

GPS Treasure Hunt

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Declaration

This work has not been previously accepted in substance for any degree and is not being con- currently submitted in candidature for any degree.

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Abstract

Mobile gaming is an increasingly popular trend that challenges the foundations of the gaming industry. Traditionally, games require the passive indoor sitting of players for prolonged periods of time. Location-based, outdoor games can provide a solution to this unwanted burden of the industry, whilst keeping players engaged through providing exciting tasks and objectives.

This dissertation is about the development of a GPS location-based game for Android devices with the theme of a pirate treasure hunt and the objectives of a game. This document covers the motivations behind this idea and discusses related projects. We analyse the implementation of this project and explore its mechanics and game flow in detail including its different game modes and its scoring algorithm. We have also conducted a user evaluation study which has provided us with insights into how the audience responds to the idea of a semi-virtual treasure hunt. Additionally, this document covers the challenges that occurred during the development and reflects upon the initial aims and the proposed development timeline of this project.

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Chapter 1

Introduction

For anyone who is commercially aware of the fields of IT and marketing, it comes as no surprise that video games have a significant presence in the software market today. In fact, video games have been turning heads since their rapid emergence in the late twentieth century, when industry revenue was out-earning that of movies and records. [7] Today gaming is one of the most valued industries, with its market forecasted to surpass 138 billion dollars by the end of 2021 [9]

Gaming was initially thought of as a hobby for the youth. Through the '80s arcades were filled with youthful crowds playing the earliest retro games on sizable consoles. Later came the first handheld devices and consoles which gave birth to the hobby of “gaming at home” and it was not long until these had given their place to the well-known online games that the millennial generation is familiar with today.

Throughout the decades, video games have served society as the preferred way for millions of individuals to escape reality and break out of the matrix of their routines. Putting yourself in the shoes of a made-up character gives players a powerful feeling of accomplishment and success. Games are different from films and books as they tell a new story for every person who engages. “Each page of a book and each scene in a movie is predetermined before you see it, and it is the same for every reader”. [8]. This is where games differ from other means of mass entertainment. According to Michael Z. Newman, games form a part of the new media, which are participatory rather than passive [7]. The interactive nature of video games is what justifies the satisfaction that players get filled with when playing them.

One can easily observe that gaming on mobile devices has been on the rise during the last decade. The statistics reflect this, with sources reporting that traditional gaming consoles are getting very challenged by mobile gaming. [10] This is due to a few factors. The first one is accessibility. In the UK far more people own gaming-capable smartphones than do consoles, with 91% of smartphone owners reporting playing games on their phone within the last month.[10] Besides, smartphones are no longer a privilege of rich western countries, as they are just as popular in developing countries of the east. Game developers can make money from in-app advertising and offer their creations for free, targeting an even broader audience. This gives smartphones a great advantage over gaming consoles in terms of popularity. As a second factor, smartphones are now more capable of running ever more demanding games than ever. Furthermore, mobile games can often feature alternative means of interaction such as touchscreens, haptic feedback, location tracking and even VR, to provide enhanced gaming experiences compared to consoles.

The alternative means of interaction encourage developers to be very creative when designing for mobile. Location tracking is a great example of a feature offered

by smartphones, which has opened doors to new types of games, as we shall see in chapter 2 – and it also allowed for the gamification¹ of many everyday activities.

1.1 Overview of this project

This project was about the development of a location-based mobile game that implements the idea of a Treasure Hunt – also known as Scavenger Hunt – modified and adapted in ways to fit in the gaming culture of the 21st century. It was inspired by the success of some similar games discussed in Chapter 2 of this document. This game does not target a specific demographic. It is suitable for all genders and ages who have access to a GPS-enabled Android device.

The game is called “GPS Treasure Hunt” and its plot is defined by the following, philosophy: Players travel to specific urban, suburban, or rural locations, set up by their peers. They have to interact with every location they visit by collecting clues from their surroundings. The clues can be used to solve puzzles, riddles and other tasks and can be validated through the app. On successful validation, a new location is revealed until players reach a final location which forms the treasure and get awards. Players can also hide treasures for their peers to find and get even more points. Ideally, every game should be unique and tell its own story. It can either walk players through less known yet interesting paths, show them around a new city or make use of the clues as a medium to teach the history of a place. It is an open-ended game with great flexibility.

It promotes physical activity through walking and makes players aware of their surroundings and the area they play within. It has the potential to expand globally as it depends on its community of players for growth. It is also supported by an intelligent scoring system that encourages players to contribute to the expansion of the game and rewards them for doing so.

¹ Gamification: Transferring some of the positive characteristics of the game to something that is not a game

1.2 Motivations

It is an unfortunate reality that obesity levels have only risen in past decades. While factors contributing to this infelicitous fact are numerous, some studies have pointed a finger at electronic games for driving up obesity levels, especially among the teenage population of wealthy nations like Switzerland [11]. The very nature of many traditional video games, in particular, console games require players to be stationarily sat indoors, often for long periods of time².

As a result of the lockdowns from the coronavirus pandemic, many people have been given large amounts of free time. Some decided to fill much of this time with gaming, which sadly often happened indoors, despite the fact that many countries – like the UK – had never prohibited outdoor exercise. People like gaming and this is well understood. What is also understood is that circumstances affect people differently. On the other side of the spectrum, many people decided to fill in their free time with activities in nature. In fact, according to a study from The University of Vermont [12], outdoor walks have increased by 70% over the first round of restrictions in 2020. According to the same study, the pandemic has taught people to better value time spent outdoors. The findings were positive, the study however suggests that they mostly apply to the female population, which interestingly happens to be the minority of the gaming community. This also happens to be the demographic the gaming industry traditionally caters the least to, despite their rising numbers. [7]

The main motivation behind this project was to develop a game for mobile devices, which implements the concepts of Treasure Hunt in a modern way. We believe that this is the right time to develop a large-scale, global outdoor game. We also believe that gaming can be used as a nudging³ technique to drive people outside and promote physical activity. This has been achieved before, as we shall see in section 2.1 of this document. The idea is that players will be interacting with their real-world surroundings to collect information and put them back into the game through the app. The goals of the game were simple. It had to promote physical activity as well as to encourage the exploration of the outdoors. To have a healthy dose of competition amongst its players so that it keeps them engaged. To have an educational side, and additionally to provide a simplistic and intuitive UI, to make it suitable and accessible for everybody.

² Nintendo Wii & Wii Fit are notable exceptions as they encourage the physical movement of players

³ Nudging: A term used for changing peoples behaviour by modifying the context of the choice.

Chapter 2

Background

2.1 Related work

In this section, we will be looking into some similar projects that implement ideas related to this project and cover resources that helped us achieve the final result. A lot of inspiration has been drawn from these projects and especially Geocaching.

2.1.1 Scavenger Hunts

Scavenger Hunt is a basic game implementation of the treasure hunt concept. Scavenger Hunt typically takes place outdoors. In this game, players participate either solo or in teams to collect either a number of clues or a number of objects, set up by the organisers. Scavenger Hunts are often organised at social events where many people meet for the first time, for example at university open days. Scavenger Hunts are a popular, effective and quick way to break the ice between members of a group and help introduce them to the concept of the event through an engaging activity.

The University of Illinois has been organising Scavenger Hunts for incoming students to introduce them to their undergraduate life and foster a sense of community within its Computer Science department. This has been done in an effort to fight the increasing drop-out rates of first-year Computer Science students, and the institution found the Scavenger Hunts to be very successful in increasing student participation. [13]

Scavenger Hunts have also been used as a form of interactive tour guiding for large groups and are effective in encouraging urban exploration, enabling participants to learn the history of places through searching for clues. In 2005 a group organised a Scavenger Hunt in King's Cross, London in an attempt to teach people the historical significance of this popular location and show them features of the area that are usually overseen. [14]

2.1.2 Geocaching

The game of Geocaching is one of the most concrete and well-thought implementations of the treasure hunting concept. It is considered by many as the treasure hunt solution of the 21st century. Geocaching has been around since the beginning of the century and it began as an outdoor recreational activity with the objectives of a game. It was established in 2000 in the US, shortly after the GPS infrastructure became available for the wider public, and the first personal GPS receivers emerged in the market. [15] A geocache is a weather-proof container of variable size hidden at some specific location. A user places the geocache at some location that they consider of interest and publishes the coordinates online. Other users will then attempt to find it and log their attempt. This practice is what people call Geocaching. According to the game's rules, geocaches must contain a logbook, usually a piece of paper or small booklet, where players sign their names to claim a successful find. This is before publishing their find on the online community, and possibly swapping treasure items, depending on its size of the container. [16]

Geocaching had been released and was widely played before the introduction of GPS into mobile phones. For the first decade of its existence, geocache hunters made use of portable GPS devices to navigate to the geocache locations. Nowadays, most players go geocaching with their GPS-enabled smartphones, making use of geocaching client apps. The most popular of which is the official Geocaching app by Groundspeak Inc. Geocaching client apps download the locations of nearby geocaches from an API and present them to the user on a map in a user-friendly way. The app makes use of the device's location sensors and drives users to the final location of the geocache. From the client apps, players can read all about the location of a geocache and the motivation of the user who placed it there, gathering clues for the hide. Players can log their finds or report their unsuccessful attempts, share their experiences with fellow players, and message other users directly. Geocaching client apps function as the modern one-stop solution for geocachers to engage both with the game itself but also with the community.

Being a two-decade-old game, Geocaching has a strong and well-established community with millions of active members. Many geocachers have reported that geocaching is more than a casual game to them and that it has well integrated into their lives. [17] The importance of the geocaching game does not lay in the treasure container, the geocache – although some of them are impressively smart – but in the overall searching experience, and the satisfaction of engaging in an outdoor activity. [17] Games like Geocaching give their players reasons to be outdoors, whether that is for a simple walk or exploring new places, both in conjunction with a gaming session. It is easy to see why many experienced players have integrated the game deeply into their lives.

Geocaching offers more than one type of geocache. The ones discussed above – which form the backbone of the game – are called Traditional Geocaches. Other types include Multi-Caches, Virtual caches, Puzzle Caches and Mystery Caches. The

Multi-Cache type geocaches are of particular relevance to this project. As the name suggests, Multi-Caches involve at least one stage in addition to the final location which hosts the physical treasure container. Additional stages can be physical or virtual. At every non-final stage of a Multi-Cache, the geocacher must complete some tasks and collect some clues which will help them access the final location. It is worth noting that all stages of a Multi-Cache are visible and accessible at all times of the game, and this sometimes includes the final location as well. In our game, this is not the case, as explained in section 3.2.2 of this document.

Geocaching and Multi-Caches in particular, have been a primary source of inspiration for this project. GPS Treasure Hunt aims to excel where geocaching traditionally fails. This is usually in areas of high popularity such as city centres, where searching for a small container where crowds of people gather might seem suspicious. GPS Treasure Hunt does not suffer from this as the hunting happens virtually.

2.1.3 Pokémon Go

Pokémon Go is a popular location-based augmented reality game launched in 2016 for Android and iOS. It was the first augmented reality game to reach the top of the download charts for mobile platforms. [20]

Pokémon Go was proven very popular for giving its users an alternative way of interacting with characters from the well-known “Pokémon” franchise. On a high level, in this game, players have to search, capture, and train Pokémon creatures, which they collect by visiting real-world locations provided by the algorithm. The game uses GPS data from the phone’s sensor to match the player’s location with the virtual world, where Pokémon live. [19] Once at the location, they can use their phone’s camera to see the creatures in an augmented reality way.

Pokémon Go players report great experiences from playing this game, with many mentioning that they particularly enjoy the game’s socialising aspect, which is the creation of communities and group play. [19] Similar to Geocaching, many have mentioned that “moving in the real world was fun” and that they enjoy visiting places through the game that they would not visit otherwise. [19] Some health specialists have seen this model of outdoor gaming as a potential solution to the physical inactivity crisis. A study has called Pokémon Go “the most successful population level physical activity program the modern history has seen”. [18] They also found that Pokémon Go might help increase the time players spent walking, as participants have reported replacing time that would have been passively spent indoors with physically active time outdoors through this game.

This project is inspired by the great popularity of Pokémon Go as it demonstrates that a location-based game for mobile can be used as a nudging technique to increase time spent outdoors.

2.2 Tools Used

This was a very technical-oriented, software development project. It involved more implementation than reading and research. In this section, we will list the principal tools used for the development of this project.

Android Studio

The development of GPS Treasure Hunt took place entirely in Android Studio. Android Studio is the official integrated development environment (IDE) for the development of Android apps. It is the recommended development tool by Google and provides many features that speed up the project development such as code formatting, automatic indentation, prevention of compile-time errors, automatic project structuring (files and directories), a comprehensive debug tool, and a complete Android Virtual Device Emulator (AVD). All code was written in the Kotlin language, as recommended by Google. There are 3 main reasons which led to the choice of Kotlin over Java for the development of this game:

1. Kotlin is Google's preferred choice for Android app development [1].
2. Kotlin results in significantly less boilerplate code compared to Java, making the source code more readable and maintainable
3. Kotlin provides many standard functions to query collections that would require manual querying or the use of third-party libraries in Java.
4. Previous experiences

The developer has undertaken a mobile app development during the first semester of his studies, which was taught in Kotlin.

At the very initial stages, Unity Game Engine was also considered, but the idea was quickly dropped as Unity applies better to platform or FPS games. In this game, there is no digital arena or playground as it takes place in the real world.

Git

As with every modern approach to software engineering, all code of GPS Treasure Hunt was backed up by the git version control system. This has enabled us to work independently on different work branches for isolated tasks. The use of git made experimenting with the code a lot easier as it enables easy rollback to previous, stable versions of the app, should a feature under development failed, which was also helped with debugging. The source code was pushed to our remote repository on GitHub to allow development on different machines and provide a backup should the main development machine failed, and source code was lost. The code is also available on request.

Google Maps SDK for Android

GPS Treasure Hunt is a location-based game for Android and relies heavily on the Google Maps SDK. This SDK allows users to see their current live location on the map, visualise locations they need to travel to, and also provides accurate distance and bearing calculations between two location points. Every instance of a map in this game utilises this service. A free API key is used in this application which is subject to restrictions such as querying but is more than adequate for this stage.

Icons & Graphics

This App makes use of the Android Material Icon Library, licensed under Apache License 2.0. The App icon and all other graphics of this app have been sourced from FlatIcon <http://www.flaticon.com> under their licence which permits distribution with attribution. For more details about icons and graphics refer to the “About” section of the app.

Chapter 3

Implementation

In this section, we will look into the development phase of GPS Treasure Hunt and explore its mechanics and flow in detail.

3.1 Development methodology

The Agile development model has been chosen for the development of this project which is also known as scrum. As explained in the relevant section of the initial document, despite scrum being the main choice for team development is also suited to solo developers. Agile development provides flexibility and welcomes changes to the initial plan, which was very beneficial in the case of GPS Treasure Hunt. At the beginning of every scrum iteration, the workload was broken down into separate manageable units, referred to as tasks. Tasks were developed and tested in parallel and reviewed at the end of the iteration. Each iteration has a length of one week and at the end of every iteration, deliverables were reviewed and evaluated and in some cases dropped completely. The development was supported by Trello, a project-planning software for the organisation and spreading of tasks on the development timeline.

3.1.1 Testing

As prescribed by the chosen software development model (Agile/Scrum), testing was performed continuously at the completion of every deliverable and at the end of every iteration. This method of testing rather than a long testing phase towards the end of the development allowed for much faster detection of bugs and greater flexibility.

Testing was conducted both on virtual devices using the Android Emulator of Android Studio and physical android devices to gain a better idea of how users will experience the game. All devices were running on API version 27 or greater as it is a requirement for the app (Android 8.1 +). We found that testing on a physical device provides a much better testing experience and can expose flaws and imperfections that are hard to detect on a virtual device, such as haptic feedback, micro-animations, font, and colour choices, and the overall responsiveness of the app.

3.2 Game Mechanics

The player is initially greeted with a login/signup screen. An account is required to play this game. It is designed in such a way to enable synchronization across different devices, progress backup, and store no user data on the device for security reasons. Signup requires players to provide a name (referred to as Pirate Name in the game) and does not have to be the user's real name, an email address which at the current stage is not verified, and a password consisting of a minimum of 6 characters which is only stored in a hashed form. The login/signup system makes use of Firebase Authentication (more in section 3.3.1), and all data is stored on the cloud. Section 3.3.3 provides a deeper look into security issues.

Once logged in, the players will be taken to their Dashboard, which behaves as a home screen in this game. Players are greeted with their pirate name in a comical, pirate-style fashion. The use of pirate words and graphics throughout the app is essential to maintain the "Pirate" theme of this game and keep players engaged. From the dashboard, users can see their score (more in section 3.2.4) and engage in one of the two gameplay modes, namely Treasure Burial or Treasure Hunt. Additionally, players can swipe from the left to access the drawer menu for more options such as the tutorial.

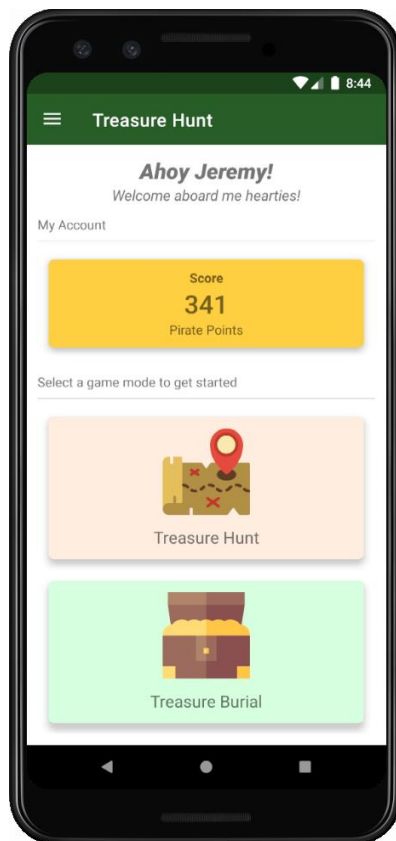


Figure 3.1 – Dashboard Activity
(Navigation Drawer Closed)

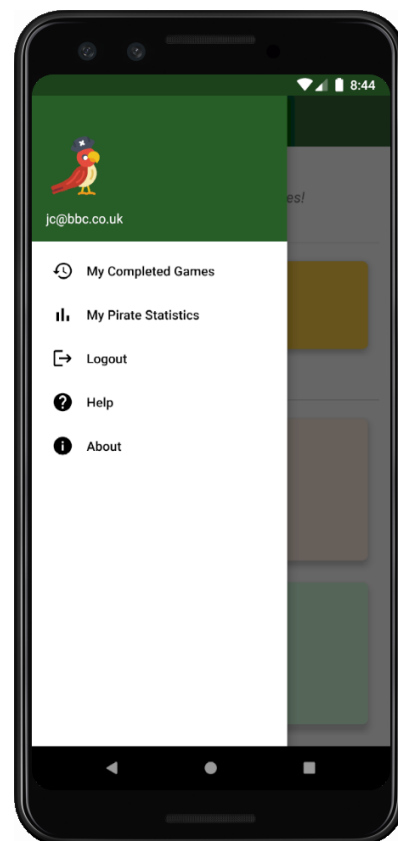


Figure 3.2 – Dashboard Activity
(Navigation Drawer Open)

3.2.1 Treasure Burial Mode

In this mode, the player is acting as a Pirate, hiding a virtual treasure and leaving clues leading to it. The player is called to construct a path of locations – which the game addresses as waypoints – leading to a final location where the virtual treasure is “buried”. For every waypoint, the Pirate will have to record the location – the game provides an interface for that – and think of a task the hunter will have to perform when they visit that location in the Treasure Hunt mode. The task can be a riddle to solve or any other sort of clue. The only requirement is that one must be physically present at the waypoint to be able to solve the task, hence clues that a cheater could easily search for on the internet should be avoided. Pirates are encouraged to create challenging, informative, and creative games that are exciting for others to attend. In the end, they’ll be asked to enter a general description of the game they created and enter its difficulty. The algorithm takes care of the rest. Pirates are awarded 20 pirate points for every Treasure they bury as a reward for contributing to the community of the game.

Refer to Appendix A, figure 3.3 for screenshot

3.2.2 Treasure Hunt Mode

This is expected to be the most popular of the two game modes. On this occasion, the player is acting as a Hunter, in search of a Treasure buried by a Pirate in the other mode. Hunters select a Treasure Hunt to attempt and begin by travelling to the first waypoint of it using the navigation instructions provided. At the waypoint, they collect clues from their surroundings and try to find the answer to the task they were given. There are unlimited attempts for every waypoint. When the correct answer is found, the next waypoint becomes available, and the procedure is repeated until the final location is revealed. When the game is finished, Hunters are awarded Pirate Points, and a digital Trophy – that is different for every level of difficulty – for their collection. Hunters cannot attend the same Treasure Hunt more than once, as this would form a loophole allowing them to gain unlimited points.

A design alteration was to omit the unlocking of a digital file at the final location. This feature was proposed in the initial document but was abandoned early on in the development phase. The reasoning behind this decision is explained in detail in section 4.3 of this document.

Refer to Appendix A, figure 3.4 & figure 3.4.1 for screenshots

3.2.3 Scoring System

The implementation of a scoring system was a very high priority when designing the app. GPS Treasure Hunt is a game that depends on its community of players for growth and expansion rather than its developers. As explained in the initial document, it is common in games of this nature to see more players going after the Treasure Hunt process which is understood to be more exciting, rather than the Treasure Burial, which is the one that contributes to the expansion of the game. GPS Treasure Hunt addresses this issue with the use of a scoring system.

The score of a player is measured in Pirate Points. Each player is given 50 Pirate Points upon creation of their account to get started. To attend a Treasure Hunt session, players must “pay” a certain amount of Pirate Points, depending on the session’s difficulty. Upon successful completion of the game, some points will be rewarded back, as the following table explains

	Easy	Medium	Hard
Cost	5	10	15
Reward	6	12	20

Table 1: The playing cost and solving reward for Treasure Hunt sessions in response to their difficulty, in Pirate Points.

As we can see, as the difficulty level increases so do the cost and reward. Should a Hunter ever be in a position with insufficient Pirate Points to attend any Treasure Hunt, they will have to play in Treasure Burial mode and contribute to the community. Upon publishing their buried treasure, the algorithm will award them with 20 Pirate Points.

The scoring algorithm ensures that all players will have to play in both modes to boost their score and rewards them for helping the game expand whilst balancing the number of Hunters and Pirates. A player can view details about their score and performance from the Statistics screen, which can be accessed from the navigation drawer in their Dashboard.

Refer to Appendix A, figure 3.5 for screenshot

3.2.4 Usage Scenario

In this section, we will look into a simple example of a player interacting with this game. Actress Alice will be acting as a player.

Alice has just downloaded the app. She first needs to create an account. She doesn't feel comfortable using her full name as it will be visible to other players, so she signs up with the pirate name "alice_sparrow98" and her email address.

She is ready to play. The Dashboard shows her that she has 50 Pirate Points, and she quickly dives into Treasure Hunt mode. She decides to attend the Treasure Hunt closer to her location, which is classified as hard. She pays 15 pirate points and begins the treasure hunt. When she arrives at the first waypoint, she is rather confused and can't seem to find the required clues. She decides to give up and attend another 3 Treasure Hunts, also classified as Hard. Alice struggles a lot to solve them. Obviously, she lacks experience, so she decides to travel to the only "Easy" Treasure Hunt in her city. She starts playing and arrives at the first waypoint. The task was easy, she only had to solve a small riddle with words from a big sign at the location she was taken to. Now she understands how to use clues from her surroundings to play. The next waypoint is now revealed. When she solves the final waypoint, she is awarded 6 points and a bronze trophy for her collection. She now feels confident to attend Treasure Hunts of "Medium" difficulty.

Unfortunately, she only has 6 points, which are not enough for a Medium game, and there are no other Easy games in her city. Alice has no other option than to play as a pirate in Treasure Burial Mode. She sees that as an opportunity to hide some Easy games in her town, and to tell the world about the series of artistic graffiti and street art at the alleys of her old neighbourhood, so she buries a treasure there.

Now Alice has successfully gained 20 Pirate Points for completing a Treasure Burial and she is ready to play again. She also contributed to the expansion of the game and she is showing a usually overlooked part of her city to other explorers.

3.3 The Server side

In this section, we will be looking into technical details about the back end of this project and touch on a few security considerations that were made.

3.3.1 Authentication

As mentioned in the Game Mechanics section, every player has to create an account to play. Authentication defines the first level of security for the app. It allows for cloud synchronization, progress monitoring, storing of preferences, and more personalised in-app experience.

In this game, authentication is provided by Firebase Authentication Service. The reasons which led to the choosing of Firebase over other authentication providers or a custom system are the following:

Android Studio integration

Firebase is owned and supported by Google. It is very well integrated into Android Studio and it is a very common authentication choice for many Android apps.

Security

Firebase offers a well-established cloud authentication system that can be considered relatively secure. It is unlikely that the development of a custom authentication system for this app would result in a product more secure than what Firebase has to offer, especially with the given time and budget. With that being said, if the security of Firebase gets compromised one day, resulting in a data breach, Firebase would be responsible for the potential data leak. In the case of a data leak in a custom developed system, the developer would have been responsible.

It is important to note that in the case of GPS Treasure Hunt, no personal user data is ever stored other than the user's email address.

3.3.2 The Database

This game makes use of an online database for cloud backup and cross-device synchronization purposes. The database is provided by Cloud Firestore. Firestore is a flexible database for mobile and web development which is provided by Firebase and Google cloud. [2] It is a non-relational database (NoSQL) that organises data in collections and documents. Firestore stores documents in a JSON-like manner, which allows for easy querying, and permits the storing of many data types and even custom reference type objects that implement the Java/Kotlin Serializable interface.

The database holds serialized data for Treasure Hunts and Users, both of which are deserialized into Kotlin objects on the client-side.

It is worth mentioning that the database location is set to “Western Europe” with “Central US” being the only alternative provided by Firestore. The Western Europe option was chosen mainly for reduced latency time since most users would initially be located in Europe. Firestore documentation does not specify if data stored on their European servers is subject to stricter protection according to the GDPR.

Firestore also allows the developer to specify CRUD (create-read-update-delete) rules for accessing the database. The following code snippet gives an insight into those:

```
service cloud.firestore {  
  match /databases/{database}/documents {  
    // Treasure Hunts Collection  
    match /treasure_hunts/{th} {  
      allow read: if isLoggedIn();  
      allow create: if isLoggedIn();  
      allow update, delete: if isOwner();  
    }  
    // Users Collection  
    match /users/{user} {  
      allow read: if isLoggedIn();  
      allow create: if true;  
      allow update: if isOwner();  
      allow delete: if false;  
    }  
  }  
}
```

Code Snippet 1: Part of the CRUD rules for our database.

3.3.4 Diagram of server-side

The following figure illustrates 3 simple transactions between the client (user) and the server (online database)

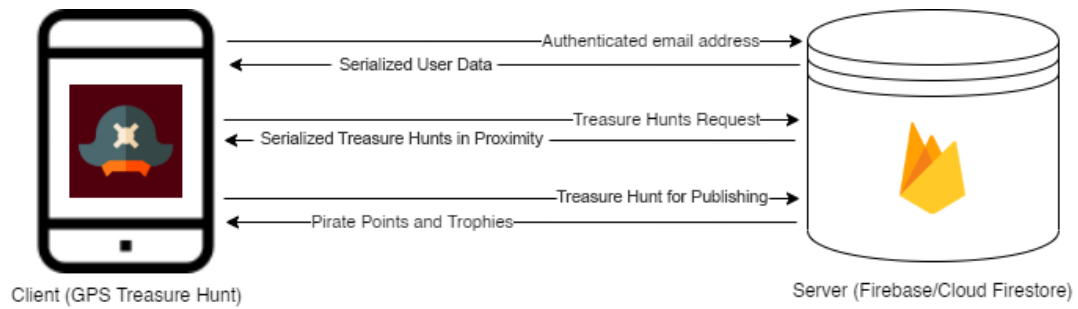


Figure 3.6: A simple client-server diagram

3.5 Emphasis on HCI

While developing this game, a lot of attention was paid to applying correct HCI principles. It is often said that “things that look good, give the impression that work good”. One of the broader aims of this project, found in the initial document, was the design of a simplistic, intuitive, yet aesthetically pleasing user interface for the app. This has been achieved in the following ways.

Material Design

Material Design is a design language created by Google, consisting of guidelines and principles that apply across device types. [4] It was officially introduced to Android in version 5.0. Material is intended to mimic the look and feel of paper, featuring shadows, elevation, edges, and animations. “Any motion should have a real-world behaviour as if the moved elements are real, physical objects” [5] The Material philosophy assists with the creation of responsive UIs by providing feedback on user input, that developers don’t have to manually take care of. [5]

The entirety of the front-end of GPS Treasure Hunt was developed using material libraries – instead of the androidx legacy support library – for an enhanced user experience. The use of a navigation drawer on the Dashboard screen (*figure 3.2*), visual elements wrapped in CardViews (*Appendix A, figures 3.5, 3.6*), the colour scheme choice, icons, fonts, and placement of buttons and dialogs in this app all follow the Google Material guidelines and reflect a high level of polishing.

Prompts and dialogs.

A fluid user interface that encourages in-app exploration should also protect users from “dangerous”, non-reversible actions, such as exiting the app, logging out, or in our case, abandoning an unfinished game – which results in loss of points. This app addresses this issue using confirmation dialogs and prompts for such actions. This was one of the key findings of self-evaluation

Refer to Appendix A, figure 3.7

The combination of material design elements with prompts and exit dialog, besides other details, give the impression of a solid, well-thought, and polished app.

Chapter 4

Evaluation & Results

Evaluation is a critical milestone of every development cycle, which usually follows the implementation phase. Evaluation enables us to check whether the design is appropriate for its intended user population. In this section, we will look into the evaluation phase for this project and discuss what could have been done differently.

4.1 Self-testing

Due to the nature of this game, evaluation can be time-consuming. Thus, a self-evaluation phase preceded the user evaluation study to ensure that end-users would not run into unexpected errors preventing them from finishing the study and wasting their time.

The study began with some back-end stress testing on a virtual device. That consisted of intentionally sending wrong user input to the server, to test its behaviour. A couple of vulnerabilities were discovered and fixed with user input sanitization on the client-side.

At a later stage, the developer used a beta version of the app on a physical Android device and attempted to play in Treasure Burial mode. The findings were that the app was usable, and the back end was reliable. The developer was able to successfully bury a virtual treasure using the Treasure Burial interface. On the other hand, the experience was not great with many accidental exits (back button presses) that resulted in the loss of progress. Furthermore, it was observed that the Game Mode selection screen did not positively contribute to the workflow of the game and that although functional, it did not aesthetically fit into the rest of the UI.

Code changes were made to include confirmation dialogs for actions that could result in loss of progress, and a Dashboard screen was created to replace the older Game Selection screen.

The following figure depicts the design changes from the Game Selection Screen to the Dashboard Screen.

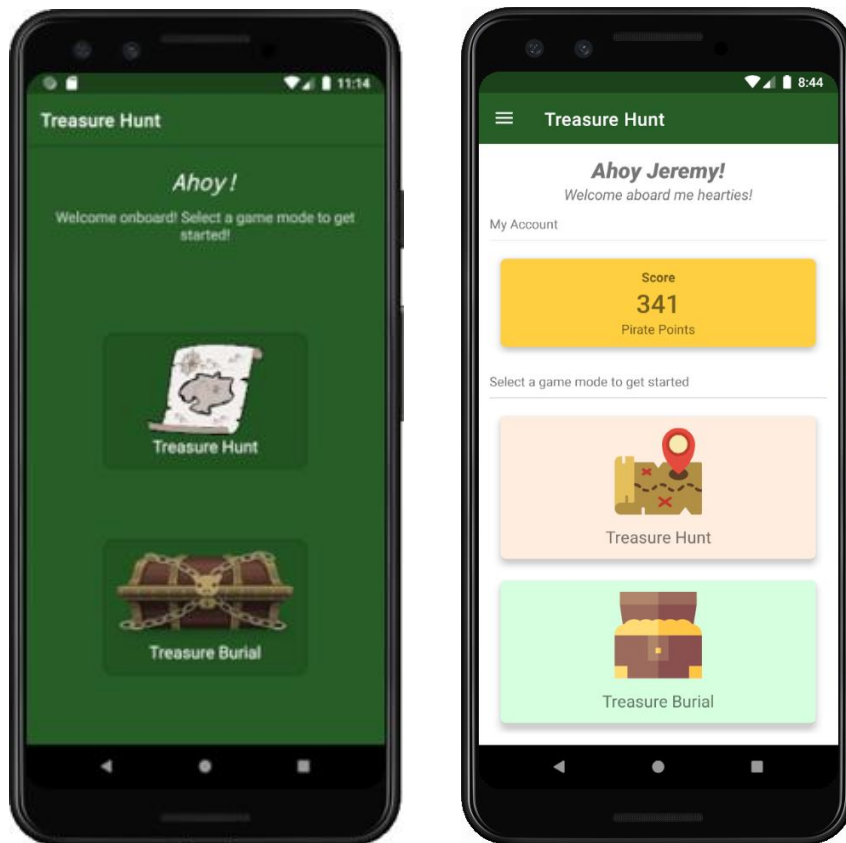


Figure 4.1 – The former Game Mode Selection Activity (left) and its replacement Dashboard Activity (right)

4.2 User Evaluation study

User evaluation is particularly important, as developers tend to be emotionally attached to their designs. A second point of view is often needed to spot imperfections that developers might oversee.

The development of this project took place in October 2020 – April 2021, during the COVID-19 pandemic. Specifically, the implementation phase was completed in March and was meant to be followed by a user evaluation study. Unfortunately, COVID restrictions were still present in Wales at that time, which prohibited gatherings. This was not an unexpected turn, as we had mitigations for this scenario, which included remote, solo evaluation by users. However, the study took place in Easter break, when most students – which were the main demographic of the study – had left Swansea. In combination with pressuring deadlines, upcoming exams, and the time-expensive process of evaluating an app that required some form of travelling led to low participation interest, which was unforeseen. It was very unfortunate that the study was not conducted to the standard we hoped for. Nevertheless, a few participants showed interest, and despite the low number of subjects, the study provided valuable qualitative feedback that was re-invested into the game.

A total of 4 subjects had taken part in this study. Subjects were first given a briefing of the study and stated their consent to participate. They were given a release candidate version of the game to install on their devices and were asked to engage in either of the gameplay modes at their own time. We shall note that prior to the study the developer had placed 3 fully functional Treasure Hunts in the Swansea region so that the participants could get a taste of the game. Since this is the case of a casual game, we tried to keep the style of the study relaxed, casual and informal so that the subjects could enjoy the game with no pressure and give better real-world feedback.

At the end of the study, participants were thanked for their time and feedback. As compensation for their time, everybody was offered gluten-free chocolate bars and a boost of 300 Pirate Points in their account of the game.

4.2.1 User evaluation - Findings

As already explained in the previous section, the study consisted of 4 people who contributed in the following ways:

- Participant 1 (Male 21): UI and program flow evaluation only
- Participant 2 (Female 22): UI evaluation & Treasure Burial Mode evaluation
- Participants 3,4 (Male 22, Male 23): Comprehensive evaluation

It is noteworthy that Participant 1 performed the evaluation before the other subjects and made some useful findings that caused changes to the app before the study continued. Specifically, Participant 1 used an older android device with dark mode enabled and made the following observation:

Participant 1:

“- Some icons do not fit well in the screen of my device, and the colour of some text is barely readable”

Indeed, all devices used for testing were set to bright (default) mode, and none of them had a screen smaller than 5.5 inches. Minor changes were made to the app after this observation, which fixed those issues before the study continued.

The majority of the feedback was greatly positive, with all participants who had the chance to play in either of the game modes reporting that they were fascinated by the idea of a real-world treasure hunt through the guidance of their own smartphone.

All subjects reported enjoying the opportunity to leave the house and do something outdoors. Some reported that they really liked the educational side of the game and that they can imagine it having great success in the world of interactive education.

Below are some snippets of feedback by the participants of the study:

Participant 2

“- I really enjoyed Treasure Burial mode! I’ve hidden a treasure at Victoria Park where I pass every day on my way to Uni. I can’t wait to see people start looking for it!”

Participant 3

“- This is such a great idea, I’ve been living next to the (Swansea) Marina for the last 2 years and I have never seen most of the monuments the “Bridges and Statues” Treasure Hunt has taken me to, and I certainly did not know the history behind them!”

“- I will make sure that I bury a treasure in Cardiff when I visit it next month”

“- The UI is great, especially the arrows in the “Select a treasure hunt” screen that show you which direction to go from where you stand.”

The participant is referring to one of the last detailing additions of the polishing phase, namely the arrows found in “Treasure Hunt Selection Activity”. These point to the first waypoint of every treasure hunt, in respect to the player’s current position.

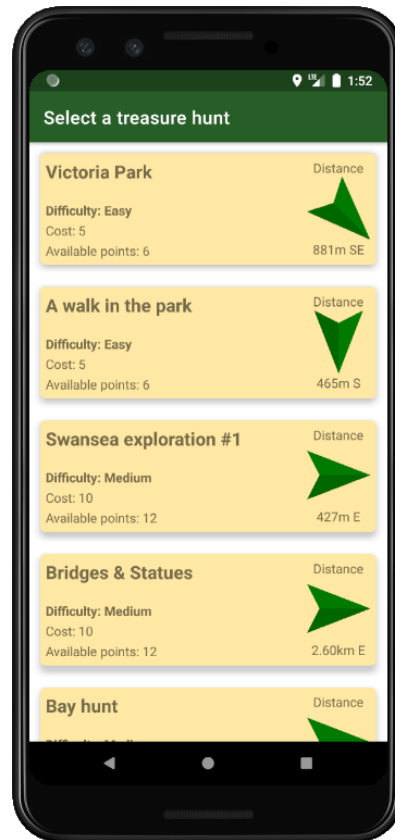


Figure 4.2 – Treasure Hunt Selection Activity, with arrows point to the direction of the first waypoint for each game

Participant 4

“The UI feels modern, I like the icons and colours and the transitions are smooth. The game itself is very interesting. I wish there were an iPhone version as well”

Of course, not all feedback was positive. Participant 3 reported that he did not like that he had to log in every time he opened the app. He would instead prefer it if the app remembered his credentials. This was an intentional design decision, however (see section 4.3 for more). The same participant also reported that if he solved some waypoints for a game without finishing it, then closed the app, and then went back the next day, his progress was lost. According to the scoring system, quitting a game before completion should indeed result in a loss of points. However, the specific participant seems to desire the ability to resume from where he left off, should he decide to attend the game again. This is something that justifies further investigation.

4.3 Alternative approaches

In this section, we will discuss alternative design decisions that were considered but never reached to the final product and compare them with their alternatives.

Virtual Treasure Hunt

The idea was that players would follow a completely virtual path made up of waypoints only relative to their current location. Once at a waypoint, they would perform tasks such as puzzle solving and then be taken to a final location to retrieve a virtual file. This idea originated from the project's description on the project catalogue and made its way to the initial document but was later dropped in favour of the current implementation. The project has taken a more real-world approach to treasure hunt and it was deemed that such an approach would neither encourage outdoor exploration, nor would it provide educational insights, hence it was discarded.

Digital file for final treasure

According to the original description of the project "...at the final location players will be able to unlock digital files such as picture or audio files". This idea was carried until the project presentation in December 2020. It was abandoned shortly after for the following two reasons:

- **Time limitations and increased complexity.**

The existing database does not support the storage of non-serializable files such as pictures. This would require the use of a secondary database to host the digital files and securely link them to the primary one. The linking of the two databases would also increase complexity. The idea was judged too complex for the given timeframe.

- **Deviation from the primary goals of the game.**

As previously explained, the principal goal of the game is to make players engage with their surroundings, explore the outdoors, and promote physical activity. This feature could potentially distract the users from the main motive of the game and drive their attention only to the final location and the treasure file. Additionally, it could also increase cheating through external file sharing. Therefore, its development was abandoned.

Storing data locally on the device

Currently, no data other than cache is ever stored on the device. All required user data is fetched from the server on start-up and Treasure Hunt data is delivered on the go. It was implemented in such a way for the sake of security and synchronization, but it has received criticism from the user evaluation study where a participant mentioned he did not like that the app did not remember his account details and had to sign in every time. This is something to consider changing in future versions.

Chapter 5

Reflection & Review

In this section, we will reflect upon the final outcome of this project and compare it against its initial aims and its development timeline to see what has been achieved.

5.1 Compare and contrast with original aims and goals

The following table compares the final products against the original aims of the game.

ORIGINAL AIM	ACHIEVED	REFLECTION
Use device GPS signal to show player location on the map ⁴	YES	The Player's location is shown on the map in Treasure Burial Activity and Treasure Hunt Activity.
Display location of waypoints on map ⁴	YES	Location of every unlocked waypoint displayed in Treasure Hunt activity (Appendix A, figure 3.4)
Use compass heading to navigate players between waypoints ⁴	ALTERNATIVE PROVIDED	Navigation using compass heading interface was not provided. Such an interface would cause confusion in urban environments or even trespassing.
Provide a waypoint calculation interface ⁵	NO	The project had evolved to a more exploration-oriented game and the focus was shifted to showing people interesting locations rather than complicated puzzle solving. This feature was no longer suited to the game.
Give players directions to the next waypoint ⁵	YES	Navigation directions to waypoint provided via any capable app installed.
Give feedback on waypoint calculation ⁴	YES	Use dialogs in case of wrong waypoint calculation (incorrect task answer) and use of a congratulating screen upon completion of the game. (Appendix A, figure 5.1)
Make use of a scoring system ⁴	YES	An efficient scoring system is used which encourages players to engage in both modes and rewards users for their actions.

Table 2: Evaluation of original project aims

⁴ Aim proposed at the Initial Document in October 2020

⁵ Aim first proposed at Gregynog presentation in December 2020

5.2 Reflection with Proposed Development Timeline

Most critical dates have been met. The main development phase started in January 2021 as initially planned and lasted until the second week of March, when the milestone “Partially working prototype ready” was met.

The “Polishing” phase was moved from the last week of February to the very end of the development cycle, as more important tasks such as database organisation and debugging required more time than initially estimated. The user evaluation phase was moved forward by two weeks and the first Release Candidate version was ready by the first week of April, and the milestone was reached on time.

As with every software development project, some features required much more effort than planned, and the opposite was true for others. Nonetheless, the agile development methodology allowed for flexibility and the parallel development of features and the final deadline could be met.

Please refer to Appendix B, Chart 1 for the development timeline.

5.3 Development Challenges

This sub-section considers some of the prominent challenges we encountered during the development of this project

- **Working with a non-relational database**

The chosen database (Cloud Firestore) implements a non-relational data model. [3] This was the first time the developer was called to work in such an environment. The database does not have rows and columns, only collections and documents. At the initial stages of development, all data was stored locally. For the introduction of the database, further documentation reading was required, in addition to many structural changes in the code.

- **Serialization**

Since the database only stores serialized objects in a JSON-style structure, all data models had to be changed and implement the Kotlin Serializable interface. This meant that waypoints could no longer hold a reference to the Treasure Hunt object they belong to. The object reference was replaced with the UUID⁶ of the parent game.

- **Asynchronous nature of chosen APIs**

All external APIs used in this app (Firebase, Firestore, Google Maps API) fetch server data asynchronously. To inform different parts of the code about work done asynchronously, we implemented the Observer on the database instance, following an online tutorial. [6]

⁶ Universally Unique Identifier

Chapter 6

Conclusion

We have seen that the popularity and social integration of games has been on the rise and there is no evidence supporting that this will stop anytime soon. We have also seen that mobile gaming is emerging rapidly and it is starting to shake the foundations of the traditional gaming industry, with mobile games being far more accessible and often more interactive than their legacy counterparts. Traditional gaming is increasing the time the youth spends indoors and this comes with many health implications. On the other hand, studies have suggested that – especially as a result of the COVID-19 pandemic – people have learned to appreciate time spent outdoors more than they did in the past. We have also seen that location-based games that involve people getting outside have enjoyed great popularity and success in the past, and subsequently increase the physical activity levels of their players.

We have developed a mobile game implementing the very old concept of Treasure Hunting in a modern and contemporary way that is accessible and appropriate for the game consumers of the 21st century. This game utilises the GPS location tracking capabilities of modern smartphones and it is taking users to locations chosen by the community. Our game promotes the exploration of the outdoors by having its players interact with their surroundings in order to progress. It also provides educational insights on the location it takes place at by using smart clues that require players to take a deeper look into interesting locations that are often overseen.

This document covered the motivations behind this project and examined similar projects with their impact on the society. We have also seen how this game differs from others in this area. We have analysed the development phase of this game and went into detail about its mechanics and the design decisions behind them. We have also discussed the importance of human-computer interaction in app development and explained how simplistic UIs can improve the usability and user experience in a mobile app.

The user evaluation study has provided us with valuable feedback on how our audience uses the app, including what they do and do not like about it. We used the findings to make adjustments in the game to improve the gaming experience. We have learned that developing a game is a challenging task, that requires planning, testing and flexibility. We consider this project a success despite the challenges occurred during development. Feedback from the user evaluation study was greatly positive, with all participants applauding the novel idea of a semi-digital, interactive treasure hunt. Most of them have enjoyed playing the game with some reporting playing it again in their own time. This allows us to be optimistic about the future of this game.

We believe that GPS Treasure Hunt has a lot of potential for expansion in the future. Its intelligent scoring system allows us to depend on the community of players

for growth. Potential features that could be implemented in the future include additional gameplay modes such as team multiplayer, more achievements and improved algorithms for waypoint solution checking. The development of an iOS version is also a consideration for the future.

In conclusion, we have demonstrated how a location-based mobile game can be used to fight the inactivity crisis, and how a scoring algorithm can make the game's community contribute to its expansion. Moreover, we have proved how people are willing to be outdoors more often and for longer by exploring their surroundings, through the motivations and objectives of this game.

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Appendix A

Supplementary GUI Screenshots

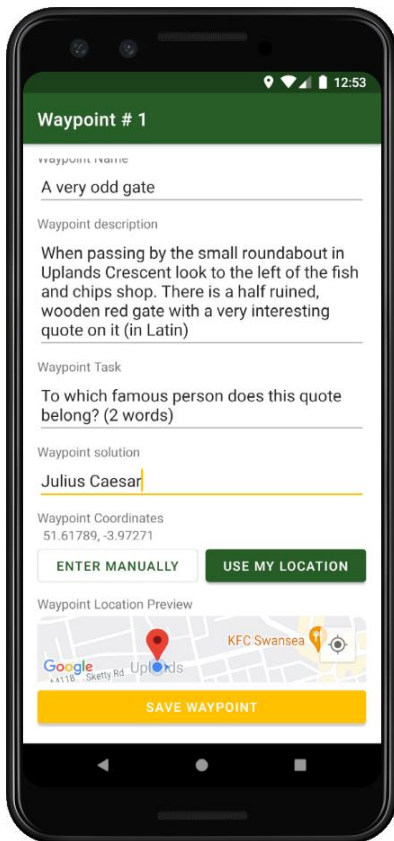


Figure 3.3 – Adding waypoint information in Treasure Burial Mode

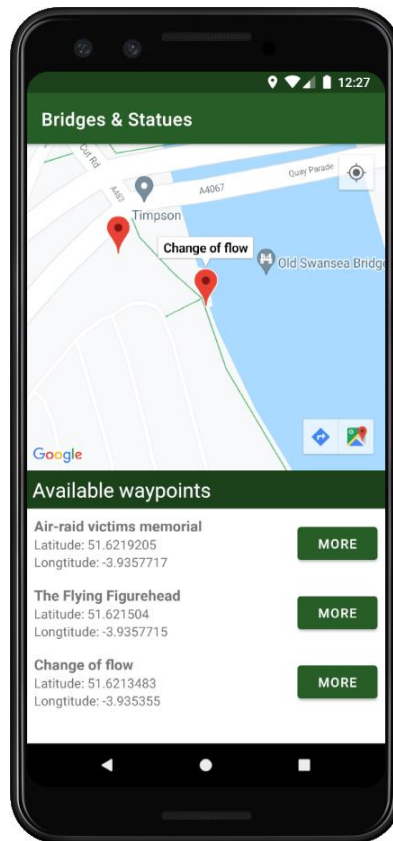


Figure 3.4 – Treasure Hunt Activity, List of unlocked waypoints

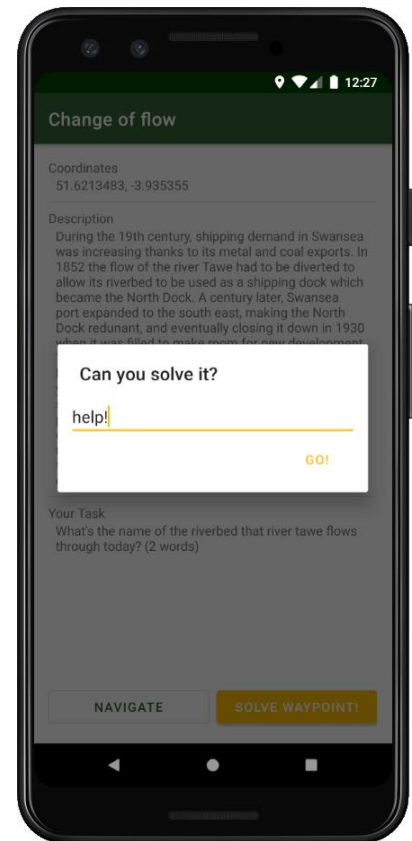


Figure 3.4.1 – Solving a waypoint task in Treasure Hunt Mode

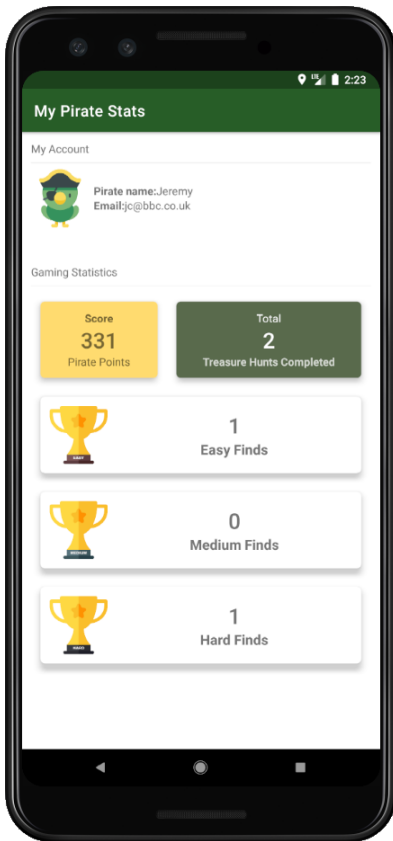


Figure 3.5 – The Statistics & Awards Activity

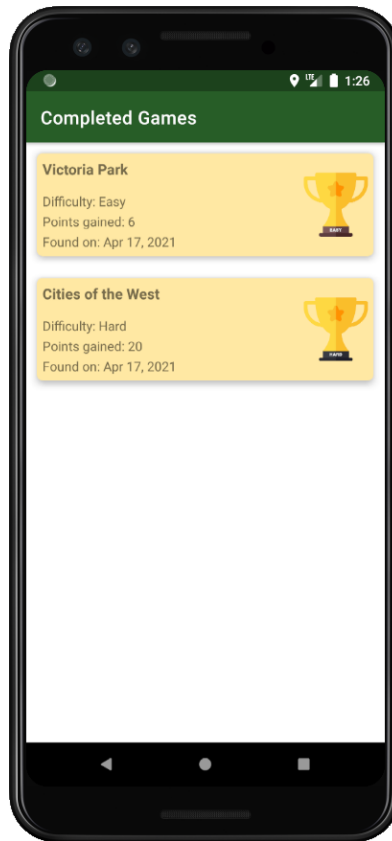


Figure 3.6 – Completed Games Activity, featuring Card Views

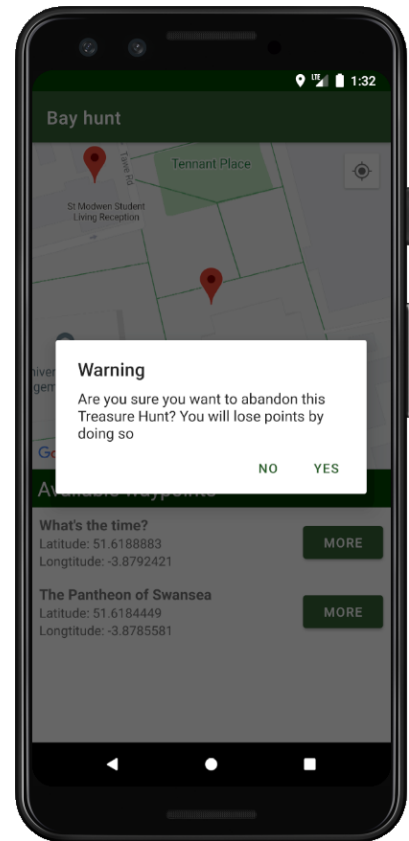


Figure 3.7 – An exit confirmation prompt



Figure 5.1 – Congratulation Activity, shown upon completion of a game

Appendix B

Supplementary Data

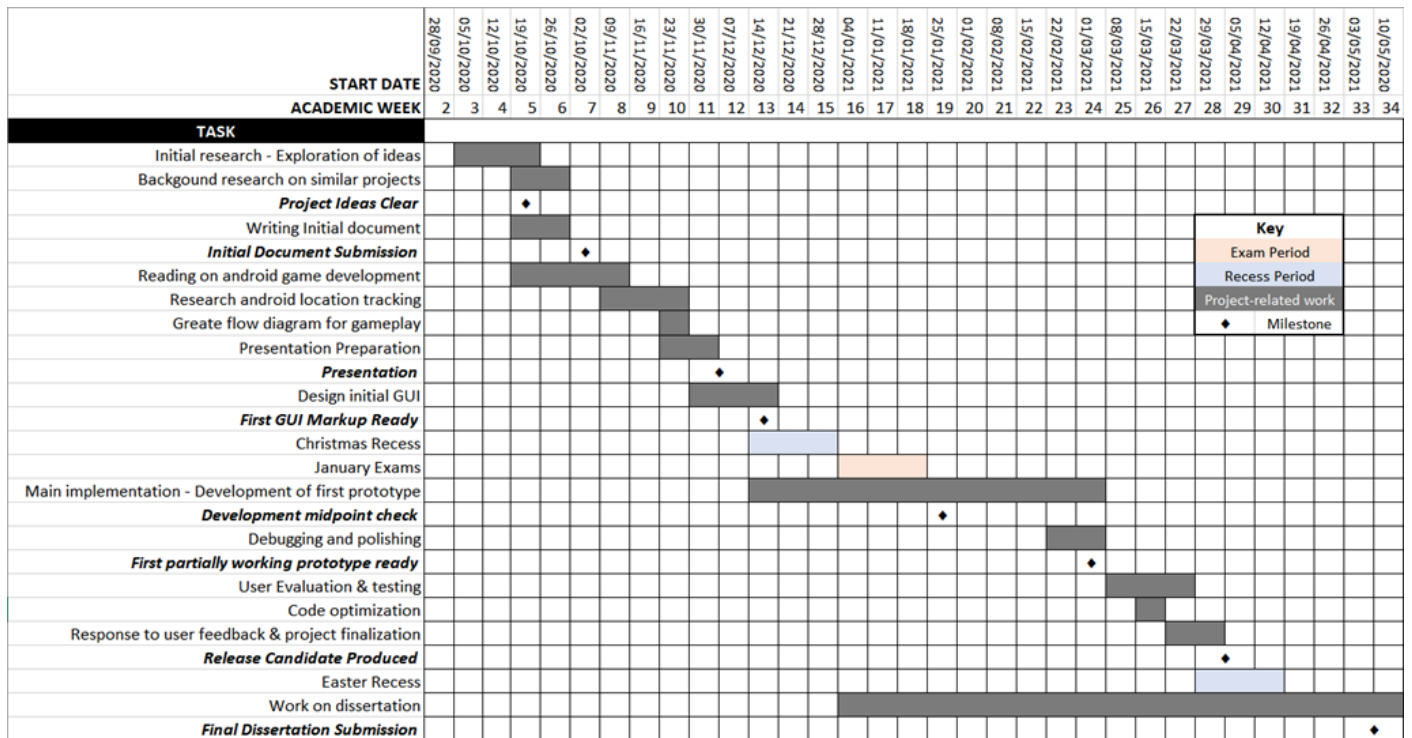


Chart 1 – Proposed project development timeline, as seen at the Initial Document, October 2020