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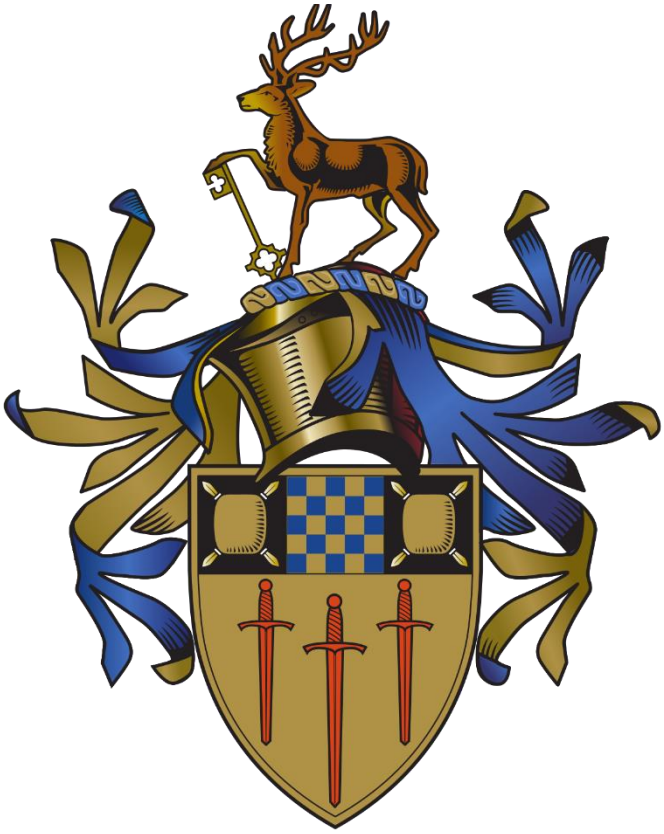

Developing an application for visitors of EPICs Nature Reserve

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Declaration of Originality

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Abstract

This dissertation details an Android phone application for visitors to the EPIC wildlife and conservation project. EPICs mission statement is twofold: To create a small but significant wildlife reserve in an area primarily targeted for new housing, and to make the reserve accessible and of maximum interest to the public in order to promote physical and mental well-being and education.

The application functions as follows: Visitors will be prompted to download the app on arrival via notice boards at site entry points. After registration/login they will be presented with a map of the reserve which will then show their location as they move along the trails. As they approach areas of interest “pop-ups” will display relevant information. Augmented Reality features have also been incorporated with the aim of providing an enhanced experience. A species identification feature will allow visitors to recognise many of the hundreds of animals and plants that they are likely encounter across the reserve. Visitors will also have an opportunity to record their sightings which will be stored in a central cloud database (stamped with time and location by the application). Finally, when visitors exit the site, they will be prompted to give feedback about their experience.

The main goal of the application is to provide a much richer experience than is normal when visiting sites of this type, where generally the only information available is in the form of interpretation boards, wooden signs, finger posts and nature signs. It is hoped the application will provide “something for everyone”: Children may enjoy the AR features and an “I-Spy” challenge to see how many species they can “collect”, whereas the serious naturalist may find the species identification feature particularly useful.

Data gathered and stored in the cloud database also has significant potential value. Species logging will be useful to EPIC (e.g. to populate the EPIC website: “Number of visitors”, “Species seen today”, “Best spotter award” etc.), to the scientific community (e.g. as a resource for on-going national record keeping. The Sussex Biodiversity Records Centre, located a few miles from the site, accepts sighting records in various formats) and to the returning visitor who will be able to grow their tally of sightings with each visit. Visitors feedback will be useful to EPIC in helping identify issues, making improvements and guiding future direction.

The application has been designed to be readily portable to similar sites without significant recoding. For example, site specific information is maintained in the cloud database and downloaded to the application on login. This approach also allows ongoing maintenance, such as adding species, to be made via changes to the database rather than to the application (i.e. by EPIC staff & volunteers), and consequently updates are available on login.

Acknowledgements

I would like to thank my supervisor Lee Gillam for his expertise, encouragement and critical evaluation throughout this project which have helped keep me on track and strive to produce a successful project.

I would also like to thank Peter King from EPIC. He has been a delight to work with and made the entire process much simpler by providing quick responses and impactful feedback.

Finally, I would like to thank my family, in particular, my father, who has provided me with lots of support and my mother who originally introduced me to EPIC. Without them, this project would not have come to life.

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Abbreviations

EPIC – Enhancing Places, Inspiring Communities

AR – Augmented Reality

API - Application programming interface

USGS - United States Geological Survey

NOAA - National Oceanic and Atmospheric Administration

FAA - Federal Aviation Administration

OS – Ordinate Survey

SLDC – Software Development Life Cycle

AWS – Amazon Web Service

1 Introduction

The goal of this dissertation is to produce a mobile application that is ready to be used by visitors to a new nature reserve that opens to the public in 2021 and that has the potential to be used on similar sites throughout the UK in the future.

1.1 Project Background

The Ouse & Adur Rivers Trust and Sompting Estate have partnered to create a new communal nature area. Significant funding from the Heritage Lottery Fund grant was awarded with further financial support from the Environment Agency, Offshore Wind Ltd and GSK pharmaceuticals. Construction began last year. The project was entitled EPIC - Enhancing Places, Inspiring Communities and is managed by Peter King, who I had the opportunity to work closely with for the duration of the dissertation. Peter stated "We are delighted to have been given the opportunity to deliver this project. It will make a real difference, not only to the local environment but also to the residents of the surrounding area. The project is keen to create a 'visitors app' to engage visitors and enhance their experience by being informative and educational." (Estate, 2018). The new reserve is small but lies in the middle of the Brighton / Worthing / Littlehampton conurbation which has a population of around 500,000 people and a population density second only to Greater London (Wikipedia, 2011).It therefore has the potential to have many thousands of visitors each year with the attraction of nature trails, hides and visitors centre.

Many volunteers have assisted with the construction phase, including my parents, and it was through them that I heard about the project teams aspiration to provide some sort of mobile app for visitors. Soon after I met with Peter King and discovered that his ideas were quite simple, envisaging a series of text pages giving overviews of the project, the local environment and resident wildlife. During the meeting I was able to suggest other options such a “tracking” map, triggered “pop ups” related to location, visitor feedback and wildlife identification and recording that together would provide a fully interactive experience for visitors and data gathering for the reserve. Peter was very excited by this prospect and immediately gave the go ahead from the EPIC side.

Although visitors apps of this nature are well established for indoor venues such as museums and art galleries, initial research indicated that they did not exist for outdoor places such as nature reserves, nature trails and even National parks, National Trust sites, RPSB reserves and other similar places. This was a surprise and so the idea was born for this project – to develop an interactive and informative visitors app, initially tailored for EPIC but with the potential to be readily ported to many other outdoor attractions that are open to the public.

1.2 Project Motivation

I have always had a keen interest in nature, and the benefits from getting outside and experiencing nature first-hand as often as possible are well publicized. A key motivation has been the hope that this application could benefit many people by giving them a further driver to get outside, get healthier and learn more about nature and the environment. Also, having the ability to collaborate with a real customer throughout the project lifecycle has been a very enjoyable and useful experience. Finally, I hope that, in the future, this application can be ported to similar sites, thus increasing its audience and impact.

1.3 Project Benefits

This application aims to encourage more visitors to EPIC's new nature site and enhance their experience by providing educational and informational features. It seeks to explore how various technologies, ranging from interactive maps to Augmented Reality, can improve the visitor's experience and encourage them to return many times. Doing so will have a positive effect on their wellbeing, since studies have shown strong connections between nature and mental health (University of Essex & Leeds Beckett University, 2017). If this application is successful for EPIC, it could also benefit many other bodies who are trying to encourage people to visit their sites by tailoring a similar app for each location.

1.4 Project Aim and Objectives

The overall aim of this project is to provide an application that will enhance the experience of visitors to nature reserves. Visitors will have the opportunity to gain a better understanding of the history of the reserve, ecological principles and to increase their knowledge of local wildlife. The new system will initially be deployed by the EPIC scheme in West Sussex, which is creating a new nature reserve encompassing watercourses, walks, wildlife areas and a visitor centre. The project aims to satisfy the following objectives:

1. Research into nature reserves, environmental projects and wildlife and an understanding of how this project will be beneficial to wildlife, visitors and the local community.
2. Research into existing applications and applicable technologies.
3. Learn how to work with a real customer e.g. requirements capture, periodic reviews, delivery & handover, managing expectations
4. Define a set of functional and non-functional requirements.
5. Design a solution that fits the stated requirements
6. Implement a solution for EPICs scheme in West Sussex
7. Test all aspects of the system and make use of user feedback where appropriate.
8. Discuss and Evaluate the success of the application.
9. Define how the project is going to be maintained in the future.
10. Evaluate the project.

1.5 Project Success Criteria

Setting out success criteria provides a benchmark to measure against during the evaluation phase. These are the high-level requirements that the project must meet for it to be deemed successful. The criteria are as follows:

1. A working application has been developed which meets EPICs standards
2. The application has met various ethical standards
3. The applications data is stored in a secure database that can be analysed by EPIC to retrieve visiting and sighting statistics

1.6 Time Management

Given that the scope of this project is relatively ambitious, time management is critical. It is vital to perform sufficient planning before the development phase to ensure the project stays on track. Figure 1 illustrates the main steps that this project will take to ensure its success. During the evaluation phase of the dissertation, a second Gantt chart will be produced to compare what happened versus what was planned for, ascertaining its effectiveness.

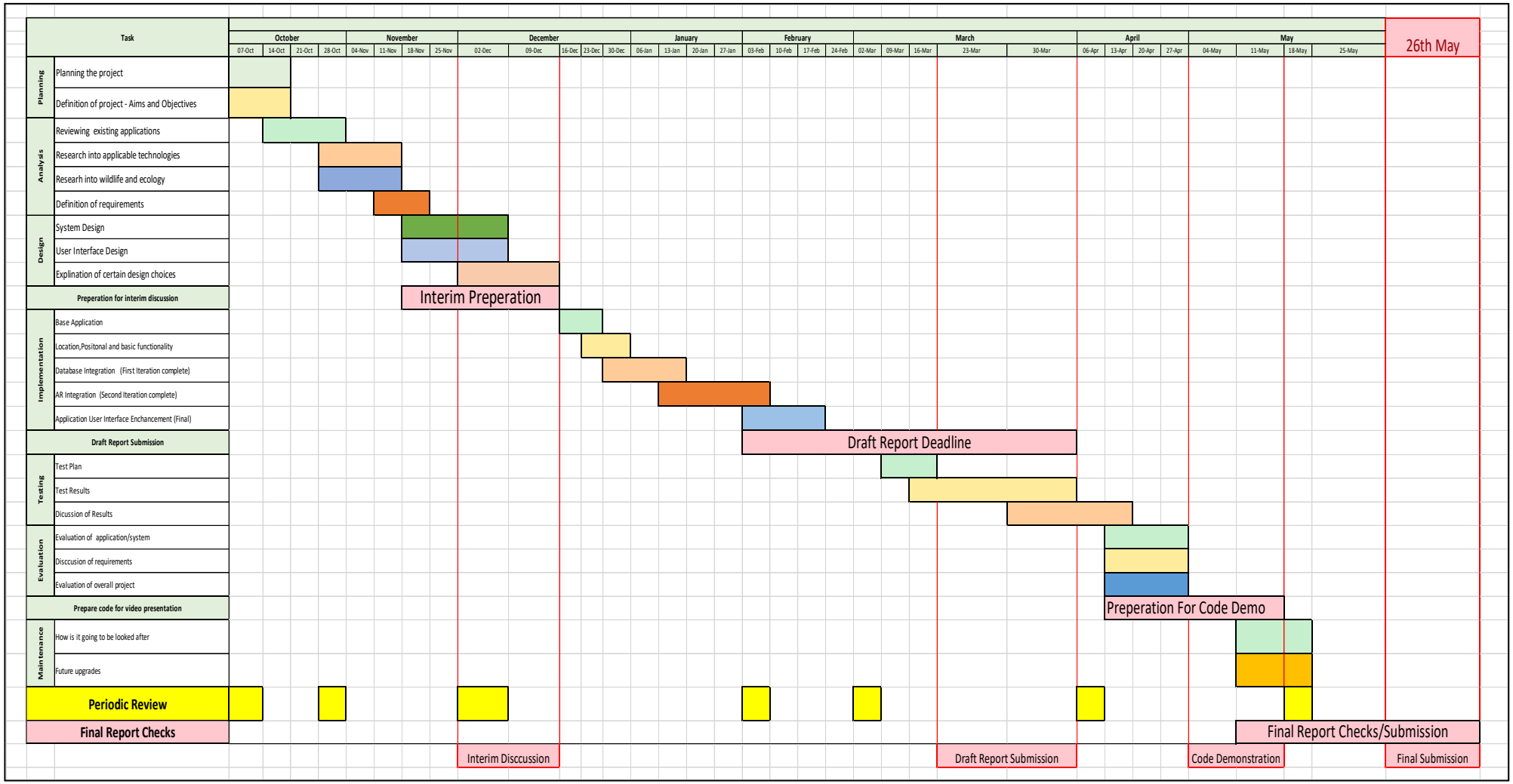


Figure 1: Chant chart for planning and tracking the project.

1.7 Project Structure

This component includes an overview of each step of the project's lifecycle and its included contents.

Section 1 – Introduction

This section introduces the reader to the project, outlining the background from which the concept materialised. It describes the critical motivations of the project and the benefits that can come if it is successful. It also discusses the primary aim of the project and the objectives that will be achieved during its lifecycle. Success criteria are provided to aid with the evaluation stage of the project.

Section 2 – Literature Review

This section focuses on reviewing technologies that are relevant to the application. Mirroring this project, it analyses apps from three distinct areas: Mapping, Wildlife and Augmented Reality. Apps were chosen based on their popularity and rating, providing useful insight into what should and shouldn't be taken forward. Research has also been carried out to in wider fields to provide concrete evidence to support the need for this project.

Section 3 – System Requirements & Specifications

This section focuses on obtaining and outlining the functional and non-functional requirements of the application via work carried out with EPIC to establish a consensus on what the final product should contain. Various methodologies are also discussed in a bid to find the one that is best suited to project.

Section 4 – System Design

This section explores various architectural choices which will define the implementation phase of the project. This ranges from the selection of programming language, development environment, APIs and the design of the server backend of the project. All options relevant to this project are considered, and the choice will be justified during the implementation phase.

Section 5 – Implementation

When the system has been designed and all relevant research has been conducted the application is ready to be implemented. This section outlines specific decisions that were made and any problems that were encountered during this phase.

Section 6 – System Testing

This section covers a range of testing techniques from user-acceptance tests to j-unit tests and system tests, used to ensure that the system meets both the functional and non-function requirements outlined in section 3.

Section 7 – Project Evaluation & Conclusion

This section assesses whether the project met the aims and objectives outlined during the introduction to determine if it was successful. It also describes how the application will be maintained and any further development that might occur.

2 Literature Review

2.1 Introduction

In this chapter, a selection of wildlife, mapping and Augmented Reality applications that are currently available to the consumer and relevant to this project will be investigated and analysed. The primary goal is to review existing implementations of the type of features that are likely to be used in the EPIC application and thereby identify optimum solutions and pitfalls. Each application will be analysed against the same set of criteria.

2.1 Wildlife Reserves

Each year the Wildlife Trust publishes an annual report containing statistics on nature reserves. In the year 2017/18, there were over 10 million visits to nature reserves across the UK. There are currently a staggering 850,000 members of this trust with numbers expected to reach 1,000,000 very soon. In total, there are 2300 nature reserves, none of which presently promote or use any form mobile app (Trusts, 2017/2018) (Trusts, 2017).EPIC is currently in the middle of building a new nature reserve with its opening to the general public in 2021. "A wide range of public events will be held to raise awareness of water conservation, pollution and urban wildlife. These activities will involve practical conservation, photography, heritage investigations and educational programmes based on water quality and ecological surveying. Skill development workshops will train volunteers who can help with the maintenance and management of the site into the future" (Family, 2017). As well as providing all the above, EPIC has a keen eye for ecology and looks to provide useful and new information to scientists. There are over 500 species at the site and a wide range of historical artefacts, dating back to the Palaeolithic period, have been unearthed. The organisation wants to encourage users to visit the reserve regularly by hosting events and providing an application which will improve their experience and make it easier to identify different species. Many wildlife trusts are associated with thousands of businesses across the UK, leading to:

- More wildlife on farmland
- More funding raised for nature conservation
- Educating children about wildlife
- Improving employee wellbeing

As a collective, they bring in a total income of over £143.1M which, with total expenses of £129.2M, leads to a profit of £13.9M. This profit is primarily spent on promoting new opportunities for new reserves across the country, for example, EPIC. National Parks are also heavily visited and promote very similar benefits. It was estimated that over 73 million people visited these parks across the UK in 2009. Since then far more people have become interested in wellbeing and how nature promotes it. It is estimated that the number is now well over 100M (Parks, 2014). With all this traffic, it is surprising that there are no applications that provide visitors to these parks with basic features such as navigation or a simple means of logging sightings of species during their visit. While providing helpful information for scientific research, this could also incentivise users to travel to other locations. If the application at EPIC is a success, it could be rolled out by many organisations managing sites across the country.

2.2 Wellbeing

The last 20 years have seen a rapid increase in reported mental health issues. There is an indication that some of this is due to the rise in computer technology leading to people being less inclined to spend time outdoors. It is estimated that one in six people over the age of 16 have experienced some mental health problem (Foundation, 2016). The University of Essex conducted a study which investigated how exposure to nature can improve mental health. According to their key findings, 95 % of participants with low levels of mental wellbeing reported a signification improvement over a six-week period, with 69 % of all participants seeing significant improvements. The overall conclusion was that "prescribing nature" as a form of medication would not only improve wellbeing but also save money (University of Essex & Leeds Beckett University, 2017). An application like EPIC could encourage users to venture outside more often, leading to beneficial effects on their mental health.

2.3 Popularity of Mapping Technology

A study was conducted on smartphone users to determine how many made use of navigation applications. It is estimated that 77% of users regularly use some form. Although 67% derived from Google maps alone, there is an apparent demand for any apps that offer navigation (Panko, 2018). It is estimated that Google Maps uses approximately 0.73MB of data every 20 minutes, which is tiny compared to the bandwidth provided by mobile subscription services offered today and there is thus no longer any network cost concerns for users. (Clark, 2018)

2.4 Augmented Reality

Another feature of particular interest and relevance is Augmented Reality. The concept itself was entirely new to me 6 months ago but it was important to investigate if and how it might be relevant to this app. Studies show that it is increasingly in demand by mobile users and has become progressively more capable due to advances in deep learning. Some of the most popular applications such as Snapchat now use it for their filters, enhancing photos taken by users. The most exciting feature use for AR is likely to be in its ability to improve modern-day education. It is estimated that the tech education industry is set to be valued at £252 billion by the end of 2020, with an annual growth rate of 17% (Aleksandrova, 2018). With the use of AR, learning can be made more engaging and entertaining. AR has also proven that it provides a faster and more effective learning process (Safe, Practical, etc…). A recent study stated "AR and navigation have always been tied together and have been a major driver for the need of some visual navigation aids. While we often think of GPS as something that helps us navigate a road, this might only be the beginning. Think of visiting a large department store and imagine that a pair of AR glasses might direct you to the aisle that you were looking for – it's an unprecedented state of both indoor and outdoor navigation." (Lawrence, 2018). Although I have not worked with AR previously, I have found the field thoroughly exciting and have enjoyed exploring options for its possible integration into this application. Research has shown that there are two main components to AR. The first is the identification and classification of the target object image. The second is the overlaying of the computer-generated object (Virtual object) to be displayed on the user's live camera feed (Superimposing).

2.4.1 Image Classification

Image classification is a process by which an application identifies an image according to its visual content. There are a variety of techniques available. For example, visual classification algorithms detect what objects are in an image, or other meaningful information about that object. This process is trivial for humans but significantly complicated for computers. There is an array of problems that

generally occur with this kind of processing, the first being the dataset itself. Most machine learning algorithms require a significant amount of data to learn on. However, if the model is trained too much on this initial data, it becomes 'overfit' and generalises poorly on unseen data.

One paper looks at the three most critical factors when performing species recognition. These three factors were: "Size of the training set", "Application to new locations" and "Imbalanced datasets". Their focus was on accurately identifying images with a small dataset since generating large datasets is impractical for most ecological projects, especially in EPIC's case. Results show that animals could be identified in specific locations at around 95% accuracy; however, in unseen locations, this accuracy dropped to about 68%. From their research, they also found that over 1000 images were needed per animal to produce accurate results (Stefan Schneider, 2020).

2.4.2 Superimposing

Superimposing is the process of overlaying a computer-generated image or performing some action on the users view of the real world to produce a composite view. An example of this is PokémonGos feature that displays a 3D generated model in the users live camera feed and allows them to walk around it or capture it. Similar systems may bring significant benefits for enhancing education in the years to come. One paper looks at providing educational benefits to young children by displaying 3D models of animals situated in tideland areas (Youngo Lee, 2014).

Presenting a 3D model or an animation dependent on what the user is viewing could have several benefits for this project. For example, some animals are notoriously hard to spot and rarely leave their sheltered habitats. By incorporating this technology, users could view these animals at any time. The concept itself seems relatively straightforward, but the benefits are outstanding. Research into these two areas of AR, have highlighted two ideas for this project:

1. Labelling the user's camera feed to give them information on their landscape.
2. Displaying some 3D model dependent on what the user is currently looking viewing.

2.5 Application Review

In this section existing applications currently available on the market are reviewed. Their key features and popularity have been used as the main criteria to determine their relevance to this project. Popularity has been defined by the number of downloads and rating the application has received. From previous discussion the choice of applications has been based on three main subjects: mapping, wildlife and Augmented Reality. At the end of this section, there is a direct comparison between applications. This helped determined what features were considered for inclusion in the app.

2.5.1 Mapping Applications

2.5.1.1 Avenza Maps – Offline Mapping

Avenza is the most popular mapping application on Google Play Store with over 1 million downloads and a 5-star rating with its emphasis on providing offline mapping to the user. The app determines the users location and offers a series of maps. Some of the maps are free whilst others can be purchased with prices dependant on complexity. The user can then download the map and display it as a new layer on top of the basic Google Maps implementation. This apps most outstanding features are its ability to provide maps that are unavailable to the general public and to provide the option of layering maps over one another. It uses a variety of map sources such as National Parks, US Forest Service, Topographic maps from USGS, Marine charts from NOAA and FAA for north America.

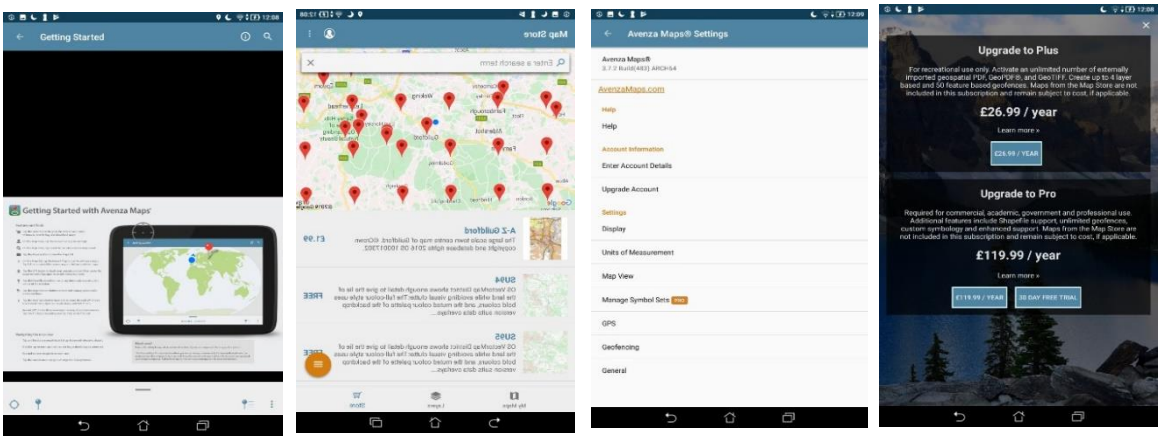


Figure 2: Avenza Maps Screenshots

There are Other features of this application are only enabled via subscription, with two different options, Plus and Pro-Plus. Plus is designed for recreational use and allows the user to import an unlimited number of geospatial pdfs. On top of this, the user can have up to 4 layers active at once for a cost of £26.99 yearly. This version is aimed more towards the general public. Meanwhile, Pro is designed for academic/organisational use and allows for an unlimited number of geofences (a virtual geographic boundary) and includes shapefile support which is a unique data storage format that enables the user to save location, shapes and attributes of geographic features. This does, however, come at a high cost with a yearly subscription of £119.99. In both versions maps must still be purchased individually. Despite the high costs associated with this app, it is incredibly successful due to its broad audience and many positive reviews. The app is available both the Google Play Store and Apple App Store under the name “Avenza” (Systems, 2018) (Systems, 2018).

2.5.1.2 Google Maps – Navigate & Explore

Google Maps is the most popular navigation tool on the market with over 5,000,000,000 downloads (that’s almost one download for every human on the planet) and has managed to maintain a 4-star rating. A powerful feature is its real-time traffic capabilities such as identifying delays, updates and rerouting suggestions depending on the ETA and incidents that may affect your journey. It also provides bus and train times and other forms of transport that could be used to make a journey. Users can also search for food & drink, things to do, shopping and services. It is free to all users and does not charge for any feature. Most data has been acquired by allowing users to contribute. A user can write reviews, add photos and suggest missing places. With respect to my application, a similar system could be used when identifying animals in specific parts of the nature reserve.

There is also the option to download maps to use offline. Again, this process is entirely free, and the user can determine the coverage.

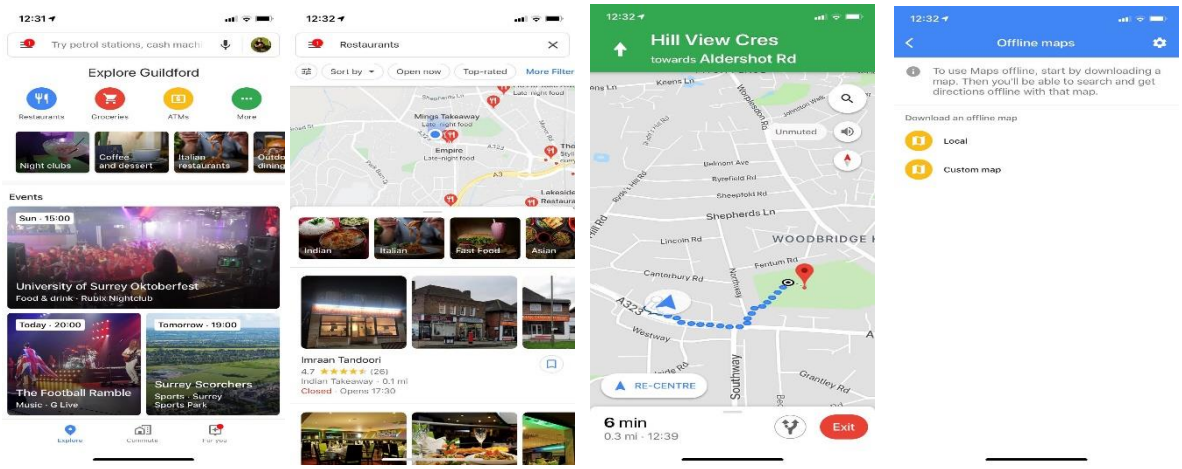


Figure 3: Google Maps Screenshots

The user interface is very contemporary and conforms to the materialistic guideline approach. It is straightforward to navigate between different features. The application is readily available and can be accessed on both iOS and Android as well as online. The website can be found here "https://www.Google.com/maps" and it can be found on both the Google Play Store and Apple App Store for mobile devices *(LLC, 2005) (LLC, 2012)*.

2.5.1.3 OS Maps

OS Maps is the third most popular mapping application after Avenza and Google Maps, offering a slightly different take on the concept with the implementation of Augmented Reality. It has over 500,000 downloads but only a 2-star rating due to a series of poorly designed updates. Nevertheless, I still chose to include it in my review due to its early adoption of AR. The application shares similar functionality with Avenza by providing the ability for the user to download maps and customise layers.

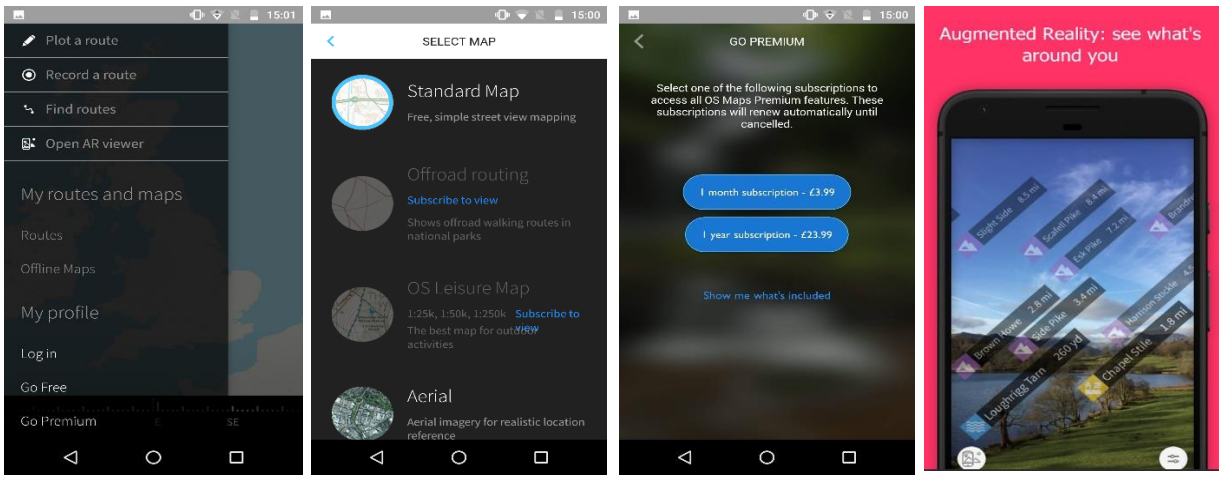


Figure 4: OS Maps Screenshots

The Augmented Reality feature superimposes labels on the users live feed allowing them to gain information about the landscape around them, for example, the name of a mountain. The final screenshot in figure 4 demonstrates how this function looks. When a user pans over a geographical area, specific objects are labelled, these labels give useful information and help when determining a

location. However, to make use of this the user is required to have an ongoing subscription. This caused the application to receive some negative press. Without a subscription, the user has minimal access to any of the worthwhile features. They can only access a standard map view and the option of an aerial view, features which are all available in Google Maps. If the user wishes to make use of off-road routings such as national parks or OS maps, they must pay a monthly fee of £3.99 or a yearly fee of £23.99. Membership does also allow the user to download the maps for offline use. Overall, the execution of the application is excellent, the user interface is friendly and easy to navigate. However, it lacks the free functionality that might attract users away from apps that provide similar services such as Google. The app is available on both the Google Play Store and Apple App Store under the name "OS Maps" (Survey, 2017) (Survey, 2017).

2.5.2 Wildlife Applications

2.5.2.1 iNaturalist

iNaturalist is the most popular nature app on the market with over 1 million downloads and a rating of 4-stars. It is used to record plants, animals with time and location data. This data is then reviewed by an expert to determine validity. This app makes use of a server-side database that stores vast amounts of data. My application will include a similar service for site-specific Sightings. Thus, it is a relevant choice for review. If the user cannot identify the species in a photo, it can be assessed by an expert. It is also currently used by EPIC as they have no alternative for recording data but, since it is tailored for use by experience naturists it will be unsuitable for the average visitor.

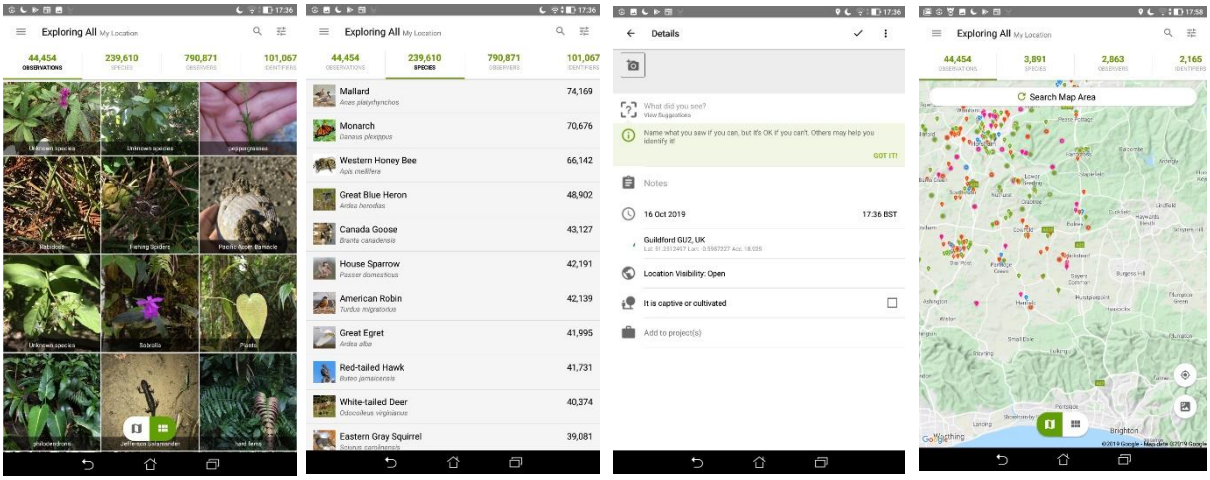


Figure 5: iNaturalist Screenshots

In figure 5, the first screenshot displays all observations that have been found around the current location. Clicking on one of the photos opens a new page, which shows where the life form was found along with any information that was logged by the user. The app also provides the user with information about that species global distribution and instructions on how to make useful observations. The final screenshot is a view that shows the entire area with data based on all the observations that have been made. Clicking on one of the pinpoints it will provide detailed information. The application is entirely free. It is an excellent tool as it builds a growing database for analysis and keeps users engaged by giving them the sense that they are contributing to real-world science while being educated at the same time. The app has some powerful features, such as the logging observations and centralised storage, which are potentially a good fit for my requirements. This app is available on both the Google Play Store and Apple App Store for mobile devices under the name "iNaturalist." *(iNaturalist, 2017) (iNaturalist, 2017)*.

2.5.2.2 Wildlife Trusts' Nature Finder

Nature Finder is the most popular app for nature reserves in the UK and has a rating of 4-stars. The application is hosted by the Wildlife Trust organisation which was founded in 1912 and is responsible for looking after over 2000 wildlife locations in the British Isles. It provides the user with the ability to find Wildlife Trust trails in their neighbourhood which range from rivers to hills and even bogs. Another feature is that it provides information about events. These include talks, guided walks, volunteering opportunities and family activities.

The user can explore Trust sites near them and learn details about reserves. However, the information provided to the user is minimal; there is no inclusion of a map or list of species specific to that reserve. It generally limited to an address, contacts and a short overview. The user can also traverse a tree-like structure to access more information on a specific animal, e.g. Animal -> Birds -> Birds of prey -> Buzzard. Once they have selected their Animal, they are presented with statistics and information about that specific item but there is no logging capability.

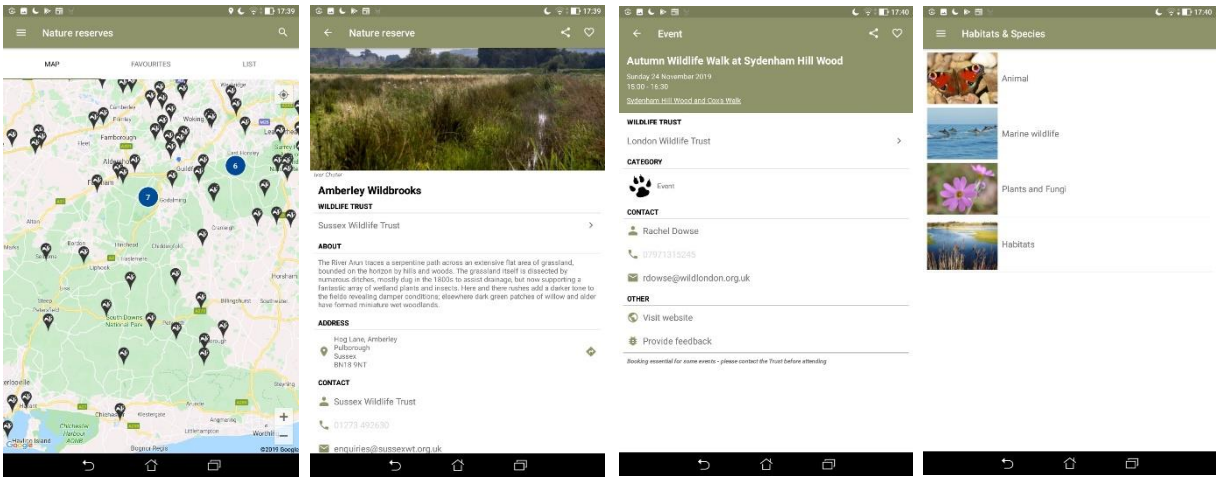


Figure 6: Wildlife Trust Nature Finder Screenshots

Figure 6 shows a representation of the main features of the app. The final screenshot depicts the tree-like structure mentioned earlier, by which the user can identify specific animals/habitats. The application is entirely free and acts as an information hub. The website can be found here "https://www.wildlifetrusts.org/", and it can be found on both the Google Play Store and Apple App Store for mobile devices (Trusts, 2013) (Trusts, 2013).

2.5.2.3 BirdID

BirdID is a little different from the previous two applications with its primary focus being to assist with species identification, specifically birds. It is the most downloaded application that offers this feature with over 50000 downloads and a rating of 4-stars. It includes a list of images and sounds to help identify birds. The addition of sounds is useful as it can be challenging to identify by sight alone. It supports a variety of languages allowing the app to be used globally. It has over 370 species and provides an online voting system for which bird should be added next. The user is required to have up to 1.5GB of free storage for downloading bird guides and bird sounds which could be an issue for users with old phones or storage issues. The most exciting feature is the leader board section which judges' users on their speed to complete a quiz and the accuracy of their answers. Humans love the aspect of competition, and this helps keep the application engaging.

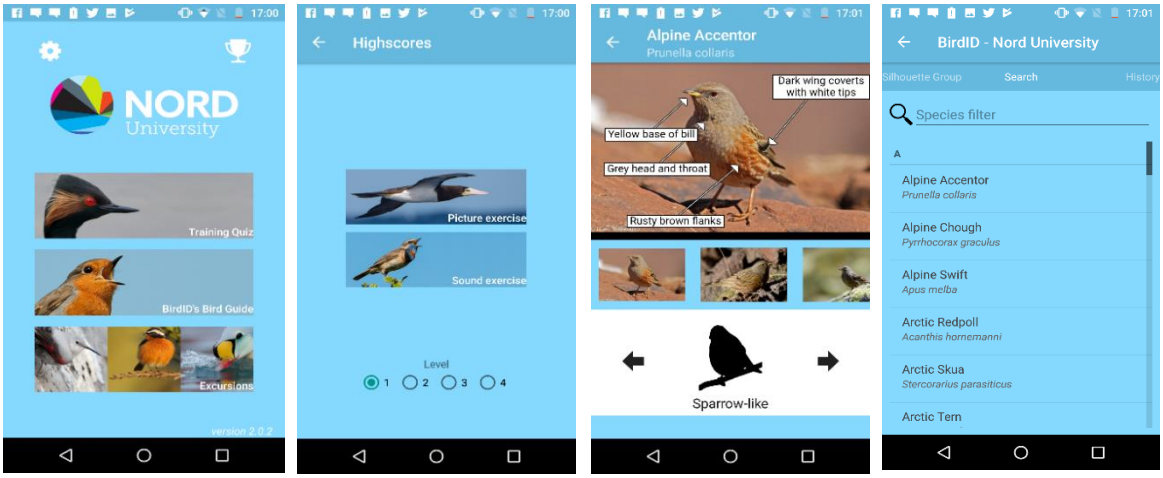


Figure 7: BirdID Screenshots

Figure 7 shows the essential functions of the application. The user interface is very dated by today's standards. The labelling of images when describing birds is an excellent feature. The concept of being able to choose the difficulty of the quiz adds another dynamic to the product. In conclusion, the functionality of the app is excellent, but the UI leaves a lot to be desired. The website can be found here "https://www.birdid.no/bird/", and it is available on both the Google Play Store and Apple App Store for mobile devices (BirdID, 2016) (Eriksen, 2016).

2.5.3 Augmented Reality Applications

2.5.3.1 Pokémon GO

Pokémon GO is the most popular AR application and arguably the most popular gaming app on the market with over 100,000,000 downloads on Android and an app rating of 4-stars. Figure 8 shows how Pokémon GO displays objects in the real-world using AR. This creates an immersive and exciting user experience as it appears real. An option is also provided to turn the real world view off so that the user can roam across a fantasy map of the world catching Pokémon.


Figure 8: Pokémon GO Screenshots

The app displays different Pokémon characters overlaid on the user's real-world view. Which can then be collected as with other Pokémon games. It also considers what type of Pokémon are available dependent on the users location. For example, if the user were near the sea, it would only display water-type Pokémon. All features are available to all users at no cost, which is a crucial ingredient in the apps success. However, the application does offer exclusive items that give the user

an advantage over other players, but with a charge which has led to a lot of poor reviews. It is difficult to fault this application as it has so many great features and a well-built UI. The only issues are the in-app purchases and issues with the greater accuracy of the GPS on specific devices giving some users advantages. From a safety perspective the app has directly caused a number of accidents as users became so distracted with the game they forgot about what was going on around them, leading to property damage and serious injuries (News, 2017). It could be argued that with so many issues prior to release the manufacturers had not properly tackled the ethical side of their application. The website can be found here "https://www.pokemongo.com/en-gb/" and is available on both the Google Play Store and Apple App Store for mobile devices (Niantic, 2016) (Niantic, 2016).

2.5.3.2 ViewRanger: Trail Maps for Hiking, Biking, *Skiing*

ViewRanger is currently one of the most popular tracking apps on the market and provides the ability to use AR. It has over 1 million downloads on Android with a rating of 4-stars. I selected this application because it fits the functionality of my project whilst also suppling an element of AR. It makes use of Ordinance Survey maps which provide the user with detailed pathing when they are on nature trails (something lacking on Google maps). It won multiple awards such as: "2018 Android Excellence award" -Google Play, "Editor's Choice & #1 Outdoor App" -Google Play, "Five-star must have app" - The Sunday Times and is even used by over 400 rescue teams.

The most exciting part of the app is called Skyline. It makes use of different recognition techniques to provide the user with data about the objects surrounding them. This technique also allows for navigation using directional arrows and waypoints. Essentially it is a digital hiking instructor that accompanies the user.

Figure 9 shows various views of ViewRanger. The left screenshot shows different walks that are available at a given location plus associated hiker skill level and time to complete. The next screenshot depicts how the user can plan and record different routes. The final photo shows that, when a user takes a photo of the location, labels appear to on significant features.

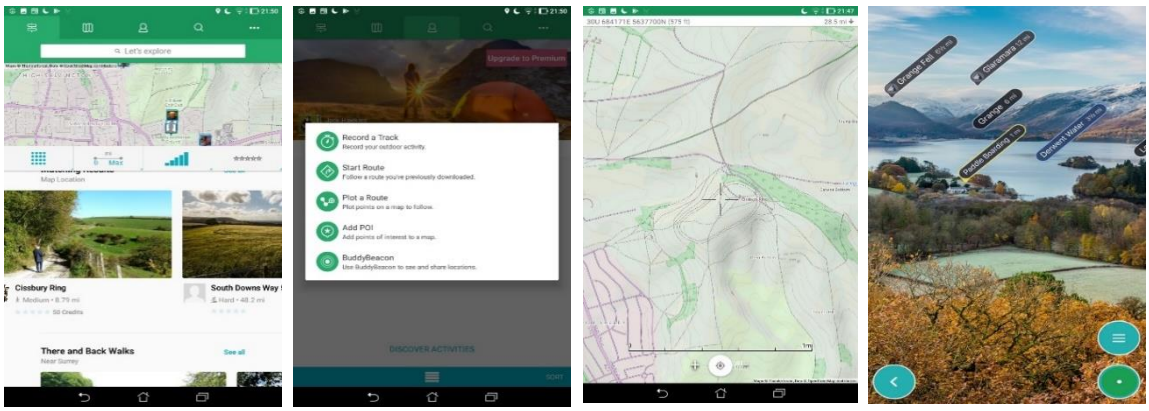


Figure 9: ViewRanger Screenshots

The application has a few options when it comes to purchase. The premium version comes at cost of £4.99 a year but does not provide any maps. For access to Ordinance Survey maps the user must pay £4.99 a month or £24.99 a year. This more expensive service also provides the user with access to the brilliant AR features. It does however require Android 7.0, something that would prove problematic to some users. It is available on both the Google Play Store and Apple App Store for mobile devices (Augmentra, 2015) (Augmentra, 2015).

2.6 Summary

Table 1 Summarizes the review above and highlights those features that are to be taken forward to the design phase and those that are to be excluded.

From research into mapping applications, it is clear from the sheer number of downloads that they have become an essential tool for navigation for mobile users. Whilst all apps offer the ability to overlay maps on top of existing ones, only Google Maps provides this feature for free. Providing the option to overlay a bespoke map on top of a nature reserve is not catered for by any existing application. Use of a bespoke map for the EPIC application is a key requirement because, since the site has yet to finish construction and will change for some time after, no public maps or satellite images currently exist. Another feature absent in most apps is user location tracking. This is important for EPIC because the site is small, and objects of interest could be easily missed.

It is evident that from research that there are wildlife applications that provide a means of identifying species and/or recording observations. Some are aimed at experts; most are designed to cover all the species found in the UK and beyond. There is no good fit for the EPIC requirement i.e. to be usable by all and to only include those species that can been found at a specific site. A driver for this requirement is that, if the feature is quick and easy to use, more visitors will use it. A hierarchical system of photos of known species together with a one click “record sighting” button would seem the optimal implementation. The idea of adding a game dynamic to the application is also relevant as it may encourage younger generations to become involved.

The use of Augmented Reality was found to be limited to a few simple implementations in mapping applications. Nothing was found in apps associated with nature reserves or wildlife. OS Maps and ViewRanger both use AR to identify and label major geographical features such as mountainous skylines and lakes. These are features that do not change physically and appear similar under different weather conditions and seasons etc. Image classification is therefore relatively easy and cheap to implement and usable on typical phone hardware. On the other hand, AR for nature reserves and wildlife would have to handle image classification on objects with large variations and that change over time, making implementations complex, expensive and resource hungry. This will present a challenge with respect to implementation on the EPIC application.

App Name	Why it was selected	Popularity	Rating	Price	Features taken forward	Features excluded
Avenza Maps	• Provides Map layering technologies. • Offers a variety of maps that are difficult to acquire. • Provides offline mapping, useful for areas with intermittent connection e.g. “wildlife reserve’s”.	1,000,000+	5-Stars	Pro: £26.99 Plus: £119.99	• Bespoke map layering. • Availability of wildlife Trust Maps. • Some form of offline mapping.	• Archaic design. • Poor navigation system. • Overpriced additional features.
Google Maps	• Ability to scan users location and provide a list of nearby features. • Provides indoor mapping could be useful in creating an immersive effect. • Provides real-time updates about traffic, could be used in correlation with wildlife populations or new historical findings on the site.	5,000,000,000+	4-Stars	Free	• Apply outdoor mapping to EPICs wildlife reserve. • The idea of real-time updates to what’s happening around the user could be exciting and innovative. • ability to display areas of interest.	• The ability for users to add new places as this is focused more towards animals and historical features. • Satellite view of map. • Transport features.
OS Maps	• Heavy focus on Ordinance Survey maps and artists impressions. • Provides the ability of off-road routing. • User can record their own route to reuse. • Augmented Reality feature that labels nearby objects of significant value	500,000+	2-Stars	Monthly: £3.99 Yearly: £23.99	• Some sort of rendition of the AR feature • Ordinance Survey maps • Routing ability	• Subscription feature severely limits the users ability to use the app. • Normal features are already supplied in free apps

iNaturalist	• Most popular nature application on the market • Provides the ability to record data • Community provides data for scientific research • Gives a breakdown of what's near you using GPS	1,000,000+	4-Stars	Free	• Ability to record data but tailor it to EPICs reserve • Observations specific to the user to provide a sense exploration (What they still need to find) • Logging of what's been seen near a specific location	• Lack of explanation of different species. • The User interface is unclear and confusing • Mapping feature can be very messy depending on how busy the location is.
Wildlife Trusts Nature Finder	• Run by the Wildlife Trust organisation – official application for nature reserves. • Offers a breakdown of all the species that can be find in the UK • Provides information on different nature reserves in the UK	10,000+	4-Stars	Free	• Some sort of hierarchical view on different species in the area • Take the Capabilities of displaying the nature reserve to the next level by providing a map.	• Lack of information provided to the user about the reserve. • Events feature is exciting but has no correlation to the project • Lack of observation features
BirdID	• Provides a system of identifying different species of birds • Provides sounds of each bird to help identification • Quiz game to teach users different birds • Labelled images of birds provide a more immersive learning experience	50,000+	4-Stars	Free	• The inclusion of a game dynamic could provide a long-lasting feature to returning users. • Identification system • Labelling system • Voting system on website for what birds are added next is a nice touch	• Old design will put off new users • Clunky settings make it hard to navigate • The amount of data required to install the application will prevent downloads. • Foreign language support
Pokémon GO	• Most popular AR application of all-time • User can catch Pokémon anywhere in the real world	100,000,000	4-Stars	• All features are free • In-app Purchases	• Use of camera to provide AR functionality • Personal map design could be useful for reserves	• In-app purchases have always been controversial, there will be no need for them in this app.

	• Uses its own map design that considers different weather features • User can use the camera to look at different creatures in real life			provide advantages	• UI design is clean and effective.	• Will not be catching animals. • Weather feature does not seem applicable
ViewRanger	• Won numerous awards such as the "2018 Android Excellence award -Google Play" • Specifically designed for wildlife hiking and makes use of AR to guide the user. • AR provides the user with directions depending on where they wish to go, and labels nearby features e.g. a lake. • Provides the user with details on the difficulty of the route and how long it takes to complete • There is also a feature that allows users to compete on timed events	1,000,000+	4-Stars	Premium: 4.99 yearly Premium Plus: £4.99 monthly – £24.99 yearly.	• Some sort of AR version that provides similar features catered to a specific reserve • The relationship with user feedback and updates is excellent. This has allowed them to maintain a high standard since 2015 • Clean app design that follows materialistic designs allows for easy navigation • The routing feature could be useful when planning days at nature reserves	• The idea of racing through nature trails is fun but also takes away from the point that users will be trying to relax • The cost of premium features is quite extensive and will put of new users

Table 1: Comparison between applications

3 System Requirements & Specifications

3.1 Introduction

This section will review different methodologies and decide which one best fits the scope of this dissertation. It will assess feasibility and detail the steps needed to deliver the product. It will also quantify Functional and non-functional requirements and identify any dependencies that may occur during implementation.

3.2 Methodologies and Architectures

The Software development Lifecycle (SDLC) consists of six distinct phases which are Planning, Analysis, Design, Implementation, Testing & Integration and Maintenance. SDLC facilitates creation of the highest quality software at the lowest cost and in the shortest possible time. I will define the requirements of the new system based partially on the research covered in the previous sections. The software will be then developed through the design, implementation and testing phase before it's released to the market, from which point it will be managed by the maintenance phase. There are a variety of implementations of the SDLC, each of which is suited to a specific scenario. For example:

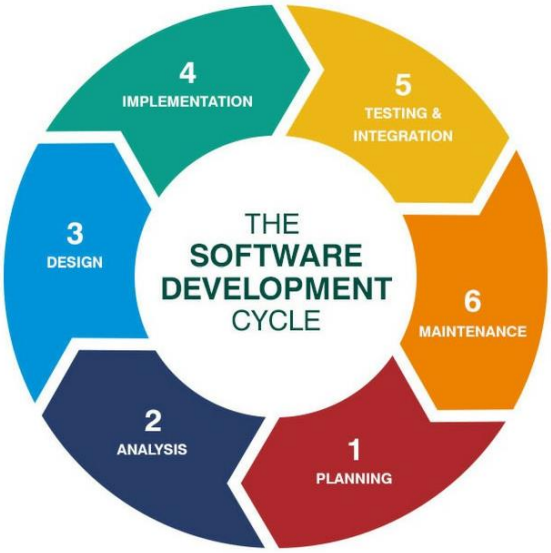


Figure 10: SDLC

As a project progresses, requirements or design may change. When choosing the best methodology, it is essential to find a solution that will provide the appropriate level of iterations over the lifetime of the project. At the first iteration the system can be compared to the requirements to determine if any changes need to be made. If there are discrepancies between the product and the requirements, the entire development process can be repeated. This leads onto the second iteration of the product and the iteration sequence repeats until the final product satisfies the requirements and needs of the customer. Approaches such as Waterfall are not appropriate to this project as they require the developer to go all the way back the planning phase if they need to make changes to the system. This technique is generally regarded as backwards and outdated. Details about this design method can be found here (Powell-Morse, 2016). I have also ruled out any form of Agile methodology as it focuses on team development. Since this is an individual project, any form of team-based activities would not be applicable. Agile methodologies are detailed here (Blueprint, 2019). This project will have the following phases:

- Plan
- Research
- Design
- Implementation
- Testing
- Evaluate
- Maintain

In context of this dissertation, most of the planning and research has been covered in the previous sections. Thus, when choosing a methodology its important that it fits the aims and objectives of the project within the time frame available.

3.2.1 Prototyping

Prototyping is a model that focuses on producing a working system as quickly as possible. The system is repeatedly tested and reworked where necessary until an acceptable outcome has been achieved. It is designed for projects where some requirements are unknown at the start of the development phase. It is an iterative process that works on a trial and error basis between the developer and the customer. There are different types of prototype models; for example, Rapid Throwaway prototypes, Evolutionary prototype, Incremental prototype and Extreme prototyping which all tackle the same problem from a slightly different perspective. Since this project has a short timeline, Rapid Throwaway prototyping will not be applicable, and neither will Extreme prototyping, which focuses on web development projects. The rest of this section will analyse both Evolutionary prototyping and Incremental prototyping to determine which is more suitable for this application.

3.2.1.1 Incremental Prototyping

Incremental prototyping is an approach that focuses on splitting the product into different components and combining them all at the end. This is usually a team focused approach as different areas of expertise can work on different segments of the project in parallel, for example, the front-end and back-end of the project. Since this is an individual project, it does not seem fitting to take this approach, although it does share similar advantages to Evolutionary prototyping in that the customer can respond to each increment.

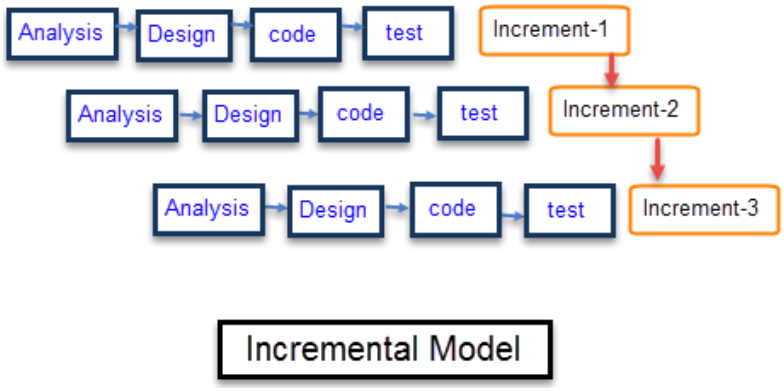


Figure 11: Incremental Development Approach *(Guru99, 2020)*

3.2.1.2 Evolutionary Prototyping

The **Evolutionary** approach is continuous, in that the system is refined after each iteration dependent on customer/user feedback. This software development approach appeared to be the best fit for my project since reliance is primarily on EPICs' feedback regarding what is changed and what is kept with each iteration (Rouse & Lewis, 2019). Figure 12 indicates that the deliverability of a project is entirely dependent on the user acceptance results. If these do not pass then new requirements are fed back into the design and development phase and a new prototype is produced until one is fully accepted, which becomes the final solution.

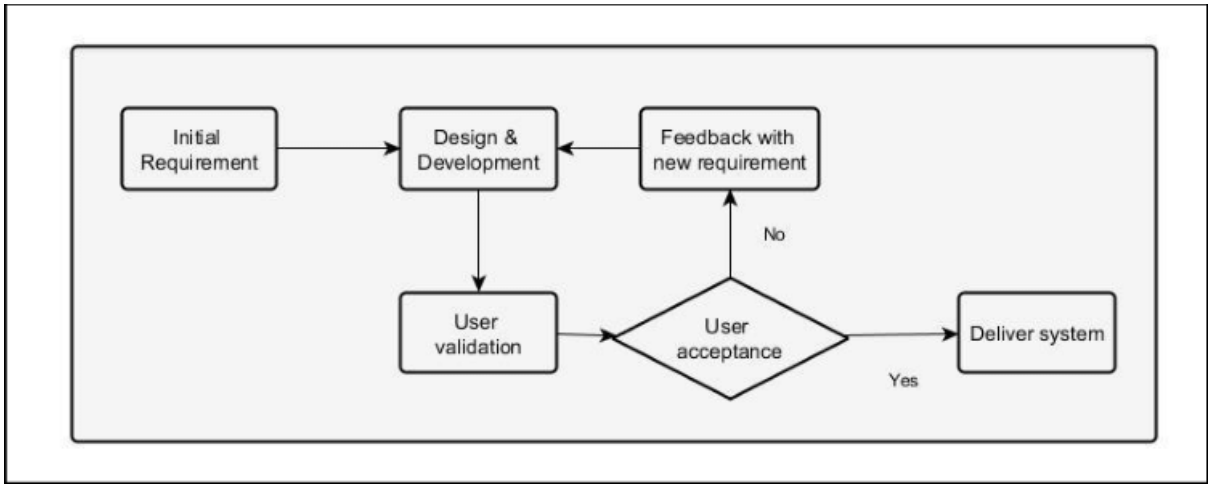


Figure 12: Evolutionary Development Approach *(Saad & Shaharin, 2016)*.

3.2.2 Methodology Summary

My project is characterized by one individual working and communication with the customer. Since implementation/testing will be a continuous phase, the **Evolutionary** prototyping model will be used. It allows for continuous modification and testing of the system with changes being made according to customer feedback. Also, since each iteration is based on the previous one, time can be saved which can be used elsewhere. Other advantages of this model are that any missing functionalities or errors spotted by the customer in one iteration can be ironed out in the next one. It provides a continuous stream of feedback throughout the entire process instead of just at the end, which facilitates development of a more user focused product. This selection will be assessed at the end of the project to determine whether it was the correct appropriate method.

3.3 Investigation

It was essential to organise meetings with EPIC to finalise a set of requirements that could be achieved during this project's short lifespan. To understand if it would be possible to deliver all the features EPIC were requesting, detailed research into the different APIs available to Android was necessary. This would avoid promises being made during the requirements gathering phase that could not be delivered. The specific details discussed in each meeting have been documented in Appendix A. The first meeting outlined what EPIC wanted and this is how the requirements, detailed on the following pages, were created.

3.4 Functional Requirements

The following table contains details of the functional requirements for the system which have been defined with EPICs' envolvement. Apart from the Augmented Reality function, all other elements are essential for this application's success. A unique ID allows for cross-referencing throughout the

report as well as defining dependencies between requirements where appropriate. To conclude, this has been configured to cover the main functionalities of this application which are; Mapping, User-Specific Information, Accounts, Species Identification, Recording, Feedback, Cloud Database integration and finally Augmented Reality.

ID	Function	Description	Inputs	Source	Outputs	Destination
1.1	Account registration	The system will provide the user with the ability to register an account with the service.	Users basic information such as email address and password. Validation Checks will ensure input fields are entered correctly.	Data input from user.	Users account will be created.	Information will be stored in the database.
1.2	Sign into an account	The system will provide the user with the ability to log into the service once they have registered.	The user must have created an account with the service (r1.1). The information entered matches the information stored within the database.	Users input data.	User is successfully authenticated.	Login details will be compared to the information stored within the database, if there is a match, they will be successfully logged in and taken to the home page.
1.3	Sign out of an account	The system will allow the user to log out of their account provided they are logged in.	The user must have signed up (r1.1) and be logged in (r1.2).	User clicks sign out button on application.	User will be logged out of application and prompted to login again.	Users connection to services is terminated and they are returned to the login page.
1.4	Deletion of user account	The system will allow a user to delete their account provided they are logged	The user must have signed up (r1.1) and be logged in (r1.2).	User clicks the delete account button	Users account will be deleted from the database and they will be returned to the login page	Users connection to services is terminated and they are returned to

ID	Function	Description	Inputs	Source	Outputs	Destination
		into the service			of the application	the login page
1.5	Show Site map	The system will display a map specific to EPIC Nature reserve.	User must have enabled their location for this to feature to work.	Map file retrieved from cloud storage.	Bespoke map will be overlaid on top of existing map.	A fragment will display this information on-top of the main screen
1.6	View all species	The system will display a list/photo of all species specific to the EPIC Nature reserve.	The user has clicked the display species button.	Data will be retrieved from cloud storage and cached once loaded.	A hierarchical photographic list depicting all the different species in the area.	A fragment will display this information on-top of the main screen
1.7	Submit Feedback	The system will provide a form of feedback that allows EPIC to update the app/ any species that were not on the initial list	This will include what could be improved about the application, the reserve and any other concerns the user has.	Data that has been inputted by the user	A generated email containing the users input	Data will be sent to an email address that is managed by EPIC
1.8	Display specific information depending on user's location.	As the user walks through the reserve specific information will be displayed for each waypoint.	A combination of (r1.4) & (r1.5) will be used to dictate this feature	The users GPS location will be used.	Information about the wildlife in that area will be displayed. Information about historic findings in that area will be displayed.	This will be displayed as dialog boxes to the user (pop up boxes that they can click).
1.9	Navigation Bar	The system will provide a side-menu that allows users to access other features of	It is dependent on what route the user wishes to take.	The users input on the screen will determine if this feature is displayed or not.	The menu will be displayed	This will be overlaid on the main screen.

ID	Function	Description	Inputs	Source	Outputs	Destination
		the application.				
1.10	About	Will display general information about the site and the organisations involved.	This will be accessible if the user has accessed the navigation bar (r1.9)	The menu option available.	The different help features available	This will be displayed as an overlay to the main page
1.11	Record Sightings	The system will provide the user with the ability to record their own sightings when visiting the EPIC site.	Specific information about that email to the required fields.	The button allowing users to record sightings.	The user's input will be stored in the cloud database.	The user will be taken back to the map or the sightings page dependent on what route they took.
1.12	Augmented Reality	The system will display models dependent on the image identified by the user's phone	Dependent on whether permissions have been granted.	The camera on the mobile phone.	3D Rendered model	The camera screen overlaying the application.

Table 2: Functional Requirements

3.5 Non-Functional Requirements

These requirements specify the criteria that can be used to judge the operation of the system, whereas the functional requirements define specific behaviours of the app. These ensure that the application performs as expected and does not have any unintended performance issues.

ID	Category	Description
2.1	Accuracy	The system will validate all user-inputs to prevent any data discrepancies. For example, their email address is valid, and the password must match some specified regex.
2.2	Accuracy	The system should display the users location within a 3-meter radius
2.3	Accessibility	A user should be able to sign up at any time of the day and should not experience any issues. They should be able to sign up with multiple accounts provided the data is valid.
2.4	Accessibility	A user should be able to log-in/out at any time. It should be clear and intuitive on how this can be achieved.

2.5	Permissions	The system will request permission to access the user's location. If the user does not accept, they will be prompted once more before the mapping features are disabled. They will still be able to turn it on in the settings if they change their mind.
2.6	Permissions	The AR feature will not be available to systems that do not have the required architecture
2.7	Compliance	A privacy policy will be available, so the user is aware of what data is being processed.
2.8	Interface	Navigation within the application should be clear
2.9	Interface	Different features within the application should be easily accessible and intuitive to use.
2.10	Environmental	The application will display differing information depending on the users position within the environment
2.11	Security	Data should be stored securely against common vulnerabilities so that identifiable information is not accessible
2.12	Security	All user information will be transmitted, processed and stored securely to ensure privacy is maintained.

Table 3:Non-Functional Requirements

3.6 Project Scope

As detailed in meetings with EPIC, there were initially a few requirements that ultimately become out of the scope of this project. Similarly, some requirements were not listed by EPIC but were added to enhance the user experience. Before going forward it is essential to clarify deliverables.
Features which are not essential but will be attempted are:

- Augmented Reality integration with labelling of surroundings
- Google Play Store integration

Features which are out of the scope of this project and will not be attempted at this time are:

- Integration of cloud database with Somptings website to provide live updates on what species have been spotted for that day.
- Identification of species quiz
- IOS version

4 System Design

4.1 Introduction

This section provides a detailed design overview of the application and describes the implementation of each system component. The requirements gathered in the previous section are analysed in order to determine design choices to be used for the implementation of the system. These include database design, server, API and mobile design. For each of these components, the positives and negatives of potential implementation options will be considered before making a final choice.

4.2 Use Case Diagram

Use case diagrams are used to provide a high-level overview of the system and illustrate system requirements in layman's terms to stakeholders and other non-technical areas of the business. The requirements that were defined in *section 3.4* have been used to construct the following diagram. From this, EPIC were able to gain an understanding of the Administrator role.

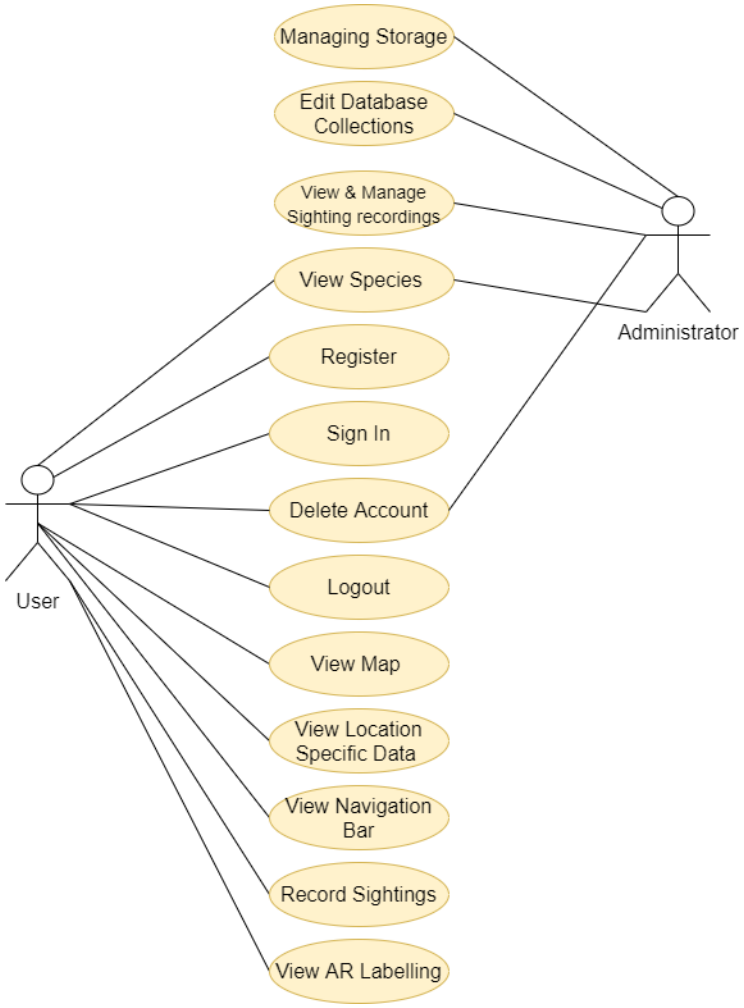


Figure 13: Use Case Diagram (draw.io)

4.3 Flow Diagram

Figure 14 displays a possible flow of the application. By creating a graphical representation of the flow, processes and interactions can be visualised allowing problems and improvements to be readily identified and solutions to activities chosen. Flow diagrams depict the processes that must take place to achieve a specific outcome; for example, the user cannot access the home activity unless they have logged in and been successfully authenticated. Developing this diagram speeds up the implementation process by providing a simple illustration of how process works together. As stated, this is not the final flow diagram for the application but was used to produce the first prototype.

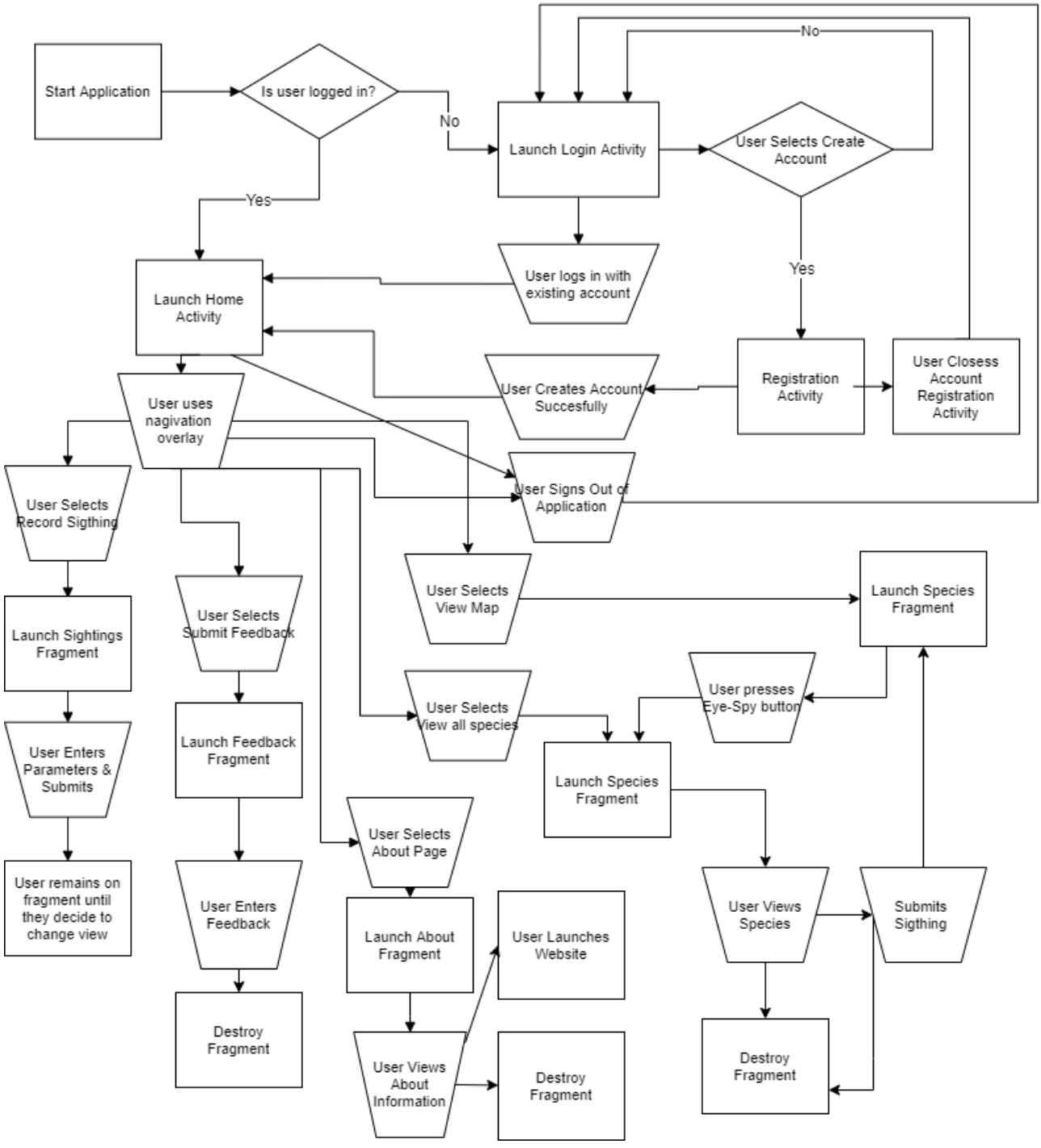


Figure 14: Application Activity Flow Chart (draw.io)

4.4 Database & Server-Side

Requirements 1.1-1.4, 1.6, 1.8 and 1.11 all require some form of database in order to be implemented. Thus, when designing this application, a choice between the use of relational and non-relational databases was needed. Relational databases are designed to handle complicated querying and high rates of transaction. However, since they were not initially designed to integrate with object-oriented programming, checks for referential integrity throughout the schema must be made. Since this project handles significant amounts of data in terms of daily logging of species, there would be a potential cause of errors. NoSQL databases are designed to work with large amounts of data and handle simple queries without the administrator referencing the master schema. There are a variety of types available such as key-value stores and document databases. Key-value stores assign a unique key with each value; however, this does not follow the hierarchical search mechanism, which forms a core part of this project. Document databases, however, store all data in a JSON file. This file can consist of a variety of collections which contain documents, which themselves can then contain collections in a tree-like structure. It is important to note that choice will be dependent on the cost of available solutions and that the selection will not be made until the implementation phase. The two significant candidates for selection are Amazon Web Services (AWS) and Firebase (Google). Since this application will be used by EPIC, we need to consider scalability and cost when identifying the best platform. The data provided by the system will be in a variety of formats, and the database must be able to handle this. The key factors to be considered when choosing a solution are:

- Data accessibility
- Speed and scalability
- Multiple database scope
- Flexibility
- Platforms being supported
- Data Security (Authentication)
- Data Conflicts
- Cost

4.4.1 Amazon Web Services

When it comes to storing and accessing data, AWS offers a variety of services with a choice of over 14 purpose-built engines including relational, key-value, document and many other types of databases. Their implementations mean that scalability is never a problem and they also offer higher performance than other commercial options. AWS also provides continuous monitoring, checking that every component is working correctly and running “self-healing” processes when necessary. The Key-value service is designed for applications and provides fast response times that can fit any scale (AWS, 2019).

Amazon also offers a service called Cognito, which provides secure user authentication. It works via a directory which can handle millions of users and is easy to set up. As with Firebase, a user can sign up with many platforms such as “Google” or “Facebook”. It supports “identity and access management standards” such as “Oauth 2.0” and “SAML 2.0”. It also comes with a built-in UI which allows for easy configuration that can be added to an application in minutes. The main drawback with AWS is that a lot of the features this project requires are behind pay gates. AWS does provide a 12 Month Free plan but this is not suitable for EPIC as it will be active for the foreseeable future (Amazon, 2019).

4.4.2 Google Firebase

Firebase offers a variety of services such as Cloud Firestore, Authentication, Cloud Storage and Realtime Database. Firebase uses NoSQL to provide a flexible database which can sync data for both client and server-side development. It also provides offline functionality to improve user experience if the connection is lost. Finally, it offers strong user-based security that facilitates the restriction of data using a series of commands. Firebase Authentication enables users to register with any platform as well as supporting email and password accounts for users that do not use popular platforms. Firebase is straightforward to integrate and can be implemented in under ten lines of code. Its pricing varies depending on product usage. Since EPIC are looking for a product that is free to operate, it was essential to find a service that provided this. Firestore allows for 1GB of stored data, 20000 writes and deletes along with 50000 reads a day, with authentication allowing 10000 phone authentications a month. The real-time database supports 100 simultaneous connections and 1GB of storage. There is also a storage focused service that provides 5GB of storage, which equates to about 2500 high-resolution photos. All these allowances are sufficient to meet EPICs' requirements, thus Firestore can provide all the necessary services at no cost. Firebase provides two plans should the application exceed limits. The "Flame Plan" greatly increases the number of reads and writes the app can make along with increases in storage capacity. The "Blaze Plan" offers a pay as you go plan which would be more suitable to this project (Firebase, 2019).

4.4.3 Summary

AWS and Firebase both offer similar products. The final choice was driven by cost to the customer. Since EPIC intends to run this project for as long as possible with no overhead, it was essential to find a service available at zero or negligible cost. With predicted usage being well within Firebases free allowance is seems like the perfect fit. The NoSQL database will also function well with the model intended for the application. Firebase provides free storage of up to 5GB which is more than sufficient for this project. The Cloud database fits the requirements for 1.6, 1.8 and 1.8 by allowing data to be retrieved and sent at any time. The real-time database also supports seamless integration of accounts meeting requirements 1.1-1.4. Since all requirements are met by Firebase, and there are other postive factors such as cost and experience, it stands out as the best choice for this project.

4.5 Mobile App Design

4.5.1 Android vs iOS

Since this project runs over a short, fixed time frame it is not possible to develop the application for both IOS and Android. It was therefore important to determine which mobile device platform was more dominant in the UK and hence would allow most people access. It is estimated that globally Android owns 74.5% of the market share, whereas iPhone only owns roughly 23% (Casserly, 2019). This is a significant difference; these figures would indicate for every iPhone there are 3 Android phones. Thus, we can conclude that by developing the application on Android, the user base is likely to be 3x higher. Catering for other mobile platforms is potential future endeavour. This choice was agreed at a customer meeting, see appendix A for more details.

4.5.2 Programming Languages

A variety of languages can be used to develop Android applications and it is therefore essential to consider the pros and cons of each when deciding which one to select. It was also important to ensure that the language chosen was supported by the APIs required to implement the application.

4.5.2.1 Java

The official language of Android development is Java, and most of its APIs are designed to be called using Java. Java is also actively promoted by Google. It is free to use which is obviously vital as use of some IDE's and programming languages do have an associated cost. Java is a mature language and there are plenty of tutorials available on implementing Java solutions. I already have experience of programming with Java including with Android application development, so the learning curve will be smaller than with Kotlin or Xamarin. The main downside of using Java is that the entire project will have to be rewritten if the application is required to become multi-platform.

4.5.2.2 Kotlin

Kotlin is a cross-platform programming language designed to reduce the time it takes to implement multi-platform solutions. By allowing users to write the same logic for both iOS and Android, it provides parallel integration onto both platforms. This removes the need to learn and rewrite the entire application in Swift (iOS development language) if deployment on iPhone is also required.

4.5.2.3 Xamarin

Xamarin is like Kotlin in that it promotes reusability of code in order to get an application running on multiple platforms. However, it is written in C# and a lot of the APIs available to Android are not yet available with this open source solution. Also, since all Google tutorials are written in Android, development time could become an issue. It is less widely used than the other alternatives and finding documentation on specific implementations proved difficult. It does have the advantage of generating applications that work on multiple platforms, which might compensate for the initial time overhead if multiple platform capability had been a requirement.

4.5.3 Summary

Since a project developed for Android will support 75 % of users and given the severe time constraint on delivery date, it felt sensible to select Java as the programming language. The idea of using Kotlin was very appealing and could save time in the long run. However, given that there is still limited support for this language, and that the initial time to develop the application might cause project overrun, the risks would seem too high. Since Java is still actively promoted, and there is clear and precise documentation available, it will be used to develop the application.

4.6 Mapping APIs

When selecting a mapping API, pricing and functionality to ensure requirements 1.6 & 1.8 can be met, as well as its difficulty to learn, need to be considered. This project requires a mapping API that only needs to support the use of simple overlaying functions and interactive map display. It would be a waste of time and effort to use more sophisticated alternatives. The overlay functionality is the key consideration as it provides the ability to display maps in specific locations defined by their co-ordinates. In relation to this project, it will provide the capacity to view the EPIC map. Three different APIs were reviewed in order to identify the best solution.

4.6.1 Google Mapping

Google's mapping API is by far the most well known and most used in the industry. It provides the most features and seamless integration. However, in the last year or so there has been some controversy over pricing, which has discouraged new developers from using the service. It now supports up to 28000 maps calls per month before charging starts (Platform, 2020). This is more than adequate for this project. However, since EPIC is a non-profit organisation, Google provides a scheme which allows them to make more calls for free if expansion is needed, in the future. One main advantage of using Google mapping is that it has a dedicated API for Static maps, which potentially fits requirements 1.6 and 1.8.

Pros	Cons
Favourite for geolocation services	28000 maps calls per month without charge
Contains the most data (Location, Satellite, store-front etc)	$7 per 1000 extra over cap
Integration simple compared to alternatives	Google tracks all the data from its users (Requires a browser key to be generated in order to facilitate this tracking)
Keyword search on over 100 filters	Must include the Google logo and branding
Provides a Map Static API (Ground overlays)	Many features are behind a pay wall
Prior experience working with Google maps	Most Features are available in competing APIs

Table 4: Google P&C

4.6.2 Mapbox

Mapbox is used by Snapchat and provides the developer with a good toolbox of functionality and customizable map settings. It is also cheaper than Google as it allows 25000 users to make as many calls as they wish within a 1-month period. The main downside is that it brings a steep learning curve for new developers and there is a lack of documentation (mapBox, 2020).

Pros	Cons
25000 monthly users without charge	Strict data standardisation can pose issues
Provides custom maps, location searches, navigations	No official support for major languages apart from JavaScript
Tiles Maps, Vector maps, markers.	Slow rendering speeds
Opensource SDK	System is too complex for simple projects or maps
Design your own custom map	Steep learning curve for developers

Table 5: Mapbox P&C

4.6.3 TomTom

TomTom pride themselves on a reputation for satellite navigation and accuracy. Their mobile maps SDK provides up to 2500 free transactions per day. Only by using TomTom does the developer gain access to 19 trillion location data points, all their APIs, SDKs and applications (TomTom, 2020).

Pros	Cons
2500 daily transactions without charge	Must register with TomTom and sign up to make use of their products
Provides personalised support for developers	Focused less on mapping and more on routing which is not appropriate for this project
Provides complex map features.	Used for business solutions and not for small projects
Most Accurate Navigation system	Another focus is on providing traffic APIs
Search for specific locations, view traffic density, also provides algorithms which match the shortest route from A to B	Only been offering location base services for the last year

Table 6: TomTom P&C

4.6.4 Summary

In conclusion, Google Maps is the best fit for the project since its Static Mapping API provides all the functionality required for this project. Pricing will not be an issue due to the scale of this project, and if there should be more users than expected at any time Google provides free schemes to charitable organisations. Integration with Android Studio is straightforward and intuitive. Google Maps provides the most functionality of all the mapping APIs and has specific features designed for the static mapping which this project is heavily dependent on. It has been the lead mapping API for the past few years, providing extensive documentation and solutions to common issues developers encounter. Other mapping APIs would have been workable but, given the time frame imposed by this project, it was not sensible to pick an option such as Mapbox with its associated steep learning curve or TomTom which is designed for large-scale projects.

4.7 Augmented Reality APIs

It was important to discover what APIs were available to implement requirement 1.12 and assess their advantages and disadvantages. The aim of this section is to decide what API will be taken forward when exploring a possible implementation of this feature.

4.7.1 Vuforia

Vuforia is arguably the most popular platform for Augmented Reality development. It provides a series of different functionalities: recognition of visual objects, text and environment recognition and VuMark, which is a QR-code and picture recognition system. The recognition process can be implemented by using either a local or a cloud database. Vuforia is available for Android, IOS, UWP and Unity. However, it does not support a wide variety of devices. Vuforia also has a payment plan that only allows the user to make 1000 recognition calls before charging commences, which may be problematic for this project. With the basic plan costing $42 dollars per month, selection of Vuforia is effectively discounted (Vurforia, 2020).

4.7.2 ARToolKit

ARToolKit is an open-source SDK for creating AR apps that allow virtual imagery to be overlaid on the physical environment. It is easy to learn, fast to develop and available for Linux, IOS, Android and Windows. It was one of the first AR SKDs available, being released in 2015, and has since gathered a large customer base. Since ARToolKit is free there are no associated cost concerns. The downside is that the API is relatively basic and restrictive; it has poor functionality when considering the users location and surroundings and can only be used for simple close-quarter functionality. Since this project is based on the user's location, this API will not meet requirements (ARToolKit, 2016).

4.7.3 ARCore

ARCore is Google's answer to AR. It focuses on objects in the users environment and reacts to them, one of the main requirements of this project. Its three main features are Motion Tracking (relative to the users surroundings), Environmental Understanding (detect the location of objects) and Light Estimation, which allows the application to compensate for the real time conditions. It supports a wide variety of Android devices that are 7.0 or higher and also supports IOS devices. The developer can store a series of images in the database, which can then be used for detection. The API is free to use and integration is simple, and since Google Maps has been selected, it makes sense to use another Google API. ARCore also works in unison with Firebase cloud storage giving an easier implementation phase (ARCore, 2019) .

4.7.5 Summary

The main consideration when choosing the AR API was avoiding any cost overheads. It is difficult to estimate how much this feature would be used but Vuforias allowance of 1000 calls before charging is likely to be exceeded, resulting in substantial charges. To meet requirement 1.12 the API needs to be able to react to the user's surroundings. This is something AR Toolkit struggles with, which is expected given that it is outdated, basic and restrictive. ARCore provides Environmental Understanding, allowing it to be precise with object tracking and location determination, which in turn meets requirement 1.12. Since ARCore also has no charges associated with it, it is perfect for this project. The only downside is that it only works on Android devices that have an OS of 7.0 or higher. In conclusion, ARCore will be used for this project since it provides all the functionality required at no cost.

5 Implementation

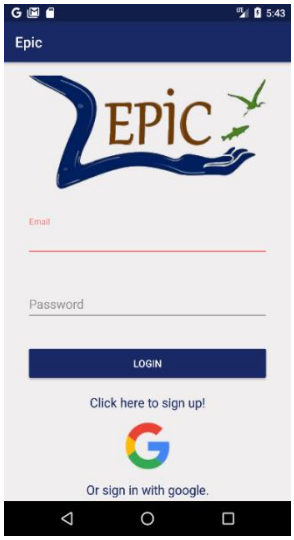
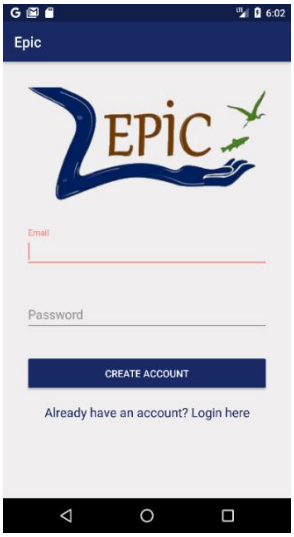
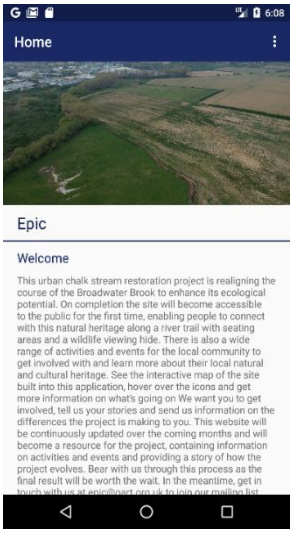
5.1 Introduction

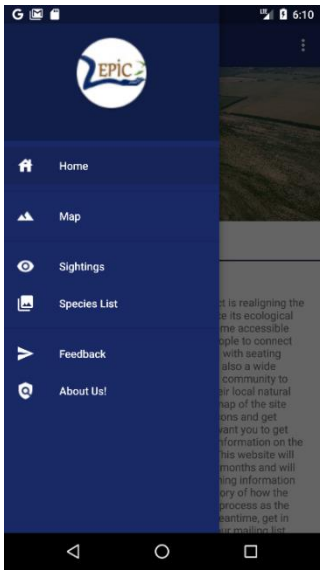
This section details the functions of the application and the requirements they meet. Trivial code has not been included as it can be found within the Android application listing. Only where implementation was challenging has it been documented. This section is split into two, detailing the implementation of the first and second prototypes.

5.2 Prototype 1

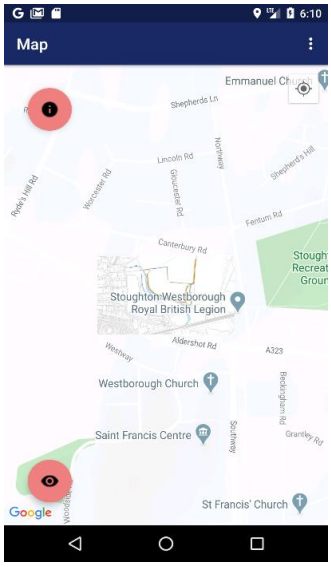
5.2.1 User Interface

The user interface was one of the first segments of the application to be developed. The primary influence for the selection of the colour scheme was EPIC's website which employs a white and blue theme, and this was carried over to the application. Table 7 contains example pages from the first prototype after initial development. These pages were potentially subject to change during the user acceptance testing.

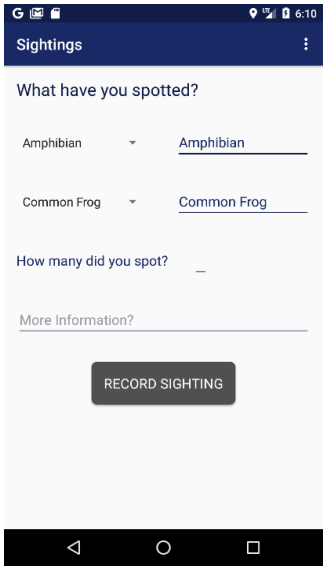
		
This screenshot is the initial page the user will see when they launch the application for the first time and are not logged in.	This screenshot illustrates the registration page if a user wishes to sign up manually using their email and password.	This is the home page. From here, the user can use the navigation bar to slide between fragments (Pages).



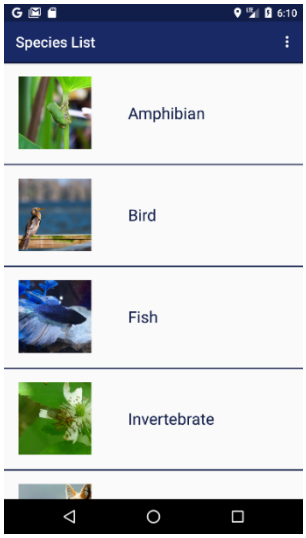
This screenshot illustrates how the user will navigate through the application. The home page acts as the host, and each feature can be accessed via the navigation bar (Requirement 1.9)



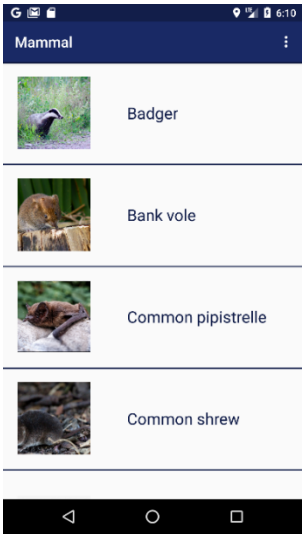
This screenshot illustrates the mapping page which the user will use to navigate around the site. The image is subject to change as EPIC wish to use Google Maps base view once it has been updated via satellite imaging.



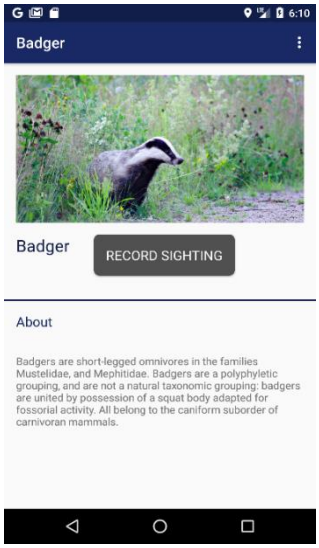
This is the sightings page. From here, the user can select the animal they spotted during their visit to the site. They can add extra information if they wish. Once submitted, this is stored in a cloud database for EPIC analysis.



This screenshot depicts the first page of the species list. The view will update depending on what family the user selects.



In this case, the user chose to view all the mammals that are specific to that site. If the user wishes to find out more information on a particular animal, they will click on it.



This is the final view a user would see when working their way down the hierarchy. They can also record a sighting if they wish to.

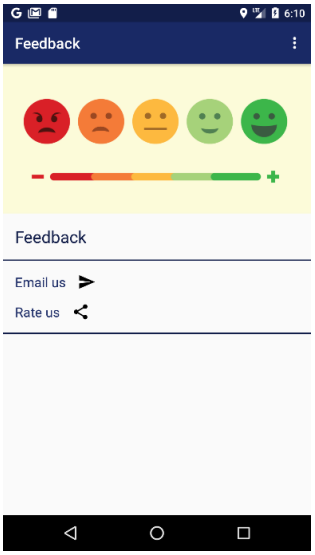
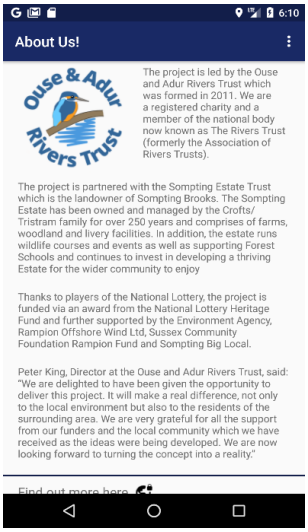
 This is the feedback page which is subject to change.	 This is the final page of the application and contains information about the EPIC project with a link if the user wishes to find out more or get involved as a volunteer	

Table 7: User Interface

5.2.2 User Authentication

To meet requirements 1.1,1.2,1.3 and 1.4, sign up, login and logout functionality were integrated into the application using Firebase Auth (Auth, 2020). When initially designing the application, the specification for accounts was not identified as a requirement since the need was not apparent. However, by integrating account functionality into the app, the security of the database increases by ensuring that only when users that have been successfully authenticated can they make read and write calls.

The authentication stage consists of two activities: the login activity and the registration activity. When the application is first started, a method calls a built-in firebase function "*getCurrentUser()*" which checks whether the user exists within the users database. The login page makes use of Firebase's built-in function *"signInWithEmailAndPassword"*, which takes the users email and password and checks them against the accounts stored in the database. If a match is found, then the user is logged in, if not the user must try again. An Android function checks whether the email address is valid and unique regex is used to ensure the password meets the criteria stated.

The registration activity follows a very similar protocol to the login activity, except it makes use of the built-in function *"createUserWithEmailAndPassword"*. Once the input has been validated, the user's account will be created. To add another feature to the login page, Google authentication was also included as an alternative. Since Firebase was designed with this in mind, it was straightforward to implement. Figure 15 shows a list of users that have created accounts using the application. Each user is assigned a 'uniqueID' which is included in the sightings database and can be used to determine who made specific sightings.

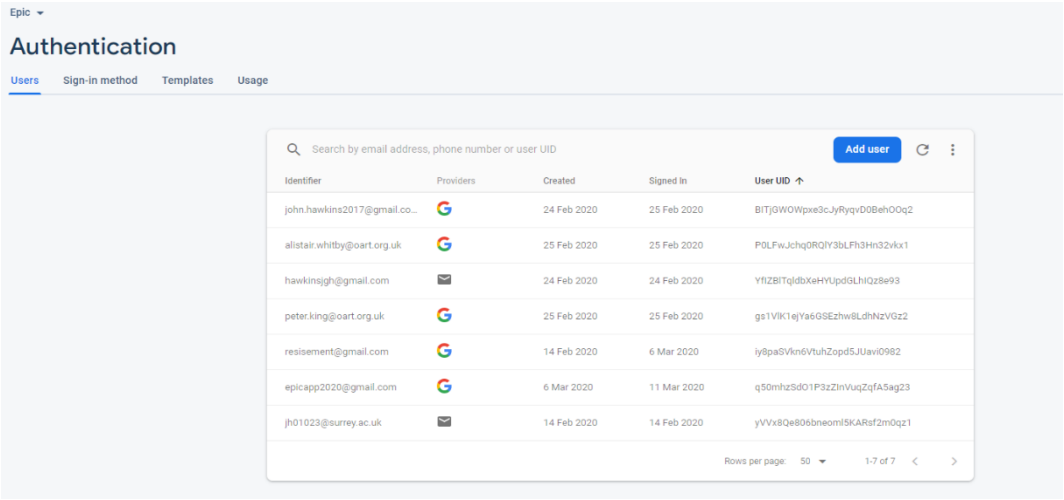


Figure 15:Firebase User Database

5.2.3 Mapping Functionality

Mapping is an important part of this project as EPIC want to make the site more interactive for visitors and want to avoid the cost of building and maintaining signboards along the trail. Making this virtual not only saves money but gives the user a choice of whether they wish to receive extra information or purely use the application for navigation (Requirements 1.5 and 1.8**).** It is important to note that the user will not be able to access this feature if they have not authorized access to their location. When a user loads the mapping fragment there is a brief delay as the map initialises itself, and a progress bar was added to improve this experience.

The code checks whether the user was granted permission and whether they have an active network connection (there is no WIFI option available on the site). Once this check is complete, "requestLocationUpdateListener" is initiated which monitors the user's location for changes every 10 seconds and determines if they have moved more than 1 meter from their previously known location. The location listener is an essential aspect of this fragment as it allows the application logic to track a user's movement accurately. Many applications do not consider network or battery usage, and do not bother implementing usage controls. With this application, the location listener is removed if the user closes the app or it goes to background. Once they open the app again, it initiates a new listener, saving resources.

The next step was to find a way to display EPIC's custom map while maintaining availability of all the Google features required. It is important to note that during a meeting with Pete, this map was defined as a temporary solution. Eventually, they prefer like to use satellite images from Google once they have eventually updated to show the new landscape. Integration was achieved using ground overlay objects, which essentially allows setting of an image (the map) within a given set of boundary points (boundary points are the Latitudes and Longitudes of the north-east and south-west corners of the map).

Now that the location was successfully updating and the overlay was displaying accurately, it was time to work on the interactive side of the map. Allowing the users to enable or disable certain features was necessary as some users may not want popups of information when they are using the application for navigation. A dialogue box was used to provide a choice of options. The choices are: "Display Map Legend", "Display points of Interest", "Display Facts Based on Location". "Display Map Legend" overlays an image onto the map explaining what each colour represents. "Display points of Interest" makes a call to the cloud database and retrieves all the points of interest, equivalent to the signboards often seen on nature trails. These act as markers on the map; if a user interacts with one, they will receive information for that location. "Display Facts Based on location" was more complicated to

implement and required some understanding of mathematics in order to calculate the user's location relative to each point.

```
private void calculateDistance(Location currentLocation){
    double markerlat;
    double markerlong;
    if(CheckBoxTicked) {
        for (Marker m : mMarkers) {
            markerlat = m.getPosition().latitude;
            markerlong = m.getPosition().longitude;
            Location markerLocation = new Location( provider: "currentlocation");
            markerLocation.setLatitude(markerlat);
            markerLocation.setLongitude(markerlong);
            float distance = currentLocation.distanceTo(markerLocation);
            if (distance <= 10) {

                dialogMarker = new Dialog(getActivity());
                dialogViewMarker = getLayoutInflater().inflate(R.layout.location_popup_dialog, root: null);
                final TextView markerTitle = dialogViewMarker.findViewById(R.id.markerTitle);
                markerTitle.setText(m.getTitle());
                final TextView markerInfo = dialogViewMarker.findViewById(R.id.markerInfo);
                markerInfo.setText(m.getSnippet());
                break;
            } else {
                // do nothing
            }
        }
        dialogMarker.setContentView(dialogViewMarker);
        dialogMarker.create();
        dialogMarker.show();
```

Figure 16: Distance Calculations

Googles location API has a built-in function for calculating the users distance relative to two sets of coordinates. As shown in figure 16**,** each time the user's location updates a function is called, and their location is compared to all the markers to determine if they are within 10 meters of a trigger point, in which case a dialogue box displays information specific to that marker. It is crucial to understand how distance is calculated to ensure its accuracy. The "distanceTo" Function defines distance using a formula devised by Thaddeus Vincenty "for calculating geodesic distances between a pair of latitude/longitude points on the earth's surface, using an accurate ellipsoidal model of the earth" (Vincenty, 2016). It is accurate to within 0.5mm distance and each calculation on average takes 5 microseconds, not noticeable by the user. Employees at EPIC can log on to the Firebase portal and add new markers. This means that no java knowledge is required if or when new areas are added to the map. Thus, to add a new board to the site simply requires adding a new document to the database. This was designed to negate EPIC ever having to change the Android code. Instead, they can make the changes they want to the database, and the application will update on the next database read.

5.2.4 Sightings

To meet requirement 1.11, two different approaches to recording sightings have been implemented. The first solution is a standalone page that allows users to record species and quantity as well as any extra information desired. In the background, the user's location, date & time is added as this is vital information for scientific records. Validation is performed before the data sent off to the cloud database to ensure the non-functional requirements are also met. Since the species list is retrieved from the cloud database in the first place, minimal validation is required. User input is kept to a minimum to aid visibility for example, if they do not specify the number of animals spotted the default is set to one. If the user loses connection or closes the app as they make a sighting, the recording is cached until reconnection, and is then sent to the cloud server.

Figure 17 shows sighting records stored in the database. It is important that these are stored in plain text format and thus readable by EPIC administrators. Sightings are 'named' by the date and time of submission. In this example, we can see that the user spotted a "common frog" on the 1st of march

at 13:57 and their location is given by the coordinates. This is an easy way to visualise records, and the validation ensures that no false records are made.

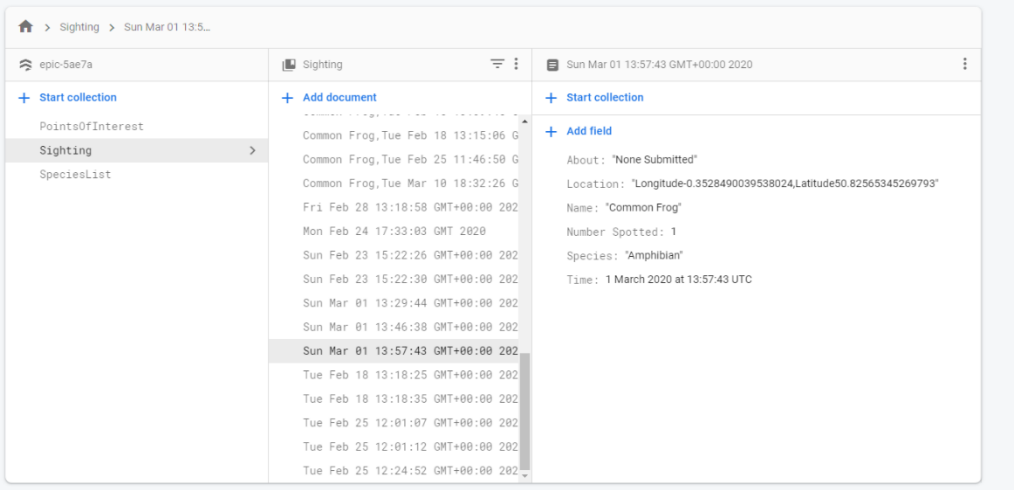


Figure 17:Recorded sighting in database

5.2.5 Species List

A hierarchical view of a species list has been implemented with the data being provided by EPIC (Requirement 1.6). This is an essential part of the application, since lay visitors may not know the name of an animal or plant, but they can recognise it via a photo. The photos are stored in cloud storage, and the database is populated with these photos using a tree-like structure. The species list contains a list of families and species: Amphibian, Bird, Fish etc. Amphibian will then include a list of amphibian species such as the Palmate Newt or Common Toad. Screenshots in table 7 above illustrate what the species list looks like and how it functions. This was a complicated implementation process as it involved building one RecyclerView within another. RecylerViews are more efficient than listViews as they populate the data only when the user scrolls through the screen, whereas a ListView loads all the data immediately. The amount of the cells that fit on the screen is dependent on the phone screen size. An internet connection is required for first-time use, but everything the user accesses is cached locally for the rest of the session.

```
    mBirds.addSnapshotListener(MetadataChanges.INCLUDE, (querySnapshot, e) -> {
                    if (e != null) {
                        Log.w(TAG,  msg: "Listen error", e);
                        return;
                    }
                    for (DocumentChange change : querySnapshot.getDocumentChanges()) {
                        if (change.getType() == DocumentChange.Type.ADDED) {
                            String name = change.getDocument().get(KEY_NAME).toString();
                            String imageUrl = change.getDocument().get(KEY_Image).toString();
                            Log.d(TAG,  msg: "Offline Name :" + change.getDocument().get(KEY_NAME).toString());
                            Log.d(TAG,  msg: "Offline ImageUrl :" + change.getDocument().get(KEY_Image).toString());
                            mAnimalImages.add(imageUrl);
                            mAnimalNames.add(name);
                            Log.d(TAG,  msg: "Offline Add :" + change.getDocument().getData());
                        }
                        String source = querySnapshot.getMetadata().isFromCache() ?
                                "local cache" : "server";
                        Log.d(TAG,  msg: "Data fetched from " + source);
                    }
                    initRecyclerView();

            });
    // [END offline_listen]
}
```

Figure 18: Offline Caching

Figure 18 displays the code that is called if the user's network connection is lost. Essentially it takes a snapshot of the current database when the user first loads it. If the database is updated, the user will then receive a snapshot of the new data. If the user does not have an internet connection, then the RecyclerView will be populated using the snapshot. This also satisfies the non-functional requirement of making the features easy and intuitive to use. It also provides the educational aspects that EPIC were looking for by including information about each animal. It is important to note that the user must have an internet connection initially for this to work. However, EPIC has stated that the connection on the site is reliable, and this has never been found to be an issue.

5.2.6 Server Side

Firebase was selected to implement the server-side database and storage functionality. The primary purpose of this approach is to allow EPIC to make content changes to the application without having to invest time in learning Android or any form of programming. Making changes to the database or uploading new photos is a straightforward process that can be done by anyone with a basic knowledge of computers. Since the app is unlikely to exceed the allowances provided by Firebase, the application will remain free to host. The code for this section is trivial and mostly centred on Firebases API, so there is no need to consider it further.

5.2.7 Summary

Requirements 1.7 and 1.10 have also been met, and their implementation is very straightforward, thus discussion seems unnecessary. The next stage of the project was to collect user acceptance data and feedback from EPIC and thus implement the second prototype with the addition of an Augmented Reality feature to meet requirement "r.1.12". From here, another round of user acceptance testing would be conducted to determine whether any further changes were required or if this would be the final prototype. Please see the "Systems Testing" section to review the test results.

5.3 Prototype 2

5.3.1 Bug Fixes

Only one bug found during user acceptance testing of the first prototype - location-dependent data was not displaying when a user was close to a marker. The issue was caused by the location listener not being updated and resulted in flags not being reset correctly once a marker had been triggered. This was rectified, and validation for this can be seen in 6.3.2.1 requirement testing.

5.3.2 Changes Requested

EPIC proposed a variety of changes that would enhance the user experience. These can be seen in the section "6.2". Most of these modifications were UI edits which have been made, along with a fix for a bug in distance calculations. Table 8 illustrates these changes. Discoveries 3&4 have been reviewed and were not change requests.

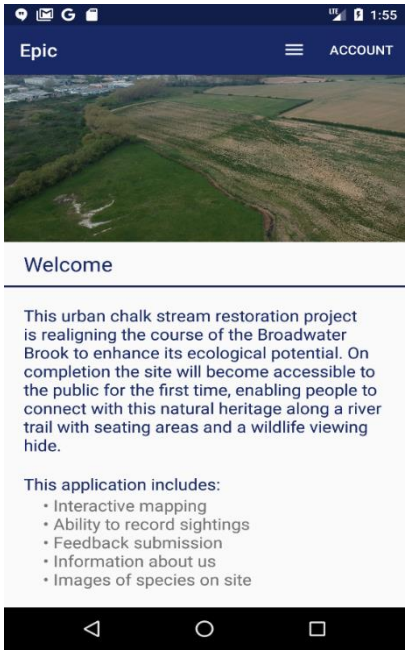
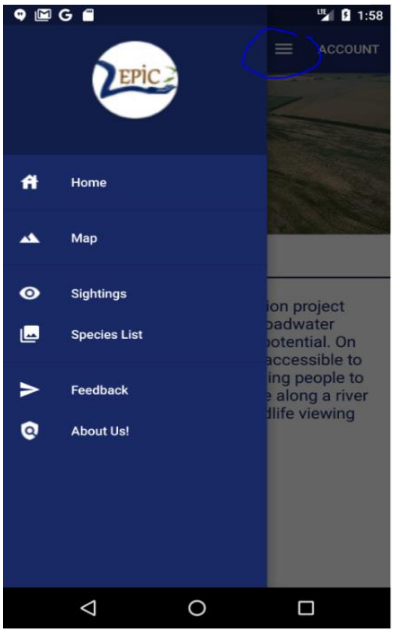
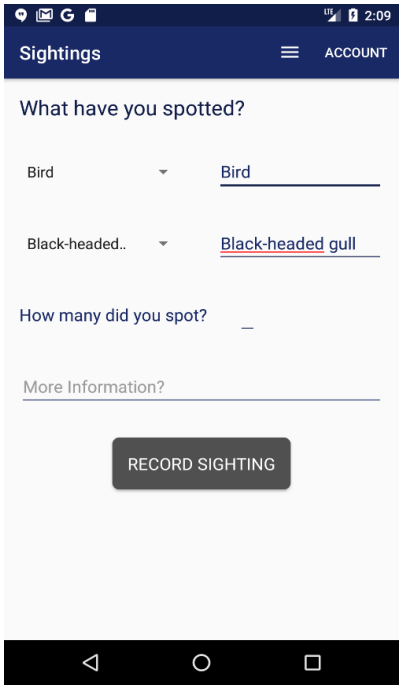
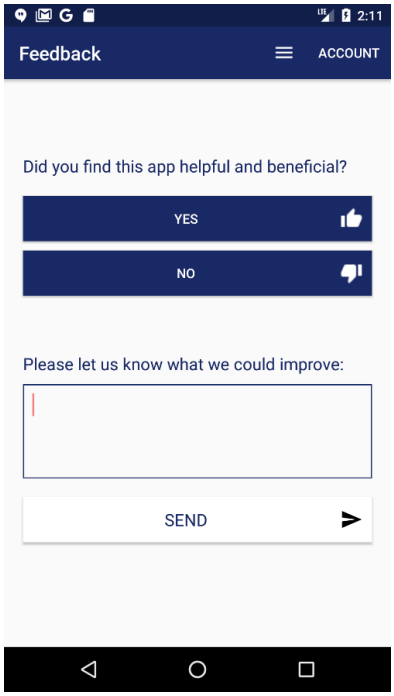
Change Request 1	Change Request 2
The text on home page has been reduced in size and become more specific. 	As requested, a button has been added to provide another means of navigating through the application 
Change Request 5	**Change Request 6**
The texts for animals and species now display on one single line. Previously “Black-Headed gull” would be displayed on 3 lines. 	The feedback page has been completely remodelled for this request, the buttons now work, and the page is intuitive to use. 

Table 8: Updated User Interface

5.3.3 Augmented Reality

The first significant issue that was encountered during AR development was the lack of access to the site due to covid-19, and consequently having no image dataset with which to test implementations. Instead, I decided to focus on something that I could test from the security of home that would still be applicable to the site once the pandemic had subsided. Referencing section 2, the two original concepts were:

1. Labelling the user's camera feed to give them information about their landscape.
2. Displaying 3D model dependent on what the user was viewing.

It was essential to investigate the possibilities of implementing these features in more depth without any delay, given the time frame. The 'skyline' feature, which was used as the basis for idea 1, was far more complicated than I had first anticipated. It makes use of the compass, GPS, gyroscope, and accelerometer within the phone. Using these components, it obtains height and location data and searches a variety of databases to retrieve information about the area. The main issue with this method with respect to this application was that there are no significant landscape features documented for the EPIC site in any open-source databases. This meant that I would have to collect GPS, height and various other data in order to generate my own database, something that would take a considerable amount of time. Additional research indicated that it took the team three years to develop a working version of this feature for the Skyline application, an indication of the effort required to implement even a simple instance. Thankfully, 3D model display turned out to be a much more workable approach and could still deliver the benefits of AR that this application was seeking. Thus, the remaining research and implementation was focused on this approach.

5.3.3.1 ARCore Example Application

For the first few days, various APIs examples were tested to identify a suitable fit for this application. ARCore has a variety of examples, the most notable being their image augmentation app. In essence the developer generates a database of up to 1000 image. When the user then scans one of these images, it overlays a frame around the image. An example of this can be seen in figure 19.

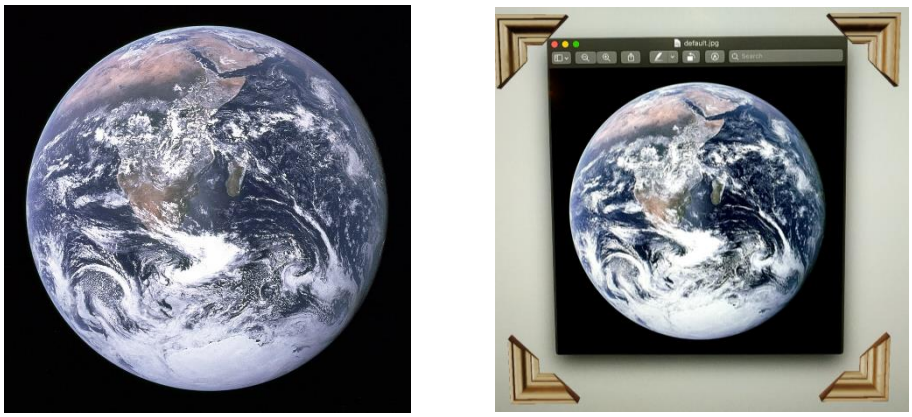


Figure 19: Augmented Image

The requirements for an image to be deemed suitable are:

- Fill at least 25% of the camera frame (to be initially detected).
- Be flat (for example, not wrinkled or wrapped around a bottle).
- Be in clear view of the camera. Images should not be partially obscured, viewed at an oblique angle, or viewed when the camera is moving significantly.
- Avoid images with spare features

- Avoid images with repetitive features

This could be applied to the nature reserve if there were a series of stationary images/platforms around the site that the user could scan. Once the image had been scanned, instead of framing it like the example above, a 3D model could be displayed. This would, for example, allow visitors to experience "contact" with species that would otherwise be unseen (due to shyness, nocturnal habits etc.).

5.3.3.2 Firebase Example application

Firebase provides the ability to create custom models. These models are heavily dependent on the dataset offered. There are a variety of different applications available: Text Recognition, Face Detection, Barcode Scanning, Image labelling, Object Tracking and Detection and Landmark Recognition. The standout approaches for this application were Landmark Recognition and Image Labelling. The issue with Landmark Recognition is that it only recognises well-known landmarks from generic databases - similar to the issue discussed with the Skyline feature. Figure 20 illustrates the labelling results from scanning an image of a football match. As can be seen, they are relatively generic and do not provide anything exciting that would enhance the user experience.

On-device	
Description	Stadium
Knowledge Graph entity ID	/m/019cfy
Confidence	0.9205354
Description	Sports
Knowledge Graph entity ID	/m/06ntj
Confidence	0.7531109

Figure 20:Image Labelling Results

5.3.3.2 Meeting with EPIC

After a meeting with EPIC where we discussed the possible use of AR, it was established that Landscape labelling would not be feasible given the conditions of the site. The use of stations containing images of animals around the site was considered as a possible way of providing an exciting feature, especially with younger audiences. However, EPIC stressed that is was not essential to have AR and that the application already had all the features they had hoped for. Therefore, any design choices with respect to AR were left entirely to me.

5.3.3.3 Implementation

ARCore's API provides a variety of helper classes to aid with image identification. The majority of code in this section has been taken from Google example projects and modified to produce a system that works for EPIC. I have made specific changes at certain points. It is important to note that the AR feature will not be available on devices that do not appear on the supported-devices list: "https://developers.google.com/ar/discover/supported-devices".

The main logic for this feature resides in the "AugmentedImageActivity" file. Its initial steps are to check that the device is supported, and that camera permissions are enabled. Most of its methods do not need to be explained, as their function is evident. This chapter will therefore focus on the complex issues that arose during the development of this feature. Figure 21 contains the code for a function called "onDrawFrame"; this function stores the current state of the camera in a frame. The first step is to clear any pixels from the previous frame. Once the frame is ready, the preview image is rendered to the GL surface using the background renderer. The projection matrix, camera matrix and light intensity are then calculated and passed to the draw augmented image function.

```
@Override
public void onDrawFrame(GL10 gl) {
    GLES20.glClear( i: GLES20.GL_COLOR_BUFFER_BIT | GLES20.GL_DEPTH_BUFFER_BIT);

    if (session == null) {
        return;
    }
    displayRotationHelper.updateSessionIfNeeded(session);

    try {
        session.setCameraTextureName(backgroundRenderer.getTextureId());
        Frame frame = session.update();
        Camera camera = frame.getCamera();
        trackingStateHelper.updateKeepScreenOnFlag(camera.getTrackingState());

        backgroundRenderer.draw(frame);

        float[] projmtx = new float[16];
        camera.getProjectionMatrix(projmtx,  i: 0,  v: 0.1f,  v1: 100.0f);

        float[] viewmtx = new float[16];
        camera.getViewMatrix(viewmtx,  i: 0);

        final float[] colorCorrectionRgba = new float[4];
        frame.getLightEstimate().getColorCorrection(colorCorrectionRgba,  i: 0);

        drawAugmentedImages(frame, projmtx, viewmtx, colorCorrectionRgba);
    } catch (Throwable t) {
        Log.e(TAG,  msg: "Exception on the OpenGL thread", t);
    }
}
```

Figure 21: Stores the current camera state in a frame.

Figure 22 contains the logic for detecting images. The first step is to iterate through the augmented image map. When an image is in a paused state it has been detected but is not yet being tracked. Once the image is being tracked, the scan view overlay is removed from the camera feed, and the user becomes aware that the image is being augmented. An anchor is then created for the image. The anchor is stored with the detected image in a HashMap object.

```
private void drawAugmentedImages(
        Frame frame, float[] projmtx, float[] viewmtx, float[] colorCorrectionRgba) {
    Collection<AugmentedImage> updatedAugmentedImages =
            frame.getUpdatedTrackables(AugmentedImage.class);
    for (AugmentedImage augmentedImage : updatedAugmentedImages) {
        switch (augmentedImage.getTrackingState()) {
            case PAUSED:
                String text = String.format("Detected Image %s",  augmentedImage.getName());
                messageSnackbarHelper.showMessage( activity: this, text);
                break;
            case TRACKING:
                this.runOnUiThread(
                        new Runnable() {
                            @Override
                            public void run() { fitToScanView.setVisibility(View.GONE); }
                        });
                if (!augmentedImageMap.containsKey(augmentedImage.getIndex())) {
                    Anchor centerPoseAnchor = augmentedImage.createAnchor(augmentedImage.getCenterPose());
                    augmentedImageMap.put(
                            augmentedImage.getIndex(), Pair.create(augmentedImage, centerPoseAnchor));
                }
                break;
            case STOPPED:
                augmentedImageMap.remove(augmentedImage.getIndex());
                break;
            default:
                break;
        }
    }
```

Figure 22:Image Detection Function

An anchor is what differentiates Augmented Reality from Virtual Reality. It allows the developer to know where to place content in the real world. There are a variety of different anchors available, ranging from horizontal and vertical anchors to object and image anchors. This project will use image anchors. It is vital that the image provides enough detail to be recognisable and, for this test, I used EPICs artists impression map which can be seen in figure 23.

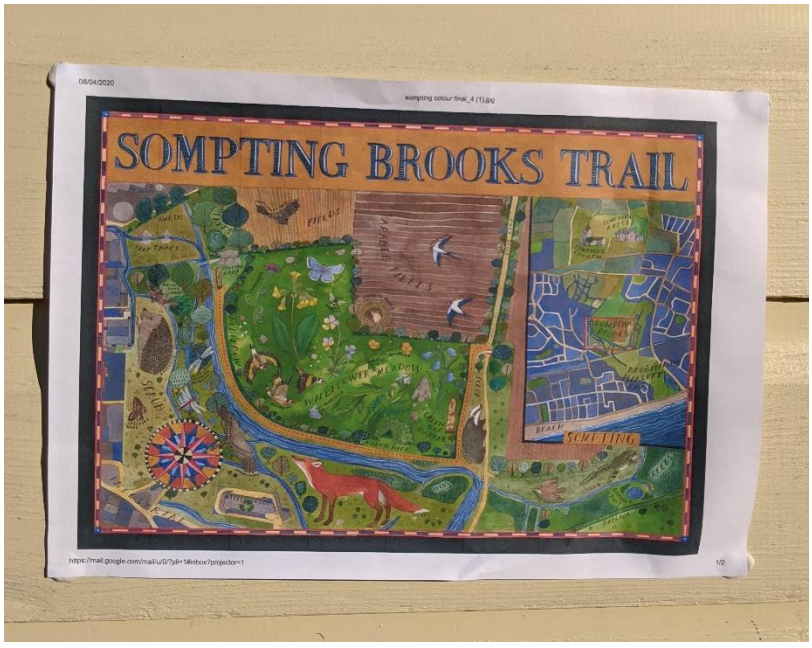


Figure 23: Testing Image

Once the image was identified the next step was to display the 3D rendered model in the users live view by generating a composite view. Figure 25 shows the initial function written to display 3D models. The issue here was that an entirely new activity was created and did not display the composite view on the users live feed unless the user tracked through about five different screens first. Obviously, this implementation needed to be improved upon.

```
public void display3DModel(){
    Intent sceneViewerIntent = new Intent(Intent.ACTION_VIEW);
    sceneViewerIntent.setData(Uri.parse("https://arvr.google.com/scene-viewer/1.0?file=https:
    sceneViewerIntent.setPackage("com.google.android.googlequicksearchbox");
    startActivity(sceneViewerIntent);
}
```

Figure 24: Initial 3D Model Function

Instead of performing the above method, we iterate through all the images in the HashMap that have been identified and perform a draw function. This function takes a rendered object and displays it at the calculated anchor point. Figure 27, shows the four corners of the image and from this the anchor point about which the new rendered object will sit is calculated. Now there was a new issue in that the object was displayed protruding from the image, as seen in figures 25 and 26. After performing a lot of research, it was apparent this was due to an issue with the matrix being generated by the anchor.

```
public void draw(
        float[] viewMatrix,
        float[] projectionMatrix,
        AugmentedImage augmentedImage,
        Anchor centerAnchor,
        float[] colorCorrectionRgba) {
  float[] tintColor =
        convertHexToColor(TINT_COLORS_HEX[augmentedImage.getIndex() % TINT_COLORS_HEX.length]);

  Pose[] localBoundaryPoses = {
        Pose.makeTranslation(
                v: -0.5f * augmentedImage.getExtentX(),
                v1: 0.0f,
                v2: -0.5f * augmentedImage.getExtentZ()), // upper left
        Pose.makeTranslation(
                v: 0.5f * augmentedImage.getExtentX(),
                v1: 0.0f,
                v2: -0.5f * augmentedImage.getExtentZ()), // upper right
        Pose.makeTranslation(
                v: 0.5f * augmentedImage.getExtentX(),
                v1: 0.0f,
                v2: 0.5f * augmentedImage.getExtentZ()), // lower right
        Pose.makeTranslation(
                v: -0.5f * augmentedImage.getExtentX(),
                v1: 0.0f,
                v2: 0.5f * augmentedImage.getExtentZ()) // lower left
  };
  Pose anchorPose = centerAnchor.getPose();
  Pose[] worldBoundaryPoses = new Pose[4];
  for (int i = 0; i < 4; ++i) {
    worldBoundaryPoses[i] = anchorPose.compose(localBoundaryPoses[i]);
  }

  float scaleFactor = 1.0f;
  float[] modelMatrix = new float[16];

  worldBoundaryPoses[0].toMatrix(modelMatrix,  i: 0);
  imageFrame.updateModelMatrix(modelMatrix, scaleFactor);
  imageFrame.draw(viewMatrix, projectionMatrix, colorCorrectionRgba, tintColor);
}
```

Figure 27: Display Rendered Object Function

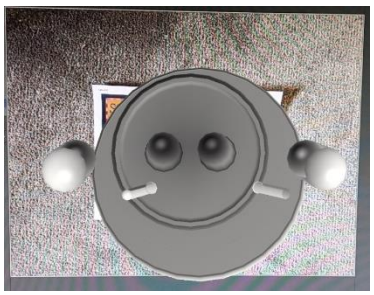


Figure 25:Rendered Object Front View

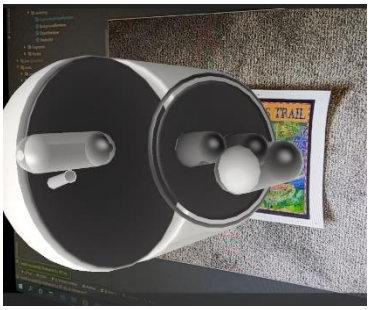


Figure 26:Rendered Object Side View

It became apparent that, to overcome this issue, it as necessary to find a way to manipulate the matrix for the object around a plane that was horizontal to the screen and not vertical. I then discovered "Quaternions", a complex matrix system used to manipulate object rotation. Quaternions contain 4 scalar variables known as Euler Parameters; from this, we can calculate the Euler angles. The issue with using Euler angles is that sometimes two of the axes can line up, which means loss of a degree of

rotation; this is known as “Gimbal Lock”. However, this was not an issue here as the object would not be rotated after it is rendered. With this knowledge, the first step was to gather the quaternion values from the tracked images anchor, then generate the Euler Angles. In this case, for the “roll” axis, more commonly known as the x-axis. Figure 28 illustrates how the different axis rotations can be obtained using quaternions (Euler Angles, 2020).

$$\begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} = \begin{bmatrix} \operatorname{atan2}(2(q_0 q_1 + q_2 q_3), 1 - 2(q_1^2 + q_2^2)) \\ \operatorname{asin}(2(q_0 q_2 - q_3 q_1)) \\ \operatorname{atan2}(2(q_0 q_3 + q_1 q_2), 1 - 2(q_2^2 + q_3^2)) \end{bmatrix}$$

Figure 28: Quaternion to Euler Angle

To determine the roll axis of the object we calculate the sine and cosine angles and then pass them into the arctan function. This gives use the angle in radians which then needs to be converted to degrees. The next step is to use the “rotateM” function which takes a series of parameters:

- The models matrix
- The index for where the result matrix will start
- The new angle we want to rotate the object by
- The 3 axis components x, y, z

By removing the y and z rotations and then multiplying by the inverse of the x-axis the rendered object can be manipulated to appear as expected (all these steps can be seen in figure 31). The final step is to update the rendered object with the new manipulated matrix before displaying it to the user. Figures 29 and 30 illustrate what these changes look like. It can be seen that the object is facing the user correctly and provides a front view of the model instead of a top-down view.

```
public void draw(
        float[] viewMatrix,
        float[] projectionMatrix,
        AugmentedImage augmentedImage,
        Anchor centerAnchor,
        float[] colorCorrectionRgba) {
  float[] tintColor = convertHexToColor(TINT_COLORS_HEX[augmentedImage.getIndex() % TINT_COLORS_HEX.length]);

  Pose anchorPose = centerAnchor.getPose();
  float scaleFactor = 1.0f;
  float[] modelMatrix = new float[16];
  anchorPose.toMatrix(modelMatrix, 0);

  /*
  Get the Quaternions from the anchor for the recognised image.
   */
   wQuart = centerAnchor.getPose().qw();
   xQuart = centerAnchor.getPose().qx();
   yQuart = centerAnchor.getPose().qy();
   zQuart = centerAnchor.getPose().qz();

  // roll (x-axis rotation)
  double sinr_cosp = 2 * (wQuart * xQuart + yQuart * zQuart);
  double cosr_cosp = 1 - 2 * (xQuart * xQuart + yQuart * zQuart);
  xAngle = Math.atan2(sinr_cosp, cosr_cosp);

  // Convert Angles to degrees for matrix function.
  xAngle = Math.toDegrees(xAngle);

  // Remove Roll Rotation, Inverse xangle keeps the model upright, Screenshots in documentation explain what
  Matrix.rotateM(modelMatrix, mOffset: 0, (float) -xAngle, x: 1f, y: 0f, z: 0f);

  /*
  Update the model and draw it.
   */
  imageFrame.updateModelMatrix(modelMatrix, scaleFactor);
  imageFrame.draw(viewMatrix, projectionMatrix, colorCorrectionRgba, tintColor);
  virtualObjectShadow.updateModelMatrix(modelMatrix, scaleFactor);
  virtualObjectShadow.draw(viewMatrix, projectionMatrix, colorCorrectionRgba, tintColor);

}
```

Figure 31:Rewirtten Draw Function

Figure 29:Rendered Object Front View Fixed

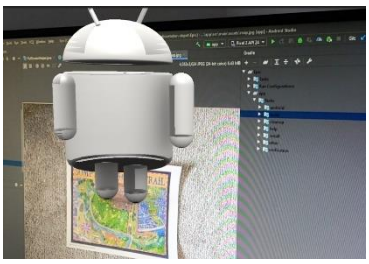


Figure 30: Rendered Object Side View Fixed

To finish off this segment, I wanted to demonstrate a few other 3D models. It was challenging to find models that match the application requirements. They needed to be very small in size in order to avoid the application running into memory issues on certain phones when rendering. Figure 32 illustrates a stag overlaid on the image scanned. Unfortunately, I could not find any textures available for this example; hence it is black. This would not be an issue for EPIC as they could create custom 3D models made for them which match the required criteria.

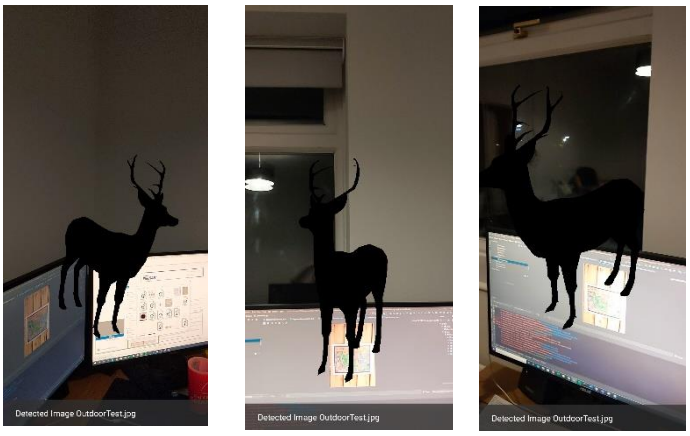


Figure 32: Different Model Example

5.4 Summary

In the initial planning stage, it was assumed that there would be two prototypes and then a final model. However, EPIC stated that they were completely satisfied with the 2nd prototype and deemed that no additional changes were required. The 2nd prototype became the baseline version. I then went on to explore Augmented Reality in depth, attempting to make use of the user's location, accelerometer and gyroscope to produce an interactive experience, something like Pokémon Go, but wildlife related. However, given the complexity, lack of experience and steep learning curve, this would take a long time to fully implement and was not feasible given the short timescales. Yet, the current implementation provides options. For example, instead of displaying a 3D model, a video or animation could run and provide a useful educational experience. The issue around the object rotations was the most complex element of the entire development phase and required a lot of trial and error to solve.

6 System Testing

6.1 Introduction

Once coding is complete, a system must be rigorously tested to ensure that all aspects are working as expected, and that there are no issues which would cause the application to fail. This section covers the UAT results for the two prototypes developed, as well as the overall testing of the application including requirements testing, Android testing and cross-device testing. The results will be used as part of the evaluation of the project to determine whether or not it was a success.

6.2 User Acceptance Testing Results

6.2.1 Prototype 1

The UAT results shown in the testing sheet in Appendix D were extremely promising. Most EPIC employees found the application intuitive and straightforward to use, stating that it had a 'professional' look. One described it as "an application that he wouldn't question if he saw it on the Google play store". No users have raised issues with any of the tasks in the sheet. Their feedback was beneficial in identifying changes for the 2nd prototype. After summarizing the results, a couple of bugs were identified, and some possible improvements mentioned. Table 9 below contains the average ratings from EPIC for each element of the application. The main concern raised was that the navigation scheme was not immediately obvious when the application first launched.

Registration	10
Login	10
Home	8
Mapping	9
Sightings	9
Species List	10
About	10
Feedback	9
Navigation of application	8

Table 9:Prototype 1 Results

Although the results table shows that there are no fundamental problems with the application, there is always room for improvement. EPIC responded with a few items they found to be working incorrectly and some quality changes they would like to see. Example feedback included:

1. "The home page is quite text rich and the text is quite small but other than that the app is amazing, easy to use and full of relevant information".
2. "Navigation is a little confusing, it might be worth having a little arrow or some indicator which says pull from the left to access the menu, I would naturally go to the three buttons at the top, but this just allows you to logout".
3. "It might be worth having the default of display facts on location rather than people having to turn it on".
4. "The overlay map looks good but as discussed is a temporary solution and hopefully Google Maps will update so we can have that on there instead".
5. "Some of the species names are quite condensed on the right (i.e. Black Headed Gull in birds is over three lines) – is it possible to spread this out a bit better?".

6. “On the feedback page it seems like you can tap one of the different coloured faces, but this doesn’t appear to do anything”.
7. “The location-based data sometimes doesn’t trigger when you’re within a 10-meter radius, perhaps this needs more testing and development”

These were all minor changes that could be quickly rectified during the development of the 2nd prototype. The only serious concern raised was that the location dependant feature was not working as expected. This was reworked and tested to ensure the function worked correctly in the next prototype. It was encouraging that no issues associated with accounts or submission of animal sightings to the cloud database were found. This was a concern as these were key features of the application. Overall, the feedback was constructive, and the 2nd phase of development was able to commence with the main focus on Augmented Reality.

6.2.2 Prototype 2

The approach for gathering UAT results for the 2nd prototype was pretty much identical, although I could not physically meet with EPIC and discuss the results and changes with them. The results are shown in Table 10. The only feature which did not quite meet their satisfaction was the mapping fragment, but as Pete stated earlier, they want to use the official Google Maps satellite image once it has been updated. The potential use of Augmented Reality was met with great excitement and a few ideas were put forward. One of them being that it could be used to overlay images of historical artefacts that had been found on the site. The final consensus was that the application was ready to be deployed in the Google Play Store, with an Augmented Reality feature potentially added later.

Registration	10
Login	10
Home	10
Mapping	9
Sightings	10
Species List	10
About	10
Feedback	10
Navigation of application	10
Augmented Reality	8

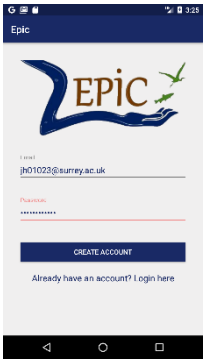
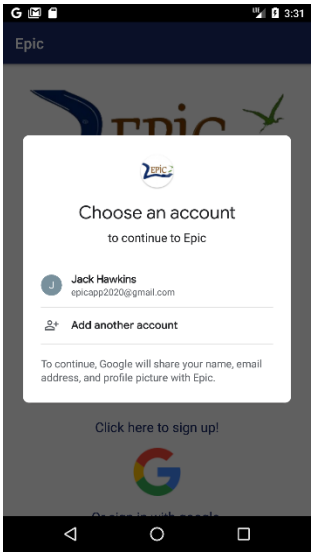
Table 10:Prototype 2 Results

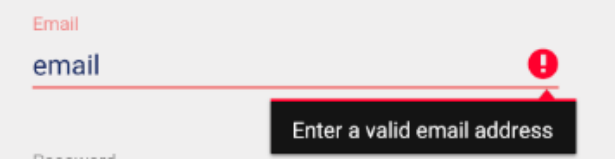
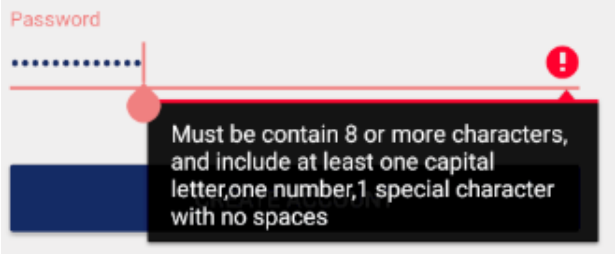
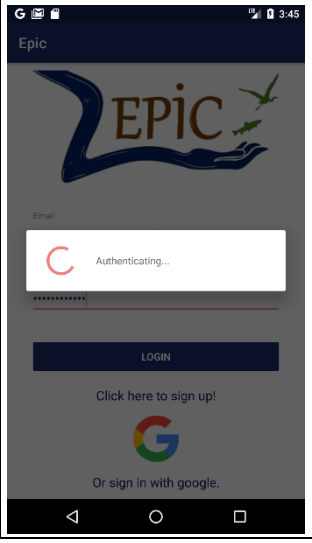
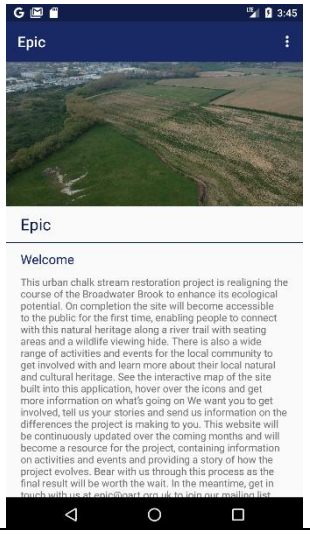
6.3 Requirement Testing

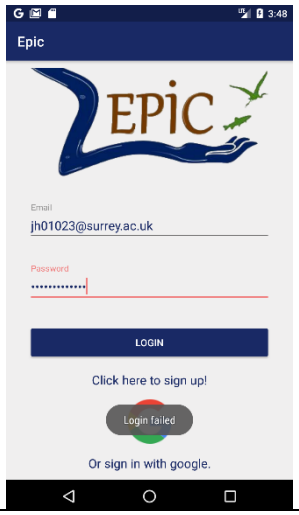
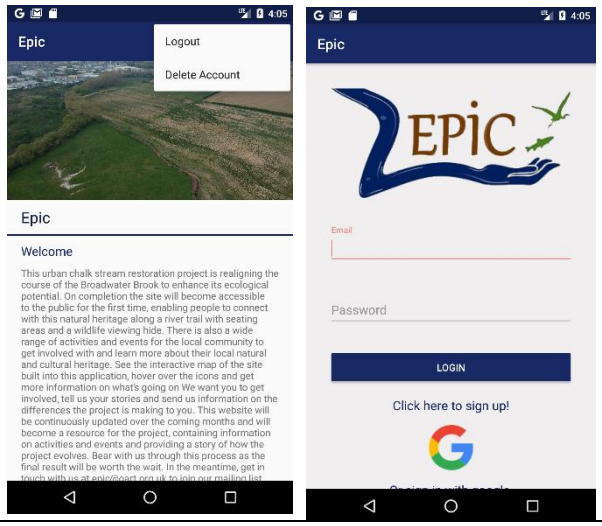
6.3.1 Prototype 1

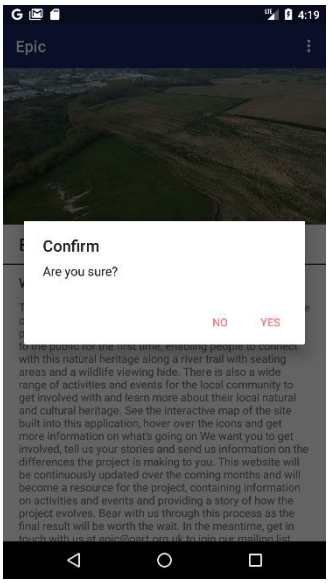
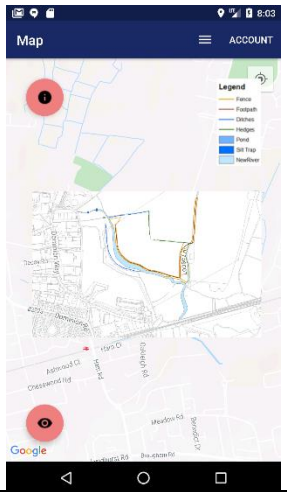
6.3.1.1 Functional Requirement Testing

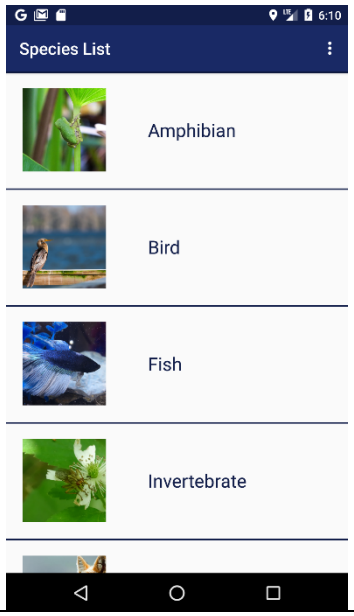
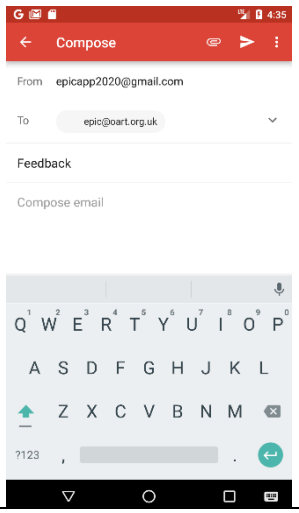
Apart from 1.12 all other requirements were met and are documented in the following table.

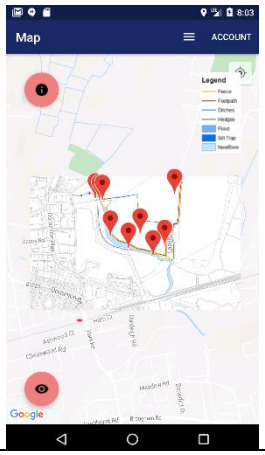
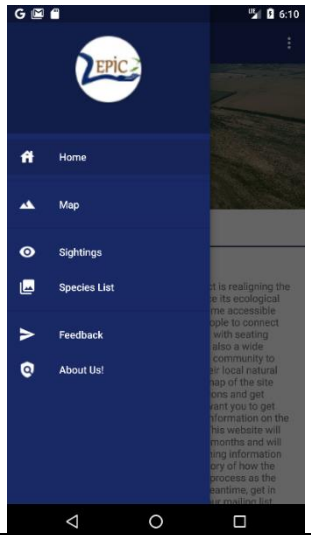
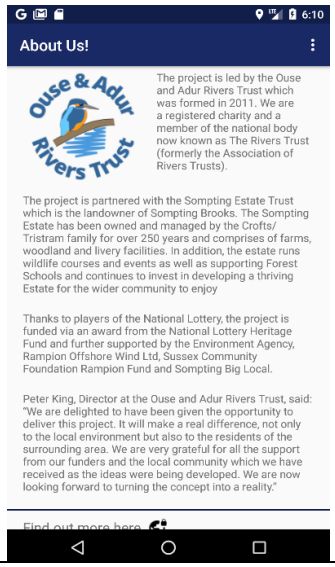
Requirement ID	Expected Result	Actual Result	Test Passed?
1.1	The system will provide a registration service asking for an email and password. Submission will result in the creation of an account that is populated within the database.	Fields are completed is as expected, the screenshot below shows the evidence of the registration form being filled in.  A new user is added to the database. 	**Yes**
1.1	The system will provide an alternative means of authentication via the use of Google accounts.	The Google sign-in option is selected, and the user chooses an account to register with. This can be seen below.  The account is then added to the database with the Google symbol: 	**Yes**

Requirement ID	Expected Result	Actual Result	Test Passed?
1.1	Validation checks will ensure input fields are entered correctly, if not the user cannot register an account.	When an invalid email is enterred the following is returned.  When an password is entered that does not match the specified regex the following is returned.  If both fields are invalid then both errors will display until rectified.	**Yes**
1.2	The system will provide a login service for users that have already successfully registered an account with the service. Once logged in they will be presented with the home page	The first screenshot shows the users input being validated against the database. The second screenshot shows the user at the home page once they have been successfully logged in.  	**Yes**

Requirement ID	Expected Result	Actual Result	Test Passed?
1.2	The user cannot log into account if their details do not match the details stored in the database.	The password did not match in the database, thus the user was prompted with a failed login attempt toast. 	**Yes**
1.3	The application allows the user to sign out of their account if they are logged into the application. They will be returned to the login page.	The screenshots below portray a user sucessfully logging out of the application and being returned to the login page 	**Yes**
1.4	The application will provide the user with the ability to delete their account when logged into the application. It will ask for confirmation on whether they are sure they want to perform this task or not.	The user is asked to cofirm their actions:	**Yes**

Requirement ID	Expected Result	Actual Result	Test Passed?
		 The EPICapp202@gmail.com email is no longer present within the database Identifier / Providers / Created / Signed In / User UID john.hawkins2017@gmail.co... / 24 Feb 2020 / 25 Feb 2020 / BITjGWOWpxe3cJyRyqvD0BehOOq2 alistair.whitby@oart.org.uk / 25 Feb 2020 / 25 Feb 2020 / P0LFwJchq0RQlY3bLFh3Hn32vkx1 hawkinsjgh@gmail.com / 24 Feb 2020 / 24 Feb 2020 / YfIZBITqldbXeHYUpdGLhlQz8e93 jh01023@surrey.ac.uk / 17 Mar 2020 / 17 Mar 2020 / dOP1sW706TdWWCHjz5cSCkncg... peter.king@oart.org.uk / 25 Feb 2020 / 25 Feb 2020 / gs1VlK1ejYa6GSEzhw8LdhNzVGz2 resisement@gmail.com / 14 Feb 2020 / 6 Mar 2020 / iy8paSVkn6VtuhZopd5JUavi0982	
1.5	The system will display a map specific for EPICs nature reserve using the Google Maps overlay feature	The map displays on top of Google Maps bound by specific coordinates 	**Yes**

Requirement ID	Expected Result	Actual Result	Test Passed?
1.6	The system will display a list of photos of species found at to EPIC's Nature Reserve	The screenshot below shows the first level of the hierachical species view. The user can navigate through lists to find the animal they are looking for 	**Yes**
1.7	The system will allow the user to submit feedback to EPIC via email	The screenshot below illustrates the button avaiable for the user to submit feedback  If the user decides they wish to submit feedback a new page will be opened with all the presets defined. 	**Yes**
1.8	The system will display site specific information		**Yes**

Requirement ID	Expected Result	Actual Result	Test Passed?
	based on the user's location	The markers contain information about the site that can be retrieved when clicked, or if the user walks close to them with the feature selected 	
1.9	The system will provide a side-menu that allows for seamless navigation between features of the application	The use scrolls to the right and the side menu is revealed: 	**Yes**
1.10	The system will display general information about the site and the organisations involved.		**Yes**

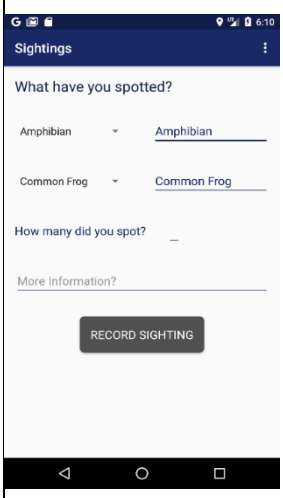
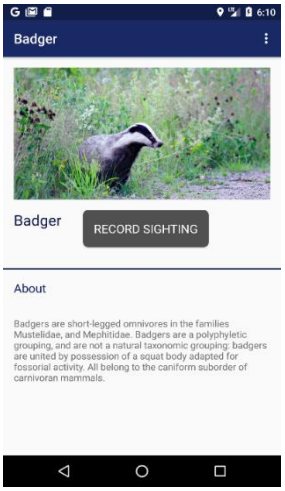
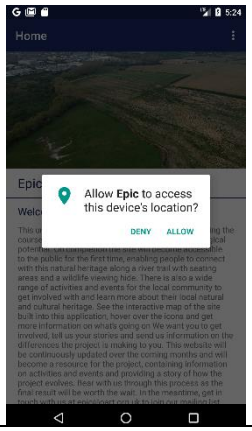
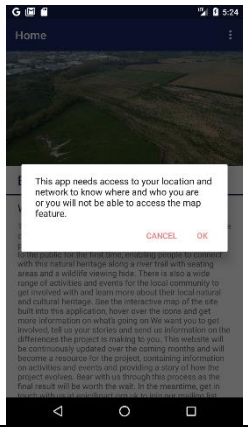
Requirement ID	Expected Result	Actual Result	Test Passed?
1.11	The system will allow the user to record sightings when visiting the site	There are two ways to record sightings within the application. One by the sightings page and two via the species list which can be seen below  	**Yes**
1.12	The system will display information around the site using the camera depending on the user's location	Scheduled for prototype 2	**No**

Table 11: Functional Requirement Testing Results Prototype 1

6.3.1.2 Non-Functional Requirement Testing

Table 11 lists the non-functional requirements. Requirements 2.2, 2.6, 2.7, 2.10 and 2.11 were not met in prototype 1.

Requirement ID	Expected Result	Actual Result	Test Passed?
2.1	All user inputs will be validated against a set of criteria	Working as expected, See Testing for 1.1 and 2.2. User sightings are also validated to ensure database is populated correctly	**Yes**
2.2	The system should display the user's location within a 3-meter radius	The average error for GPS ranges between 1 to 4 meters on the site, this is just outside the range of the expected result. However, there is no WIFI available on the site, so it is very difficult to improve on this result. (Possible prototype 2 calculations may compare GPS to Network location)	**No**
2.3	The system should allow the user to sign-up at any time during the day without experiencing any issues.	See test evidence in Functional requirements table for 1.1. It is working as expected, the threshold for the number of accounts that can be created is currently set at 100 per day but this can be set depending on the traffic the application receives.	**Yes**

Requirement ID	Expected Result	Actual Result	Test Passed?
2.4	The system should allow the user to log in/out of the application at any time and this should be obvious on how to do so.	Working as expected. See test 1.3 for test evidence	**Yes**
2.5	The system will request the user's permission to access their location otherwise mapping will be disabled. If they decline the permission check, they can change this within the settings at anytime	Below is evidence that this is working as expected. If the user denies access the first time, the next time they will be prompted with a reasoning as to why the location is needed. This process will repeat until they given permission and the map function will remain unusable until so.  	**Yes**
2.6	The AR feature will be disabled in systems that do not have the required architecture	Scheduled for prototype 2	**NA**
2.7	Users must agree to a privacy agreement allowing the system to use their information.	Scheduled for prototype 2	**NA**
2.8	Navigation within the application should be clear	As expected, see test results for 1.9	**Yes**
2.9	Different features within the application should be easily accessible and intuitive to use.	Working as expected, see UAT results for clarification	**Yes**
2.10	The application will display different information depending on the users position within the environment	A bug is currently preventing this from full working. Will be fixed in prototype 2	**NA**

Requirement ID	Expected Result	Actual Result	Test Passed?

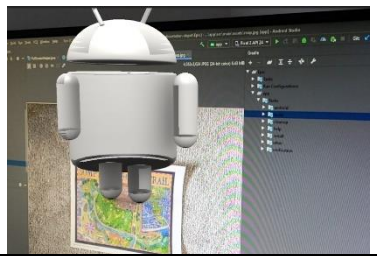
2.11	Data should be stored securely against common vulnerabilities so that sensitive information is not accessible	The data is secured within a Firebase cloud server and is only accessible via authenticated users. Only the system administrators have access to the actual database. The screenshot below shows the rules for the database, i.e. if a username is not recognised they cannot access its features
		`rules_version = '2';`
		`service cloud.firestore {`
		`  match /databases/{database}/documents {`
		`  match /{document=**} {`
		`  allow read, write: if request.auth.uid != null;`
		`  }`
		`  }`
		`}`
			Yes

Table 12: Non-Functional Requirement Testing Results Prototype 1

6.3.2 Prototype 2

6.3.2.1 Functional Requirement Testing

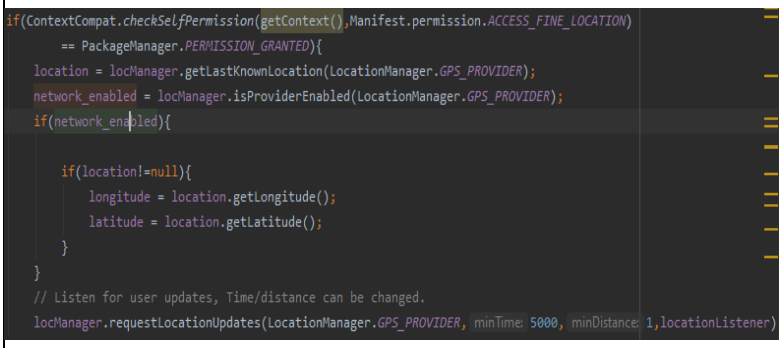
All functional requirements were satisfied in this iteration of the application. The results for requirement 1.12 can be seen below

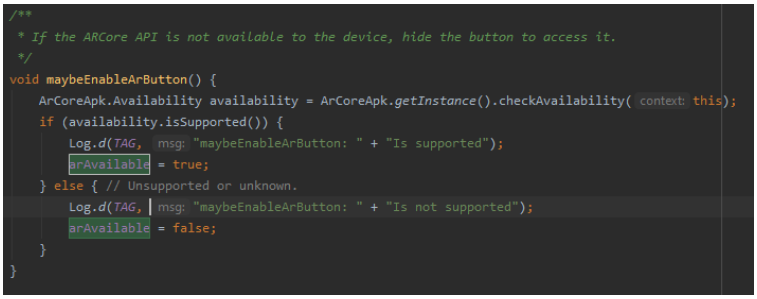
Requirement ID	Expected Result	Actual Result	Test Passed?
1.12	Once an image is scanned and loaded in the Augmented Image database a 3D model will be displayed	Up to 1000 images can be added to the database. The first screenshot shows the image which is to be scanned. The second screenshot shows the 3D model being displayed in the user's camera view once the image has been scanned.  	**Yes**

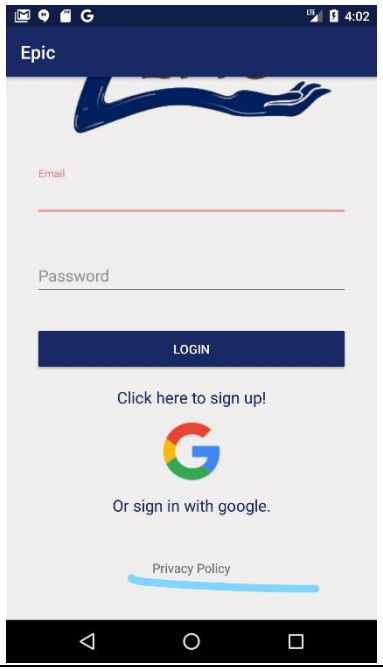
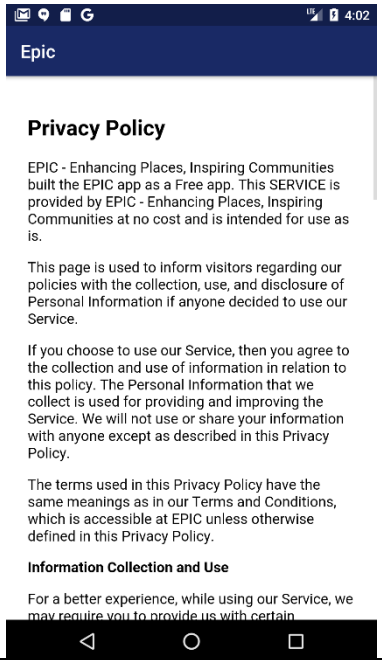
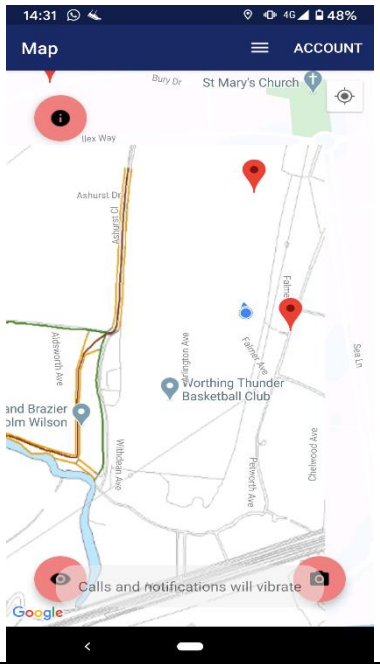
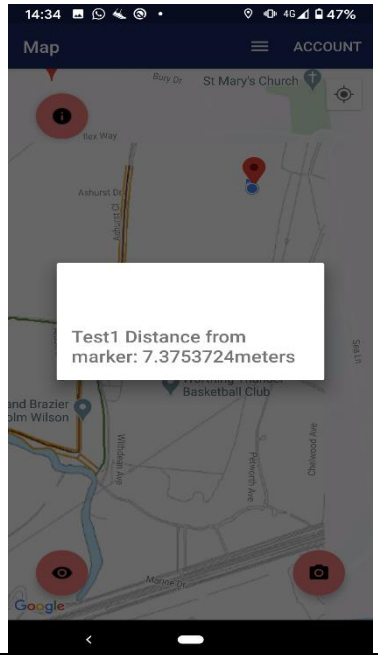
6.3.2.2 Non-Functional Requirement Testing

All non-functional requirements were satisfied in this iteration of the application.

Requirement ID	Expected Result	Actual Result	Test Passed?

2.2	The system should display the user's location within a 3-meter radius	The estimated accuracies of each possible solution are as follows (Idris, 2010):
		• GPS – 6-meters
		• Network – 60 meters
		• CellID Lookup – 1615 meters
		Since none of the available options provides the accuracy required this requirement has not been met. GPS has been used as it provides the highest accuracy possible which can be seen in the screenshot below.
		 
		`if(ContextCompat.checkSelfPermission(getContext(),Manifest.permission.ACCESS_FINE_LOCATION) == PackageManager.PERMISSION_GRANTED){`
		`location = locManager.getLastKnownLocation(LocationManager.GPS_PROVIDER);`
		`network_enabled = locManager.isProviderEnabled(LocationManager.GPS_PROVIDER);`
		`if(network_enabled){`
		`if(location!=null){`
		`longitude = location.getLongitude();`
		`latitude = location.getLatitude();`
		`}`
		`}`
		`// Listen for user updates, Time/distance can be changed.`
		`locManager.requestLocationUpdates(LocationManager.GPS_PROVIDER, minTime: 5000, minDistance: 1,locationListener)`
			No

2.6	The AR feature will be disabled in systems that do not have the required architecture	The code below checks if the ARcore APK is available on the user's phone or not. A Boolean is set depending on the result. If it is not available, the navigation bar will not display the option available.
		 
		`/**`
		`* If the ARCore API is not available to the device, hide the button to access it.`
		`*/`
		`void maybeEnableArButton() {`
		`ArCoreApk.Availability availability = ArCoreApk.getInstance().checkAvailability( context: this);`
		`if (availability.isSupported()) {`
		`Log.d(TAG, msg: "maybeEnableArButton: " + "Is supported");`
		`arAvailable = true;`
		`} else { // Unsupported or unknown.`
		`Log.d(TAG, msg: "maybeEnableArButton: " + "Is not supported");`
		`arAvailable = false;`
		`}`
		`}`
			Yes

Requirement ID	Expected Result	Actual Result	Test Passed?
2.7	There will be a privacy agreement available for viewing when logging into the application	The two screenshots show how the privacy policy can be viewed and what its contents are.  	**Yes**
2.10	The application will display information content depending on the users position within the environment	This images below display that the functionality of the method is working. The first screenshot shows a few markers that exist in the real world, their visibility can be toggled according to user wishes. When a user walks within 10 meters of the marker information specific to that marker is displayed. For the purpose of the test to ensure distances were working as expected the user's distance from the marker was displayed.  	**Yes**

6.4 Android Tests

Testing the application in Android studio allowed the app's functional behaviours and usability to be verified prior to release. There are two types of unit test available with Android: local and instrumented. Local tests are standard j-unit tests which provide function, event loop and component lifecycle testing. For this app, this also includes tests to confirm that the validation, location, and database functions were working as expected. Instrumented tests are tests that run on a physical device or emulator and evaluate the behaviour of the app, i.e. UI. The next segments describe the tests that were undertaken to ensure application validity.

6.4.1 Instrumentation Tests

There are a variety of APIs available to perform UI test. Expresso was chosen because of it's extensive documentation and because it covers all aspects of this project. "Espresso tests state expectations, interactions, and assertions clearly without the distraction of boilerplate content, custom infrastructure, or messy implementation details getting in the way" (Test, 2019). There are three basic components: "ViewMatchers", "ViewActions" and "ViewAssertions". ViewMatchers allows discovery of the current view hierarchy, ViewActions allows actions on views and ViewAssertions all assertations to be performed as information on the state of that view is gathered. For example, when the user clicks the logout button, are they returned to the login screen as expected? Testing user interaction with an app helps to ensure that users do not encounter unexpected results. The majority of tests for this application involved ensuring that the navigation to each fragment worked as expected and that buttons performed as anticipated. The two testing classes "MainActivityTest" and "loginRegisterActivityTest" cover all UI aspects of the application. As seen in figure 33, this function checks that no issues are encountered when using the navigation menu to navigate to the species list fragment. It then checks that the ReyclerView is working as intended, with the result matching a specific string. Similar tests were carried out for other applications fragments/activities.

```
@Test
public void TestNavigationToSpeciesList() throws Exception {
    onView(withId(R.id.drawer_layout)).perform(DrawerActions.open());
    onView(withId(R.id.drawer_layout)).check(matches(isOpen()));
    onView(withId(R.id.nav_view)).perform(NavigationViewActions.navigateTo(R.id.nav_species_list));
    onView(withId(R.id.species_recycler))
            .perform(RecyclerViewActions.actionOnItem(
                    hasDescendant(withText("Amphibian")),
                    click()));
    onView(withId(R.id.species_recycler))
            .perform(RecyclerViewActions.actionOnItem(
                    hasDescendant(withText("Common Frog")),
                    click()));
    onView(withId(R.id.record_sighting_now)).check(matches(withText("Record Sighting")));
}
```

Figure 33:SpeciesList NavigationTest

Another example of a test can be seen in Figure 25. This test checks that the user can log out of the application and then log back in using their account, provided they enter the details correctly.

```
/*
 Tests the logout button is working as expected and that you can log back in.
 */
@Test
public void TestLogoutButton() throws Exception {
    onView(withText(R.string.account)).perform(click());
    onView(withText(R.string.action_logout)).perform(click());
    onView(withId(R.id.email_input)).perform(typeText( stringToBeTyped: "jh01023@surrey.ac.uk"));
    onView(withId(R.id.password_input)).perform(scrollTo()).perform(typeText( stringToBeTyped: "Testing123!"));
    onView(withId(R.id.login_button)).perform(scrollTo()).perform(click());
}
```

Figure 34: Login Espresso Test

13 tests were written for the first prototype. These tests looked for issues in the various navigation options. Since the completion of the final prototype a total of 34 tests have been created, as seen in figure 35. These tests assess various features from logging in to going through the hierarchical list of species. There is no aspect of the app available to the user that has not been tested.

```
Tests passed: 34 of 34 tests – 1 m 26 s 945 ms
Testing started at 19:57 ...

05/06 19:57:50: Launching 'Tests in 'com.example.epic'' on Pixel 2 API 24.
Running tests

$ adb shell am instrument -w -r    -e package com.example.epic -e debug false com.example.epic.test/androidx.test.runner.AndroidJUnitRunner

Started running tests

Connected to process 5414 on device 'Pixel_2_API_24 [emulator-5554]'.
Tests ran to completion.
```

Figure 35: UI Espresso Tests

6.4.1 Local J-Unit Tests

There was very little to undertake in terms of J-unit testing with this application. A total of 13 J-unit Tests were written. These tests check login methods and the simple getter and setter methods used when accessing models. Figure 36 is an example of a registration test that checks the password field is not empty and that it matches the required regex.

```
@Test
public void PasswordIsInValid() {
    boolean valid = false;
    if (INVALID_PASSWORD.isEmpty() ||!INVALID_PASSWORD.matches( regex: "^(?=.*[0-9])(?=
        valid = true;
    }
    assertTrue(valid);
}
```

Figure 36: Example Registration J-Unit Test

6.5 Device Testing

The main purpose of these tests was to ensure that the application worked on all devices running SDK 21 upwards. This permits the application to reach 99.3% of the Android audience (Distribution, 2020). The app was tested on each version between 21 and 28, with the Augmented Reality functional only available on SDK 24 or higher. As shown in figure 37, the minimum SDK has been set to 21. A simple check will manage devices that do not meet the required version for AR functionality.

```
android {
    compileSdkVersion 29
    buildToolsVersion "29.0.2"
    defaultConfig {
        applicationId "com.example.epic"
        minSdkVersion 21
        targetSdkVersion 29
        versionCode 1
        versionName "1.0"
        testInstrumentationRunner "androidx.test.runner.AndroidJUnitRunner"
    }
```

Figure 37: Minimum SDK requirement

The images in Figure 38 show the login page displayed on different screen sizes. The same look is maintained across multiple devices and does not lose its materialistic design. Hopefully, this indicates that the application will be usable across all Android devices provided they meet the minimum requirements. All features worked on each of these devices and no new issues were found.

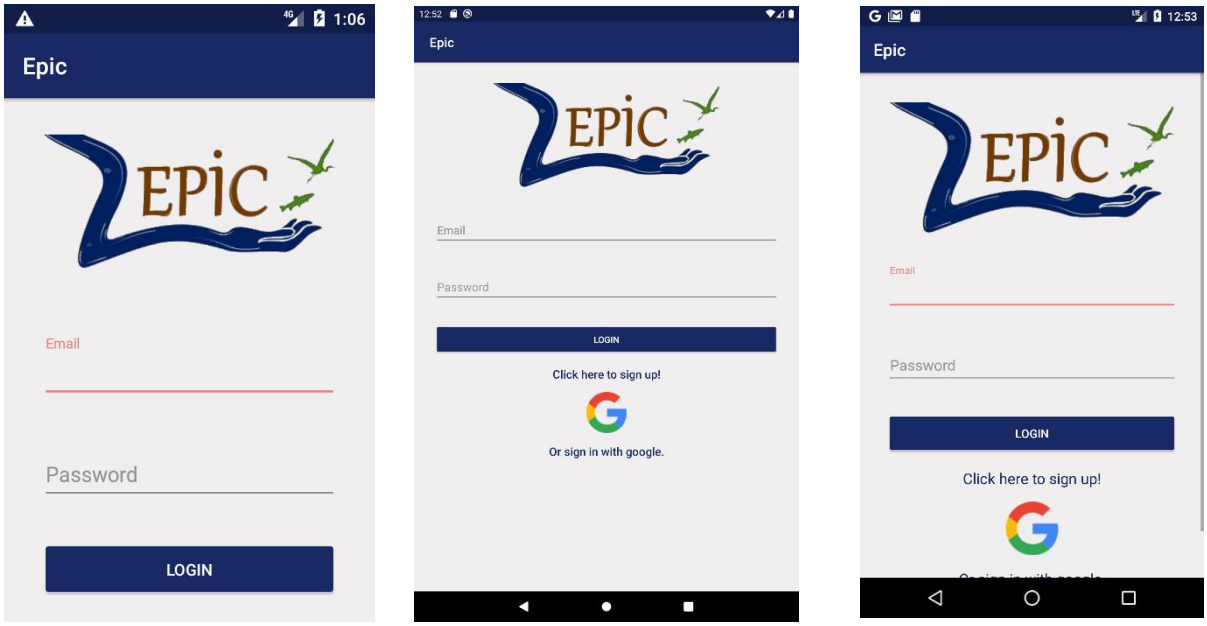


Figure 38: Login UI tests on variety of screen sizes

6.6 Augmented Reality Outdoor Testing

Although the AR feature worked on a PC, it was important to ensure it worked on a phone “in the field”. The first image in Figure 39 shows an image to be scanned, the second image shows the image after recognition with the 3D model overlay correctly displayed. In practice there would be an array of different images around the site (e.g. attached to wooden posts) and each image would display a different animal/animation.

Figure 39:Outdoor Tests

6.6 Summary

This section describes the testing of both prototypes and the baseline version using a range of different techniques to ensure all aspects of the application were validated. The user acceptance tests were most important. These highlighted bugs which had not been discovered in-house and provided useful feedback when tailoring the application to meet EPIC’s needs. It also provided proof that the application would work on multiple devices. UI testing was an aspect of Android development that I previously had limited experience of, and I now appreciate how important it is. As seen in the test results, all the requirements, bar non-functional requirement 2.2**,** have been met, establishing this as a successful project. Whilst there is always more testing that can be performed, I believe that the depth and coverage undertaken provides an adequate level of confidence for a project of this type.

7 Project Evaluation and Conclusion

7.1 Introduction

This section evaluates the overall outcome of the project and the application. It compares the functionality of the application against the project objectives. It also assesses how well the requirements defined early in the project's lifecycle were met. It includes a comparison between the schedule devised at the start of the project vs the actual schedule. Customer handover, future enhancements and the maintenance of the application are also discussed.

7.2 Evaluation Against Project Aims and Objectives

All the objectives set out at the start of the project were met. Although the main deliverable was the application itself, there were other objectives that were potentially detrimental to the overall success of the project. Objectives 1 and 2 established the foundation of the project and provided guidance on what was available in the public domain. They also provided vital insight into what should be taken forward to the design and development phases. Objective 3 was very important; without a clear line of communication with EPIC the application might not have met their needs. Customer feedback provided during the test phase of this project proved that this objective was successful. Objectives 4,5 and 6 have also been achieved, with the application now ready for deployment. All features were rigorously tested and feedback from UAT was actioned. Objectives 8,9 and 10 are discussed in detail in this section.

Objective	Description	Accomplished
1	Research into nature reserves, environmental projects and wildlife to gain an understanding of how this project will be beneficial to wildlife, visitors and the local community.	✓
2	Research into existing applications and applicable technologies.	✓
3	Learn how to work with a real customer e.g. requirements capture, periodic reviews, delivery & handover, managing expectations	✓
4	Define a set of functional and non-functional requirements.	✓
5	Design a solution that fits the stated requirements	✓
6	Implement a solution for EPIC's scheme in West Sussex	✓
7	Test all aspects of the system and utilize user feedback where appropriate.	✓
8	Discuss and Evaluate the success of the application.	✓
9	Define how the project will be maintained in the future.	✓
10	Evaluate overall project success.	✓

Table 13: Evaluation against project objectives

7.3 Evaluation Against Project Success Criteria

Success Criteria 1 links closely with the 3rd objective and its success has been demonstrated via feedback provided and EPIC have expressed their complete satisfaction with the outcome. In terms of Criteria 2, the statement of ethics demonstrates that due consideration has been given to this matter. The application database can only be accessed by authorised persons and the content is available only to EPIC staff for data gathering and statistical analysis, thus fulfilling Criteria 3.

Success Criteria	Description	Accomplished
1	A working application has been developed which meets EPIC's standards	✓
2	The application has met important ethical standards	✓
3	The applications data is stored in a secure database that can be analysed by EPIC to retrieve visiting and sighting statistics	✓

Table 14:Evaluation against project success criteria

7.4 Evaluation of Project Schedule

It is evident that I was extremely optimistic when developing the initial schedule for this project. I did not appreciate the length of time it would take to complete the pre-development tasks of literature review, requirements definition and design. The original schedule, as shown in Appendix B, predicted that the project would start development in December and end mid-February. In reality development did not start until February, with the final prototype completed only in the early weeks of May. Although this did not affect the completion of the project, deviations this large meant that the original schedule was of limited value. The actual schedule can also be seen in Appendix B. Whilst I had not factored in the breaks at Christmas and Easter needed to work on other coursework and exams, it is clear that my lack of experience was the main issue. This project has given me the opportunity to learn more about how effort should be allocated on medium to large software projects.

7.5 Customer Handover and Maintenance

The next step in this project's lifecycle will be to deliver the application "to market". It is vital to ensure that everything has been adequately tested and meets Googles guidelines before uploading to the Google Play Store. Personally, I find this is a very exciting prospect, and I look forward to my first application being available in the public domain. The customer handover process will take place as soon as COVID rules allow. A manual will be supplied to EPIC detailing relevant "how to" information such as Administrator management, database species and information additions, sighting data access etc., together with the source code. Very little maintenance is anticipated with this application. EPIC have stated that they will manage any future updates that the application requires.

7.6 Future Enhancements

A significant enhancement would be to develop this application for the iOS community. Sadly, this was not a realistic option for a Year 3 dissertation, given time availability and my lack of experience with Swift. Android was chosen due to its broader community. A further valuable enhancement would be to add a 'game' aspect to the application in the form of a "Pokedex" for real animals. This might give users the incentive to revisit sites so they could expand their "collection". Users with the most

extensive lists at the end of each year could receive awards etc. Similarly, a wildlife identification quiz would be simple to implement using the photographs already stored in the database.

7.7 Conclusion

In terms of what is currently available for visitors to sites like EPIC, this application delivers a unique collection of features which I believe will significantly enhance their experience in many ways. I am also excited about the potential prospect of its use on other sites in the future and aim to investigate this possibility with bodies like the National Trust and RSPB in the coming months.

I spent a significant amount of time researching and testing various libraries and technologies that offer AR features. This is a complex subject which, unfortunately, left me with little time to develop a fully mature feature. I am slightly disappointed with the current integration of AR but given more time I would like to make improvements. However, given that this has not been detrimental to the success of this application from the customers perspective, I do not feel that this limited the outcome of the project.

I have learnt a great deal from working with a real customer and acting as a “Freelancer”. I hope this will kick start new opportunities, and I look forward to working with other clientele on other mobile applications in future years.

8 Statement of Ethics

This application has been developed with due regard to ethics. This statement details considerations that were made on important ethical issues relating to this project.

8.1 Do no harm

In terms of research, discovery and data scope, this project does not deal with any sensitive data. Any data that has been referenced comes from academic papers or published materials that are available to the public. The project itself has focused on providing educational and navigational benefits to visitors to EPIC's nature reserve. There is an opportunity for users to stray off the path when using the application and potentially injure themselves. However, the possibility of this happening is extremely low, and I do not believe that this is a consideration in respect of this application - users are expected show a common-sense level of caution when walking outdoors. In addition, I do not believe that any laws or legislative rules have been challenged or breached. Finally, to align with the Computer Misuse Act (CMA), sufficient steps have been taken to ensure that unauthorised personnel do not have access to sensitive information - only named administrators have access to any of the database records and users must authorise access before they can make any submissions.

8.2 Informed Consent

Feedback during the project came only from EPIC employees who work on the nature reserve on a day-to-day basis and understand the associated risks. They have all read and given verbal consent stating that any feedback & evaluation of the application provided at each stage would only be used for application development and that a consolidated version would be referenced within this document. No other data has been collected and therefore there is no requirement to gain consent from others. Users are presented with a privacy policy during account creation to ensure that they understand what happens with any data they submit.

8.3 Confidentiality of Data

The only person named in the report, outside of the acknowledgements, is Peter King. As stated, Peter is the director of the EPIC program and as such has had a huge influence on the direction of the application. It felt important to mention him by name when and where customer decisions were made. Only one piece of personal information is collected from the users, their email address. This is not made public and is only available to authorised administrators. This project adheres to all the principles of the General Data Protection Regulation (which replaced the Data Protection Act) and at no time puts any users personal information at risk (Policies, 2020). If the user wishes to remove their account from the system, they can readily do so at any time via a menu option within the application.

8.3.1 General Data Protection Regulation

The GDPR applies to any applications that collect and process the personal data of EU citizens. My application collects the email addresses of users and must therefore be subject to GDPR considerations. The main purpose of this regulation is to provide improved privacy protection, and any business or organisation that makes use of personal data must comply or face legislation fines.

8.3.2 Active Consent

The most important requirement of GDPR is the acquisition of active and informed consent of users before the collection and processing of their personal information. This can be found in recital 42 of the GDPR. In order to comply with this, an application must provide the users with information about the data being collected as well as a checkbox so they can actively confirm their consent before any data is collected. Figure 40 illustrates how this is implemented in my application. Users must consent when registering. If they do not agree to comply with the policy, they cannot use the application, and thus the application meets requirements.

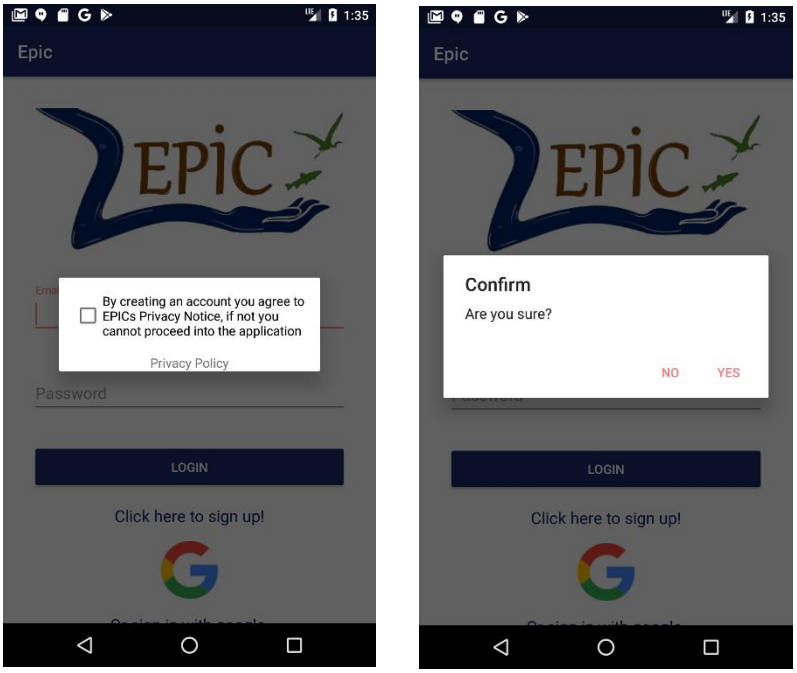


Figure 40: Active Consent Compliance

8.3.3 Right to Access Data

Another important requirement of GDPR that relates to this application is “The Right to Access Data” which can be found in article 15. The requirement states that if a user makes a request for information under the GDPR it must be honoured. In this case any user can directly contact EPIC and their request will be processed by the staff.

8.3.4 Right of Restriction of Processing

Users have the right to ask for their data to stop being processed and compliance must be immediate. In this case, users can follow the option of removing their account from the system at which point all personal data is destroyed.

8.3.5 Right to Data Portability

Users may make use of this act in instances where data is processed automatically by devices or machines. Users have the right to transmit the data they provided from one application to another or other businesses without interference. In the case of EPIC, the only information users provide is email addresses, which of course they can also provide to any other organisation. Any sightings data submitted can be retrieved and given to the user if requested.

8.3.6 Right to Object

Via Article 21 users can request that their data is no longer processed. This is not relevant to this application and the only option required to be made available to users is the removal of their account and any associated data.

8.3.7 Right to Rectification

Article 16 allows users to modify their data if it is inaccurate or incomplete. This only applies to email addresses with this application. If a user wants to change email address, they can simply delete their old account and create a new one, or just create an additional account.

8.3.8 Right to Be Informed

The user has the right to be informed of who is collecting their information and for what purpose. The privacy policy provided by EPIC, which is displayed when logging in and at registration, contains information covering this regulation.

8.3.9 Right to Erasure

The user has the right to request the erasure of their personal data without undue delay. This application allows the user to delete their own account and thus any personal data at any time.

8.3.10 Further Scope

Additional requirements, such as the role of a Data Protection Officer, are out of scope for this application but may need to be considered by EPIC themselves if they intend to process information further. Another consideration was the use of a Data Protection Impact Assessment, which quantifies and assesses the risks of a security breach. This application has carefully implemented the main GDPR considerations and is fully compliant.

8.4 Social Responsibility

I believe that this application can contribute to society and human wellbeing in a number of important ways. Not only does it encourage people to go sightseeing and discover wildlife, it also gives them a sense of fulfilment through knowing their input may contribute to biological studies and scientific record keeping. And, given that studies show strong links between improved mental health and nature, it supports increased activity in beneficial pursuits. Finally, it provides an educational aspect by providing information on wide range of subjects such as animals, plants, ecology, geology, and archaeology.

8.5 Professional Competence and Integrity

In order to comply with the BCS Code of conduct throughout the project I have ensured that I have not offered or engaged in a service that is not within my professional competence and have never

claimed any level of competence that I do not possess. Where a professional opinion was provided by someone else it was always objective and reliable.

8.7 Legal Considerations

The legal aspects of this project are important and must be considered. This section covers various relevant factors such as the intellectual property, copyright, and liability.

8.7.1 Computer Misuse Act 1990

The CMA legislation provides guidance on offences that may arise with when handling personal data. It consists of three main areas:

1. Unauthorised access to computer material
    a. It is imperative that information within the application cannot be accessed or reproduced unless authorised. Various checks have been put in place which prevent users sending or accessing data unless they have been authenticated
    b. There is no company specific information which EPIC did not want to be disclosed anywhere within this project.
2. Unauthorised access with intent to commit offences
    a. There is no hidden functionality built within the application which has the intentions to impair the operational functionality of the device.
    b. There is no information that could be accessed by which any user could commit or be a victim of an offence.
3. Unauthorised acts with intent to cause impairment of operation to the computer.
    a. Many of the services provided by this application are handled by API calls to other third-party providers, and it is their responsibility, within the contract, to handle any denial of service attacks etc. that may affect the functionality of this application.

8.7.2 Public Liability Insurance

Public liability insurance is designed to provide the organisation with financial protection if a user suffers an accident whilst on its property or as a direct result of its business operations. Figure 41 is an extract from the Terms & Conditions available to the user at any point during their use of the application. It States that EPIC is not responsible in anyway if they should suffer harm when using the app. Users must agree to this and before accessing the app.

> You agree that in conjunction with your use of the Services, You will not trespass, or in any manner attempt to gain or gain access to any property or location where you do not have a right or permission to be, and will not otherwise engage in any activity that may result in injury, death, property damage, nuisance, or liability of any kind. If you have a dispute with any third party relating to your use of Services, you release EPIC from all claims, demands, and damages (actual and consequential) of every kind and nature, known and unknown, suspected and unsuspected, disclosed and undisclosed, arising out of or in any way connected with such disputes.

Figure 41: Terms & Conditions for public liability

8.7.3 Copyright, IP, Patents & Ethical Considerations

All code in this application has been written by me unless stated otherwise in the comments. All terms of service for each API have been read to ensure that there are no issues. Any written work that has been quoted from another source has been referenced appropriately. It may be wise for EPIC to request the copyrights for the application to prevent other organisations from reproducing the same work without seeking permission, but bearing in mind that this is an expensive process and can take a considerable length of time. In terms of patents, I do not think they are applicable to this project as most processes are generic in nature. Since this application will be EPICs property it will be their decision whether to seek and a patent or not. To Finish, all images found within the application have been provided by EPIC avoiding any copyright issues.

8.8 SAGE self-check Form

To satisfy university requirements, a SAGE self-check form was completed when objectives had been sufficiently understood. This process was overseen by my supervisor to ensure that it was followed correctly and truthfully. No further action was deemed necessary. This form is attached as Appendix F.

8.9 BCS Code of Conduct

As I am a member of the BCS it was my responsibility to ensure that their code of conduct was fully adhered to during the entirety of the project. The Code comprises of four key principles:

1. **You make IT for everyone**: Regarding this project, public health, privacy, security, and wellbeing of others has been considered where necessary. The rights of third parties have been examined and there has been no discrimination based on any condition or requirement. An attempt has been made to promote equal access across all sectors of IT whenever the opportunity has arisen. I believe that promoting a user-interface designed with simplicity in mind has ensured that this requirement has been met.
2. **Show what you know, learn what you don't**: At no point throughout this project have I claimed to possess any skills that I do not have. Any required expertise that was not already within my skill set was learnt and understood before it was included within the application itself.
3. **Respect the organisation or individual you work for:** EPIC's feedback on the application has always been prioritised - this helped reduce conflict and was beneficial to all parties.
4. **Keep IT real. Keep IT professional. Pass IT on**: I understand that it is my duty to uphold the professional reputation BCS members carry and always seek to improve my professionalism in the IT world. If any deviations or non-ethical conducts are found, the BCS will be notified immediately.

After fully reviewing the BCS code of conduct I believe that this project follows all guidelines and does not raise any ethical issues.

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Appendix

Appendix A: EPIC Meetings & Investigation

Android App Meeting 20-10-19

Below are the summarised minutes from a meeting with EPIC at which the scope and contents of the application were agreed (based on the timeframe of the project). Further considerations may be made further down the line, but they are out of scope for this project.

1. Bespoke **Map** showing "you are here"
    - Use **GPS** to determine Lat, Long
    - Limitations of "**Beacons**" (hardware costs, maintenance, no direction capability
2. **General Information** (Overview, how to get here, Facilities and access, Website URL, Links)
3. **Specific information** related to map and/or position
    - **User initiated**
        - Triggered via "push" buttons and/or zones on map.
        - Relating to EPIC project, ecology, wildlife, archaeology, palaeontology, geology (different coloured buttons)
        - Text, photos, animations, audio clips, links to websites (e.g. bird calls)
        - "Audio Tour" using audio clips triggered by Lat, Long
    - **Augmented Reality**
        - Any form of AR is acceptable.
4. **Identify common species** from photo hierarchy. Click photo for information.
5. "**Record your sighting**". Build and pull down a list as photo album. Add to on subsequent visits
6. **Visitor feed back**
7. **Cloud server database** records all sightings (e.g. what, when, where, who). Data can be passed on (e.g. to SBRC)
8. **Cloud server database** records all visitor information (e.g. arrive time, how long did they stay, voluntary info provided (where did they come from, number in group, ages, feedback)

Out of scope for dissertation

- Out of scope: Integrating data from cloud databases into EPIC SOMPTING website (e.g. scrolling list of live sightings, what to see now, totals per species per time frame, visitor count)
- Finished app will be available by the end of May 2020

- Android only
- Project Schedule – university require that the app development follow the full software lifecycle. With full documentation of each phase etc. This will mean less hours for coding but will facilitate future maintenance, updates and conversion to iOS (for apple phones)

Information Required to begin implementation

- Provide an aerial map of the reserve? An “artists impression” style map would be better than OS style for example
- Think about how the map could be broken down into zones and/or location of info buttons
- Think about how Augmented Reality might be used
- Provide a first cut list of species that visitors might encounter? I know this has already been started. Divide into Birds, Mammals, Reptiles & amphibians, Insects, Flowers and fungi etc. This can be expanded as the project progresses
- Start assimilating the “general” and “specific” information that the app will display - Text, photos, animations, audio clips etc

Android App Meeting 22-12-19

During this meeting, a number of design considerations were discussed in order to identify the best solution for EPIC. These ranged from site specific information such as the names of the animals recorded at the site so that the species database could be populated, to the choice of map to be used for the overlay. After discussing various options for the map, it was decided that a bespoke map accurately showing feature locations on the finished site would be used as a temporary solution until Google Maps updates with photographs of the site after construction has finished (1-3 years). Using a temporary overlay would allow testing of the location functionality of the app. It was agreed that an initial prototype would be finished by the end of February and that any subsequent meetings would be to answer my questions about specific functionality of the application and provide the necessary resources.

Android App Meeting 25-02-20

Met to install the application on EPIC staffs' devices for UAT testing. The test criteria provided can be found in Appendix D. From this, certain changes were identified and fixed during the second prototype.

Android App Meeting 30-03-20

Unfortunately, due to COVID-19, it was not possible to meet with EPIC face-to-face and discuss the changes proposed for the second prototype and other potential new features that might be incorporated. This and all subsequent meetings have been virtual. The next meeting was scheduled to discuss the testing of the second prototype.

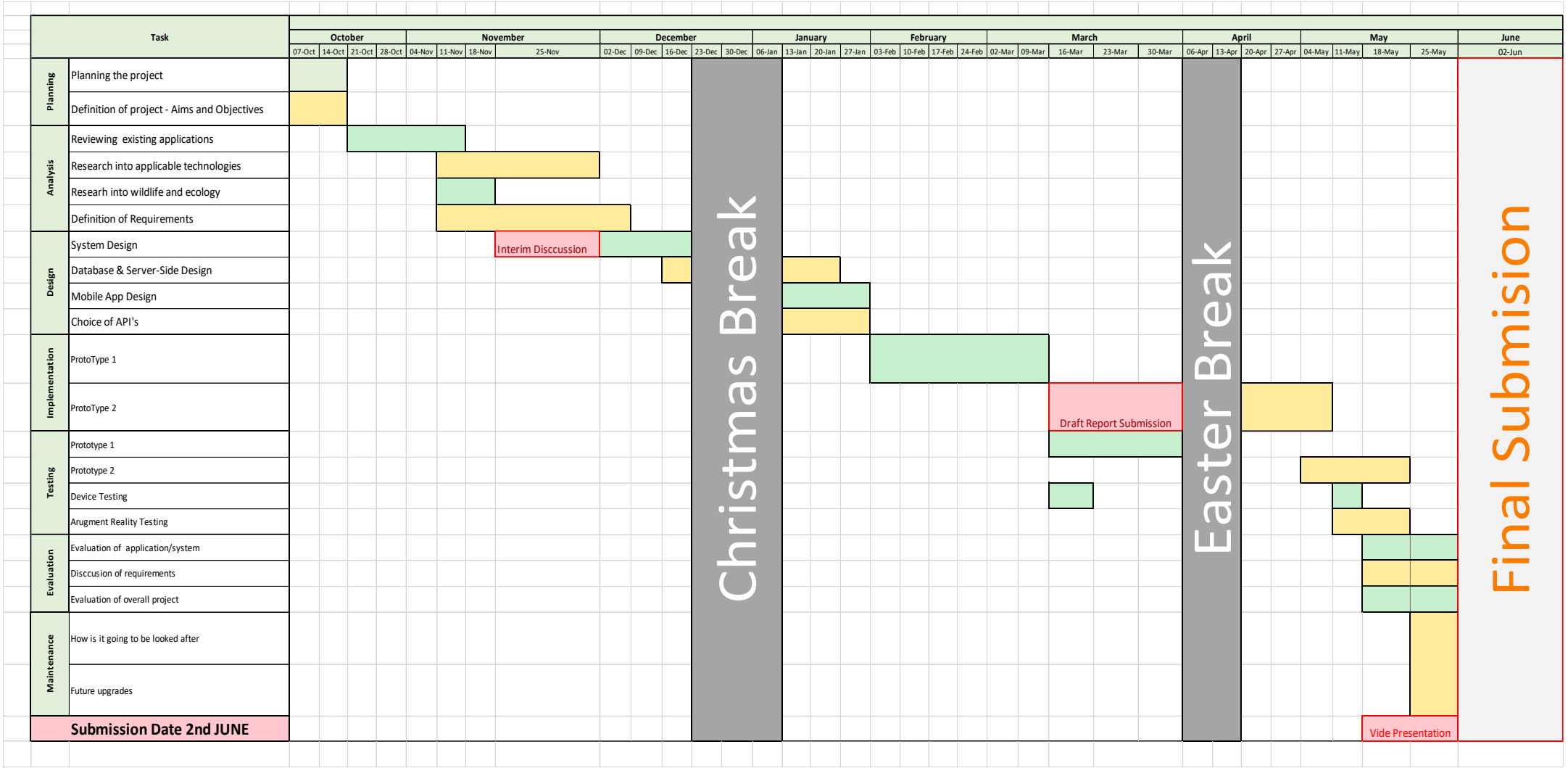
Android App Meeting 21-04-20

During this meeting, EPIC was shown the changes actioned after the first UAT. They then performed a second round of UAT, the results of which can be found in Appendix E. On completion confirmed that they were happy with the current state of the app, and I was left to work AR functionality.

Android App Meeting 19-05-20

This was the final scheduled meeting. EPIC was shown the AR feature and its possible benefits were discussed. They expressed their excitement with the concept and looked forward to testing it in the field as soon as possible. They also agreed that the app met all their requirements and did not require another prototype/test cycle. Deployment to the Google Play store will be action during Q3.

Appendix B: Revised Gantt Chart - Post Completion



Appendix C: Milestones

Below are the milestones that were assigned at the start of the project in order to produce a working project within the given time frame:

- Planning (Aims and objectives) – 14th October - 20 hours
- Analysis – 18th November – 60 hours
- Prep for interim - 25th Nov – 10 hours
- Design – 23rd December – 50 hours
- Implementation – 10th February – 120 hours
- Draft Report Submission – 23 March – 60 hours
- Implementation – 9th April – 100hours
- Testing – 20th April – 80 hours
- Evaluation – 20th April – 40 hours
- Maintenance – 11th May – 30 hours
- Final Report Check/Submission – 30 hours

Appendix D: User Acceptance Testing Prototype 1

1.) Create a new account using your own details or using your Google account.
    a. Did you find this process easy or difficult? If you had any problems, please note them down.

    b. Now that you have created your account, did you find the process of logging in easy?

    c. On the first reaction, what are your thoughts on the home page and the application as a whole? If you have any suggestions or changes you wish to make, note them down.

2.) Navigation throughout the application, does this seem intuitive or confusing? Please note down any thoughts.

3.) Navigate to the mapping page
    a. Is it clear how this page works?

    b. Are the extended features helpful?

    c. Is it easy to record sightings from this page?

    d. Is there anything that's not working as intended?

    e. Do you have any specific things you would like to see?

4.) Navigate to the sightings page

a. Is this page intuitive and easy to use?

b. Is there any confusion on how to submit a sighting?

c. What would you like to change or see within this page?

5.) Navigate to the species list page

a. Is this page intuitive and easy to use?

b. Is there any confusion when using this feature?

c. What would you like to change or see within this page?

6.) Navigate to the feedback page

a. Is it obvious how to submit feedback?

b. Is there anything you would want to change about this page?

7.) Navigate to the about page

a. Do you find this page helpful or needed?

b. Is it easy to navigate to the website from here?

8.) Logging out/ deleting an account

a. Do you find this process simple and straight forward? Please note any concerns.

9.) Finally, Please Rate each from 1-10, one being awful and ten being perfect.

Page	Rating (1 -10)
Registration	
Login	
Home	
Mapping	
Sightings	
Species List	
About	
Feedback	
Navigation of application	

Appendix E: User Acceptance Testing Prototype 2

Uses the same Sheet as prototype 1 with a new section on AR

1.) Navigate to the AR Page

a. Is it obvious how this feature works?

b. What did you think of the feature itself?

c. Could you see this feature being integrated into the release of the application?

Appendix F: – Ethics

If you wish to view the full ethics PDF you can access it via the PDF below, note no further documentation is need as questions 22-27 are not relevant to this project.

EthicsReviewSage.pdf

SAGE

Response ID	Completion date
514292-514283-56453047	6 Mar 2020, 14:07 (GMT)

1	**Applicant Name**	Jack George Henry Hawkins
1.a	**University of Surrey email address**	jh01023@surrey.ac.uk
1.b	**Level of research**	Undergraduate
1.b.i	**Please enter your University of Surrey supervisor's name. (If you have more than one supervisor, enter the details of the supervisor who will check this submission).**	Lee Gillam
1.b.ii	**Please enter your supervisor's University of Surrey email address. (if you have more than one supervisor, enter the details of the supervisor who will check this submission)**	l.gillam@surrey.ac.uk
1.c	**School or Department**	Computer Science

2	**Project title**	EPIC - Enhancing Places, Inspiring Communities

3	**For Undergraduate and Masters students, will your student research project be conducted according to a faculty standard study protocol? Your module lead or supervisor can advise if you are unsure.**	NO

4	**Are you making an amendment to a project with a current University of Surrey/NHS REC/other favourable ethical opinion in place?**	NO

5	**Does your research involve any animals, animal data or animal derived tissue, including cell lines?**	NO

6	**This question is deliberately left blank.**	Please click here to continue

7	**Does your project involve* human participants, their data and/or any human tissue?**	YES

8	**Does your funder, collaborator or other stakeholder require a mandatory ethics review (e.g. Institutional Review Board (IRB) review) to take place at the University of Surrey?**	NO

9	**Does your project process personal data1? Processing covers any activity performed with personal data, whether digitally or using other formats, and includes contacting, collecting, recording, organising, viewing, structuring, storing, adapting, transferring, altering, retrieving, consulting, marketing, using, disclosing, transmitting, communicating, disseminating, making available, aligning, analysing, combining, restricting, erasing, archiving, destroying.**	YES

10	**Does your project require the processing of special category2 data?**	NO

11	**If you are an undergraduate or Masters student, are you ONLY using name and contact details for recruitment purposes, and no other personal data is being collected as listed in questions 9 and 10 above?**	NO

13	**Does your research involve exposure of participants to any hazardous materials e.g. chemicals, pathogens, biological agents or does it involve any activities or locations that may pose a risk of harm to the researcher or participant?**	NO

14	**Will you be accessing any organisations, facilities or areas that may require prior permission? This includes organisations such as schools (Headteacher authorisation), care homes (manager permission), military facilities etc. If you are unsure, please contact RIGO.**	NO

15	**Will you be working with any collaborators or third parties to deliver any aspect of the research project?**	NO

16	**Will you be travelling to non-UK countries for any of your research activities?**	NO

17	**Will any research activities be conducted outside of the UK?**	NO

18	**Does your research involve lone working?**	NO

19	**Certain types of research require ethics approval from a nationally recognised research ethics committee (REC) which operates to standards set out by the Department of Health's Governance Arrangements for Research Ethics Committees. Recognised research ethics committees (REC) include NHS RECs and the MoDREC. Does your research involve any of the following? (select all that apply)**	None of the above

20	**Have you selected any of the options between A-O from question 19?**	NO

21	**Does your project require ethics review from another institution?**	NO

28	**Declarations**	• *I confirm that I have read the University's Code on Good Research Practice and ethics policy and all relevant professional and regulatory guidelines applicable to my research and that I will conduct my research in accordance with these. • I confirm that I have provided accurate

and complete information regarding my research project

- I understand that a false declaration or providing misleading information will be considered potential research misconduct resulting in a formal investigation and subsequent disciplinary proceedings liable for reporting to external bodies
- I understand that if my answers to this form have indicated that I must submit an ethics and governance application, that I will NOT commence my research until a Favourable Ethical Opinion is issued and governance checks are cleared. If I do so, this will be considered research misconduct and result in a formal investigation and subsequent disciplinary proceedings liable for reporting to external bodies.
- I understand that if any of my responses to the governance questions have requested additional documents, that these will be provided with my ethics and governance application if my project is to proceed.
- I understand that if I have selected any options from Qu 22-27 I MUST submit an ethics and governance application (EGA) for review in order to proceed with this research project UNLESS I am an undergraduate or Masters student, in which case I have completed Qu 29 below.

29	**If I am conducting research as a student:**	I confirm that I have discussed my responses to the questions on this form with my supervisor to ensure they are correct.