INTERACTIVE MELAKA HISTORICAL SITES IN MARKERLESS AR APPS

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This report is submitted in partial fulfilment of the requirements for the Bachelor of Computer Science (Interactive Media) with Honours.

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY
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DECLARATION

I hereby declare that this project report entitled

INTERACTIVE MELAKA HISTORICAL SITES IN MARKERLESS AR APPS

is written by me and is my own effort and that no part has been plagiarized without citations.

STUDENT : ________________________ Date 30/8/2024

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I hereby declare that I have read this project report and found this project report is sufficient in term of the scope and quality for the award of Bachelor of Computer Science (Interactive Media) with Honours.

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DEDICATION

Completing this final year project has been a big part of my academic journey. I couldn't have done it without the support and help of many wonderful people. I want to express my deep gratitude to everyone who has been there for me.

To my beloved parents and family, your constant love, encouragement, and belief in me have been my biggest source of strength. Through all the late-night study sessions and challenging times, you have been my rock. Your sacrifices and support have made this achievement possible, and I dedicate this work to you with all my heart.

To my supervisor, Ms. Shafina Binti Abd Karim Ishigaki, your guidance, patience, and valuable advice were important in helping me complete this project. You have been more than a mentor. Your dedication and belief in my abilities have inspired me to work hard. Thank you for always being there and for pushing me to do my best.

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ABSTRACT

This project aims to develop an interactive augmented reality (AR) application designed to enhance the user experience of exploring historical sites in Melaka, Malaysia. By utilizing markerless AR technology, users can engage with detailed 3D models of Melaka's historical sites without the need for physical markers. The project seeks to address the challenge of making cultural heritage more accessible and engaging in the digital era by combining immersive technology with educational content. The development process involved using the Blender for 3D model creation and the Unity engine and AR Foundation toolkit for integrating AR functionalities. The application features seven significant historical sites, each meticulously reconstructed in 3D and paired with informative descriptions. This blend of interactive technology and educational material is intended to provide users with a deeper understanding and appreciation of Melaka's rich cultural history. The primary objective of this project is to deliver an engaging, user-friendly experience that brings history to life through advanced AR technology.

ABSTRAK

Projek ini bertujuan untuk membangunkan aplikasi realiti tambahan (AR) interaktif yang direka untuk memperkaya pengalaman pengguna menerokai tapak bersejarah di Melaka, Malaysia. Dengan menggunakan teknologi AR tanpa penanda, pengguna dapat berinteraksi dengan model 3D terperinci tapak bersejarah Melaka tanpa memerlukan penanda fizikal. Projek ini berusaha untuk menangani cabaran menjadikan warisan budaya lebih mudah diakses dan menarik dalam era digital dengan menggabungkan teknologi imersif dengan kandungan pendidikan. Proses pembangunan melibatkan penggunaan enjin Unity untuk penciptaan model 3D dan kit alat AR Foundation untuk mengintegrasikan fungsi AR. Aplikasi ini menampilkan tujuh tapak bersejarah penting, masing-masing dibina semula dengan teliti dalam bentuk 3D dan disertakan dengan penerangan yang bermaklumat. Gabungan teknologi interaktif dan bahan pendidikan ini bertujuan untuk memberikan pengguna pemahaman dan penghargaan yang lebih mendalam terhadap sejarah budaya Melaka yang kaya. Objektif utama projek ini adalah untuk menyediakan pengalaman yang menarik dan mesra pengguna yang menghidupkan sejarah melalui teknologi AR yang canggih.

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LIST OF ABBREVIATIONS

FYP	**-**	**Final Year Project**
AR	**-**	**Augmented Reality**
MR	**-**	**Mixed Reality**
XR	**-**	**Extended Reality**
VR	**-**	**Virtual Reality**
RV	**-**	**Reality-Virtuality**
UNESCO	**-**	**United Nations Educational, Scientific and Cultural Organization**

LIST OF ATTACHMENTS

CHAPTER 1 INTRODUCTION

1.1 Introduction

The concept of Augmented Reality (AR) specifies an environment where digital information seamlessly integrates with the real world, enhancing user's perception of reality by overlaying virtual elements onto their physical surroundings (Benassi et al., 2020). AR is also one of the components lying within the Reality-Virtuality (RV) continuum, which encompasses AR, Extended Reality (XR), Mixed Reality (MR), and Virtual Reality (VR) (Milgram et al., 1994).

One of the main components of AR is the ability to detect and recognise the features point, allowing virtual items to be placed on them (Syed et al., 2023). However, the use of markerless AR, which eliminates the need for actual markers, has also increased in popularity because to its flexibility and simplicity to be used (Silva et al., 2003). Markerless AR can be especially beneficial in situations when physical markers are not practicable or practical, such as outdoors.

The stunning seaside city of Melaka is recognised as the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site. Its many historical resources are being renovated to serve as venues for modern cultural activities, and its festival and events industry is expanding (Tom Fleming, 2021). Preserving and promoting Melaka's historical sites is important to maintain its own identity and attracting tourists to come to Melaka (Jani et al., 2018).

1.2 Problem Background

AR has become a technology that is more and more common in a variety of applications, including as tourism and cultural heritage protection. But one of the biggest issues of AR is that it can operates only on certain devices due to requirement of specific devices to run the applications (Billinghurst et al., 2014). Many AR applications are developed for smartphones or tablets, which may limit their accessibility to certain demographics or visitors who do not own these devices or perhaps their device doesn’t meet the AR specification. Additionally, the performance and quality of the AR experience can be heavily dependent on the hardware capabilities of the user's device, which can lead to inconsistencies in the user experience (Allcca-Alarcón et al., 2023).

Due to the flexibility and user-friendliness of markerless AR, it has gained more popularity nowadays. It is because it doesn't require physical markers or tags to activate the virtual content (Blair et al., 2011). However, reliable mapping and feature identification remain as a biggest challenge for markerless AR systems, particularly in dynamic or complex landscapes (Grubert et al., 2017). The accuracy of markerless AR can be affected by multiple factors such as lighting conditions, occlusions, and the presence of similar features in the environment which can overlap or trigger the content inside of the AR (Wagner et al., 2008). The user experience or general efficacy of the AR application may suffer because of these difficulties, which may cause the virtual content to jitter or misalign.

Melaka, a Malaysian ancient city is renowned for its well-preserved historical monuments and rich cultural legacy that has been exist for decades (Bunnell, 2002). However, due to elements like ageing, weathering, and human interference, it has caused many of these sites’ present difficulties for preservation and restoration (Abdul Aziz et al., 2023). These historical sites may deteriorate because of improper repair and maintenance, which might have a negative impact on both their look and the general experience of tourist (Bunnell, 2002). Furthermore, it's possible that the way these historical locations are presented using traditional techniques, such static displays or guided tours, isn't interesting or engaging enough to draw in tourists from today's generation (Chung et al., 2015).

1.3 Problem Statement

Melaka, the oldest cross-cultural legacy in Southeast Asia with a history going back to the 15th century, is one of Malaysia's cultural world heritage sites (UNESCO, 2011) There are varieties of historical sites in this city, such as St. Paul's Church, the A Famosa Fort, and the Muzium Istana Kesultanan Melaka. However, issues with ageing and obsolesce have affected many ancient buildings and most of them have now been negated or in some degree of a state of deterioration (Abdul Aziz et al., 2023). This, in turn, resulted in a decrease in general tourist satisfaction and engagement with the heritage of the city.

Furthermore, study indicates that conventional approaches of showcasing historical locations, including static museums, pamphlets, and guided tours, are insufficient and unable to draw in tourists (Telfer & Hashimoto, 2024). According to Abdul Aziz et al. (2023), when tourists do not engage with or experience Melaka's cultural legacy through interactive technology such as AR, they miss out on genuinely engaging with the city's rich past. This may result in a decrease in tourist numbers and money, which would have major ramifications for Melaka's tourism sector and economy.

The lack of innovative and engaging ways to depict cultural assets in Melaka exacerbates the problem of old and outmoded historical sites. Many of the city's historical attractions are presented in two-dimensional, static forms, such as pamphlets and posters, which do not give the type of contact and involvement that tourists of current generations need (Ibiş & Çakici Alp, 2024). This has resulted in a lack of interest and involvement among tourists, leading to a decrease in the entire tourist experience and a lack of respect for Melaka's cultural legacy (Md Khairi et al., 2022).

1.4 Project Aim

The aim of this project is to create an interactive AR experience that brings the vibrant history of Melaka, Malaysia to 3D.

1.5 Project Objectives

There are three objectives that need to be achieved. The objectives are as follows:

1. To identify the technical requirements for developing mobile application that features markerless AR and interactive 3D models of Melaka historical sites.

2. To develop an AR mobile application that includes interactive 3D models of Melaka historical buildings.
3. To evaluate the effectiveness of the AR application in enhancing users' understanding and engagement with Melaka historical sites.

1.6 Project Scope

The scope of this project is focused on developing an interactive AR application that showcases seven historical sites in Melaka, Malaysia. The application will feature 3D models of the following sites:

1. A Famosa
2. Muzium Istana Kesultanan Melaka
3. Christ Church Melaka
4. Stadthuys
5. Muzium Rakyat
6. Muzium Setem
7. Muzium Yang di-Pertua

The project will utilize markerless AR technology to allow users to interact with the 3D models without the need for physical markers or tags. The application will be designed for mobile devices, ensuring accessibility for a wide range of users.

The application is focusing on providing an engaging and informative experience for users, highlighting the cultural heritage and significance of these historical sites.

1.7 Project Significant

The project aims to enhance tourist engagement and appreciation of Melaka cultural heritage by providing an interactive and immersive experience through the AR application. By focusing on the seven historical sites mentioned, the project will showcase the city's rich history and architectural diversity while adhering to the limitations of available reference materials and time constraints for 3D modelling.

1.8 Report Organization

This report is structured into six chapter, that are organized as follows:

Chapter 1 is the initial part of the project which consist brief explanation of the project and provides a quick summary of its scope and relevance. It opens with an overview of AR and its possible uses in improving cultural heritage discovery. The project is explained, with an emphasis on Melaka's rich cultural legacy and the difficulty of engaging modern tourists. The problem statement summarises the present challenges and suggests markerless AR technology as a possible solution. This chapter also includes the study objectives, study questions, theoretical framework, scope of study, study importance, operational definitions, report structure, and chapter summaries.

Chapter 2 is details of the project which explain in depth of literature that relevant to this study. It covers the evolution and types of AR technology, with a focus on markerless AR. The chapter explores how AR has been used in cultural heritage preservation and tourism, highlighting case studies and previous projects. Theories pertinent to the development and application of AR in education and heritage are discussed. Additionally, this chapter reviews usability studies and prior study on similar AR applications.

Chapter 3 summarises the project methodology and describes the project design in depth. It takes an organised approach with three phases which is analysis, design, development, and evaluation. The analysis step comprises gathering initial needs via surveys and other techniques. The design and development phase describes how to create the AR application based on these criteria. The assessment phase outlines the tools used to measure the application's efficacy and examines the obtained data.

Chapter 4 discussed the practical aspects of the project's implementation. It details the process of designing and developing the AR application, including thorough explanations of the user interface design. The chapter also discusses how key elements specific to the project's goals are incorporated into the application. Documentation of the development process, including the challenges encountered and solutions devised, is provided.

Chapter 5 presents the results and findings from the evaluation phase of the study. It analyses data collected through various instruments, focusing on user feedback regarding the AR application's design and functionality. The chapter discusses user acceptance, expert evaluations, and usability interaction patterns, providing a comprehensive assessment of the application's impact on user engagement with Melaka's cultural heritage.

Chapter 6 concludes the project by summarizing the key findings and discussing their implications. It highlights the main contributions of the projects, including the innovative use of markerless AR technology for cultural heritage exploration. The chapter also addresses the limitations of the study and provides recommendations for future study in this field.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature on augmented reality (AR) technology and Melaka's historical sites is reviewed. This section provides essential knowledge for understanding the project's technological and cultural contexts.

2.2 Augmented Reality Technologies

2.2.1 Definition

According to Ma & Choi (2007), AR combines real-world elements with computer-generated virtual elements. Images are fluidly synthesized and projected, either on a monitor or using optical see-through technology. In contrast to lifelike virtual items and real-world scenes in films, this type of composition needs audience engagement. Rather than creating a virtual environment ahead of time, the entire process should take place in real time. AR encompasses both what we see and what is happening. AR is also one of the components within the Reality-Virtuality (RV) continuum as illustrates in Figure 2.1, which includes AR, Extended Reality (XR), Mixed Reality (MR), and Virtual Reality (VR).

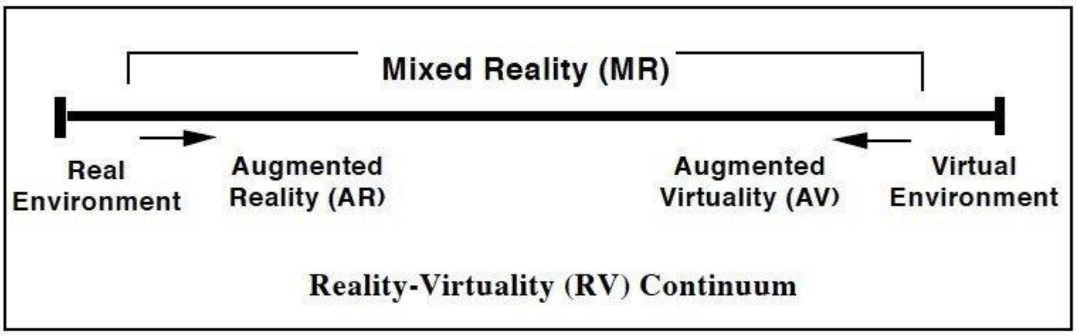


Figure 2.1: Reality-Virtuality Continuum

2.2.2 Tracking Types

Various methods of tracking in AR are examined, encompassing markerless AR and marker-based AR, with particular emphasis on the properties and applications, followed by a comparative analysis.

a) Markerless AR

According to Bogue (2013), Markerless AR does not require markers and instead uses localization technologies and gyroscopes to calculate the relative location and angle of virtual objects. Markerless AR apps seldom use SDKs and instead rely on complex algorithms to ensure position accuracy, which can still be impacted by external variables and localization technology performance. Despite possibly poorer position precision than marker-based AR, markerless AR provides more stability, making it ideal for a wide range of mobile applications. Markerless AR, which is mostly supported on mobile devices, is ideal for developing immersive experiences that seamlessly blend virtual and actual material.

b) Marker-based AR

According to Brito & Stoyanova (2018), fiducial markers are used in AR tracking where image descriptions are given in advance. There is no need to use an accelerometer or compass. The recognition library may be able to compute the pose matrix (rotation and translation) of the observed picture relative to the device's camera. An inexpensive detection algorithm. Strong enough to withstand illumination fluctuations but it does not work if partially overlapped. The fiducial marker graphic is black and white and square in shape, making it easy to recognize.

c) Comparison between Markerless AR and Marker-based AR

Table 2.1 below illustrates the comparison between two tracking types of AR which is Markerless AR and Marker-based AR:

Table 2.1: Comparison between Markerless AR and Marker-based AR

Features	**Markerless AR**	**Marker-based AR**
Tracking Method	Localization technology and gyroscopes are used to compute relative	Tracks objects using fiducial markers and picture descriptors.
SDK Usage	Hardly uses SDKs. • ARCore • ARKit • Vuforia	Commonly uses SDKs • Vuforia • ARToolkit
Stability	More stable, appropriate for a variety of mobile applications.	Stable, can resist light variations, but not partial overlap.
Hardware Support	Mostly supported on mobile devices	Supported on various devices

2.3 Markerless AR

Markerless AR technology has gained popularity in recent years because of its potential to provide immersive experiences without the need of physical markers. This section dives into the fundamental concepts of markerless AR and considers its possible applications in cultural heritage interpretation and tourism.

2.3.1 Types of Markerless AR Tools – AR Foundation

AR Development Kits, such as Apple's ARKit for iOS and Google's ARCore for Android, make it easier for developers to create AR applications. These platforms aim to simplify access to the technology for developers (Oufqir et al., 2020).

a) ARCore

ARCore, developed by Google, is a platform designed for creating immersive AR experiences on mobile devices. It uses several APIs to help phones see their surroundings, interpret the environment, and interact with digital information. Notably, several of these APIs are interoperable with both the Android and iOS platforms, allowing enabling shared AR experiences across many devices.

ARCore provides three essential features that help integrate virtual content with the real-world environment as captured by the device's camera:

i. Motion Tracking: This capability allows the phone to understand and track its position and orientation relative to the surrounding environment.
ii. Environmental Understanding: ARCore enables the device to recognize and comprehend the size, shape, and placement of various surfaces in the environment.
iii. Light Estimation: ARCore incorporates light estimation technology, allowing the device to assess the current lighting conditions in the environment.

These capabilities collectively enable developers to create compelling AR applications that seamlessly blend virtual content with the user's physical surroundings, enhancing immersion and interactivity.

b) ARKit

ARKit, Apple's groundbreaking AR framework, marks a big step forward in immersive digital experiences. ARKit enables developers to create rich and engaging AR apps that seamlessly integrate virtual and real-world information by utilising a range of cutting-edge technologies.

Latest version of ARKit which is ARKit 6 now able to supports 4K video, allowing you to shoot spectacular high-resolution footage of AR experiences, ideal for professional video editing, film production, social media apps, and more. The video and capture capabilities have been improved to include HDR video and high-resolution background picture capture. Based on case study by Andrew (2024) list out 3 features that can be explore through ARKit which is:

i. Face-Tracking: Face-tracking AR face masks and filters are used to enhance the user experience and increase engagement. ARKit analyses data to generate tracking data, face meshes, and blend shapes. Tracking data allows developers to better understand how to show material when the user moves their face.

ii. Object and Scene Recognition: ARKit's object and scene recognition capabilities were used to facilitate AR indoor navigation. Visual markers served as a frame of reference for precise interior placement, allowing users to explore buildings utilising AR technology.

iii. Meshing and Rendering: In the AR measuring tools case study, combining meshing and rendering capabilities made it easier to create 3D floor plans of building interiors. The LiDAR scanner in iPhone and iPad devices allowed for precise measurements and detection of room size and furniture kinds.

c) Comparison between ARCore and ARKit

Table 2.2 below illustrates the comparison between two types of tools to develop markerless AR:

Table 2.2: Comparison between ARCore and ARKit

Feature	**ARCore**	**ARKit**
Motion Tracking	Allows the gadget to recognise and monitor its location and orientation in relation to the surroundings.	Allows the phone to understand and track its position with reference to the surrounding environment.
Environmental Understanding	Recognises and comprehends the size, shape, and location of different surfaces in the surroundings.	Allows the gadget to recognise the size and location of surfaces, both horizontal and vertical.
Light Estimation	Uses light estimate technologies to analyse the current lighting conditions in the surroundings.	Evaluates the current illumination conditions in the surroundings, enabling more realistic representation of virtual objects.

Interoperability with Platforms	Several APIs are compatible with both Android and iOS systems, allowing for shared AR experiences.	Offers strong support for iOS devices, including face tracking and object recognition.
Device Support	Supported on a variety of Android devices, offering developers and consumers with a diverse set of possibilities.	Primarily built for Apple devices, such as iPhones and iPads, with optimised performance and functionality.

2.3.2 Challenges of Markerless AR

According to Sonia (2024), the three most typical obstacles that developers will face while designing markerless AR are as follows: the first is reliance on flat and textured surfaces. AR applications commonly use flat, textured surfaces to correctly position virtual objects. This dependency may limit AR's applicability in areas where such surfaces are not easily available. Second, markerless AR has a high-power consumption on mobile devices. This is because running AR apps on mobile devices consumes a large amount of power, causing the battery to vary rapidly. Users may be concerned about this, particularly if they use AR apps for an extended period.

Markerless AR, according to her, is also being adopted quite slow. Despite advances in AR technology, widespread acceptance of AR applications may be delayed. This might be due to several factors, including limited user knowledge, technology restrictions, or the need for compelling use cases to stimulate adoption. Furthermore, Gatis (2022) believes that the most difficult aspect of building markerless AR is ensuring that AR material is contextually relevant.

One of the challenges with AR material is ensuring that it makes sense in a certain context. In certain cases, the layout of virtual goods may be inconsistent with the real-world surroundings or look out of place, thereby impacting the overall user experience. Reliance on textured surfaces for computer vision. AR apps usually require users to find flat, textured surfaces to precisely position virtual objects. However, this reliance on textured surfaces may be problematic since they are difficult to distinguish in some contexts, particularly with white or monochromatic backdrops.

2.4 Melaka Cultural Heritage

2.4.1 Background

According to United Nations Educational, Scientific and Cultural Organization UNESCO (2011), Melaka is one of the ancient towns of the Straits of Melaka, where East and West have traded and exchanged cultures for over 500 years. Asia and Europe's influences have given the towns a distinct multicultural legacy that is both tangible and intangible. Melaka, with its administrative buildings, churches, squares, and defences, exemplifies the early stages of this history, beginning with the 15th-century Malay sultanate and continuing through the Portuguese and Dutch periods, which began in the early 16th century.

2.4.2 Historical Sites in Melaka

a) A Famosa

According to Mohamad et al. (2010), A Famosa is a historical fortress located in Melaka, Malaysia. It was built by the Portuguese in 1511 after they defeated the Melaka Sultanate. The fortress played a significant role in the history of Melaka as it served as a strategic defence structure during the colonial era. Over the years, A Famosa has undergone various occupations by different colonial powers such as the Portuguese, Dutch, and British, each leaving their mark on the fortress.

A Famosa, that shown in Figure 2.2 which translates to "The Famous" in Portuguese, is one of Southeast Asia's oldest remaining European architectural relics. The fortification was initially built to safeguard Portuguese interests in the area and regulate the spice trade. It is made up of a succession of walls and towers, and the main entrance is known as the Porta de Santiago. Despite being substantially ruined throughout the years, A Famosa is still a famous tourist destination and a symbol of Melaka's rich historical legacy.

(a) (b)

Figure 2.2: (a) Old and (b) New A Famosa

b) Majid Selat

Masjid Selat which shown in Figure 2.3 is a contemporary architectural masterpiece on the beaches of the Melaka Strait. Its distinctive architecture blends aspects of both Moorish and contemporary designs, providing stunning views of the surrounding sea. The mosque represents religious variety and cultural peace in Melaka.

Figure 2.3: Masjid Selat

c) Stadthuys

The Stadthuys which shown in Figure 2.4 is one of Southeast Asia's oldest Dutch colonial structures, having been established by the Dutch in the 17th century. Its unique crimson façade and towering construction make it a well-known icon in

Melaka's historic area. Today, it contains the History and Ethnography Museum, which displays artefacts and exhibits about Melaka's rich cultural legacy.

Figure 2.4: Stadthuys

d) Muzium Istana Kesultanan Melaka

Muzium Istana Kesultanan Melayu Melaka which shown in Figure 2.5, popularly known as *"Melaka Sultanate Palace"* is a recreation of the Melaka Sultanate's original palace. Located at the foot of Bukit Melaka, the museum provides information on Melaka's royal history and cultural legacy. Visitors may visit a variety of galleries and exhibitions that highlight the Sultanate's history and historical artefacts.

Figure 2.5: Muzium Istana Kesultanan Melaka

e) Muzium Setem

Muzium Setem which shown in Figure 2.6, sometimes known as the *"Stamp Museum"* is dedicated to the history and art of postage stamps. Located in Melaka's historic area, the museum houses stamp collections from Malaysia and throughout the world. Visitors may learn about the history of postal stamps and their cultural importance through interactive exhibitions and displays.

Figure 2.6: Muzium Setem

f) Muzium Rakyat

Muzium Rakyat, which in English is *"People's Museum"* is a community-driven museum that highlights Melaka's rich cultural legacy. The museum which shown in Figure 2.7, housed in a typical Malay home, showcases local customs, traditions, and ways of life. Visitors may visit numerous galleries and artefacts, learning about Melaka's rich cultural legacy.

Figure 2.7: Muzium Rakyat

g) Muzium Yang di-Pertua

The Muzium Yang di-Pertua shown in Figure 2.8, located on Bukit melaka in Melaka City, Malaysia, may be an exhibition hall displaying the personal belongings of Melaka's governors from the country's inception. The buildings had formerly functioned as the official house and office of the Dutch senator in Melaka, as well as the official residence of Melaka's Yang di-Pertua Negeri until 1996. It was publicly opened to the public in 2002 and has exhibits on Melaka's history and governors. The historical centre is an important social and genuine landmark in Melaka, providing visitors with a unique insight into the region's rich past.

Figure 2.8: Muzium Yang di-Pertua

2.4.3 Existing Historical Sites AR Applications

This part reviews the current systems and establishes the project's baseline. Even though the specific system that relevant to this project is hardly to be found, the following three existing systems have been picked as the most likely to be related to my project:

a) Cultural Compass

Figure 2.9: AR Cultural Compass

Figure 2.9 shows the "Cultural Compass" apps which was created to give travellers with a unique approach to discover cultural areas of interest using geographical, semantic, and temporal navigation methods. This programme uses AR to superimpose old photos onto real-time settings, allowing users to observe the progression of historical locations in an engaging way.

b) KnossosAR

Figure 2.10 shows KnossosAR apps which is a standalone Android application. It describes the iterative development and testing steps, as well as how interpretative information for specific Points of Interest (POIs) was included into the AR framework. The application design process included content selection, authorship, use case description, and user interface prototypes to solicit feedback from archaeologists, educators, and students. The file also discusses improvements including hidden markers for obscured POIs, a dual AR/map view, and handling of physical challenges.

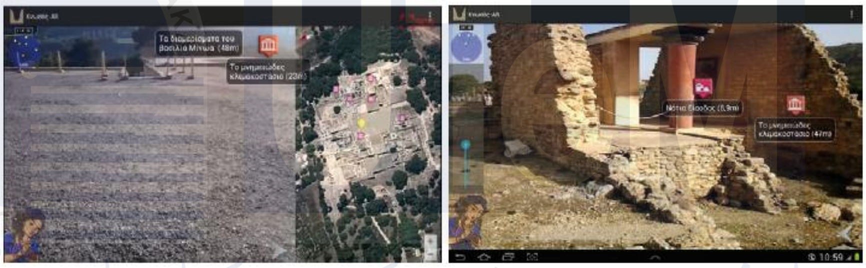


Figure 2.10: KnossosAR

c) AR Mobile Application for Malolos' Kamestisuhan (Malolos Heritage Town, Philippines)

Figure 2.11: AR Mobile Application for Malolos' Kamestisuhan (Malolos Heritage Town, Philippines)

Figure 2.11 shows The AR Mobile Application designed for Malolos' Kamestisuhan (Dennis R. dela Cruz1, Jerico S.A. Sevilla2, Joshua Wilfred D. San Gabriel3, Angelica Joyce P. Dela Cruz4, 2018)uses AR technology to digitally reconstruct missing riches. It provides users with 3D reconstructions of historical structures, trivia, maps, and postcards to enhance the interactive experience. The app raises user knowledge and appreciation for cultural heritage locations in Malolos City by boosting historical and cultural significance through personalised features and immersive learning.

2.5 Summary

Chapter 2 gave a thorough literature study on AR technology and Melaka's cultural heritage. The study of AR technologies, such as markerless and marker-based AR, has created the groundwork for comprehending the project's technical components. Insights into the capabilities of ARCore and ARKit, as well as the constraints of markerless AR, provide important considerations for the development process. Furthermore, an investigation of Melaka's cultural history, which includes prominent structures such as A Famosa and Melaka Straits Mosque, as well as museums and historical sites, demonstrates the region's cultural richness and variety. Each landmark has a particular historical importance, adding to Melaka's diverse identity.

Additionally, reviewing current cultural heritage AR apps, while not directly connected to the project, provides significant insights into how AR technology has been used in comparable situations. The "Cultural Compass," "KnossosAR," and the AR Mobile Application for Malolos' Kamestisuhan showcase AR's potential to improve the investigation and interpretation of cultural heritage sites. Finally, Chapter 2 establishes the project's framework by offering a thorough grasp of AR technology and its uses in cultural heritage contexts, as well as an overview of Melaka's rich cultural heritage. This insight will help to inform the development process and lead the building of a unique AR application for exploring and enjoying Melaka's cultural riches.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter will discuss the project technique that was employed to bring this project to reality which called methodology. Structured processes were taken to assess, design, create, and test the Augmented Reality (AR) application. The aim of this methodology was to guarantee that the markerless AR mobile application efficiently increases people's exploration and appreciation of Melaka's rich cultural heritage.

3.2 Project Methodology

This section focuses on the project approach followed during the development process. Figure 3.1 illustrates the project technique for the creation of create the Interactive Melaka's Historical Sites in Markerless AR Apps. The technique is structured around its objectives and aims.

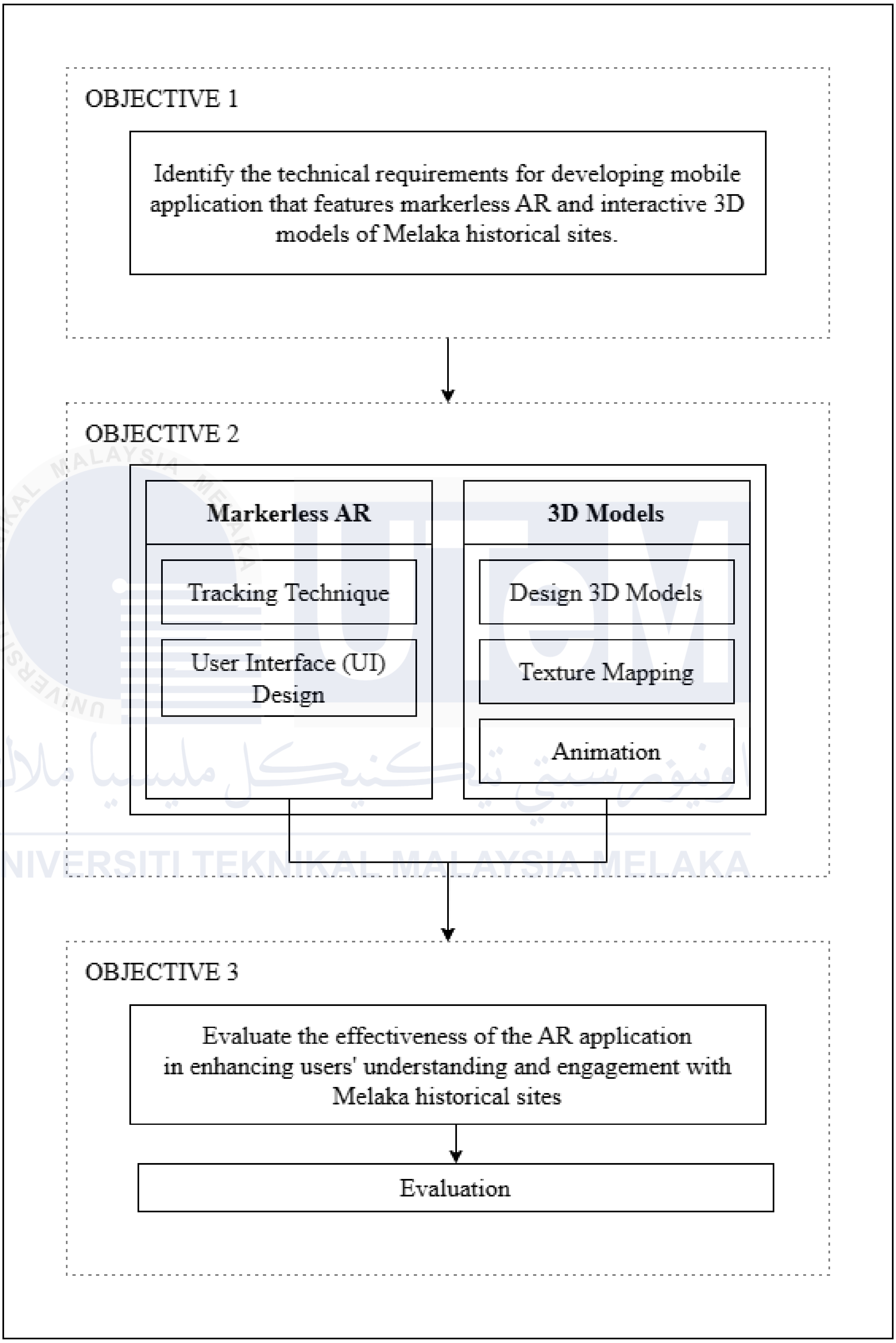


Figure 3.1: Project Methodology

Phase 1: Identify the technical requirements for developing mobile application that features markerless AR and interactive 3D models of Melaka historical sites.

In the first phase, the project begins with identifying the technical requirements necessary to develop a mobile application that incorporates markerless AR and interactive 3D models. The data from previous studies is collected as part of the study, including architectural features, historical significance, and visual attributes, which are important for the design of the 3D models of Melaka's historical sites. Alongside this, the project investigates the current state of AR technology, particularly focusing on markerless AR techniques and a comparative analysis is conducted to evaluate various AR platforms and technologies, ensuring the selection of the most suitable tools for the project. This phase was described in Chapter 2 to achieve the project's first goal. This initial phase created the essential framework needed for creating and integrating AR features in the next stages of the project.

Phase 2: Develop an AR mobile application that includes interactive 3D models of Melaka historical buildings.

Phase 2 expands the basic knowledge gained in Phase 1 by concentrating in the development of the AR mobile application itself. During this phase, we create 3D models of Melaka's historical sites, using texture mapping techniques to increase realism and aesthetic appeal. To increase user engagement, these models were animated and merged with interactivity. The next step is to implement advanced markerless AR tracking methods, which ensure that these 3D models are accurately anchored and smoothly tracked in the user's environment, regardless of changes in device position or lighting. At the same time, we provide a user-friendly interface that facilitates interaction with the AR application, making it simple and straightforward for users to explore and engage with historical material. This phase is significant because it transforms the theoretical and historical foundation created in Phase 1 into practical, interactive digital experiences that users may interact with directly.

Phase 3: Evaluate the effectiveness of the AR application in enhancing users' understanding and engagement with Melaka historical sites.

After the development process, the final phase would be to evaluate the effectiveness of the AR application in enhancing users' understanding and engagement with Melaka historical sites. This integration guarantees that the models are not only correctly tracked but also realistically reconstructed in the user's environment, resulting in a realistic representation of Melaka's historical sites. Comprehensive testing is conducted to discover and fix any issues with performance, usability, or tracking accuracy. The application is optimized to run smoothly across various devices and conditions. User testing is a critical part of this phase where users interact with the application and provide feedback through questionnaires or interviews. This feedback is analysed to assess the application's usability and educational value, and insights from users are used to improve the application. By the end of this phase, the project aims to deliver a fully integrated, user-tested AR application that effectively showcases Melaka’s historical sites and meets the project's goals of enhancing user engagement and understanding.

3.1 Markerless AR

This section discusses three main components in creating Markerless AR. The components are tracking technique and User Interface (UI). The following subsections have been explained in detail.

3.1.1 Tracking Technique

The markerless AR tracking technique used in this application takes a strategic approach to smoothly integrating digital material into the user's real-world surroundings without the usage of fixed markers. Figure 3.2 show process of developing Markerless AR. Based on Figure 3.2, this process includes many important phases designed to ensure correct placement and realistic representation of AR information, with particular focus on historical sites in Melaka. The process begins with the AR Scene, which displays an animated 3D model of Melaka Maps, giving a focus for the AR experience. Within this environment, pick-point locations representing historical sites are layered on top, serving as entrance points for users to explore further.

After selecting a pick-point location, the markerless AR system begins a series of complex methods to attach the appropriate 3D representation of the historical place into the user's real-world environment. This starts with detecting and tracking features in the environment using the device's camera. They serve as reference points for accurately determining the camera's pose, which includes its position and orientation in relation to the detected features.

Once the camera's pose is determined, the next step involves registering the 3D model of the historical site to the detected features, ensuring precise alignment and placement within the user's view. This registration procedure is critical for sustaining the illusion that virtual material blends smoothly with the actual environment. After properly registering the 3D model, the markerless AR system renders the AR content in real time, dynamically overlaying the historical site's digital representation onto the user's camera feed.

In addition to visual representation, the AR application gives users essential information about the historical place, such as descriptions and narration sound, which improves the educational and immersive components of the experience. By seamlessly merging digital material with the real environment, the markerless AR technology used in this application provides users with an engaging and interactive way to discover Melaka's rich cultural history.

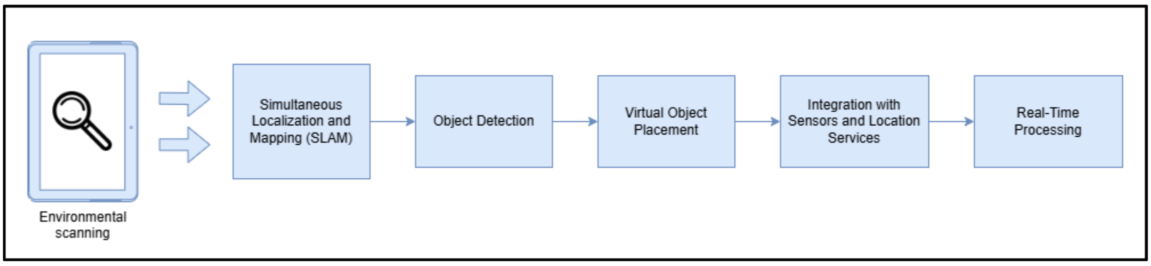


Figure 3.2: Process of developing Markerless AR

3.1.2 User Interface (UI)

Designing the user interface (UI) is an important part of creating a successful and entertaining markerless AR application. A user-friendly UI allows users to interact with the programme in a straightforward and efficient, improving their overall experience and engagement with the content.

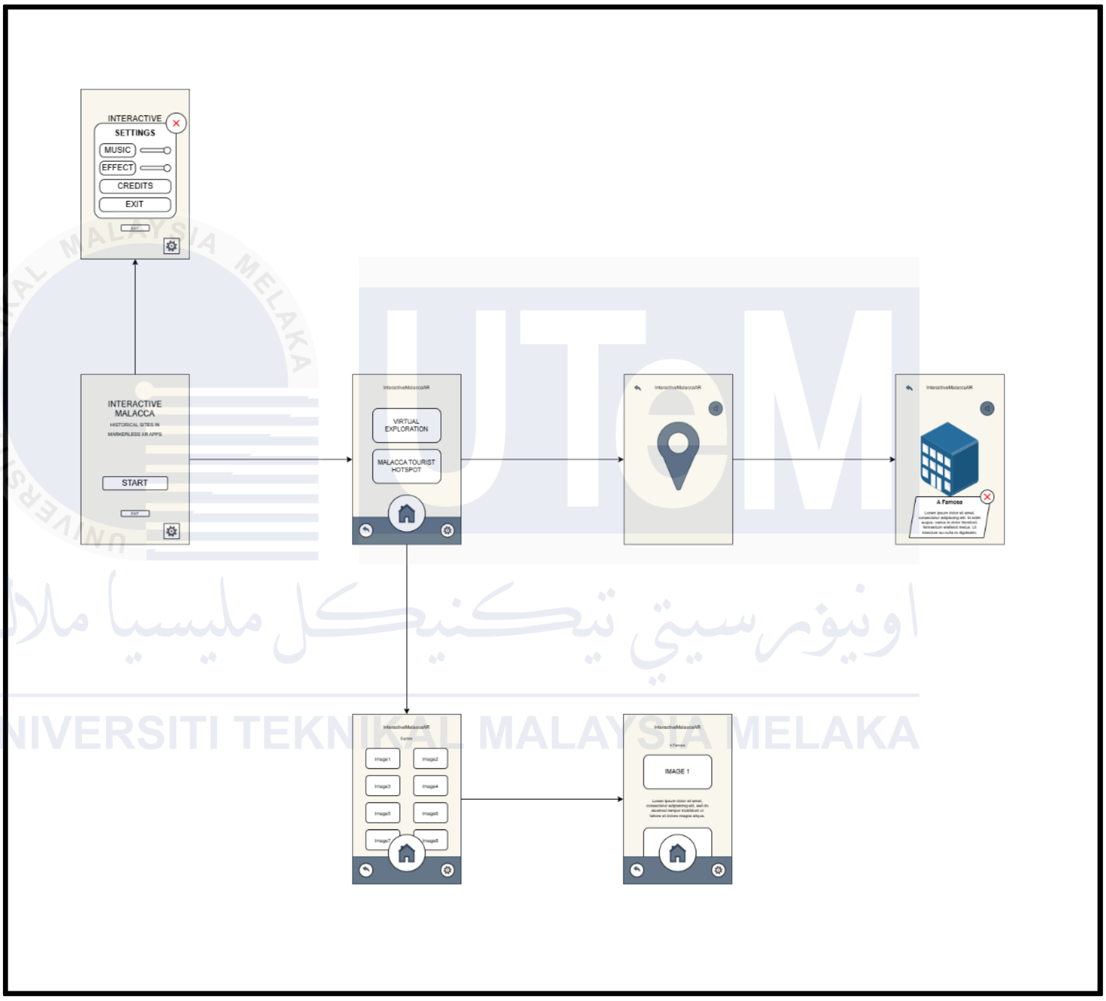


Figure 3.3: Wireframe of UI for the AR application

Based on Figure 3.3, there are seven expected UI for this application. The first UI is for main page. The second UI is the settings panel which user can set their preferred volume for the background sound and the sound effects. The third UI is the second page after users click on the 'Start Exploring' button. The second page give user 2 options button which is ‘Virtual Exploration’ button which redirect user to AR Scene which is on the 4th and 5th UI or ‘Melaka Tourist Hotspot’ button which redirect user to infographic explanation about 10 tourist hotspot places in Melaka or 6th and 7th UI.

3.2 3D Models

This section discusses three main components in creating 3D models. The components are designing, texture mapping and animation. The following subsections have been explained in detail.

3.2.1 Designing

In the design process, broad study and conception provide a structure for producing realistic and engaging 3D reconstructions of historical sites. Figure 3.3 show the process of designing 3d model. Based on Figure 3.4, a solid understanding of the subject would be obtained if oneself immerse in historical records, architectural plans, and visual references. Sketching out basic designs helps figure out the design direction and serves as an outline for the digital modelling phase.

Using specialised 3D modelling software like Blender to convert these conceptual ideas into digital models, beginning with fundamental structures and finally perfecting them to capture specific details and architectural aspects. During this stage, designers focus attention to detail, adding finer elements and subtleties to the 3D model while maintaining size, proportions, and historical authenticity. Finally, optimisation methods are used to guarantee that the 3D model is optimised for performance and efficiency, while also balancing visual quality and resource utilisation.

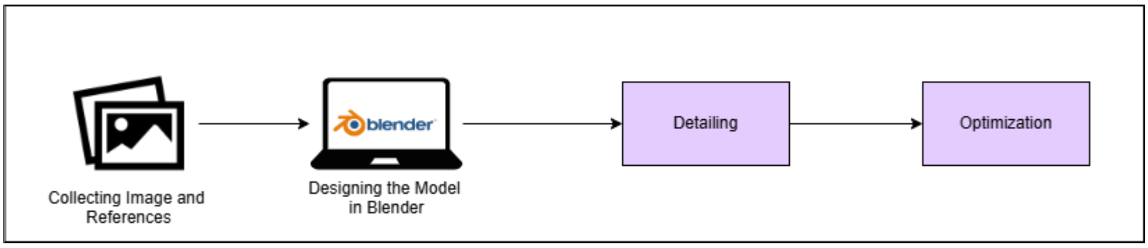


Figure 3.4: Process of designing 3d model

3.2.2 Texture Mapping

Texture mapping brings 3D objects to life by increasing the realism and depth of their surfaces. The procedure starts with UV unwrapping, which involves unwrapping the 3D model's geometry into 2D space to produce a UV map that can be used to apply textures. Figure 3.5 shows the process of texture mapping. Based on Figure 3.5, high-quality textures are then generated or obtained to reflect the historical site's materials and surfaces. These textures are cautiously added to the UV map using texture mapping techniques, with precise alignment and scaling to provide realism and uniformity across the 3D model.

Modifications may be required to correct edges, distortion, or various other issues, with texture properties like roughness, specular magnitude, and colour modified to produce the desired visual impact. Accurate texture mapping will improve the visual attractiveness and authenticity of the 3D model, immersing viewers in a real virtual environment.

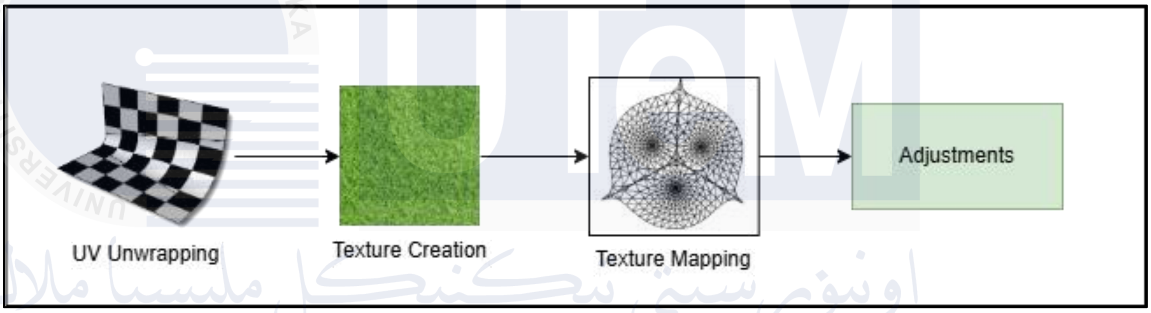


Figure 3.5: Process of texture mapping

3.2.3 Animation

Animation brings 3D objects to life, enhancing the AR experience with interactive animation and engagement. The process begins planning, in which the sequence of animations and interactions inside the AR application is defined. Figure 3.6 illustrates the process of animating 3d model. Based on Figure 3.6, keyframe animation methods were utilised to animate the movement and behaviour of objects in the 3D environment. Keyframes are placed at key points in time to designate the start and finish locations of objects, and the software calculates the motion between keyframes.

Finally, the animations are integrated into the AR application and tested to ensure smooth playback, proper timing, and alignment with user interactions and events. Through interactive animations, users are taken into an interactive virtual environment in which historic sites come to life before their own eyes.

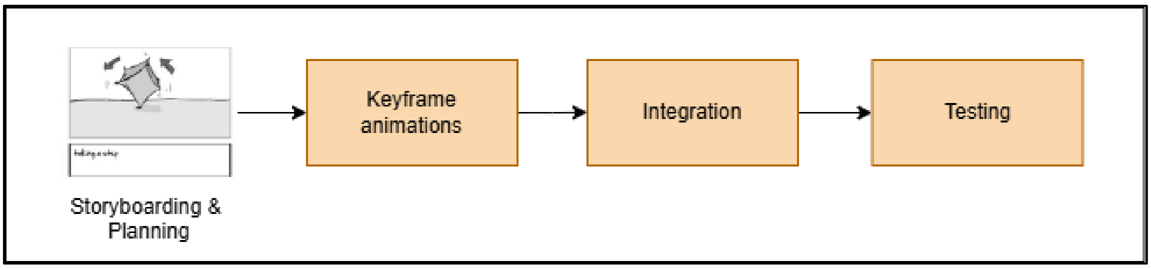


Figure 3.6: Process of animating 3d model

3.3 Evaluation phase

The evaluation phase of the project methodology is important to ensure that the markerless AR application effectively increases people's exploration and appreciation of Melaka's rich cultural heritage. This phase involves assessing the application's performance, user experience, and educational value through a structured evaluation process. The target respondents for this evaluation are local people who never went to Melaka Historical sites.

Figure 3.7 shows the evaluation procedure flow for this project. The evaluation procedure includes usability testing and user acceptance testing, where respondents are given a pre-test questionnaire to gather information about their background and experiences in the field of cultural heritage and AR technology. Respondents then interact with the AR application, exploring and testing its features, and are given a post-test questionnaire to gather feedback about their experience.

The feedback is analysed to identify areas for improvement and assess the overall effectiveness of the application. The evaluation phase is critical in refining the application and ensuring that it meets the standards of performance and user experience, ultimately delivering a high-quality product that achieves the project's goals.

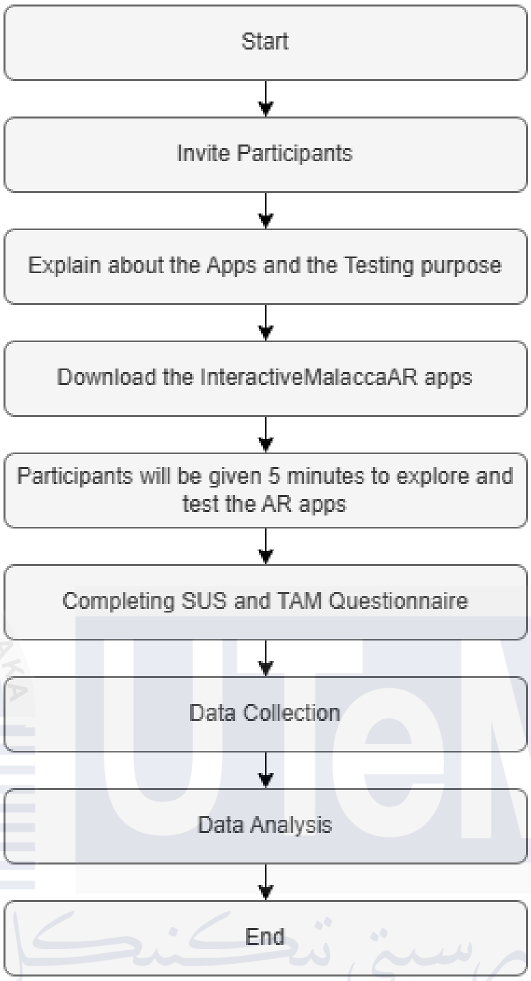


Figure 3.7: Procedure flow for the evaluation testing

3.4 Requirement and Specification

The most important part of designing apps is choosing the correct hardware and software. The correct hardware and software should be used to build a high-quality application with few faults. Table 3.1 summarises the hardware and software specs.

Table 3.1: The specification of hardware and software

Hardware	Software
AMD Radeon (TM) R5 M330	Microsoft Windows 10

12.0 GigaBytes of memory (RAM)	Unity 2022
Android that supported ARCore	Visual Studio 2022
-	Blender
-	Adobe Illustrator

Based on Table 3.1, The hardware uses to develop the applications are AMD Radeon (TM) R5 M330 as the processor with 12.0 Gigabytes of memory (RAM).

While, for the software specification the first one is Microsoft Windows 10 as the operating system. Next, Unity 2022 is the main platform for this AR project development. Visual Studio 2022 to generate coding for Unity. Additionally, Blender for 3d modelling Melaka historical sites and Adobe illustrator for UI design.

3.5 Summary

This chapter outlined the methodology used to develop the Interactive Melaka Historical Sites using Markerless AR Apps. The methodology is structured around three phases which is studying historical sites and identifying requirements, developing 3D models and markerless AR tracking techniques, UI design and integrating the interactive 3D models with markerless AR technology. The markerless AR technique used in this application ensures the correct placement and realistic representation of AR information, focusing on historical sites in Melaka. Finally, the chapter outlined the hardware and software specifications necessary for the development and testing of the application.

CHAPTER 4 IMPLEMENTATION

4.1 Introduction

This chapter outlines the implementation process of the project, detailing the system architecture and design elements that will bring the project to life. It provides a comprehensive overview of the steps involved in transforming the project's concept into a functional and interactive product

4.2 Implementation of AR

This section explains how this project brought augmented reality (AR) to life. The goal was to create a smooth and interactive AR experience, allowing users to explore the historical sites of Melaka in an engaging way. This were achieved through several key steps, which are detailed in the following parts.

4.2.1 Enabling AR Markerless

This subsection focuses on the technical steps and tools used to enable markerless AR. Markerless AR does not require physical markers to place virtual objects in the real world. Instead, it uses features such as object recognition and spatial mapping, allowing for a more seamless user experience.

a) Setting Up AR Foundation

   i. Using AR Foundation: Unity’s AR Foundation were used to build those AR features.

   ii. Starting AR Sessions: AR sessions were set up in Unity to start tracking the environment and configured the camera to display augmented content correctly.

b) User Interaction

i. Objects Manipulation: Users can also scale and rotate the objects by interacting with it directly.

c) Testing and Adjusting

i. Testing: The AR system was tested in various settings to ensure it works well under different conditions.

ii. Adjustment: It is adjusted to improve accuracy and stability, making the experience smooth and reliable.

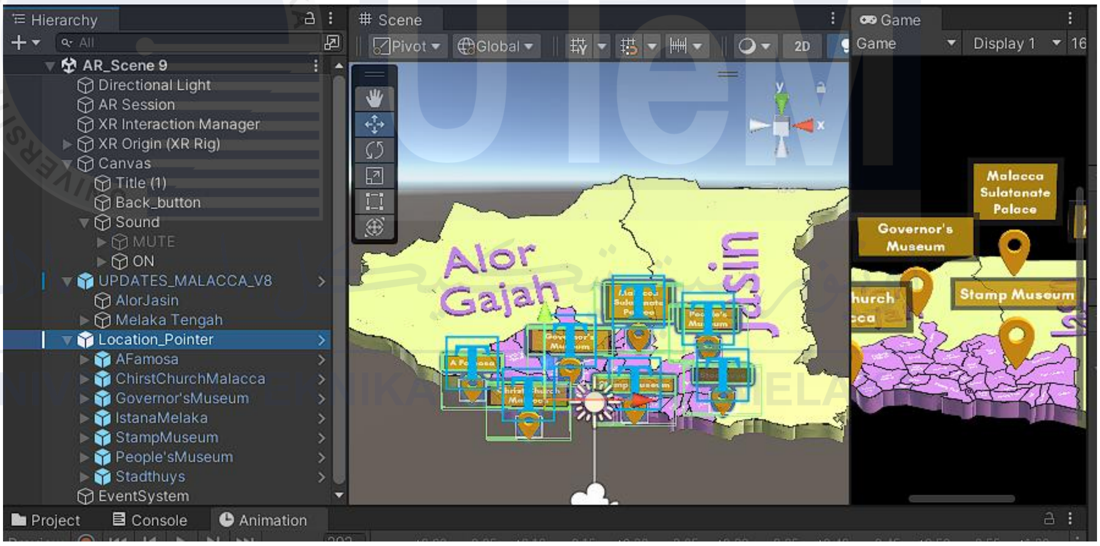


Figure 4.1: Markerless AR Environment Setup

4.2.2 User Interface Design

The user interface (UI) design is important to ensure that the application is user-friendly and intuitive. This subsection details the design principles and methodologies used to create an engaging and easy-to-navigate interface. It involves the creation of wireframes, layout designs, and the overall aesthetic considerations for the application.

a) Study and Planning

i. User Study: Started by understanding the targeted audience and their needs. This involved studying how users interact with AR applications and identifying common challenges.

ii. Requirement Analysis: Based on the user study, the essential features and functionalities that the UI needs to support were listed out, such as navigation, interaction with AR content, and access to information about the historical site.

b) Designing Visual Elements

i. UI Elements: Various UI elements such as buttons, icons, and menus. The design aimed to be clean and modern, ensuring that elements are easily recognizable and accessible.

ii. Consistency: To maintain a consistent look and feel, a style guide that included colours, fonts, and design patterns. This guide helped ensure that all UI elements followed the same design principles.

c) User Interaction Design

i. Gesture Controls: Since the app involves interacting with AR content, gesture controls such as tap, swipe, and pinch were designed. These controls needed to be intuitive and responsive.

ii. Feedback Mechanisms: Visual and haptic feedback were integrated to enhance user interaction.

Figure 4.2: Final User Interface

4.2.3 Input and Output Design

The implementation of the AR experience for exploring historical sites in Melaka involved several key aspects related to input and output design

a) Input Design:

i. Gesture Controls: The application incorporated intuitive gesture controls, such as tap, swipe, pinch, and drag, to allow users to interact with the AR content in a natural and seamless manner.

ii. Responsive Interactions: The gesture controls were designed to be highly responsive, providing immediate feedback to the user's actions and enhancing the overall interactivity.

Table 4.1: Input Design

Input Design	**Function**
Device (Android Tablet) 	To use the application
Start Button 	To start the application
Back Button 	To go back to previous scene
Setting Button 	To open the settings which contains music setting, credits and also exit button.

b) Output Design:

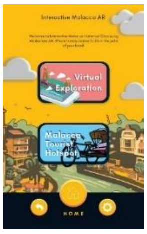
i. Visual Feedback: The application provided clear visual feedback to users when interacting with AR elements, such as highlighting interactive objects or displaying informative overlays.

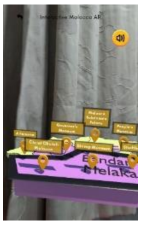
ii. Haptic Feedback: Haptic feedback, such as vibrations, was incorporated to further enhance the user's sense of engagement and immersion when manipulating virtual objects.

iii. Spatial Audio: Spatial audio was used to create a more immersive experience, with sound effects and narration positioned relative to the user's perspective within the AR environment.

iv. Multimedia Integration: The application seamlessly integrated various multimedia elements, including 3D models, animations, and informative content, to enrich the educational and exploratory experience for users.

Table 4.2: Output design

Output Design	**Function**
Device (Android Tablet) 	Display the AR that integrated into the application
Speaker of the device Dolby ATMOS	To play the background music and sound effect
Second Page 	This is output design after clicking the Start button

AR Scene 	This is output design after Virtual exploration button were clicked which contain AR scene.

4.3 Implementation of Assets

4.3.1 Production of 3D Modelling

This part describes the process of creating the 3D models of historical sites in Melaka. Using software such as Blender, detailed and accurate 3D representations of the sites are produced, which are then integrated into the AR application to provide a realistic and immersive experience.

Figure 4.3: Top view of 3D models of Melaka Maps

Figure 4.4: Front view of 3D models of Melaka Maps

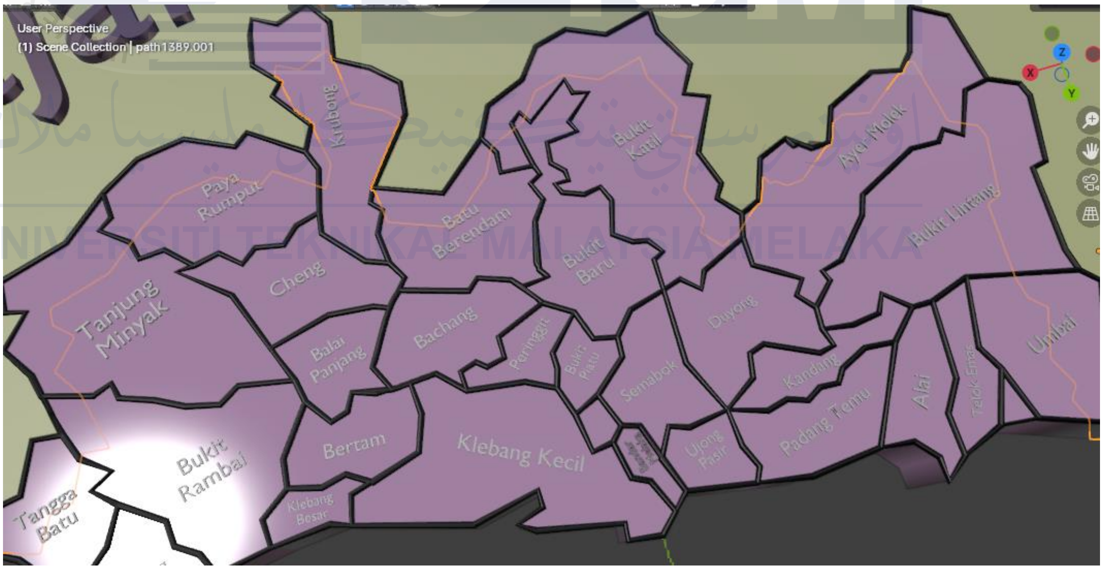


Figure 4.5: Close-up view of 3D models of Melaka Maps

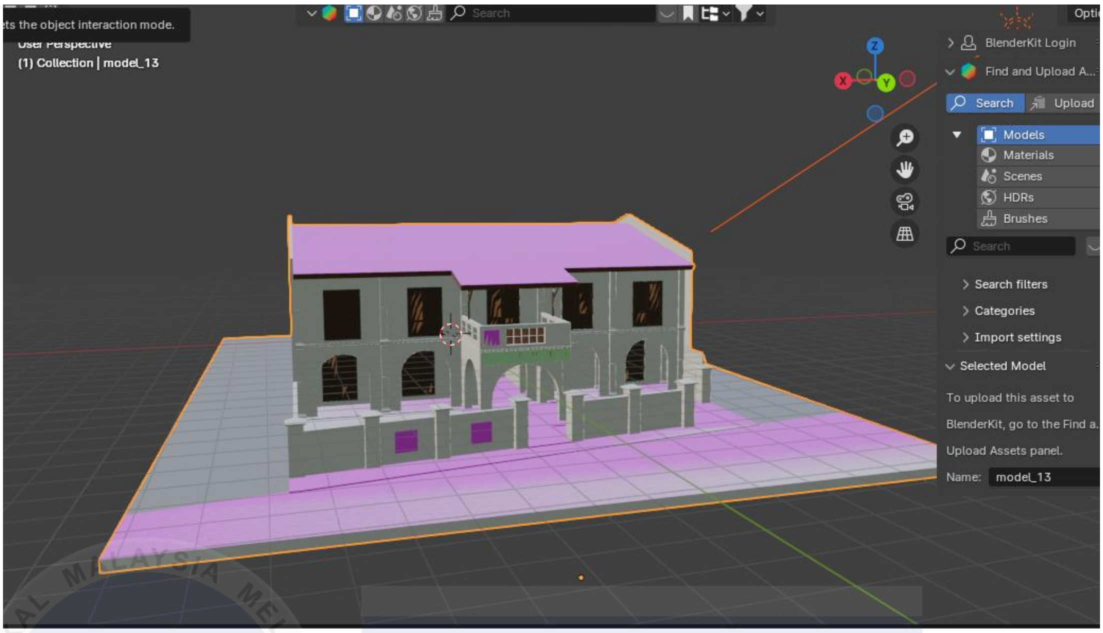


Figure 4.6: Example one of the historical sites 3d model without texture

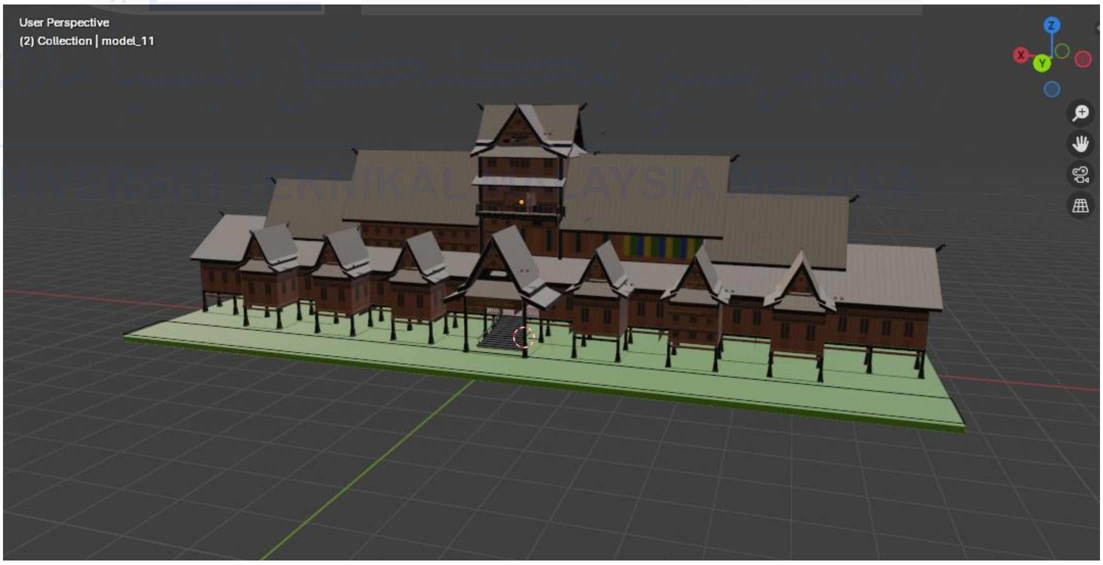


Figure 4.7: Example one of the historical sites 3d model with texture

4.3.2 Production of Audio

Audio production involves creating or sourcing sound effects, background music, and narration that enhance the interactive experience of the AR application. This subsection would cover the audio, and techniques used for audio integration.

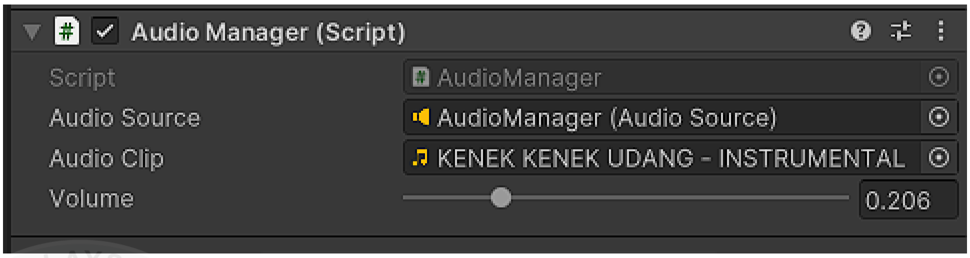


Figure 4.8: Background music of the application

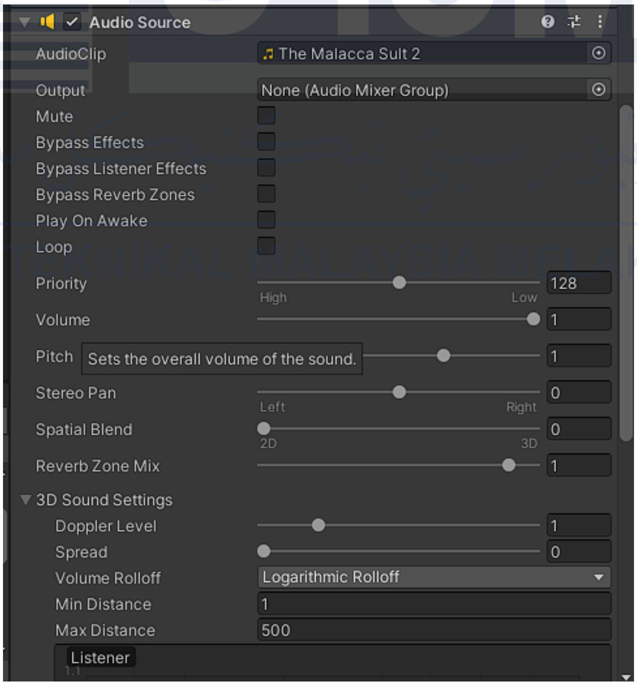


Figure 4.9: Narration audio

```
1 reference
private IEnumerator PlayAudioWithDelay(GameObject popup)
{
    yield return new WaitForSeconds(seconds: 2f);

    AudioSource audioSource = popup.GetComponent<AudioSource>();
    if (audioSource != null)
    {
        audioSource.mute = soundManager.IsMuted();
        audioSource.Play();
    }
    else
    {
        Debug.LogError(message: "No AudioSource component found on the popup prefab.");
    }
}
```

Figure 4.10: Narration audio activation time setup

Figure 4.11: Sound effects for 3d model popup

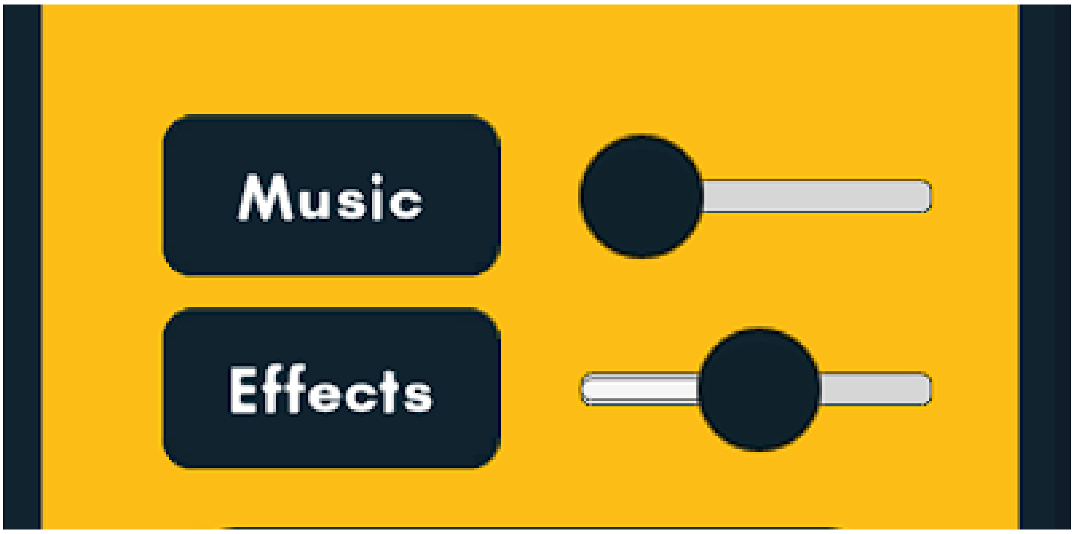


Figure 4.12: Slider for volume controller

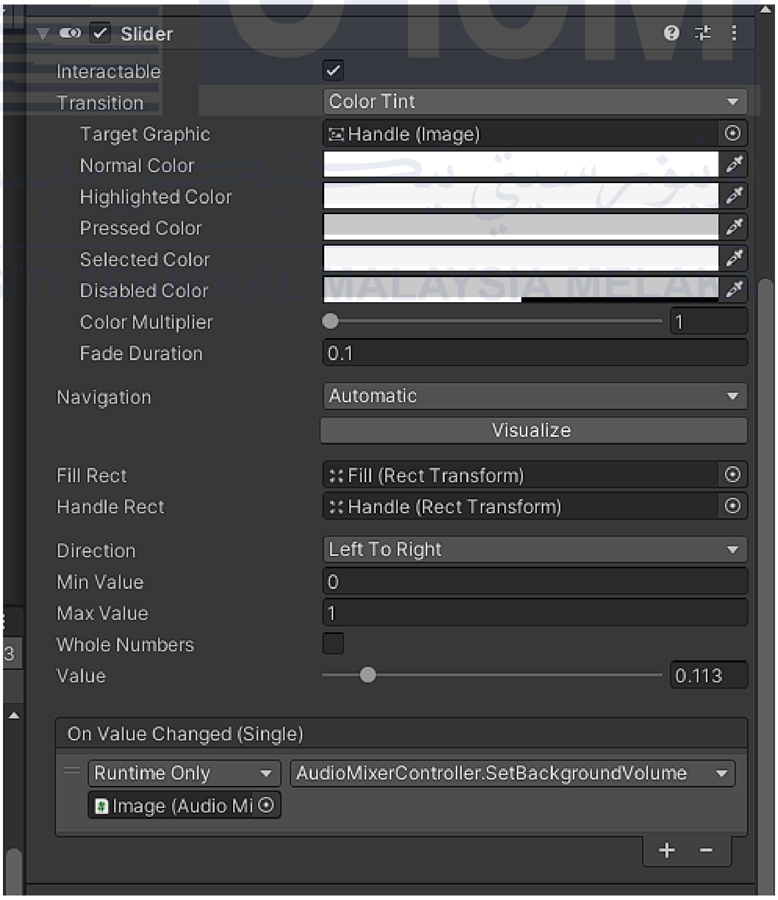


Figure 4.13: Setup for volume controller slider

Figure 4.14: Sound Manager to mute and unmute the narration sound inside the AR scene

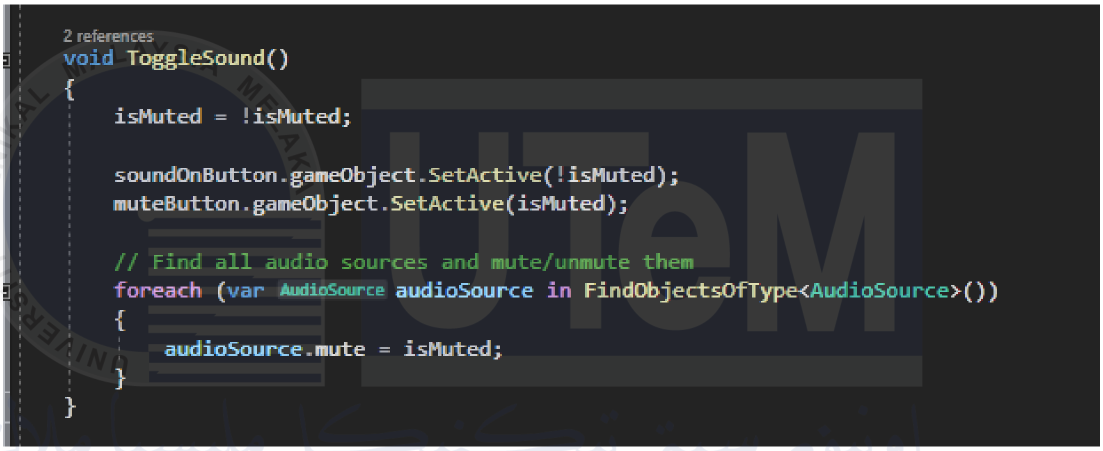


Figure 4.15: Script that manage the sound manager

4.3.3 Production of Animation

Animating the 3D models is important for making the AR experience more dynamic, interactive and engaging. This subsection outlines the animation techniques and software which is Unity that were used to animate the historical sites, bringing them to life in the AR environment.

a) Melaka Maps Animation

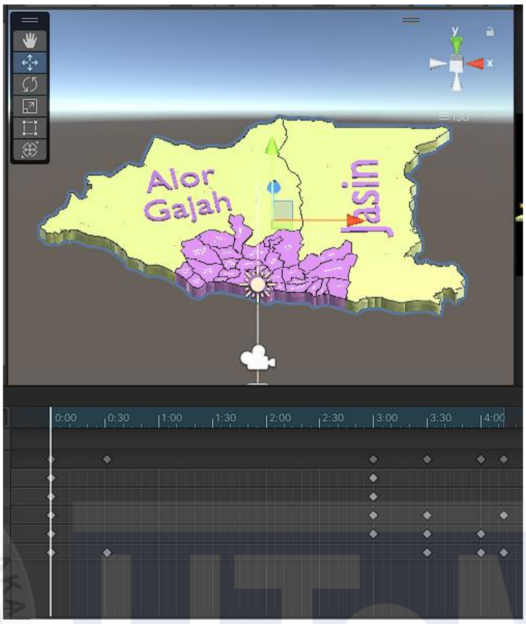


Figure 4.16: Keyframe of the Melaka Maps animation (1)

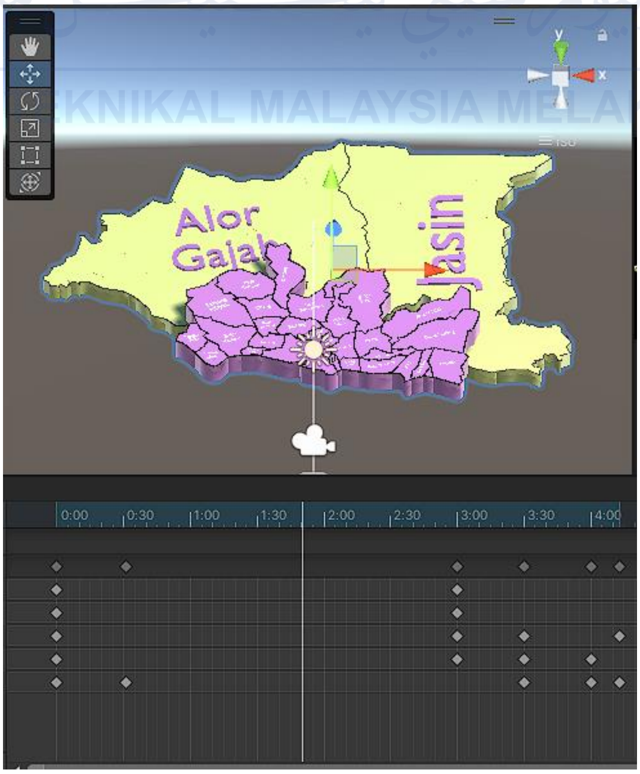


Figure 4.17: Keyframe of the Melaka Maps animation (2)

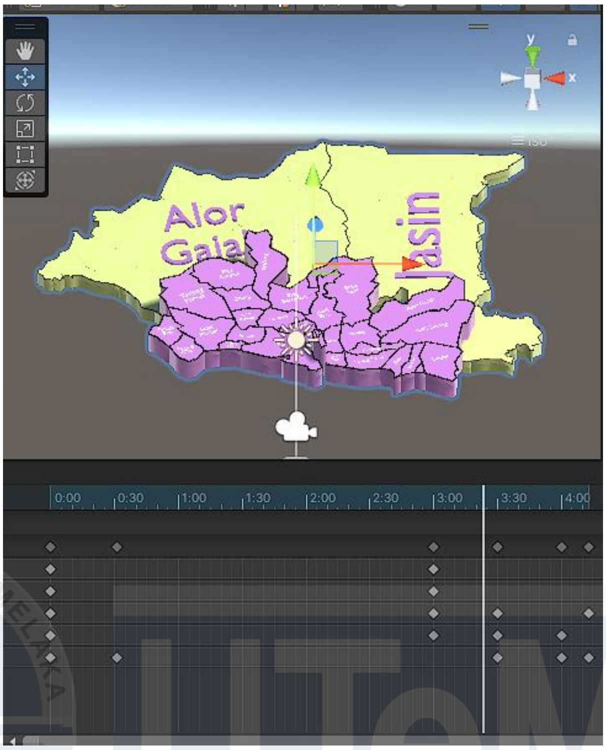


Figure 4.18: Keyframe of the Melaka Maps animation (3)

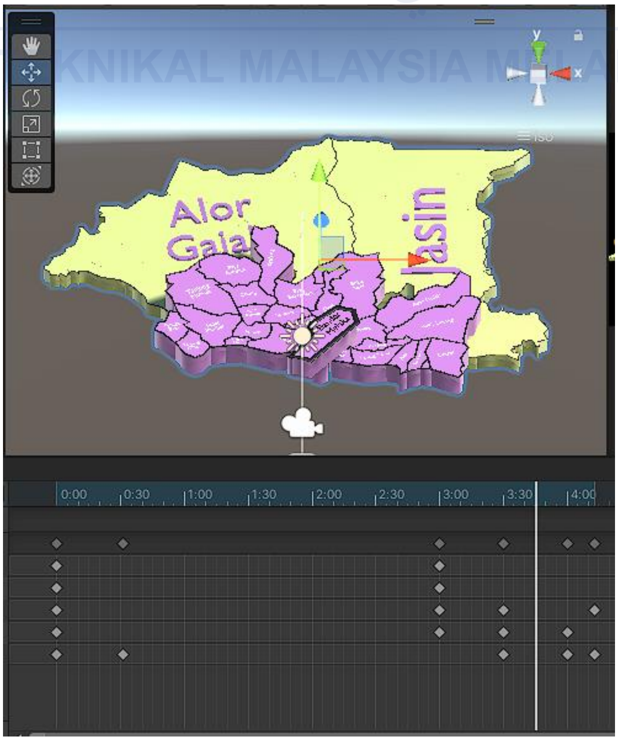


Figure 4.19: Keyframe of the Melaka Maps animation (4)

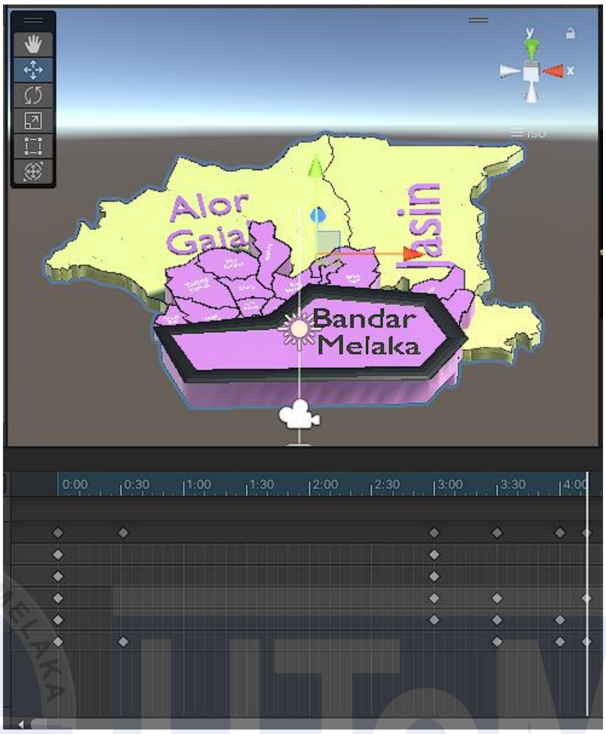


Figure 4.20: Keyframe of the Melaka Maps animation (5)

b) Pin-Point Locations Animation

```
Unity Message | 0 references
private void Start()
{
    if (locationPointers.Length == 0)
    {
        Debug.LogError(message: "No location pointers assigned!");
        return;
    }

    // Store the original positions of the location pointers
    originalPositions = new Vector3[locationPointers.Length];
    randomOffsets = new Vector3[locationPointers.Length];
    for (int i = 0; i < locationPointers.Length; i++)
    {
        originalPositions[i] = locationPointers[i].transform.position;
        randomOffsets[i] = new Vector3(
            Random.Range(-floatDistance, floatDistance),
            Random.Range(-floatDistance, floatDistance),
            Random.Range(-floatDistance, floatDistance)
        );
```

Figure 4.21: Script to handle pin-point locations animation

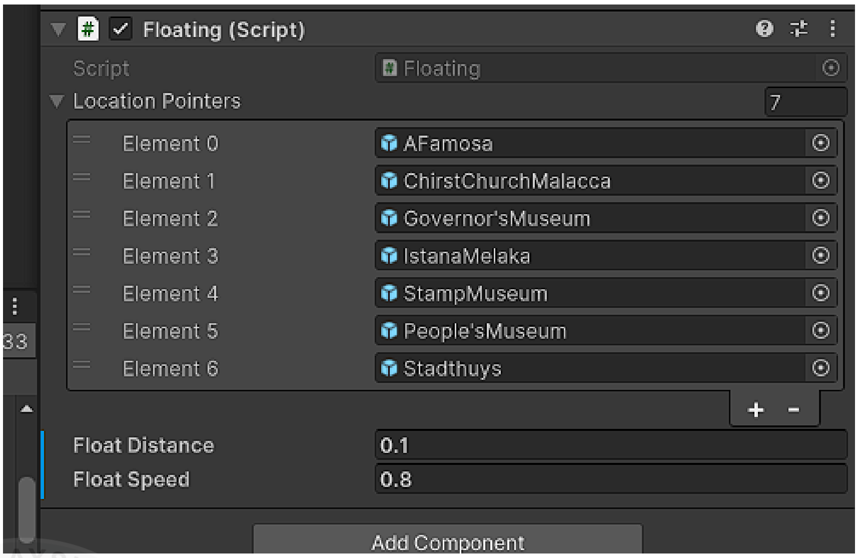


Figure 4.22: Attached all of the pin point locations on the properties

Figure 4.23: Final look of the pin-point location animation position

c) Historical Sites Animation

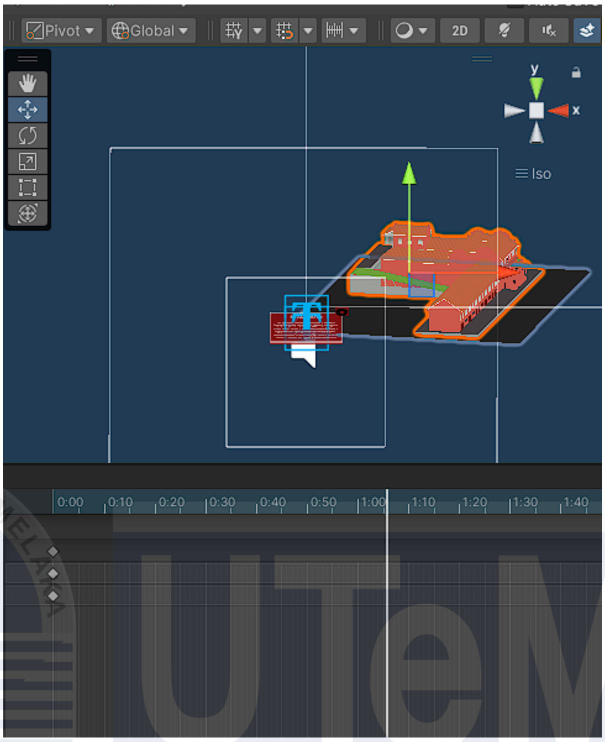


Figure 4.24: Animation of Stadthuys animation (1)

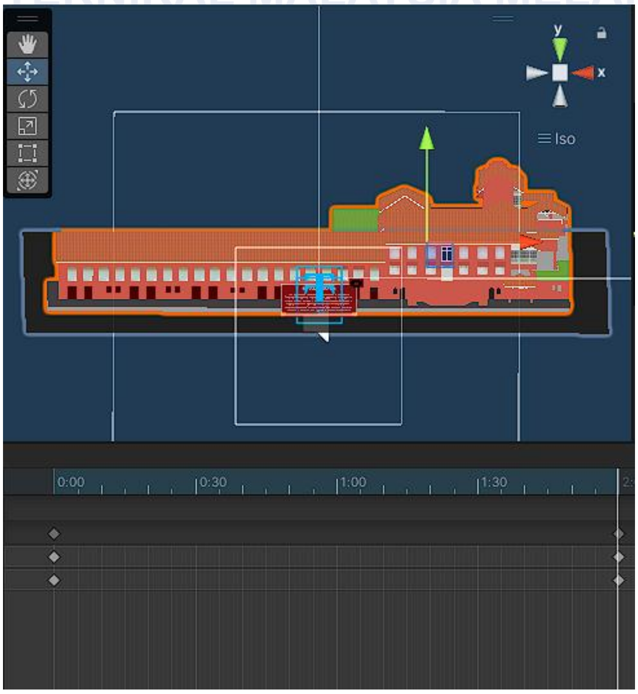


Figure 4.25: Animation of Stadthuys animation (2)

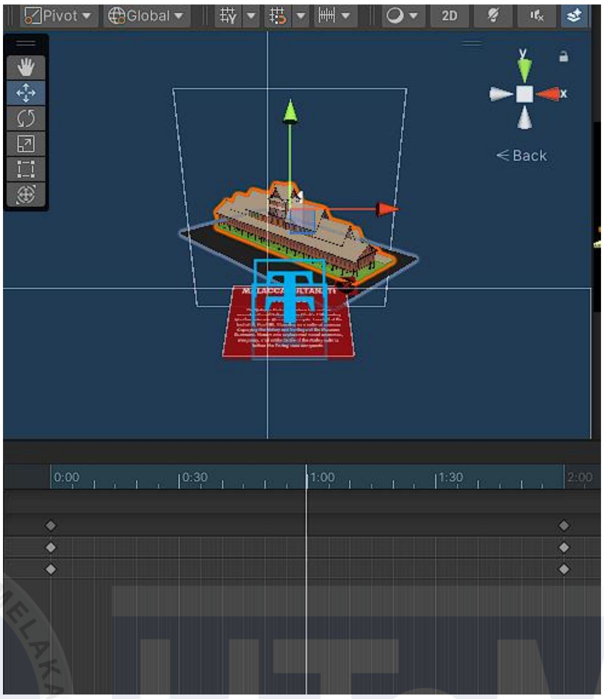


Figure 4.26: Animation of Muzium Istana Kesultanan Melaka animation (1)

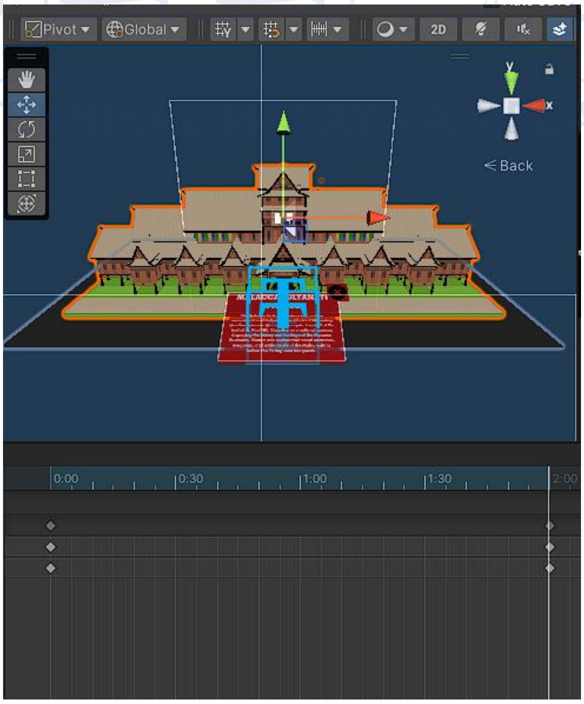


Figure 4.27: Animation of Muzium Istana Kesultanan Melaka animation (2)

4.4 Integration Technique

4.4.1 Blender

Blender is a powerful open-source 3D modelling and animation tool used extensively in this project for creating and preparing 3D assets. Here's a detailed breakdown of how Blender was utilized:

a) 3D Modelling

i. Mesh Creation: Constructing the basic geometry of the models using various tools such as extrude, scale, and loop cuts.

ii. Detailing: Adding finer details to the models, such as textures and materials, to make them realistic.

iii. UV Unwrapping: Unwrapping the 3D models to apply 2D textures correctly.

b) Texturing and Shading

i. Texture Painting: Manually painting textures on the 3D models for a more customized look.

ii. Material Creation: Using Blender's node-based material editor to create complex materials that react realistically to light.

c) Exporting Models

i. Once the models were completed, they were exported in formats compatible with Unity, such as FBX and the materials and texture were set to copy, ensuring all textures and animations were preserved.

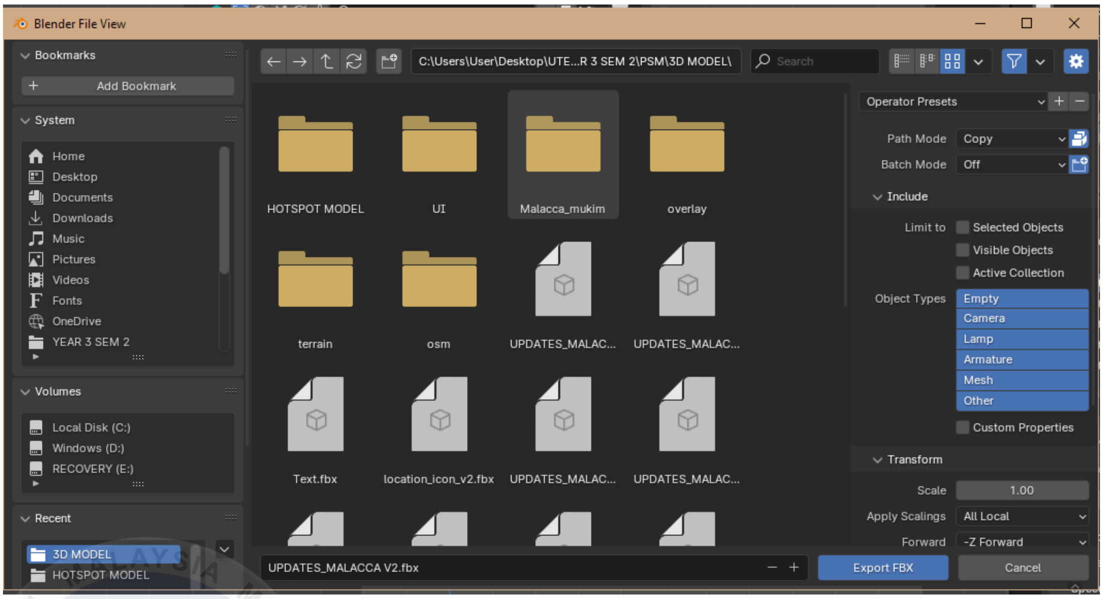


Figure 4.28: Exporting 3D Models from Blender

4.4.2 Adobe Illustrator

Adobe Illustrator were used to create the visual design elements of this application. This includes designing the user interface, icons, and other graphical components that contribute to the application's overall aesthetic and usability.

a) Designing User Interface (UI):

i. Layout Design: Create wireframes and layout designs for the application's UI, ensuring a user-friendly and intuitive interface.

ii. Icon Design: Design icons and buttons that are visually appealing and easy to understand, facilitating smooth navigation within the app.

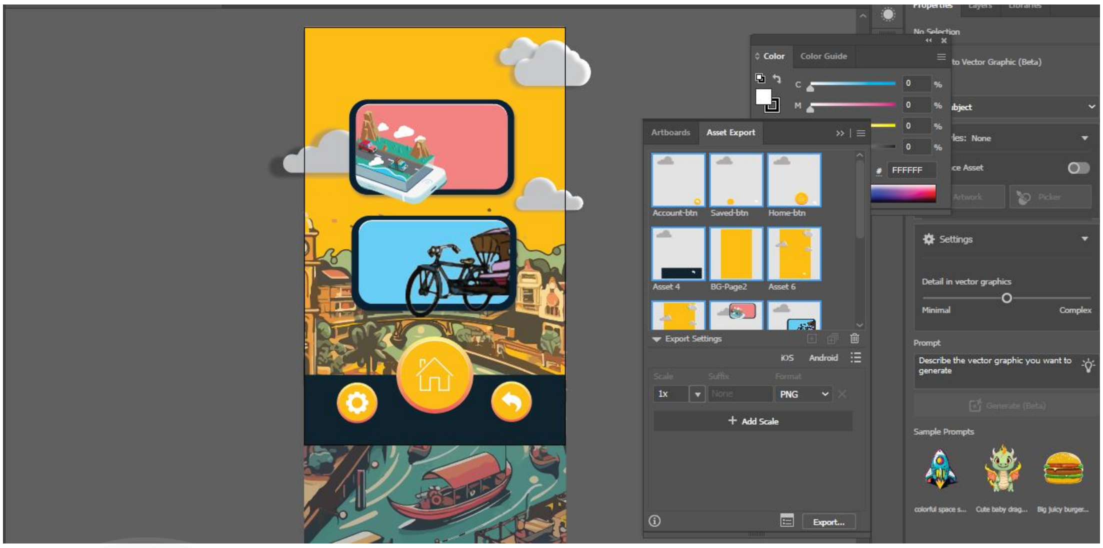


Figure 4.29: UI Design Process in Adobe Illustrator

Figure 4.30: Final Icons and Buttons Design

b) Creating Visual Assets:

i. Graphics Creation: Develop high-quality graphics for educational content, including diagrams, charts, and illustrations that support the chemistry lessons.

ii. Consistency: Ensure that all visual assets maintain a consistent style and colour scheme, aligning with the overall design aesthetic of the application.

c) Exporting Assets:

i. Format: Export visual assets in formats compatible with Unity, such as PNG or SVG, ensuring they retain their quality and transparency.

ii. Organization: Organize exported assets into appropriate folders for easy integration into the Unity project.

d) Integration into Unity:

i. Importing Assets: Import the exported visual assets into Unity, organizing them within the project structure.

ii. Application: Apply the visual assets to the UI components, ensuring they are correctly positioned and functioning as intended.

4.4.3 Unity

Unity is the primary development platform for this project where all the assets were integrated to create the final application. Unity integrates 3D models, visual assets, AR functionalities, UI and interactive components to build an interactive application.

a) Project Setup

i. Configuration: Configure the Unity project settings, including resolution, platform-specific settings (Android), and AR support using Google ARCore Plugin.

ii. Scene Management: Set up the initial scenes, organizing them logically to streamline development and navigation.

b) Importing Assets:

   i. 3D Models: Import 3D models and animations created in Blender, ensuring they are properly scaled and oriented.

   ii. Visual Assets: Import UI elements and graphics designed in Adobe Illustrator, placing them in the appropriate scenes and UI canvases.

c) Programming and Interactivity:

   i. Scripting: Use C# to script the interactive elements, such as touch inputs, AR interactions, and educational feedback mechanisms.

   ii. Functionality: Develop core functionalities, including navigation, content display, and AR capabilities using Unity and Google ARCore Plugin.

   iii. Animation: Creating keyframe animations for different actions or movements.

d) Building AR with Google ARCore Plugin:

   i. Integration: Integrate the Google ARCore Plugin into Unity to enable markerless AR functionality.

   ii. AR Anchors: Set up AR anchors to ensure stable placement of virtual elements in the real world.

   iii. Interactive AR Elements: Implement AR interactions that allow students to manipulate 3D models of Period 3 elements in their physical environment.

   iv. Testing: Conduct extensive testing to ensure AR elements are accurately tracked and provide a seamless user experience.

e) Testing and Debugging:

   i. Functionality Testing: Test all interactive elements and AR functionalities to ensure they work as intended.

ii. Performance Optimization: Optimize the application for mobile devices, ensuring smooth performance and quick loading times.

f) Final Build:

i. Compilation: Compile the final application into an APK file for Android devices.

ii. Deployment: Deploy the application for user testing and gather feedback for further improvements.

4.5 Summary

In this chapter, detailed explanation of the conceptual design of this AR application into a fully functional product that allows users to explore the historical sites of Melaka in a novel and engaging way. Utilizing Unity's AR Foundation, we enabled markerless AR, which allows virtual objects to be overlaying onto the real world without the need for physical markers. This technology was paired with intuitive user interfaces designed through extensive user study and iterative development. We ensured that user interactions, including gestures like tap and swipe, were natural and responsive, enhancing the overall experience.

The implementation process involved the integration of various multimedia assets. Using Blender, we created detailed 3D models of historical landmarks, while Adobe Illustrator was used to design clean and consistent visual elements for the application's interface. These assets were then brought together in Unity, where they were animated and programmed to interact seamlessly within the AR environment. Additionally, we integrated audio elements, such as spatial sound effects and background music, to further immerse users in the virtual exploration of Melaka's rich history.

Overall, the project successfully achieved its goal of enhancing user engagement and understanding. The combination of advanced AR technology, engaging multimedia content, and a user-friendly interface resulted in a robust application that is both educational and entertaining. Moving forward, there is potential to expand the application by adding more historical sites and incorporating additional AR features. This project not only highlights the potential of AR in cultural and educational contexts but also lays the groundwork for future innovations in this exciting field.

CHAPTER 5 RESULTS AND EVALUATION

5.1 Introduction

This chapter presents the evaluation process and the corresponding results of the study. The prototype of the "Interactive Melaka Historical Sites in Markerless AR Apps" was evaluated through usability testing, user acceptance testing, and expert testing. The focus was on assessing the effectiveness, usability, and user experience of the application, as well as gathering feedback from respondents and experts.

5.2 Evaluation and Testing

The evaluation process was carried out in two primary phases. The first phase involved usability and user acceptance testing, where respondents interacted with the app, and their feedback was assessed using the System Usability Scale (SUS) and Technology Acceptance Model (TAM) questionnaires. The second phase consisted of expert feedback, where domain experts evaluated the app based on specific criteria relevant to their expertise, providing insights and critiques that informed the development process.

The evaluation was conducted in alignment with the methodologies outlined by similar studies of Elshahawy et al. (2023); Li et al., (2022), adapted to the context of Melaka's historical sites. Each testing type is described in detail in the following subsections.

5.2.1 Usability Testing

The Usability Testing was conducted to evaluate how easily respondents could interact with the Interactive Melaka Historical Sites in Markerless AR Apps. This testing aimed to identify any issues in the user interface and overall user experience that could obstruct effective interaction with the app. Respondents were asked to complete specific tasks within the app, such as exploring virtual historical sites and navigating between different features.

Their performance was then evaluated using the SUS questionnaire, a reliable tool for measuring perceived usability. The SUS consists of 10 questions with a five-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree." The usability questionnaire is a low-cost usability scale adapted from Brooke (1995). The results of the SUS provided a quantitative measure of usability, highlighting areas where the app performed well and identifying opportunities for improvement. The usability questionnaire is listed in Table 5.1 accordingly.

Table 5.1: Usability questionnaires.

System Usability Scale Questionnaires	
No	**Statements**
1	I would like to use this system frequently.
2	The system is straightforward and easy to understand.
3	The system was easy to use.
4	I can use this system independently without needing technical support.
5	Various functions in this system were well integrated.
6	The system is consistent and reliable.
7	Most people would learn to use this system very quickly.
8	The system is easy to manage and user-friendly.
9	I felt very confident using the system.
10	The system is easy to start using without needing much prior learning.

5.2.2 User Acceptance Testing

The User Acceptance Testing in this study focused on evaluating the Perceived Ease of Use of the Interactive Melaka Historical Sites in Markerless AR Apps. This aspect is a critical component of the TAM and was chosen to assess how easily users could learn and use the app. Respondents were given a set of tasks like those in the Usability Testing phase, allowing them to interact with various features of the app.

After completing the tasks, respondents filled out a questionnaire designed to measure their perceptions of the app's ease of use.

The TAM questionnaire, which also uses a five-points Likert scale, was administered to gather this data. By focusing on Perceived Ease of Use, the study aimed to ensure that the app could be comfortably used by a broad audience, regardless of their familiarity with AR technology or historical content. The user acceptance questionnaire is a cost-effective evaluation tool based on the model proposed by Davis (1989). The user acceptance questionnaire is listed in Table 5.2 accordingly.

Table 5.2: User acceptance questionnaires.

Technology Acceptance Model Questionnaires (Perceived Ease of Use)	
No	**Statements**
1	Learning to operate the AR apps would be easy for me.
2	It is easy to get the AR apps to do what I want it to do.
3	My interaction with the AR apps would be clear and understandable.
4	I found that the AR apps to be flexible to interact with.
5	I found that the AR apps easy to use.

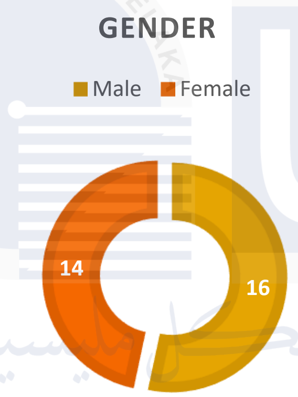
5.3 User Testing

This section presents the outcomes of the user testing on this prototype, along with the evaluation results including usability testing, and user acceptance. The evaluation tasks and procedures of user testing were explained in detail in the following subsections.

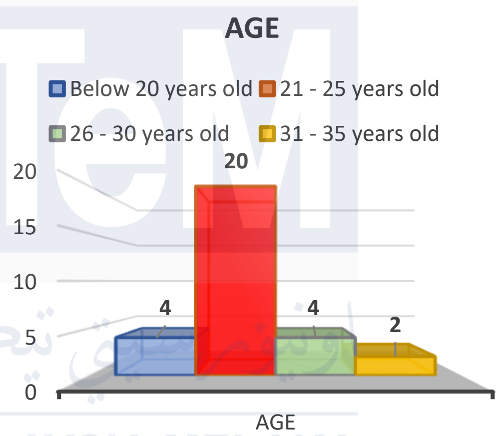
5.3.1 Respondents and Tasks

In this evaluation, 30 respondents were recruited which consist of Universiti Teknikal Malaysia Melaka (UTeM), Melaka tourists, residents and other educational institutions students for user testing on the prototype. Figure 5.1(a) shows the respondent's gender, Figure 5.1(b) shows the respondents' age, Figure 5.1(c) shows respondents' ethnicity and Figure 5.1(d) shows respondents' occupation.

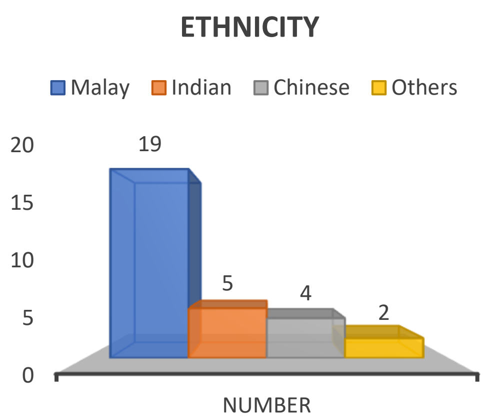
In Figure 5.1(a), 16 respondents out of 30 are male, and 14 respondents are female. Meanwhile, in Figure 5.1(b), the age range of the respondents is from below 20 years old up to 35 years old. Based on Figure 5.1(c), most of the respondents are Malay which consists of 19 out of 30 respondents while there were 5 Indians, 4 Chinese, and 2 other ethnicities. In Figure 5.1(d), most of the respondents which are 24 out of 30 were students while 4 of them were working professionals and only 2 of them were self-employed.



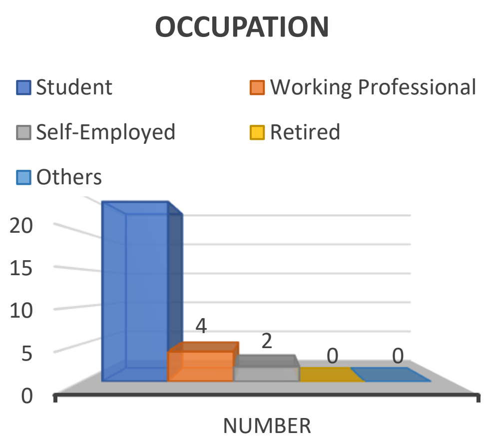
a) Gender



b) Age



c) Ethnicity



d) Occupation

Figure 5.1: Respondents Demography; (a) Gender, (b)Age, (c) Ethnicity, (d) Occupation

User testing was conducted to evaluate usability and user acceptance of the prototype. The task performed in this evaluation refers to Elshahawy et al. (2023); Li et al., (2022) which use SUS and TAM to measure the usability and user acceptance of the prototype. The primary goals of this evaluation were to assess how intuitive and user-friendly the application is and to understand users' willingness to adopt the technology.

5.3.2 Procedure and Data Collection

Before the session started, the respondents were explained about the apps and the purpose of this testing conducted. The task procedure for this testing involves the procedure where respondents test the applications and complete a questionnaire form consisting of SUS and TAM items to measure the usability and user acceptance of the apps.

Figure 5.2(a) shows that respondents tested the applications using the Android device provided. After respondents tested out the apps, respondents were asked to scan the QR code as shown in Figure 5.2(b) to answer the questionnaire form which is shown in Figure 5.2(c). In Figure 5.2(c), shows respondents answering the questionnaire using the online platform Google Form to save time and paper. The questionnaire form is attached the Appendix B.

(a) (b) (c)

Figure 5.2: The respondents test the apps (a), scan the QR code (b) then answer questionnaire (c)

Before the testing, the respondents were also questioned on their familiarity with using the Augmented Reality (AR) applications and their prior visits to Melaka historical sites. Figures 5.3 and 5.4 show the results of the respondent's responses to the questionnaire. Regarding familiarity with the AR apps, most respondents were familiar with or have used AR apps before which is 24 out of 30 respondents while only 6 respondents that is not familiar with AR apps. The results for respondents' familiarity with AR apps are displayed in Figure 5.3.

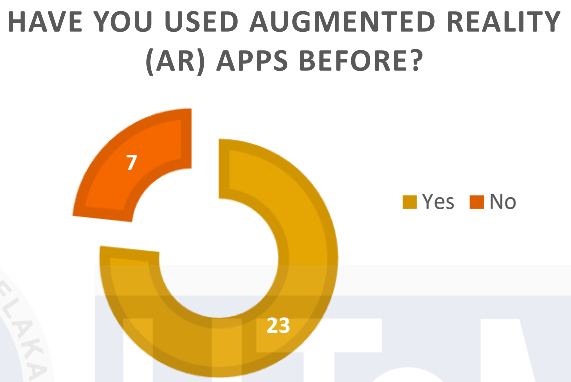


Figure 5.3: Respondents' familiarity with AR apps

Regarding respondents' prior visits to Melaka historical sites, most respondents have prior experience visiting Melaka as a tourist before which is 23 out of 30 respondents. There are just 7 respondents who have never been to Melaka at all. The results of respondents' prior visits to Melaka are displayed in Figure 5.4.

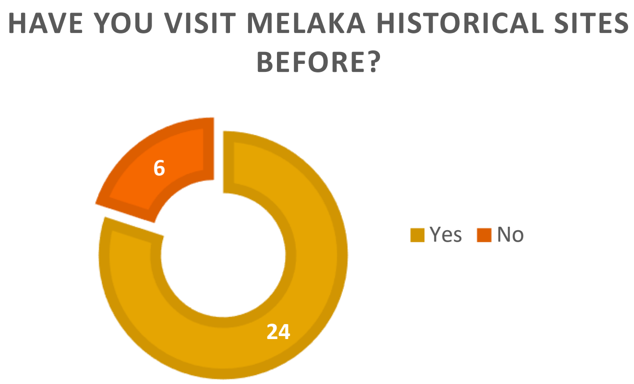


Figure 5.4: Respondents' prior visits to Melaka historical sites

5.3.3 Results of Usability Testing

As shown in Table 5.3 and Figure 5.5, the mean and standard deviation value for the usability questionnaire is calculated which then plotted in a bar chart. Based on the table in Table 5.3, the mean and standard deviation values for each usability question were calculated resulting in varied user experience with the system. While some questions received high mean values above 4.0, indicating positive feedback, others fell below this threshold, suggesting areas for potential improvement. The highest mean value was observed for question SUS7, with a mean value of M = 4.60. This indicates that most respondents strongly agree that the system is easy to learn. Following closely, question SUS1 (M = 4.40) and question SUS5 (M = 4.30) also received high values, reflecting that user found the system appealing for frequent use and appreciated the well-integrated functions.

However, not all feedback was entirely positive. question SUS10, which had the lowest mean value of M = 2.70, indicates that respondents found the system somewhat challenging to use and require some learning before using it. Similarly, question SUS6 (M = 3.63) shows that some users can't use the apps without the assistant of technical support. Overall, the mean for the usability questionnaire is M = 4.00, indicating a higher level of user satisfaction with the system. These results suggest that while users generally found the system satisfactory, there are specific areas that may require attention to enhance the overall user experience.

Table 5.3: The analysis value for usability questionnaire (User Testing).

No	Statements	Mean	SD
1	I would like to use this system frequently.	4.40	0.77
2	The system is straightforward and easy to understand.	3.73	1.05
3	The system was easy to use.	4.47	0.68
4	I can use this system independently without needing technical support.	3.63	1.16
5	Various functions in this system were well integrated.	4.30	0.87
6	The system is consistent and reliable.	3.93	1.01

7	Most people would learn to use this system very quickly.	4.60	0.67
8	The system is easy to manage and user-friendly.	3.87	1.14
9	I felt very confident using the system.	4.33	0.93
10	The system is easy to start using without needing much prior learning.	2.70	1.39

Number of respondents: 30

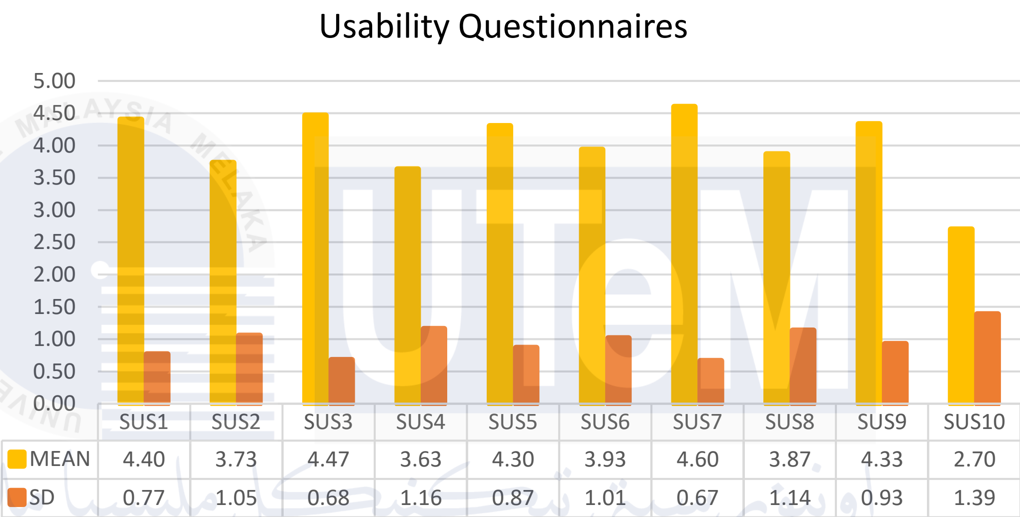


Figure 5.5: Bar chart for usability questionnaire (User Testing).

5.3.4 Results of User Acceptance Testing

Based on the Technology Acceptance Model (TAM) questionnaire results for Perceived Ease of Use shown in Table 5.4 and Figure 5.6, the mean and standard deviation values for each question indicate a generally positive perception of the AR applications. The mean values for all statements are above 4.0, reflecting a strong agreement among respondents regarding the ease of use of the AR apps. The highest mean value was observed for question TAM5, with a mean value of M = 4.33, indicating that respondents found the AR apps particularly easy to use. Question TAM1 follows closely with a mean value of M = 4.30. This suggests that respondents believe they can quickly learn to use the AR applications without significant difficulty.

Questions TAM2 and TAM4 both have an equal mean value of M = 4.23, showing that users find the AR apps easy to control and flexible to interact with. Finally, question TAM3, with a mean value of M = 4.10, indicates that respondents generally find the interaction with the AR apps clear and understandable, though slightly less so compared to other aspects. Overall, these results suggest that the respondents perceive the AR applications as user-friendly, with minor variations in how different aspects of ease of use are experienced.

Table 5.4: The analysis value for user acceptance questionnaire (User Testing).

No	Statements	Mean	SD
1	Learning to operate the AR apps would be easy for me.	4.30	0.94
2	It is easy to get the AR apps to do what I want it to do.	4.23	0.92
3	My interaction with the AR apps would be clear and understandable.	4.10	0.93
4	I found that the AR apps to be flexible to interact with.	4.23	0.94
5	I found that the AR apps easy to use.	4.33	0.93

Number of respondents: 30

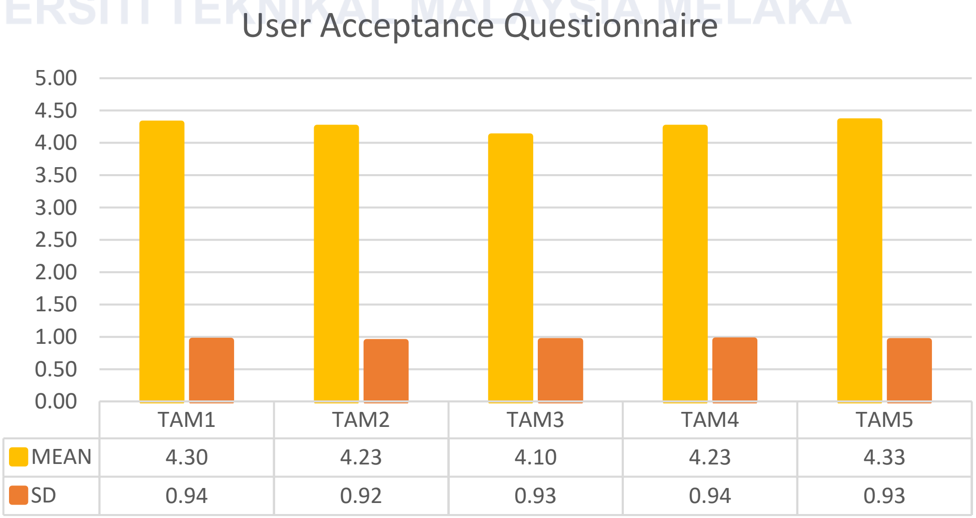


Figure 5.6: Bar chart for user acceptance questionnaire (User Testing).

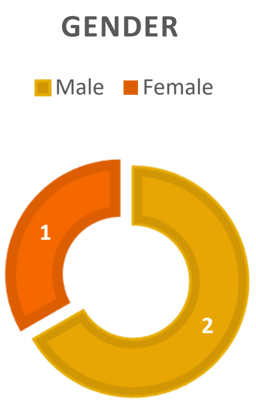
5.4 Expert Testing

This section presents the outcomes of the expert testing on the prototype, along with the evaluation results including usability testing, and user acceptance, and expert feedback. The evaluation tasks and procedures were explained in detail in the following subsections.

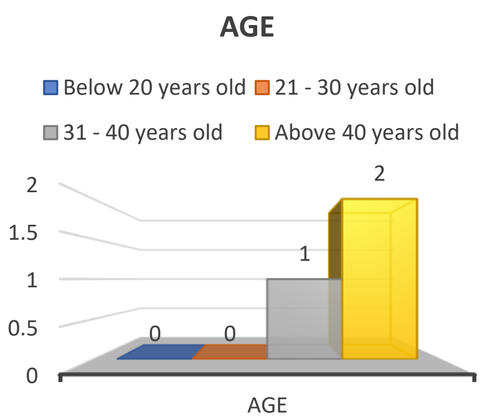
5.4.1 Experts and Tasks

In this evaluation, 3 experts were recruited consisting of UTeM lecturers who are experts in various domains related to AR and Human-Computer Interactions (HCI) for expert testing on the prototype. Figure 5.7(a) shows the experts' gender, Figure 5.7(b) shows the experts' age, Figure 5.7(c) shows the experts' ethnicity, Figure 5.7(d) shows the experts' professional background, and Figure 5.7(e) shows experts' year of experience.

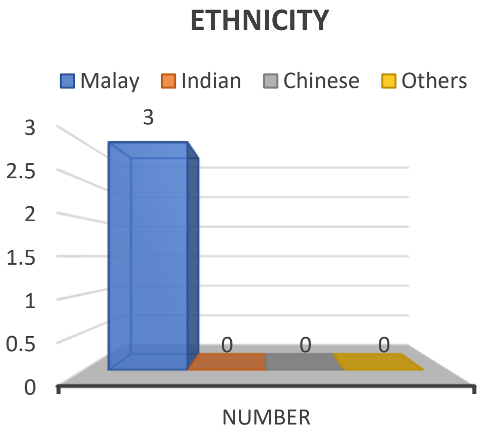
In Figure 5.7(a), 2 experts out of 3 are female and there's only 1 male expert. Meanwhile, in Figure 5.7(b), the age range of the experts is from 31 years old and above. Based on Figure 5.7(c), all 3 experts are classified as ethnic Malay. In Figure 5.7(d), 2 of the experts' professional backgrounds are AR/VR developers while the other 1 expert professional background is HCI lecturer/UI expertise. Figure 5.7(e) shows that only 1 expert out of 3 has experience in their expertise field for 4-6 years while the other 2 experts have experience in their expertise field for more than 10 years.



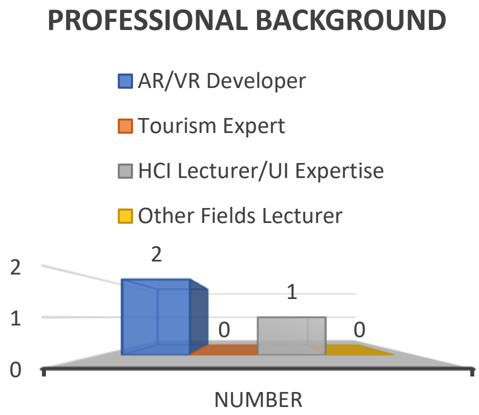
a) Gender



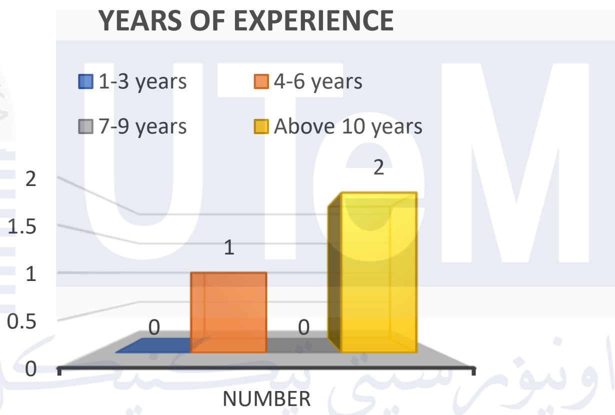
b) Age



c) Ethnicity



d) Professional Background



e) Years of Experience

Figure 5.7: Expert Demographics; (a) Gender, (b) Age, (c) Ethnicity, (d) Professional Background, (e) Years of Experience

5.4.2 Procedure and Data Collection

Before the session started, the experts were explained about the apps and the purpose of this testing conducted. The task procedure for this testing involves the procedure where an expert tests the applications and completes a questionnaire form consisting of SUS, TAM, and expert feedback items to measure the usability, and user acceptance and gain expert feedback on the apps.

Figure 5.8(a) shows that experts testing the applications using the Android device provided. After the expert tested out the apps, the expert was asked to answer the questionnaire form which is shown in Figure 5.8(b). In Figure 5.3(b), shows experts answering the questionnaire using the online platform Google Form to save time and paper. The questionnaire form is attached the Appendix C.

(a) (b)

Figure 5.8: The experts test the apps (a) then answer questionnaire (b)

5.4.3 Results of Usability Testing

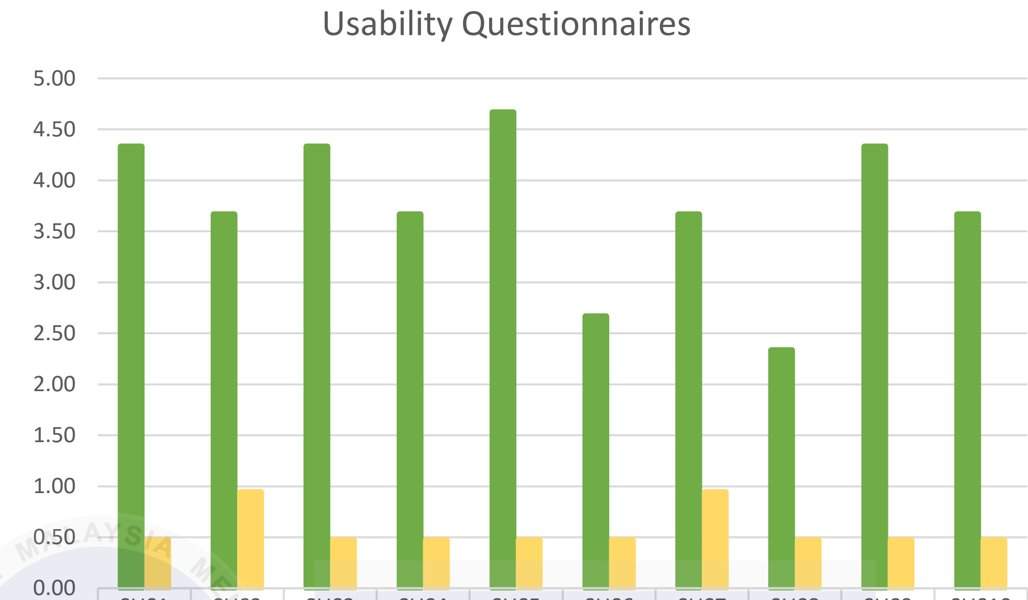
As shown in Table 5.5 and Figure 5.9, the mean and standard deviation values from the usability questionnaire have been calculated which then plotted in a bar chart, revealing a range of user experiences with the system. The analysis shows that while certain questions received high mean values above 4.0, indicative of positive expert feedback, others fell below this mark, pointing to areas that may need improvement. The highest mean value was observed for question SUS5 with a mean value of M = 4.67. This suggests that experts strongly agree that the system's functions are well integrated, which is a positive aspect of the system's usability. Question SUS1, SUS3 and question SUS9 all received a high mean value of M = 4.33, reflecting the experts' tendency to use the system regularly and their overall satisfaction with its ease of use.

On the other hand, some aspects of the system received lower values. Question SUS8 had the lowest mean values of M = 2.33. These lower values suggest that experts found the system to be somewhat complex and potentially require technical support, highlighting areas where the system's usability could be enhanced. Overall, the mean score across all questions was M = 3.73, indicating a moderately positive user experience from the expert perspective, but with certain usability issues that need to be addressed. The overall SUS score, calculated according to Brooke's (1995) methodology, resulted in a score of 68.33% with a grade of B. This suggests that while users generally find the system usable, there is significant room for improvement to ensure a more seamless and satisfying user experience.

Table 5.5: The analysis value for usability questionnaire (Expert Testing).

No	Statements	Mean	SD
1	I would like to use this system frequently.	4.33	0.47
2	The system unnecessarily complex.	3.67	0.94
3	The system was easy to use.	4.33	0.47
4	I would need the support of a technical person to be able to use this system.	3.67	0.47
5	Various functions in this system were well integrated.	4.67	0.47
6	There was too much inconsistency in this system.	2.67	0.47
7	Most people would learn to use this system very quickly.	3.67	0.94
8	The system very cumbersome(unmanageable) to use.	2.33	0.47
9	I felt very confident using the system.	4.33	0.47
10	I needed to learn a lot of things before I could get going with this system.	3.67	0.47

Number of experts: 3



	SUS1	SUS2	SUS3	SUS4	SUS5	SUS6	SUS7	SUS8	SUS9	SUS10
MEAN	4.33	3.67	4.33	3.67	4.67	2.67	3.67	2.33	4.33	3.67
SD	0.47	0.94	0.47	0.47	0.47	0.47	0.94	0.47	0.47	0.47

Figure 5.9: Bar chart for usability questionnaire (Expert Testing).

5.4.4 Results of User Acceptance Testing

Based on Table 5.6 and Figure 5.10, the mean values for the Technology Acceptance Model (TAM) questionnaire, specifically focusing on Perceived Ease of Use, are summarized and analysed. The results indicate a generally positive perception of the system's ease of use, with mean values consistently around or above 4.0. The highest mean value was observed for question TAM1 with a mean value of M = 4.33. This suggests that experts agree that the system is easy to learn, which is a critical factor in user adoption. Questions TAM3, TAM4, and TAM5 all received a mean value of M = 4.00, reflecting a positive evaluation of the system's usability across these dimensions.

TAM2 question had a slightly lower mean value of M = 3.67, indicating that while the experts found the system generally easy to use, there might be slight challenges in achieving specific tasks within the AR apps. This could point to areas where the system's functionality could be further refined to meet user expectations.

Overall, the mean value for Perceived Ease of Use was M = 4.00, and all experts rated the system's ease of use favourably, resulting in a consistent value across the board. These findings suggest that the system is well-received in terms of usability, with room for minor improvements to further enhance user experience.

Table 5.6: The analysis value for user acceptance questionnaire (Expert Testing).

No	Statements	Mean	SD
1	Learning to operate the AR apps would be easy for me.	4.33	0.47
2	It is easy to get the AR apps to do what I want it to do.	3.67	0.47
3	My interaction with the AR apps would be clear and understandable.	4.00	0
4	I found that the AR apps to be flexible to interact with.	4.00	0
5	I found that the AR apps easy to use.	4.00	0

Number of experts: 3

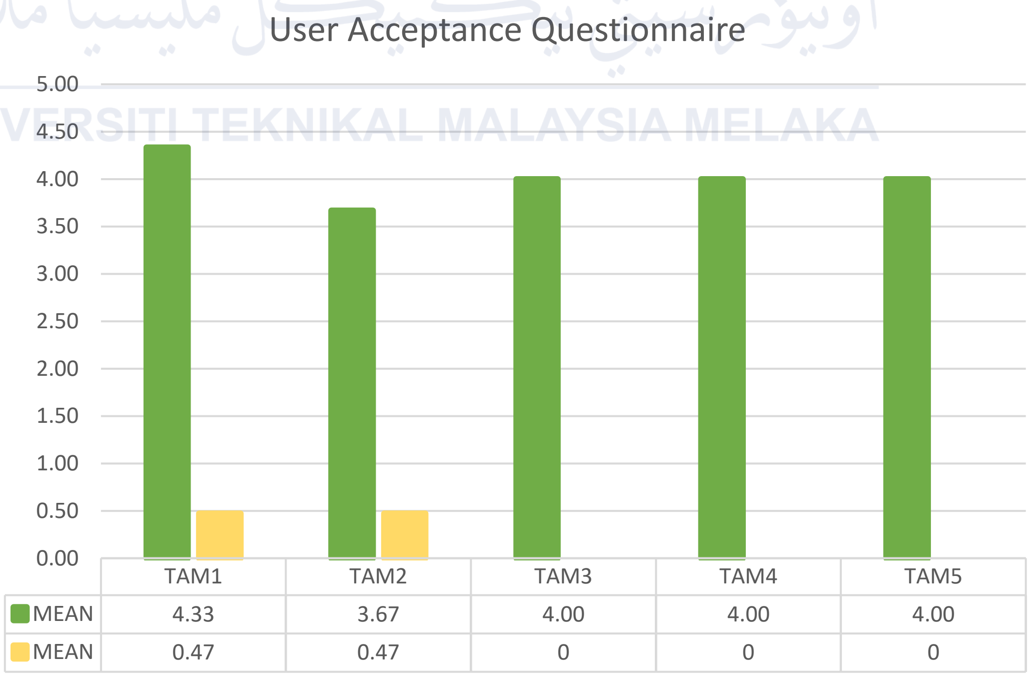


Figure 5.10: Bar chart for user acceptance questionnaire (Expert Testing).

5.4.5 Expert Feedback and Suggestions

Besides the quantitative data collected from the questionnaires, the qualitative data were also collected from the expert evaluation form. The table shows the overall comments from the experts on the Prototype. The feedback, summarized in the following tables, shows that experts generally had positive opinions about the overall design and functionality of the AR app. Below is a detailed analysis of the expert comments.

Table 5.7: Key Strength of this AR apps

Expert	Example of Response
E1	The system effectively highlights places in Banda Hilir that provide useful information to tourists, making it easy for users to find relevant sites.
E2	The system allows tourists to explore Melaka virtually, offering a convenient way to experience the city from afar.
E3	The system has a aesthetically pleasing design, which enhances the overall user experience.

Table 5.8: Weakness or usability issues of this AR apps

Expert	Example of Response
E1	While the system is generally responsive, there are instances where it could be improved.
E2	The system lacks the ability to allow users to virtually walk through buildings, limiting the depth of the virtual visit experience.
E3	There are some errors present in the system; however, they do not significantly impact the overall functionality.

Table 5.9: Recommendations for Improvement

Expert	Example of Response
E1	It is suggested to improve the user interface and user experience by perhaps following the colour theme of Visit Melaka 2024 logo.
E2	To enhance the tourist hotspot feature, it is recommended to include real pictures of the locations, ideally taken by the team, to provide a more authentic and engaging experience.
E3	It is suggested to focus on improving the functional consistency of the system to ensure a smoother and more reliable user experience across all features.

Apart from the quantitative data gathered from the experts, the qualitative results obtained from the experts have been done by giving open-ended questions included in the evaluation form to evaluate the developed markerless AR apps. There are 3 questions given to get their opinion on the developed prototype. The questions are to get the key strengths, weaknesses, and suggestions for improvement of the prototype. Most of the comments provided by the experts on the AR app design are very constructive.

Based on Table 5.3, expert evaluations highlight several key strengths of the AR application. One of the primary strengths is the system's ability to effectively highlight significant sites in Banda Hilir. This feature is particularly useful for tourists, as it provides them with relevant information about the historical locations, making it easier to explore and learn about these sites. Additionally, the system's capability to offer a virtual exploration of Melaka is highly appreciated, as it provides tourists with a convenient way to experience the city without physically being there. The application's aesthetically pleasing design is another positive aspect noted by the experts, as it significantly enhances the overall user experience, making the app not only functional but also visually attractive.

From Table 5.4, despite the strengths, the experts also identified several areas where the AR application could be improved. One recurring issue is the system's responsiveness. Although the system is generally responsive, there are limits where it lags or doesn't perform as expected, which could disrupt the user experience. Another limitation pointed out by the experts is the lack of a virtual walkthrough feature for buildings, which limits the depth and immersion of the virtual visit. This could be a significant drawback for users who are interested in a more detailed exploration of historical sites. Additionally, some experts noted that there are minor errors in the system. While these errors do not severely impact the functionality, addressing them could further enhance the user experience.

Based on Table 5.5, The experts provided several constructive recommendations for improving the AR application. One suggestion is to enhance the user interface (UI) and user experience (UX) by aligning the colour theme with the Visit Melaka 2024 logo, which could create a more cohesive and visually appealing experience. Another recommendation focuses on the tourist hotspot feature, suggesting that real pictures of the locations, ideally taken by the development team, be included to provide users with a more authentic and engaging experience. Lastly, the experts emphasized the importance of improving the functional consistency of the system. Ensuring that all features operate smoothly and reliably across the application would significantly enhance the overall user experience and make the app more dependable for users.

5.5 Summary

This chapter discussed about data findings analysis of the study conducted followed by the discussion of the findings. In this study, there are several analyses have been conducted statistically. The analysis started with user testing where usability and user acceptance are tested. Then, followed by expert testing where they tested the same thing as user testing but in addition with open-ended questions for expert feedback. User testing was conducted with 30 respondents who completed tasks and questionnaires, revealing generally positive feedback on the app's ease of use and design, although some users highlighted areas for improvement, particularly in system responsiveness and navigation.

Expert testing was carried out with three UTeM lecturers specializing in AR and HCI, who provided both quantitative and qualitative feedback. The experts appreciated the app's effective highlighting of historical sites, virtual exploration features, and visually pleasing design, but also noted limitations such as occasional system lags, the absence of a virtual walkthrough feature, and minor errors. Their recommendations included improving the user interface by aligning it with the Visit Melaka 2024 logo, incorporating real images of tourist hotspots, and enhancing the system's functional consistency. Overall, the feedback from both users and experts emphasized the app's strengths while identifying areas for refinement to enhance the user experience.

CHAPTER 6 CONCLUSION

6.1 Introduction

This chapter concludes all the findings obtained throughout the conducted study. The conclusion presented includes the development and evaluation of the markerless AR application, the user acceptance, and the usability of the app in promoting Melaka's historical sites. Additionally, this chapter emphasise the contributions of the study to the fields of cultural heritage preservation and AR technology. Furthermore, the implications of the findings are discussed from various perspectives, including users, experts, user interface (UI) designers, and AR developers. Finally, this chapter provides suggestions for further studies that could be conducted to enhance and expand upon the current work.

6.2 Project Achievement

A study was conducted to determine to how augmented reality (AR) is used to improve historic sites, with a focus on markerless AR technology. This evaluation was necessary to guarantee that the project's progress was based on solid study. In Chapter 2, each significant piece of literature was thoroughly reviewed. The studies are focusing on AR, markerless AR, and how they are applied in cultural heritage. Chapter 2 successfully completed its initial goal of identifying the technical requirements for developing mobile application that features markerless AR and interactive 3D models of Melaka historical sites.

After gathering the necessary data, the next phase was to develop an AR mobile application that includes interactive 3D models of Melaka historical buildings. The development process followed the project methodology specified in Chapter 3. This step comprised creating 3D models, implementing markerless AR technology, and designing the user interface. The second goal of developing an AR mobile application that includes interactive 3D models of Melaka historical buildings was met by completing development using Unity3D and other associated tools and technologies.

The software was later updated to include interactive aspects that allow users to virtually tour historical sites in Melaka and the evaluation regarding usability, user acceptance and expert feedback was also conducted in this study. The evaluation resulted which user found the apps is very easy to use and user-friendly. This stage successfully meeting the third goal which to evaluate the effectiveness of the AR application in enhancing users' understanding and engagement with Melaka historical sites.

6.3 Limitations

During the development of this project, several limitations were encountered. One significant limitation is that users need compatible devices capable of supporting AR functionalities, such as smartphones with specific hardware requirements. Additionally, the effectiveness of the AR experience depends on the environment, such as lighting conditions and the availability of sufficient space to properly view the 3D models. Another limitation is the need for a stable internet connection, particularly when accessing external resources or additional content linked within the app.

Furthermore, the application is designed primarily for individual use, which limits its potential for group-based learning or collaborative exploration. The scope of the AR content is also restricted to the selected historical sites, which may not fully represent the richness of Melaka's cultural heritage. These limitations highlight areas where future improvements can be made to enhance the overall user experience.

6.4 Implications of Findings

This study's outcomes have a broad impact. Users benefit from the application's creative and entertaining approach to learning about Melaka's historical sites, which has the potential to increase people interest in cultural heritage specifically in Melaka. For cultural heritage experts, the project highlights AR technology's potential as a tool for education and preservation, providing a contemporary way to engage with history.

UI designers and AR developers can learn from the development process and the application's user interface design, which balances aesthetics and functionality. The project also includes a case study for game creators who want to integrate educational content with interactive technology, demonstrating how AR may be used to create meaningful and instructive experiences.

6.5 Future Works

By developing an interactive augmented reality application that highlights Melaka's historical sites without the need for markers, the project successfully met its goals. However, there are several areas in which the application could be improved to increase its effectiveness, user satisfaction, and overall impact.

Firstly, it is recommended for the app to be improved in the future by adding a wider variety of historical sites to give users more engaging experience when learning about Melaka's rich cultural legacy. Furthermore, adding more immersive components to AR interactions, like virtual avatar-led augmented tours, has the potential to significantly boost user engagement.

An additional potential area for future study could involve implementing multilingual support to enable a wider range of users to utilize and gain advantages from the software. Ultimately, enhancing the app's features to allow for group adventures or teamwork-based learning activities could offer extra benefits, particularly for educational use in schools.

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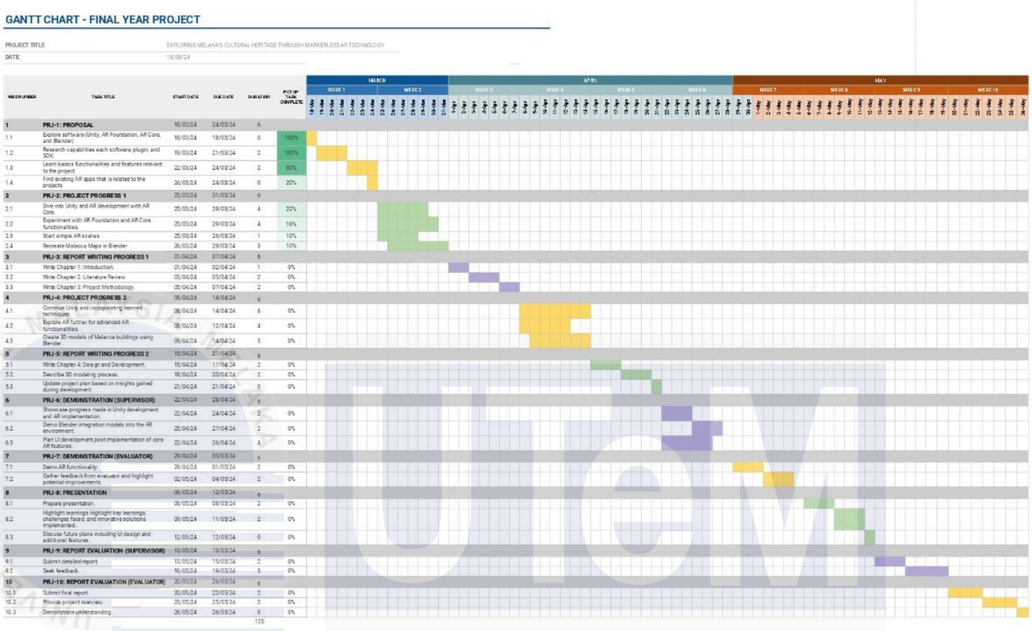
APPENDIX

APPENDIX A - GANTT CHART



GANTT CHART - FINAL YEAR PROJECT

PROJECT TITLE: EXPLORING MELAKA'S CULTURAL HERITAGE THROUGH MARKERLESS AR TECHNOLOGY

DATE: 18/03/24

WBS NUMBER	TASK TITLE	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**PRJ-1: PROPOSAL**	18/03/24	24/03/24	6	
1.1	Explore software (Unity, AR Foundation, AR Core, and Blender).	18/03/24	18/03/24	0	100%
1.2	Research capabilities each software, plugin, and SDK.	19/03/24	21/03/24	2	100%
1.3	Learn basics functionalities and features relevant to the project.	22/03/24	24/03/24	2	90%
1.4	Find existing AR apps that is related to the projects	24/03/24	24/03/24	0	20%
2	**PRJ-2: PROJECT PROGRESS 1**	25/03/24	31/03/24	6	
2.1	Dive into Unity and AR development with AR Core.	25/03/24	29/03/24	4	22%
2.2	Experiment with AR Foundation and AR Core functionalities.	25/03/24	29/03/24	4	16%
2.3	Start simple AR scenes.	25/03/24	26/03/24	1	10%
2.4	Recreate Malacca Maps in Blender.	26/03/24	29/03/24	3	10%
3	**PRJ-3: REPORT WRITING PROGRESS 1**	01/04/24	07/04/24	6	
3.1	Write Chapter 1: Introduction.	01/04/24	02/04/24	1	0%
3.2	Write Chapter 2: Literature Review.	03/04/24	05/04/24	2	0%
3.3	Write Chapter 3: Project Methodology.	05/04/24	07/04/24	2	0%
4	**PRJ-4: PROJECT PROGRESS 2**	08/04/24	14/04/24	6	
4.1	Continue Unity and incorporating learned techniques.	08/04/24	14/04/24	6	0%
4.2	Explore AR further for advanced AR functionalities.	08/04/24	12/04/24	4	0%
4.3	Create 3D models of Malacca buildings using Blender.	09/04/24	14/04/24	5	0%
5	**PRJ-5: REPORT WRITING PROGRESS 2**	15/04/24	21/04/24	6	
5.1	Write Chapter 4: Design and Development.	15/04/24	17/04/24	2	0%
5.2	Describe 3D modeling process.	18/04/24	20/04/24	2	0%
5.3	Update project plan based on insights gained during development.	21/04/24	21/04/24	0	0%
6	**PRJ-6: DEMONSTRATION (SUPERVISOR)**	22/04/24	28/04/24	6	
6.1	Showcase progress made in Unity development and AR implementation.	22/04/24	24/04/24	2	0%
6.2	Demo Blender integration models into the AR environment.	25/04/24	27/04/24	2	0%
6.3	Plan UI development post-implementation of core AR features.	22/04/24	26/04/24	4	0%
7	**PRJ-7: DEMONSTRATION (EVALUATOR)**	29/04/24	05/05/24	6	
7.1	Demo AR functionality.	29/04/24	01/05/24	2	0%
7.2	Gather feedback from evaluator and highlight potential improvements.	02/05/24	04/05/24	2	0%
8	**PRJ-8: PRESENTATION**	06/05/24	12/05/24	6	
8.1	Prepare presentation.	06/05/24	08/05/24	2	0%
8.2	Highlight learnings Highlight key learnings, challenges faced, and innovative solutions implemented.	09/05/24	11/05/24	2	0%
8.3	Discuss future plans including UI design and additional features.	12/05/24	12/05/24	0	0%
9	**PRJ-9: REPORT EVALUATION (SUPERVISOR)**	13/05/24	19/05/24	6	
9.1	Submit detailed report.	13/05/24	15/05/24	2	0%
9.2	Seek feedback.	16/05/24	19/05/24	3	0%
10	**PRJ-10: REPORT EVALUATION (EVALUATOR)**	20/05/24	26/05/24	6	
10.1	Submit final report.	20/05/24	22/05/24	2	0%
10.2	Provide project overview.	23/05/24	25/05/24	2	0%
10.3	Demonstrate understanding.	26/05/24	26/05/24	0	0%
				125	

APPENDIX B - USER TESTING QUESTIONNAIRE

INTERACTIVE MELAKA HISTORICAL SITES IN MARKERLESS AR APPS: USER TESTING

Welcome to the survey for evaluating the usability of our newly developed augmented reality (AR) application designed for exploring historical sites in Melaka. Your feedback is crucial in helping to improve the app and ensure it meets user needs.

Instructions:

1. Download the App: Please download the Interactive Melaka Historical Sites AR app by clicking **[HERE]**. Follow instructions stated in that link.
2. Test the App: Spend approximately 5 minutes fully testing the app. Explore its features, interact with the virtual elements, and navigate through the historical sites. *(at the end of this questionnaire form, respondent were required to upload the proof of testing)*
3. Complete the Survey: After testing the app, please return to this form to provide your feedback. The survey consists of 3 pages with 3 sections:
- **Section A : Demographic Section**
- **Section B : System Usability Scale (SUS) Questionnaire**
- **Section C : Technology Acceptance Model (TAM) Questionnaire**

(at the end of this questionnaire form, respondent were required to upload the proof of testing)

Please answer the following questions honestly based on your experience with the app. Your responses will remain confidential and will only be used for research purposes. The survey will take approximately 10 minutes to complete.

Thank you for your participation!

* Indicates required question

Section A: Demographic Respondent

1. 1. Gender *

Mark only one oval.

( ) Male
( ) Female

2. 2. Age *

Mark only one oval.

- Below 20 years old
- 21 - 25 years old
- 26 - 30 years old
- 31 - 35 years old

3. 3. Ethnicity *

Mark only one oval.

- Malay
- Chinese
- Indian
- Other: ____________________

4. 4. Occupation *

Mark only one oval.

- Student
- Working Professional
- Self-Employed
- Retired
- Other: ____________________

5. 5. Have you used augmented reality (AR) apps before? *

Mark only one oval.

- Yes
- No

6. 6. Have you visit Melaka historical sites before? *

Mark only one oval.

- Yes
- No

Section B: System Usability Scale (SUS)

7. 1. I think that I would like to use this system frequently. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

8. 2. I found the system unnecessarily complex. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

9. 3. I thought the system was easy to use. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

10. 4. I think that I would need the support of a technical person to be able to use this system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

11. 5. I found the various functions in this system were well integrated. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

12. 6. I thought there was too much inconsistency in this system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

13. 7. I would imagine that most people would learn to use this system very quickly. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

14. 8. I found the system very cumbersome (unmanageable) to use. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

15. 9. I felt very confident using the system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

16. 10. I needed to learn a lot of things before I could get going with this system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Section C: Technology Acceptance Model (TAM)

17. 1. Learning to operate the AR apps would be easy for me. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

18. 2. I would find it easy to get the AR apps to do what I want it to do. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

19. 3. My interaction with the AR apps would be clear and understandable. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

20. 4. I would find the AR apps to be flexible to interact with. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

21. 5. I would find the AR apps easy to use. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

22. **Recommendations/Comments:**

23. Proof of testing the apps. (Screenshot/Image of the apps) *(optional)*

Files submitted:

APPENDIX C - EXPERT TESTING QUESTIONNAIRE

INTERACTIVE MELAKA HISTORICAL SITES IN MARKERLESS AR APPS: EXPERT TESTING

Welcome to the survey for evaluating the usability of our newly developed augmented reality (AR) application designed for exploring historical sites in

Melaka. Your feedback is crucial in helping to improve the app and ensure it meets user needs.

Instructions:

1. Download the App: Please download the Interactive Melaka Historical Sites AR app by clicking **[HERE]**. Follow instructions stated in that link.
2. Test the App: Spend approximately 5 minutes fully testing the app. Explore its features, interact with the virtual elements, and navigate through the historical sites. *(at the end of this questionnaire form, respondent were required to upload the proof of testing)*
3. Complete the Survey: After testing the app, please return to this form to provide your feedback. The survey consists of 4 pages with 4 sections:

- **Section A : Demographic Section**
- **Section B : System Usability Scale (SUS) Questionnaire**
- **Section C : Technology Acceptance Model (TAM) Questionnaire**
- **Section D : Expert Feedback**

(at the end of this questionnaire form, respondent were required to upload the proof of testing)

Please answer the following questions honestly based on your experience with the app and your expertise. Your responses will remain confidential and will only be used for research purposes. The survey will take approximately 15 minutes to complete.

Thank you for your participation!

* Indicates required question

Section A: Demographic Respondent

1. 1. Gender *

Mark only one oval.

- ⬭ Male
- ⬭ Female

2. 2. Age *

Mark only one oval.

- ⬭ Below 20 years old
- ⬭ 21 - 30 years old
- ⬭ 31 - 40 years old
- ⬭ Above 40 years old

3. 3. Ethnicity *

Mark only one oval.

- ⬭ Malay
- ⬭ Chinese
- ⬭ Indian
- ⬭ Other: ____________________

4. 4. Professional Background *

Mark only one oval.

- ⬭ AR/VR Developer
- ⬭ Tourism Expert
- ⬭ HCI Lecturer/UI Expertise
- ⬭ Other Fields Lecturer
- ⬭ Other: ____________________

5. 6. Years of Experience in Your Field *

Mark only one oval.

- 1-3 years
- 4-6 years
- 7-9 years
- Above 10 years

Section B: System Usability Scale (SUS)

6. 1. I think that I would like to use this system frequently. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

7. 2. I found the system unnecessarily complex. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

8. 3. I thought the system was easy to use. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

9. 4. I think that I would need the support of a technical person to be able to use this system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

10. 5. I found the various functions in this system were well integrated. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

11. 6. I thought there was too much inconsistency in this system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

12. 7. I would imagine that most people would learn to use this system very quickly. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

13. 8. I found the system very cumbersome (unmanageable) to use. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

14. 9. I felt very confident using the system. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

15. 10. I think that I would like to use this system frequently. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Section C: Technology Acceptance Model (TAM)

16. 1. Learning to operate the AR apps would be easy for me. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

17. 2. I would find it easy to get the AR apps to do what I want it to do. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

18. 3. My interaction with the AR apps would be clear and understandable. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

19. 4. I would find the AR apps to be flexible to interact with. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

20. 5. I would find the AR apps easy to use. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Section D: Expert Feedback

21. What are the key strengths of the AR app? *

22. What are the main weaknesses or usability issues you identified? *

23. What improvements would you recommend? *

24. Any additional comments or suggestions?

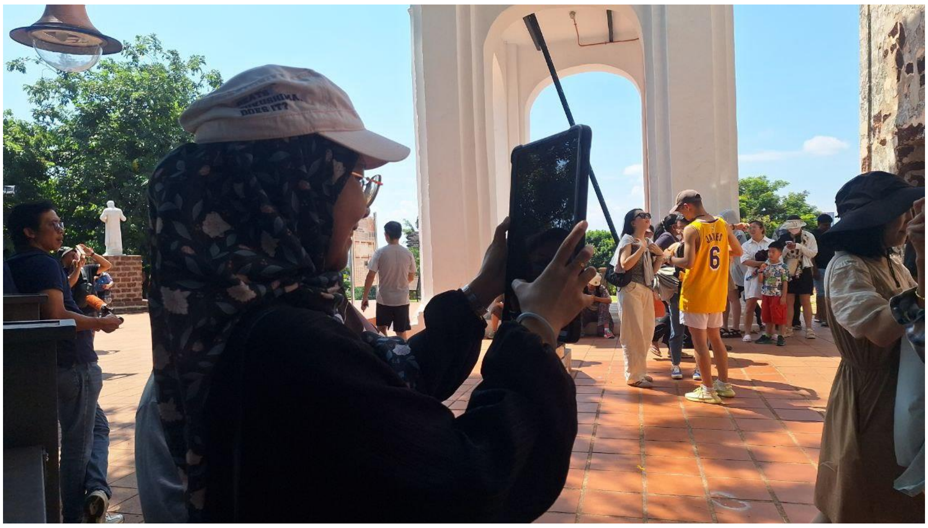
25. Proof of testing the apps. (Screenshot/Image of the apps)

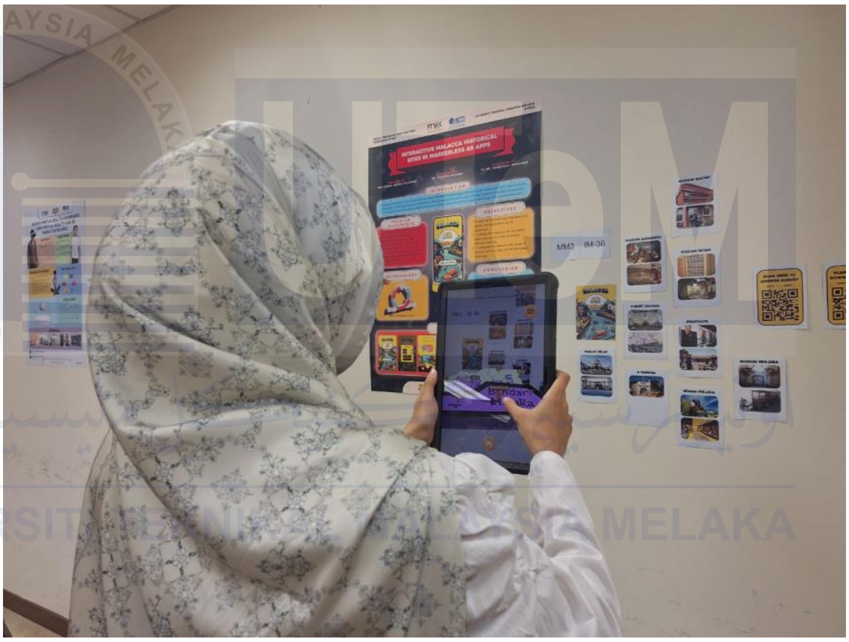
Files submitted:

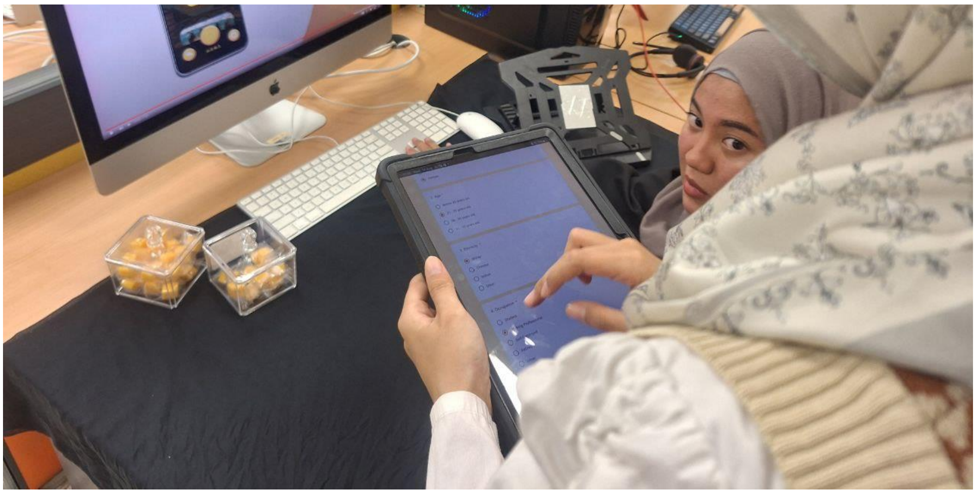
This content is neither created nor endorsed by Google.

Google Forms

APPENDIX D - USER TESTING SESSION




INTERACTIVE MALACCA HISTORICAL SITES IN MARKERLESS AR APPS



APPENDIX E - EXPERT TESTING SESSION


MALACCA
AR


MALACCA
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START EXPLORING