Faculty of Computer Science and Information Technology

ENHANCEMENT OF USER EXPERIENCE USING AUGMENTED REALITY IN "OMEN BIRDS OF BORNEO" (BORNEO CULTURES MUSEUM)

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ABSTRACT

The "Omen Birds of Borneo" exhibition at the Borneo Cultures Museum in Kuching highlights the cultural and ecological significance of Borneo's bird species. While aiming to provide an immersive experience, the exhibition faces challenges that hinder its educational and interactive potential. Overlapping bird sounds create confusion, misaligned display elements disrupt visual flow, and poorly illuminated text further impairs information accessibility. To address these issues, this project proposes the integration of Augmented Reality (AR) technology. AR offers a dynamic solution by providing personalized auditory experiences, real-time alignment of bird information with interactive 3D models, and enhanced visual clarity. Visitors can use the AR app to access detailed information, view high-quality 3D representations of birds, and hear synchronized audio through their own devices thus eliminating overlapping noises. This project aims to transform the "Omen Birds of Borneo" exhibition into an engaging, accessible, and educational experience. The AR-enhanced platform not only improves visitor interaction but also serves as a tool to promote awareness of Borneo’s unique bird species and their cultural heritage. Ultimately, this initiative contributes to enhancing the museum's appeal and preserving local biodiversity.

ABSTRAK

Pameran "Omen Birds of Borneo" di Muzium Budaya Borneo di Kuching menonjolkan kepentingan budaya dan ekologi spesies burung Borneo. Walaupun bertujuan untuk memberikan pengalaman yang mengasyikkan, pameran ini menghadapi cabaran yang menghalang potensi pendidikan dan interaktifnya. Bunyi burung yang bertindih menimbulkan kekeliruan, elemen paparan yang tidak sejajar mengganggu aliran visual dan teks yang kurang pencahayaannya seterusnya menjejaskan kebolehcapaian maklumat. Untuk menangani isu ini, projek ini mencadangkan penyepaduan teknologi Augmented Reality (AR). AR menawarkan penyelesaian dinamik dengan menyediakan pengalaman pendengaran yang diperibadikan, penjajaran masa nyata maklumat burung dengan model 3D interaktif dan kejelasan visual yang dipertingkatkan. Pelawat boleh menggunakan aplikasi AR untuk mengakses maklumat terperinci, melihat perwakilan 3D burung yang berkualiti tinggi dan mendengar audio yang disegerakkan melalui peranti mereka sendiri sekali gus menghapuskan bunyi yang bertindih. Projek ini bertujuan untuk mengubah pameran "Omen Birds of Borneo" menjadi menarik, boleh diakses, dan pengalaman pendidikan. Platform yang dipertingkatkan AR bukan sahaja meningkatkan interaksi pelawat tetapi juga berfungsi sebagai alat untuk mempromosikan kesedaran tentang spesies burung unik Borneo dan warisan budaya mereka. Akhirnya, inisiatif ini menyumbang kepada meningkatkan daya tarikan muzium dan memelihara biodiversiti tempatan.

CHAPTER 1: INTRODUCTION

1.1 Title

Enhancement of User Experienced using Augmented Reality in “Omen Birds of Borneo” (Borneo Culture Museum).

1.2 Introduction

The Borneo Cultures Museum, located in the centre of Kuching next to Padang Merdeka, is a modern five-story structure that showcases Sarawak's traditional crafts and rich cultural history with its unique architectural elements. According to Sarawak Tourism Board (n.d.), “In Harmony with Nature Gallery” is the largest gallery within the museum, covering 2,188 square meters. This gallery explores the element relationship between local communities and the natural environment, taking visitors on a journey through Borneo's geographical landscapes. "Omen Birds of Borneo" is one of the exhibitions that focuses on the cultural and environmental significance of Borneo's bird species as shown in Figure 1.1. Eight different kinds of Borneo birds are on display. These are the eight types of Borneo bird which are Grey-and-Buff Woodpecker(*kalirë*), the Rufous Piculet (*Ketupong*), the Bat Hawk, the Scarlet-rumped Trogon (*Beragai*), the Dark Hawk-Cuckoo (*Manuk Asi*), the Banded Kingfisher (*Embuas*), the Reddish Scops Owl (*Manuk Wek*), and the Spiderhunter (*Isit*).

Figure 1.1 Omens Birds of Borneo Exhibition

My project aims to enhance the user experience in the Omen Birds of Borneo exhibition at the Borneo Culture Museum (BCM). This exhibition faces challenges such as poor lighting, making it difficult for visitors to read information about Bornean birds. Some visitors struggle

to synchronize the audio with the projected bird model since there is no clear guide to navigate the projection onto the wall. To address these issues, I aim to transform the traditional exhibition into a digital experience using Augmented Reality (AR) to allow visitors to better learn and understand the traditional beliefs in Borneo.

Augmented Reality (AR) is a system that combines the actual and virtual worlds, allows for real-time interaction. The augmentation is being performed out in real time here (Aggarwal & Singhal, 2019). AR is an interactive technology that enhances learning experiences for today's generation. While a few museums in Malaysia have implemented AR, Borneo Culture Museum is still a relatively new museum. I would like to propose AR technology specifically for Sarawak's museum sector. I also wanted to promote AR as we move towards a more technology-driven era that can give both tourism and education benefits.

Numerous studies found that having a mobile guide improved learning and focus, as well as providing encouragement and inspiration to try out new methods to engage with the exhibit. Additionally, it has become apparent that employing technology for alternate interpretation may potentially draw in new audiences (Roussou & Katifori, 2018). According to Paliokas et al. (2020), we can determine that from a user-centred perspective, augmented reality presents visitors with another form of interaction, which may stimulate curiosity and engagement and ultimately promote a sense of satisfaction. Statista estimated that the number of mobile augmented reality users globally would reach 2.4 billion by 2023, up from 1.96 billion in 2021 as shown in Figure 1.2 (caroline, 2021). These users are more likely to enjoy the convenience and fun of travel and culture at anytime, anyplace in the fast-paced world of today. Digital transformation is the main goal in order to attract people's attention in a wide range of tourism and cultural promotions (caroline, 2021).

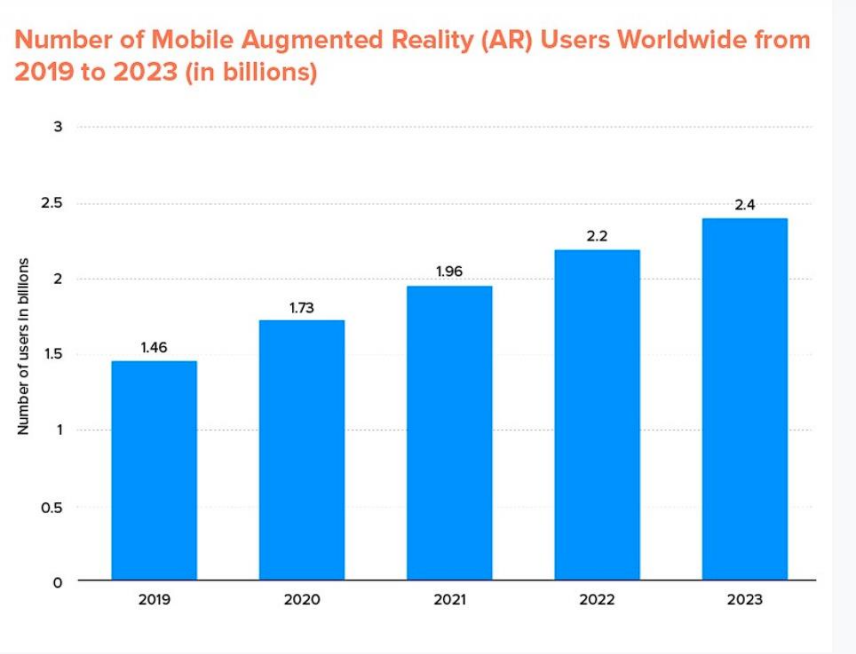

Figure 1.2 Number of Mobile AR User Worldwide from 2019 to 2023 (in billions) (caroline, 2021)

One more example of how AR can help museums is a case study done by cuseum (2018). In a survey of 103 museum visitors that took place on-site, people were asked to use AR-enhanced mobile technology and give feedback. The findings showed a high level of public interest in experiences made possible by AR:

- According to 90% of respondents, mobile technology enhanced information access.
- AR is an interesting new method to interact with museum content, according to 91% of respondents.
- 87% of respondents said augmented reality improved their visit, and they wanted the technology to be widely used in museums.
- 85% of respondents indicated they would tell others about AR-enhanced museum experiences.

Participants evaluated their experiences with AR as "easy," "enhancing," "fun," and "immersive," showing how this technology could completely transform museum visits. These results highlight AR's potential as a game-changing technology to improve accessibility, visitor contentment, and engagement the backgrounds in culture.

One of museums have successfully utilized augmented reality (AR) applications to enhance the visitor experience through personalized and interactive solutions. For example, the

Sanxingdui Museum in China (Reality, 2023). The Sanxingdui Museum is an example of a themed museum that holds and displays thousands of coppers, jade, and gold items from the Shu period, which was 3,000 years ago. With the help of AR, the art of China's vanished history and culture is coming to life. There are several mobile AR applications that could serve as references for improving the "Omen Birds of Borneo" exhibition. *Mek Mulung* (DreamEDGE Sdn Bhd, 2021) provides culturally rich augmented reality experiences by combining storytelling with traditional elements, Museum Alive App (Alchemy Immersive Ltd, 2021) makes exhibitions come to life with dynamic, engaging narratives, and apps like FeelTheArt (LIVDEO, 2022) allow users to interact with 3D models and examine artwork in depth.

These examples show how AR can change things by making experiences more personalized, educational, and fun. They are great examples for making the Omen Birds of Borneo exhibition more interactive and appealing. According to Alakhtar (2020), the preservation and exhibition of historical artifacts rely significantly on AR. For example, the well-known holographic augmented reality software TombSeer, a digital cultural heritage (DCH) program, can recreate the Royal Ontario Museum's (ROM) historic interior chapel of the Egyptian Tomb of Kitines. Historical artifacts provide a solid connection to the past and the way of life in different cultures, which aids in their connection to their ancestors. This project seeks to use augmented reality technology to improve the tourist experience at the "Omen Birds of Borneo" exhibition.

1.3 Problem Statement

The "Omen Birds of Borneo" exhibition, which features a range of birds that have a significant role in local culture and natural history, intends to offer people with an immersive experience that highlights the importance of these species. Several kinds of challenges happened that draw away from what is expected user experience. One of the exhibition's significant elements is the use of bird sounds to immerse visitors in Borneo's natural environment. The audio of the birds is to create an ambient environment. As mentioned by Yang and Gábor Sörös (2019), to allow people to experience the paintings through a variety of senses, the Tate Sensorium exhibition which located at Tate Museum, London, accompanied them with music, fragrances, and tactile sensations that were all intended to complement the artist's vision. The lack of personalization to adjust these improved experiences to each visitor's actions and viewing habits yet was a major obstacle. Visitors tend to feel disconnected from their planned immersive experience because of this lack of personalization. As a result, the educational value of the display is limited since visitors are unable to precisely associate the sounds with individual birds.

The pillars are designed to resemble trees, aligning with the museum's aesthetic vision for the exhibition as shown in Figure 1.3. However, the position of the pillars and bird boxes is not well coordinated which leading to confusion. According to research (Roussou & Katifori, 2018) we can determine that to enhance the visitor experience, it’s essential to understand their position within the space to guide their movement and direct them effectively. However, achieving precise location awareness in indoor museum settings remains a challenging general term, orientation issues have been poorly addressed. As visitors seek out exhibits and navigate the area, a lack of accurate location and position information about indoor museum settings can cause confusion and frustration. The present approach to the "Omen Birds of Borneo" exhibition, while based on aesthetic and educational ideals, fails to sufficiently address significant usability issues.

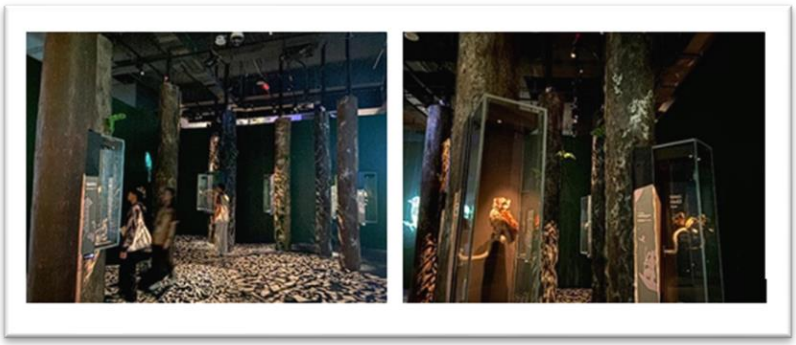

Figure 1.3 Pillars in Omen of Birds Exhibition

The exhibition could transform from its current physical display into a more dynamic and personalized digital platform using augmented reality (AR) through smartphone. To solve the issue of overlapping sounds, visitors will be using their own headphones/earphones that will allow them to hear the correspondent bird sound in the AR system. This device able to provide a more personalized auditory experience. According to research (Yang et al., 2019), we can determine that an activation zone was designated for each image to prevent sound interference from other images. The sound could only be heard when the user was within the corresponding zone, ensuring they could focus on one image at a time without disturbance. Furthermore, AR will enable real-time alignment of bird's information in 3D models, images of bird's belief and the audio of the birds allowing visitors to scan exhibitions with their devices for specific information and eliminating concerns with misaligned projections.

1.4 Project Scope

Scanning any of the five selected Borneo birds which are Grey-and-Buff Woodpecker (*kalirë*), Scarlet-Rumped Trogon (*Beragai*), Dark Hawk-Cuckoo (*Manuk Asi*), Banded Kingfisher (*Embuas*) and Reddish Scops Owl (*Manuk Wek*). Visitors can access detailed 3D models, birds' belief in images and audio of correspond birds in their device. The personalized auditory experience allowing users to hear bird sounds through their own earphones with minimized overlapping noises, focusing on the specific bird they are viewing. The AR system was designed to be adaptable enough to support additional exhibitions or gallery renovations in the future. To further engage visitors and enhance their learning experience, the system will incorporate interactive quizzes that test their knowledge about Borneo birds. These feature able to make the exhibition more immersive thus encouraging deeper engagement with the cultural and ecological significance of Borneo's birds.

1.5 Objectives

- To study existing challenges in traditional exhibition displays, such as overlapping audio and misaligned projections thus to figure out how AR may handle them.
- To implement an Augmented Reality (AR) system that improves the visual and audio experience at the "Omen Birds of Borneo" exhibition.
- To evaluate the enhancement of user experience using Augmented Reality in the *Omen Birds of Borneo* exhibition at Borneo Culture Museum.

1.6 Significant of Project

The "Omen Birds of Borneo" exhibition serves as essential for promoting knowledge of the region's unique bird population, which is important to cultural heritage and ecology. By using an augmented reality (AR) technology, the project aims to create an enhanced and dynamic learning environment that allows visitors to learn more about bird species, improving their understanding and enjoyment of Borneo's wildlife richness. As mentioned by caroline (2021), Augmented reality in the tourist industry significantly increases visitor positive and develops good brand impressions by using 3D models, unique sounds, visual effects, and immersive virtual tour experiences. Meanwhile, the exhibition may revive cultural and creative products.

1.7 Project Schedule

Table 1 : FYP1 Project Schedule

Task	Start Date	End Date	Duration (Days)
Phase 1 : Requirement Planning	**10/9/2024**	**13/12/2024**	**94**
Define project objectives and scope	10/9/2024	1/10/2024	21
Brief proposal	1/10/2024	20/10/2024	19
Review on existing AR system	20/10/2024	3/11/2024	14
Submission Full Proposal	3/11/2024	14/11/2024	11
Refine the proposal	15/11/2024	19/11/2024	4
Submission Chapter 1 after amendment	19/11/2024	21/11/2024	2
Prepare a questionnaire	21/11/2024	25/11/2024	4
Collect feedback from visitors	25/11/2024	29/11/2024	4
Conduct a detailed requirements analysis of AR system	29/11/2024	8/12/2024	9
Submission of Chapter 2	8/12/2024	13/12/2024	5
Phase 2: User Design	**13/12/2024**	**12/1/2025**	**30**
Design the wireframe	13/12/2024	18/12/2024	5
Design the initial user interface prototype Figma	18/12/2024	20/12/2024	2
Test the prototype with users and gather feedback	20/12/2024	24/12/2024	4

Incorporate final feedback to create a high-fidelity prototype in Figma	24/12/2024	27/12/2024	3
Submission Chapter 3	27/12/2024	5/1/2025	9
FYP 1 report and paper	5/1/2025	9/1/2025	4
FYP 1 report and paper after amendment	9/1/2025	12/1/2025	3

Table 2 : FYP2 Project Schedule

Task	Start Date	End Date	Duration (Days)
Phase 3: Implementation	**4/02/2025**	**15/05/2025**	**103**
Setting up the software	4/02/2025	4/02/2025	1
Creating images and 3D model of birds	05/02/2025	11/02/2025	**7**
Implement images,3D models and audio	12/02/2025	10/05/2025	88
Start coding and development of AR	13/02/2025	10/05/2025	87
Submission of Revised structured of FYP report	30/03/2025	1/04/2025	3
Submission of First Draft for Chapter 4	12/05/2025	15/05/2025	4
Phase 4: Verification & Testing	**16/05/2025**	**31/05/2025**	**16**
Prepare a questionnaire	16/05/2025	17/05/2025	2
Test the prototype with users and gather feedback	18/05/2025	21/05/2025	4
Submission of First Draft for Chapter 5,6 & Abstract & Paper	22/05/2025	31/05/2025	10
Phase 5: Maintenance	**1/06/2025**	**28/07/2025**	**61**
Submission of First Draft for FYP 2 Full Report and Paper	1/06/2025	10/06/2025	11
Submission of Final Report for Assessment	11/06/2025	23/06/2025	13
Updates bugfix, improve performances	24/06/2025	30/06/2025	6
Symposium FYP 2025	1/07/2025	2/07/2025	3
Amendment and Modification for FYP	1/07/2025	18/07/2025	18
Submission of Final Report	19/07/2025	28/07/2025	10

Figure 1.3 Gantt Chart for FYP1

TASK	START	END	SEP				OCT				NOV				DEC				JAN			
			WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4
Phase 1 : Requirement Planning	**10/9/2024**	**13/12/2024**																				
Define project objectives and scope	10/9/2024	1/10/2024																				
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Review on existing AR system	20/10/2024	3/11/2024																				
Submission Full Proposal	3/11/2024	14/11/2024																				
Refine the proposal	15/11/2024	19/11/2024																				
Submission Chapter 1 after amendment	19/11/2024	21/11/2024																				
Prepare a questionnaire	21/11/2024	25/11/2024																				
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Conduct a detailed requirements analysis of AR system	29/11/2024	8/12/2024																				
Submission of Chapter 2	8/12/2024	13/12/2024																				
Phase 2: User Design	**13/12/2024**	**12/1/2025**																				
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Design the initial user interface prototype Figma	18/12/2024	20/12/2024																				
Test the prototype with users and gather feedback	20/12/2024	24/12/2024																				
Incorporate final feedback to create a high-fidelity prototype in Figma	24/12/2024	27/12/2024																				
Submission Chapter 3	27/12/2024	5/1/2025																				
FYP 1 report and paper	5/1/2025	9/1/2025																				
FYP 1 report and paper after amendment	9/1/2025	12/1/2025																				

Figure 1.3 Gantt Chart for FYP2

TASK	START	END	FEB				MAR				APR				MAY				JUN				JULY			
			WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4	WK1	WK2	WK3	WK4
Phase 3: Implementation	**4/2/2025**	**15/05/2025**																								
Setting up the software	4/2/2025	4/2/2025																								
Creating images and 3D model of birds	5/2/2025	11/2/2025																								
Implement images,3D models and audio	12/2/2025	10/5/2025																								
Start coding and development of AR	13/2/2025	10/5/2025																								
Submission of Revised structured of FYP report	30/3/2025	1/4/2025																								
Submission of First Draft for Chapter 4	12/5/2025	15/5/2025																								
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Submission of First Draft for FYP 2 Full Report and Paper	1/6/2025	10/6/2025																								
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Submission of Final Report	19/7/2025	28/7/2025																								

1.8 Expected Outcome

A prototype of the AR app will be developed for the "Omen Birds of Borneo" exhibition, providing visitors with comprehensive information about Borneo's birds through engaging 3D models of the birds, personalized audio experiences, and image for each bird's belief. This app is an educational tool that can encourage future generations to value and preserve local bird species in addition to improve the visiting experience.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter 2 includes the literature reviews that are needed to confirm the objectives of this project. The review is mainly focused on the functionalities, comparison between the existing systems and the benefits of Augmented Reality (AR) in museums experiences. This studies and reviews of the chapter will help to decide which type of basic interaction method, technique and application method criteria that are suitable for user experiences in museum experiences. According to Germak et al. (2021), we can determine that utilization of technology at museums should not be considered an add-on to the visitor experience, but instead as a key element of the setting in which it can be used. For the technical tool to be accepted, factors such as usability, usefulness, effectiveness, and management must be taken into perspective.

This chapter will review five existing museum applications with the feature of augmented reality. The existing AR mobile application that will discuss in this chapter are *Mek Mulung*, *Muzium Perak AR*, Civilisations AR, Boulevard AR and Tanah Airku. In this chapter also highlight the flow of the project function and will be analysed to compare the strengths and weakness of those learning materials thus, include the features that I am planning to incorporate into my project.

2.2 Review on Existing Museum AR Applications

2.2.1 MekMulung AR

MekMulung by DreamEdge is an Augmented Reality application that displays traditional MekMulung performance into a digital form as shown in Figure 2.1. This AR app is mainly targeted for tourists, students and learners. MekMulung able to run in both devices (Android and IOS). This bile application with Augmented Reality feature uses interactive 3D animations, talking, singing, and dancing to introduce users to the six characters of this cultural art form.

Figure 2.1 MekMulung (DreamEDGE Sdn Bhd, 2021)

The first screen allows users to select their preferred language, either Bahasa Melayu or English. They can also download the AR marker by clicking the "AR Marker" button. The app includes two main buttons: "Info" and "Character." The "Info" button provides an in-depth history of MekMulung, while the "Character" button offers six-character options for use in scene recreation: King, Princess, Young Servant, Servant, Maidservant, and Old Sage. For example, selecting the "King" character displays a detailed description as shown in Figure 2.2. The app also enables users to scan an AR marker to reveal a 3D model of the selected character. Before activating the AR scanning function, a safety warning ensures users are aware of their

surroundings. Upon scanning the AR marker, the 3D model of the chosen character appears on the screen along with three additional feature buttons such as character characteristics, Audio Integration and Dancing as shown in Figure 2.3.

Figure 2.2 Description of the MekMulung's character (DreamEDGE Sdn Bhd, 2021a)

Figure 2.3 3D Model of character with audio and animation (DreamEDGE Sdn Bhd, 2021a)

These features create an interactive experience that bridges traditional storytelling with modern technology. The AR markers and user-friendly interface allow users to explore the unique storylines and aesthetic qualities of the traditional MekMulung show in augmented reality. However, despite its engaging content, vibrant 3D models, and detailed information, the app has some navigational drawbacks. Users may find it challenging to locate the back button for returning to the previous page, as they need to use the "Main" or "Character" buttons to navigate back to the main page. Overall, this AR app is an innovative approach to preserving and promoting Malaysia's cultural heritage. By making MekMulung more accessible and engaging, the app ensures that this traditional art form is passed down to future generations, safeguarding it from extinction.

2.2.2 Muzium Perak AR

Muzium Perak AR, developed by DreamEDGE, is an augmented reality application designed to enhance museum visits by providing digital versions of real-world artifacts. This AR app creates for tourists, students, and learners, and it is compatible with both Android and iOS devices. The application features interactive 3D augmented reality markers that display significant artifacts such as the twin wagons of the Perak State Railways, prehistoric pottery, and the skeleton of an Asian elephant.

Figure 2.4 Muzium Perak AR Interface (DreamEDGE Sdn Bhd, 2021b)

The app's first screen introduces Muzium Perak, displaying all updates and historical information about the museum as shown in Figure 2.4. The navigation menu includes options like About Us, Visit Us, AR | Augmented Reality, Maps, and Contact Us. Within the Augmented Reality section, users can access a list of six galleries, of which five support AR functionality: Gallery Nature, Gallery Culture, Gallery Pottery, Gallery Orang Asli, and Outdoor Exhibition. The first gallery, Gallery A is a temporary exhibition. Users can select any of the five AR-enabled galleries. For example, selecting Gallery Culture displays the gallery's description. By tapping "AR Start," all AR-featured items in the gallery are shown. When users scan the AR marker, a 3D representation of the item appears on the screen. Additional features include the ability to zoom in and move the object, as well as view step-by-step instructions on crafting traditional items through pictures as shown in Figure 2.6.

Figure 2.5 Description of the Cutam (Gallery Culture) (DreamEDGE Sdn Bhd, 2021b)

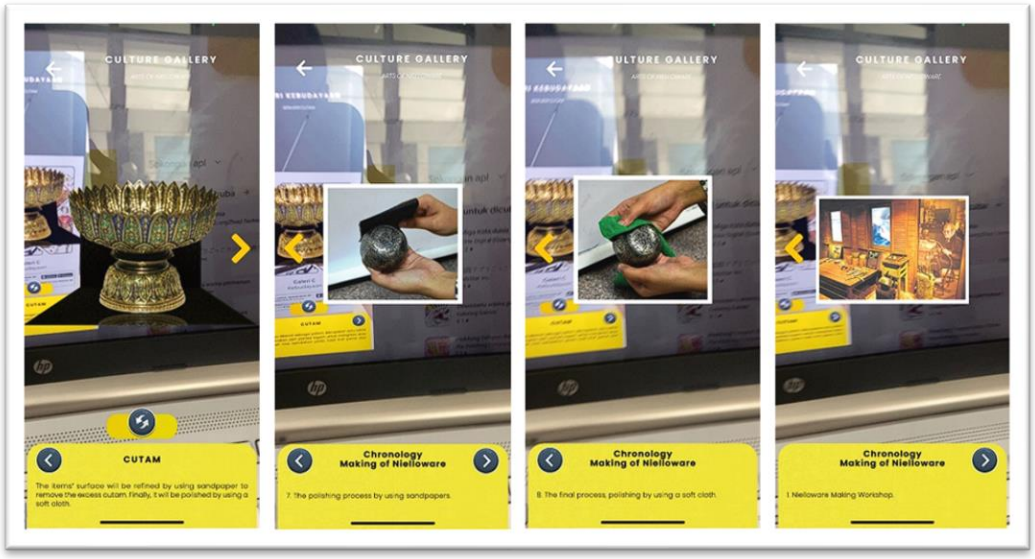


Figure 2.6 3D Screenshots of Step-by-Step Instructions on Crafting Traditional Item

In conclusion, this app makes cultural learning both interactive and accessible by combining storytelling with digital learning, appealing to tourists and learners.

2.2.3 Civilisations AR

Figure 2.7 Civilisation AR interface (AR, 2014)

Figure 2.7 is The Civilisations AR app, developed by Nexus Studio on 2022.According to research (AR, 2014) we can determine that it was the BBC's first ever Augmented Reality app Civilisations AR brings art and culture. The app offers users with a virtual trip across time, with more than 40 historical artifacts from international collections.

Figure 2.8 AR Function Civilisation AR (AR, 2014)

The ability of Civilisation AR to rotate, resize and move items as well as utilize an X-Ray function to discover the secrets hidden within the item as shown in Figure 2.8. It is to see inside a sarcophagus or what lies beneath a painting. Artifacts like Rodin's sculptures, Egyptian mummies, and works by famous artists like Tintoretto and Turner are brought to life with the use of audio guides. This app are not available in Play Store and App Store but available in Aptoide. This AR software has the power to totally transform the way people see cultural and historical knowledge and making it a teaching tool for audiences around.

2.2.4 Boulevard AR

Figure 2.9 is Boulevard AR App which focused on the educational value of arts with AR technology. This is a free IOS-based application developed by Nice Shoes. Boulevard AR designed to offers users a close-up look at significant paintings in 8K image quality from the National Portrait Gallery in London.

Figure 2.9 Boulevard AR Interface (Arts, 2018)

The portraits include figures like Sir Henry Unton, Dorothy Hodgkin, and Victorian creatives Dante Gabriel Rossetti and Theodore Watts-Dunton.Boulevard AR promotes interaction and detail by enabling users to expand models while scanning photos as shown in Figure 2.10. A practical technique for art education helps its target audience such as teachers, students, and lifelong learners for a better understanding historical characteristics and their contexts.

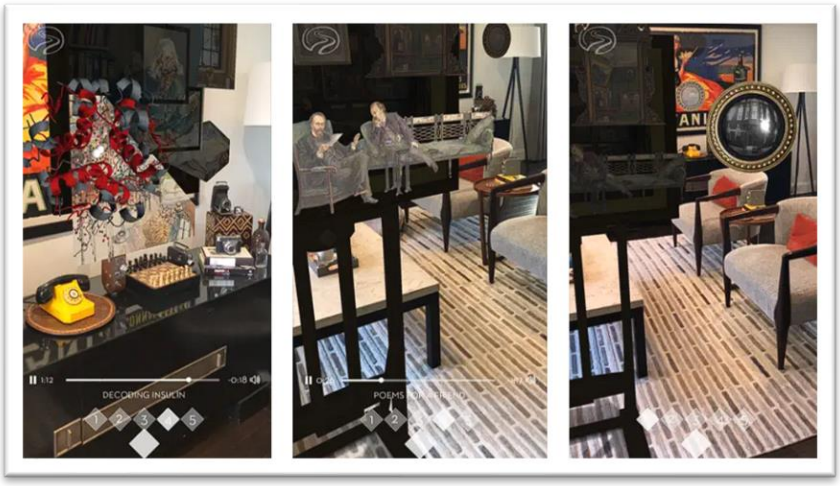


Figure 2.10 The display expanded (Arts, 2018)

Boulevard AR is an immersive art experience. However, from a functionality point of view, there are numerous shortcomings in the app. First, it lacks a typical back button instead, the application uses its logo as a substitute to navigate back, which may easily cause confusion for users by pressing it and being routed back to the home screen when they intended to go back a page. The app also lacks comprehensive features that a gallery should have thus limiting its performance. It currently only contains three sections of portraits with no introduction of the app or of the gallery. That really leaves users out of context, which, if continued building, can greatly enhance the overall user experience of this app.

2.2.5 Tanah Airku

Tanah Airku is a free mobile application that implementing augmented reality feature to introduce the Indonesian culture for local and international tourist. The main purpose of this application is for user to learn about Indonesia culture. Tanah Airku was developed by UNIKOM CodeLabs. As the user tap "Start", it will lead the user to the camera to access the

AR function with the book. To trigger the augmented feature, user needs to scan the pages in the book in order to view the 3D mode of Indonesia culture pop out in their scene as shown in Figure 2.11.

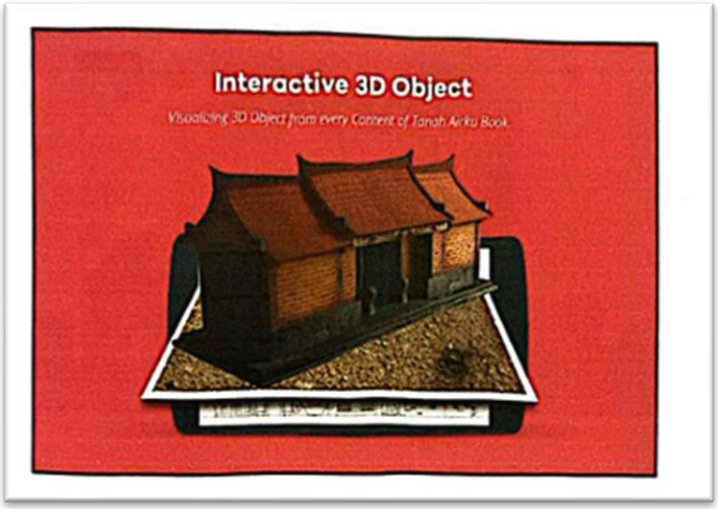


Figure 2.11 3D Model of Indonesia Building (TheGreatApps, 2015)

The most excitement section in this mobile application with trivia quizzes you can increase your knowledge about Indonesian culture. By learning Indonesian culture, we will feel more tolerant with other culture so that racism in Indonesia will be decrease (TheGreatApps, 2015). Although the application is useful to users, it might be inconvenience to them as they need the marker to trigger the Augmented Reality int the application using book. The book is huge and it will be hard for user to carry the book everywhere due to its size. The UI interface is not engaging, which could cause students or learners to lose interest in exploring it. Additionally, the absence of a back button for navigation may lead to confusion.

According to interview research (UNIKOM CodeLabs, 2016), we can determine can Tanah Airku AR App enables children to understand and respect Indonesian culture. Besides, it is an interesting application for kids. Moreover, this AR app also contains a quiz that can test your dexterity and stimulate the children's mindset on Indonesian traditions and their historical heritage which able to help them to develop a deeper appreciation for the country's cultural diversity.

2.3 Comparison between Existing Museum AR Applications

The general characteristic of five existing applications have been summarized in the following Table 2.1.

Application	Features	Strengths	Weakness
MekMulung AR (DreamEDGE Sdn Bhd, 2021a)	• 3D AR characters with audio and animation language options (Bahasa & English) • Display history of the culture	• Rich cultural immersion with interactive 3D animations • Safety features for AR use Multilingual support • Provides 3D model, personalized audio for users, details of the character.	• Navigation issues • Lack of intuitive back button functionality
Muzium Perak AR (DreamEDGE Sdn Bhd, 2021b)	• Interactive 3D AR galleries • Zoom & movement functions • Crafting instructions using of AR	• Provides detailed artifact interaction • Combines storytelling with education • Supports zoom and movement functionality for better exploration, 3D models (able to zoom).	• Limited to gallery-specific items • No personalized audio • Navigation issues
Civilisation AR (AR, 2014)	• 40+ artifacts displayed • X-Ray function, rotate/resize/move objects • Unavailable on standard app stores.	• Unique X-Ray function to explore hidden details • Supports deep artifact examination (e.g., sarcophagi interiors) • Immersive historical context, 3D models • Audio personalization, standard UI navigation.	• Limit of description of the artifacts • Accessibility issues (not in major app stores)
Boulevard AR (Arts, 2018)	• Expanded paintings • Close-up details of art • Interactive portrait features	• Offers in-depth art appreciation • Facilitates close-up exploration for learners • Good UI design • 8K image popout with interactivity.	• Non-standard navigation with logo as a back button • Limited content with only three portrait sections • No app introduction • No personalized audio
Tanah AirKu (TheGreatApps, 2015)	• AR triggered by scanning book pages • Trivia quizzes, cultural education about Indonesia	• Educates users about Indonesian culture interactively • Encourages tolerance and cultural understanding through quizzes, 3D models.	• Requires large physical marker book • No personalized audio • UI interface lacks engagement

Table 2.1 Strengths and Weakness of Existing Application

The Omen Birds of Borneo AR application will incorporate several key features from existing AR museum applications to enhance the visitor experience. Inspired by MekMulung AR, the app will include a personalized audio experience which allowing visitors to hear specific bird calls through their own headphones in more personalized, reducing sound overlap. It will also include 3D augmented reality models, similar to Muzium Perak AR and Tanah Airku, enabling users to explore detailed bird representations.

To improve accessibility, the app will utilize interactive AR markers, like those in MekMulung AR, allowing users to scan bird exhibits for additional information. Additionally, real-time alignment of information, based on Civilisations AR, will ensure bird descriptions and visuals match correctly.

Lastly, a quiz-based learning feature, inspired by Tanah Airku, may be included to test visitors' knowledge. These features will make the exhibition more immersive, educational, and engaging for users.

2.4 Summary

Chapter 2 discussed about the similar existing mobile application with the proposed project such as the function and the project flow of the application. This discussion includes the strength and the weakness of the existing AR application in a table form as shown in Table 2.1. The details of the prototype design framework of the proposed AR mobile application will be further discussed in the following chapter.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter is one of the crucial steps to develop AR mobile application. Therefore, this chapter describes about the chosen methodology and requirement details to develop the augmented reality in the Omen Birds of Borneo exhibition. The methodology chosen will be the guideline to explain the process involved in analysis and identify requirements, design, implement, testing and maintain the application. Among the methodologies, Waterfall is chosen to develop and deliver a quality application with minimal development time.

3.2 Waterfall Methodology

The methodology used for this AR Mobile Application is Waterfall. According to Lutkevich (2022), in software engineering and product development, the Waterfall model is a widely used linear, sequential approach to the software development lifecycle (SDLC). There are five phases in Waterfall methodology which are requirements, design, implementation, verification and maintenance as shown in Figure 3.1.

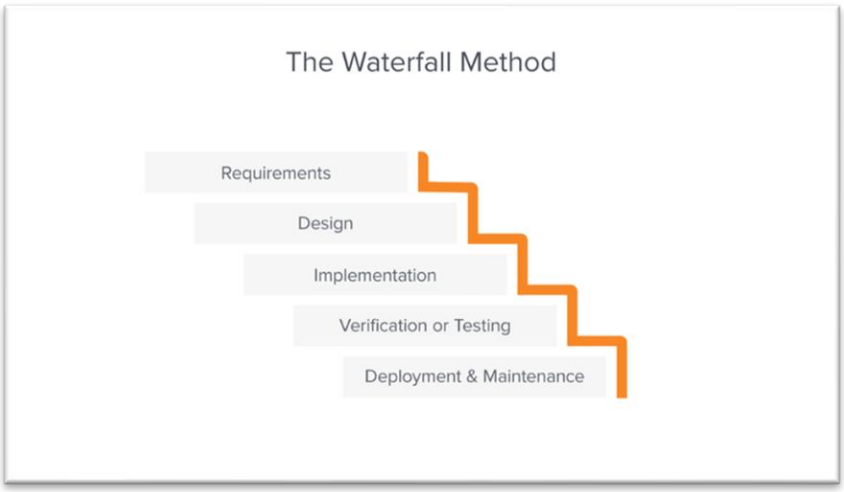


Figure 3.1 Waterfall Methodology (Adobe Communications Team, 2022)

The first phase is Requirements. This phase involves gathering and analysing all relevant data for the proposed project. It clearly defines the problems to be solved and the project objectives. It also thoroughly evaluates the hardware and software requirements for developing the application to ensure a solid foundation for the development process.

Design phase focuses on developing prototypes and creating the logical design for the application. This includes producing artifacts such as use case diagrams, use case activity and sequence diagrams which visually depict the application’s functionality, structure, and user interface. This phase is also known as system architecture, as it establishes the blueprint for the application's development and integration.

During the Implementation phase, both the prototype and accompanying documentation are developed based on the framework set in the Design phase. The AR mobile application is built using the hardware and software resources defined during the Requirements Planning phase. This phase translates the design into a fully functional application, adhering to the project's outlined goals and requirements.

The fourth phase is Verification. any product must be tested before use, software also requires thorough verification and testing. All software functions must be verified to ensure they are free from errors and perform strictly in accordance with the previously defined requirements. This ensures reliability and aligns the software with user expectations.

The final phase is Maintenance. During operation, small bugs that were not caught earlier may appear, or new needs arise that require the addition of new features. Development can also be necessary due to external factors, such as changes in the operating system or compatibility with new devices. The feedback is collected from users to identify areas that require improvement or additional features. Maintenance and updates will keep the software functional, adaptable, and responsive to emerging user needs.

3.2.1 Requirements

In this requirement planning phase, the requirement for this project will be determined and documented in more details as shown in Table 3.1. To develop the purposed the minimum hardware requirement is considered which include access memory (RAM), processor for both develop equipment and testing equipment.

A. Hardware and Software Requirement

Hardware and Software	Description
Laptop	AMD Ryzen 5 AMD RADEON Graphics RAM of 8GB
Android Smartphone	Android with minimum version of 7.0 (JellyBean) RAM of 4GB Screen resolution of 1080p (1920 x 1080 pixels) Camera of minimum 1Mp
Wireless Headphone	To listen the audio of the AR mobile app
Unity 3D	To access the asset to create the user interface of Augmented Reality mobile app
Vuforia	A database to store the marker of Augmented Reality mobile apps
Canva	Design the graphic marker of Augmented Reality
Meshy ai	A structural build of a 3D model from images

Table 3.1 Hardware and Software Requirement

B. User Requirement and Analysis

Surveys are described as the social examinations of people's demands and consciousness. To ensure that relevant inquiries and items are taken into consideration in a way that reflects certain constructs to be examined in a research study, designing a questionnaire involves detail-oriented preparation (Yusoff et al., 2021). Using a questionnaire will allow for the efficient collection of data thus it is helpful for this project. A survey was created using Google Forms and distributed to potential visitors of the *Omen Birds of Borneo* exhibition. The form is given after the potential visitors have visited the exhibition, and they are required to answer the survey as shown in Appendix A. There are 45 respondents in total (35 respondents are 18-24 years old, 6 respondents are 25-34 years old, 2 respondents 35-44 years old and 2 respondents 45 years old and above).

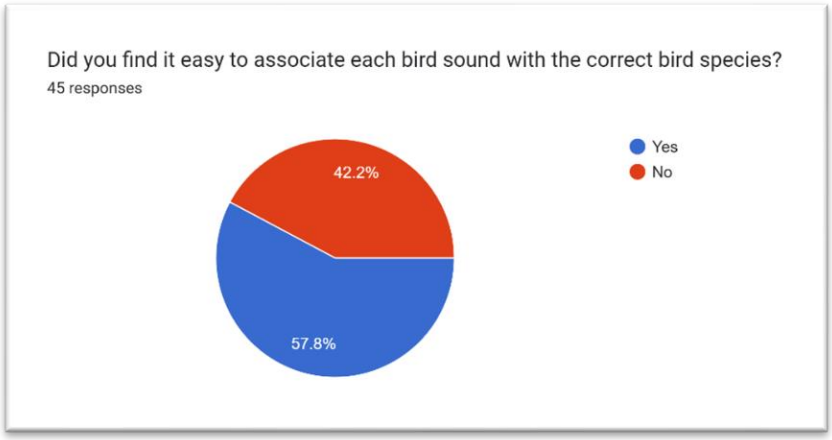


Figure 3.2 Analysis Review for Current Exhibition

Based on the result of the survey as shown in Figure 3.2, there are 57.8% respondents who found it easily to associate bird sound with the correct bird species while 42.2% of respondents are not able to bird sound species correctly. This indicates that a significant portion of visitors face challenges in distinguishing bird calls accurately.

This finding supports the need for AR technology implementation, as it can enhance the learning experience by providing more interactive and targeted audio guidance. By integrating AR, users could receive real-time visual cues or guided explanations when listening to bird sounds, helping them make better associations between the sounds and the bird species. This would address the difficulty faced by the 42.2% of respondents who had trouble recognizing the correct bird calls.

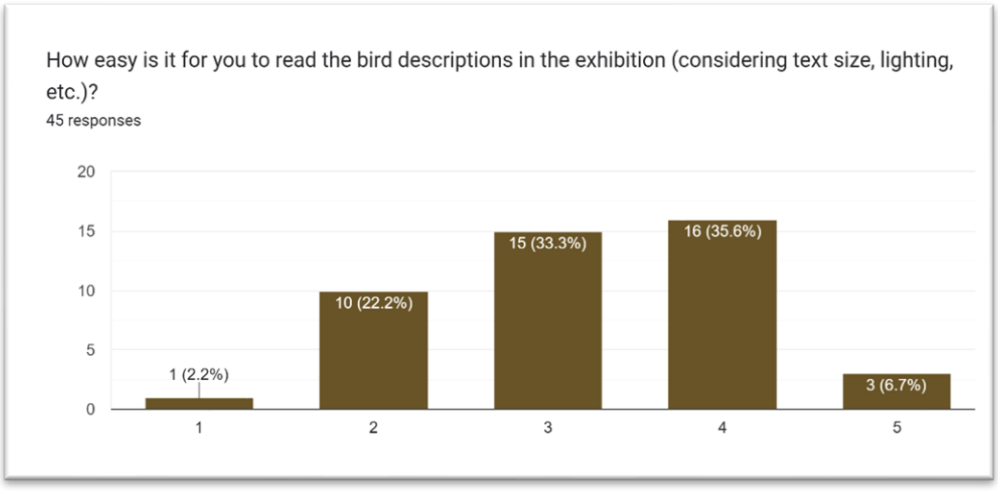


Figure 3.3 Analysis Review for Current Exhibition

Figure 3.3 shows the second question that were asked is about how easy for them to read the descriptions of the bird in the exhibition. The difficulty level of the task was evaluated on a scale from 1 to 5, where 1 represents 'very difficult' and 5 represents 'very easy. Most visitors found the text and the descriptions to be moderately to easily readable. This is because the largest proportions of responses fall within the middle to upper range. 33.3% rated the readability at 3, while 35.6% gave it a rating of 4 on the scale. This is well reflected in the low number of those visitors who had extreme difficulties, since only 2.2% gave the lowest rating. Since only 6.7% gave the highest rating of 5, there does seem to be scope for improving the presentation of text in the exhibition and the lighting of this text.

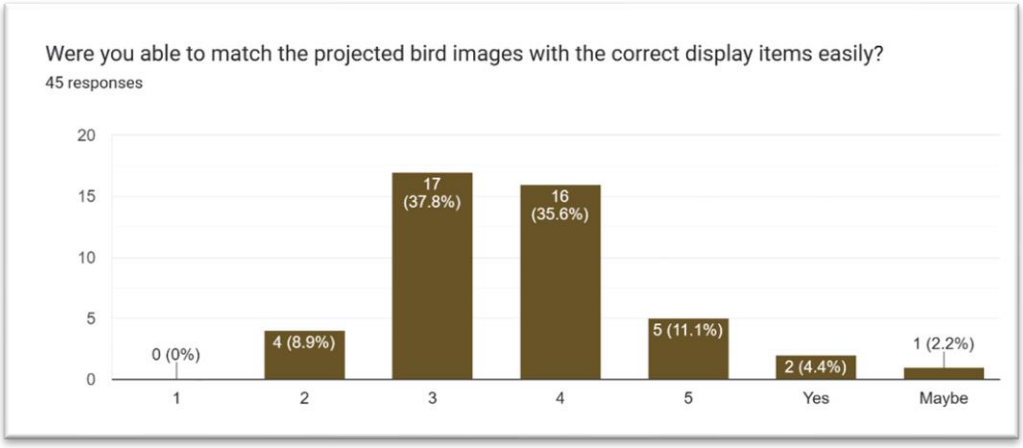


Figure 3.4 Analysis Review for Current Exhibition

In the case of matching projected bird images with display items, the survey reflects moderate success but also suggests room for improvement as shown in Figure 3.4. The difficulty level of the task was evaluated on a scale from 1 to 5, where 1 represents 'very difficult' and 5 represents 'very easy. Most responses fell within the middle range, with 37.8% rating at scale 3 and 35.6% rating at scale 4. The small percentage of "Yes" (4.4%) and "Maybe" (2.2%) responses further suggest that, while the system is functional, there are still opportunities for enhancement.

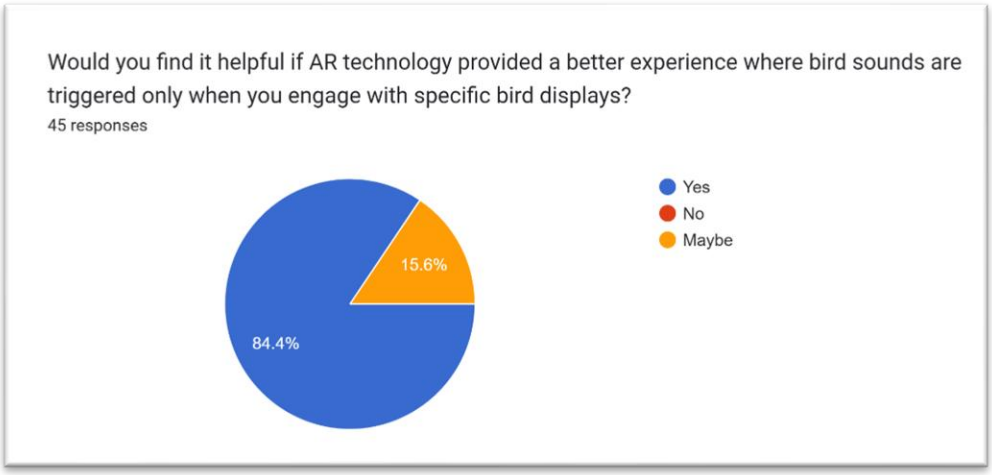


Figure 3.5 Analysis Review for AR Implementation of Exhibition

Based on Figure 3.5, 84.4% of respondents expressed interest in having AR-triggered bird sounds at exhibits, according to the results. Notably, there were no negative responses, and the remaining 15.6% of respondents expressed ambiguity with a "Maybe" response. This significantly positive response implies that using AR technology might greatly improve the exhibition experience.

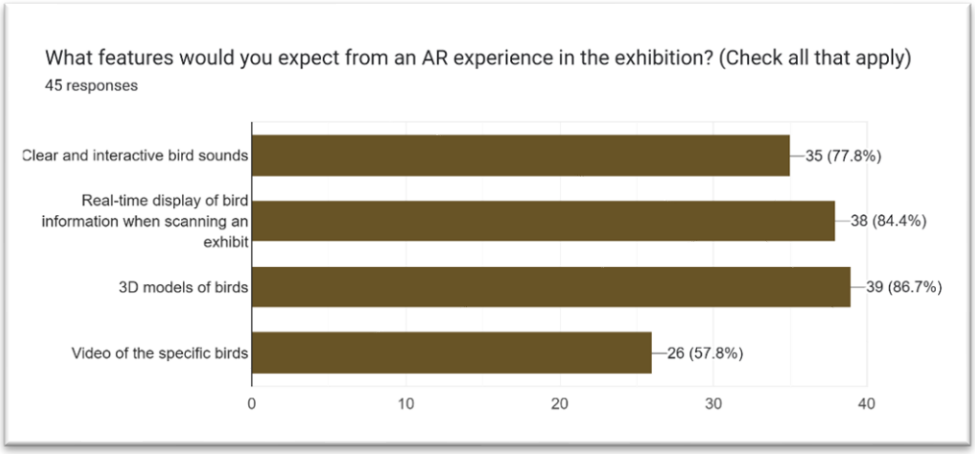


Figure 3.6 Analysis Review for AR Implementation of Exhibition 2

Based on Figure 3.6, the survey reveals clear preferences for AR features in the Omen Birds of Borneo exhibition. 3D models of birds emerged as the most desired feature at 86.7%, followed closely by real-time display of bird information at 84.4%. Interactive bird sounds

attracted 77.8% interest, while videos of specific birds received 57.8% support. This data indicates visitors strongly prefer interactive and immersive features that offer immediate access to bird information and visual representations, rather than passive viewing experiences. These preferences provide clear direction for implementing AR technology to enhance the exhibition experience.

3.2.2 Design

In this phase, the design of the system will be defined in detailed. This phase shows the purpose of project framework will be implemented. Specification of the project requirement in defining the overall architecture will be done in this phase.

A. Use Case Diagram

Use case diagram is to describe a set of action or activities that should perform by the user. The use case diagram for purposed project is shown in Figure 3.7.

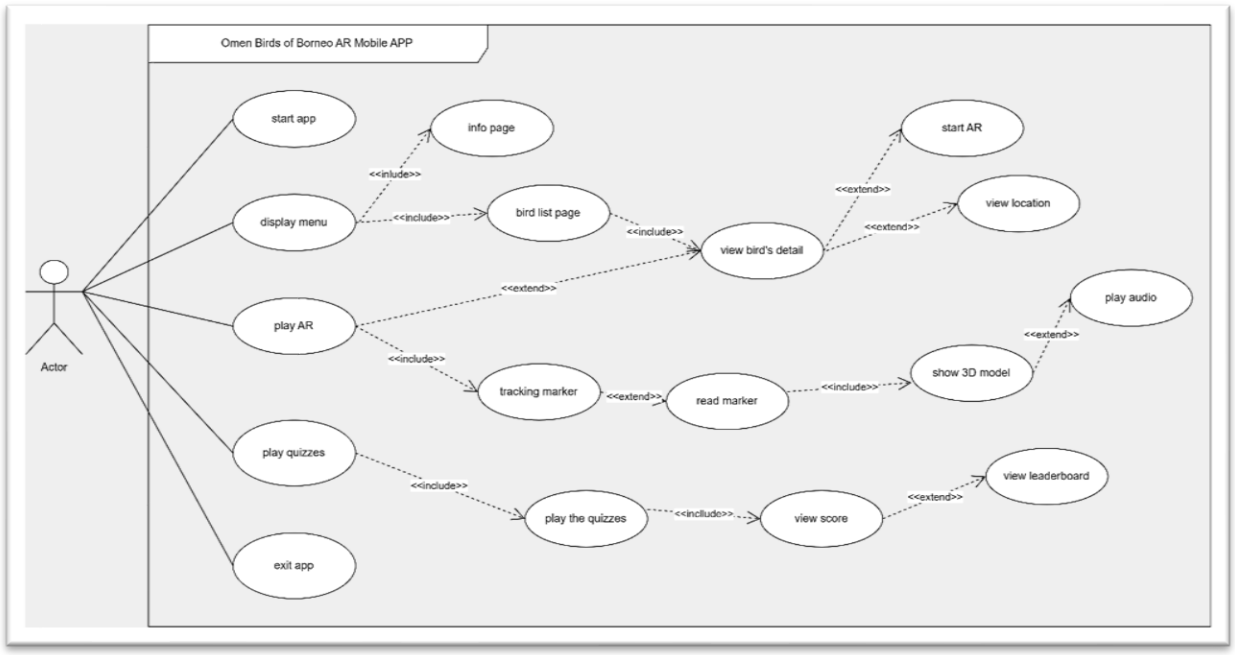


Figure 3.7 Use Case Diagram AR Mobile App Omen Birds of Borneo

B. Use Case Activity

The use case consists of a series of potential interactions between the user and the system in a specific setting and with a certain objective. Use case activity for seven sections is described in the section that follows; view info (Table 3.2), view bird species lists (Table 3.), Selecting Bird Species (Table 3.3), viewing bird details (Table 3.4), scanning for AR model (Table 3.5), explore in AR feature (Table 3.6) and plays the quizzes (Table 3.7).

View Info (Introduction of Omen Birds)

Use Case	View Info (Introduction of Omen Birds)
Short Description:	Displays the historical background of Omen Birds in Borneo.
Actors:	User
Pre-Condition:	The app is launched successfully
Post-Condition:	The app shows the “Info” page
Trigger Event:	User taps on the “Info”
Main Flow:	User taps the "Info" button. The app displays a page with the info(history) of omen birds in Borneo.

Table 3.2 Use case for user view Info of application

View Bird Species List

Use Case	View Bird Species List
Short Description:	Allow the user to view a list of bird species found in Borneo
Actors:	User
Pre-Condition:	The app is launched successfully
Post-Condition:	The app shows the "Bird Species" list
Trigger Event:	User taps on the “Bird Species” button
Main Flow:	User taps the "Bird Species" button. The app displays a list of Borneo bird species.

Table 3.3 Use case of user view bird species lists

Select Bird Species

Use Case	Select Bird Species
Short Description:	Enables the user to select and explore a specific bird species.
Actors:	User
Pre-Condition:	User is viewing the bird species list.
Post-Condition:	The app shows the bird's details
Trigger Event:	User selects a bird species from the list
Main Flow:	User selects a bird species. The app displays details of the selected bird.

Table 3.4 Use Case of Selecting Bird Species

View Bird Details

Use Case	View Bird Details
Short Description:	Presents detailed information, symbolism, and a location for each bird
Actors:	User
Pre-Condition:	User has selected a bird species
Post-Condition:	User discovered the bird details
Trigger Event:	User navigates to the bird details page
Main Flow:	App shows detailed information about the bird. User can view the location of the bird through map. User can access the bird's symbolism and characteristics. User can use the AR feature to view a 3D model of the bird.

Table 3.5 Use case of user viewing bird details

Scan Marker for AR Model

Use Case	Scan Marker for AR Model
Short Description:	Allow the user to scan a physical marker to display the correct AR bird model
Actors:	User
Pre-Condition:	User has selected the AR feature
Post-Condition:	The correct 3D bird model is displayed in AR
Trigger Event:	User scans the appropriate marker(code)
Main Flow:	User scans a marker using the app's camera. The app recognizes the correct marker(code). The app displays the 3D model of the bird associated with the marker

Table 3.6 Use case of user scanning for AR model

Explore Bird in AR

Use Case	Explore Bird in AR
Short Description:	Provides an interactive 3D AR model of the bird
Actors:	User
Pre-Condition:	User is viewing a bird's details
Post-Condition:	User completes viewing the bird in AR
Trigger Event:	User scans the appropriate marker
Main Flow:	The app launches the AR model of the bird. User interacts with the model using gestures to zoom in/out User able to listen the audio of the bird using headphone.

Table 3.7 Use case of user explore in AR feature

Play Quizzes

Use Case	User plays the quizzes
Short Description:	Providing the quiz and view the score and leaderboard
Actors:	User
Pre-Condition:	User has accessed the quiz page
Post-Condition:	The system displays the result of the quiz
Trigger Event:	The user initiates the quiz by starting it
Main Flow:	The user begins the quiz. The user selects the answer they believe is correct from multiple options. If the answer is correct, the system shows a "Correct" message and moves to the next question. If the answer is incorrect, the system shows an "Opps, You're Worng" message and moves to the next question. The system displays the result. User required to insert their name after done the quiz The system view the leaderboard.

Table 3.8 Use case of user plays the quizzes

C. Sequence Diagram

The sequence diagram shows describe how the application behaviour and show how the interaction between projects. The sequence diagram below shows display the step and process on the user and the system interact when the player uses the application. It consists of five sequence model starting from the enter the application (Figure 3.8), select "Bird Lists" option (Figure 3.9), select AR option (Figure 3.10), play quizzes (Figure 3.11) and exit the application (Figure 3.12).

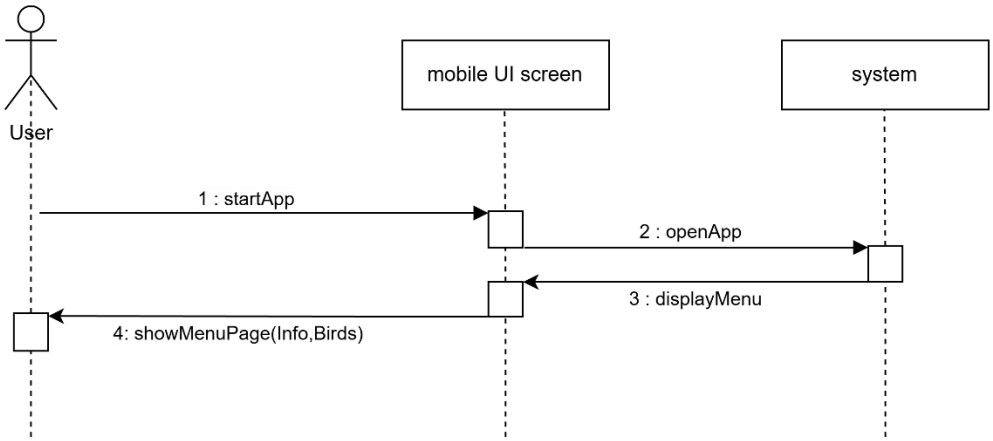


Figure 3.8 Sequence Diagram of Starting the Application

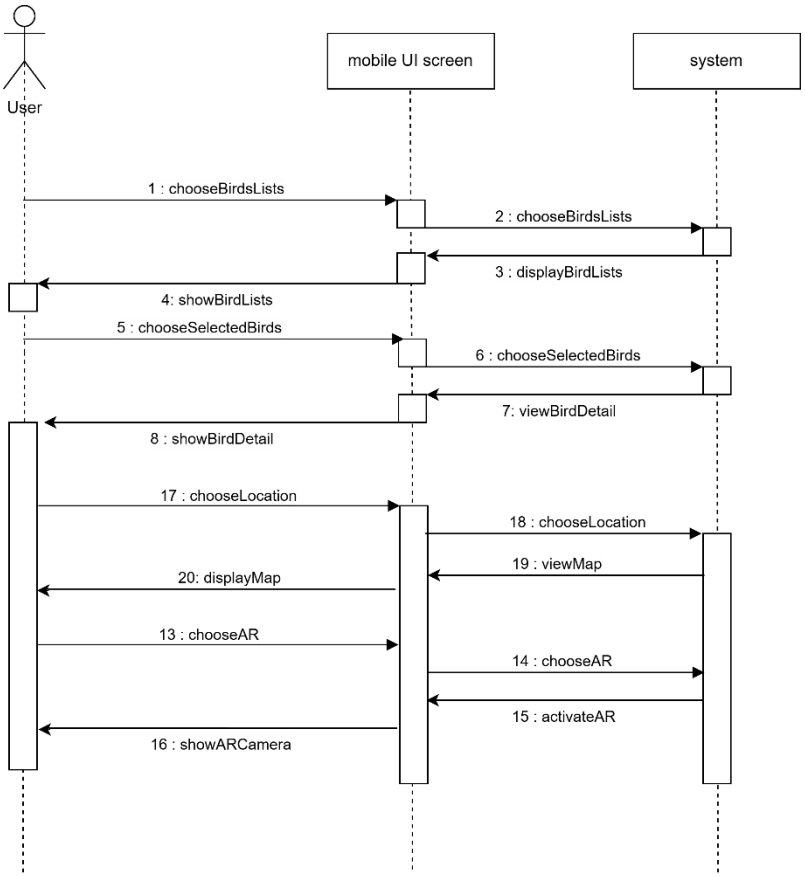


Figure 3.9 Sequence Diagram of Selecting “Birds Lists” Option

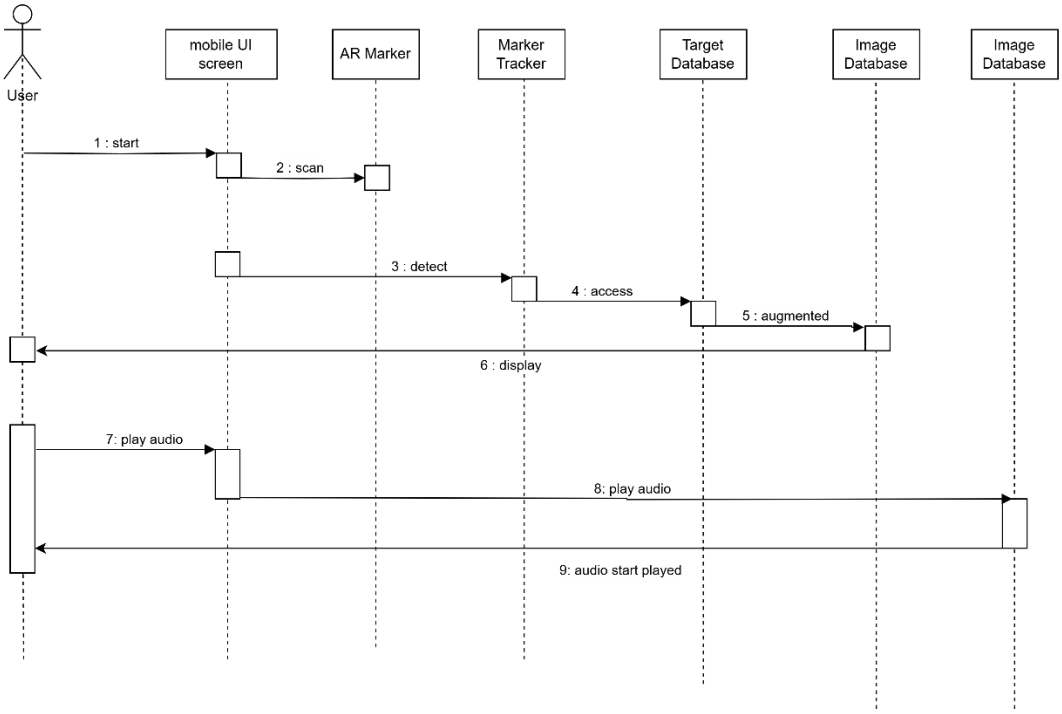


Figure 3.10 Sequence Diagram of Selecting AR Option

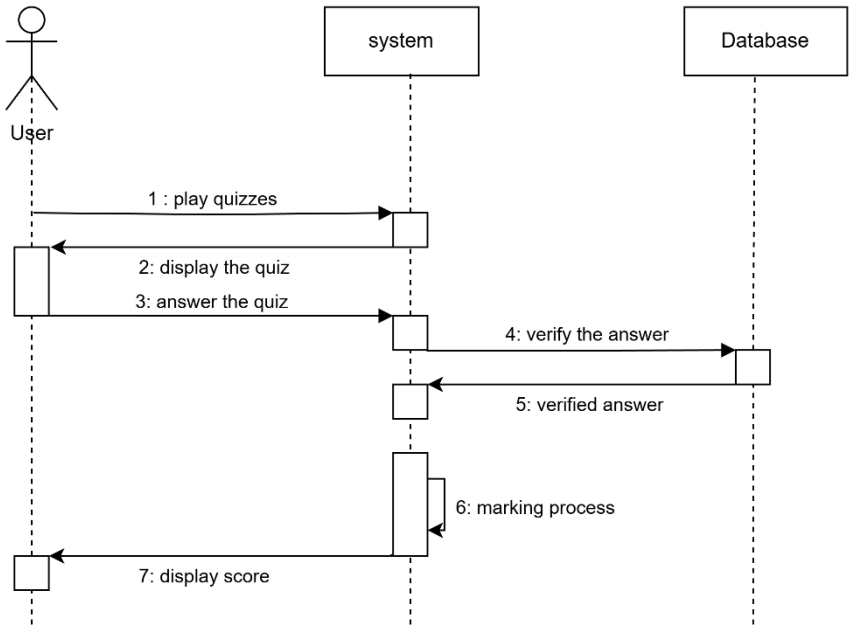


Figure 3.11 Sequence Diagram of Selecting “Birds Lists” Option

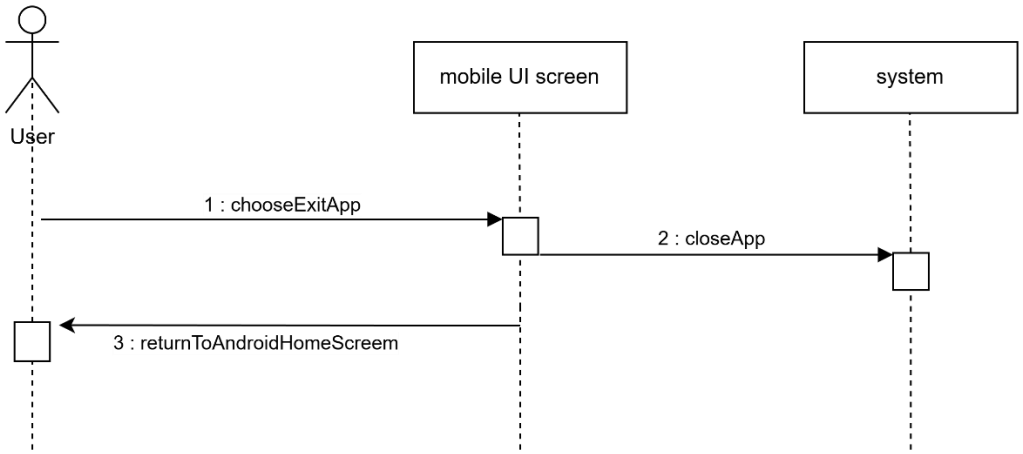


Figure 3.12 Sequence Diagram of Exit the Application

D. Class Diagram

Class diagram is a type of static structure diagram to describe the structure of a system through showing the system's class, attributes, operations and relationships between objects as shown in Figure 3.13.

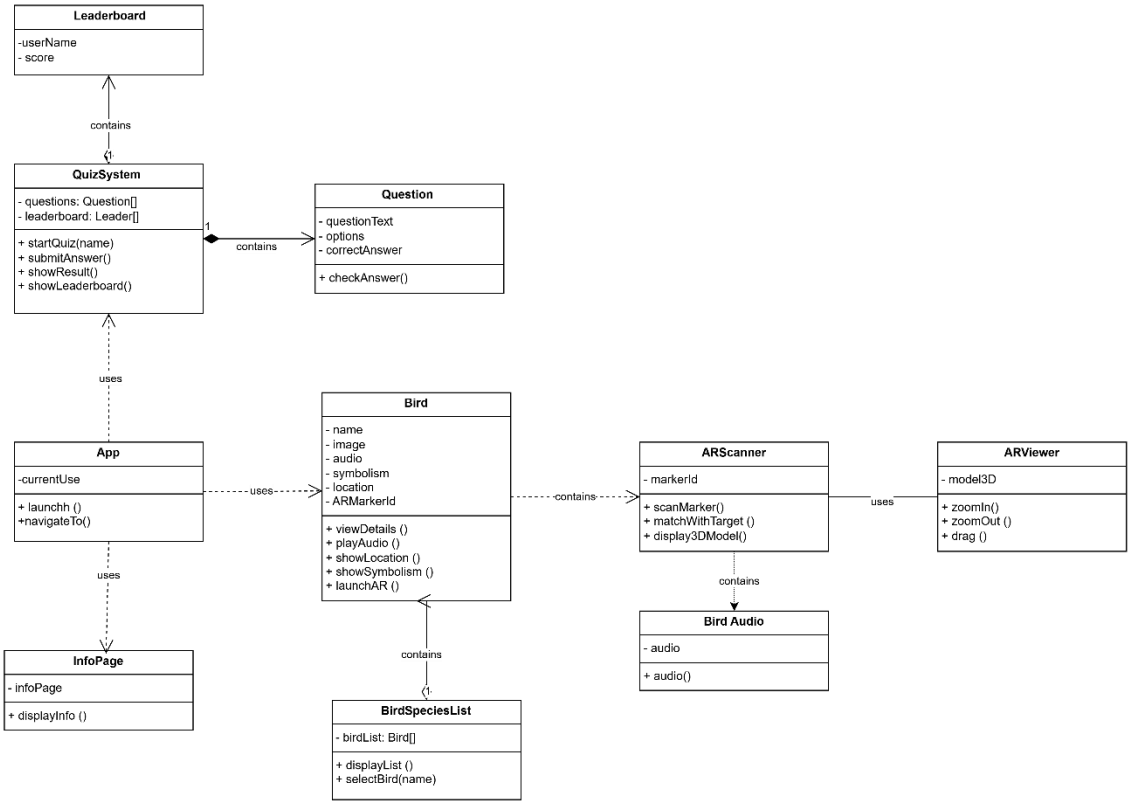


Figure 3.13 Class Diagram of Omen Birds of Borneo AR

E. Proposed Architecture

Flowchart can be used to show the sequences of the process and how the user use and what decision to make while using the application. As shown in figure 3.14 in the flowchart below, it shows the list and sequences of activities for user to interact with the AR mobile application.

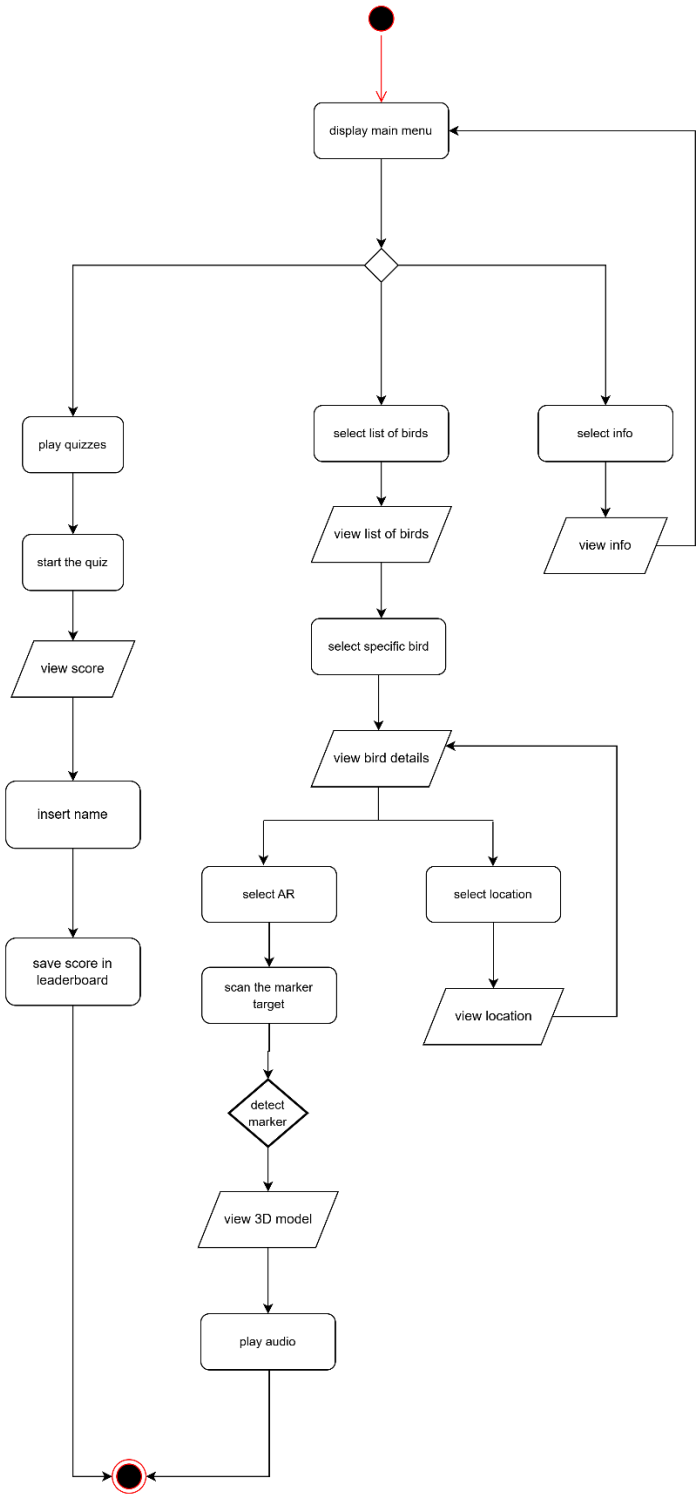


Figure 3.14 Flowchart of AR Mobile App Omen Birds of Borneo

D. User Interface Design

A good design interface is an important thing to facilitate the communication between the user and the application. The colour palette for an AR mobile app has been chosen with great thought to celebrate the cultural and natural heritage of Sarawak as shown in Figure 3.15. Each colour deeply resonates with Sarawak's rich traditions, history, and identity while reflecting the architectural influence of the Borneo Cultures Museum as a modern symbol of Sarawak's commitment to preserving its heritage.

Figure 3.15 Colour Theme for AR Mobile App

Pale Yellow: This shade captures the warmth and light of Sarawak's sense of openness and harmony (Poposki, 2023). It symbolizes the welcoming nature of Sarawak's diverse communities, including the Iban, Bidayuh, Orang Ulu, and Melanau peoples, who take pride in their hospitality.

Vivid Yellow: A bright yellow, this colour mirrors gold, symbolizing wealth and glory. Sarawak's historical ties to trade and prosperity are reflected in this hue. It also represents the golden threads of Sarawak's rich textile traditions, such as the Pua Kumbu, a handwoven fabric (Lush, n.d.). This shade is perfect for dynamic elements in your app, creating energy and focus.

Golden: Inspired by the Borneo Cultures Museum, reflects the richness of Sarawak's heritage while signifying progress and resilience. This shared gold cladding serves as a unifying symbol, representing the state's commitment to preserving its cultural identity while embracing modern development (*SteelPedia - Borneo Cultures Museum*, 2020).

Dark Brown: An earthy brown, this colour represents Sarawak's natural landscape lush rainforests and iconic wildlife (*Sarawak Forestry*, n.d.), such as the hornbill, which holds cultural and spiritual importance. This tone anchors the palette, adding depth and stability, and reflects Sarawak's enduring heritage and ecological importance.

Figure 3.16 AR Mobile App Background

Based on Figure 3.16, this design wonderfully captures the essence of Borneo's cultural heritage through its rich visual elements. Birds in Bornean cultures are often symbols of freedom, prosperity, and spiritual connection. Their presence here could represent harmony and balance, as reflected in their symmetrical arrangement. The intricate patterns surrounding the birds are likely inspired by traditional motifs from Borneo's art, particularly in Dayak and Orang Ulu designs. These motifs often focus on themes of nature, connectivity, and tribal identity. The swirling patterns evoke the hand-carved artistry found in Sarawak's woodcraft and traditional textiles, preserving the natural flow and organic feel of the Borneo environment.

Figure 3.17 AR Mobile App Main Menu

Figure 3.17 displays the main menu of the Omen Birds of Borneo AR mobile app. From this page, users can select between two buttons: "Info" and "Bird Species" sections.

Figure 3.18 Info about Omen Birds of Borneo

When the user presses the “Info” button, the application will display the historical background of Omen Birds of Borneo as shown in Figure 3.18.

Figure 3.19 Omen Birds of Borneo Lists

When the user the button “Bird Species”, the lists of birds will display at the screen as shown in Figure 3.19. There are 5 lists Birds of Borneo such *as Kalire,Beragai,Manuk Asi,Embuas and Manuk Wek.*

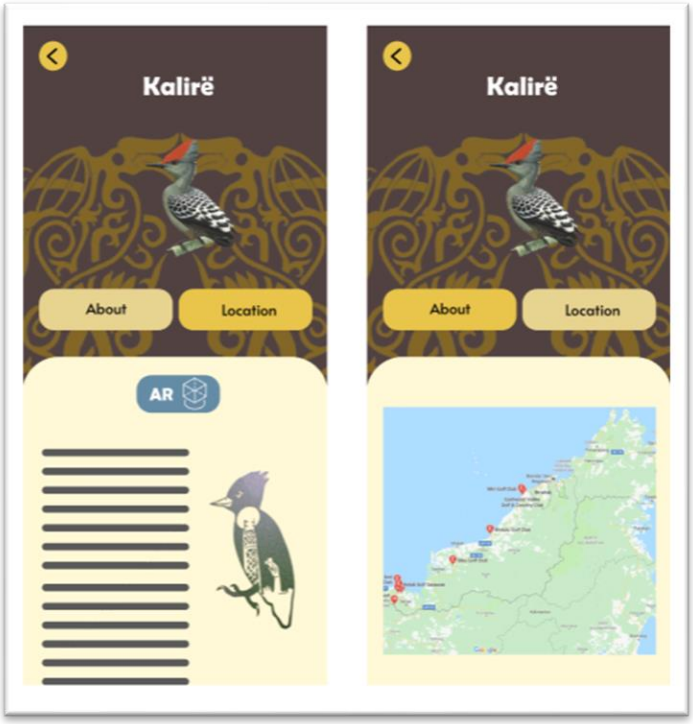


Figure 3.20 View Details of Selected Bird (*Kalire*)

Figure 3.20 displays the details of a selected bird after the user presses one of the five bird options listed on the screen (for example, Kalire). There are two options or screen whether user wants to choose the details of the bird such as the image symbolism go to AR feature of the bird or view the location of the specific bird located in Sarawak.

On this page, two types of quizzes are available for the user in the quizzes section by asking question based on question given as shown in Figure 3.21. The first screen shows the question, and the selection of answers displayed at the screen. The second screen shows the scores overall from the quizzes. After user completed the quizzes, user able to save their score record in the leaderboard. These features will be incorporated into the mobile app to enhance the user experience during the exhibition.

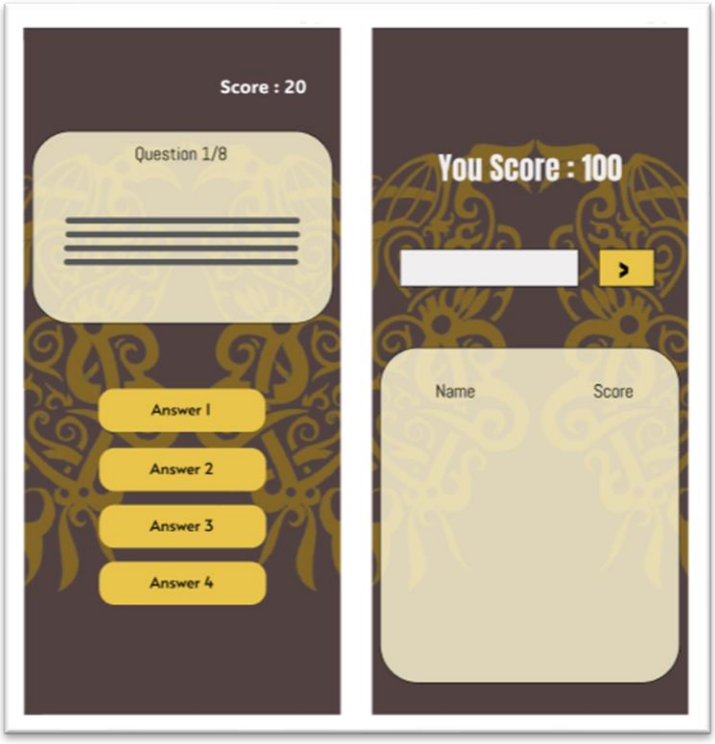


Figure 3.21 View of Play Quizzes

3.2.3 Implementation

During this phase, the actual coding of the app will be done as per the design specifications. The tools mentioned in the requirements phase will be utilised in this stage to develop the prototype. Unity with ARCore or ARKit framework will be used to build the proposed mobile application. The user interface design for the proposed mobile application will be designed to make it easy for users to use and understand when using it.

3.2.4 Verification

In this stage, the application will be testing to ensure the app meets all specified requirements. It involves functional testing to check if all the AR features are working accordingly, such as object detection and rendering. The survey test will also be carried out to ensure the app is intuitive and provides an engaging experience for users. The bugs and issues of the application identified at this stage are resolved and retested on, till it comes out stable for deployment.

To measure user satisfaction with the prototype AR application, a form using a *System Usability Scale (SUS)* to evaluate the usability of the mobile app will be provided to users. Their feedback will offer insights into the overall experience and effectiveness of the solution.

3.2.5 Maintenance

In Maintenance phase, the user interface, the features and concepts of the previous prototype will keep maintain to ensure the app remains functional and relevant over time. Feedback is collected from the users, which helps develop an understanding of whether there is some scope for making things better, or if more features need to be added. Further updates bugfix, improve performances, and cure compatibility issues caused by new forms of operating systems and device models that come out regularly. In case of an augmented reality app, this may also extend to updating the application on newer and enhanced functionality of augmented reality libraries, or frameworks so that application stays up to date.

3.3 Summary

It provides an overview of the Waterfall methodology applied throughout the development of the application to enhancement of User Experience using Augmented Reality in 'Omen Birds of Borneo'. This chapter explains each phase of the Waterfall methodology

process in the context of the purposed application. In Requirements phase, both the user and developer collaborate to define the problem statement and objectives for the application. This is followed by an analysis that involves distributing a questionnaire to target users to collect relevant data. Use Case Diagram, Class Diagram and Sequence Diagrams illustrate are the logical sequence of the proposed application. They also present the interface designs, which describe the user interface and the experience flow during interactions with the application The chapter proceeds to the Implementation phase, detailing the development process and how it ensures the application aligns with the defined user requirements. Finally, the Maintenance phase is discussed, emphasizing the importance of ongoing updates and enhancements to ensure the application remains functional, relevant, and error-free over time.

CHAPTER 4: IMPLEMENTATION

4.1 Introduction

This chapter describe prototype implementation and database creation for the proposed application. The prototype implementation is mainly to discuss about the implementation process of interface creation, 3D model creation. This chapter aims to provide insights on how the design and the implement the proposed application based on the AR interaction design framework as mentioned in the previous chapter.

4.2 Design and Creation of 3D Model

4.2.1 Unity

Unity powerful, cross-platform game engine developed by Unity Technologies. It is widely used for creating 2D, 3D, VR, and AR applications across multiple platforms including mobile, desktop, web, and consoles (*Augmented Reality (AR) App & Game Development Solution*, n.d.). It is a software that is used to create AR Mobile Application for the proposed project such as create bird models and to set the 3D position on the marker as shown in Figure 4.1. Unity is used to create the Augmented Reality features and user interface.

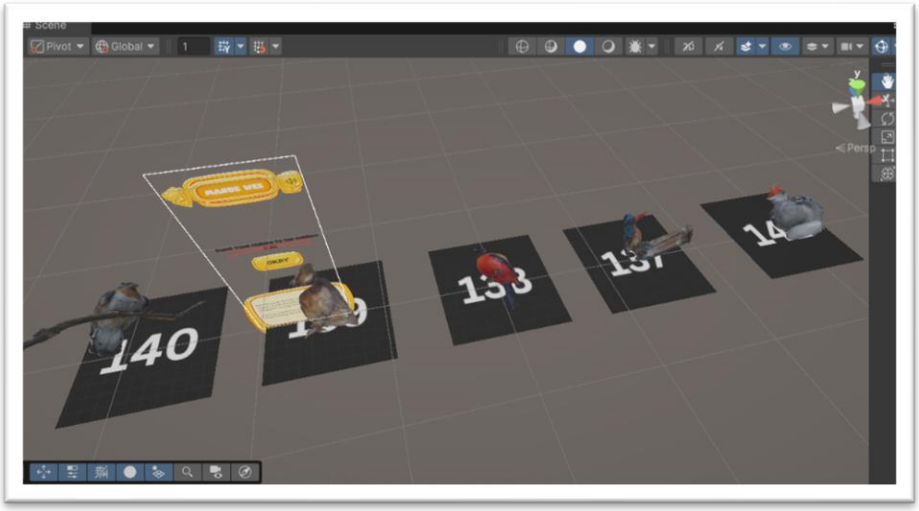


Figure 4.1 3D Models of Borneo Birds

4.2.2 Meshy AI

Meshy AI is an AI-powered tool that helps to quickly generate 3D models and animations (*Take 3D Models for Free Download - Meshy*, 2025). Instead of manually sculpting models from scratch, users can simply upload photos. This online software converts them into detailed 3D structures. This makes it a great option for those looking to speed up their workflow

while still achieving high-quality results. All the 3D models are saved in. fbx format as Unity can only read in .fbx, .obj, .dea and more.

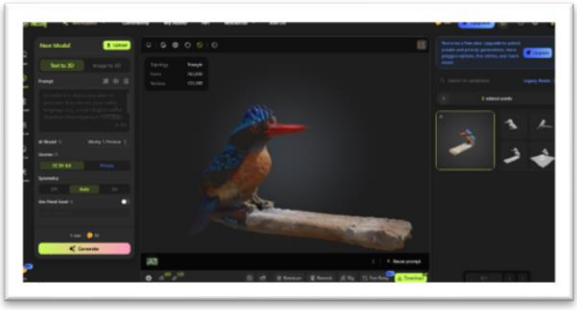


Figure 4.2 3D Model of *Embuas*

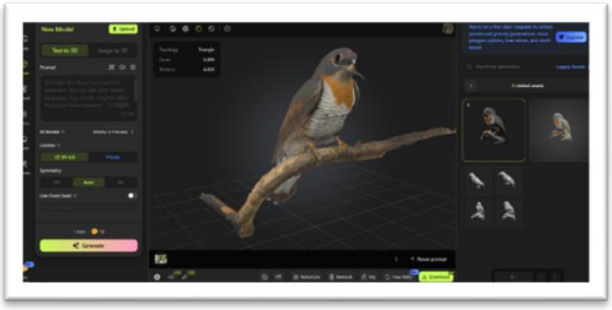


Figure 4.3 3D Model of *Manuk Asi*

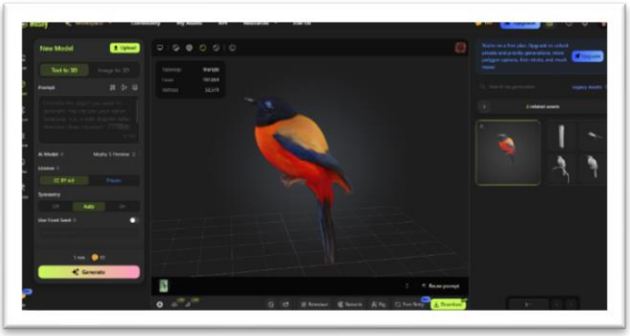


Figure 4.4 3D Model of *Beragai*

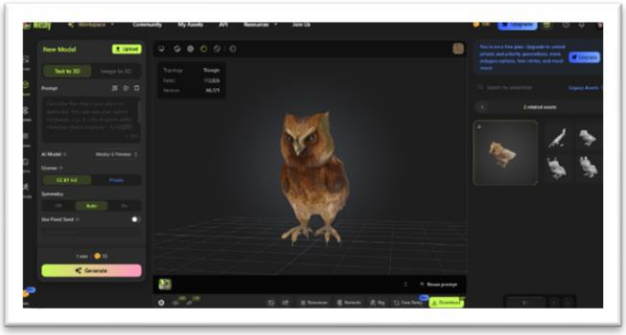


Figure 4.5 3D Model of *Manuk Wek*

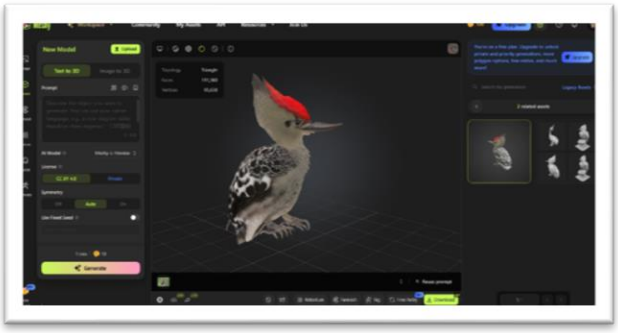


Figure 4.6 3D Model of *Kalire*

4.3 Marker Design and Bird's Belief Creation

Canva

Since the proposed project uses marker-based augmented reality, the markers were designed using Canva. Canva is a free and user-friendly tool that allows you to create and edit images, videos, and custom graphics (Wikipedia Contributors, 2019).

For the marker design, the developer chose to use code numbers that match those already displayed on the wall of the current *Omen Birds of Borneo* exhibition. Each unique code corresponds to a specific bird featured in the exhibition. These are unique codes for all birds; Kalire (Figure 4.7) , Beragai (Figure 4.8), Manuk Wek(Figure 4.9), Manuk Asi (Figure 4.10) and Embuas(Figure 4.11).

Figure 4.7 Code for *Kalire*

Figure 4.8 Code for *Beragai*

Figure 4.9 Code for *Manuk Wek*

Figure 4.10 Code for *Manuk Asi*

Figure 4. 11 Code for *Embuas*

4.3 Creation of AR Feature

Vuforia

Vuforia is an augmented reality (AR) SDK for mobile platforms that enables real-time tracking of planar images and 3D objects using computer vision technology (*Vuforia Augmented Reality SDK*, 2019)**.**

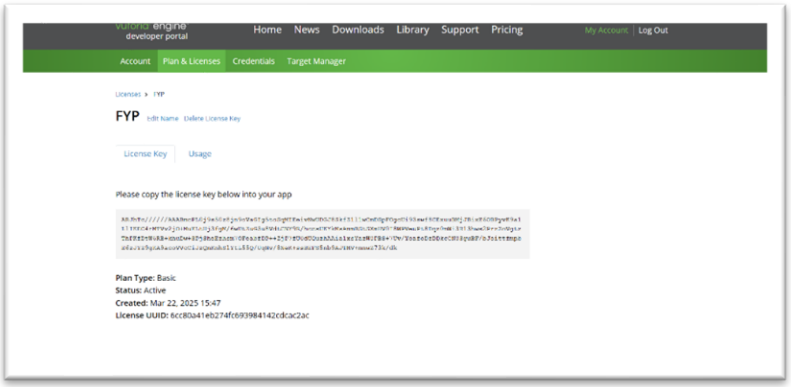


Figure 4.12 License for Vuforia Unity

After creating Vuforia account, the Vuforia license key must configure inside Unity software as shown on Figure 4.12. The prefabs are downloaded from the Vuforia official website, and the package are installed then the AR camera will able be accessed by the user. User needs to click the AR Camera from the hierarchy to open the inspector where user must access the Vuforia engine configuration to add the License as shown in Figure 4.13.

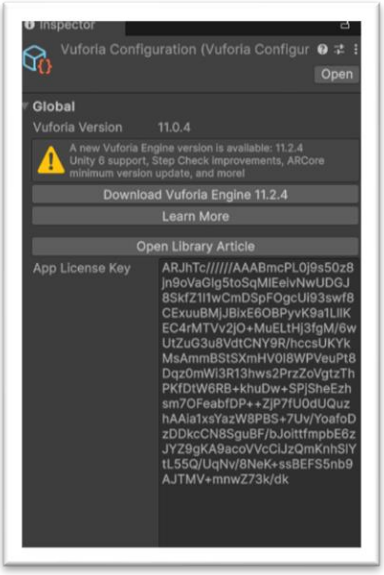


Figure 4.13 License Vuforia Setting in Unity

Next, the marker databse is uploaded in Vuforia Target Manager where it stored and the sensitivity of the marker is automatically as shown in Figure 4.14. More details in the marker creation, the better augmentable(rating) it will be and the lower the risk of error while scanning the marker

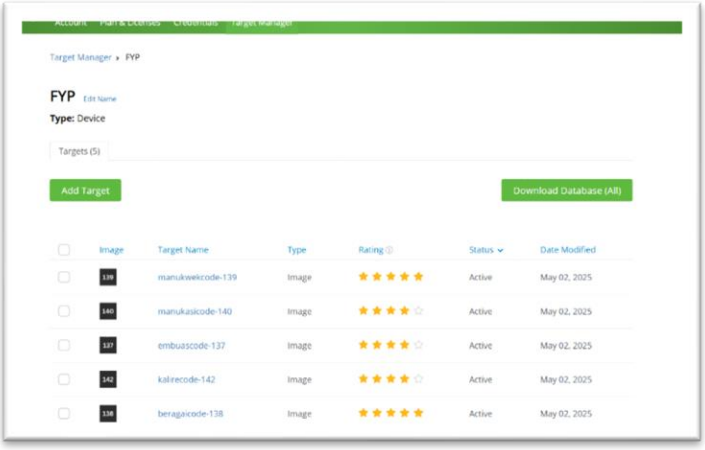


Figure 4.14 Features of Marker in Vuforia

4.4 Integration of Google Map

Google Map is integrated into the Unity project. The main goal of adding this map is to help users easily identify where each Borneo bird species is commonly found throughout Sarawak. The integration is done using the Google Maps API Key, which provides access to a range of features such as map visuals, location data, and routing information.

To use the Google Maps API in Unity, an API key must be generated through the Google Maps Platform, under the Keys & Credentials section as shown in Figure 4.15. Once the key is obtained, it is added to the Unity (Inspector) project to enable map functionality as shown in Figure 4.16.

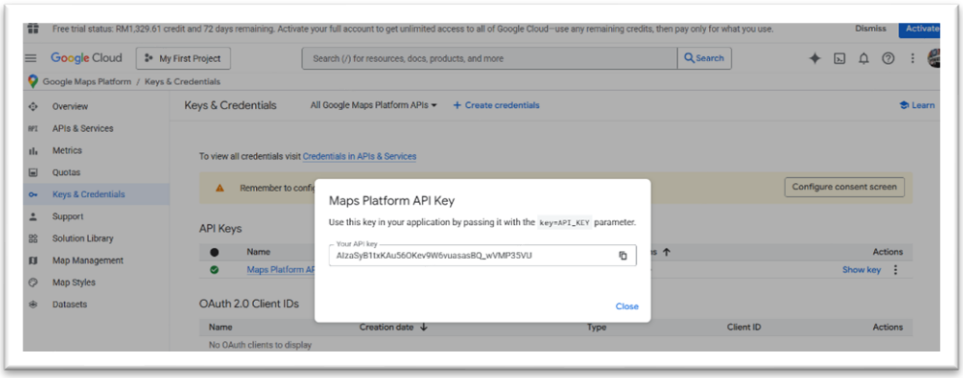


Figure 4.15 API Key Google Map Platform for Unity

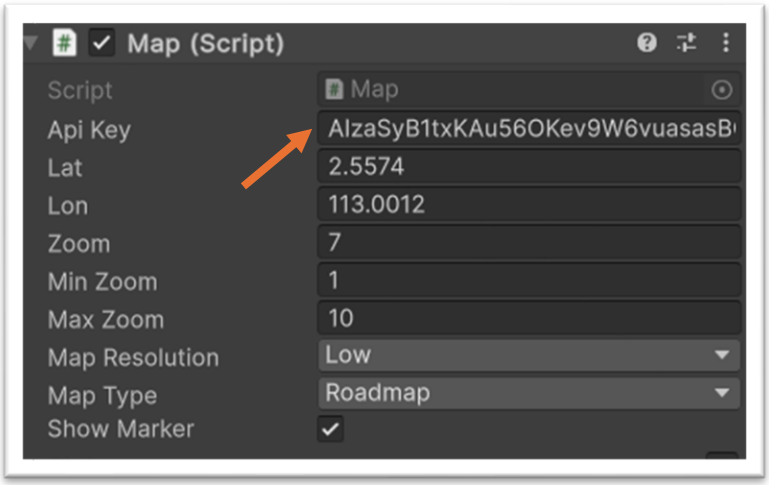


Figure 4.16 API Key Google Map Setting in Unity

4.5 System Implementation

This section describes the prototyping of the proposed mobile application of *Omen Birds of Borneo AR Mobile App*. This AR mobile application is using English as an international language. There are seven UI for this AR mobile app which are Figure 4.17 (Interface of Start Screen), Figure 4.18 (Interface of Info Omen Birds of Borneo), Figure 4.19 (Interface of Selecting Birds), Figure 4.20 (Interface of Bird Details), Figure 4.21 (Interface of Location of Birds), Figure 4.22 (Interface of AR Bird Model) and Figure 4.23 (Interface of Quizzes).

4.5.1 Start Screen

Figure 4.17 Interface of Start Screen

4.5.2 Info

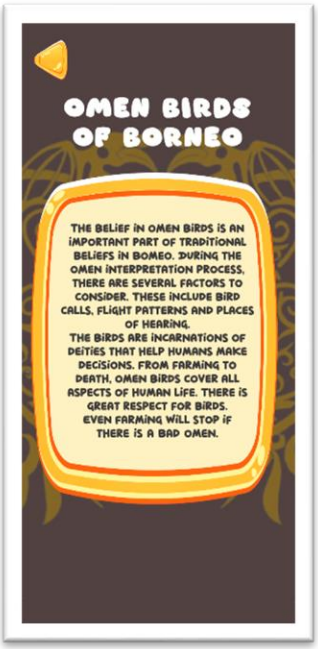


Figure 4.18 Interface of Info Omen Birds of Borneo

4.5.3 Select Birds

Figure 4.19 Interface of Selecting Birds

4.5.4 Bird Details

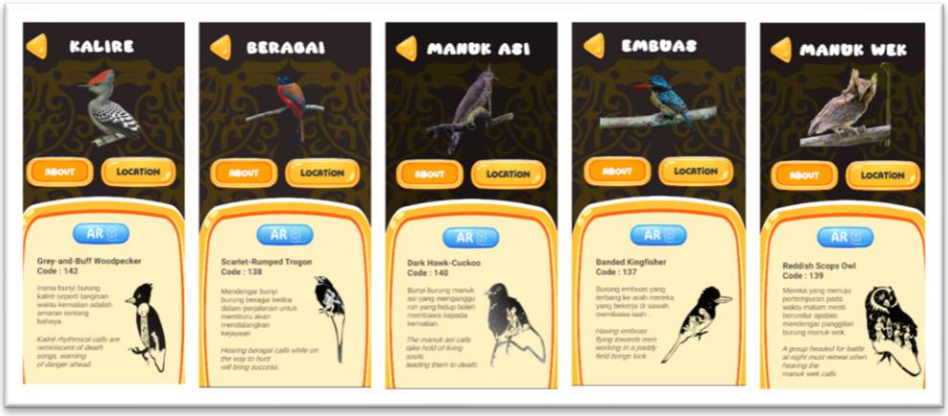


Figure 4.20 Interface of Bird Details

4.5.5 Bird's Location

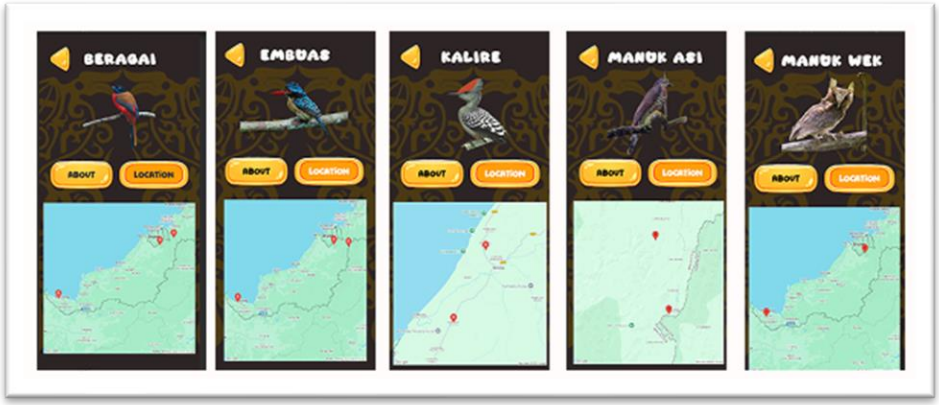


Figure 4.21 Interface of Location of Birds

The red pins on the map indicate the most observed Bornean bird species in Sarawak. All bird data shown are based on collected field observations and records from eBird websites.

a) *Kalire* (Gray-and-buff Woodpecker) (eBird, 2025c)
b) *Embuas* (Banded Kingfisher) (eBird, 2025a)
c) *Beragai* (Scarlet-rumped Trogon) (eBird, 2025e)
d) *Manuk Wek* (Reddish Scops-Owl) (eBird, 2025d)
e) *Manuk Asi* (Dark Hawk-Cuckoo) (eBird, 2025)

4.5.6 Bird's Model AR

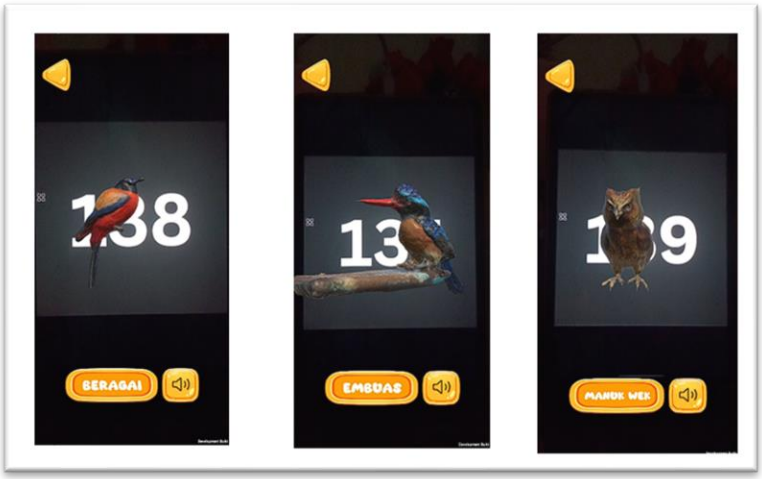


Figure 4.22 Interface of AR Bird Model

The sound recordings for all five birds were sourced from free, publicly available resources. Specifically, the bird song data were collected from **xeno-canto**, a global platform dedicated to sharing wildlife sound recordings from around the world.

a) *Kalire* (Gray-and-buff Woodpecker) (xeno-canto, 2025c)
b) *Embuas* (Banded Kingfisher) (xeno-canto, 2025a)
c) *Beragai* (Scarlet-rumped Trogon) (xeno-canto, 2025e)

d) *Manuk Wek* (Reddish Scops-Owl) (xeno-canto, 2025d)
e) *Manuk Asi* (Dark Hawk-Cuckoo) (xeno-canto, 2025b)

4.5.7 Play Quizzes

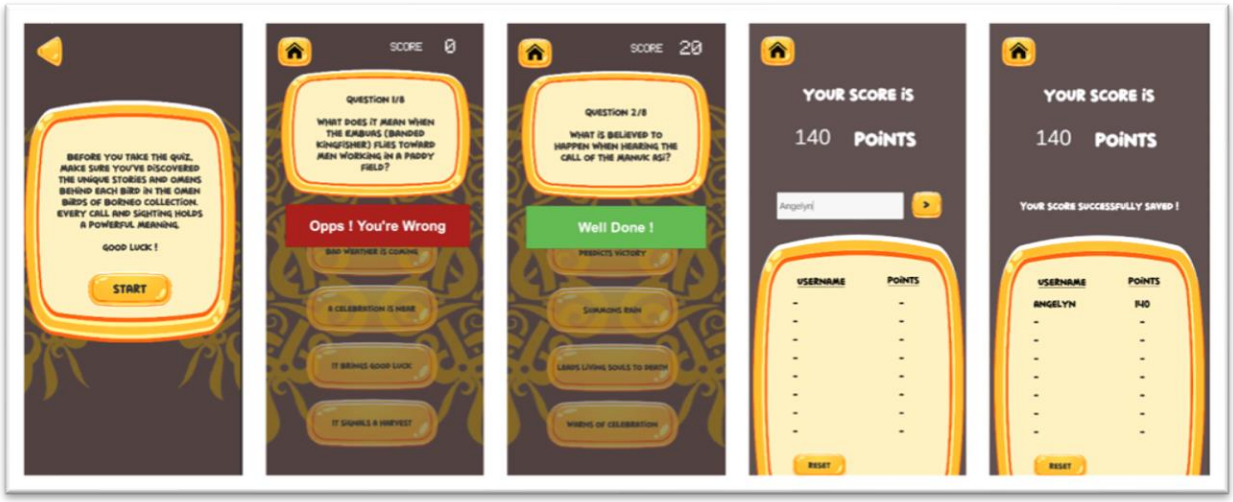


Figure 4.23 Interface of Quizzes

4.6 System Features

When developing Omen Birds of Borneo AR Mobile App, certain parts of the application need to be coded for it function accordingly. The codes for Load Scene (Figure 4.24), Map(Figure 4.25 - 4.27), QtsData (Figure 4.28 – 4.31), Question Manager (Figure 4.32-4.33) and Leaderboard(Figure 4.34- 4.35) is shown below.

4.6.1 Load Scenes

Assets > SceneSwicther.cs > ...

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;
0 references
public class SceneSwitcher : MonoBehaviour
{
    // public void info()
    0 references
    public void home()
    {
        SceneManager.LoadScene(0);

    }
    // public void info()
    0 references
    public void info()
    {
        SceneManager.LoadScene(1);
    }

    //open scene select bird
    0 references
    public void select_bird()
    {

        SceneManager.LoadScene(2);

    }
    //open scene beragai
    0 references
    public void beragai()
    {

        SceneManager.LoadScene(3);
```

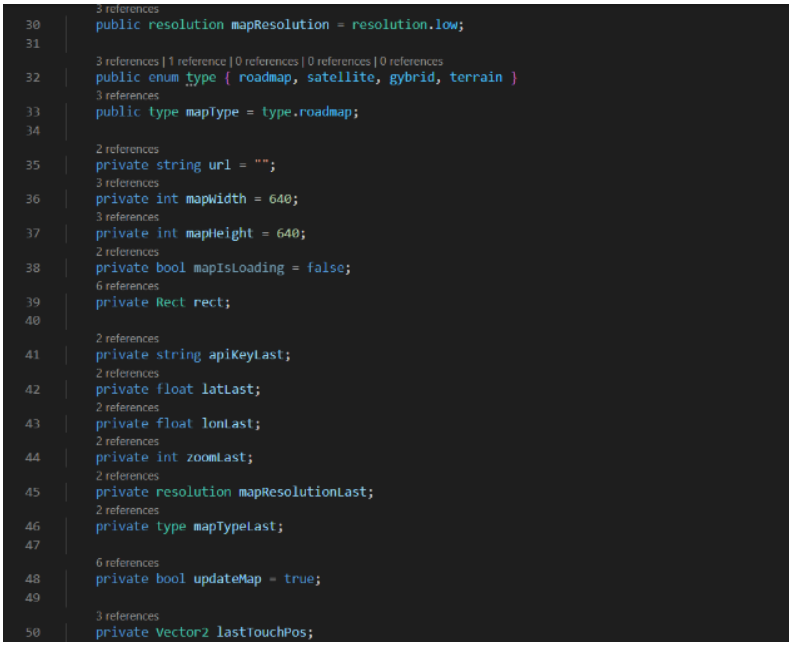
Figure 4.24 Code for Load Scene

4.6.2 Map Feature Implementation

Assets > scripts > Map.cs > Map > GetGoogleMap

```
[System.Serializable]
2 references
public class BirdLocation {
    1 reference
    public float lat;
    1 reference
    public float lon;
}

[System.Serializable]
2 references
public class Bird {
    0 references
    public string name;
    1 reference
    public string label = "B"; // 1-character label
    1 reference
    public List<BirdLocation> locations = new List<BirdLocation>();
}

0 references
public class Map : MonoBehaviour {
    3 references
    public string apiKey;
    5 references
    public float lat = 2.5574f;
    5 references
    public float lon = 113.0012f;
    9 references
    public int zoom = 7;
    1 reference
    public int minZoom = 1;
    1 reference
    public int maxZoom = 20;

    3 references | 1 reference | 0 references
    public enum resolution { low = 1, high = 2 }
```

Figure 4.25 Map Implementation Part 1



```
3 references
public resolution mapResolution = resolution.low;

3 references | 1 reference | 0 references | 0 references | 0 references
public enum type { roadmap, satellite, gybrid, terrain }
3 references
public type mapType = type.roadmap;

2 references
private string url = "";
3 references
private int mapWidth = 640;
3 references
private int mapHeight = 640;
2 references
private bool mapIsLoading = false;
6 references
private Rect rect;

2 references
private string apiKeyLast;
2 references
private float latLast;
2 references
private float lonLast;
2 references
private int zoomLast;
2 references
private resolution mapResolutionLast;
2 references
private type mapTypeLast;

6 references
private bool updateMap = true;

3 references
private Vector2 lastTouchPos;
```

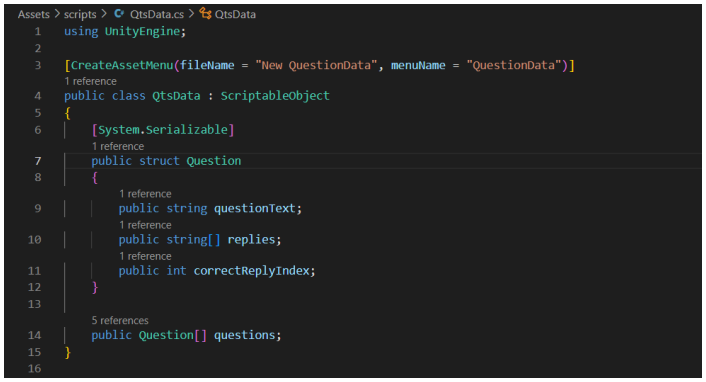
Figure 4.26 Map Implementation Part 2

```
Assets > scripts > Map.cs > Map > GetGoogleMap

2 references
IEnumerator GetGoogleMap() {
    string markerStr = "";
    if (showMarker) {
        foreach (var bird in birds) {
            foreach (var loc in bird.locations) {
                markerStr += $"&markers=color:red%7Clabel:{bird.label}%7C{loc.lat},{loc.lon}";
            }
        }
    }

    url = $"https://maps.googleapis.com/maps/api/staticmap?center={lat},{lon}&zoom={zoom}&size={mapWidth}x{mapHeight}&scale={(int)mapResolution}&m

    mapIsLoading = true;
    UnityWebRequest www = UnityWebRequestTexture.GetTexture(url);
    yield return www.SendWebRequest();

    if (www.result != UnityWebRequest.Result.Success) {
        Debug.Log("Map Error: " + www.error);
    } else {
        gameObject.GetComponent<RawImage>().texture = ((DownloadHandlerTexture)www.downloadHandler).texture;

        apiKeyLast = apiKey;
        latLast = lat;
        lonLast = lon;
        zoomLast = zoom;
        mapResolutionLast = mapResolution;
        mapTypeLast = mapType;
    }

    mapIsLoading = false;
}
```

Figure 4.27 Map Implementation Part 3

4.6.3 QtsData

QtsData is a custom Scriptable Object class that stores a list of quiz-style questions, each with multiple possible answers.



```
Assets > scripts > QtsData.cs > QtsData
using UnityEngine;

[CreateAssetMenu(fileName = "New QuestionData", menuName = "QuestionData")]
1 reference
public class QtsData : ScriptableObject
{
    [System.Serializable]
    1 reference
    public struct Question
    {
        1 reference
        public string questionText;
        1 reference
        public string[] replies;
        1 reference
        public int correctReplyIndex;
    }

    5 references
    public Question[] questions;
}
```

Figure 4.28 Code for QtsData

4.6.4 Question Manager

```
0 references
public class QuestionManager : MonoBehaviour
{
    1 reference
    public Text questionText;

    1 reference
    public Text scoreText;

    6 references
    public Text FinalScore;

    7 references
    public Button[] replyButtons;

    5 references
    public QtsData qtsData;

    3 references
    public GameObject Right;

    3 references
    public GameObject Wrong;

    2 references
    public GameObject GameFinished;

    5 references
    private int currentQuestion = 0;

    3 references
    private static int score = 0;

    0 references
    void Start()
    {
        SetQuestion(currentQuestion);
```

Figure 4.29 Code for Question Manager Part 1

```
    void Start()
    {
        SetQuestion(currentQuestion);
        Right.gameObject.SetActive(false);
        Wrong.gameObject.SetActive(false);
        GameFinished.gameObject.SetActive(false);
    }

    2 references
    void SetQuestion(int questionIndex)
    {
        questionText.text = qtsData.questions[questionIndex].questionText;


    foreach (Button r in replyButtons)
    {
        r.onClick.RemoveAllListeners();
    }

        for (int i = 0; i < replyButtons.Length; i++)
        {
            replyButtons[i].GetComponentInChildren<Text>().text = qtsData.questions[questionIndex].replies[i];
            int replyIndex = i;
            replyButtons[i].onClick.AddListener(() =>
            {
                CheckReply(replyIndex);
            });
        }
    }

1 reference
void CheckReply(int replyIndex)
{
    if (replyIndex == qtsData.questions[currentQuestion].correctReplyIndex)
```

Figure 4.30 Code for Question Manager Part 2

```
IEnumerator Next()
{
    yield return new WaitForSeconds(2);

    currentQuestion++;

        if (currentQuestion < qtsData.questions.Length)
    {
        //reset the UI and enable all reply buttons
        Reset();
    }
    else
    {
        //game over
            GameFinished.SetActive(true);

            float scorePercentage = (float)score / qtsData.questions.Length * 100;
            FinalScore.text = "You scored " + scorePercentage.ToString("F0") + "%";

            if (scorePercentage < 50)
            {
                FinalScore.text += "\nGame Over";
            }
            else if (scorePercentage < 60)
            {
                FinalScore.text += "\nKeep Trying!";
            }
            else if (scorePercentage < 70)
            {
                FinalScore.text += "\nGood Job!";
            }
            else if (scorePercentage < 80)
            {
                FinalScore.text += "\nWell Done!";
            }
            else
            {
                FinalScore.text += "\nYou Are Genius!";
            }
        }
        }
```

Figure 4.31 Code for Question Manager Part 3

4.6.5 Score Manager

ScoreManager.cs

Assets > scripts > ScoreManager.cs > ...

```
using UnityEngine;
using TMPro;
using UnityEngine.Events;
using System;

0 references
public class ScoreManager : MonoBehaviour
{
    1 reference
    [SerializeField] private TextMeshProUGUI inputScore;
    1 reference
    [SerializeField] private TMP_InputField inputName;

    1 reference
    public UnityEvent<string, int> submitScoreEvent;

    0 references
    public void SubmitScore()
{
    string baseName = inputName.text.Trim();
    string uniqueName = baseName + "_" + System.Guid.NewGuid().ToString().Substring(0, 4);
    submitScoreEvent.Invoke(uniqueName, int.Parse(inputScore.text));

}

}

```

Figure 4.32 Code for Score Manager

4.6.6 Popup Manager

```
Assets > PopupManager.cs > PopupManager
1   using UnityEngine;
2
    0 references
3   public class PopupManager : MonoBehaviour
4   {
        1 reference
5       public GameObject popup;
6
        0 references
7       public void ClosePopup()
8       {
9           popup.SetActive(false);
10      }
11  }
```

Figure 4.33 Code for Popup Manager

4.6.7 Leaderboard

```
Assets > scripts > Leaderboard.cs > ...
1   using UnityEngine;
2   using System.Collections.Generic;
3   using TMPro;
4
    0 references
5   public class Leaderboard : MonoBehaviour
6   {
        3 references
7       [SerializeField] private List<TextMeshProUGUI> names;
        3 references
8       [SerializeField] private List<TextMeshProUGUI> finalScores;
9
        13 references
10      private List<(string username, int score)> localEntries = new(); // Local memory list
        3 references
11      private const int MaxEntries = 8;
12
        0 references
13      private void Start()
14      {
15          LoadLocalLeaderboard();
16      }
17
        0 references
18      public void SetLeaderboardEntry(string username, int score)
19      {
20          if (localEntries.Count >= MaxEntries) return;
21
22          localEntries.Add((username, score));
23          SaveLocalLeaderboard();
24          UpdateUI();
25      }
26
        1 reference
27      private void SaveLocalLeaderboard()
28  {
29      for (int i = 0; i < localEntries.Count; i++)
30      {
31          PlayerPrefs.SetString($"Username_{i}", localEntries[i].username);
32          PlayerPrefs.SetInt($"Score_{i}", localEntries[i].score);
33      }
34      PlayerPrefs.SetInt("EntryCount", localEntries.Count);
35      PlayerPrefs.Save();
36  }
37
    1 reference
38  private void LoadLocalLeaderboard()
39  {
40      localEntries.Clear();
41      int count = PlayerPrefs.GetInt("EntryCount", 0);
42      for (int i = 0; i < count; i++)
43      {
44          string name = PlayerPrefs.GetString($"Username_{i}", "-");
45          int score = PlayerPrefs.GetInt($"Score_{i}", 0);
46          localEntries.Add((name, score));
47      }
```

Figure 4.34 Code for Leaderboard part 1

```
47      }
48      UpdateUI();
49  }
50
        0 references
51      public void ResetLeaderboard()
52      {
53          localEntries.Clear();
54          PlayerPrefs.DeleteKey("EntryCount");
55
56          for (int i = 0; i < MaxEntries; i++)
57          {
58              PlayerPrefs.DeleteKey($"Username_{i}");
59              PlayerPrefs.DeleteKey($"Score_{i}");
60          }
61
62          PlayerPrefs.Save();
63          UpdateUI();
64          Debug.Log("Leaderboard has been reset.");
65      }
66
        3 references
67      private void UpdateUI()
68      {
69          // Sort the list by score in descending order
70          localEntries.Sort((a, b) => b.score.CompareTo(a.score));
71
72          int safeCount = Mathf.Min(MaxEntries, names.Count, finalScores.Count);
73
74          for (int i = 0; i < safeCount; i++)
75          {
76              if (i < localEntries.Count)
77              {
78                  names[i].text = localEntries[i].username.Split('_')[0];
79                  finalScores[i].text = localEntries[i].score.ToString();
80              }
81              else
82              {
83                  names[i].text = "-";
84                  finalScores[i].text = "-";
85              }
86          }
87      }
88
89
90  }
91
```

Figure 4.35 Code for Leaderboard part 2

4.7 Summary

This chapter explains how the main parts of the project were brought to life to improve the overall experience for visitors. One of the key features is the use of marker-based Augmented Reality (AR), where custom markers were designed using Canva. Each marker includes a unique code number that matches the birds displayed in the *Omen Birds of Borneo* exhibition, making it easier to link the digital content with the real exhibits.

To make the interaction more exciting, 3D bird models were created and connected to the markers, allowing users to view the birds in AR. A map was also added using Google Maps Platform to show where each bird species is commonly found in Sarawak and it is giving users a better sense of their natural habitats.

Beyond just displaying information, the project also includes extra features to support tourists as it easier to find and learn about each bird, improving the flow of the exhibition, and creating a more engaging and user-friendly experience.

CHAPTER 5: TESTING

5.1 Introduction

This chapter will discuss on the testing *Enhancement of User Experience using Augmented Reality in Omen Birds of Borneo*. The main purpose of this chapter is to recognise any bugs or errors within the mobile application and to make sure it is executable and runs accordingly. It is also to test its functionality, usability and consistency of the AR mobile application.

5.2 Functionality Testing

Functionality testing checks whether all the app's features are working properly. This ensures that users can perform different actions in the app without problems. The testing was done using a test case method, which breaks down each feature and checks if it works correctly within the context of the Omen Birds of Borneo experience.

5.2.1. Test Case

A total of ten test cases were created based on the app's main features. These include main menu, view info, view list of birds, view each bird details, view the location for each bird, scanning for AR model, explore the 3D model, play the audio of the bird, play the quizzes and view leaderboard. The test case is conducted as shown in Table 5.1,5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9 and 5.10 respectively.

Module Name: View Main Menu								
Test Objectives: To test if the user able to view the Main Menu								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
1	TC-1	Users press the button the application	The screen displays the Main Menu of the application	The screen displays the Main Menu of the application	Pass	None	None	-

Table 5.1 Test Case 1 (Main Menu)

Module Name: View Info								
Test Objectives: To test if the user able to view Info								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
2	TC-2	Users press the button Info	The app displays the information of the exhibition	The app displays the information of the exhibition	Pass	None	None	-

Table 5.2 Test Case 2 (View Info)

Module Name: View List of the Birds								
Test Objectives: To test if the user able to view list of the Birds								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
3	TC-3	User pressed the button “Bird Species”	The app displays all five list of birds	The app displays all five list of birds	Pass	None	None	-

Table 5.3 Test Case 3 (View List of the Birds)

Module Name: View Bird Details								
Test Objectives: To test if the user able to view the details of Bird								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
4	TC-4	User pressed one of the lists of the birds (eg; *Kalire*)	The app displays the details of the bird selected	The app displays the details of the bird selected	pass	none	none	-

Table 5.4 Test Case 4 (View Bird Details)

Module Name: View the Map								
Test Objectives: To test if the user able to view the Map								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
5	TC-5	User pressed button "location"	The app displays the view of the Map	The app displays the view of the Map	pass	none	none	-

Table 5. 5 Test Case 5 (View the Map)

Module Name: Scan Marker for AR Model								
Test Objectives: To test if the user able to scan the AR marker								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
6	TC-6	Users scan the AR marker (code)	The 3D model of the respective bird will display	The 3D model of the respective bird will display	pass	none	none	-

Table 5.6 Test Case 6 (Scan Marker for AR Model)

Module Name: Explore Bird in AR								
Test Objectives: To test if the user able to zoom, rotate and drag the bird model								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
7	TC-7	User interact the bird model by zooming, rotate and move the	The 3D model of the respective bird interacts (zoom,	The 3D model of the respective bird interact (zoom,	pass	none	none	-

		bird model	rotate and move)	rotate and move)				

Table 5.7 Test Case 7 (Explore Bird in AR)

Module Name: Play the audio sound of the bird in AR								
Test Objectives: To test if the user able to play the audio (bird sound)								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
8	TC-8	User pressed audio button	The audio of selected bird played	The audio of selected bird played	pass	none	none	-

Table 5.8 Test Case 8 (Play the audio sound of the bird in AR)

Module Name: Play quizzes								
Test Objectives: To test if the user able to play the quizzes and show the results								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
9	TC-9	User plays the quizzes	The system displays the result of the quiz	The system displays the result of the quiz	pass	none	none	-

Table 5.9 Test Case 9 (Play quizzes)

Module Name: Save name and score in the leaderboard								
Test Objectives: To test if the user able to save their score in the leaderboard								
Test ID	Test Case	Input Data	Expected Result	Actual Result	Pass/ Fail	Severity of Defect	Summary of Defect	Comments
10	TC-10	User submit their name and	The system saved the name and score.	The system saved the name and score.				

		score in the system	The name and score display at leaderboard	The name and score display at leaderboard				

Table 5.10 Test Case 10 (Save name and score in the leaderboard)

5.3 Users Testing

A total of **32** respondents tested the AR mobile application and completed a feedback survey. The survey was conducted over a period of three days where participants were invited to explore the app and share their thoughts. This survey is conducted by using System Usability Scale (SUS) to evaluate the usability of my AR mobile app.

5.3.1 System Usability Scale (SUS)

According to research (Thomas, 2019), one of the most effective methods for obtaining statistically valid data and providing a clear and reasonably precise score for your website is the System Usability Scale. This survey consisted of 10 questions, where users rated their experience on a scale of 1 to 5. A score of 5 indicated strong agreement with the statement, while a score of 1 indicated strong disagreement. The purpose of this survey was to gather insights on the app's usability, functionality, and overall user experience. The list of survey questions can be found in **Appendix B**. The data displayed as shown in Figure 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8 5,9, 5.10, 5.11, 5.12, 5.13 and 5.14 respectively.

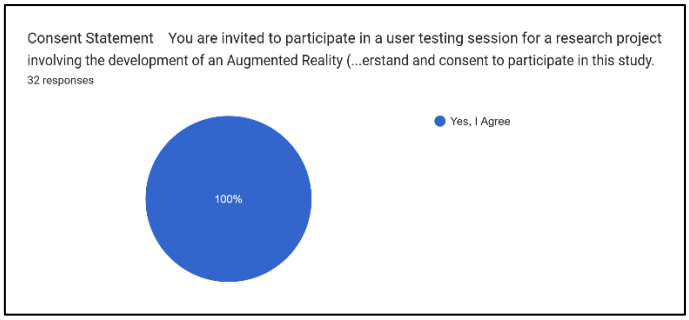


Figure 5.1 Consent Statement

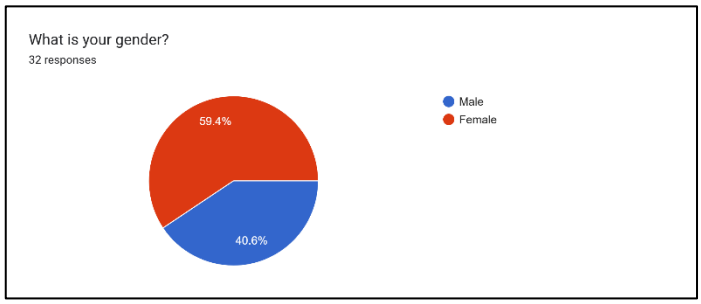


Figure 5.2 Demographic (Gender)

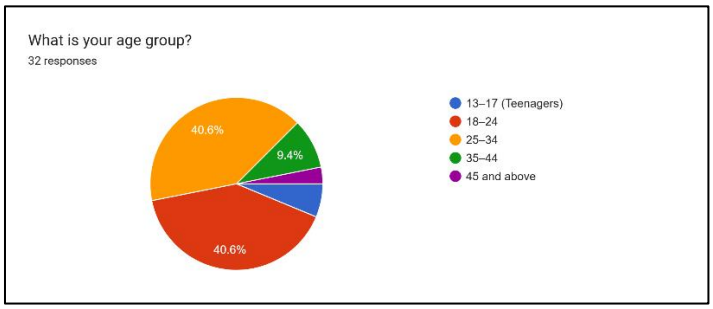


Figure 5.3 Demographic (Age Group)

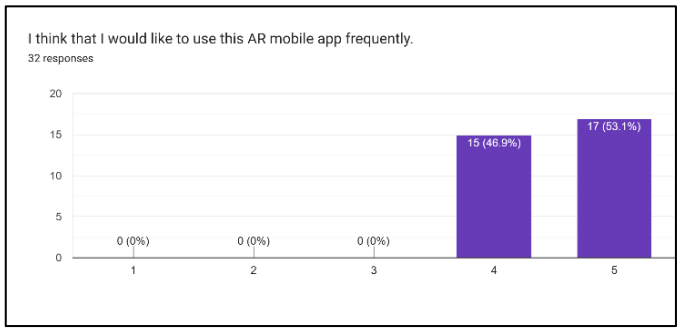


Figure 5.4 User willingness to use the AR mobile app frequently.

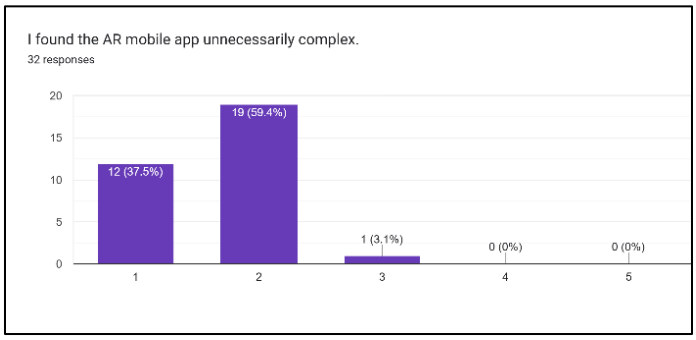


Figure 5.5 Perceived complexity of the AR mobile app.

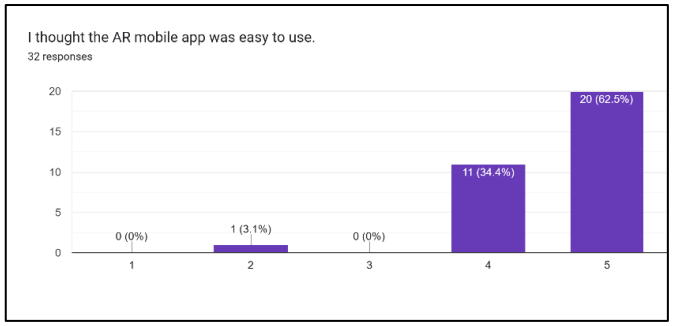


Figure 5.6 Perceived ease of use.

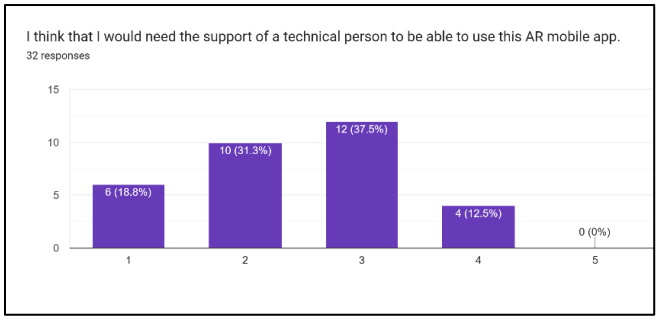


Figure 5.7 Need for technical support when using the AR mobile app.

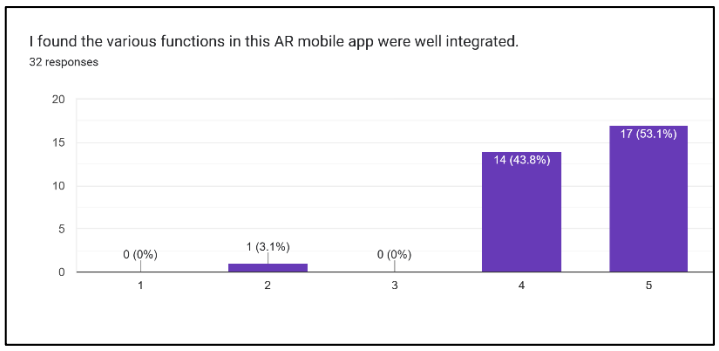


Figure 5.8 Integration of AR mobile app functions.

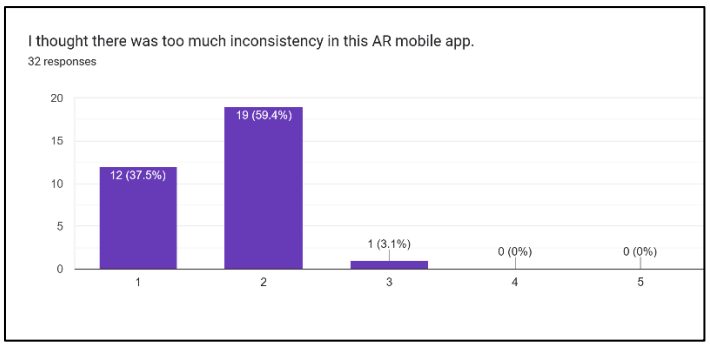


Figure 5.9 Perceived inconsistency in the AR Mobile App.

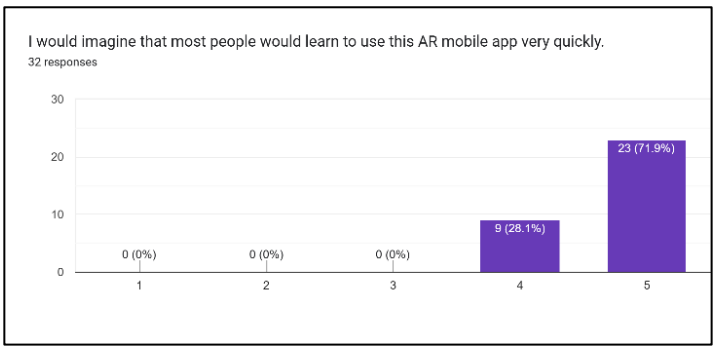


Figure 5.10 Ease of learning the AR mobile app for new users.

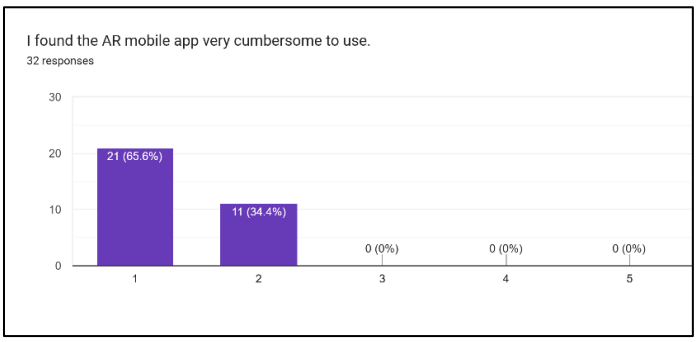


Figure 5.11 AR mobile app's level of cumbersomeness.

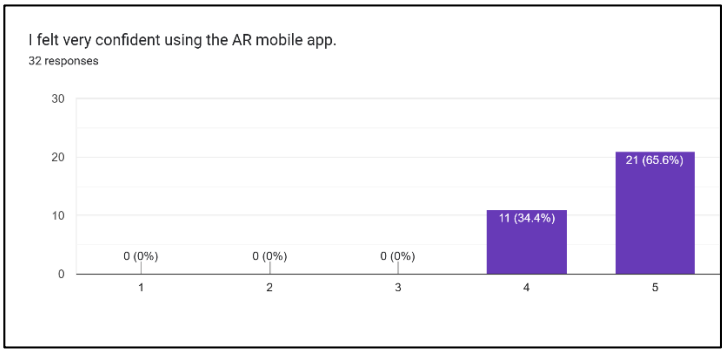


Figure 5.12 User confidence while using the AR mobile app.

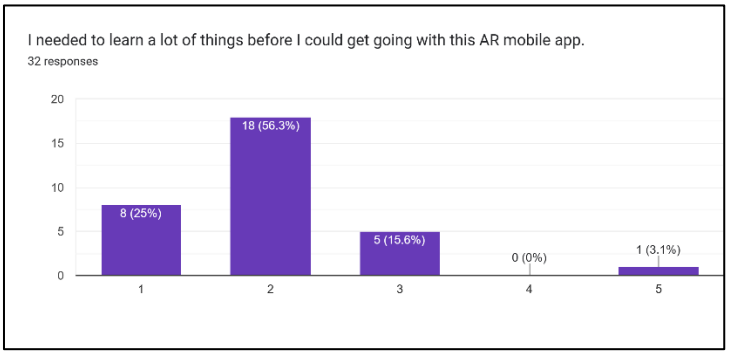


Figure 5.13 Amount of learning required before using the AR mobile app

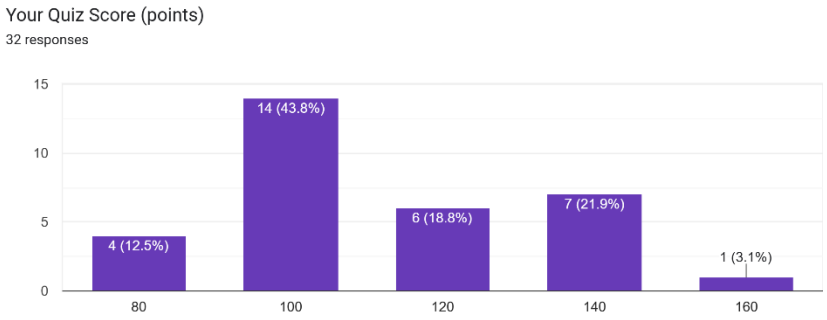


Figure 5.14 Quiz Score in AR mobile app.

Discussion

Based on Figure 5.1, 100% of the respondents (n = 32) agreed to participate in the Omen Birds of Borneo AR mobile app user testing session. This indicates full voluntary engagement and consent from all users. Figure 5.2 illustrates the gender distribution, where 59.4% (n = 19) of the respondents were female and 40.6% (n = 13) were male. Meanwhile, Figure 5.3 presents the age group demographics, showing that most respondents were aged 18–24 years and 25–34 years, each accounting for 40.6% of the sample. This age range is ideal for testing technology adoption and usability among digital-native and early-career adult users.

In Figure 5.4, most respondents expressed a positive outlook regarding the app's usage, with 46.9% rating it 4 and 53.1% rating it 5. This suggests that most users would be interested in using the AR mobile app regularly, indicating strong potential for future engagement and AR promotion in cultural heritage settings. Figure 5.5 shows the perceived complexity of the app. A total of 12 respondents rated it 1, 19 rated it 2, and only 1 rated it 3, indicating that most users did not find the app unnecessarily complex. This reflects effective system design and a user-friendly interface. According to Figure 5.6, 62.5% of respondents rated 5 and 34.4% rated 4 for ease of use, while only 3.1% (n = 1) disagreed slightly. This strong consensus suggests that users found the AR mobile app intuitive. The minor disagreement may be attributed to unfamiliarity with AR technologies or first-time use.

Figure 5.7 shows a curved response pattern: 18 respondents rated 3, and 4 rated 4, indicating some users anticipated needing technical support. This may cause from unfamiliarity with AR features such as gesture recognition, 3D object interaction, or image markers. However, 56.3% (n = 18) and 25% (n = 8) rated 2 and 1 respectively, suggesting that the majority were able to operate the app independently without much assistance.

As shown in Figure 5.8, 53.1% rated 5 and 43.8% rated 4 in agreement that the app's key features such as bird audio, quizzes, and location-based info were well integrated. This demonstrates strong cohesion in feature implementation and interface design. In Figure 5.9, 59.4% (n = 19) rated 2 and 37.5% (n = 12) rated 1 for perceived inconsistency. This indicates minimal confusion and a consistent user experience while navigating the app. Figure 5.10 reveals that 23 respondents rated 5 and 9 rated 4, suggesting high confidence that most users would quickly learn how to use the app. This validates the app's low learning curve. Figure 5.11 further supports this, showing that 65.6% (n = 21) and 34.4% (n = 11) disagreed that the app was cumbersome. This confirms that the app's design was accessible and not perceived as difficult to use, even within a museum setting.

In Figure 5.12, 65.6% (n = 21) of respondents rated 5 and 34.4% (n = 11) rated 4, stating they felt confident while using the AR app. This suggests the app's interaction model was successful in building user confidence, an important factor for first-time AR users. According to Figure 5.13, most respondents rated 2 (n = 18) and 1 (n = 8) regarding how much they needed to learn before using the app. This shows that the system was easy to understand and required minimal training. A small portion, 15.6% (n = 5) and 3.1% (n = 1), gave higher ratings (3 and 4), likely due to less experience with AR technology.

Finally, Figure 5.14 shows quiz performance results. Most respondents scored between 80 and 140 points, and only 3.1% (n = 1) achieved a perfect score of 160 (full marks for 8 questions). Notably, 14 respondents scored 100 points, indicating that the learning material was moderately challenging yet engaging. These results suggest that the educational content was well-aligned with the learning objectives and successfully reinforced through the AR experience.

5.3.2 Calculation Usability Score using SUS

Here is an overview of the method used in finding SUS score. The user will have ranked each of the 10 questions from 1 to 5 based on their level of agreement. This is the example for SUS score for Respondent 1.

a) For each of the odd numbered questions, subtract 1 from the score. For each of the even numbered questions, subtract their value from 5.

Question	Response	Adjusted Score
Q1 (odd)	5	5 – 1 = 3
Q2 (even)	2	5 – 2 = 3
Q3 (odd)	5	5 – 1 = 4
Q4 (even)	3	5 – 3 = 2
Q5 (odd)	4	4 -1 = 3
Q6 (even)	2	5 – 2 = 3
Q7 (odd)	4	4 – 1 = 3
Q8 (even)	2	5 – 2 = 3
Q9 (odd)	5	5 – 1 = 4
Q10 (even)	2	5 – 2 = 3
Total Score		32

Table 5.11 Total Score of Respondent 1

b) Take these new values which you have found and add up the total score. Then multiply this by 2.5.

SUS Score Respondent 1 = 32 x 2.5 = 80

c) Once you have the SUS score for each participant, add them all 33 SUS scores.

Respondent	SUS Score
Respondent 1	80
Respondent 2	90
Respondent 3	75
Respondent 4	82.5
Respondent 5	75
Respondent 6	80
Respondent 7	80
Respondent 8	77.5
Respondent 9	85
Respondent 10	90
Respondent 11	85
Respondent 12	100

Respondent 13	82.5
Respondent 14	87.5
Respondent 15	75
Respondent 16	87.5
Respondent 17	85
Respondent 18	100
Respondent 19	85
Respondent 20	82.5
Respondent 21	85
Respondent 22	75
Respondent 23	90
Respondent 24	85
Respondent 25	92.5
Respondent 26	85
Respondent 27	72.5
Respondent 28	80
Respondent 29	90
Respondent 30	90
Respondent 31	90
Respondent 32	87.5
Total	**2707.5**

Table 5.12 Total Score of 32 Respondents

d) Calculate the average SUS score by using the formula :

$$\text{Average SUS Score} = \frac{Sum\ of\ all\ 32\ SUS\ Scores}{32}$$

$$\text{Average SUS Score} = \frac{2707.5}{32} = \mathbf{84.61}$$

e) Here is an overview of how scores should measure according to research (Thomas, 2019).

- 80.3 or higher is an A. People love your system and will recommend it to their friends

- 68 or thereabouts gets you a C. You are doing OK but could improve.
- 51 or under gets you a big fat F. Make usability your priority now and fix this fast.

The average System Usability Scale (SUS) score for the **Omen Birds of Borneo AR Mobile App** is **84.61 out of 100**. This indicates a high level of usability, suggesting that users found the app intuitive, efficient, and easy to use.

5.4 Summary

In this chapter, the AR mobile application was thoroughly tested to ensure it worked as intended and provided a smooth user experience. The system, interface, and functionality testing were carried out, followed by real user evaluations. Feedback collected from users helped assess the app's effectiveness and identify areas for improvement. Overall, the testing and evaluation phase played a key role in validating the project's goals and enhancing the outcome.

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 Introduction

This chapter reviews the completed project of the Enhancement of User Experience using Augmented Reality at Omen Birds of Borneo Exhibition (Borneo Culture Museum It emphasizes how the project's objectives were achieved, analyses the challenges and constraints encountered by the developers, and makes recommendations for changes and future work that might improve the system's functionality and effectiveness.

6.2 Objective Achievement

This achievement of the Enhancement of User Experience using Augmented Reality at Omen Birds of Borneo Exhibition (Borneo Culture Museum) is based on the objectives stated in early chapter of the thesis the success of this AR mobile application can be determined by analysing and evaluated the mobile application to ensure it meets all the objectives and the user's requirements as shown in Table 6.1.

Objectives	Achievements
To study existing challenges in traditional exhibition displays, such as overlapping audio and misaligned projections thus to figure out how AR may handle them.	Identified issues through observations and feedback, then applied AR to separate overlapping audio and correct visual misalignment using clearer 3D models and interactive elements.
To implement an Augmented Reality (AR) system that improves the visual and audio experience at the "Omen Birds of Borneo" exhibition	Successfully developed a marker-based AR mobile app with 3D bird models, audio playback, and improved visual interaction.
To evaluate the enhancement of user experience using Augmented Reality in the Omen Birds of Borneo exhibition at Borneo Culture Museum.	Successfully developed a marker-based AR mobile app featuring 3D bird models, audio playback, and enhanced visual interaction. Additional features include an interactive map showing the common locations of each bird and the inclusion of scientific names for better educational value.

Table 6.1 Objective Achievement

6.3 Project Limitation and Constraints

This AR mobile app comes with a few limitations and challenges. Not all mobile devices support AR, so compatibility might be an issue, especially for older models with limited hardware capabilities. Some features may also need an internet connection, which could be a problem in areas with weak network coverage. Additionally, the app's performance depends on the device's processing power, meaning older phones might experience lag or slower responses. Since the AR experience requires users to hold their devices steady for scanning, how well it works can vary based on how each person interacts with it. Lastly, since the app uses Google Maps API to show certain location-based features, there are some limitations related to API usage. The API has usage limits and may require payment if those limits are exceeded in the future. This could become a concern if the app grows and attracts more users, or if the museum relies on these features regularly.

6.4 Future Work

To improve this AR mobile app in the future, we can focus on making it more accessible, smoother, and easier to use. Expanding support for more devices, especially older ones, would help more people experience it without needing the latest technology. Adding offline functionality or reducing the need for an internet connection would make it more reliable, especially in places with weak network coverage. Optimizing performance could also make the AR experience smoother, reducing lag and improving responsiveness. Since holding a phone steady for scanning can be tricky, exploring hands-free options like voice commands or wearable AR devices could make interactions more natural. In the future, we'd also love to animate the 3D models in the app. Instead of static images, animated models could help bring the content to life and make it more engaging, especially for younger audiences. Lastly, gathering user feedback and refining the app based on real experiences in the museum would help make it even better over time.

6.5 Significant of the Project

This project serves as an example of how Augmented Reality could create traditional displays more engaging, instructive, and interesting. It improves the environment for visitors to learn about Bornean birds by resolving problems like overlapping sounds and misleading

pictures. It also demonstrates how technology, particularly in museum contexts, may improve cultural preservation and education.

6.6 Summary

In conclusion, this chapter reviewed the outcomes of the AR mobile app project, highlighting the achievements, challenges, and potential improvements. While the system performed well and fulfilled its objectives, several technical and practical limitations were identified. Moving forward, further development and refinement based on user needs and feedback will help ensure the app continues to deliver value to both the museum and its visitors.

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Appendix

Appendix A : User Requirement Survey Form

How would you rate the current auditory experience of the bird sounds in the exhibition? *

	1	2	3	4	5	
Very poor	○	○	○	○	○	Very good

Did you find it easy to associate each bird sound with the correct bird species? *

- ○ Yes
- ○ No

Were you able to match the projected bird images with the correct display items easily? *

	1	2	3	4	5	
Very difficult	○	○	○	○	○	Very easy

How easy is it for you to read the bird descriptions in the exhibition (considering text size, lighting, etc.)? *

	1	2	3	4	5	
Very difficult	○	○	○	○	○	Very easy

Did you feel that you had enough access to relevant information about each bird species? *

- ○ Yes
- ○ No

Would you find it helpful if AR technology provided a better experience where bird sounds are triggered only when you engage with specific bird displays? *

- ○ Yes
- ○ No
- ○ Maybe

How beneficial would it be if AR could align digital bird images and data with real-life exhibits to enhance your understanding? *

	1	2	3	4	5	
Not beneficial	○	○	○	○	○	Highly beneficial

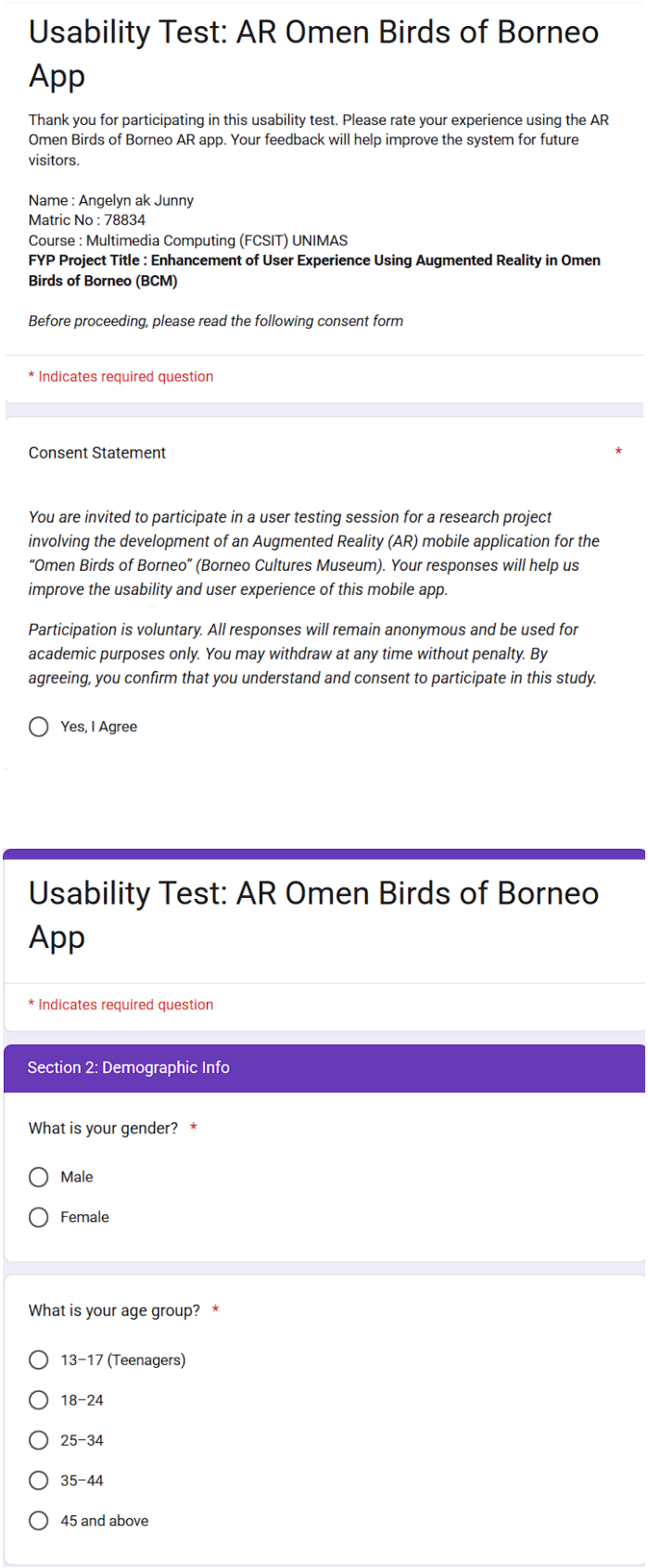
What features would you expect from an AR experience in the exhibition? (Check all that apply) *

- ☐ Clear and interactive bird sounds
- ☐ Real-time display of bird information when scanning an exhibit
- ☐ 3D models of birds
- ☐ Video of the specific birds
- ☐ Other...

Would you use an AR application in the exhibition if it were available on your smartphone or a provided device? *

- ○ Yes
- ○ No
- ○ Maybe

Appendix B: Evaluation User using System Usability Scale (SUS) score



Usability Test: AR Omen Birds of Borneo App

Thank you for participating in this usability test. Please rate your experience using the AR Omen Birds of Borneo AR app. Your feedback will help improve the system for future visitors.

Name : Angelyn ak Junny
Matric No : 78834
Course : Multimedia Computing (FCSIT) UNIMAS
FYP Project Title : Enhancement of User Experience Using Augmented Reality in Omen Birds of Borneo (BCM)

Before proceeding, please read the following consent form

* Indicates required question

Consent Statement *

You are invited to participate in a user testing session for a research project involving the development of an Augmented Reality (AR) mobile application for the "Omen Birds of Borneo" (Borneo Cultures Museum). Your responses will help us improve the usability and user experience of this mobile app.

Participation is voluntary. All responses will remain anonymous and be used for academic purposes only. You may withdraw at any time without penalty. By agreeing, you confirm that you understand and consent to participate in this study.

- ◯ Yes, I Agree

Usability Test: AR Omen Birds of Borneo App

* Indicates required question

Section 2: Demographic Info

What is your gender? *

- ◯ Male
- ◯ Female

What is your age group? *

- ◯ 13–17 (Teenagers)
- ◯ 18–24
- ◯ 25–34
- ◯ 35–44
- ◯ 45 and above

Usability Test: AR Omen Birds of Borneo App

* Indicates required question

Section 3: Usability Testing (Change of System into AR Mobile App)

Instruction: Please rate your agreement with the following statements based on your experience with the AR mobile app.

Scale: 1: Strongly Disagree - 5 : Strongly Agree

I think that I would like to use this AR mobile app frequently. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I found the AR mobile app unnecessarily complex. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I thought the AR mobile app was easy to use. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I think that I would need the support of a technical person to be able to use this AR mobile app. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I found the various functions in this AR mobile app were well integrated. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I thought there was too much inconsistency in this AR mobile app. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I would imagine that most people would learn to use this AR mobile app very quickly. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I found the AR mobile app very cumbersome to use. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I felt very confident using the AR mobile app. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I needed to learn a lot of things before I could get going with this AR mobile app. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Your Quiz Score (points)

Your answer

Please share any thoughts, issues, or suggestions you have about using the AR Omen Birds of Borneo app.

Your answer