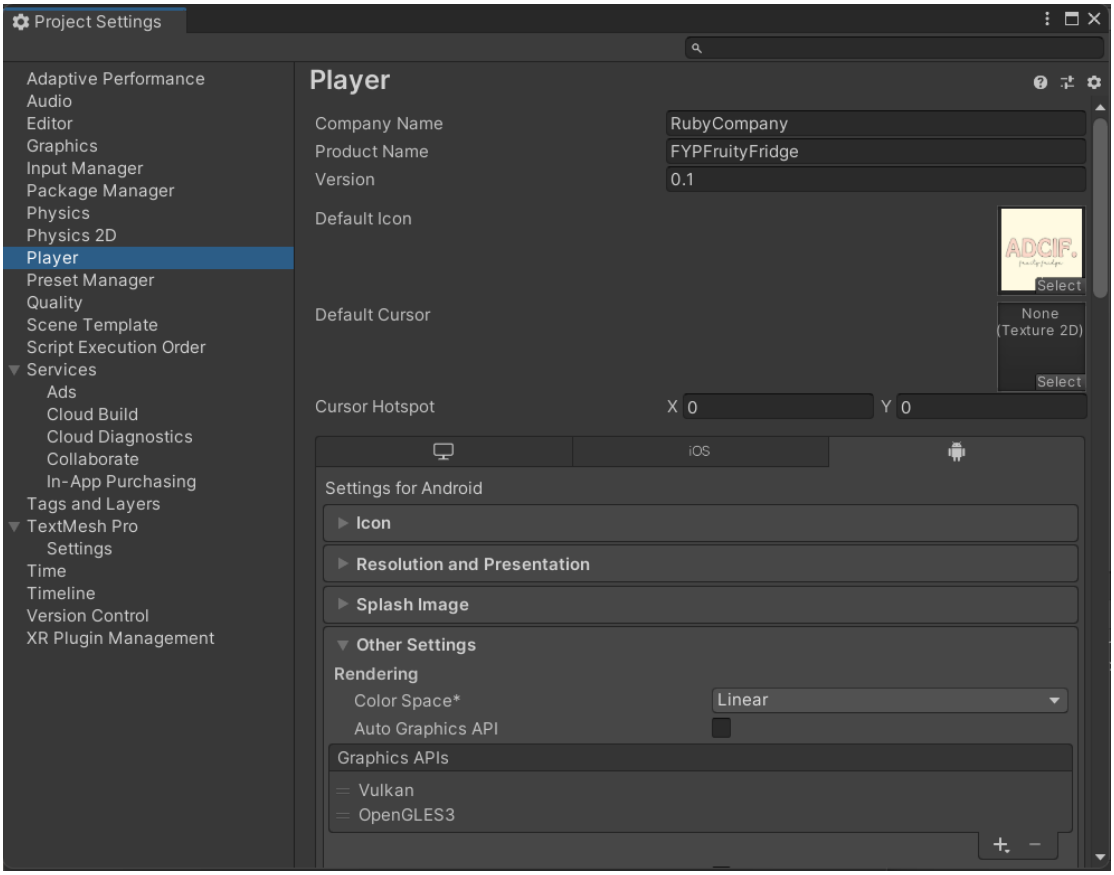


Figure 6.2.1.2 Player settings in Unity3D

- In the player settings, ‘RubyCompany’ is set as the company name while ‘FYPFruityFridge’ is set as the product name.
- In the ‘Default Icon’ attribute, the proposed application’s logo is set.

Vuforia Marker Feature Points

In the following diagrams, the feature point areas used to place the virtual buttons in this application are shown by the red boxes.

Figure 6.2.1.3 Apple food packaging image marker feature points area

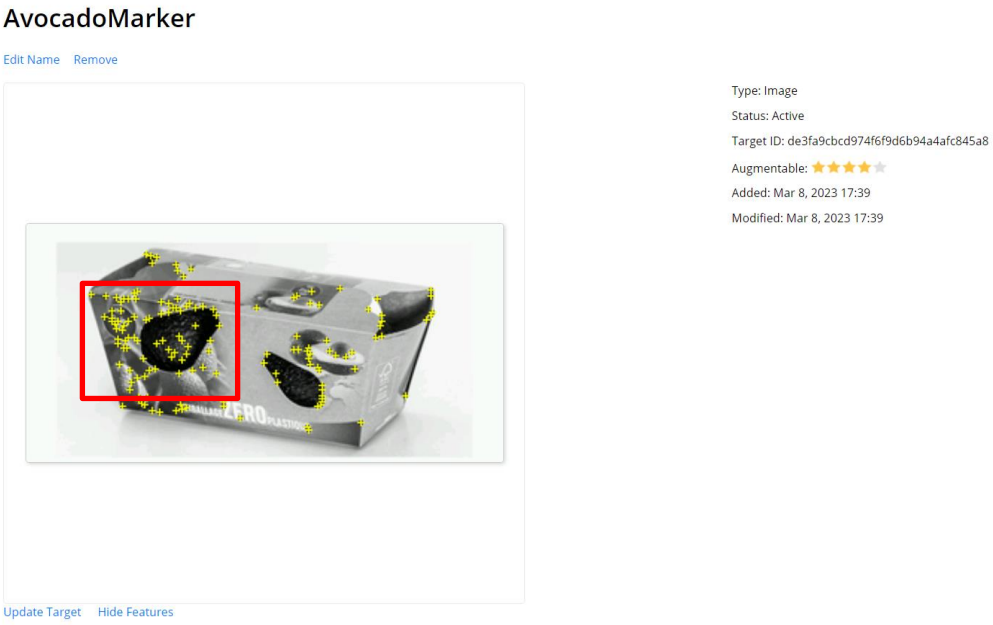


Figure 6.2.1.4 Avocado food packaging image marker feature points area

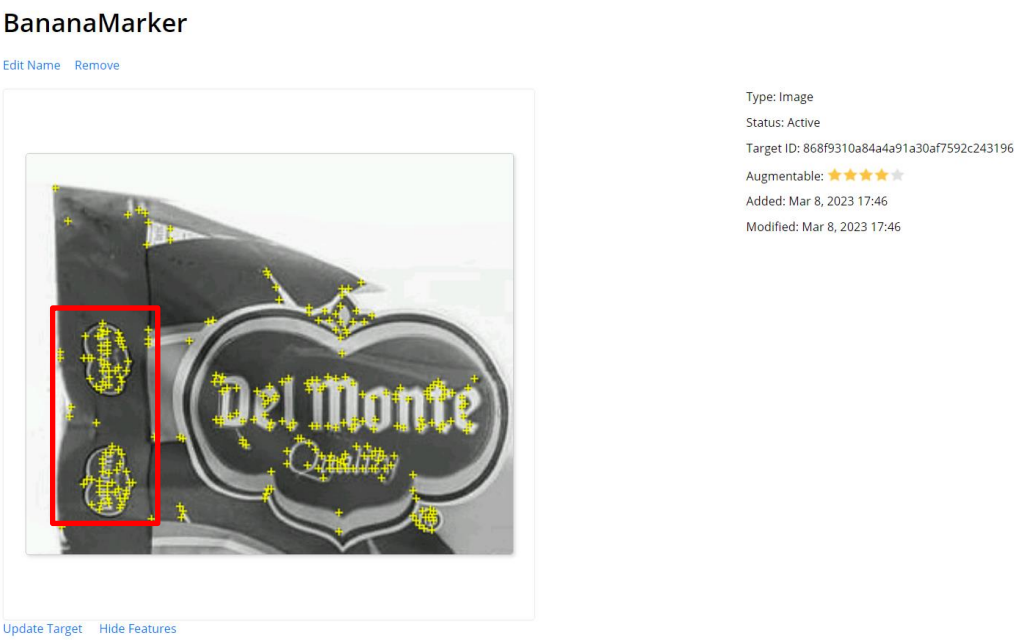


Figure 6.2.1.5 Banana food packaging image marker feature points area

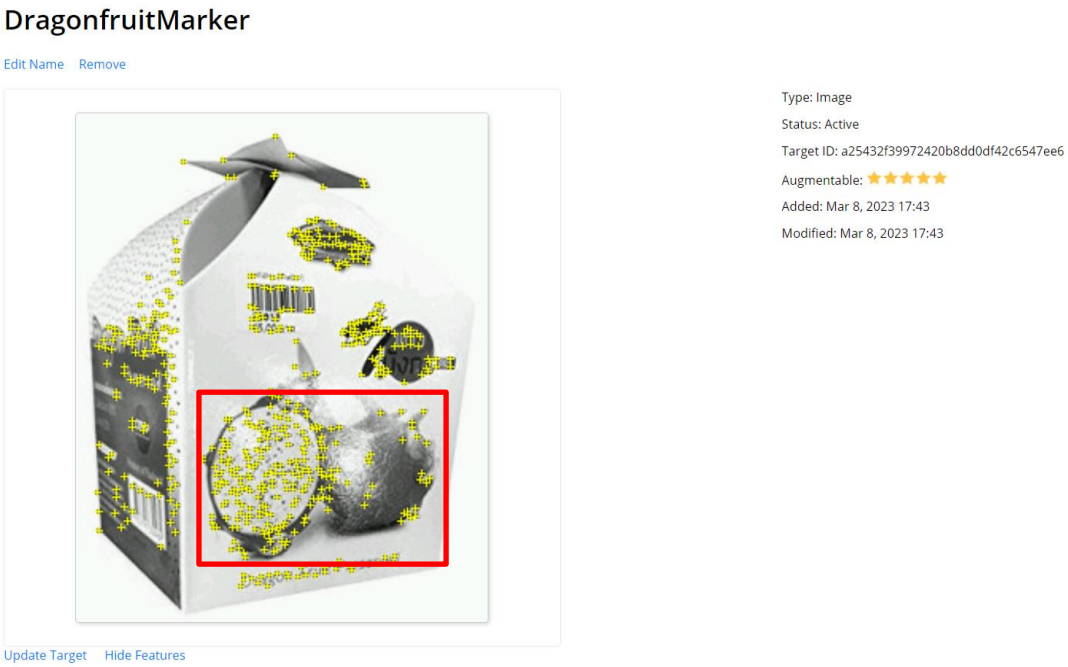


Figure 6.2.1.6 Dragonfruit food packaging image marker feature points area

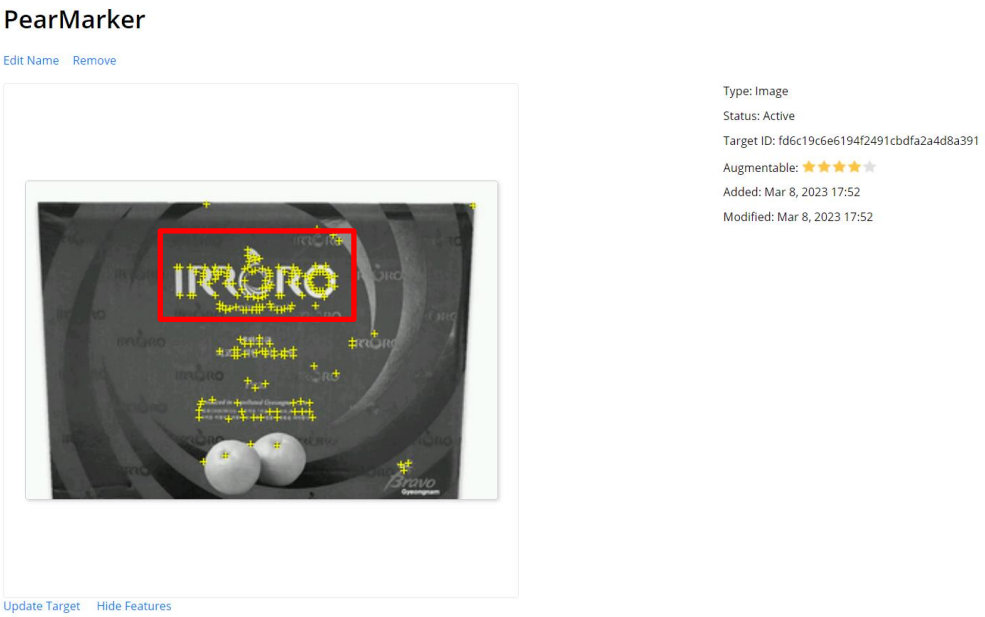


Figure 6.2.1.7 Pear food packaging image marker feature points area

6.2.2 Testing Result

Game Scene

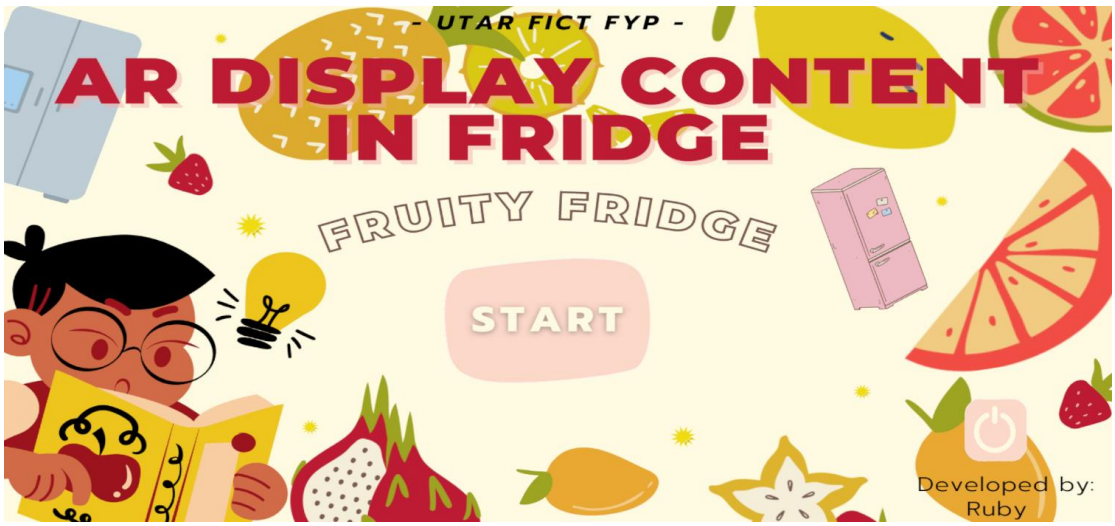


Figure 6.2.2.1 MainMenu proof

Figure 6.2.2.2 SubMenu proof

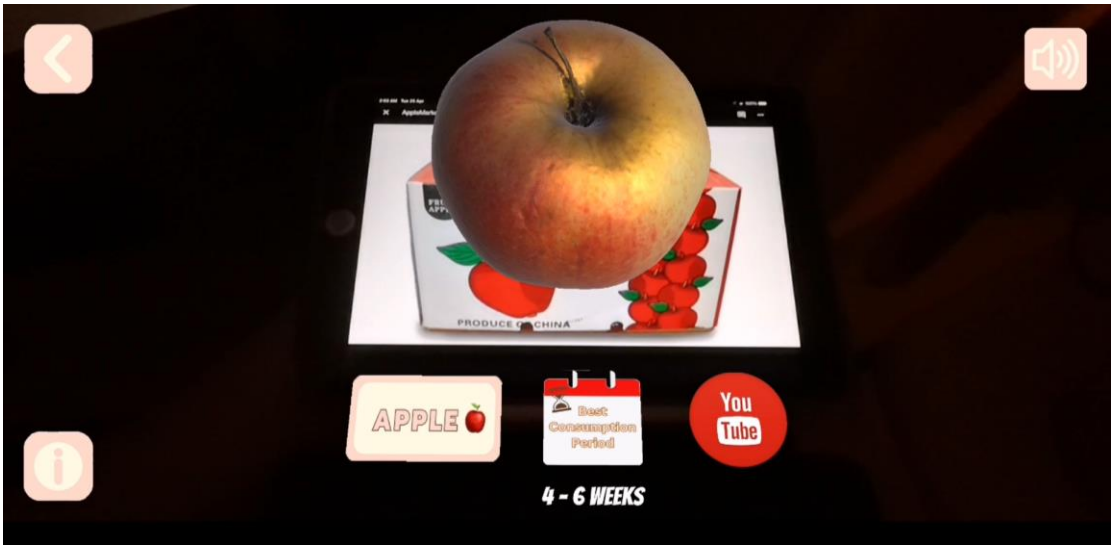


Figure 6.2.2.3 ARScene proof

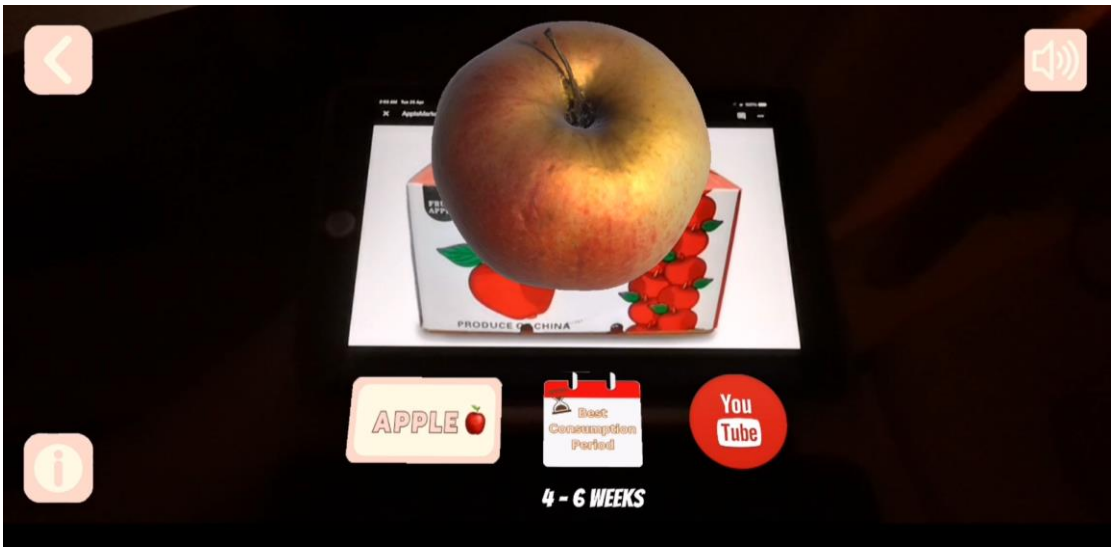


Figure 6.2.2.4 ModelScene proof

Console Response

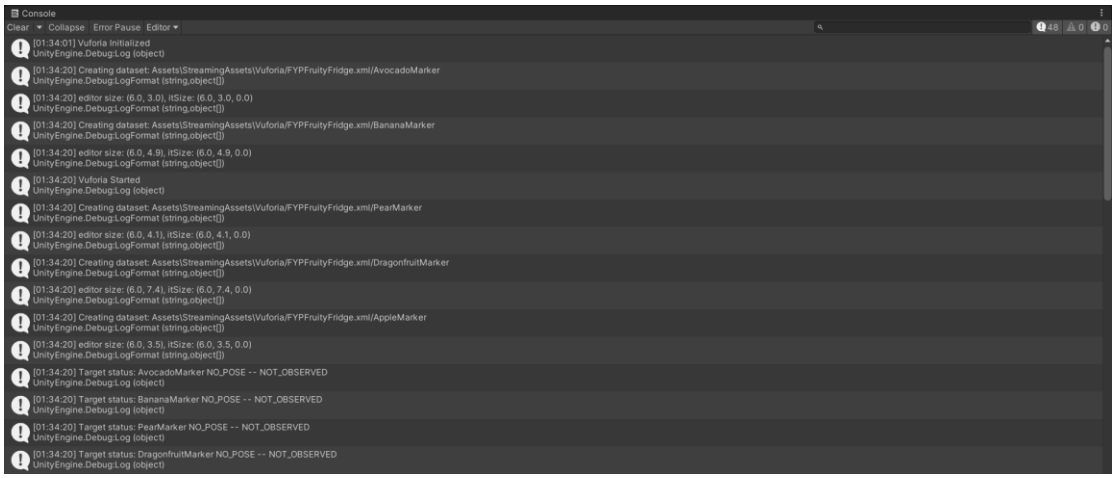


Figure 6.2.2.5 Console response for the launching of application

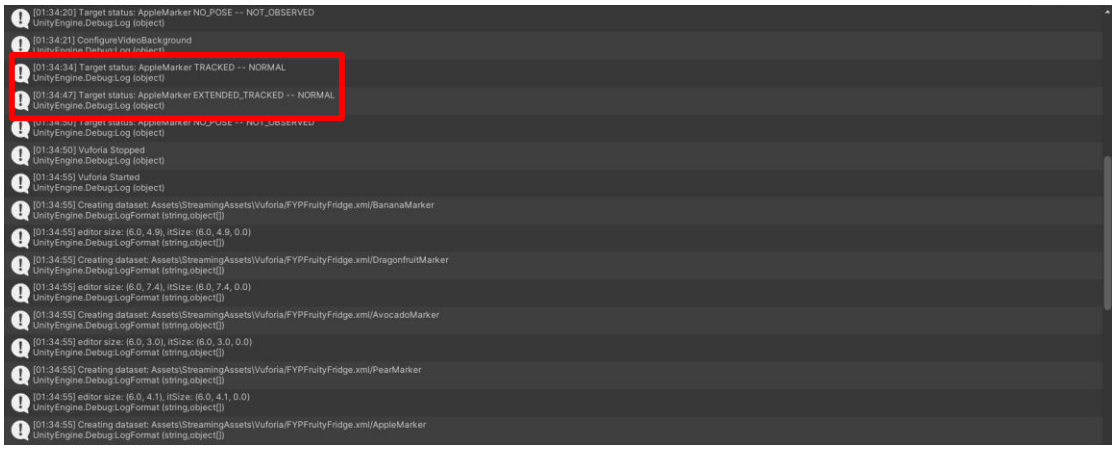


Figure 6.2.2.6 Console response for tracked image marker

Figure 6.2.2.7 Console response for the hovering of virtual button

6.3 Project Challenges

The linguistic differences challenge is one of the main concerns when aiming to serve the proposed application to be used by global audiences as its community contribution. This is especially true if the application is intended for use in multiple regions and languages. Due to the cultural and linguistic differences that exist between different regions and communities, the application may face potential obstacles in achieving its societal engagement goals. The primary issues that arise from linguistic differences is the difficulty in accurately translating text from one language to another. Translating text is not as simple as using a dictionary to find the corresponding word in another language. Often, words and phrases can have multiple meanings depending on the context in which they are used. This complexity is further compounded by cultural differences, which can result in certain words or phrases being interpreted differently in different regions.

Collecting accurate and comprehensive data on fruits is also considered as a significant challenge due to the complexity and diversity of fruits as the target food item. Fruits come in different shapes, sizes, colours, textures, and tastes, and they may have different names, characteristics, and nutritional values in different regions and cultures. This requires extensive research and data collection to ensure that the information presented in the augmented reality application is accurate and up to date.

In the context of an augmented reality application that scans food packaging, accurately recognising and identifying fruit packaging is crucial. However, there are several challenges associated with this task. One of the main challenges is the condition of the packaging itself. Food packaging can be damaged, dirty, or poorly printed, making it difficult for image recognition software to accurately identify the packaging. Additionally, different types of packaging may have different designs or labelling, which can further complicate the identification process. By capturing the food packaging image before using it as the image marker or use the same image from online resources can be a temporary solution. This is a more basic and manual solution to ensure the usability of food packaging image. However, this should not be the long-lasting solution as it is not considered as a qualified solution and the fact that such solutions are too untechnical do not guarantee accuracy and avoid human error.

6.4 Objectives Evaluation

Objective 1: To implement marker-based augmented reality to the AR display content in fridge application that specifically uses the scanned food packaging as markers.

Evaluation: The objective was achieved, as the AR technology was successfully integrated into the application and food packaging were used as the image marker. Testing result proved that the application was responsive and stable in performing image target detection and tracking.

Objective 2: To develop a 3D model of scanned marker's food item that allows real-time interaction with the user.

Evaluation: The objective was achieved, as the retrieving of 3D models was successfully implemented to ensure engaging and immersive experience. Testing result proved that the application provided an accurate representation of scanned marker's food item for users interacting.

Objective 3: To develop a rapid retrieval module to retrieve information about fruit by scanning food packaging.

Evaluation: The objective was achieved, as the testing result proved that the application's outputs were informative and educational. However, testing also showed that further testing and optimisation are needed to deliver better performance in upgrading features.

6.5 Concluding Remark

In conclusion, the system testing, and performance metrics have been completed, and the results show that the application is functioning well with all its features and functions working as expected. The testing setup has been done in a well-organised manner to ensure optimal performance. There is no critical area in the application that needs further optimisation or improvement at the current status.

However, the project challenges included significant obstacles in the development of the application. The linguistic differences challenge is a major concern as accurate translation of text from one language to another is not always straightforward and cultural differences can further complicate this issue. Collecting accurate and comprehensive data on fruits is another challenge due to their complexity and diversity. The application also requires accurate recognition and identification of fruit packaging, which can be complicated by the condition and design of the packaging. While capturing food packaging images from online resources can be a temporary solution, it is not considered a qualified solution as it can lead to inaccuracies and human errors.

Despite these challenges, the objectives of the project have been achieved, although improvements, optimisations, and upgrades are necessary to enhance the application's features and functions to offer the best user experience. The continuous improvement process is essential to maintain and improve the application's quality and competitiveness in the market.

Chapter 7
Conclusion and Recommendation

7.1 Conclusion

In conclusion, the problem statement presented in this project included the nonexistence of a marker-based augmented reality application that scans and displays the contents of food packaging for fridge-related items, the inability of performing a real-time interaction between the scanned food's packaging 3D model and the user, as well as the limitation of rapid scanning and retrieving the retrieval module of virtual content. Therefore, four scenes are designed and developed in the proposed AR application to address the issues encountered. For example, the Main Menu scene, the Sub Menu scene, the AR scene, and the Model scene. Each scene will be implemented with suitable modules and adequate technologies or plug-ins.

In addition, the development of the proposed application was primarily driven by the need to develop more useful support tools for ECE, especially for younger users. This can provide them with a fun and unique learning environment throughout their childhood. Instead of learning and exploring new knowledge through boring textbooks and tedious 2D diagrams, an AR application can greatly motivate and enthuse them to acquire knowledge.

Finally, the essential preliminary work such as statement of the encountered problems, background thesis, and the documentation reviewing has been undertaken. While throughout the development of this project, major setup and configuration along with the system architecture design was implemented as well. After the application is deployed, system testing, performance assessments, and run-time are performed to evaluate the behaviour of the proposed application.

Last but not least, although potential imperfections or errors are inevitable, the solution can still be implemented to permit refinements and modifications in subsequent developments. As a result, a more rewarding and fruitful product will be delivered.

7.2 Recommendation

There are some optimisations and upgrades can be performed to enhance the overall application's performance as well as solving the encountered issues.

In order to ensure that this application is sensitive to serving diverse audiences, multilingual setups is recommended to be implemented. After completing in-depth research and literature acquisition, there are two solutions can be implemented to solve this problem. Firstly, the Google Cloud Translation API. It is a machine learning-powered service that allows the automation of user-generated content translating to over 100 different languages in real-time [18]. Besides that, LocX Unity Localization is a plugin for Unity3D game engine that facilitates the translation of game content into multiple languages [19]. It offers support for localising different types of content, such as text, UI elements, images, and game data. Additionally, it comes equipped with features like in-game language switching and automatic text resizing that adapt to the target language. The plugin also supports several platforms like iOS, Android, PC, Mac, Linux, and web. It is designed to work harmoniously with Unity's asset pipeline, which makes it convenient to implement into ongoing projects.

Next, to ensure the accuracy and completeness of the collected data for the AR application, a combination of public and private data sources is recommended. Public sources such as fruit databases provide information on different types of fruits, including nutritional content, cultivation, and harvesting practices. Research papers can also be used to gather information on the latest scientific findings related to fruits. In addition to public data sources, consulting industry experts in the field of fruit cultivation and harvesting can provide valuable insights into the specific requirements and challenges associated with collecting data on fruits. Furthermore, implementing automated tools for data cleaning, validation, and integration can help reduce the likelihood of errors in the collected data. For example, data cleaning tools can be used to identify and remove any inconsistencies or inaccuracies in the collected data.

Besides that, to improve the accuracy and robustness of recognising and identifying fruit packaging, advanced image recognition techniques such as deep learning and neural networks can be utilised. However, to ensure the effectiveness of this approach, it is recommended to use multiple algorithms and models that can account for different lighting conditions, angles, and variations in packaging design. By implementing a variety of algorithms and models, the system can better handle different scenarios and improve its ability to accurately recognise and identify fruit packaging.

Moreover, it is recommended that to further develop this application to be able in both iOS and Android platforms. The availability of cross-platform in this proposed application is vital in ensuring larger consumer base which helps this application to be more competitive in the market as well as increasing its societal contributions. In order to achieve this, since Unity already provides a robust platform for developing AR applications, and it has built-in support for both iOS and Android platforms. It is recommended to use Unity's built-in features and tools for developing the AR application for iOS and Android, and then use web development technologies such as HTML, CSS, and JavaScript to create the website version of the application. On the other hand, Flutter can also be considered to achieve this because it supports both iOS and Android platforms, as well as web and desktop platforms. Flutter uses a single codebase to develop apps for multiple platforms, allowing for efficient cross-platform development [40]. However, this approach may require more effort and may not be the most efficient way to develop an AR application in Unity as it requires additional plugins or third-party libraries to integrate Flutter with Unity.

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FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T3, Y3	**Study week no.: 2**
Student Name & ID: Ruby Ong Fang Yi, 19ACB03262	
Supervisor: Ts Saw Seow Hui	
Project Title: AR Displsy Content in Fridge	

1. WORK DONE

- Development of application

2. WORK TO BE DONE

- Background research
- Literature review

3. PROBLEMS ENCOUNTERED

- Surveys on usable Unity plug-ins and extensions
- Collecting of intensive information of research papers

4. SELF EVALUATION OF THE PROGRESS

- Should pay more attention on usable and effective Unity C# function to be used in necessary scripts

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T3, Y3	**Study week no.: 4**
Student Name & ID: Ruby Ong Fang Yi, 19ACB03262	
Supervisor: Ts Saw Seow Hui	
Project Title: AR Displsy Content in Fridge	

1. WORK DONE

- Finalisation of application development
- Chapter 1: Background Introduction

2. WORK TO BE DONE

- Chapter 2: Literature Review

3. PROBLEMS ENCOUNTERED

- Collecting of intensive project-related background information

4. SELF EVALUATION OF THE PROGRESS

- Should do more in-depth analysis and studies for information collecting task

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T3, Y3	**Study week no.: 6**
Student Name & ID: Ruby Ong Fang Yi, 19ACB03262	
Supervisor: Ts Saw Seow Hui	
Project Title: AR Displsy Content in Fridge	

1. WORK DONE

- Chapter 2: Literature Review

2. WORK TO BE DONE

- Chapter 3: System Methodology/Approach

3. PROBLEMS ENCOUNTERED

- Collecting of project related existing application

4. SELF EVALUATION OF THE PROGRESS

- Should perform more in-depth analysis on the overview, strengths, and weaknesses of the existing application reviewing

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T3, Y3	**Study week no.: 8**
Student Name & ID: Ruby Ong Fang Yi, 19ACB03262	
Supervisor: Ts Saw Seow Hui	
Project Title: AR Displsy Content in Fridge	

1. WORK DONE

- Chapter 3: System Methodology/Approach

2. WORK TO BE DONE

- Chapter 4: System Design

3. PROBLEMS ENCOUNTERED

- Design of the system architecture

4. SELF EVALUATION OF THE PROGRESS

- More detailed and enhanced system design should be planned

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Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T3, Y3	**Study week no.: 10**
Student Name & ID: Ruby Ong Fang Yi, 19ACB03262	
Supervisor: Ts Saw Seow Hui	
Project Title: AR Displsy Content in Fridge	

1. WORK DONE
- Chapter 4: System Design
- Chapter 5: System Implementation

2. WORK TO BE DONE
- Chapter 6: System Evaluation and Discussion

3. PROBLEMS ENCOUNTERED
- The arrangement of the complicated system implementation

4. SELF EVALUATION OF THE PROGRESS
- A more stable system implementation process should be implemented
- Need to improve the skills in processing the massive amount of information

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Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: T3, Y3	**Study week no.: 12**
Student Name & ID: Ruby Ong Fang Yi, 19ACB03262	
Supervisor: Ts Saw Seow Hui	
Project Title: AR Displsy Content in Fridge	

1. WORK DONE

- Chapter 6: System Evaluation and Discussion
- Chapter 7: Conclusion and Recommendation
- Poster

2. WORK TO BE DONE

- Presentation and submission of report

3. PROBLEMS ENCOUNTERED

- In-depth analysis on performance metrics data
- Theme and colour code to be used in poster designing

4. SELF EVALUATION OF THE PROGRESS

- Time dragging should be avoided

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Student's signature

POSTER

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UNIVERSITI TUNKU ABDUL RAHMAN

AR DISPLAY CONTENT IN FRIDGE

Faculty of Information and Communication Technology

Introduction

This project aims to develop a marker-based AR mobile application that educates children about fruits by displaying AR virtual content when scanning the fruit packaging. The project addresses the lack of integration of AR with fridge-related applications in pre-school education, inability to real-time interact with 3D models, and the limitation of fruit information retrieval module.

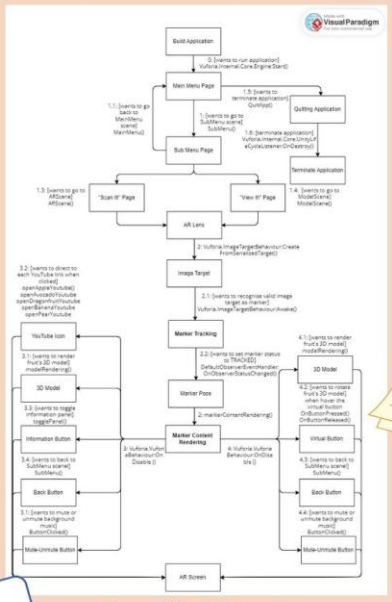
Problem Statement

- The nonexistence of a marker-based augmented reality application that scans and displays the contents of food packaging for fridge-related items.
- The inability of performing a real-time interaction between the scanned food's packaging 3D model and the user.
- Limitation of rapid scanning and retrieving the retrieval module of virtual content.

Objectives

- To implement marker-based augmented reality to the AR display content in fridge application that specifically uses the scanned food packaging as markers.
- To develop a 3D model with scanned food packaging marker which allows real-time interaction with the user.
- To develop a rapid retrieval module to retrieve information about fruit by scanning food packaging.

System Design



System Block Diagram

Methodology

- Technology: Marker-based AR
- Operating System: Android
- Software: Unity3D & Vuforia
- 3D Model Resource: Sketchfab.com

Functionalities

- Scan food packaging to render virtual content including fruit name, best consumption period, information panel, and 3D models.
- Scan food packaging to render 3D model in order to perform interactive actions such as drag, rotate, scale in, and scale out.
- Becoming an alternative to boring textbooks in early childhood education.
- Help adult and child users to learn more about fruit.

Optimisation Recommendations

- Multilingual setup
- Combination of public and private data sources to ensure data accuracy and completeness
- Enhancement of image recognition technology
- Availability of cross-platform capabilities

Application Main Page & Logo

ADCIF.
fruity fridge

Prepared by: Ruby Ong Fang Yi, 19ACB03262

Supervised by: Ts Saw Seow Hui

PLAGIARISM CHECK RESULT

FYP2 - AR DISPLAY CONTENT IN FRIDGE

ORIGINALITY REPORT

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2	"ICT Systems and Sustainability", Springer Science and Business Media LLC, 2021 Publication	<1%
3	M.-Carmen Juan, Jorge L. Charco, Inmaculada García-García, Ramón Mollá. "An Augmented Reality App to Learn to Interpret the Nutritional Information on Labels of Real Packaged Foods", Frontiers in Computer Science, 2019 Publication	<1%
4	"HCI International 2020 – Late Breaking Papers: Universal Access and Inclusive Design", Springer Science and Business Media LLC, 2020 Publication	<1%

5	Ozlem Durmaz Incel, Sevda Ozge Bursa. "On-Device Deep Learning for Mobile and Wearable Sensing Applications: A Review", IEEE Sensors Journal, 2023 Publication	<1 %
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FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

Full Name(s) of Candidate(s)	Ruby Ong Fang Yi
ID Number(s)	19ACB03262
Programme / Course	Bachelor of Information Systems (Honours) Information Systems Engineering
Title of Final Year Project	AR Display Content in Fridge

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Note Supervisor/Candidate(s) is/are required to provide softcopy of full set of the originality report to Faculty/Institute

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: Ts. Saw Seow Hui

Date: 27/4/2023

Signature of Co-Supervisor

Name: _____

Date: _____

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY (KAMPAR CAMPUS)

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Student Name	Ruby Ong Fang Yi
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