
TECHNISCHE UNIVERSITÄT BERLIN

# Augmented Reality Research Report

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Contents

# Abstract

In the course of the semester, research is done on recent Augmented Reality (AR) technologies for Unity in order to create an application aimed at contributing to tourism. The research includes a variety of functions of AR packages for Unity such as but not limited to face recognition, image recognition, plane detection, and anchors. In addition, geo-positioning using Global Positioning System (GPS) has been looked into for the application. However, due to the lack of open source information, a package for GPS locationing has been bought and used for the application. At the end of the research, an app for a treasure hunt of selected touristic places in Berlin -called Berlin Hunt- has been designed and implemented. Unfortunately, due to lack of time and resources, the application could not reach the testing stage as it was not functioning in the required way. However, documents regarding the testing stage and ideas on possible problem solutions are shared in the report.


# Introduction

The project had two main stages: a research stage and an implementation stage. The research stage was given four months and the implementation stage was given three weeks. The research stage aimed at discovering different abilities given to the users in open source programming with Unity with a focus on augmented reality. At the end of the research period, the goal was to know which type of new AR technologies can be used for an app for touristic purposes and then designing a prototype for such an application.

The organisation of the project is explained in the section with the title “Organisation”. This section includes information regarding the goal of the whole project, the tools required and used during the project period, and the detailed time schedule of the project.

There were small projects testing different fields of augmented reality such as but not limited to face recognition, image recognition, plane detection, and anchors. The small projects are explained and depicted with figures in the background research section of the report. Then the game’s design and development structure is shared. Following with the current problems and proposals of the game. The testing part includes information on the prepared questionnaires with further suggestions.

# Organisation

## Goal

The main goal of the project is to explore the available technologies on AR that can be used to create a game aimed at enhancing tourism. Therefore, most of the project period is designated for researching AR tools of Unity and understanding the technologies and their limitations.

After comprehending what can and cannot be achieved with the current accessible tools, the product is decided to be a game centered in Berlin that has AR generated objects around the touristic sites which will provide further information about the location. In addition, the product also has guiding AR generated objects to keep the users on the correct path to the next tourist location. In addition, the guiding objects would use voice commands or notifications to attract the attention of the user. Since the product has similar game mechanics to a treasure hunt game, it is called “Berlin Hunt”.

After the product is completed, the game is planned to be tested by the residents of an Erasmus student dormitory. Hence, getting the feedback of a variety of people from different cultures and age groups who are not native to the city but are familiar to most places. Therefore, they can benefit from the app and compare it to their own touristic experience.

## Tools Used

Many tools are used for the development of the project and to keep the communication with the responsible research assistants and professeur. For the communication with superiors Skype is used for synchronous communication and email is used for asynchronous communication. In addition, biweekly meetings are arranged (with some exceptions in the month June) with Google Calendar. The tools required for the development environment are Unity Game Engine 2020.3.0f1 with Android integration SDK and an Android mobile phone which has an Android version lower than 11 because the Android 11 version is not fully compatible with the Unity Engine yet. The packages required for the game development is listed as follows:

- AR Foundation 4.0.12
- ARCore XR plugin 4.0.12
- ARKit XR plugin 4.0.12
- AR + GPS Location 3.5.5 by Daniel Fortes [1]
- Animated PBR Chest Demo 1.01 by quiArt [2] (optional)

It is important to mention that the versions given here are the latest versions available during the time period for the research. The compatibility and functionality of older or newer versions might or might not work as well. It has not been experimented.

## Schedule

The research period was four months and the development stage was a month. There is a detailed timetable with deadlines and a Gantt chart to show the length of the processes for the development stage. A tool named Miro is used to produce the Gantt chart. The link to the chart in this tool is given in the references part of this report with the reference number stated in the figure description.

| Stage / Activities | Deadlines |
|---|---|
| Completion of Game Mechanics | 05.08.2021 |
| Completion of the Game with Media | 13.08.2021 |
| Preparation of Questionnaires | 16.08.2021 |
| Testing | 22.08.2021 |
| Report Completion and Presentation | 27.08.2021 |
| Grade Submission for Home University | 27.08.2021 |

Table 1: Deadlines for stages in the development stage


Figure 1: Gantt chart for showing the process length of the activities during the development stage [3]

The coloring in the Gantt chart represents different qualities of the reserved time periods. The color orange represents main stages, whereas the yellow-green color shows buffers. Furthermore, the purple color gives extra information that is not related directly with the development but can affect the development stage.

# Product Details

## Background Research

The beginning point for Augmented Reality research started with plane detection. An indicator was made to follow planes and when touched it would create a game object (a spider in this case) on the location.

Figure 2: Three arbitrary screenshots that show the indicator move and then generate an object.

After the comprehension of the plane detection system, the research shifted towards face detection and AR with front camera. In addition, switching between cameras (front and back) are also learned.

Figure 3: A face mask put on the recognised and detected face on the front camera.

Afterwards the research continued with image processing. It is found that images of objects are easily found and tracked. However, images of big objects like buildings do not give trustable results. Angle changes, shadows and lighting changes on the images are hard to be recognised by the current AR plugin of Unity. However, different QR codes are distinguished between each other even though they are two similar images which explains the attention the processor gives to the details of the images.


Figure 4: Successfully tracked images with an object instantiated on top of the image.

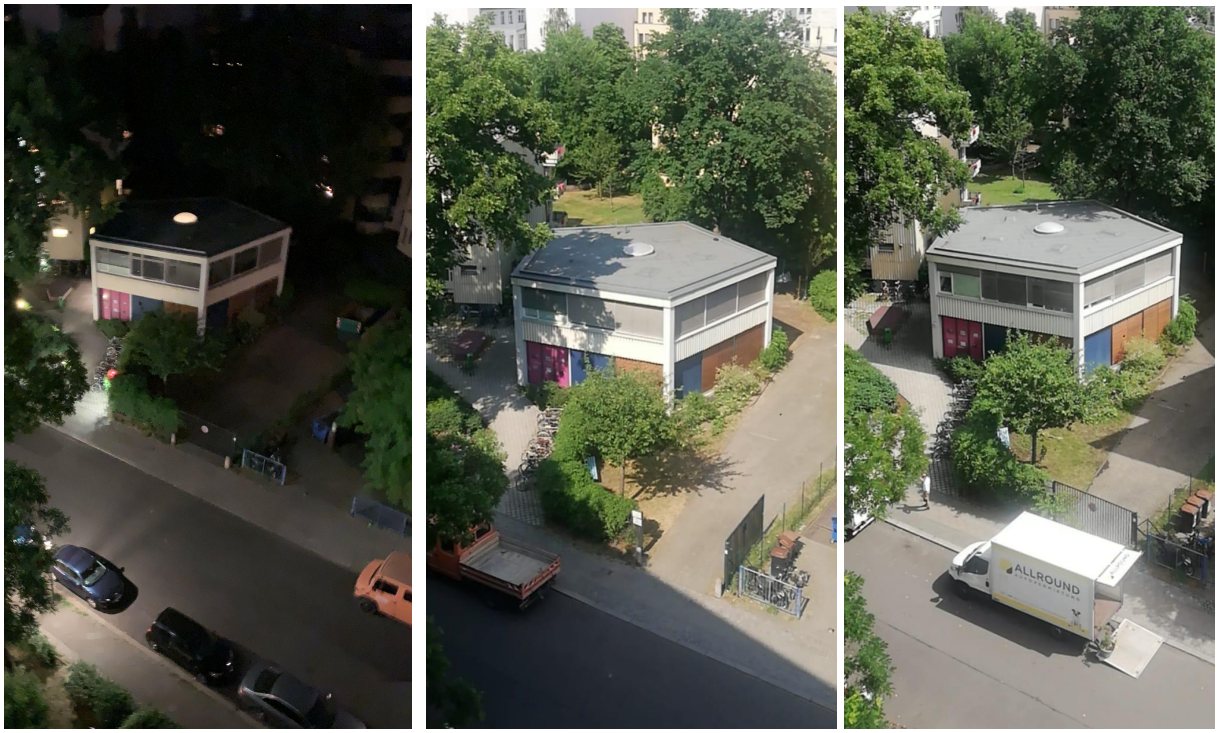


Figure 5: Unsuccessful finds of the image of the same building in the same angle but different lights.

The research phase continues with the comprehension of anchors. Anchors ensure that objects appear to stay at the same position and orientation in space, helping you maintain the illusion of virtual objects placed in the real world. [4][5] These objects have permanent world coordinate positions and can spawn multiple instances at the same time but many anchors would slow down the application. The lighting of the environment does not affect the location of the objects once they are already instantiated.

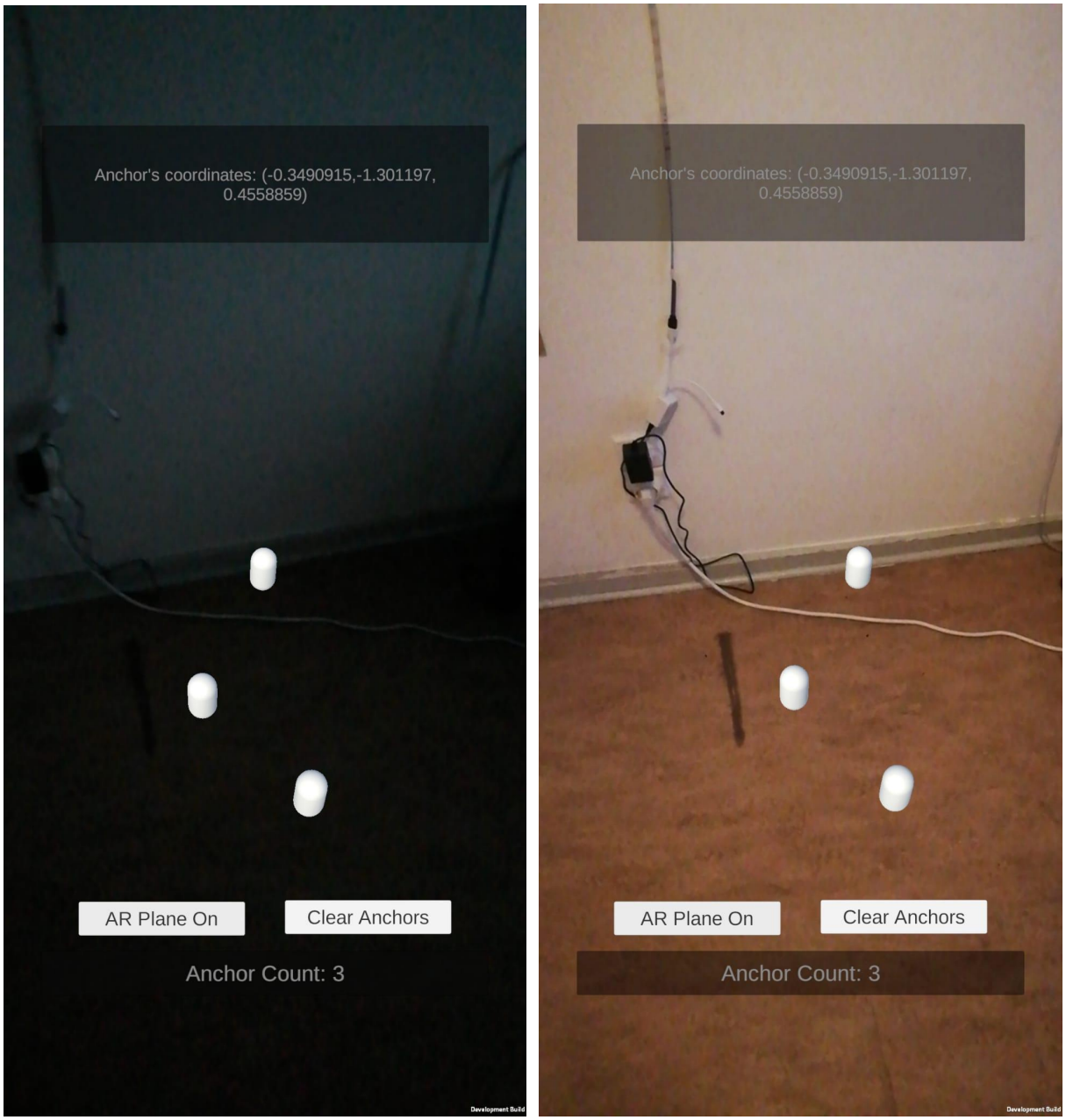


Figure 6: Two screenshots of anchored three objects in different lighting.

The research stage ends with the unsuccessful attempts of generating objects with their GPS coordinates. Resulting in the purchase of the AR+GPS Location package from Unity's Asset Store.

## Game Design

The designing stage of the game started with a storyline for the product. After the storyline for Berlin Hunt was created, a more clear vision for the app was formed. Then, a four screen method was used to visualize the user interface (UI) of the game. The complete storyline with the app logo and the four screen method is provided below.

### Logo


Figure 7: The logo of the game Berlin Hunt

### Storyline

Berlin is a beautiful, multicultural and colorful city that has over 150 museums! Exploring everywhere in Berlin would take a lot of time. However, if you are in Berlin for a short visit and want to see the best places without spending a lot of time on research, the Berlin Hunt is the best app for you! Berlin Hunt will put you in a treasure hunt adventure in Berlin that will show you all the hidden and not so hidden treasures of Berlin!

In Berlin Hunt, the user will be given a choice to select a starting point in Berlin to begin your hunting adventure. After selecting your starting point, the user will be provided with the distance to the closest treasure and a path of arrows that will guide the user to the checkpoint. When the user reaches a checkpoint, the user will be shown a media including information about that touristic place. If the app is not actively running for over ten minutes, the user will be sent a notification to remind them of the hunt. When the user reaches the last treasure, they will have finished the game and will be returned back to the main screen.

Four screen UI method


Figure 8: Four screen method for the storyline for Berlin Hunt

There were also additional remarks and features discussed for the game that were not added to the storyline but were noted for optional if the time period allowed the development. These were:

- Adding audio effects when the user is getting close to -or on the path to- a treasure,
- Sending notifications when the user is close to a treasure if the app is closed,
- Having audio directions such as GPS voice commands.

## Development Process

The development process of the app requires two scenes. First one is a main menu screen, only with a canvas with the logo image and a button to start the game. Due to time constraints the multiple choice start feature and the settings feature were not implemented.

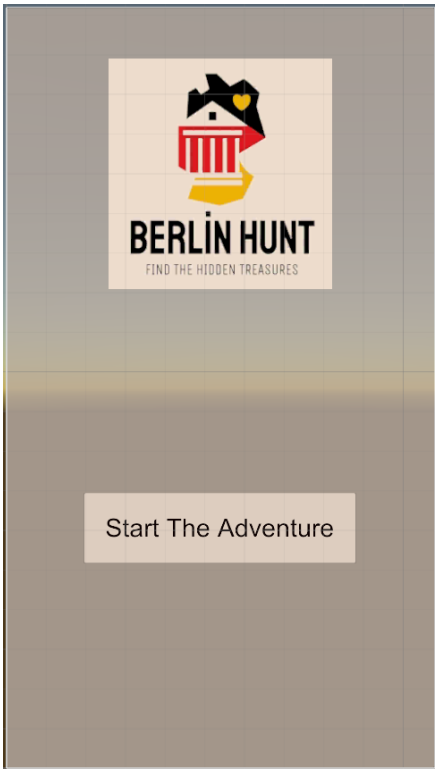


Figure 9: The welcome scene of the application

The second scene is where the game takes place. The back camera of the phone opens with the inclusion of the AR Session Origin in the scene. AR Session Origin also has an AR Floor and ARLocationRoot objects which come with the AR+GPS Location package. AR Floor enables the objects put on the world to have a shadow on the detected planes which adds to the realisticness of the AR vision. The ARLocationRoot provides and tracks the GPS coordinates of the player. The AR Session object is the key element in creating an augmented reality application.


Figure 10: A screenshot of the app interface during testing outside.

Another important object in the scene also comes from the AR+GPS package which is the GPS Stage Object. This game object is used to place game objects to real world coordinates. It has multiple ways of placement: placing an object in one location, placing an object in multiple locations, instantiating an object to move along a given path (by giving the coordinates of different points on the path) with a given speed and time. For Berlin Hunt, placing an object on multiple locations is chosen which has the script name: “Place At Locations”. In addition, an empty game object with a script that provides a text on screen with the closest distance for an arrow or an object is also present in the scene. The scene structure can be observed in the following figure.

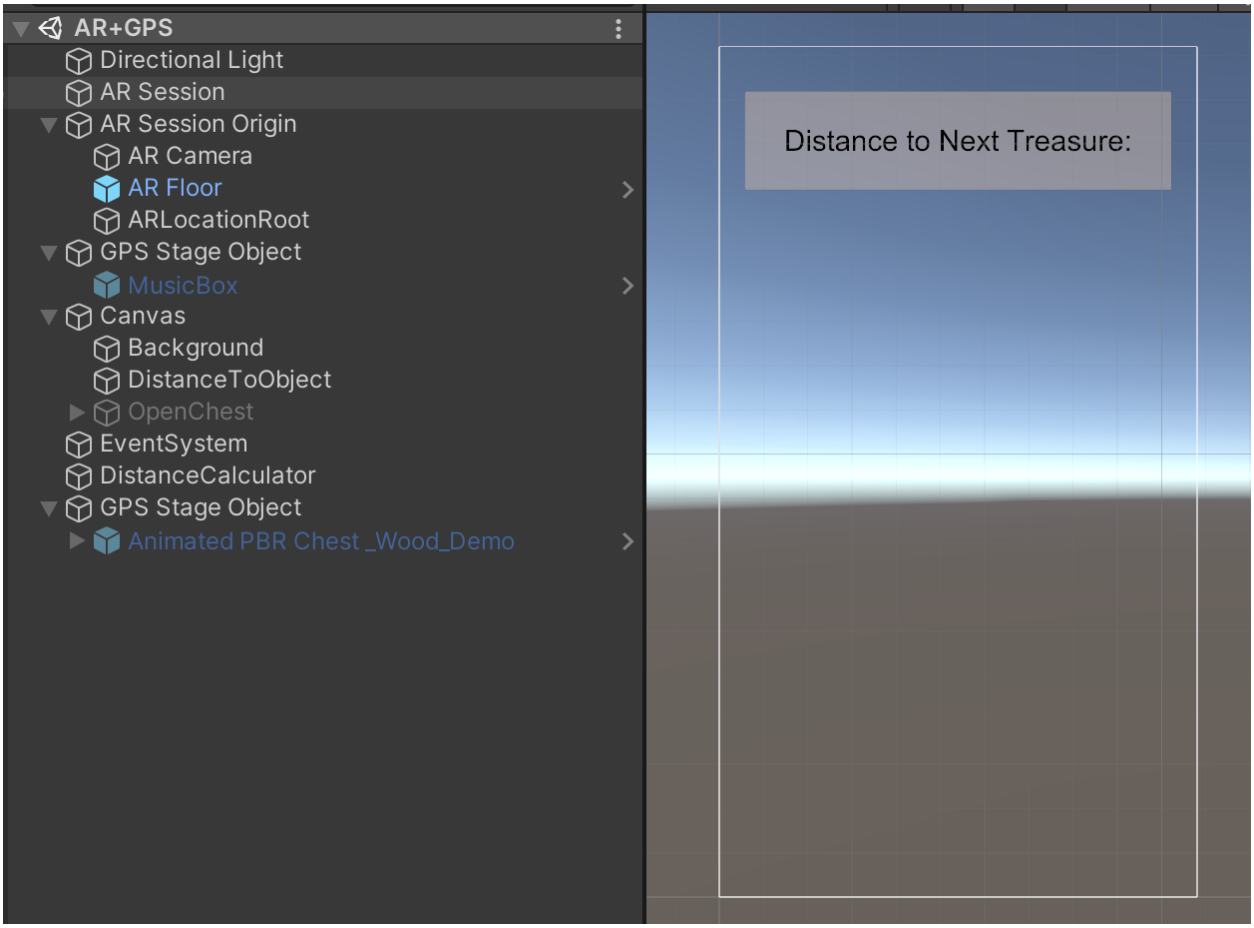


Figure 11: The scene hierarchy and the view of the second scene in Berlin Hunt.

When the player is equal or less than 10 meters away from a treasure, the canvas will show the "Open Chest" button which will open the related URL of the nearby treasure. The treasure locations are given to the GPS Stage Object with the animated chest. The altitude coordinated is decided according to the altitude of the device. These location names, their coordinates and the linked URL is given in the following table.

| Location Name | Coordinates | Video URL |
|---|---|---|
| Brandenburg Gate | 52.516306, 13.378211 | https://www.youtube.com/watch?v=QtDmK1vRIFU&ab_channel=TheTimeTravelArtist |
| Jewish Memorial | 52.514517, 13.377618 | https://www.youtube.com/watch?v=ezrWvlTHpMM&t=3s&ab_channel=RickSteves%27Europe |

| | | |
|---|---|---|
| Tiergarten | 52.516233, 13.377018 | https://www.youtube.com/watch?v=YcKSN8c-Sjg&ab_channel=FramingReality |
| Reichstag | 52.518451, 13.374166 | https://www.youtube.com/watch?v=yZ866HxCyHo&ab_channel=DWNews |
| Führerbunker | 52.512567, 13.380830 | https://www.youtube.com/watch?v=6mHhHSgiJrk&ab_channel=DWNews |
| Potsdamer Platz | 52.509653, 13.375916 | https://www.youtube.com/watch?v=v36rp-F0Ntg&ab_channel=DWNews |
| Gendarmenmarkt | 52.513403, 13.392091 | https://www.youtube.com/watch?v=vi55XA1TP4g&ab_channel=Howcast |
| Berliner Dom | 52.518852, 13.400339 | https://www.youtube.com/watch?v=_wf9IRUJ8qI&ab_channel=Panorama-bSightseeingBerlin |
| Museum Island | 52.520303, 13.399900 | https://www.youtube.com/watch?v=SCBoJLyTCOo&ab_channel=DWNews |
| Berlin Zoo | 52.508246, 13.334560 | https://www.youtube.com/watch?v=lvxDJx8ku3k&ab_channel=Trogain |

Table 2: Treasure location names, coordinates, and linked video urls for the Berlin Hunt.

Apart from the treasures, there are also the arrow objects (named as “MusicBox” in the scene) that direct the user towards treasures. This object can be observed in the following figure. The coordinates of these objects are given to be:

- { 52.515225, 13.377719},
- { 52.516355, 13.378683},
- {52.517183, 13.37742 },
- { 52.51603, 13.373376},
- { 52.517864, 13.370896},
- { 52.519493, 13.373513},
- { 52.512976, 13.377366},

- {52.510941, 13.377118},
- { 52.510125, 13.383741},
- { 52.510576, 13.389212},
- { 52.512192, 13.38972},
- { 52.515986, 13.39296},
- {52.517705, 13.398089},
- { 52.520822, 13.400794}.


Figure 12: Screenshots of the arrow objects in the game taken on a test outside.

Unfortunately, audio messages or commands when close to a treasure or an arrow object are not implemented due to time constraints. The current repository of the project can be found on Github. It can be noted that in the Github repository, there are also other scenes used during the research phase of the project that are not required in the game.

## Problems and Solution Proposals

Although the application had a lot of potential, it is currently not available for usage and thus testing. The main problem is GPS positioning. The objects have a big mistake radius which makes it hard for the player to find the treasures. Sometimes this error distance causes the object to be instantiated inside a building or a closed area where the player has no access which makes it impossible to use the application.

One probable reason for the big error gap could be due to the mobile phone (Huawei P20 Lite) used during the testing which is also damaged and has slow and low performance. Using Android phones in better conditions might mitigate the inaccurate location problem. Another problem that might be caused by the phone could be the slow RAM ability (2 GB) of the phone. It might be hard to refresh the GPS location frequently which would again cause inaccurate geopositioning.

On the other hand, the slow refresh rate is probably also caused by the heavy work of the rendering since the engine needs to render more than 25 game objects in different locations all the time. Instead of creating all the objects, a better programming solution could be to create only one arrow and treasure and move it to next destinations as the player reaches the available objects. Moreover, there can be one arrow always in front of the player to guide instead of arrow cylinders that do not give information about the direction of the distance.

Furthermore, to better the user experience, voice commands and notifications could be added to the game. Having these audio outputs be sent in 3D Audio would also make the application more interesting and engaging with the player.

# Testing

Even though the application is completed, no testing stage was applied to this project because the state of the application was not suitable for testing. However, testing materials, which are questionnaires, are already prepared for the testing stage and are given below. The questionnaires are prepared with the Google Forms tool. Order of the questionnaires:

1. Demographics questionnaire
2. System Usability Scale (SUS)
3. Final questionnaire

If the problems of the game are solved and the suggested features (in the Problems and Solution Proposals section of the report) are implemented, a with and without audio conditions

can be added to the testing of the application. Hence, having a condition will create the need for a Self-Assistant Manikin (SAM) questionnaire for each condition.

## Summary

The project started with an aim of creating a tourist app for mobile phones using AR technologies. In order to achieve this goal, Unity's AR packages are researched by doing little projects to test the abilities of the packages in the course of four months. After this month, a game similar to a treasure hunt in Berlin is designed and was planned to be implemented and tested in one month. However due to the limitations of time and the accessible GPS positioning software, a package was outsourced which then caused testing problems on the application that resulted in the incomplete product that could not be tested. However, during the course of the project a lot is learned and practised.

## References


[1] "AR GPS Location: Integration: Unity Asset Store." *Integration | Unity Asset Store*, assetstore.unity.com/packages/tools/integration/ar-gps-location-134882.

[2] "Animated PBR Chest Demo: 3D Interior: Unity Asset Store." *3D Interior | Unity Asset Store*, assetstore.unity.com/packages/3d/props/interior/animated-pbr-chest-demo-194755.

[3] "Gantt Chart for Berlin Hunt" *Miro,* https://miro.com/app/board/o9J_l4E-gcE=/

[4] Batt, Jeff. "Understanding Anchors in Augmented Reality Experiences." Learning Solutions Magazine, learningsolutionsmag.com/articles/understanding-anchors-in-augmented-reality-experiences.

[5] "Working with Anchors | ARCore | Google Developers." Google, Google, developers.google.com/ar/develop/developer-guides/anchors.