The University of Hong Kong

Department of Computer Science

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Project Plan

Sharing the Past with the Public: Augmented Reality User Experiences at Archaeological Sites

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1 Introduction

APSAP (Ararat Plan Southeast Archaeological Project) Team and development team, **Humen Chau,** and **Ada Au** wish to develop an application that acts as a gamified Extended Reality learning on mobile and HoloLens.

Our project aims to test various types of AR devices, such as smartphones, Microsoft HoloLens, and Meta Quest Pro, to determine which offers the best user experience. We plan to conduct tests outdoors and then develop apps that will guide tourists around archaeological sites. These devices should have spatial awareness, such as GPS or the ability to scan their surroundings. All the archaeological data is geolocated accurately so that we can place reconstructed models precisely on the site. XR technology can offer immersive experiences in archaeological education, from the arts and humanities to technology. 3D models provide interaction opportunities for tourists, academics, and future archaeologists to experience the finds of archaeological work as if still on an excavation site. Our goal is to create an application for mobile and Microsoft HoloLens 2 that acts like a time machine, enabling the public to excavate ancient sites anywhere and anytime.

This is a part of the ongoing APSAP supervised by Dr. Peter Cobb from the Faculty of Arts at HKU. That field project collects significant 3D data at an ancient site in the country of Armenia. They are also making interpreted reconstructions of the ruins of fortification walls and buildings at that site. They would like to share these reconstructions with tourists, schoolchildren, and other public members who visit the archaeological site in Armenia. They believe the best way to do this would be to use Augmented or Mixed Reality devices and headsets. In that way, the people visiting the site would see how the site looked thousands of years ago. They may also have video and audio tours from experts built into the device, which could be guided by GPS.

This paper first introduces the overview and objectives in Section 2. Section 3 demonstrates the functionalities and features included in the application. Section 4 discusses the development tools and techniques used in this project and analyses their advantages by comparisons between their players in the same industry and includes the pre-requirement. Section 5 shows the predictable challenges and discusses the possible solutions or alternative plans. Section 6 demonstrates the schedule, milestones and expected interim outputs for each phase.

2 Objectives

2.1 Scope of Work

The goal of the collaboration between the Parties is to create *Sharing the Past with the Public: Augmented Reality User Experience at Archaeological Site* an innovative and educational application with XR technology. It will be operated on Android, IOS and Microsoft HoloLens 2.

This application is meant to encourage the public to understand more about past human history through the lens of archaeology.

The development team, Humen Chau and Ada Au owns the intellectual property, such as plans, methods and processes that are devoted to creating an application.

APSAP Team brings archaeology knowledge, resources, and materials for building the project. These services are crucial for creating an accurate and informative gamified learning environment.

2.1.1 What do we want to accomplish?

i. Enhance their understanding of archaeology through hands-on experience.

ii. Promote public understanding and appreciation of cultural heritage in Armenia through public education and engagement, including tourism.

iii. Facilitate public education in archaeology and cultural heritage.

iv. Digital reconstruction and visualization of the heritage in Vedi Fortress.

v. Encourage the public to explore the Vedi Fortress by tracking down various inspiring virtual cultural heritages and artefacts.

vi. To promote sustainable tourism development in the Vedi River valley.

2.1.2 What do we offer?

i. An immersive experience of the past human society in Vedi Fortress using the mobile application and/or head-mounted display (HMD).

ii. Interactive games with the physical environment of the players.

iii. Interaction with the 3D models that are the replicas of actual artefacts found from the archaeological excavation.

iv. Experiential travel of the archaeological process with a gamified tour, audio guide and geolocator.

v. Personalized tourist preferences and explore options for heritages and buildings.

3 Features

This section focuses on the application design and interactive functions.

3.1 Explore Collections of Artefacts and Heritages

3.1.1 Gallery of Collections of Artefacts and Heritages

The user can browse a set of 2D images of archaeological items on the Home Page which helps give him or her a better look at the item when he first launches the mobile app.

Items are grouped by categories such as antiquity, cultural heritage, archaeological sites, etc.

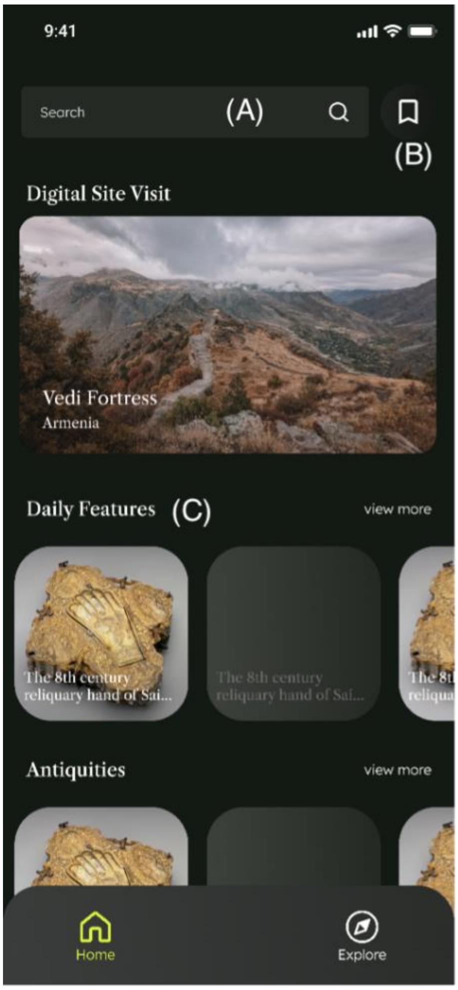


Fig. 1 UI design of the Home Page showing a set of archaeological items. (A) is a search bar that directs the user to the Search Result Page. (B) is a button that directs users to view their bookmarked articles. (C) shows the archaeological items grouped by their categories.

Fig. 1 UI design of page showing items grouped by category of "antiquity".

3.1.2 Informative Yet Attracting Retelling of the Archaeological Items

The texture description of every archaeological item is recommended to have the following sections or features.

NECESSARY	OPTIONAL
- Name - Excavation date or Publish date. - Location	- Story or assumption of the item - Physical description and the relevance between these features and history - Culture and history background/content

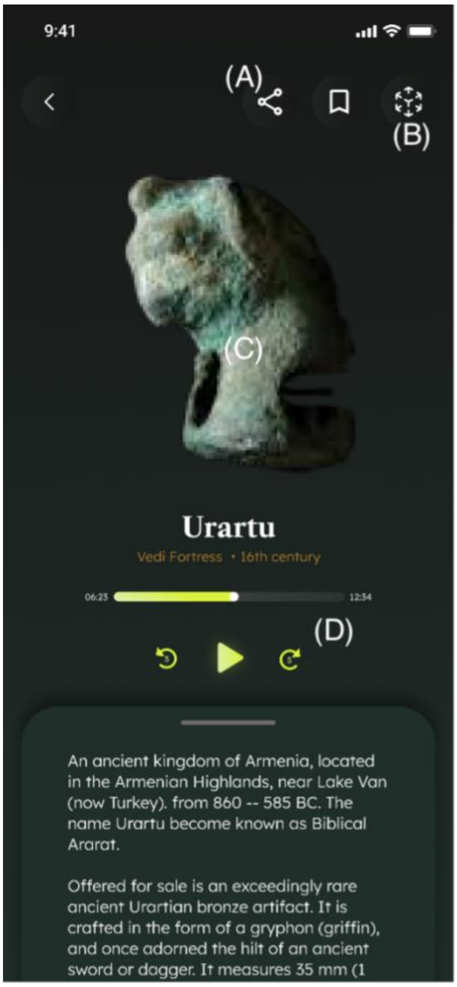


Fig. 2 UI design of Item Detail Page with dynamic 3D model on the top, tool menu on the top right, audio player in the middle and textural description on the bottom. (A) is a share button. (B) is a button that allows users to place this AR model into the physical surroundings. (C) is the 3D model that can be rotated and scaled. (D) is the audio player of the item description.

3.1.3 Digital Reconstruction and Interaction of Heritages

After pressing on the item on the Home Page mentioned in 3.1.2, the user can first interact with, more accurately speaking – rotate, and zoom in and out its 3D model.

AR of Heritages

The app should enable users to cast their browsing items in the physical environment using AR. The AR content can be rotated and scaled, and it is labelled with its accurate dimensions and scales. If time allows, lighting and shadows of AR objects are also what we aspire to accomplish in this application to bring realism and believability.

Fig. 3 UI framework of AR object placement.

3.1.4 Audio Narration

The app offers multimedia for the users to absorb knowledge of archaeology The text is converted into audio narration. Offering audio experiences is expected to ensure emotional experiences and improve engagement.

Due to the limited human resources, it is suggested to implement text-to-speech (TTS) technology to save time on voice acting. For example, Natural Reader can convert text into spoken audio [1].

To explore the full potential of audio narration, an audio player that includes a play/pause button, a seek bar, duration, and progress time, and skip and back buttons is implemented.

3.1.5 Bookmarking

The user can bookmark their favourite items or articles for future reference.

3.1.6 Share With Friends!

Users can share the archaeological objects they think are interesting with their friends via social media and communication platforms.

Two alternatives for sharing content:

	URL	**EXPORT AS PDF**
DES.	A link to the Apple Store/Google Store/ website of the application's introduction.	It is exported as a .pdf file that consists of the 2D image and textural description.
PROS	Raise the traffic and reach of the app	Preserve most information provided in the app

Given that no web domain is registered for APSAP, deep linking of applications is hardly implemented, and thereby the URL. The second method will be used unless a domain for the application is registered by APSAP.

3.1.7 Search Engine

It enables users to filter the items according to the keyword. The user can also sort the result items by relevance, date, and location.

Fig. 4 UI design of Search Result Page

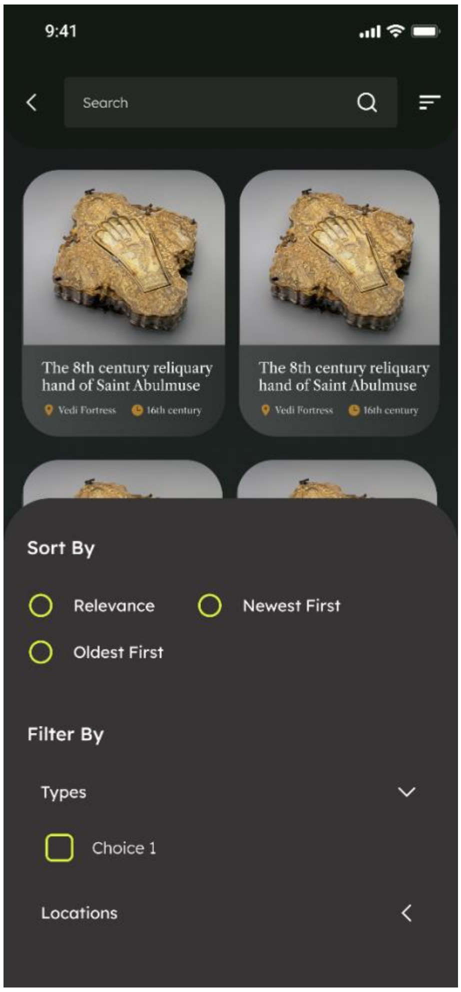


Fig. 5 Filter and sorting panel on the Search Result Page

3.2 Location-based Augmented Reality Exploration in Vedi Fortress

3.2.1 Choices of Route Difficulty

At the beginning of the tour, the user should be able to choose a route. The app should present an overview including the total length of the route, path on a map, theme or storyline and difficulty.

During the development stage, it is recommended to initially implement a single route to facilitate testing all functionalities mentioned below. Once these functionalities have been tested and configured for stability, additional paths can be added as required.

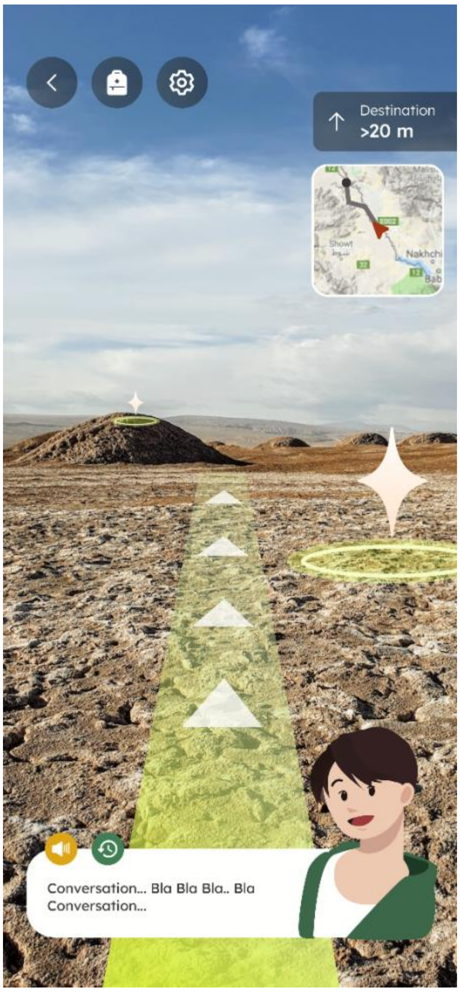
Two alternatives to display choices:

	REAL-WORLD RELATED	**FIXED TO SCREEN SPACE**
DES.	Choices are floating and located around the users. Users rotate themselves to view the options one by one.	Choices are fixed to the centre of the screen. Users swipe horizontally on the screen to view the options one by one.
PROS	- Enhance the immersion experience. - Cross-platform available	- Clear display of information
CONS	- Accuracy of the position and readability are concerns.	- Not workable for HMD

3.2.2 AR Navigation with GPS

This application should bring the users spatial awareness of the environment by introducing a geolocator such as Google Maps, Mapbox and OpenStreetMap APIs, and a site map as an interface that can be accessed at any stage during the exploration.

AR arrows are applied to guide the users to the nearby archaeological items or ultimate destination.



Fig, 6 UI design of AR exploration page (portrait) with a simple floating site map

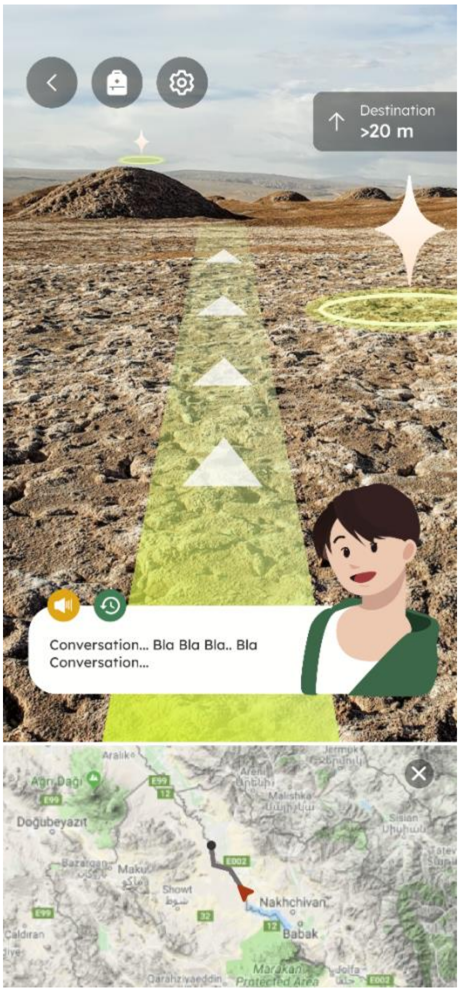


Fig. 7 UI design of AR exploration page (portrait) showing detailed map after tapping the floating map in Figure 7

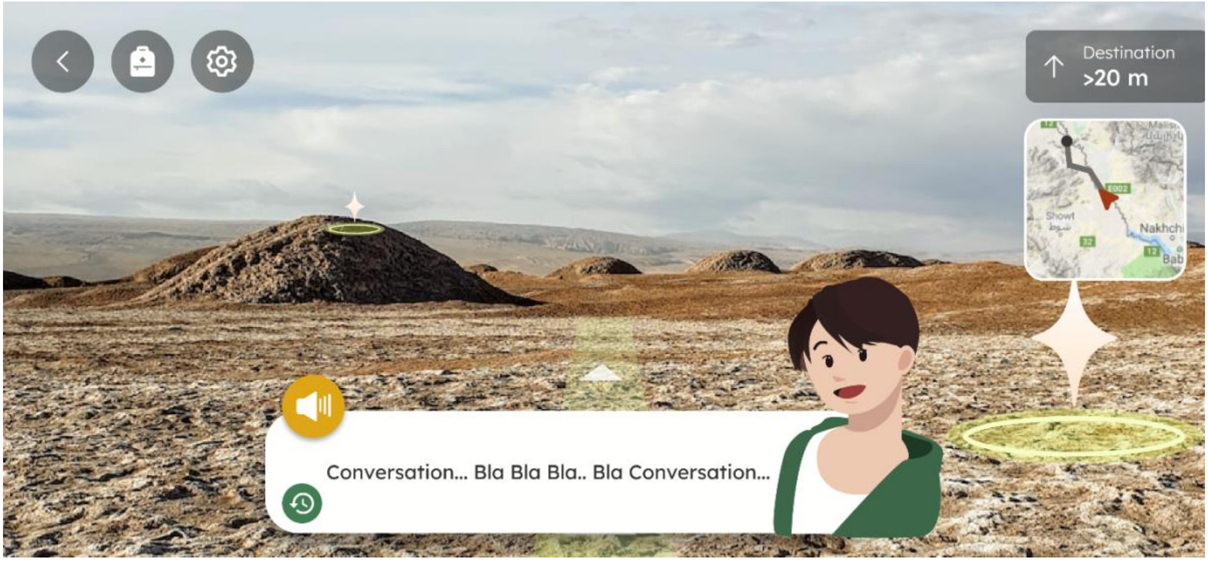


Fig. 8 UI design of AR exploration page (landscape) with a simple floating site map

Fig. 9 UI design of AR exploration page (landscape) showing detailed map after tapping the floating map in Figure 8

3.2.3 Real-time and Approximate Distance between the User and Targets

User can receive in-app help notification or hint about the distance between themselves and the nearby location anchors.

Given that the accuracy of the geolocation is always the biggest issue for location-based AR [2], it is suggested to show a description of range distance as a trade-off between stability and precision. For instance, 1-20 meters away is round-off as >20 meters.

3.2.4 Storytelling and NPC Interactions

To keep the sense of engagement, menu-driven conversations are adopted for the interaction between NPCs and the users. Menu-driven conversations are operated by making choices from different menus and options rather than by giving instructions on a keyboard.

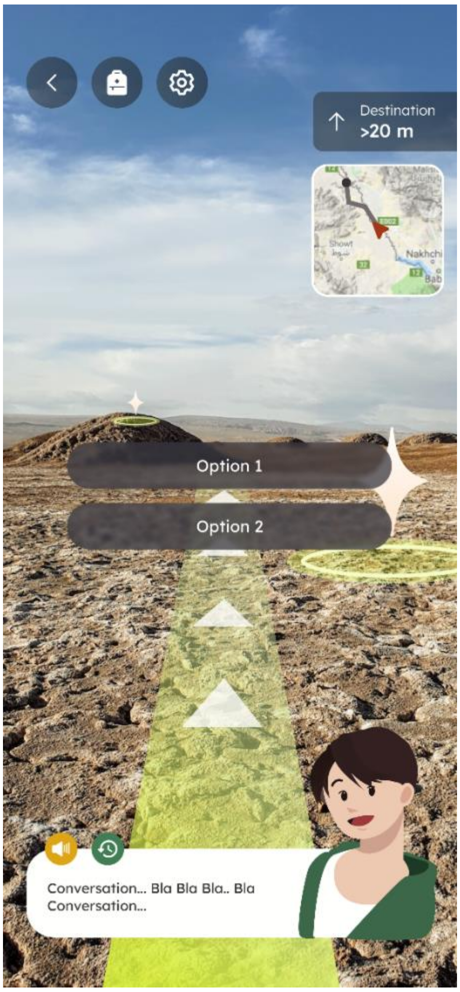


Fig. 10 Pop-up of conversation options during an important story event

3.2.5 Audio Guiding and Introduction

During the journey, users are guided by visual and audio cues from the NPC, who also helps advance the storylines.

3.2.6 Discovery of Heritages

Rendering Effects

Users can have fun of "treasure hunting" during the exploration. Artefacts are hidden across Vedi Fortress and users must find them as their mission. AR artefacts are first presented as a sparkle maker with an interaction radius shown as a circle under it. When the player gets near the location of the AR artefact, the maker transforms into the 3D model on a 1:1 scale.

Interactions

After reaching the interaction distance of the archaeological item, the player can collect it by touching it on the screen in the mobile application and touching it by hand when wearing an HMD.

It is an individual gamified location-based AR learning, that is the behaviour of other users will not affect each other in the AR space.

Fig. 11 UI design of user's collection during exploration

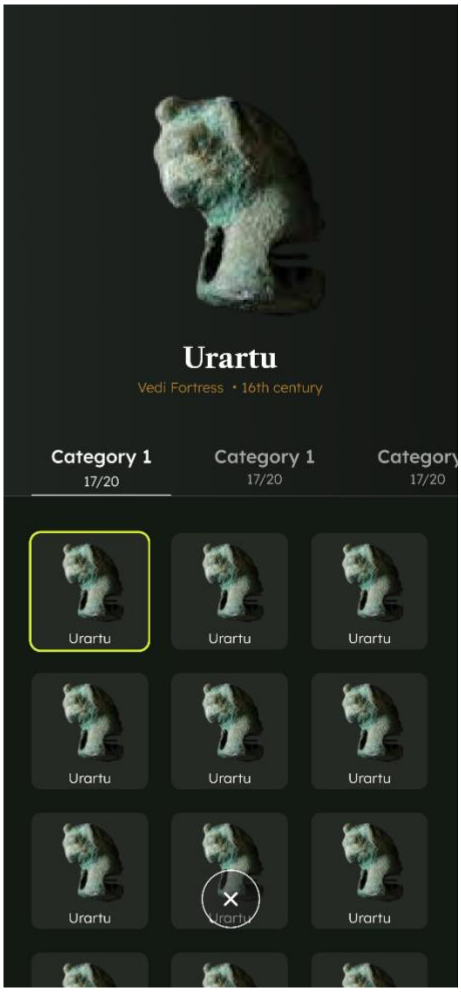


Fig. 12 UI design of browsing item in the collection after selection in Figure 12

3.2.7 Digital Reconstruction of Historic Buildings/Sites

Each reconstruction of archaeological sites along the Vedi Fortress valley is triggered once a site is reached.

A practical handbook was written on gamification and a game-based approach to cultural heritage by CINE (Connected Culture and Natural Heritage in a Northern Environment) which developed several projects that transform people's experiences of outdoor heritage sites through technology, building on the idea of "museums without walls". [3] It is a good reference for this project and can be found on cinecommunities.org and cinegamification.com.

3.2.8 Instructional Coaching the User How to Interact with the GUI

This application is supposed to be innovative and integrated with the game elements and is designed to be open for all-kind and all-aged users. Considering some groups of users might not have experience in AR game-based applications, it is suggested to implement an in-app tutorial and tooltips. New users must go through the tutorial as they enter the Explore Page for the first time.

4 Methodology

This section focuses on the techniques and development platforms used during app creation and discusses the reason for using these tools by analysing their advantages or comparison with others. It also mentions the prerequisites for this project.

4.1 Front End and Mobile Framework

Considering Android and IOS are our mobile development environments, **React Native** is used to make it cross-platform and maintain consistency in design. To simplify the connection between IOS and Android SDKs, **Expo**, which is a bundle with tools and services built for React Native, [4] is utilized. Meanwhile, **Three.js** which is a JavaScript library and API used to create and display 3D models is implemented.

The reasons for using React Native are firstly it provides a set of built-in components and is supported by various UI libraries that can save us time; secondly, the Internet has more resources and tutorials on integration of React Native and **Unity**, which is a game engine used in this project.

4.2 AR Game

Unity is a reliable game development platform. It has well-structured documentation for AR game development and the following scripting APIs to achieve the app's AR features mentioned in 3.1.3, 3.2.6 and 3.2.7.

Light Estimation

Light Estimation detects real-world lighting by the AR camera and camera in devices. The AR object can then be lit by the directional light. However, it should be aware that the light detections are dependent on the device's hardware. Not all the devices are available with this function.

Plane Detection

Plane detection finds horizontal or vertical flat surfaces in the physical surroundings. [5] This application accesses the device's camera for detection.

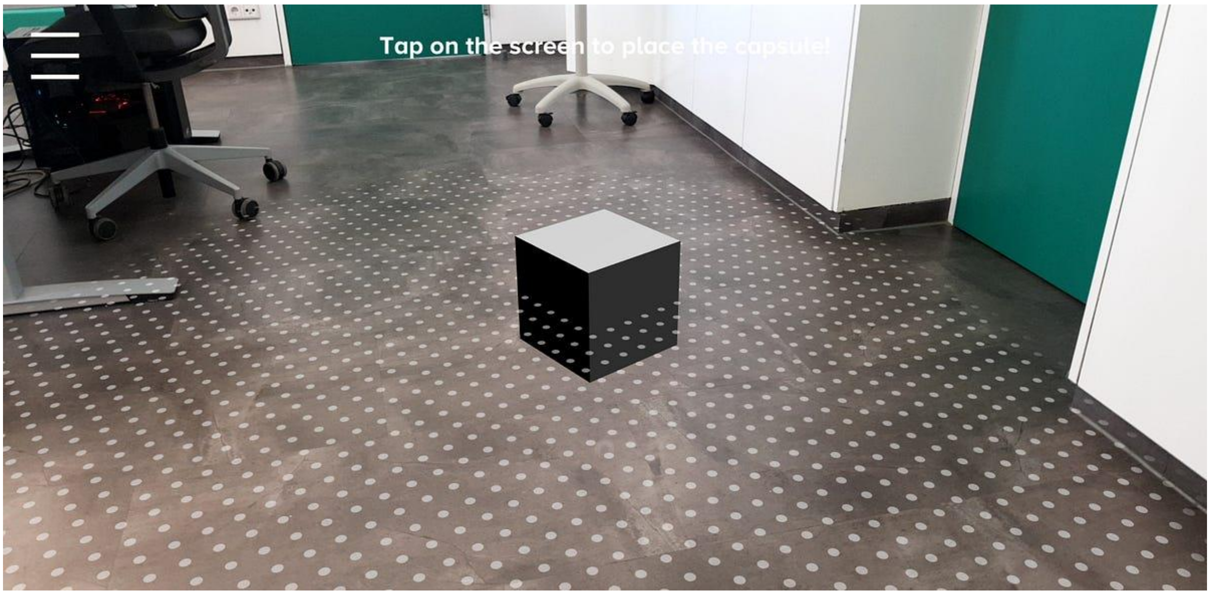


Figure 13 Plane detection with Plan Mesh in Unity Product [6]

Object Placement

After plane detection, a mesh is projected on planes and the AR objects are then placed on the mesh by touching on mobile screen.

Hand Tracking and Hand Gesture Recognition

Most interactive functions such as object scaling, collection and placement are planned to rely on hand gestures such as pinching with two fingers, grabbing by holding a fist and touching by pointing the index finger.

Unity is chosen as the game development framework despite Unreal Engine showing a better performance in visual effects and rendering. The major reason is that Unreal Engine has only Pixel Streaming for integration of the application and React-native, or other mobile development framework. According to the document of Unreal Engine, Pixel Streaming is a video streaming of packaged Unreal Engine applications on different platforms using an online streaming service. [7] It requires a web hosting service that might add additional burdens on performance.

4.3 Map Services

Mapbox, which is a geolocator information service like Google Maps, is chosen for the navigation and geolocator mentioned in 3.2.1 - 3.2.3. According to its document, its maps and location data are optimized for Unity. [8]

Navigation Service

It provides **Directions API** which supports the user's location tracking, and pedestrian routing and calculates the shortest path by using sidewalks and trails. The routing-related information such as distances and estimated time can be visualized as a notification or banner instruction by Directions API. [8]

Map Service

It offers **Maps Service** which allows the app to request map tiles for displaying a 2D site map based on user geolocation and visualizing location anchors.

4.4 Database Management System and Backend

Considering the enormous data including but not limited to 3D models, 2D images and pieces of literature on archaeological items being stored in a database, **MongoDB**, a NoSQL database, is used rather than Firebase. According to the nature of this application, it heavily depends on querying a database instead of data calculation and analysis and real-time calculation, such as the geolocation of object placement made by the user and distance between the user and targets during the exploration, will not be stored in the database, and thus customized API endpoints should not be difficult.

This project should prioritize the data storage and MongoDB outweighs Firebase for its high performance in manipulating massive data. [14 - 16] Besides, MongoDB as a NoSQL database offers data in JSON format which helps in faster data interchange and web service results. Moreover, when it comes to storing and retrieving 2D images and 3D models, MongoDB offers **GridFS**. This system enables the storage and retrieval of large documents in BSON format, which is a binary representation of JSON.

4.5 Pre-requirements

This part shows the required materials for this project and these materials are provided by the APSAP team because these materials require professional and accurate information.

4.5.1 Development and Testing Stage

Items	Sub-items	Related Features	QTY.
Cultural heritage	Textual description	3.1.2	≥ 5
	3D models	3.1.3, 3.2.6	
Historic buildings	Textual description	3.1.2	≥1
	3D models	3.1.3, 3.2.7	
NPCs	Characteristics, background, features, role, etc.	3.2.4	≥1
	Voice acting	3.2.4, 3.2.5	
Story	Game script: Text parsing and menu-driven NPC conversations	3.2.4	1
	Storyline and background		
	Player's missions		
User test cases		App performance testing and bug detection	TBD

4.5.2 Implementation Stage

Items	Sub-items	Related Features	QTY.
Cultural heritage	Textual description	3.1.2	≥ 10
	3D models	3.1.3, 3.2.6	

	Latitude, longitude, and altitude	3.2.6	
Historic buildings	Textual description	3.1.2	≥1
	3D models	3.1.3, 3.2.7	
	Latitude, longitude and altitude	3.2.7	
NPCs	Characteristics, background, features, role, etc	3.2.4	≥1
	Voice acting	3.2.4, 3.2.5	
Story	Game script: Text parsing and menu-driven NPC conversations	3.2.4	1
	Storyline and background		

5 Foreseeable Challenges

5.1 User Behaviour Differences between Mobile and HMD

The user behaviour differences during the design and keeping the consistency of the UI and UX at the same time must be taken into consideration. For instance, when mobile users see an item on the screen, their first reaction is most likely to touch it with a finger; meanwhile, users wearing HMD might first come close to the target and have a close look at it. Our initial solution is to code different approaches for each kind of device.

The spatial UX design in an HMD is also of concern. The 2D interface in the mobile device, a.k.a., the handheld device, is fixed in position steadily. It will be challenging to achieve the same stability in an HMD because it needs tracking of the user's sight and matching AR space into the physical environment, and the UI must move according to the user's view and movement speed to preserve a feeling of "fixed". Minimising the displacement of the GUI due to the head and body movement of users is an unavoidable obstacle. Besides, being blocked by the interface is a danger for the user experiencing outdoor AR. A hand menu developed by the Microsoft Team is thereby recommended presenting some tools and GUI. [9]

5.2 No Default GPS in HMD

HMDs are designed for indoor environments due to security concerns and do not have GPS support. A possible solution is to pair the Microsoft HoloLens 2 with Bluetooth devices and get their location [10].

5.3 Accuracy in Geolocations of AR Objects and Users

The key challenge to building a location-based AR application lies in maintaining the accuracy of the geolocation [2]. Especially for objects that have dimensions smaller than meters, it is difficult for the GPS to position them at a precise and correct location. The displacement of the AR objects can be severe, such as floating items flying in the sky and whole items getting buried under the ground. In the worst case, if several attempts at fixing or applying algorithms cannot solve the issue, switching to marker-based AR, which involves scanning a marker like a QR code or physical image to activate an augmented experience would be considered.

6 Schedule and Milestones

Date	Milestones
Sep 2023	Meet with the project supervisors
	Set up a project proposal
	Draft UI designs
	Project web page
Oct	Finalized system architecture design
	Finalize UI designs
	Complete basic front-end
	Set up database schema
Nov	Prepare static assets including audio and 3D models
	Implementation of Unity with AR Core, AR Foundation, and Mapbox APIs
Dec	Complete basic app features
Jan 2024	First-stage deliverables and presentation
	Interim report
Feb	Complete all app features
	Application on HoloLens
Mar	Final User Acceptance Testing
	Debug and Fine-tune of app
Apr	Finalized project web page
	Final report
	Final presentation

Phases and Desired Delivers

This project has six stages – planning, analysis, design, development, testing, and implementation.

During the first three weeks of the project, the development team is expected to propose a draft plan to the APSAP team. The necessity, feasibility, and suitability of each feature designed for the project based on the APSAP team's requirements should be discussed. After analyzing the requirements, the development team will identify the most suitable technical tools and system architecture. This will involve designing the front end, which includes user flow charts and UI, and the back end, which includes database schema, and SDKs. Before September 2023, a meeting will be held between the developers and the APSAP team to discuss the UI design.

In October, the development team should deliver the application having all basic front-end except AR exploration for the APSAP team to test the fundamental user experience and finalize the UI. Since then, a progress report announcement or meeting every two weeks shall be held by the development team and the APSAP team. Features and functionalities applied, challenges encountered, and solutions are expected in the report.

By December, the development team should deliver at least one demo app that contains all basic functionalities and part of the AR exploration features.

In February 2024, all features in the mobile application should be completed and ready for implementing real datasets that are the cultural heritages with actual locations in the Vedi Fortress. At the same time, the application will be deployed to HoloLens. Remote usability and beta testing

Section Summary*

Weeks	Phases	Outputs
04 Sep - 17 Sep	**Planning**	Project proposal, project plan, and UI design draft
	Analysis	
	Design	
18 Sep - 30 Sep	**1st Development**	Basic front-end
	Testing	Finalized UI design according to the feedback
1 Oct - 28 Oct	**2nd Development**	All basic features related to the previous front-end
	Testing	Collection of heritages
29 Oct - 18 Nov	**3rd Development**	Part of AR features
	Testing	The realism of AR, geolocator and navigator
24 Dec - 13 Jan	**4th Development**	Part of AR features
	Testing	AR placement, NPC interactions and audio
14 Jan - 17 Feb	**5th Development**	Improve mobile app performance, application to HoloLens
18 Feb - 17 Mar	**Implementation**	Application on mobile and HoloLens
	Testing	Geolocation of AR contents/items, and adventure routes

* The development activities and outputs are subject to changes and any changes will be announced to the APSA team.

7 Bibliography

[1] "AI Voice - Natural Reader," NaturalSoft Ltd., [Online]. Available: https://www.naturalreaders.com/. [Accessed 3 Sep 2023].

[2] Ryohei Hashimoto, Michael Cohen, "Outdoor Navigation System by AR," 2021. [Online]. Available: https://www.shs-conferences.org/articles/shsconf/pdf/2021/13/shsconf_etltc2021_04002.pdf. [Accessed 4 Sep 2023].

[3] "CINE see the past image the future," 2020. [Online]. Available: https://cine.interreg-npa.eu/.

[4] "Expo," 2023. [Online]. Available: https://expo.dev/. [Accessed 12 Sep 2023].

[5] U. Technologies, "Configuring Plane Detection for AR Foundation," Unity, 29 Dec 2020. [Online]. Available: https://learn.unity.com/tutorial/configuring-plane-detection-for-ar-foundation#. [Accessed 14 Sep 2023].

[6] T. Muthappa, "AR Fundamentals: Plane Detection," 1 Aug 2021. [Online]. Available: https://medium.com/codechef-vit/ar-fundamentals-plane-detection-4c128576b98c. [Accessed 16 Sep 2023].

[7] "Pixel Streaming," Unreal Engine, [Online]. Available: https://docs.unrealengine.com/5.3/en-US/pixel-streaming-in-unreal-engine/. [Accessed 1 Sep 2023].

[8] "Mapbox Documentation," Mapbox, [Online]. Available: https://docs.mapbox.com/. [Accessed 15 Sep 2023].

[9] Microsoft, "Hand Menu," Microsoft, 27 May 2021. [Online]. Available: https://learn.microsoft.com/en-us/windows/mixed-reality/design/hand-menu. [Accessed 8 Sep 2023].

[10] Gustavobb, 5 Dec 2022. [Online]. Available: https://github.com/Gustavobb/HoloLens2-Unity-Tutorial#gps.

[11] Estuary, "Firebase vs. MongoDB: Major Differences," 23 May 2023. [Online]. Available: https://estuary.dev/firebase-vs-mongodb/. [Accessed 16 9 2023].

[12] D. Fortes, "Unity AR+GPS Location Docs," 2020. [Online]. Available: https://docs.unity-ar-gps-location.com/. [Accessed 5 Sep 2023].

[13] R. Kazmi, "How Location-Based Augmented Reality Is Creating App Experiences," 1 Aug 2023. [Online]. Available: https://www.koombea.com/blog/location-based-augmented-reality-creating-app-experiences/.

[14] R. Sharma, "Firebase Vs MongoDB: Difference Between Firebase & MongoDB," 18 Jun 2023. [Online]. Available: https://www.upgrad.com/blog/firebase-vs-mongodb/. [Accessed 16 Sep 2023].

[15] M. Tech, "MongoDB vs Firebase: Which Is The Best Database In 2022," 1 Jun 2022. [Online]. Available: https://medium.com/mqos-technologies/mongodb-vs-firebase-which-is-the-best-database-in-2022-aff873566586. [Accessed 16 Sep 2023].

[16] "Tracking Geographic Locations in AR," Apple, [Online]. Available: https://developer.apple.com/documentation/arkit/arkit_in_ios/content_anchors/tracking_geographic_locations_in_ar. [Accessed 8 Sep 2023].