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# AR Temple Explorer: Development of Augmented Reality Mobile Application Based on Historical Building 'Johor Ancient Temple'

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**Abstract**

Augmented Reality (AR) technology is widely used in tourism to enhance the tourist experience by providing an interactive and informative digital overlay on real-world attractions. However, the existing approaches often lead to limited engagement because these traditional methods can fall short of delivering an immersive experience and the lack of multilanguage support limits access to the temple's cultural history. Hence, this project is proposed to develop an AR mobile application called AR Temple Explorer that helps anyone interested in history and culture exploring temple to know the story of the Johor Ancient Temple in a creative way. The objectives of this study are to design AR Temple Explorer mobile application using augmented reality approach, to develop virtual exploration on Johor Ancient Temple building using markerless-based AR on AR Temple Explorer, and to perform functional testing and use acceptance testing on the developed application to the target user. The Multimedia Mobile Content Development (MMCD) model is used for the proposed application. Functional testing and user acceptance testing have been conducted to evaluate the functionality and usability of the final developed application. Based on the System Usability Scale, an average score of 78.17% is presented to show that the developed application is highly acceptable. As a result, this project can be concluded that AR Temple Explorer is suitable for enhancing the engagement and educational experience of visitors to the Johor Ancient Temple.

## 1. Introduction

Augmented Reality (AR) is a technology that can be used to enhance a user's experience of their surroundings by incorporating digital information such as pictures, video, audio, or 3D models onto the real world. It can blend the digital and physical worlds together with computer-generated elements [1]. Nowadays, it is widely used in tourism to enhance the tourist experience by providing an interactive and informative digital overlay on real-world attractions. This allows tourists to gain deeper insights into historical sites and cultural landmarks, creating a more engaging journey [2]. The Johor Ancient Temple is one of the oldest structures in Johor Bahru, Johor, Malaysia, stands as a symbol of unity among the city's five ethnic Chinese groups which are Teochew, Hokkien, Cantonese, Hakka, and Hainan [3]. The history of the temple starts in the 19th century, specifically the early 1870s to 1880s [3]. However, the existing *methods* of exploring and understanding the temple's rituals and

history face limitations in engagement, consistency of information provided via oral storytelling, language accessibility, and impact. In response, this research introduces the AR Temple Explorer mobile application with the aim to revolutionize the interaction with the Johor Ancient Temple.

The objectives of this study are to design AR Temple Explorer mobile application using augmented reality approach, to develop virtual exploration on Johor Ancient Temple building using markerless-based AR on AR Temple Explorer, and to perform functional testing and user acceptance testing on the developed application to the target user. AR Temple Explorer application is proposed to help visitors, youngsters, anyone interested in history and culture, and individuals exploring temple those aged from 7 to 40 years old to know the story of the Johor Ancient Temple in new and creative ways. Hence, bilingual support will be used in the application to cater to a more diverse range of users to engage with the content and fully comprehend the historical and cultural aspects of the Johor Ancient Temple.

There will be two modules which are AR tour module and museum module built in the application. Firstly, the AR module will present an AR environment for Johor Ancient Temple in a three-dimensional (3D) model. Name and the information of the items in the temple will be included in this module. Moreover, museum module will include the history of Johor Ancient Temple, information and story of the relics and items in the temple and culture of Johor Ancient Temple Deities Procession, Chingay. Mr. Lee Sui Seng, a worker of Johor Ancient Temple, serves as the subject matter expert (SME) for this project.

The rest of the paper is arranged as follows: Section 2 covers the domain of study, the technology used, and the result of the comparative analysis. Section 3 discusses the methodology applied in the project, Multimedia Mobile Content Development (MMCD) and the output of the analysis and design phases of this project. Moreover, Section 4 stated the result and discussion of the current progress. Lastly, a conclusion will be outlined in Section 5.

## 2. Related Work

This section covers the study domain of this project, technology applied and the result of the comparative analysis between three existing applications and the proposed application.

### 2.1 Background of Johor Ancient Temple

Johor Ancient Temple is one of the most ancient architectural landmarks in Johor Bahru, Johor. Based on the remaining artifacts in the temple which are a plaque and a bronze bell, the history of the Johor Ancient Temple can be traced back to the year 1870 AD [3]. This temple is a place of worship for five deities, each representing distinct Chinese dialect groups: Teochew, Hokkien, Cantonese, Hakka, and Hainan. A significant part of its cultural essence has been conserved, and valuable artifacts like the century-year-old bronze bell, incense pot, and wooden tablet are still intact [5]. Because of the friendly relations that existed between the local Chinese community and the Johor royalty, Sultan Abu Bakar actively supported the construction of their places of worship by providing them with land [6]. Besides, the architecture of Johor Ancient Temple is based on southern Chinese designs, significantly featuring a Teochew architectural.

### 2.2 Augmented Reality Technologies

Augmented Reality (AR) is a technology capable of enriching a user's perception of their environment by integrating digital content like images, videos, audio, or 3D models into the real-world context. AR seamlessly merges the digital and physical world by incorporating computer-generated elements to provide an enhanced experience [7]. Nowadays, this technology is widely used in tourism since it has empowered tourism managers to elevate satisfaction of tourists by delivering memorable experiences [8]. To exploring cultural monuments and historical surroundings, travellers may engage with virtual guides that offer rich, contextual information [9]. Indirectly, this alternative way does increased awareness of protecting cultural heritage and enhancing sustainability [10].

#### 2.2.1 Markerless Augmented Reality

Markerless AR refers to augmented reality experiences that do not rely on predefined markers or images in the physical environment as a base for digital content [11]. Instead, this technology tracks and detects surfaces and objects in real-time using cameras, sensors, and algorithms, enabling virtual elements to blend in seamlessly with the user's environment [12]. This enables a more dynamic and flexible AR experience as users are not restricted to specific markers, making it suitable for a wide range of applications, including interior design, gaming, navigation, and more.

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### 2.2.2 AR Foundation

AR Foundation is a software framework developed by Unity Technologies which used to streamline the creation of augmented reality (AR) applications across multiple platforms. In addition to supporting both IOS and Android, AR Foundation also allows developers to build AR experiences using a unified codebase. This framework acts as a bridge between Unity's ARKit (for iOS) and ARCore (for Android), providing a common API that streamlines the development process [13].

### 2.2.3 AR Core

ARCore stands as Google's augmented reality (AR) software development kit that offers cross-platform APIs for building immersive experiences across Android, IOS, Unity and the Web. It aims to revolutionize how individuals engage with the world transforming activities such as gaming, shopping, learning and creating by providing contextual insights into people, places and objects. There are some fundamental tools provided to build augmented reality experiences, incorporating features such as motion tracking, anchors environmental understanding, depth understanding and light estimation [14].

## 2.3 Comparative Analysis

In this section, the difference between existing applications and the proposed application are presented. Discussion is made based on the features of the application. The first feature that can differentiate applications is the type of Augmented Reality (AR). The comparison between the existing applications which are Heraklion Museum AR, Muzium Negara AR, Muzium Perak AR, and the proposed application, namely Temple Explorer AR, is shown in Table 1.

**Table 1** *Comparison between the existing applications and proposed application*

| Features | Heraklion Museum AR | Muzium Negara AR | Muzium Perak AR | Proposed Application |
|---|---|---|---|---|
| AR-type | Marker-based AR technology is used | | | Markerless AR technology is used |
| Language | English and Greece | English and Malay | | English and Chinese |
| Content focus | Information about the artifacts. | History about Malaysia and cultural occasions. | Information about the relics and specimens in the museum. | Information about the relics in the Chinese temple. |
| Audio | There is no audio exists. | | | Background music will be provided. |
| Navigation | Lack of a back button. | Lack of an exit button. | Lack of an exit and skip button. | Exit button, back button, and skip button will exist. |

In terms of AR type, three of the existing applications utilize marker-based AR technology. In contrast, the proposed application will use markerless AR technology. The Heraklion Museum AR provides English and Greek language support, while Muzium Negara AR and Muzium Perak AR give English and Malay language assistance. The Proposed Application offers both English and Chinese language support. Notably, audio features are absent in Heraklion Museum AR, Muzium Negara AR, and Muzium Perak AR, while the Proposed Application introduces audio elements. Besides, there are differences in the navigation options. Heraklion Museum AR lacks a back button, Muzium Negara AR misses an exit button, the absence of both an exit and skip button in Muzium Perak AR, and the Proposed Application will be incorporating exit, back, and skip buttons.

## 3. Methodology

In this project, Multimedia Mobile Content Development (MMCD) is chosen as the methodology for development. MMCD refers to the process of creating interactive and engaging digital content for mobile devices that incorporates a variety of media elements. According to Abdullah and Saifuddin [14], this methodology is not

only to complete the development process swiftly, but it also optimizes data space, processor utilization and user acceptability.

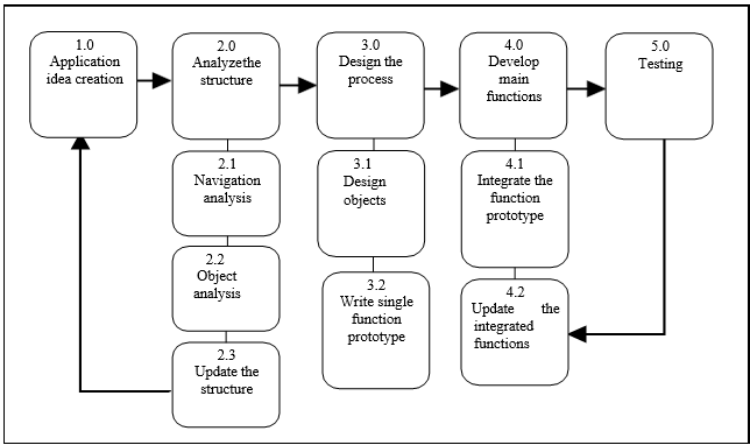


**Fig. 1** *MMCD Methodology*

## 3.1 Application Idea Creation

Application idea creation is the first stage of Multimedia Mobile Content Development model. Preparation of the required information is necessary before beginning the design and development of the project in the first stage [15]. Table 2 provides an overview of the application idea development phase. Additionally, the user requirements are identified by conducting interviews with Subject Matter Expert (SME).

Besides, a set of questionnaires is distributed to 30 respondents. From the data collected, 100% of the respondents do use their smartphone daily. However, 56.7% have prior experience with augmented reality applications. Besides, the data showcases almost 80.0% of the respondents preferred to have bilingual support and user-friendly interface in the application as well as access the application without internet. Moreover, 60.0% of the respondents agreed that interactive features are important in the proposed application, 73.3% agreed that the application should provide additional content such as video and 83.3% agreed that the detailed information of the Johor Ancient Temple should be provided. Lastly, 66.6% of the respondents are interested in this proposed application. The result of the user requirements analysis is tabulated in Table 3.

**Table 2** *Application Idea Creation Checklist*

| Item | Description |
|---|---|
| Type of application | Mobile application |
| Target device | Android mobile application. |
| Target users | Tourists, history enthusiasts, and individuals aged 7 to 40 who are interested in exploring cultural rituals |
| GUI (Graphical user interface) | Home interface, AR Tour module, Museum module. |
| Images | Background, buttons, information images of the Johor Ancient Temple. |
| Video | Information video about the Johor Ancient Temple. |
| Audio | Background music in UI scene and AR scenes. |
| Augmented Reality | Markerless AR |
| Application Synopsis | AR Temple Explorer is an augmented reality (AR) mobile application designed to enhance the exploration and understanding of the Johor Ancient Temple. This application is designed to cater to a diverse range of target users, including youngsters, visitors, anyone interested in history and culture, and individuals exploring rituals. Unlike existing methods that rely on traditional means of communication such as oral storytelling, visual aids, and guided tours, AR Temple Explorer offers users an immersive and interactive platform. The application is designed with an interactive AR module to enhance the interaction and motivation to further explore Johor Ancient Temple. |

**Table 3** *User Requirements Analysis*

| Stakeholder Category | Role in product | Design Implications | Action Needed |
|---|---|---|---|
| Subject Matter Expert | Content consultant expert in the related field | Based on the interview,<br>Simple user interface design | • All the design of buttons should be consistent.<br>• The design of the user interface such as color and font style should be simple and consistent. |
| | | Provide content in English | • Besides Chinese language, this application should also be supported with English Language. |
| | | Reliable content | • Information about the relics and specimens should be included in the museum module.<br>• Video of 'Chingay' should be provided. |
| General user | End-user of the system | Based on the questionnaire,<br>Can be accessed anytime | • The application should be created so it can run without a network connection. |
| | | Bilingual support | • The application should provide bilingual support such as English and Chinese. |
| | | Easy to use | • The application should provide a user-friendly user interface such as consistent navigation design. |
| | | Reliable content | • The application should provide detailed information about the history and cultural significance of the Johor Ancient Temple.<br>• The application should provide related information videos and graphics. |

## 3.2 Structure Analysis

Navigation analysis and object analysis are components used in the proposed application. Both analyses are included in the structure analysis phase [15]. Table 4 shows a content structure checklist which was created based on the application idea creation phase and conversations between the developers.

**Table 4** *Content Structure Checklist*

| Item | Note | Item | Note |
|---|---|---|---|
| Layers design | Layer 3: C# Scripting in Unity<br>Layer 2: Content<br>Layer 1: Background images | Number of main GUI | Logo of the application |
| Frame design | Frame 1: Language selection interface<br>Frame 2: Homepage interface<br>Frame 3: Main menu module selection<br>Frame 4: AR tour module<br>Frame 5: Museum module<br>Frame 6: Information interface<br>Frame 7: Setting interface<br>Frame 8: Tutorial interface<br>Frame 9: Hint interface<br>Frame 10: Info panel of the AR objects | Images | • Background images<br>• Buttons<br>• Images in the museum module |
| | | Video | Information video about the Johor Ancient Temple. |

**Table 4** *Content Structure Checklist (cont)*

| | | | |
|---|---|---|---|
| Menu and navigation | • Start button<br>• Back button<br>• Setting button<br>• Information button<br>• Hint button<br>• Exit button<br>• AR Tour module button<br>• Museum module button<br>• Content buttons<br>• Close button<br>• Chinese button<br>• English button | Audio | • Background music in homepage and main menu<br>• Background music in AR scene of courtyard<br>• Background music in AR scene of main hall<br>• Background music in AR scene of historical corridor<br>• Sound effects of tapping in AR scenes |
| | | AR | 3D models |

System design is the process of specifying components of a system such as architecture, modules, interface, and data according to the requirements. In order to meet the specific requirements, systems must be defined, developed and designed through this process [16]. The navigation structure created for the proposed application is shown in Figure 2 and the flowchart for main system, AR Tour module, AR scenes and Museum module are illustrated in Appendix A.

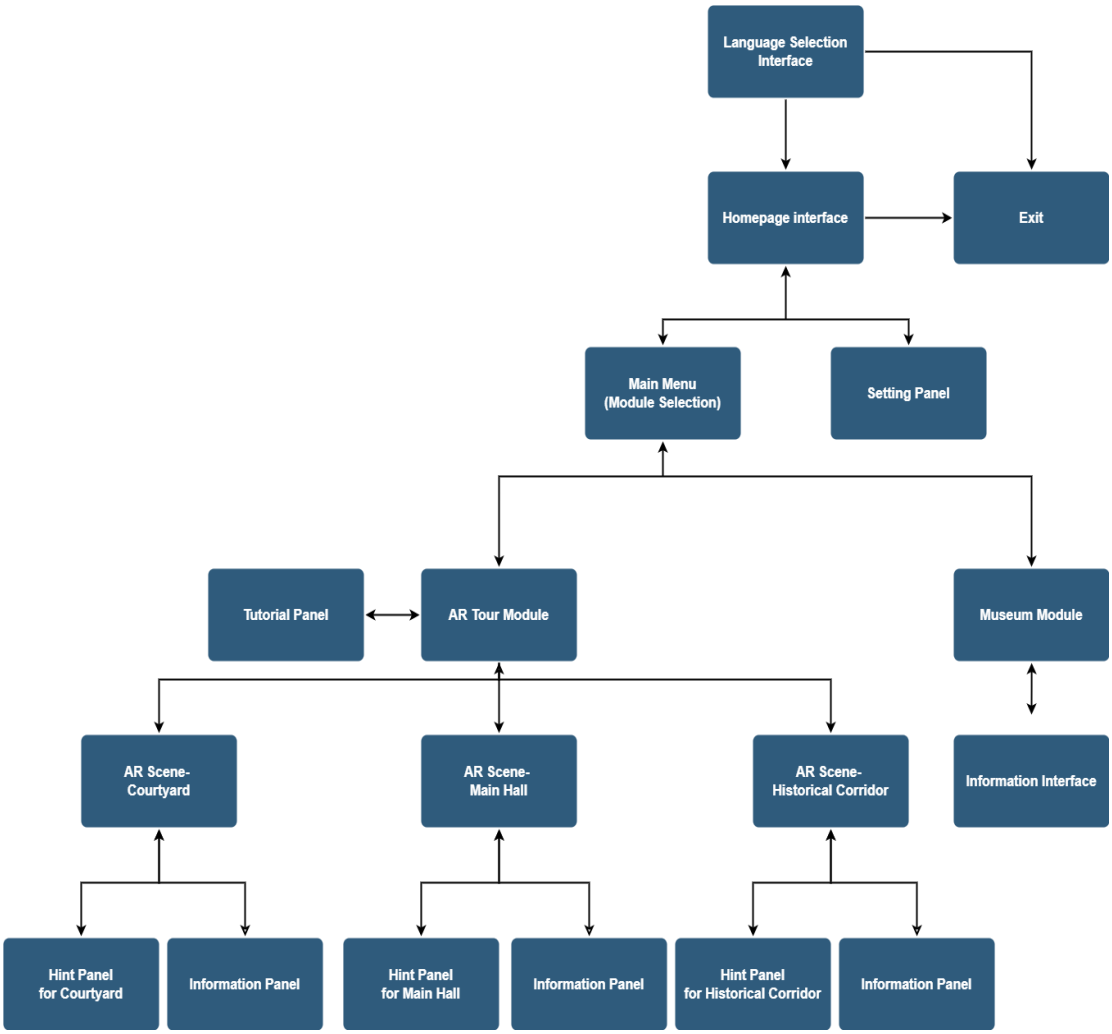


**Fig. 2** *Navigation Structure of the application*

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This phase also covers the functional requirement as shown in Table 5 and non-functional requirements which are indicated in Table 6.

**Table 5** *Functional requirements*

| Functional Requirement | Module | Description |
|---|---|---|
| User interaction support | Language selection interface | • The system shall allow users to select the preferred language by clicking on the specific button. |
| | Main menu module selection | • The system shall allow users to select a module by clicking on the specific button.<br>• The system shall allow users to return to the homepage by using the back button.<br>• The system shall allow users to open setting panel by using the setting button. |
| | AR tour module | • The system shall allow users to skip the tutorial panels.<br>• The system shall allow users to detect the plane to show AR portal.<br>• The system shall allow users to tap the 3D modeling items.<br>• The system shall allow users to close the description of each item in the AR environment. |
| | Puzzle module | • The system shall allow users to select one of the puzzles to play.<br>• The system shall allow users to drag the puzzles to the correct position. |
| | Museum module | • The system shall allow users to select the information by scrolling the page and clicking on the specific button.<br>• The system shall provide users with the ability to play the information video.<br>• The system shall display the contents selected by the users. |
| Autonomous System Activities | AR tour module | • The system shall ask the new users for their camera permission.<br>• The system shall display the 3D AR environment. |

**Table 6** *Non- functional requirements*

| Non-Functional Requirement | Description |
|---|---|
| Performance | • The application shall run smoothly & fast without lagging or crashing on user's mobile devices to allow users to complete tasks effectively and efficiently. |
| Availability | • The application and its data should be able accessed without the internet. |
| Ease of Use | • The developer shall provide an application that is easy to navigate.<br>• The developer shall provide tutorials in the application. |
| Cultural | • The application shall be developed in bilingual, English, and Chinese. |

## 3.3 Process Design

Process design phase aims to prepare all the items planned in the second phase of MMCD model. This phase would comprise object design and prototype scripting. This process will end in the completion of the first prototype. This prototype will be completed in terms of graphics and objects designs, object placement on stage

and single scripting that was placed in each frame. Canva is used for graphic design, Blender is used to make 3D models, and Unity is used to develop and integrate all the components needed for the scripting process. Table 7 presents the button designs of the application. Then, it will proceed to the main function development stage.

**Table 7** *Button Design*

| Button | Description | Button | Description |
|---|---|---|---|
|   | • These are language selection buttons. |  | • This is an AR tour module button. |
|   | • These are start buttons. |  | • This is a museum module button. |
|   | • These are exit buttons. |   | • This is the AR button. |
|   | • This is a content button. |  | • This is a setting button. |
|  | • This is a back button. |  | • This is a close button. |
|  | • This is an information button. |  | • This is a hint button. |

## 3.4 Main Function Development

This phase is to develop the main functions of the proposed application. There are 2 main activities of development involved in this phase which are development of assets and integration of all the elements in Unity. Development of assets plays a vital role in implementing a successful AR Temple Explorer application. 3D models, graphics, and audio are the assets that are required to be prepared and this activity is shown in Table 8.

**Table 8** *Development of Assets*

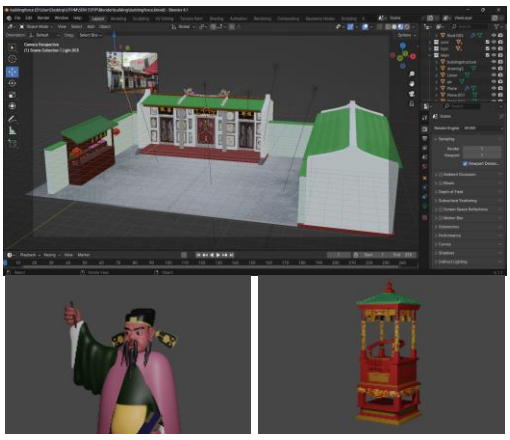
| Assets | Development | Description |
|---|---|---|
| 3D Models |  | All the 3D models are created in Blender based on the reference images captured in Johor Ancient Temple. They are created by adding a mesh and editing with tools such as extrusion, scale, loop cut, bridge, bevel, duplicate and shade smooth to shape the mesh in Blender. Modifiers such as subdivision surface and solidify are also applied in order to refine the mesh object to become more realistic. There are only two 3D models which are Su Bao Lao Ye and Huang Ling Guan Ye are created by sculpting. After these, these 3D models are texturing either by painting or applying texture image. Finally, 3D models are applied with decimate modifier before being exported as FBX (Filmbox) files. |

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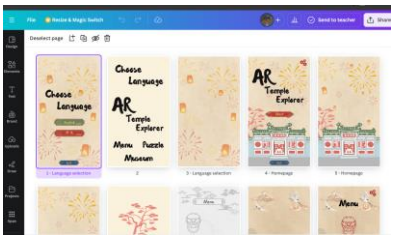
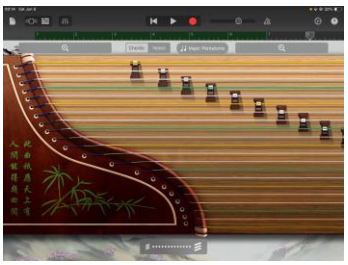
**Table 8** *Development of Assets (cont)*

| | | |
|---|---|---|
| Graphics |  | Some of the graphics are drawn and created by using software iArtbook based on the related reference images collected. Then, , the created drawings will be exported as PNG files and uploaded to Canva for use in creating backgrounds, panels and buttons of the application. |
| |  | In the Canva, the graphics and images are edit by cropping and removing their backgrounds, then integrated with the elements from resources of the Canva and applied to the design of the UI elements. |
| Audios |  | All the audio files in AR Temple Explorer application are in MP3 format. All the background music of the application is produced from Youtube by using an online converter. |
| |  | GarageBand software is used to create the sound effects of the interaction in the AR scenes. |

While the integration of various assets such as 3D models, 2D graphics, audio and scripts in Unity is also critical in the implementation phase of the AR Temple Explorer application. In this activity, integration of AR tour module, museum module and audios are outlined in Table 9.

**Table 9** *Integration in Unity*

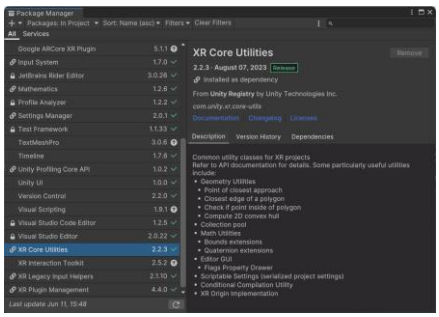
| Functions | Integrations | Description |
|---|---|---|
| Develop AR functionalities |  | The AR Foundation framework is set up to develop the AR functionalities. This includes configuring AR session origin, XR origin, AR camera, and AR planes to detect and interact with real-world surfaces. |

**Table 9** *Integration in Unity (cont)*

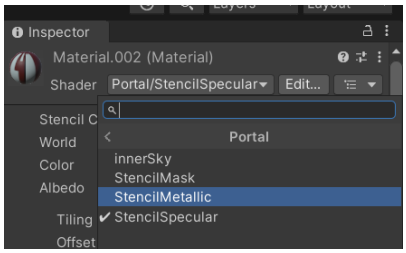
| | | |
|---|---|---|
| Manage the transitions between different worlds within application. | `void SetMaterials(bool fullRender)`<br>`{`<br>`var stencilTest = fullRender ? CompareFunction.NotEqual : CompareFunction.Equal;`<br>`foreach (var mat in materials)`<br>`{`<br>`mat.SetInt("_StencilComp", (int)stencilTest);`<br>`}`<br>`}` | PortalManager.cs is applied to the GameObject 'Portal' to enable the user to see the textures of the 3D objects only when user enter the AR portal. |
| Implements functionality in spawning object on the detected plane in AR scene. | `void Update()`<br>`{`<br>`if (Pointer.current == null \|\| isPressed == false)`<br>`return;`<br>`var touchPosition = Pointer.current.position.ReadValue();`<br>`if (aRRaycastManager.Raycast(touchPosition, hits, TrackableType.PlaneWithinPolygon))`<br>`{`<br>`var hitPose = hits[0].pose;`<br>`if (spawnedObject == null)`<br>`{`<br>`spawnedObject = Instantiate(placedPrefab, hitPose.position, hitPose.rotation);`<br>`StopPlaneDetection();`<br>`}`<br>`else`<br>`{`<br>`spawnedObject.transform.position = hitPose.position;`<br>`spawnedObject.transform.rotation = hitPose.rotation;`<br>`}`<br>`Vector3 lookPos = Camera.main.transform.position - spawnedObject.transform.position;`<br>`lookPos.y = 0;`<br>`spawnedObject.transform.rotation = Quaternion.LookRotation(lookPos);`<br>`}`<br>`}` | This `Update()` method in Placement.cs script is called once per frame to check for touch input and place or move the object. It first checks if there is a touch input (Pointer.current) and if it is pressed (isPressed). Then, the touch position is read and a raycast is performed to check if the touch position hits an AR plane. If a plane is hit, it gets the hit pose (position and rotation). If no object is spawned, it instantiates the `placedPrefab` at the hit position and stops plane detection. If an object is already spawned, it updates the object's position and rotation.<br>In addition, it makes the spawned object always look at the camera |
| Make the 3D Objects become invisible |  | Portal/StencilSpecular.Shader is applied to each texture of the 3D models except for door frame. Therefore, the 3D objects in AR scenes are invisible. |
| Implement the interaction with AR objects to pop out information panel | `void Update()`<br>`{`<br>`if (isInfoPanelActive)`<br>`{`<br>`return;`<br>`}`<br>`if (Input.GetMouseButtonDown(0))`<br>`{`<br>`Debug.Log("Pressed primary button.");`<br>`Ray ray = Camera.main.ScreenPointToRay(Input.mousePosition);`<br>`RaycastHit hit;`<br>`if (Physics.Raycast(ray, out hit, 100))`<br>`{`<br>`Debug.Log("hit");`<br>`Debug.Log(hit.transform.name + " : " + hit.transform.tag);`<br>`if (hit.transform.tag == "tgcf")`<br>`{`<br>`/*Vector3 pos = hit.point;`<br>`pos.z += 0.25f;`<br>`pos.y += 0.25f;`<br>`Instantiate(UITest, pos, transform.rotation);`<br>`infoPanel.SetActive(true);`<br>`infoTitle.text = "Incense Censer";`<br>`infoBox.text = "content of the information";`<br>`sfx1.Play();`<br>`isInfoPanelActive = true;`<br>`}`<br>`…//Repeat the same logic for hit.transform.tag`<br>`}`<br>`}`<br>`}` | This is an `Update()` function in ARTouch.cs script which is used to check if the info panel is active. If it is, the script returns, preventing further touch input processing. If not, it listens for touch input. When the user touches the screen and taps the AR object, the information panel will be activated and populates it with relevant information and images depending on the tag of the tapped AR object. Sound effects also will be played once the user taps on the AR object. |

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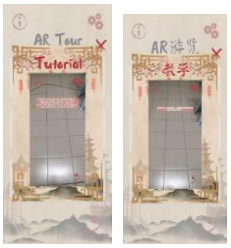
**Table 10** *Interfaces of the built application*

| Module | Interface | Module | Interface |
|---|---|---|---|
| Choose Language interface |  | Homepage |  |
| Main Menu interface |  | Setting Panel |  |
| AR Tour module |  | Tutorial Panel |  |
| Information panel |  | Hint Panel |  |
| AR Scenes |  | Museum module |  |
| Information interface |  | | |

After configuring and integrating all the application components, the build process of APK file is started. Unity will generate the APK file in the specified location. Finally, the APK file is installed on the device and tested to ensure it functions as expected. Table 10 presents the interfaces of the built AR Temple Explorer application.

## 3.5 Testing

Testing is the final stage of the MMCD model, and this phase is conducted when the application is fully completed [15]. Functional testing and user acceptance will be conducted to ensure that the application is bug-free and to determine if the target users will accept it. Table 11 performs the result of functional testing for the developed application.

**Table 11** *Functional Testing*

| Test Input | Expected Results | Actual Results | Correction Action |
|---|---|---|---|
| Language selection buttons | Navigate to the preferred language UI scene. | Works well as expected. | Not required. |
| Start button | Navigates to Main Menu. | | |
| Exit button | Exits the application. | | |
| Setting button | Displays the setting panel. | | |
| Back button | Return to previous interfaces. | | |
| AR Tour module button | Navigates to the AR Tour module interface. | | |
| Museum module button | Navigates to the Museum module interface. | | |
| Information button | Displays tutorial panel. | | |
| Hint button | Displays hint panel. | | |
| Close button | Close displayed panel. | | |
| All option buttons in AR Tour module. | Navigate to the relevant AR scenes. | Navigates to the wrong scene. | Change the arId in the button. `OnClick()` event according to the id of scenes in build. |
| All option buttons in Museum module. | Navigate to the relevant information interfaces. | Works well as expected. | Not required. |
| Sliders of BGM and SFX | Updates the volume levels of the BGM and SFX. | The volume levels do not be updated once the sliders are toggled. | Attach the function `AudioManager.Update()` on the slider. onValueChanged() for both GameObject slider. |
| Scroll function | Allows to navigate through extensive content in Museum module. | Some of the contents cannot be read due to limited scroll functionality. | Expand the GameObject Container to suite with the size of content by scaling along the Y axis. |
| | | Some of the content are overlapped with the title and background of the interface. | Activate the React Mask 2D component of GameObject Scroll Area. |
| Sound effects | Play when the user interacts with the interactable AR objects in AR scenes. | Works well as expected. | Not required. |
| Background music | Plays once the user enter the inner world of AR portal in AR scenes. | Does not play as expected. | Remove the InnerWorldMusicController.cs from the GameObject Portal and attach it to the Main Camera in the AR scenes. |

**Table 11** *Functional Testing (cont)*

| | | | |
|---|---|---|---|
| Tapping interaction with the AR objects | Allows users to interact with the AR objects to open their information panels by tapping. | Some of the AR objects does not respond to the interaction. | Check the tag of the GameObject (AR object) if it is applied correctly and check the name of tag in scripts if there is a typing error. |
| | Should be disabled when the hint panels, setting panel and information panels are opened. | Users still able to interact with the AR objects when the panel is still displaying. | A Boolean variable named `isInfoPanelActive` was initialized to stop the interaction function when the panel is displaying. |

## 4. Result and Discussion

By obtaining and examining feedback and comments from the target users, user acceptability testing aims to figure out whether the generated application is useful and acceptable to the intended users and whether further improvements to the application's functionality are necessary. 30 target users were involved in user acceptance testing, including Subject Matter Expert (SME) and target users with the age range of 7 to 40 years old based on the System Usability Scale (SUS) survey method. The overall result of analysis of the SUS questionnaire indicates positive feedback from users since most of the users reported their agreement with the positive-toned questions and disagreed with the negative-toned questions as presented in Figure 3 and 4.

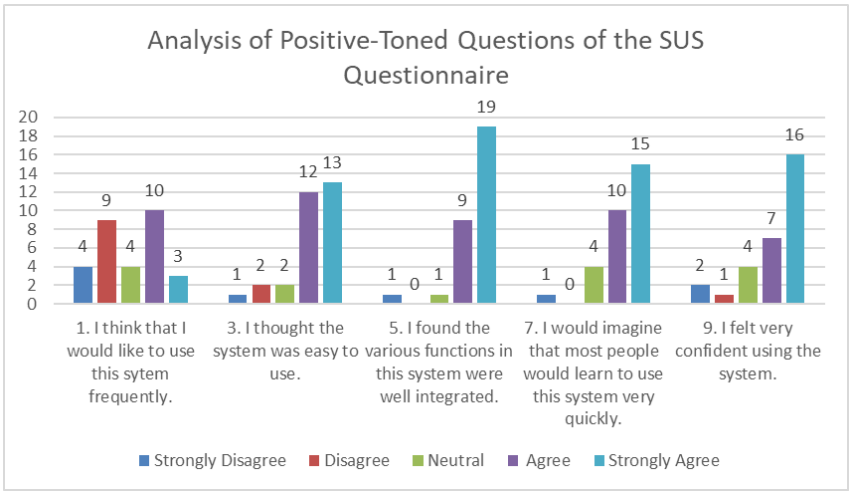



**Fig. 3** *Chart of Analysis for Positive-Toned Questions of the SUS Questionnaire*

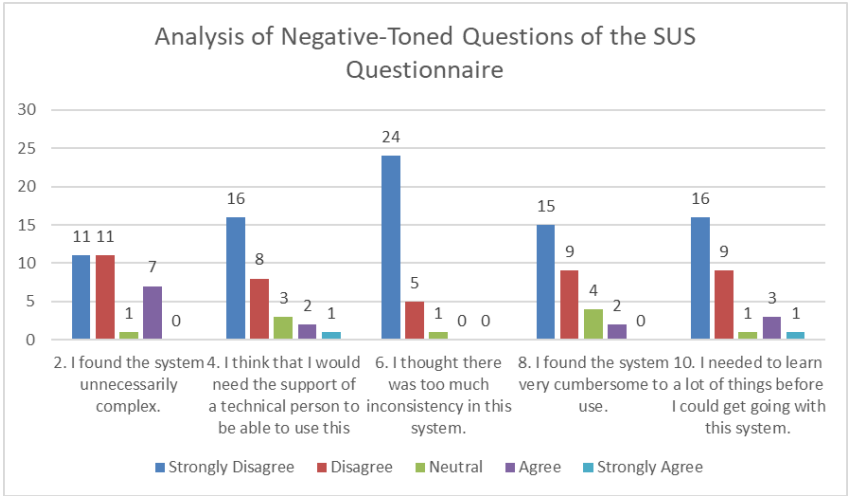



**Fig. 4** *Chart of Analysis for Negative-Toned Questions of the SUS Questionnaire*

Then, the SUS scoring is implemented to derive a quantitative measure of the usability for the AR Temple Explorer application [17]. The formula for SUS scoring shown in Figure 5 is used for this process. Then, the results of the calculation were recorded in Table 12.

```
X = Sum of the points for all odd-numbered questions
Y = Sum of the points for all even-numbered questions
Calculate:

X = (x0 - 1 + x1 - 1 + .....+ xn - 1)
Y = (5 - y0 + 5 - y1 + .....+ 5 - yn)
SUS Score = (X + Y) x 2.5
```

**Fig. 5** System Usability Scale (SUS) formula

**Table 12** *Total Score of System Usability Scale Testing*

| Respondent | Score | | | | | | | | | | Odd-number questions score | Even-number questions score | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | | | |
| R01 | 5 | 2 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 20 | 18 | 95 |
| R02 | 5 | 3 | 4 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 19 | 17 | 90 |
| R03 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 20 | 50 |
| R04 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 11 | 8 | 47.5 |
| R05 | 2 | 4 | 3 | 4 | 5 | 1 | 4 | 3 | 2 | 3 | 11 | 10 | 52.5 |
| R06 | 5 | 2 | 5 | 2 | 5 | 1 | 5 | 1 | 5 | 1 | 20 | 18 | 95 |
| R07 | 4 | 1 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 15 | 16 | 77.5 |
| R08 | 3 | 2 | 4 | 1 | 4 | 2 | 5 | 1 | 4 | 2 | 15 | 17 | 80 |
| R09 | 4 | 1 | 5 | 1 | 4 | 1 | 4 | 2 | 5 | 1 | 17 | 19 | 90 |
| R10 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 15 | 15 | 75 |
| R11 | 2 | 4 | 4 | 3 | 5 | 1 | 3 | 3 | 4 | 2 | 13 | 12 | 62.5 |
| R12 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 17 | 20 | 97.5 |
| R13 | 2 | 4 | 4 | 3 | 4 | 1 | 3 | 4 | 3 | 4 | 11 | 9 | 50 |
| R14 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 15 | 15 | 75 |
| R15 | 2 | 1 | 4 | 1 | 5 | 1 | 5 | 2 | 5 | 1 | 16 | 19 | 87.5 |
| R16 | 4 | 1 | 5 | 1 | 5 | 1 | 4 | 1 | 5 | 1 | 18 | 20 | 95 |
| R17 | 3 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 18 | 20 | 95 |
| R18 | 3 | 2 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 2 | 18 | 18 | 90 |
| R19 | 2 | 2 | 5 | 2 | 5 | 1 | 5 | 1 | 5 | 1 | 19 | 18 | 87.5 |
| R20 | 2 | 4 | 2 | 5 | 5 | 1 | 3 | 4 | 1 | 5 | 8 | 6 | 35 |
| R21 | 1 | 4 | 2 | 4 | 5 | 1 | 4 | 2 | 3 | 4 | 10 | 10 | 50 |
| R22 | 4 | 1 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 18 | 20 | 95 |
| R23 | 2 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 17 | 20 | 92.5 |
| R24 | 4 | 2 | 5 | 2 | 4 | 1 | 4 | 2 | 4 | 1 | 16 | 17 | 82.5 |
| R25 | 2 | 2 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 16 | 19 | 87.5 |
| R26 | 1 | 4 | 4 | 2 | 4 | 1 | 4 | 3 | 3 | 2 | 11 | 13 | 60 |
| R27 | 3 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 18 | 20 | 95 |
| R28 | 1 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 12 | 15 | 67.5 |
| R29 | 4 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 19 | 20 | 97.5 |
| R30 | 2 | 2 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 17 | 19 | 90 |
| Average Score (%) | | | | | | | | | | | | | 78.17 |

Table 12 shows the result of the System Usability Scale (SUS) testing for the developed AR Temple Explorer application with an average score of 78.17%. Based on the scale of SUS scores as displayed in Figure 6, the built application has successfully gotten the grade 'C' which indicates the application is highly acceptable. This indicates that there is room for improvement in enhancing the user experience.

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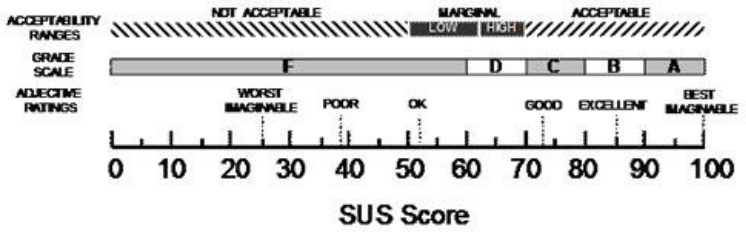


**Fig. 6** *System Usability Scale (SUS) Score Scale [18]*

## 5. Conclusion

In conclusion, AR Temple Explorer project has made significant strides in addressing the need for a modernized approach to engaging with cultural heritage sites, particularly the Johor Ancient Temple. By leveraging augmented reality technology, AR Temple Explorer offers an immersive and interactive platform for exploring the rich cultural history of Johor Ancient Temple which especially caters to the tech-savvy generation. The project aligns its objectives to develop the AR Temple Explorer mobile application, develop virtual exploration features, and conduct functional testing and user acceptance testing on the application for the target users. This project brings the advantages of enhancing both the educational experience and the Memorable Tourism Experience (MTE), appealing to younger generation, promoting cultural awareness and providing bilingual support. Despite these advantages, the application does have limitations including limited interactivity, space requirements, and large file size. All the advantages and limitations are outlined. However, these limitations present opportunities for future improvements, such as implementing additional interactive elements, integrating joystick features, adding some mini games and optimizing file size. Overall, the AR Temple Explorer project marks a significant milestone in leveraging technology to preserve and promote cultural heritage, with promising prospects for further development and impact in the future.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows:* ***study conception and design:*** *Chiew Mei Chun, Mohd Farhan Bin Md. Fudzee;* ***data collection:*** *Chiew Mei Chun, Mohd Farhan Bin Md. Fudzee;* ***analysis and interpretation of results:*** *Chiew Mei Chun, Mohd Farhan Bin Md. Fudzee;* ***draft manuscript preparation:*** *Chiew Mei Chun, Mohd Farhan Bin Md. Fudzee. All authors reviewed the results and approved the final version of the manuscript.*

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## Appendix A: System Flowchart

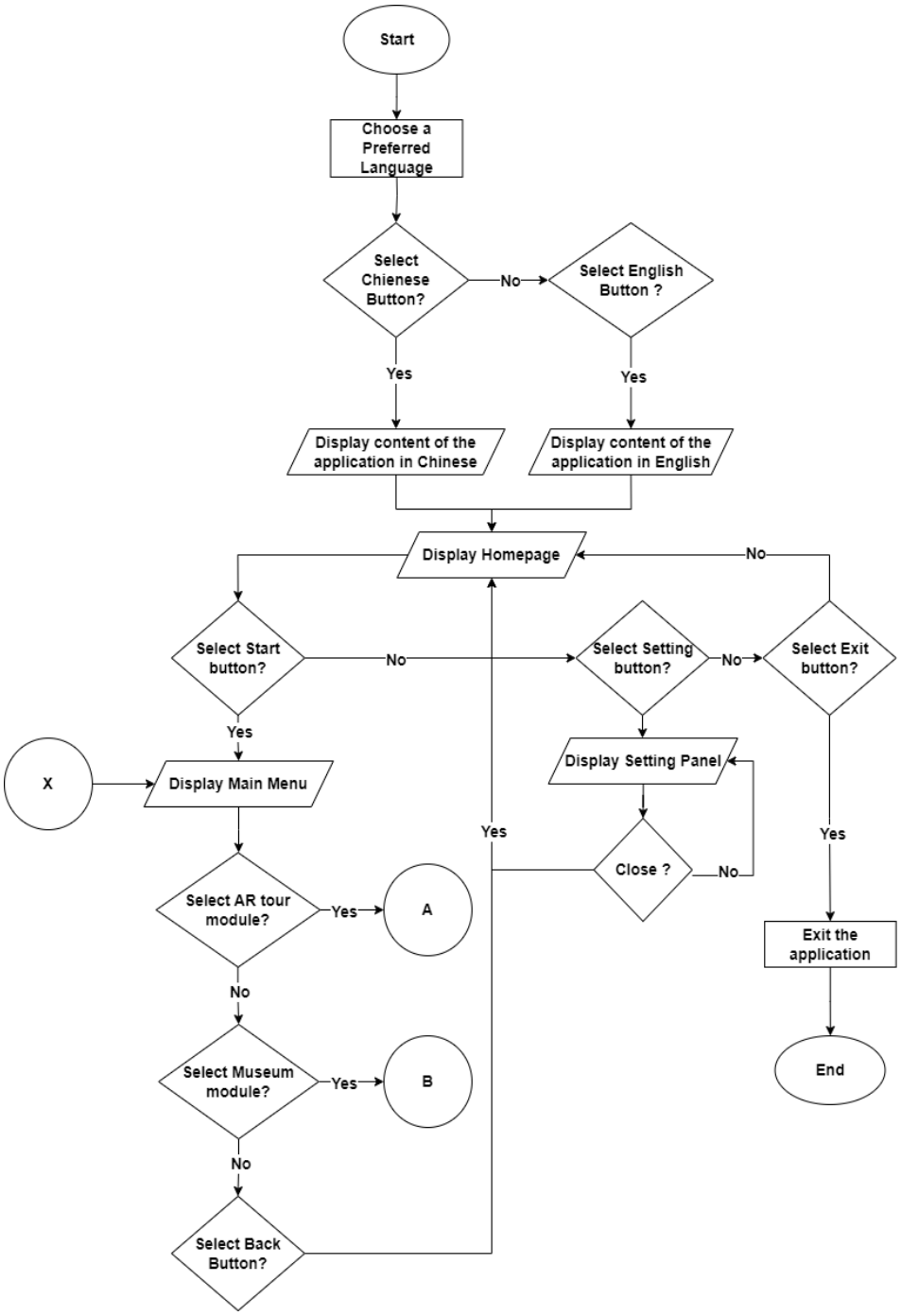


**Fig. 7** System Flowchart for Main System

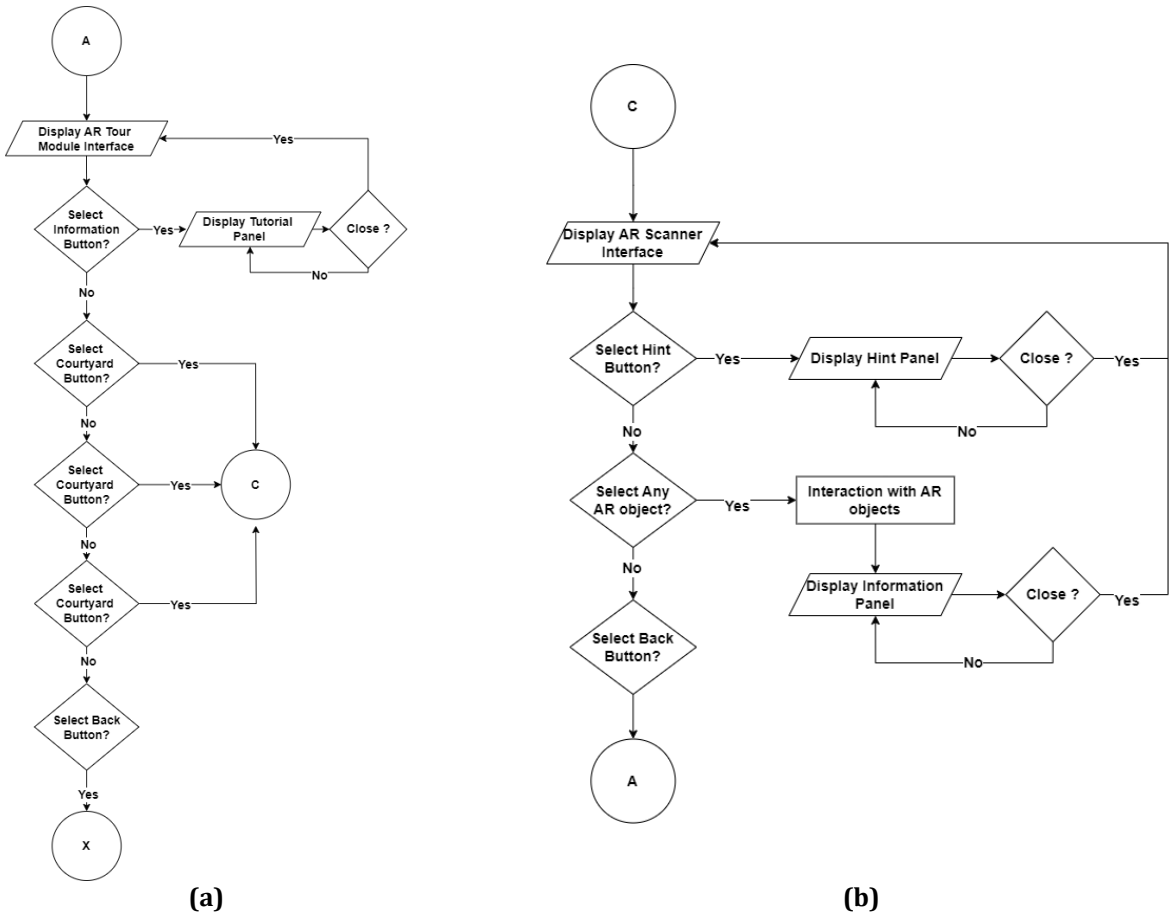


**Fig. 8** System Flowchart (a) AR Tour Module, (b) AR Scene

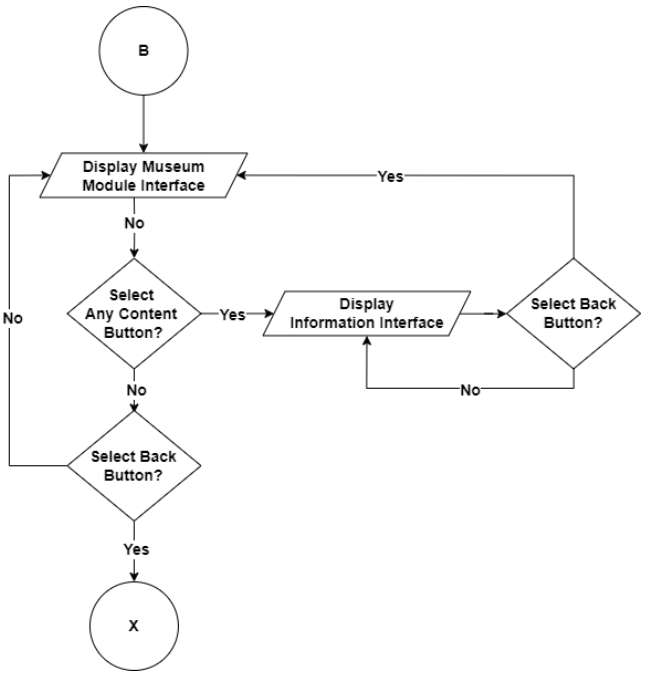


**Fig. 9** System Flowchart for Museum Module