# A Generic Augmented Reality Mobile Application

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Submitted in partial fulfilment of the degree Baccalaureus Scientiae (Honores) in Computer Science at the Nelson Mandela Metropolitan University

October 2015

# Acknowledgements

The completion of this project would not have been possible without the help, guidance and motivation from my supervisors, Prof. Jean Greyling and Dr. Melisa Koorsse. I would like to thank you for all the help you have given me throughout this year. You were both always willing to help and provided me with guidance and suggestions that allowed me to complete my project to a standard that I am proud of.

Secondly, I'd like to thank my family for their full support, and especially my girlfriend for providing me with the much needed motivation at all times. Your understanding of the amount of work I had to complete and always being by my side is greatly appreciated.

Last, but definitely not least, I'd like to thank the all my fellow Honours students for their support and ensuring that year was enjoyable. The memories made throughout this year will not be forgotten.

# Abstract

The objective of this project was to develop a generic Augmented Reality (AR) mobile application. The application provides the user with information associated with surrounding points of interest (POI) by means of augmenting the camera view of their mobile device. Each POI can have details in the form of text, audio, video as well as link to a website. Directions can be provided to the POI by means of Google Maps. The application is data driven, thus the design of the database in order to cater for all scenarios was crucial. The Design Science research methodology was followed in order to produce the prototype.

The domain of AR and extant systems were investigated in order to define the scope of the project. It was decided that the AR application would make use of location data over image recognition to identify surrounding POI's. The design of the database and application had to cater for different user types in order to allow the user's to view details of a POI relevant to them. This design was the driving force of making the application generic.

The project made use of Nelson Mandela Metropolitan University and Route 67, a collection of local artworks, as test cases for the generic nature of the application. The evaluation of the application aimed at evaluating both the generic capability and the usability of the application. The generic aspect was proven to be successful as the augmented data, displayed to the user, would be dependant on the location of the user as well as their configuration of the application. The participants indicated that, overall, they were satisfied with the application's user interface, functionality and indicated it was an easy to use application.

# Declaration of Own Work

I, Dean Gifford (212253204), declare that the entirety of the work contained in this treatise, A Generic Augmented Reality Mobile Application, is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Nelson Mandela Metropolitan University will not infringe any third party rights that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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# Chapter 1

# Introduction

## 1.1 Introduction

The purpose of this project is to develop a generic augmented reality mobile application to help users navigate various geographical areas. It will make use of augmented reality to display information of different objects or locations in an area. The development will be done in such a manner that the application can be seen as generic, which will allow the use of the application in numerous scenarios. The implementation of the application will be done for two scenarios to prove the generic ability.

## 1.2 Problem Background

To augment something means to add to, make greater or enhance. Augmented Reality (AR) is thus the real world that has been enhanced in some aspect, adding virtual data to the real world view of the user. Interest around the field of AR advanced significantly around the year 2009 (Prochazka, Stencl, Popelka, & Stastny, 2011, p.470). This was due to mobile devices being equipped with a Global Positioning System (GPS), compass, camera and an appropriate display. AR is a subset of what is known as mixed reality. Mixed reality is the combination of the real world with virtual data. Mixed reality encompasses both augmented reality and augmented virtuality as seen in Figure 1.1. The latter is similar to AR but where the scene displayed is virtual and the added information, such as objects, are from the real world (Sobota, Kore, & Hrozek, 2013, p.355).

AR is being made use of in many different areas. One aspect of AR is knowing where the user is, by making use of GPS coordinates for example. This suggests using AR to create navigation or location aware applications. Mobile devices not only have adequate tracking functionality, but also the processing power, which makes creating a mobile AR application possible. Having a mobile application is extremely convenient to the users as it can be used on-the-go.

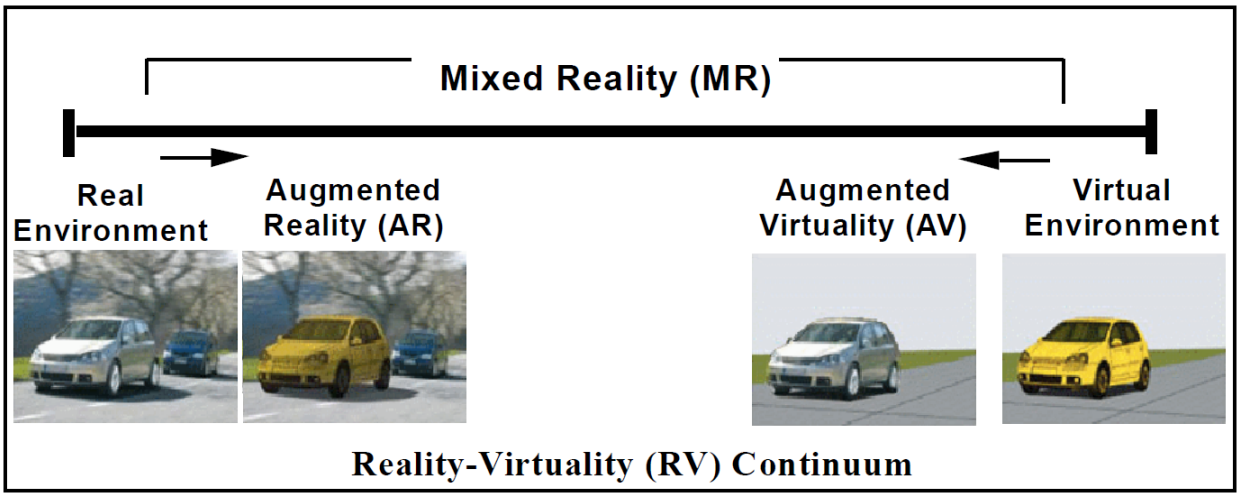



Figure 1.1: Adapted Milgram's Reality-Virtuality Continuum
(Milgram, Takemura, Utsumi, & Kishino, 1994, p.283).

The problem of needing to know where one is, where to go, and what one is looking at is quite common. A search on Google Play Store (Google, 2015b) for the word "navigation", reveals 250 results. Although many applications exist to help solve this problem, a generic data driven solution would be best as it would allow a single application to be used in multiple scenarios. This suggests making use of a general framework of which only the data needs to be manipulated to fit the context of a specific problem.

## 1.3 Problem Description

Information regarding surrounding buildings, objects such as artworks or popular locations are not always readily available for everyone to access. Sometimes the information is available, but not convenient, such as large information pamphlets or books. Developing individual applications suited to the different environments could be come expensive. These applications would function similarly and the only difference would be the data being accessed. There is thus a need for a simple and convenient method to display additional information to those who desire to know more than what meets the eye.

## 1.4 Project Objectives

The goal of this project is to develop a mobile AR prototype to run on Android devices. The prototype will be developed in a generic manner to allow the context of the application to change according to the problem scenario. The application will be data dependant in the sense that the content of database will determine which surrounding points of interest, with their respective additional information, are displayed to the user . The prototype will be tested using Route 67 in Port Elizabeth, in collaboration with Mandela Bay Development Agency (MDBA),

as well as NMMU South Campus to prove the generic nature of the application. Route 67 is a collection of public art works in Port Elizabeth. The route contains 67 artworks designed by artists in the Eastern Cape. For Route 67, an application can be used to allow for the displaying of details about the various artworks. The South campus of NMMU will be covered by displaying information of the buildings on campus, giving students additional information about the buildings.

## 1.5 Project Scope and Risks

The development of an administrative application to alter the information in the database will not be included. The administrative system would comprise of a primitive interface and queries to the database. Thus the main focus of the project is on the mobile AR application. The prototype will be developed only for the Android operating system, for mobile phones only, as they are more likely to be used than tablet devices

The fact that the project will involve collaboration with MDBA is a risk, since access to all relevant data will be needed for the test case. Another risk is due to the application being dependent on the GPS and compass only, which could cause inaccuracy in the application as the specific devices' services might not be as accurate as others available.

## 1.6 Research Contribution

This research will contribute to the method of displaying information in an AR environment as well as the idea of making generic AR applications, in which the information presented can be adapted according to the context of use and geographical location.

## 1.7 Research Methodology

This project will make use of the Design Science Research (DSR) methodology, a methodology that aims at creating and evaluating Information Technology (IT) artefacts (Hevner, March, & Park, 2004, p.77). Since the objective of this project is to produce an Android prototype application, the DSR methodology suites the needs of the project well. DSR is a combination of three main as seen in Figure 1.2.

The relevance cycle provides requirements as well as a measurable evaluation for the project. The outcome of the evaluation will further determine if another iteration of the relevance cycle is needed (Hevner, 2007, p.89). The Design Cycle is a process that rapidly iterates between the production of a prototype and the evaluation thereof (Hevner, 2007, p.91). Each iteration will result in a more refined prototype, closer to the solution of the problem. The Rigor Cycle allows

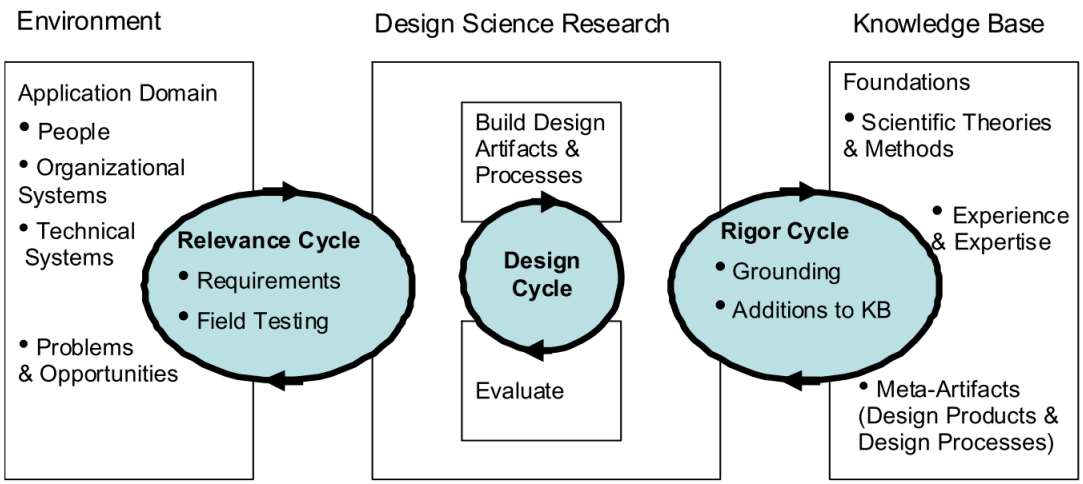



Figure 1.2: Design Science Research Cycles
(Hevner, 2007, p.88)

for past knowledge to be researched and referenced. A big part of this cycle is adding back to the knowledge base from the result of the process followed throughout the project. Additions could include extensions to theories or methods as well as any experience gained from following the process (Hevner, 2007, p.90).

Johannesson and Perjons (2012) further introduced a generic DSR methodology, inspired by Peffers, Tuunanen, Rothenberger, and Chatterjee (2007), consisting of five activities (Johannesson, Perjons, & Bider, 2013, p.5). These activities are:

1. Explicate Problem.
2. Outline Artefact and Define Requirements.
3. Design and Develop Artefact.
4. Demonstrate Artefact.
5. Evaluate Artefact

A mapping of these five steps to the chapters to follow can be seen in Figure 1.3. Despite the mapping resembling a linear progression, the activities of the DSR methodology contain iterations, specifically activity three, design and develop the artefact.

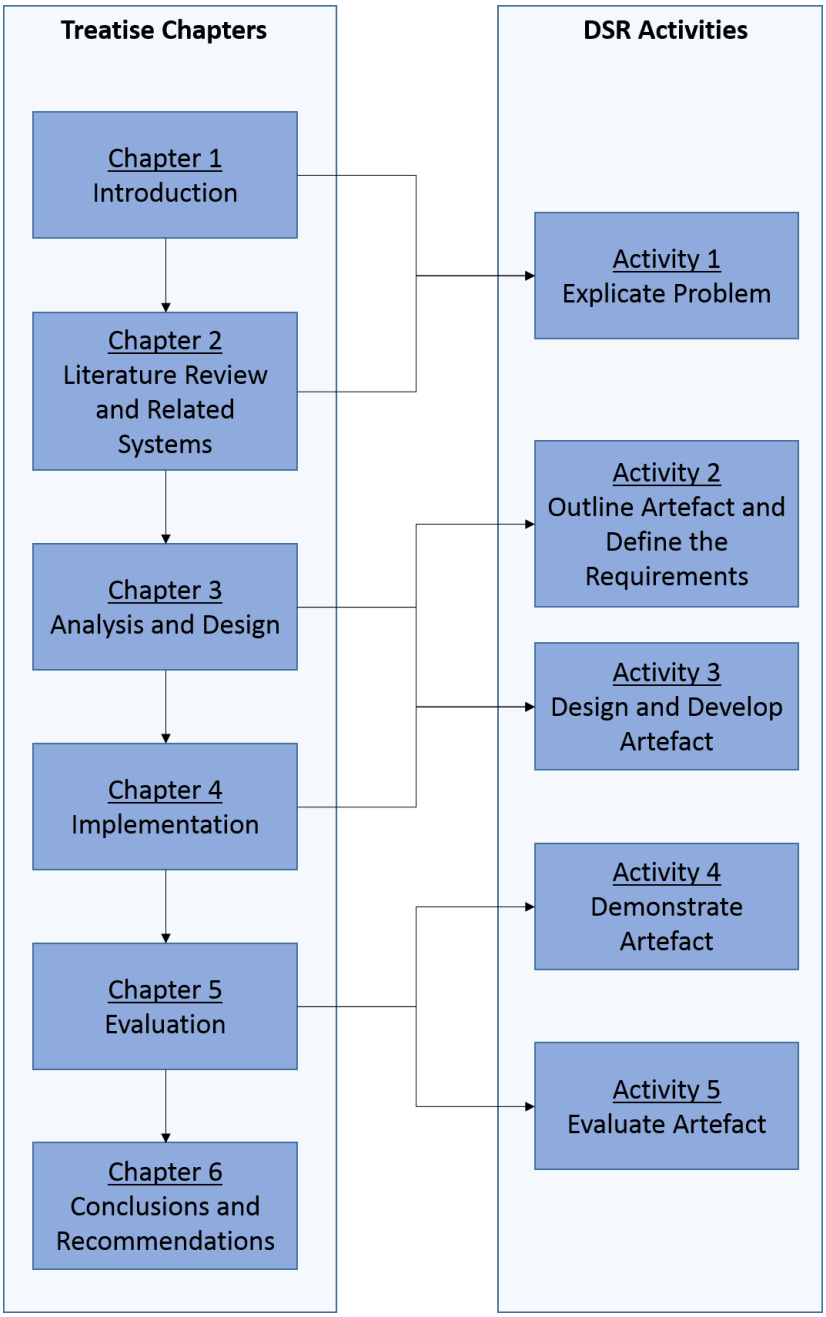



Figure 1.3: Treatise Structure mapped to DSR Activities

## 1.8 Overview of Treatise

This treatise consists of six chapters which aim to achieve the project objectives (Section 1.4). Chapter 1 initiates the first activity of the DSR methodology within the relevance cycle.

The chapters to follow Chapter 1 consist of:

- **Chapter 2 - Literature Review and Related Systems:** The literature surrounding the domain of AR will be discussed as well as a review of extant systems related to the domain. This chapter completes the first activity of the DSR methodology.
- **Chapter 3 - Analysis and Design:** The requirements of the application to be developed will be outlined in this chapter with the aim of completing the second activity of the DSR methodology. This chapter also begins the third DSR activity by providing a proposed design of the application in order to meet the requirements outlined.
- **Chapter 4 - Implementation:** This chapter will provide details as to how the application was implemented, following the designs of the previous chapter to meet the requirements outlined. Any challenges encountered during the implementation are also discussed in this chapter.
- **Chapter 5 - Evaluation:** The plan for evaluating the application developed in the previous chapter will be outlined. The results from the evaluation are then presented and discussed. Any changes that were needed to the application due to the results from the evaluation are also discussed. This chapter covers both activity four and 5 of the DSR methodology.
- **Chapter 6 - Conclusions and Recommendations:** The last chapter will conclude the project by indicating the objectives achieved as well as recommending future work to be done in the domain of the project.

# Chapter 2

# Literature Review and Related Systems

## 2.1 Introduction

This chapter aims to explore the research problem by further investigating Augmented Reality (AR). This will be done by means of a literature review as well as investigating extant systems. These aspects fall within the relevance cycle of the Design Science Research (DSR) methodology mentioned in Section 1.7 , completing the first activity in the DSR methodology. The aim of this chapter is to identify relevant methods and techniques that could be considered for inclusion in the prototype development and to ensure that the prototype adheres to certain trends evident in other AR applications.

## 2.2 Literature Review

In order to properly understand AR and how applications make use of AR, the two see-through systems are explained. The various methods used for AR applications and the different types of AR applications are then reported on.

### 2.2.1 See-Through Systems

AR is based on the viewing of virtual data which is used to augment a real world view. The way a user views the AR can be divided into two types of systems: optical see-through systems and video see-through systems (Sobota et al., 2013, p.355). Optical see through systems are where the user is able to see the real world directly and the augmentation is displayed on a semi-transparent layer. Such systems include Google Glass as well as AR windscreens in cars. Video see through systems rely on a captured view of the real world, such as through a camera.

The augmented data is then overlaid on this view and displayed to the user. Both systems can make use of one or more of the AR methods (Section 2.2.2) and fall within multiple AR application categories (Section 2.2.3).

### 2.2.2 Augmented Reality Methods

AR relies on the use of meaningful data to augment the real world view. The methods which are used in AR can be classified as location based (the geographic location of the user) or image processing (what the user is looking at). These methods determine which additional data should be displayed to the user.

#### Location Based

Location based AR applications are quite common due to the fact that it is simple to implement compared to image processing (Prochazka et al., 2011, p.470-471). The location based method has no information as to which objects are in direct sight of the user, instead it makes use of a device's sensors, mainly the compass and GPS (Prochazka et al., 2011, p.470). The GPS data indicates where the user is and the compass describes in which direction the user is facing. Using these facts, it can be deduced if the user is near, as well as facing, a predetermined Point of Interest (POI). This technique is considered simple as there are no complex, resource heavy calculations that need to be done. It is also a very common method as most devices are equipped with a GPS and compass, making it easily accessible to all users. The main types of applications that make use of this method are navigational applications.

#### Image Processing

AR applications based on image processing rely on the application being able to analyse the image and identify the objects seen by the user using the devices camera (Prochazka et al., 2011, p.471). Once the application knows which objects are in the user's view, it can decide which data is needed to augment the view. The process of analysing the image can be resource intensive. Thus the implementation of this technique is restricted by the device's limited computation ability and battery life.

Image processing techniques can furthermore be divided into two subcategories (Sobota et al., 2013, p.355), namely, the identification of artificial objects (marker systems) and the identification of natural objects (markerless systems).

Marker systems rely on special predefined tags/markers that the application will recognise in image processing. These tags will then be replaced in the augmented view with the virtual data. Making use of markers reduces the image processing overhead and is thus easier to implement.

Markerless systems rely on image recognition to decide what the user is looking at. This is particularly difficult to implement using mobile devices due to their limitations.

#### Hybrid

A hybrid method can be implemented that makes use of the location of the users to determine where they are and in which general direction they are looking, in conjunction with image recognition to determine the precise objects in the users view (Prochazka et al., 2011, p.471). This method is less intensive as the image recognition will be simplified. There would only be a certain amount of objects in the users current location and direction that the device will need to recognize. This reduces the amount of comparisons to be made.

### 2.2.3 Augmented Reality Application Categories

AR applications can be used in various situations to allow for the easier completion of tasks. The applications can be divided into three main tool categories, namely, 3D viewers, browsers and games (Augment, 2015). AR 3D viewers allows a user to visualise and interact with virtual 3D objects in their real world environment. AR browsers provide the user with a means to explore their environment, providing additional information of certain surrounding objects or locations. AR games enable users to play immersive games, mostly making use of the environment around them. Depictions of the difference between these tools are made more clear in Figure 2.1. These tools can be used to make applications that fall within three types of categories, namely, navigation, commerce and captioning applications (Singh & Singh, 2013, p.66-67).

Figure 2.1: Three AR Tool Categories
(Augment, 2015).

#### Navigation

Navigational applications could involve directing the user to a certain point or displaying the route to follow. AR could be used to augment a real world view of where the user is or to display a general direction. The navigation category would make use of the browser tool as the viewers and games would not support the features of a navigational application.

#### Commerce

Commerce AR applications are mainly for use by consumers. A common technique is to use the user's location to trigger certain advertisements to be displayed on their device (Singh & Singh, 2013, p.66). This form of AR has many possibilities for advertising. These include watching videos, playing games, 3D experiences, access to exclusive offers as well as the ability to purchase items online (Blippar, 2015b). Augmenting real world objects allow users to make a more informed decision when purchasing products. Commerce applications can make use of any of the three AR tools, depending on the product or service being advertised.

#### Captioning

Captioning applications provide the user with metadata of their current real world view or certain POI's around them (Singh & Singh, 2013, p.67). This could be as simple as showing nearby restaurants, petrol stations or other POI's. Captioning applications make would predominantly make use of the browser tools but could also make use of the viewers and games in some instances.

## 2.3 Extant Systems Review

Exploring extant systems currently available can provide good insight as to where to start and how to go about implementing certain components of the prototype. The investigation of extant systems will specifically look at:

- The type of AR application.
- The method of AR used.
- How the virtual data is displayed to the user.

### 2.3.1 AR GPS Compass Map 3D

*AR GPS Compass Map 3D* (Kettler, 2013) is a mobile application used to display direction to the user. The application overlays a 3D compass in the user's view, displaying which direction

the user is facing. An adjustable map with the user's location and direction on it is also displayed as seen in Figure 2.2. The user's orientation of the device is shown by means of a scale on the top and side of the display. The application allows users to add way-points, which are geographical locations that the user is interested in. A green arrow on top of the display indicates in which direction the specified way-point is.

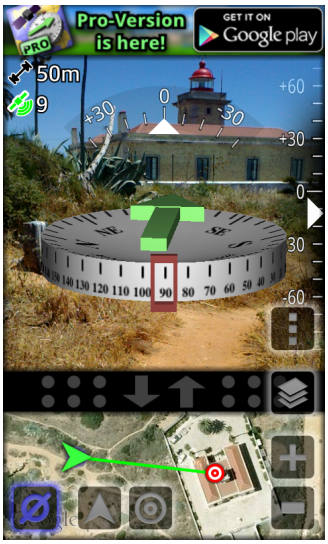



Figure 2.2: Screen shot from AR GPS Compass Map 3D
(Kettler, 2013).

*AR GPS Compass Map 3D* is a navigational application that does not provide an AR path following feature, but does show straight direction as to where the way-point is. By following the arrow, the user will reach the way-point. The AR compass is highly responsive and tilts with the device to allow users to always have the best view possible.

This application only makes use of location data and does not make use of image recognition. There is no need for any image recognition as the application is not necessarily context-aware. A highly precise reading of the users' location and orientation is obtained by using the device's compass and a fusion and filtering algorithm which utilizes the accelerometer, magnetic field sensor and gyroscope (Kettler, 2015).

### 2.3.2 Blippar

*Blippar* (2015a) is a commerce image recognition AR application. The application allows users to scan objects to reveal exclusive content and is thus used in advertising (Figure 2.3.). This content can include games, videos, animations as well as virtual interactive objects as seen in Figure 2.4. Unlike the afore mentioned applications, *Blippar's* focus is entirely on image recognition and does not have the feature to allow users to view nearby POI's.

*Blippar* makes use of image recognition to decide what augmented view the user should see. This application could be said to use a markerless system. Unlike *Layar*, discussed in Section 2.3.4, *Blippar* does not need a set marker or logo to recognise if there is AR content to be viewed.

Figure 2.3: Screen shot of Blippar revealing content on a pizza box.
(Blippar, 2015a).

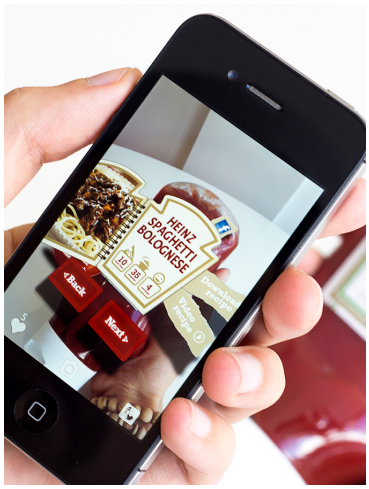



Figure 2.4: Blippar mobile application augmenting real world object with a virtual interactive object

(Blippar, 2015a).

*Blippar* instead scans the user's view and analyses the image, most probably comparing it to a database to check if that image exists. If the image is in the database with AR content linked to it, this is used to augment the user's view. The method of not making use of a set marker can make the image recognition process a bit more complex, however, it allows the use of the original product, without the need to roll out new branding with a logo recognisable by the image processing.

### 2.3.3 Junaio

*Junaio* is a leading mobile AR browser. The application allows users to select a preferred channel of interest for which they would like to see POI's. A channel is a group of specific POI's that are related in some aspect. The users can then make use of their devices to view these POI's near their location. The application also allows users to scan tags that may have AR aspects linked to it such as 3D models, a link to a website or even an AR game as can be seen in Figure 2.5.

Figure 2.5: Screen shot of Junaio's application with an Augmented Reality game (Metaio GmbH, 2014).

*Junaio* is mainly a captioning application as it displays additional data to users based on their current world view, as seen in Figure 2.6. Making use of *Junaio's* scanning capability further distinguishes the application as a commerce application if the scanned tag results in an advertisement of some sort such as in Figure 2.7. It also has the ability to advertise certain locations such as restaurants or shopping centers. As mentioned before, the users would select their channel of interest and thus ultimately decide whether the application has a commerce aspect to it or not.

The application makes use of location data to determine where the user is as well as in which direction the user is facing. This will allow the application to select the appropriate data from the relevant channel of interest to augment the user's real world view. *Junaio* also makes use of image processing, by means of a marker system. The application will recognise certain

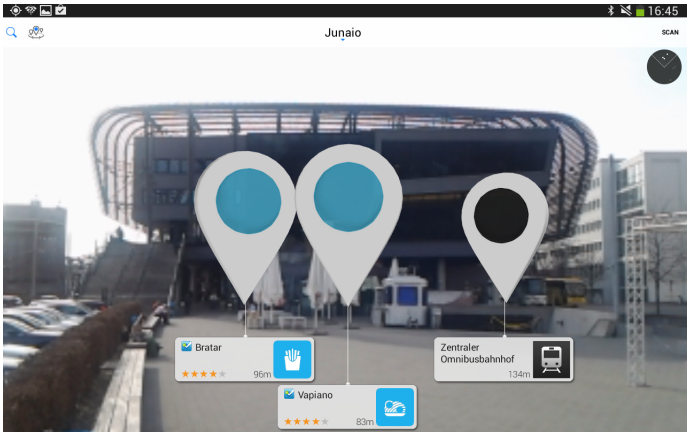



Figure 2.6: Junaio Augmented Reality application displaying points of interest in the users' view

(Metaio GmbH, 2014).

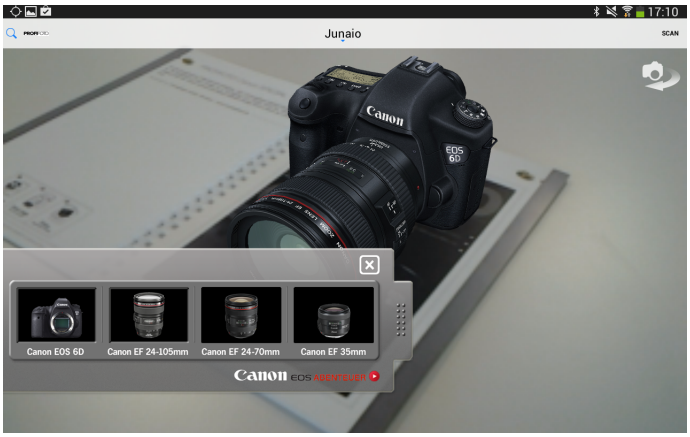



Figure 2.7: Screen shot of Junaio's application with a 3D model as well as extra accessories advertised.

(Metaio GmbH, 2014).

predetermined tags which will allow the correct functionality regarding augmentation to appear. *Junaio* could be seen as a hybrid in the sense that it uses both location and image processing, however, it does not seem to use them simultaneously, as each is used to perform separate tasks.

### 2.3.4 Layar

*Layar* is a mobile AR application, which allows users to scan printed material to reveal digital content. The digital content displayed can range from links to websites, online stores, multimedia, such as sound or video. as well as interactive 3D models (Figure 2.8). This application is similar to that of *Junaio* (Section 2.3.3) in the sense that it also supports the feature of viewing POI's near the user. The users can select certain layers to be displayed as well as their search radius. A *layer* is *Layar's* terminology for a channel, described in Section 2.3.3. This feature does, however, seem to be an extra in the application, which appears to be more focused on providing an alternative advertising technique.

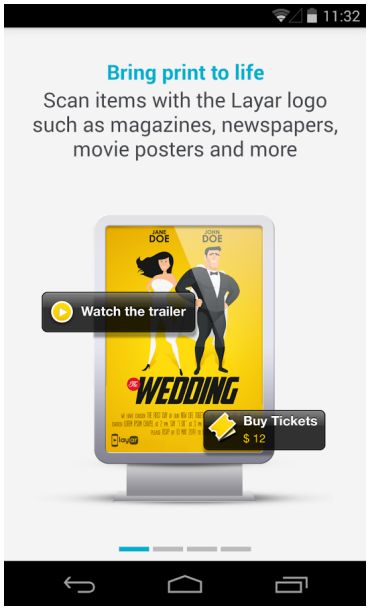
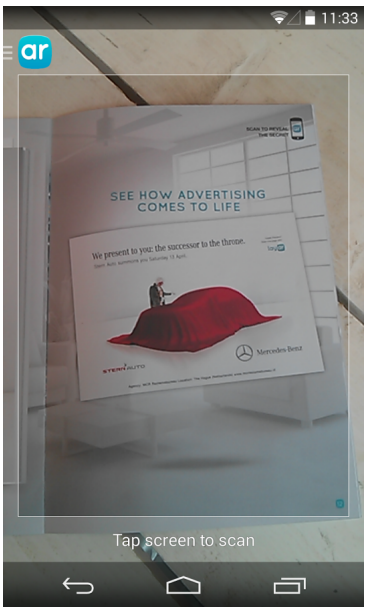


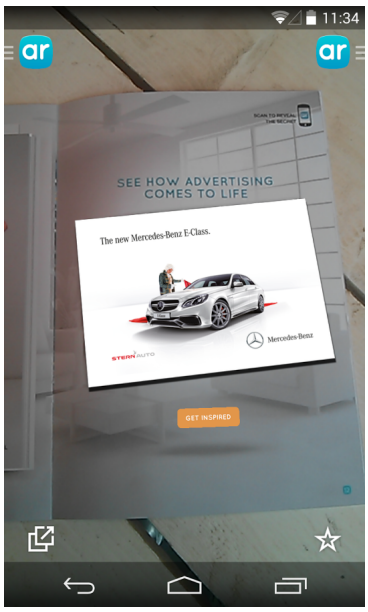

Figure 2.8: Layar application bringing a movie poster to life.
(Layar, 2015).

*Layar* is primarily a commerce application as its main focus is to display additional features linked to printed material. This is used extensively for advertising as seen in Figure 2.9. *Layar* also displays POI's near the user. Hence this application also falls within the captioning category of AR applications.

*Layar* allows the users to scan printed material to be augmented. The printed material scanned must, however, have been previously enhanced by *Layar*. The application makes use of image processing, in particular the use of markers. The marker used by Layer is quite ingenious as it makes use of the company's logo to detect AR content. This serves as a sure technique to recognise images as well as a form of advertising for the company. *Layar* also supports the scanning of Quick Response (QR) codes, as seen in Figure 2.10. By making use of location




(a) Original magazine page seen through the device's camera




(b) Augmented view of magazine page once scanned.

Figure 2.9: Screen shot of Layar application used for advertising.
(Layar, 2015, Mobile application software).

data, *Layar* allows the users to add geolocation layers of nearby POI's. Making use of the user's position, orientation and which layers the user has selected to display, *Layar* is able to determine which nearby POI's to augment the users current view with.

Figure 2.10: Layar capability to scan a QR code.
(Layar, 2015, Mobile application software).

*Wikitude* (Wikitude GmbH, 2015) is another mobile AR application very similar to that of *Junaio* (2.3.3) and *Layar* (2.3.4). The application supports the same functionality as the applications mentioned.

## 2.4 Extant Systems Summary

The extant systems reviewed in Section 2.3 are summarised in Table 2.1. The AR tools, methods and categories are indicated for each system, providing a link between the literature reviewed (Section 2.2) and the extant systems review (Section 2.3).

| **Extant System** | **Tools** | **Methods** | **Categories** |
|---|---|---|---|
| *AR GPS Compass Map 3D* | Viewer | Location Based | Navigation |
| *Blippar* | Viewer | Image Processing (Markerless) | Commerce |
| *Junaio* | Viewer<br>**Browser**<br>Game | **Location Based**<br>Image Processing (Markers) | **Captioning**<br>Commerce |
| *Layar* | Viewer<br>**Browser** | **Location Based**<br>Image Processing (Markers) | **Captioning**<br>Commerce |

Table 2.1: Summary of Extant Systems

The tools, methods and categories that are made bold in the table provide insight as to which tools and methods would be most beneficial in order to develop an application that is part of the captioning category. Both *Junaio* and *Layar* have similar features to what will be needed in the prototype to be developed, however, neither of them can be considered generic.

## 2.5 Conclusion

This chapter aimed at exploring the problem further by gathering information about AR. This was done by reviewing literature as well as investigating extant systems. The reviewed literature in Section 2.2 provided good insight into the domain of AR. It was discovered that AR applications can be divided into either viewers, browsers or games and can have three main uses, Navigation, Commerce and Captioning. The three methods of implementing AR applications were also discussed, namely Location Based, Image Processing (making use of markers or not) and a hybrid of the two.

Four related systems were then investigated to determine what the application was used for as well as which method(s) were used to make the application functional. The extant systems investigated in Section 2.3 were summarised in Section 2.4. AR Browsers were quite common (and is closely linked to the prototype to be developed). It was also evident that the most common method used was a hybrid of Location and Image Processing using markers. These

were not used simultaneously but rather as separate features in the applications. These findings add further limitations to the scope of the project (Section 1.5), with the limitation the the prototype will make use of the device's GPS and compass data only, rather than image recognition. This will allow for the viewing of POI's not in direct line of sight of the user. The designs of each application will be taken into account when designing the prototype in the following chapter.

# Chapter 3

# Analysis and Design

## 3.1 Introduction

This chapter aims at fulfilling the second activity in the Design Science Research (DSR) methodology which involves outlining the artefact and defining the requirements. In addition, this chapter initiates the third activity in the DSR methodology by providing a design of the artefact to be developed.

## 3.2 Requirements Elicitation

One of the main purposes of requirements elicitation is to identify and better understand the needs of the users as well as to clarify the goals and limitations of the system (Kannan, Mahalakshmi, & Sujatha, 2014). In order to analyse the requirements, two main methods were used to elicit the requirements. The first technique used was an Extant Systems Review (Section 2.3) which is elaborated on in this section. The second method made use of an interview as well as focus group to better understand what potential users required the system to do.

By performing an Extant Systems Review in Section 2.3, requirements could be gathered to ensure that the design of the artefact being developed is consistent with the current trend in mobile Augmented Reality (AR) applications. The AR application type that seems to meet the project objective discussed in Section 1.4 is the AR Browser. This will provide an application type that will meet the need of being generic. A common feature among the AR browsers that were reviewed is that users can filter what they are able to view. This provides a requirement that should be met by the artefact being developed as it not only conforms to the AR Browser application common practices, but also provides a useful technique to introduce the generic ability required.

In addition to the Extant Systems Review, an interview with a representative from the Mandela Bay Development Agency (MBDA), as well as a Focus Group with first year Computer Science

students at Nelson Mandela Metropolitan University (NMMU) were held to aid in defining user requirements for the two test cases described in Section 1.4.

During the meeting with the Marketing and Communications Manager of MBDA, it was made clear that the system should be able to provide information to the users using various multimedia methods. The media content currently available by MBDA for the artwork in Route 67 include text-based descriptions, images as well as audio clips. The artefact should thus be designed to support various media content. Another key requirement that was identified was the implementation of a notification system that alerts the users when they are in the proximity of certain art works as well as in the proximity of Route 67. It was also mentioned that since this is a tourism domain, being able to integrate social media sharing would add extra value to the application. The notification system and social media sharing aspect were good suggestions, however, their implementation would not contribute the research objective and were left out of the scope of the project.

The focus group held with first year students aided in eliciting additional requirements to what was obtained through the interview with MBDA. The focus group was aimed specifically at gathering requirements for the NMMU South Campus use case. The main purpose of the proposed application would be to aid first year students to navigate their way around campus. Most of the students stated that they did not get lost, while some admitted that it took them a few weeks to get used to the layout of the campus. Many of the students who had claimed they do not get lost admitted to using the map of the campus provided either by the NMMU website or in the annual diary provided by NMMU. According to these students, even though using the map was effective, it was cumbersome to use. Once the proposed application was explained to the students, they all agreed that such an application would make it much easier to orientate themselves on campus by being able to identify familiar buildings in their surrounds. The students then proposed that there be a form of filtering to allow them to see only what was applicable to them or their department. This was a good suggestion as it could further reduce the amount of data being displayed, as well as aid in the generic aspect of the project. This feature was also evident in extant systems reviewed (Section 2.3), which suggests that it would be an applicable feature to include in the prototype. Another feature that many students opted for was a navigation system, allowing shortest paths to buildings to be displayed. Although being a helpful feature to assist users, due to the scope of this project, it was not included in the requirements.

The interview and focus group provided valuable information regarding the user requirements of the application to ensure the application meets the needs of potential users. The requirements obtained were not only valuable to the specific test case but provided functionality to improve the application as a whole as well as providing methods to allow the application to be generic.

## 3.3 Functional Requirements

The process of requirements elicitation brought forth a few key requirements which the application to be developed should meet in order to meet the needs of potential users. These core requirements are summarised in Table 3.1.

| Reference | Requirement Description |
|---|---|
| FR-1 | The application should be able to be used in any context and scenario, with the ability to transition from one scenario to the next with ease. |
| FR-2 | The application should be able to display nearby Points of Interest (POI) to the user by augmenting their mobile device's display. |
| FR-3 | The user should be able to select what types of POI's are displayed to them by filtering the list of available POI's. |
| FR-4 | The user should be able to investigate a POI by viewing detailed information regarding that specific POI. The information should be presented using various types of multimedia, namely, text, video and audio. |

Table 3.1: List of Functional Requirements

The application will allow the user to have access to various Roles, only allowing for a single Role to be undertaken at once. Different Roles will have access to various Collections of POI's. A Collection of POI's will contain all POI's relevant to a certain area. For example, a Collection could be "NMMU South Campus", which would be a collection of POI's being the buildings on NMMU South Campus. Different Roles could have access to the same Collection, however, the information regarding a POI would differ based on the Role. Table 3.2 provides an explanation of the association between Roles, Collections and POI's. By allowing the user to change their Role, the application will easily be adapted to various scenario's, meeting requirement FR-1. The user will also be able to filter Collections associated to their Role and select which Collections they would like to enable at any given moment to comply with requirement FR-3. Requirement FR-4 will be explained in Section 3.4.2, discussing the requirements associated with the User Interface (UI) design.

## 3.4 Design

The project objective together with the user requirements provide a clear set of requirements from which a design can be proposed for the application. By taking both of the afore mentioned aspects into account when designing the application, it will ensure that the project goal is achieved and the user needs are satisfied. The design is split into two sub-sections, the first being the architecture of the application (Section 3.4.1), which explain how the system will work.

| Role | Collection | POI | Description |
|---|---|---|---|
| Student | NMMU South Campus | Building 123 | Lecture Halls |
| | | Main Building | Administration Offices |
| | | Madibaz | Campus Restaurant |
| | Route 67 | Fish Bird Sculpture | 41 - Mxolisi Dolla Sapeta |
| | | Great Flag | Biggest South African Flag |
| Technician | NMMU South Campus | Building 123 | Electrical mains situated to the right of the north exit. |
| | | Main Building | Service elevator access key: cy72ts |

Table 3.2: Explanation of Generic Implementation

The second subsection (Section 3.4.2) provides the initial design of the UI of the application, to suite the tasks outlined in Section 3.4.1.

### 3.4.1 Application Architecture

A conceptual architecture for the application is provided in order to outline an understanding of how the application works. This is followed by a task list, highlighting the intended steps for a user to perform in order to compete a task. Lastly, the design of the intended database is discussed.

#### Conceptual Architecture

The architecture of the proposed application will follow the conceptual architecture of an AR application seen in Figure 3.1 ((Singh & Singh, 2013)). The flow of events from the observed reality to the presented reality, containing augmented data, is depicted. The scene is captured by means of a reality sensor on the device and is then passed through to a trigger matcher as well as across to the reality augmenter. The trigger matcher analyses the original image and any associated metadata such as location tags in order to identify any metadata that matches the stored augmented data. The matched metadata is then put through an augmentation selecting process where the data to augment the image is retrieved from the database. The augmented data is then passed through to the reality augmenter where the original scene was initially sent across. The scene and augmented data are merged into a combined image and is presented as the AR.

The intended architecture of the application (Figure 3.2) is based on the conceptual architecture

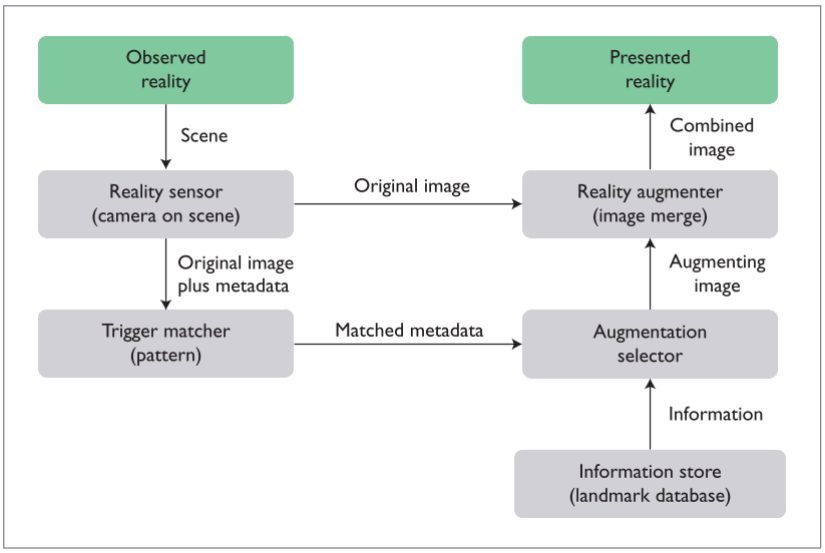



Figure 3.1: Conceptual architecture of an AR application (Singh & Singh, 2013, p.68)

in Figure 3.1. The intended architecture describes how the application is going to work, not specifically highlighting any of the user's tasks. How the user will interact with the system is described in a task analysis. In addition to the architecture layout above, a database design is provided to show how the data of the system will be represented.

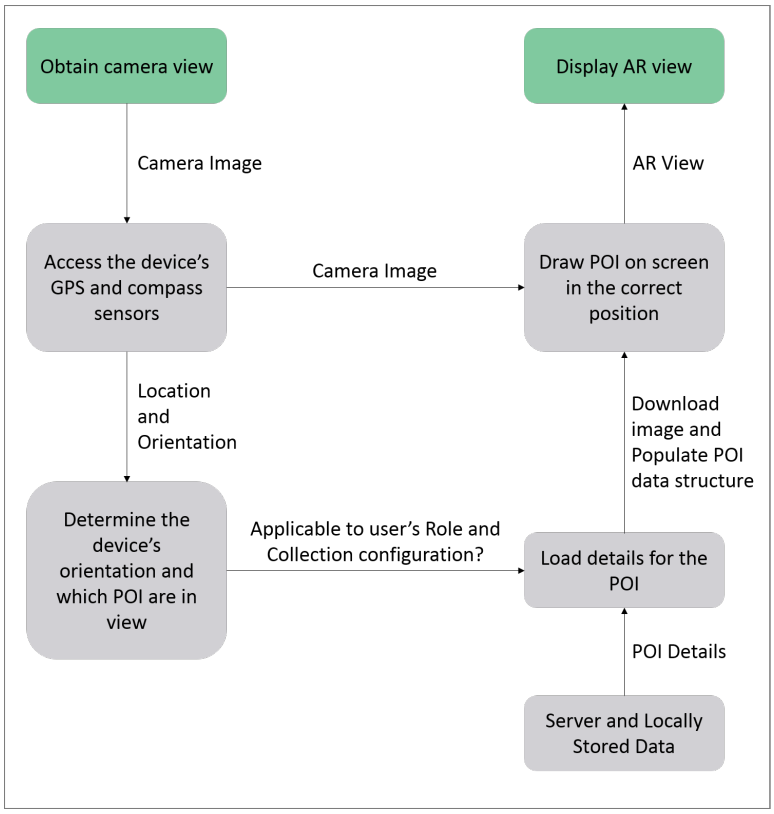



Figure 3.2: Architecture of proposed application based on Figure 3.1

### Task Analysis

This task analysis will aid in evaluating that the user's needs are met as well as meet all the requirements listed in Table 3.1 of Section 3.3. The task analysis will also be useful in designing the UI of the proposed application discussed in Section 3.4.2. The steps provided in the task analysis are based off the common interaction techniques of Android applications.

| Task | Task Scenario Sequence |
|---|---|
| Create Account | 1. Open application<br>2. Select "Create Account"<br>3. Fill in necessary details<br>4. Select "Save Details" |
| Login | 1. Open application<br>2. Enter login details<br>3. Select "Login" |
| View POI Details | 1. Tap on POI marker<br>2. Select relevant detail item to interact with:<br>(a) Click video/website link<br>(b) Tap play icon to hear audio clip |
| Toggle Roles | 1. Select "Roles" option in menu<br>2. Tap specific Role to be enabled |
| Toggle Collections | 1. Select "Collections" option in menu<br>2. Add/remove desired Collections to enable/disable them in AR view |

Table 3.3: Task Analysis of Proposed Application

### Database Design

The database for the proposed application will store all the data required for the application. Since this is a data driven application, the database is a crucial aspect of the design. The design has to cater for all probable situations to allow for the most generic application possible. The database design for the proposed application can be seen in Figure 3.3. An `Account` serves as the instance of a user. An `Account` can have one or more Roles associated with it, keeping in mind that only one of these Roles can be active on the Account. An `Account` also has one or

more Collections associated with it, these Collections being dependant on which Role is active. A Collection contains multiple POI's and a POI could belong to more than one Collection, hence a many-to-many relationship is present between the two tables. The details of a POI are dependant on the Role that is currently active and since a POI can belong to multiple Roles with each Role containing many POI's, there is another many-to-many relationship. The table `POI_Details` serves as the association table between the tables `Role` and `POI`. This table will determine which details to show for a POI based on the active Role.

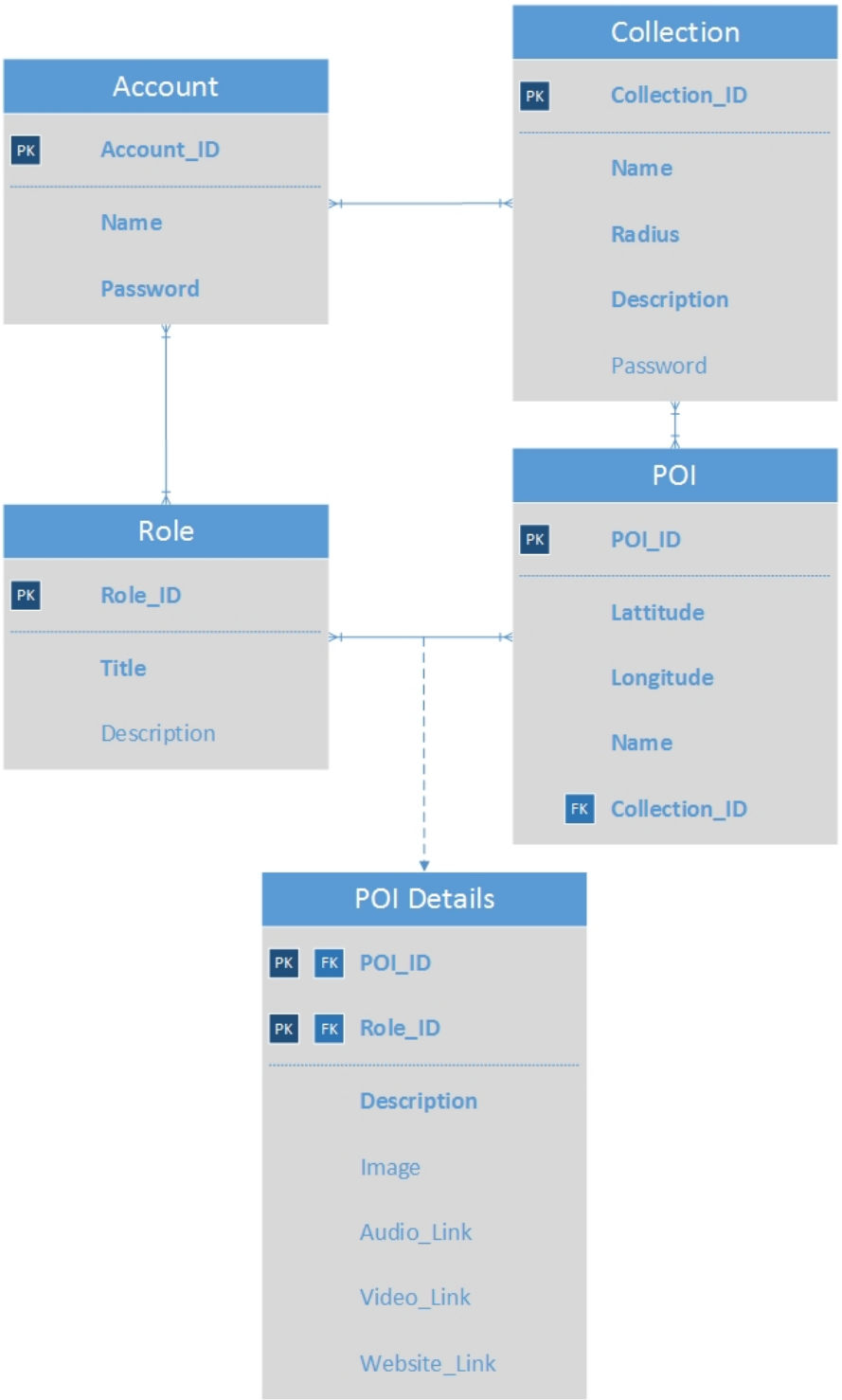



Figure 3.3: Database Design of proposed application

### 3.4.2 User Interface Design

The user interface of an application is important to ensure that the application is efficient as well as provides a good User Experience (UX). Many mobile applications are tried once, then deleted. One of the reasons is due to the application having an unappealing UI. It is therefore important to follow the correct design principles for mobile applications as well as including common aspects from other AR applications. The design principles used were Android specific. Google's Android Developer design principles are discussed below, followed by the proposed UI of the prototype.

#### Design Principles

Google announced their new UI design principles, Material Design, at their 2014 Google I/O Conference (Google, 2014). The Material Design principles are based on a metaphor that was inspired by paper and ink. These design principles aim to make applications more intuitive by providing items with shadows, edges and animations in order to provide users with visual cues as to how to interact with the item. The reason for making use of these guidelines and principles was to make sure that the prototype followed the design of all modern Android applications. The comprehensive set of guidelines pertaining to the Material Design principles (Google, 2015d) will be used to make sure that the prototype's UI meets the users' standards.

#### Proposed UI Designs

The following images are the proposed UI designs for the prototype. The designs were created with the design principles in mind as well as referencing other AR applications, such as Junaio (Section 2.3.3). The designs and reasoning for the choices made will be discussed for each design as well as the proposed navigation of the prototype.

The main view of the prototype is the augmented view. This is where the user will see the real-world view combined with the augmented POI data. The only design decision made on this screen was to decide how the augmented data would be presented. This design (Figure 3.4) was based on Junaio's augmented view (Figure 2.6). The use of markers provide a more precise direction in which the POI is situated. The details given directly to the users include the name of the POI, the distance between the users and the POI as well as an image. The two latter details help the users correctly identify the POI in the real-world. This screen meets the need of requirement FR-2 (Section 3.3).

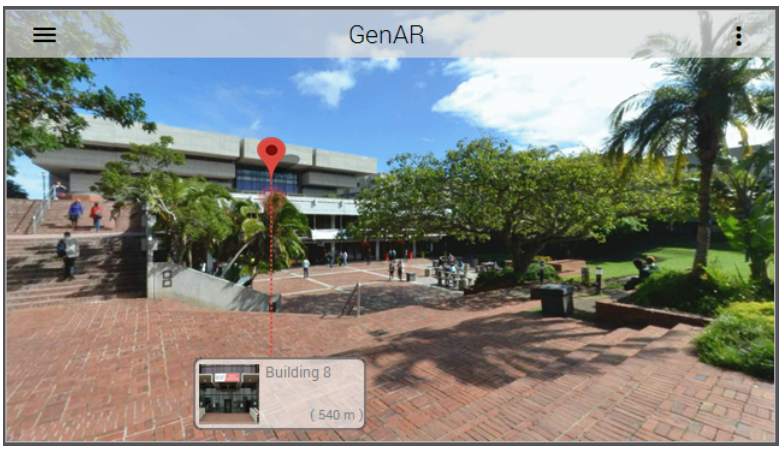



Figure 3.4: Augmented View

Since only partial details are provided to the users in the augmented view, an additional details screen is designed to allow for a more detailed description of a particular POI (Figure 3.5). The users can navigate to this screen by tapping on the POI marker in the augmented view. The design of this screen is based solely on the Material Design principles set out by Google (Google, 2015a). Each details of a POI is placed on a card by itself with which the users can select to listen to the audio, watch the video or visit the webpage. Since the description length will vary between POI's, this screen will be scrollable, allowing for any length of description. If a certain detail is not available for a specific POI, the corresponding card will not be shown. This will reduce confusion for the user, improve the look of the application as well as increase the UX achieved by the application. By providing a detailed view, requirement FR-4 is fulfilled (Section 3.3).

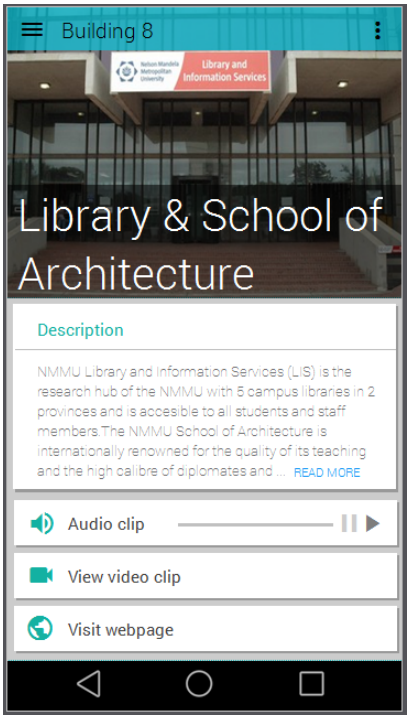



Figure 3.5: Detail View

Figure 3.6 is the design of the proposed screen to meet requirements FR-1 and FR-3 (Section 3.3). This screens allow the users to decide which Collections they have enabled. If a Collection is disabled, any POI's belonging to that Collection will not appear in the augmented view. To view the list of Collections, users will select the 'Collections' item in the menu on the action bar of the augmented view. The users will then be able to see a list of all the available Collections (Figure 3.6). The Collections are presented in a list view with circular images to the left of them as this follows the design principles specified by Google (Google, 2015c). Users can view a description of the Collection (Figure 3.7) by selecting the relevant Collection in the list. In order for users to add Collections to their augmented view, they can tap the 'plus' symbol next to the Collection name (Figure 3.6). Collections which a user has added to the augmented view are accessible on the tab bar at the top of the screen. This view will look the same as Figure 3.6 except with 'minus' symbols to allow users to remove Collections. The 'lock' symbol seen in Figure 3.6, next to the Collection "The Amazing Race PE", indicates that the Collection is locked and requires a password to enable it. For example, only participants of The Amazing Race PE will have the password to gain access to that Collection, allowing them to view the POI's associated with that Collection.

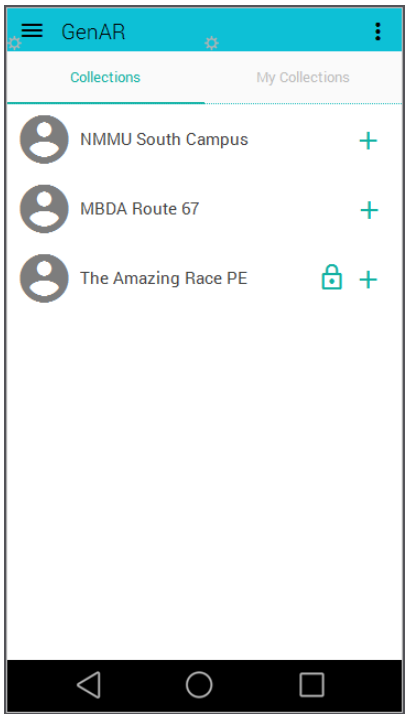



Figure 3.6: List of Collections.

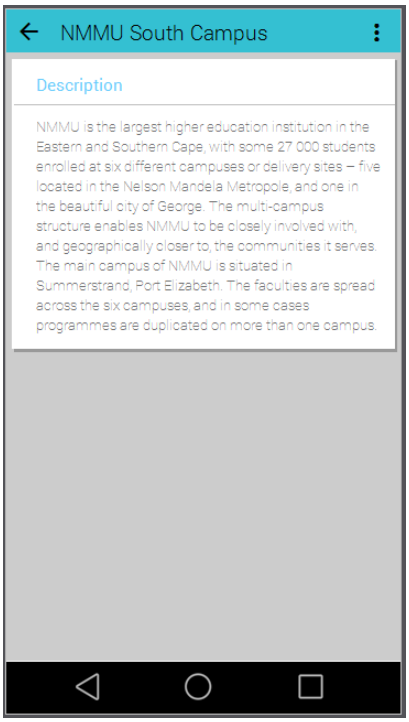



Figure 3.7: Description of Collection.

The initial designs for the screens allowing users to alter their Role are very similar to that of Figures 3.6 and 3.7. Instead of having a list of Collections that users can add, there will be a list of Roles that users can take on. The Role list will not have tabs, images or symbols to the left as the Collections do. The Role list will instead be presented as a toggle list where only one Role can be selected at a time. Changing the Role will then determine which Collections are available for the users. A user will also be able to view a description of a Role as in the case of Collections.

## 3.5 Non-Functional Requirements

Non-functional requirements are features of the application other than what the application needs to perform or support. There are four main non-functional requirements that the proposed system should adhere to: technical, performance, security and UI.

In order for the proposed application to work, it needs to be run on an Android smartphone with an active internet connection, a camera, a speaker and GPS capabilities. In order for the application to run smoothly, the internet connection should be of a relatively high speed and the GPS should be accurate. The application should be designed in such a way that it is power efficient as the devices are mobile. Response time for the proposed application is highly important as users will need accurate real time information of what they see through their devices' camera. The application should be easy and intuitive to use as a whole. The manner in which the information is displayed should follow common guidelines, paying close attention to guidelines of mobile devices. There will be a low level of security based on the locking of Collections, which only authenticated users will have access to. This security measure will be implemented by means of setting passwords in order to lock a Collection.

## 3.6 Conclusion

This chapter brought together the requirements for the proposed application. The elicitation of the functional requirements was done by means of an interview and focus group. These methods gave good insight as to the needs of the users for the two case studies being used. The functional requirements gave a good grounding to the design of the application. The design was presented in terms of the architecture of the application by making use of a conceptual AR architecture, a task analysis and a database design. The initial UI prototype was also provided, displaying what the application is expected to look like in the end. Once the design was completed, the non-functional requirements were discussed which must be kept in mind when implementing the application. The implementation will be discussed in the following chapter.

# Chapter 4

# Implementation

## 4.1 Introduction

The previous chapter outlined the artefact by defining requirements and proposing a design for the prototype. This chapter aims at completing the third activity of the Design Science Research (DSR) methodology (Section 1.7), Design and Develop Artefact. The implementation of the prototype design outlined in Section 3.4 will be explained discussing the tools used and the development of the prototype.

## 4.2 Implementation Tools

A number of different tools were selected to develop the prototype. These tools are discussed in the following subsections to explain the reason as to why they were used.

### 4.2.1 Platform

Part of the objective of this project (Section 1.4) is to develop a prototype that runs on an Android device. The prototype was developed specifically for a device with minimum Android version 5.0. The reason for this was to ensure that all the suitable design principles and guidelines outlined by Android could be met.

### 4.2.2 Development Environment

The Integrated Development Environment (IDE) used to develop the prototype was IntelliJ IDEA, which supports development for Android devices (JetBrains, 2015). IntelliJ makes use of the same code as Google's Android Studio (Jemerov, 2013), hence there are no substantial

advantages of using one over the other as of yet. The reason for using IntelliJ rather than Android Studio was purely due to experience using IntelliJ.

### 4.2.3 Server

Microsoft SQL Server was used to create and manage the database, following the design proposed in Section 3.4. The database is hosted on NMMU Computing Science's post-graduate server. Due to it being hosted in this manner, in order for the prototype to connect to the server, a connection to NMMU's Virtual Private Network (VPN) is needed. SQL Server was used as there is a driver library available, discussed in Section 4.2.4, which simplifies connecting to SQL Server directly from the prototype.

### 4.2.4 Additional Libraries

The use of additional libraries allows for added functionality not provided by IntelliJ or Android. The libraries included were jTDS library for connecting to SQL Server, the Android Support Libraries and the ObservableScrollView library, both included for User Interface (UI) design purposes.

#### jTDS

The jTDS library (The jTDS Project, 2014a) provides a free open source driver to allow the prototype to connect directly to SQL Server. The jTDS driver has the complete implementation of the Java Database Connectivity (JDBC) Application Program Interface (API). This driver is the fastest JDBC driver for connecting to SQL Server (The jTDS Project, 2014b). The use of this driver allowed the connection directly to the server to retrieve all the relevant data needed for the prototype.

#### Android Support Libraries

The Android Support Libraries provide backward compatible versions of the Android API as well as additional features only available through the support library. The two libraries that were used came from the Android v7 Support Library Package (Google, 2015). The UI components, Card View and Recycler View, were used to create lists that follow the UI guidelines set out in Section 3.4.2.

**ObservableScrollView**

The ObservableScrollView library (Soichiro Kashima, 2014) provides functionality to observe scroll events on scrollable views in the prototype. This library was also included to meet the design UI guidelines set out in Section 3.4.2. This library allows for various scroll animations to be used on lists.

## 4.3 Prototype Implementation

The implementation of the initial prototype was split into three main components: Augmentation, Data Communication and User Interface. These components formed the major iterations outlined in the DSR Methodology's Design and Develop activity. The following subsections will discuss each iteration, highlighting how the final prototype was implemented.

### 4.3.1 Component 1 - Augmentation

The Augmentation component refers to the display of Points of interest (POI's) on the device's screen in the correct position and direction. Hard coded POI locations were used in order to test if the augmentation was working correctly. The POI's to be displayed in the final prototype were implemented in the subsequent component (Section 4.3.2).

Implementation of the augmentation was guided by an augmented reality guide (Sood, 2012) as well as a free open source AR engine (Mixare, 2012). From these references, a basic augmented browser was created, which allowed for the visualisation of the POI's on the device's screen. To implement the augmentation, the device's current position and direction needed to be updated every time there was a change. The change in the device's orientation and position is sent through a low-pass filter to be smoothed in order to make the movement of the POI markers on the augmented view smooth. A low-pass filter smooths data by reducing the amplitude of high frequency noise within the data and allows for low frequency changes to pass through (Milette & Stroud, 2012) (Sood, 2012). A low pass filter has one variable, the alpha value, which is the smoothing constant. The smaller the constant, the more smoothing is performed. The implementation of the low pass filter in the prototype makes use of different values of alpha. The value of alpha to be used is determined by how much the device is moving. If the device's movement is rapid, there is no need for very fine smoothing and higher frequency data is kept. Whereas if the device moves slightly, the data should be smoothed finely to only allow the lowest frequency changes to be kept. The various alpha values had to be finely adjusted in order to find suitable values that allowed the augmentation to seem smooth when moving the device around.

The current position and direction of the device indicated if the POI was within the device's view. If so, the POI was augmented onto the devices screen by means of drawing a marker,

discussed in Section 4.3.3. The position of the marker on the device's display was determined by converting the coordinates of the marker to X-Y-coordinates on the device's screen. The Y-coordinates were set to a fixed value to always display the POI in the centre of the screen on the vertical axis. The decision to fix the POI's marker on in the centre of the device's screen was to ensure that users will always know in which direction a POI is and not have to tilt the device up or down in order to find POI's and various altitudes.

The augmentation thus worked in order to display the POI's on the device's screen by means of markers. The next step was to allow for details of the POI's to be shown as well as filtering which POI's to display depending on the user's Role and configuration of Collections by making use of the data in the database.

### 4.3.2 Component 2 - Data Communication

The second component, Data Communication, involves the connection and communication with the server as well as the storing and filtering of the data to be augmented. This component focused purely on getting the back end of the application working, not worrying about the look of the application and the presentation of the data, which was the focus of the third component (Section 4.3.3). It is reminded that the administrative system in order to manage the database is left out of the scope of this project.

As mentioned in Section 4.2, Microsoft SQL Server was used in order to store the data and the jTDS driver used in order to connect directly to the server from within the prototype. Changes were made to the original design of the database (Figure 3.3) in order to support the functionalities of the application. It was initially decided that the Collections would have passwords associated with them, however, it was decided to assign the passwords to Roles rather as it seemed more appropriate. As can be seen in Figure 4.1, the following changes were made:

**Inclusion of `Account_Role` table.**

This table was included in order to remember the Roles for which a user has been granted access to.

**Removal of `Password` and `Radius` from `Collection` table.**

Due to Collections no longer having a password, there wasno need for a password field. The radius was no longer needed as the centre point of a Collection was determined by averaging the latitudes and longitudes of the POI's within that Collection.

**Added the field `Password` to `Role` table.**

The password was moved from a Collection to a Role, and thus the Role needed a password field. If a Role had no password associated with it, the field is assigned a `null` value.

The class *SeverDataSource* was created to handle all communications from the application to the server. The class made use of individual methods for retrieving different data. Each of these methods were an implementation of an `AsyncTask`. An `AsyncTask` allows background tasks to be performed in Android, resulting in the user interface not being affected (*AsyncTask*, 2015). The different methods within the *ServerDataSource* were:

**fetchPOIMarkers()**
: This method fetched each POI from the server per active Collection that is associated with the currently selected Role. The calling of this method was done whenever the active Collections were changed as well as when the currrent Role was changed.

**fetchPOICollections()**
: This method ensured that all the data for the Collections associated with the currently selected Role were retrieved. This method was called every time the current Role is changed.

**fetchRoles()**
: This method retrieved all the Roles from the server.

**fetchAccessedRoles()**
: This method retrieved all the Role's that had access keys associated with them that the user had previously obtained access to.

**grantRoleAccess(final Role role)**
: If the user correctly enters an access key to a locked Role, this method then sets the Role as accessed for that specific user in the database.

**verifyAccount(final String email, final String pass)**
: This method was used to verify the login details of the user.

**createAccount(final String email, final String pass)**
: This method allowed users to create a new account by inserting their login details into the database after ensuring a unique email address.

Each of these methods connected to the database through the jTDS driver independently. The associated SQL statement was constructed and the database queried. A result set was returned and iteratively traversed in order to store the results within the application. All data was stored in a central location for accessibility throughout the prototype. It must be noted that all the images, audio and videos were not stored in the database itself, only a link to these items. The content was instead stored on a web server. Images were downloaded as their links were read in from the database. Audio and Video files were streamed from the links in order to save network data, device storage, as well as processing time.

This component also included the passing of data between activities of the application, specifically regarding the viewing of the POI's. Once an augmented POI marker was selected, the data would then be sent through to the next activity, where the data would be presented to

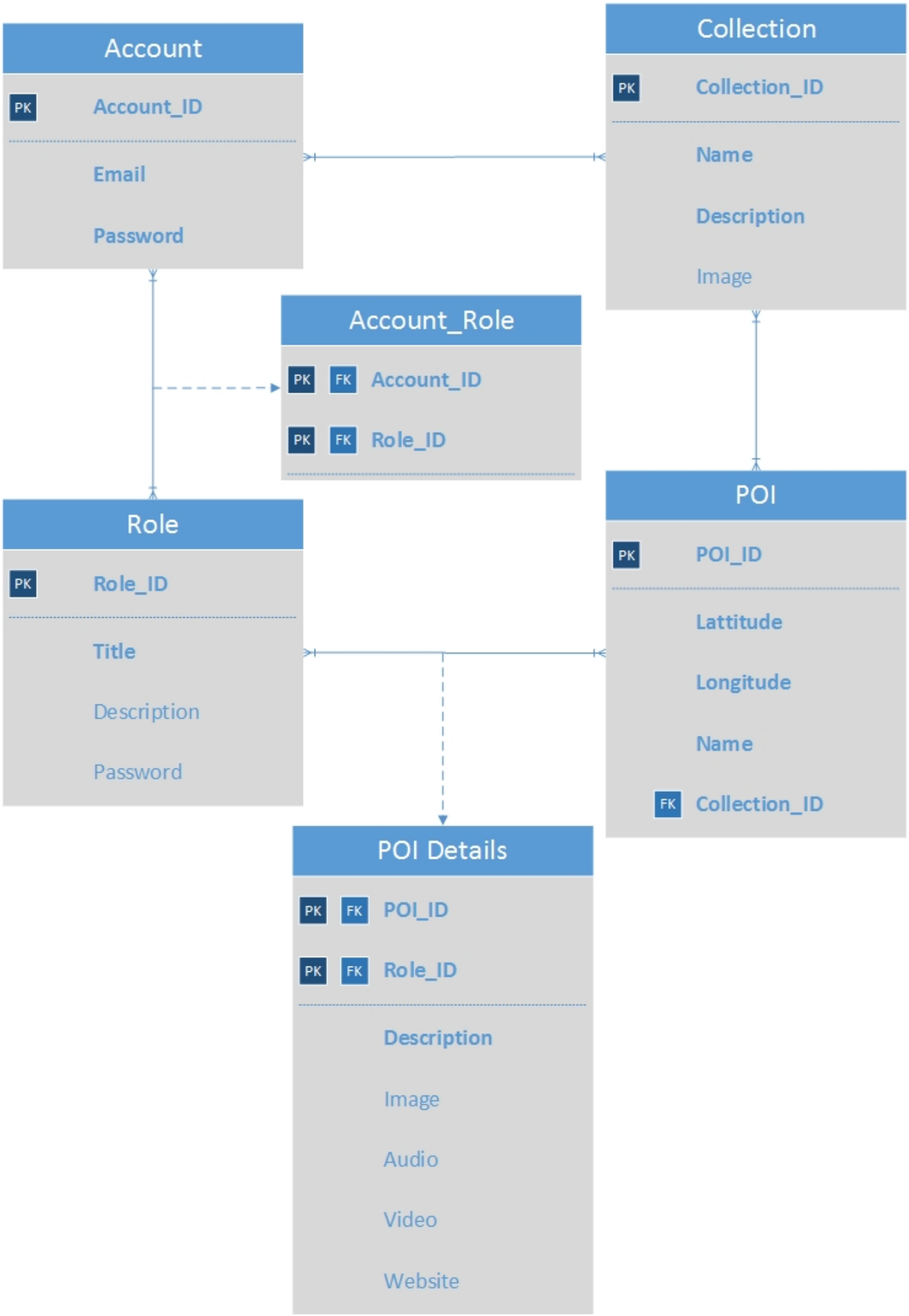



Figure 4.1: Final Database Design

the user. The data was passed through by means of attaching the specific POI's details to the Intent for staring the details activity. The altering of Roles and active Collections was also implemented in this component, however the functionality was very limited as it relied on the design of the UI which was only to be implemented in the following iteration (Section 4.3.3).

### 4.3.3 Component 3 - User Interface

The UI component focused on the design of the final application. The UI was dependent on both the Augmentation (Section 4.3.1) and Data Communication (Section 4.3.2) components to be completed in order to combine aspects from both to create a fully functional application. The following screen shots are the final screen designs of the first prototype. Each screen will be discussed as to the choices made as well as any decisions to change the design from the proposed designs set out in Section 3.4.2.

#### Login and Create Account

The initial screen that users encounter is the screen that serves as both the login and the create account screen. The screen (Figure 4.2) consists of two fields in which users enter in their email address and their password. The user is then required to select the Sign In or Register button. In the case that a user selects the button without entering any details, error dialogues appear, instructing the user to enter in the missing details. Once users selects the button, if they are not already registered for the application, they will then be presented with a dialogue prompting them to create an account. The users are then required to re-enter their password as a means of error prevention on the screen shown in Figure 4.3. After ensuring that the user's email address is unique, their details are saved in the database and they are automatically logged in and presented with the augmented view. The login and create account process consist of basic error prevention and security measures. These include enforcing a password with length of at least five characters long, as well as checking for empty fields. Users' email addresses need to be unique, thus checks against already registered users are done in order to determine if the users are returning or registering. The application also checks if the users' GPS is enabled when opening up the application. If their GPS is disabled, they are prompted to enable their location services before they can proceed to login or register as the application is dependant on GPS data. Users have the option to enable the automatic login by allowing the application to remember their login details. This can be done in the settings screen (discussed later in this section).

#### Augmented View

The augmented view (Figure 4.4) is displayed to users when they log in to the application. The view is forced to a landscape orientation as it increases the viewing angle for the user.

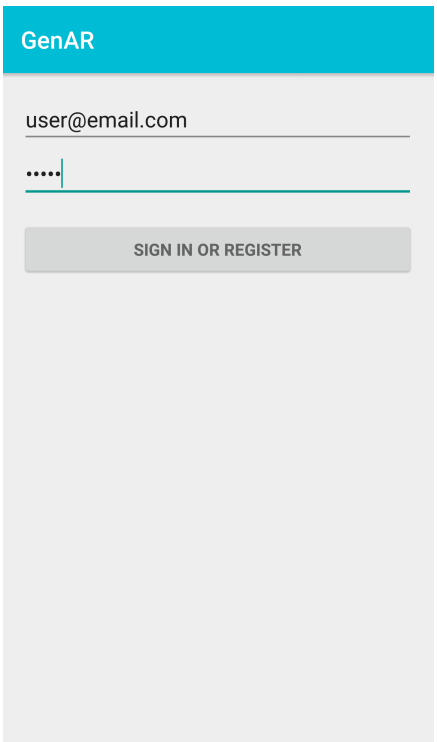



Figure 4.2: Login Screen

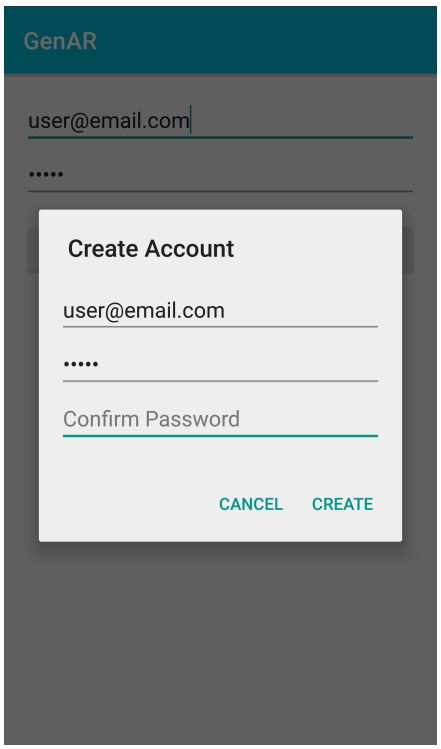



Figure 4.3: Confirmation Dialogue

The augmented view indicates the direction of the POI's on a camera view obtained from the device's camera. The POI's are generally displayed by means of a circular image as well as an information box containing the name of the POI and the distance from the user. The image used for the POI marker is the image of the POI and if this image is not available, the POI is simply displayed as a circular point. The POI's are vertically centred on the devices display to ensure that user's can always see the POI and that all POI's are displayed along the same horizontal line. Users can tap on the area of the marker and the information box in order to view additional details fo the POI. Collision detection between POI's was implemented to ensure that POI's do not overlap. The collision detection was implemented by shifting the furthest POI to the right until there is no longer any collision.

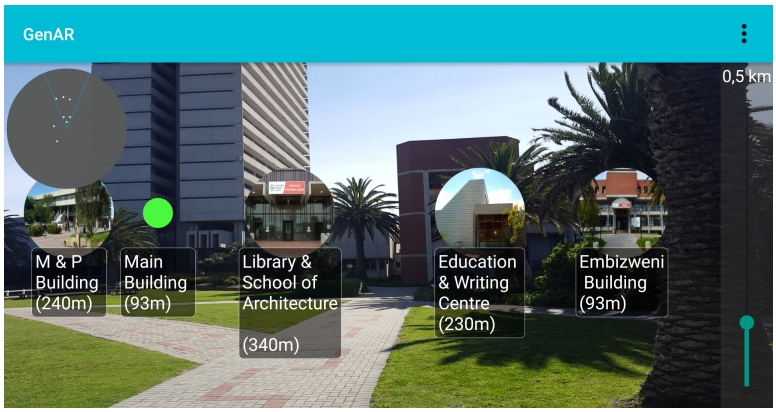



Figure 4.4: Augmented View

The application makes use of two radii, a maximum radius and a detailed radius (Figure 4.5). The maximum radius sets the limit as to the maximum distance the user will be able to see

POI's. A detailed radius is used to reduce cluttering of the display with many POI's. The detailed radius provides the radius around the user, within the maximum radius, for which individual POI's from a Collection will be displayed. If POI's fall out of this radius, but within the maximum radius, the POI's are condensed into a single marker relating to the Collection in which they belong (Figure 4.6). The single marker displayed is positioned in the centre of all the POI's within the Collection. Both of the radii can be adjusted in the settings.

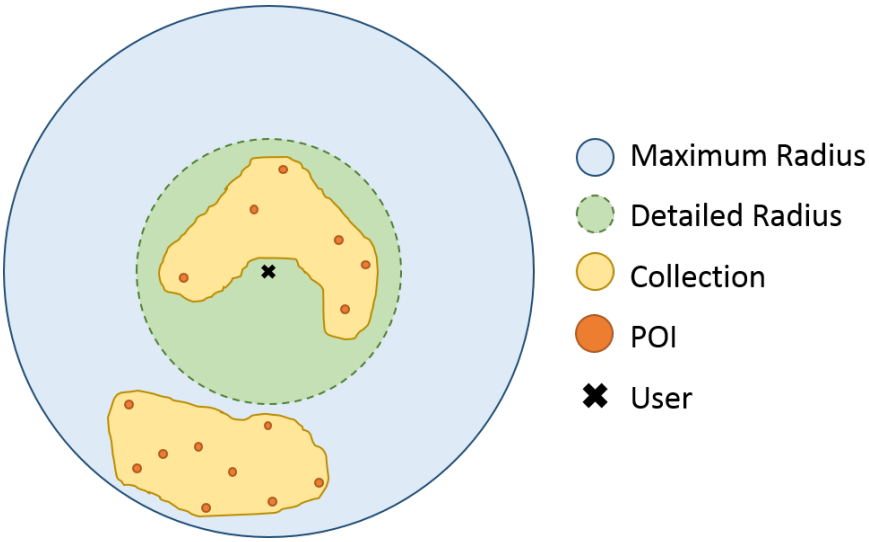



Figure 4.5: Radii Visualisation

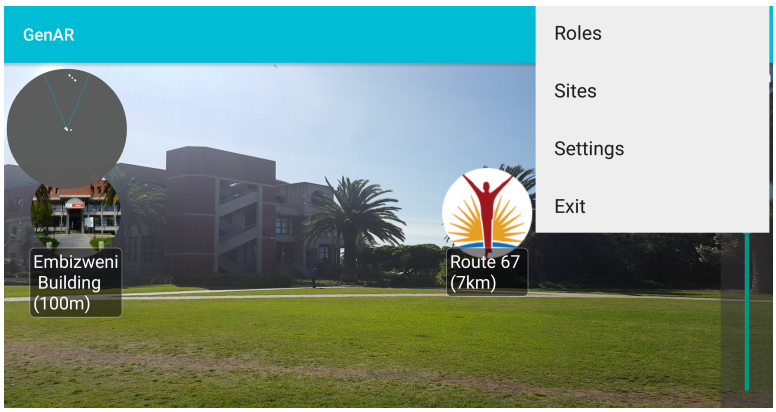
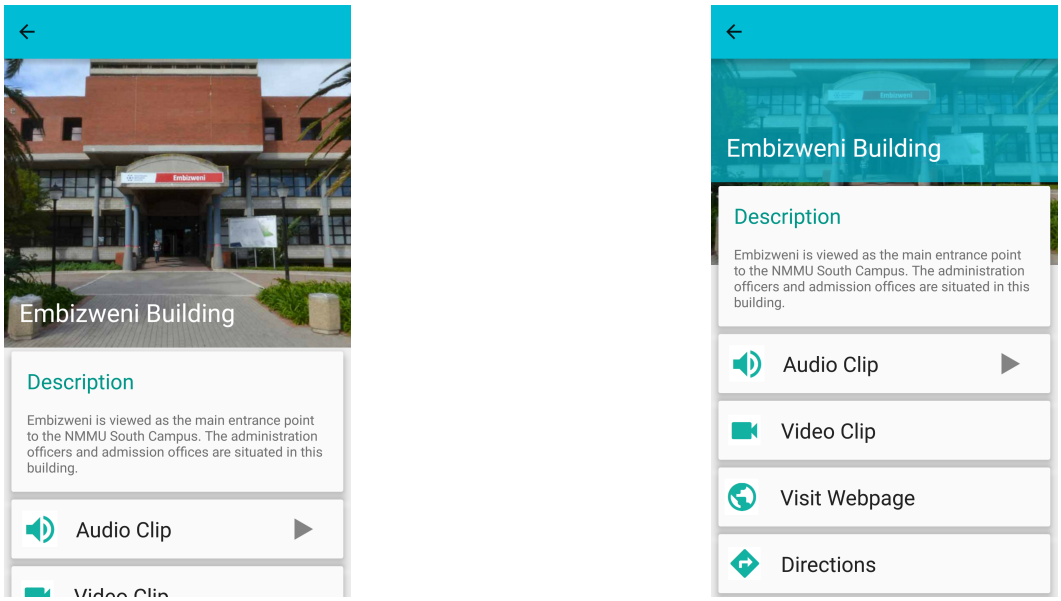



Figure 4.6: Augmented View with Site Marker and Menu

Two additional features were included in the augmented view, these being the radar and the zoom bar. The radar, common in other AR browsers, provides the user with a 360 degree overview of where POI's are relative to them within the current zoom radius. The zoom bar allows the user to limit the radius ,within the maximum radius, in which they are shown information for. Both of these components can be disabled in the settings menu. In order for users to access the settings, configure their Collections or select a Role, they need to make use of the menu which is accessible at the top right corner of the augmented view (Figure 4.6).

### Detail View

The detail view (Figure 4.7) provides additional details for a POI. These details could include, an image, a description, an audio clip, video clip, a link to a website as well as directions to the POI from the user's current location. All POI's are required to have a description, and will have directions, however, POI's are not required to have the other details associated with them. Each detail is presented on a separate tile, making use of the Card View from the Android Support Libraries (Section 4.2.4). If a POI does not have a certain detail aspect associated with it, that specific tile will not be present in the detail view. Most of the tiles act as buttons through which the content is accessed. The Audio clip tile includes soft buttons to allow the user to control when to play, pause and stop the audio clip. The video tile opens up a media player within the application in order to stream the video from the server. Directions to a POI was included as an extra feature and makes use of the Google Maps application.




(a) Scrolled up (b) Scrolled down

Figure 4.7: Details View

### List and Description of Collections

The list of Collections allows users to toggle which Collections' POI's are displayed in the augmented view. The final design of the Collections list (Figure 4.8) differs quite a bit from the original screen design (Figure 3.6). One important change to notice is that in the application, Collections are now referred to as Sites. The term Collection came across as being quite ambiguous and the term, Sites, seemed to better fit the description. The major difference between the proposed and the final screen design was the removal of the tabs evident in the proposed design. The reason for removing the tabs was to reduce the amount of navigation required from the user. The use of switches was used instead to indicate whether a Collection was currently active or not. Users can view descriptions of the Collections by tapping on the

tile, which will display the screen shown in Figure 4.9. The list of Collections was also equipped with a refresh function whereby users can 'pull down' the list to refresh the list. This will re-query the server to ensure that all Collections are being displayed. The images of a Collection are also displayed to the left of the Collection's name in order to help the users identify the various Collections.

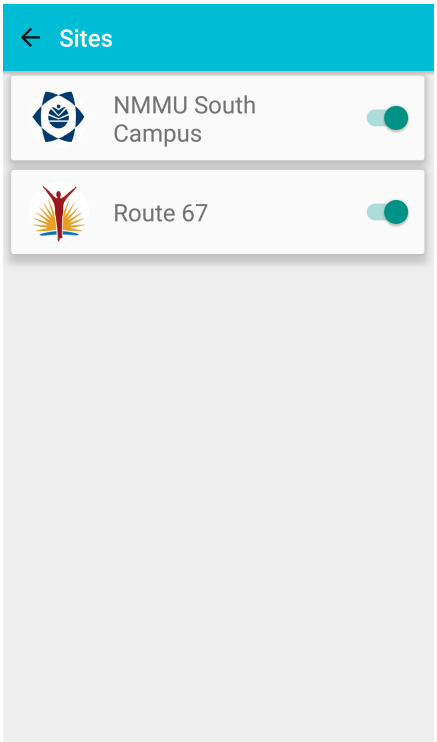



Figure 4.8: List of Sites

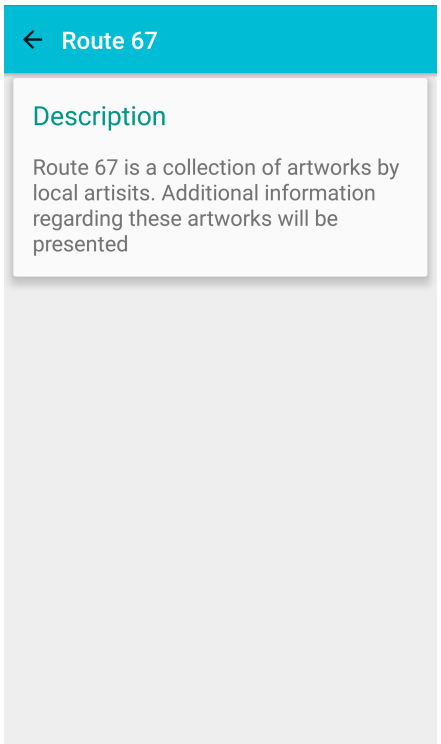



Figure 4.9: Description of Site

### List of and Description of Roles

The list of Roles provides the user with the ability to change their current Role, only allowing for one Role to be active at a time. The user will be able to change which Collections they have access to based on the Role they undertake due to the fact that Collections are associated with specific Role's. The Roles list (Figure 4.10), like the Collections list, no longer included the tabs as originally proposed. Similar to the Collections' list, this too was to reduce the amount of navigation required. Since only a single Role can be active at a time, a Radio group was used to ensure that when the user selects a particular Role, the previous Role is disabled. The Role's list is very similar to that of the Collections' list in order to keep the application's UI consistent. To view the description of a Role (Figure 4.11), the users simply tap on the tile that a Role is on. Unlike the Collections, Roles have no image associated with them, hence no image is displayed for the Roles. Some Roles do, however, have an access key associated with them. These Roles are indicated by means of a small lock next to the Role's name. A closed locked indicates that the user has not entered in the access key, whereas an open lock indicates that the user has been granted access to that specific Role. Once a user is granted access to a

Role, they will always have access to the Role and will not be required to re-enter the access key. The Role's list also supports the same refresh functionality as the Collections list.

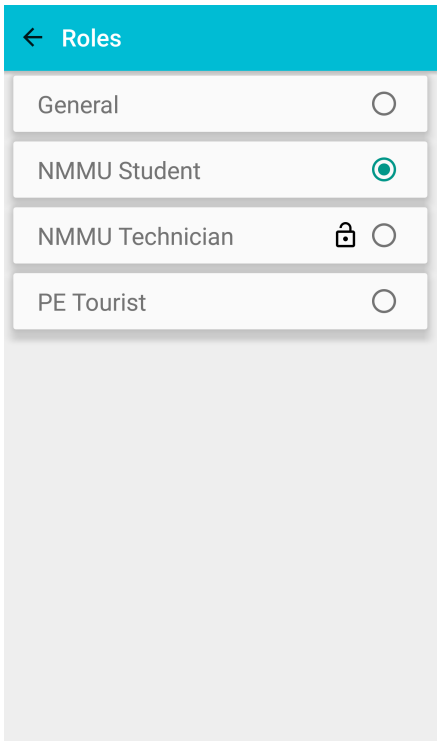



Figure 4.10: List of Roles

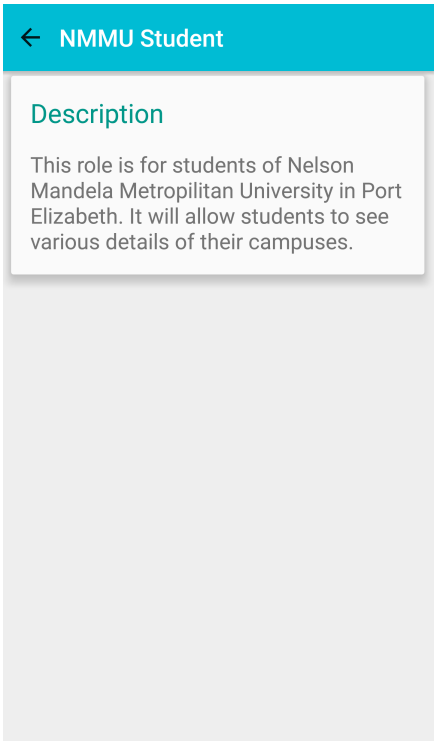



Figure 4.11: Description of Role

### Settings

The final screen design, which had no proposed design, is the settings screen (4.12). The settings screen allows the user to make adjustments to the augmented display, alter the distance variables as well as store user information. As mentioned before, the users have the option to disable the radar and zoom bar. Users can also opt to not use images as POI markers. This will force the markers to be depicted as the smaller colour filled circles instead of using a POI's image. Users also have the ability to adjust two distance variables. The detailed radius was explained previously. The maximum radius indicates the maximum distance that the augmented view will be able to show information for (i.e. the maximum of the zoom bar). The final setting allows the user's login details to be stored in the application. Making use of this option will result in the initial screen displayed to be the augmented view instead of the login screen, provided that the user's GPS is enabled.

## 4.4 Challenges Encountered

During implementation of the prototype outlined in Section 4.3, a number of challenges arose. This section will highlight those challenges and briefly discuss the approach taken towards them.

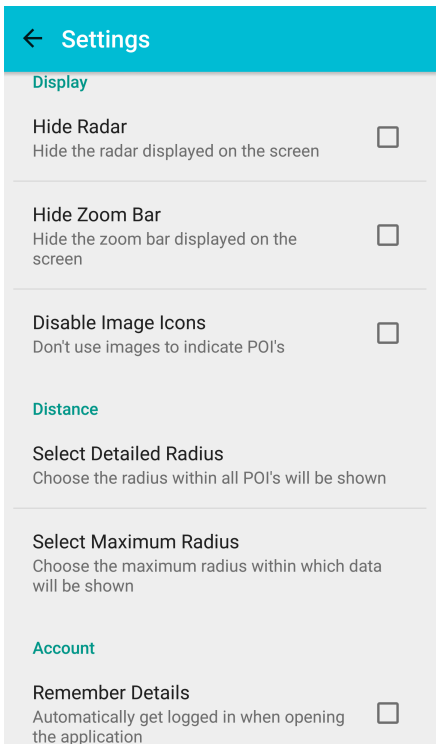



Figure 4.12: Settings Screen

The one main challenge, which can be broken up into smaller pieces, was the irregularity of the position of the POI marker on the device's screen. Using the initial implementation of the positioning of the POI marker resulted in the marker either having a very rigid movement or being displayed in such a way that the POI's could only be seen when the device was held at a specific angle.

The rigid movement was catered for by altering the various alpha values of the low pass filter discussed in Section 4.3.1. The adjusting of the values was experimental in the fact that the values had to be altered and the sensitivity evaluated. The various alpha values were altered a number of times before an acceptable smoothness was attained. It became quite a challenge as it was noted that not only the alpha values of the low pass filter controlled the movement, but also the GPS signal. This made it difficult to decisively conclude which alpha values were the best as the GPS signal would always be different, affecting the movement of the markers. Therefore alpha values were selected to what was decided to be acceptable, but cannot be concluded as the optimum values.

The issue of the marker being displayed at specific angles was due to the fact that the implementation was taking altitude into account. All the POI's were initialized with the same altitude, thus it was expected that they would all be displayed along the same horizontal line, however, this was not the case. The workaround to this issue was to determine the midpoint of the device's screen and position the maker at that specific Y-coordinate. Without realising, this in turn created another problem: The markers could only occasionally be tapped to view their corresponding details. At first, this was thought to be an error that had to do with the markers continuously moving and the user tapping the marker where it no longer is positioned on the

device's screen, even though it appeared to be in that position. It was initially accepted that there was nothing to remedy this issue. However, after further investigation, it was determined that when setting the marker at a fixed Y-coordinate, it was understood that the marker had moved, however, only the visual marker had moved, and the actual markers position had not changed. Thus a solution to the problem was attained and the markers could be selected at any angle or position of the device.

Another challenge encountered was the initial implementation of the external libraries. It took a fair amount of time to determine how to get the libraries working for the prototype. The solution being to make use of Gradle to manage the external libraries. Getting Gradle to import the external libraries was not the challenge. However, when compiling the prototypes, Gradle seemed to have slowed down the compilation process significantly. Once the libraries were imported, there was still the issue of determining how to implement the features of the library. Majority of the features were well documented, however, there were instances where no help documentation was provided and thus some libraries for certain features were not included. However, workarounds to the desired features were implemented to ensure that the feature was still present in the prototype.

## 4.5 Conclusion

This chapter completed the third activity of the DSR methodology (Section 1.7), Design and Develop Artefact. The implementation of the final prototype was discussed, highlighting how RAD was adopted as a developmental methodology within the DSR iterations. The final design of the prototype was included as one of the main DSR cycles. The challenges encountered were discussed, providing the workarounds used to overcome them. The next chapter, Chapter 5, enters the fourth and fifth activities of the DSR methodology by evaluating the prototype implemented as discussed in this chapter.

# Chapter 5

# Evaluation

## 5.1 Introduction

The previous chapter discussed the development and implementation of the prototype. This chapter aims at performing the fourth and fifth activities of the Design Science Research (DSR) methodology, namely , Demonstrate Artefact and Evaluate Artefact, respectively. The plan of the evaluation will be discussed, followed by the results obtained from the evaluations.

## 5.2 Evaluation Plan

This section will describe the plan followed in order to evaluate the prototype developed as indicated in Chapter 4. The method used for the evaluation will be explained (Section 5.2.1) and the metrics measured discussed (Section 5.2.2). The tools used for the evaluation will be highlighted (Section 5.2.3), followed by a brief explanation of the intended participants for the evaluation (Section 5.2.4).

### 5.2.1 Method of Evaluation

The evaluation of the prototype is aimed at evaluating both the generic capability as well as the usability of the application developed. The generic aspect of the application was proved to be successful by means of changing the active Role and viewing the difference in the Collection configuration as well as the details for the POI's. Both NMMU South Campus and Route 67 were evaluated and the prototype automatically adjusted for each location, depending on the Role selected. Changes to the augmented data can thus adapt based on the user's location and active Role.

The usability study was carried out as an observational study followed by a usability questionnaire. The usability study consisted of the following ten tasks for the participants (Section

5.2.4) to carry out:

1. Create an account.
2. Find the Human Movement Science (HMS) building.
3. View the details for Building 123.
4. Find Route 67.
5. Change the detailed radius to 10km in the settings.
6. Get directions to the Fish Bird sculpture at Route 67.
7. View the description of the Site 'Route 67'.
8. Disable the Site 'Route 67'.
9. Change your Role to a technician at NMMU. *[Access Key = NMMUTech]*
10. View the details for Building 123.

The task list can also be seen in Appendix B.

The evaluation environment was chosen to be outdoors at the NMMU South Campus Site. Before the participants began performing the tasks, a brief explanation of the prototype will be given, specifically regarding Sites, Roles and the various radii implementations. All participants' involvement was voluntary and all participants were required to sign a consent form(Appendix C). The tasks allows the participants to interact with the prototype in order for them to complete the usability questionnaire thereafter. The Computer System Usability Questionnaire (CSUQ) was be used in order to measure four different metrics. These metrics are: Overall Satisfaction, System Usability, Information Quality and Interface Quality (Section 5.2.2). The CSUQ was first developed by Jim Lewis (Lewis, 1995) and is very similar to the Post-Study System Usability Questionnaire (PSSUQ) which he too developed (Albert & Tullis, 2013, p.140-141). A Likert scale rating from one (Strongly Disagree) to seven (Strongly Agree) is used to rate each of the 19 statements in the CSUQ. Demographical and qualitative questions were added to the CSUQ to produce the complete questionnaire used (Appendix E) for the study. During the usability study, performance metrics (Section 5.2.2) were also recorded. Once the usability study was completed, the data will be collected for each participant and analysed.

### 5.2.2 Metrics

In order to measure the usability of the prototype it was decided to use self reported metrics. As mentioned in Section 5.2.1, the CSUQ provides four quantitative metrics which are described below. In addition to the four metrics of the CSUQ and quantitative performance data, qualitative data will also be obtained. The only metrics which are not self reported and are gathered during the usability study are the performance metrics.

### Overall Satisfaction

The overall satisfaction metric measures how satisfied the participants are with the prototype as a whole. This metric is an overall indicator based on the other three metrics. To obtain this metric, the average of all 19 statements from the CSUQ is calculated. Since the CSUQ makes use of a Likert scale from one to seven, the closer the average is to seven, the more satisfied a participant is with the prototype.

### System Usability

System usability refers specifically to how usable the system is. This metric indicates if there are any issues with the prototype in terms of functionality and navigation. This metric is obtained by calculating the mean of the ratings of statements one through eight.

### Information Quality

Information Quality indicates the quality of the information provided to the user in order to interact with the application. This metric indicates if the layout of information in the prototype is intuitive and highlights the need for any additional help or hints within the prototype. This metric is obtained by calculating the mean of statements 9 through 15 of the CSUQ.

### Interface Quality

Interface Quality, the last metric measured by the CSUQ, is obtained by averaging statements 16 through 19 of the CSUQ. This metric reports on the quality of the user interface of the prototype. Any issues regarding the look and feel of the prototype is indicated by low values of this metric.

### Qualitative Metrics

The qualitative metrics obtained from the usability study are obtained by requiring the participants to indicate both the negative and positive aspects of the prototype as well as allow them to suggest improvements. In order to analyse the qualitative metrics, common aspects for each question were be considered important.

### Performance Metrics

The performance metrics measured during the usability study provides information as to how fast and accurately the participants can complete each of the ten tasks. The time taken and number of errors is recorded for each task. Tasks that have a large mean number of errors and

long average completion time indicates that there is an issue with completing that specific task. Using this information, the problem areas within the application can be identified.

### 5.2.3 Evaluation Tools

In order to evaluate the prototype outlined in Chapter 4, it was run on a Samsung Galaxy S6. Participants made use of this device while performing the usability study. Screen captures of the participants' interaction with the prototype during the usability study was captured using Mobizen (RSUPPORT, 2015), an application that allows for the recording videos in real-time. The performance metrics outlined in Section 5.2.2 were extracted from the recordings. The metrics obtained from both the screen captures and questionnaires were be collated in a Microsoft Excel workbook in order to perform analysis on the data as well as produce graphical representations of the data.

### 5.2.4 Participant Selection

The intended participants for the usability evaluation was a convenience sample consisting of ten participants. Demographical details such as age, gender and mobile application experience were collected from each participant in order to determine the diversity of the convenience sample. If any trends are evident in the results, the cause might be due to the participant selection, thus the demographical details can be referenced to identify any possible explanation for the trend.

## 5.3 Evaluation Results

The results obtained from the evaluation outlined in the previous section (Section 5.2) will be presented in this section. The details of the convenience sample are then discussed in Section 5.3.1. The quantitative results (Section 5.3.2), results for the CSUQ questionnaire (Section 5.3.3) and the qualitative results are presented and discussed. Thereafter, any changes that are deemed necessary due to the results are then discussed (Section 5.4).

### 5.3.1 Participant Profile

The users that participated in the evaluation of the prototype made up a convenience sample of ten participants, as originally planned (Section 5.3.1). Each participant provided their age, gender and experience with mobile and android devices. The diversity within the sample is presented below.

The age of the participants (Figure 5.1) was relatively spread out with the convenience sample containing participants aged from 18 through to 30. The most common age group present was the ages between 22 - 25. There were no participants that fell within the 31+ age group.

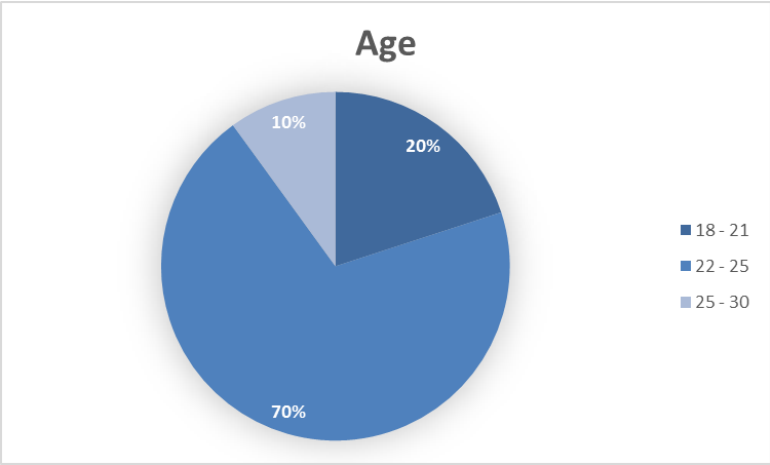



Figure 5.1: Age Distribution

Both males and females were present in the convenience sample with the males accounting for 80% of the sample (Figure 5.2).

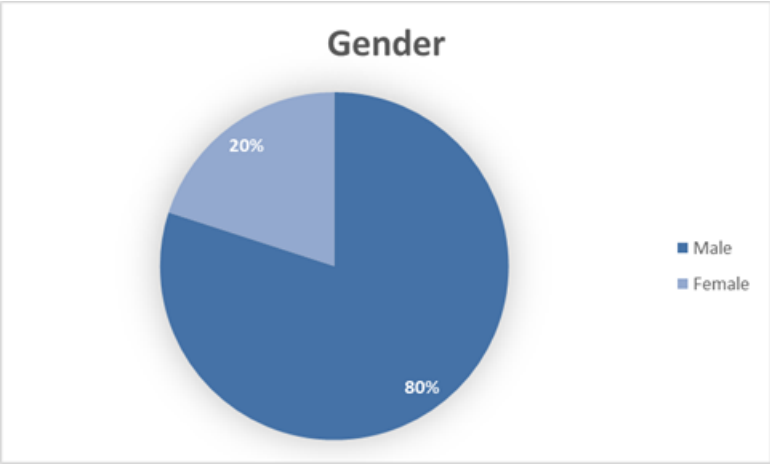



Figure 5.2: Gender Distribution

The participants were required to rate their experience with mobile applications by responding to the statement "I am experienced with using mobile applications.". The participants were required to indicate their experience on a Likert scale ranging from zero (Strongly Disagree) to seven (Strongly Agree). The results (Figure 5.3) indicates that all the participants were experienced, to some level, with mobile applications. None of the participants felt that they were not experienced and 50% of the sample considered themselves to be extremely experienced with mobile applications.

Due to the prototype being developed on Android, it was important to identify the sample's experience with the Android operating system. The participants rated their Android experience on a three-point scale consisting of the options "No Experience", "Somewhat Experienced and

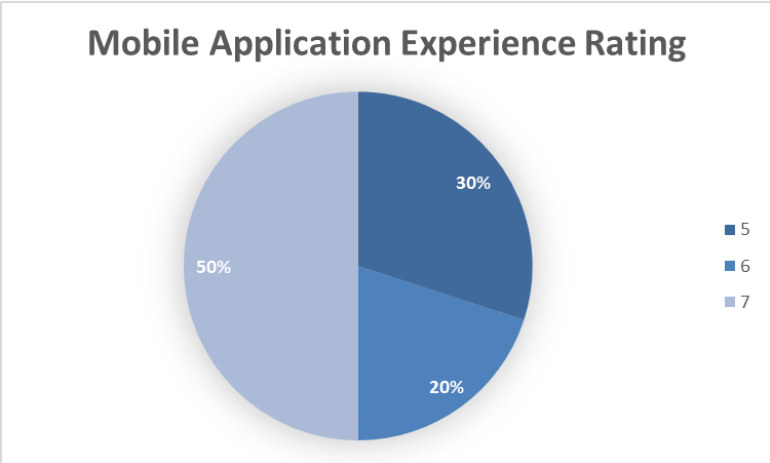



Figure 5.3: Mobile Application Experience

"Very Experienced". The results (Figure 5.4) supported the results of the mobile application experience with 50% indicating they are very experienced and the remaining 50% indicating that they were somewhat experienced with Android. None of the participants had no Android experience.

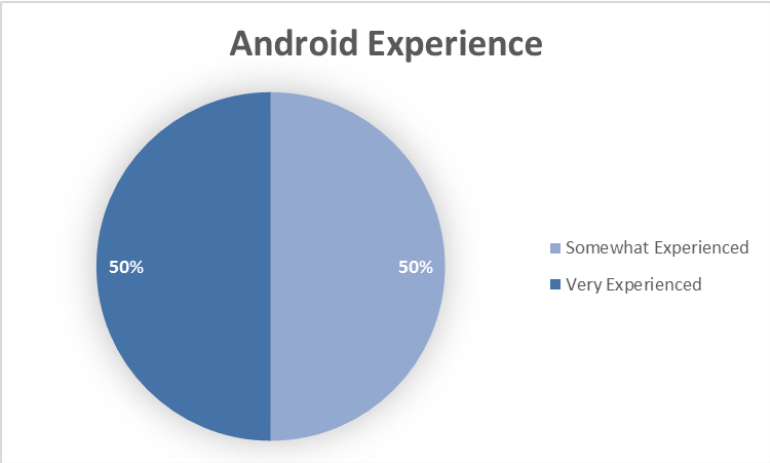



Figure 5.4: Android Experience

### 5.3.2 Performance Results

As described in Section 5.2.2, the performance results collected were time and number of errors per task. By making use of both the results from the average time (Figure 5.5) as well as the average number of errors per task (Figure 5.6), tasks with a long time as well as a large number of errors indicate an issue with performing that specific task. The two tasks that stand out are Task 1 and Task 7. Task 1 has the longest average time, however, this can be attributed to the number of steps needed to create an account. Task 1 has an average number of errors close to 0.5, for ten participants, indicating that there is no real issue with this task. Task 7 on the other hand, has a long average completion time as well as the highest average number of errors. The standard deviation for both these performance metrics for Task 7 is also quite

large, indicating that there was some inconsistency within the convenience sample used. The issue encountered with Task 7, was that majority of the participants thought they needed to reduced the detailed radius in order to see the Site marker for Route 67, and then proceeded to tap on the marker. However, the viewing of a Site's description from it's marker was not implemented, only the viewing of details for a POI. In order to complete Task 7, participants needed to view the Site list from the menu and then selected the Site, Route 67 to view it's description.

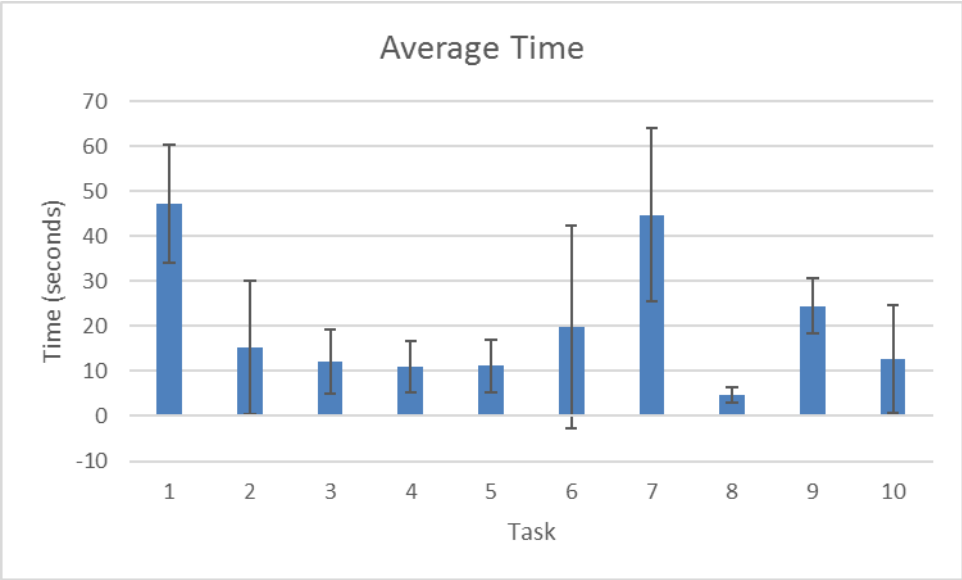



Figure 5.5: Average Time per Task

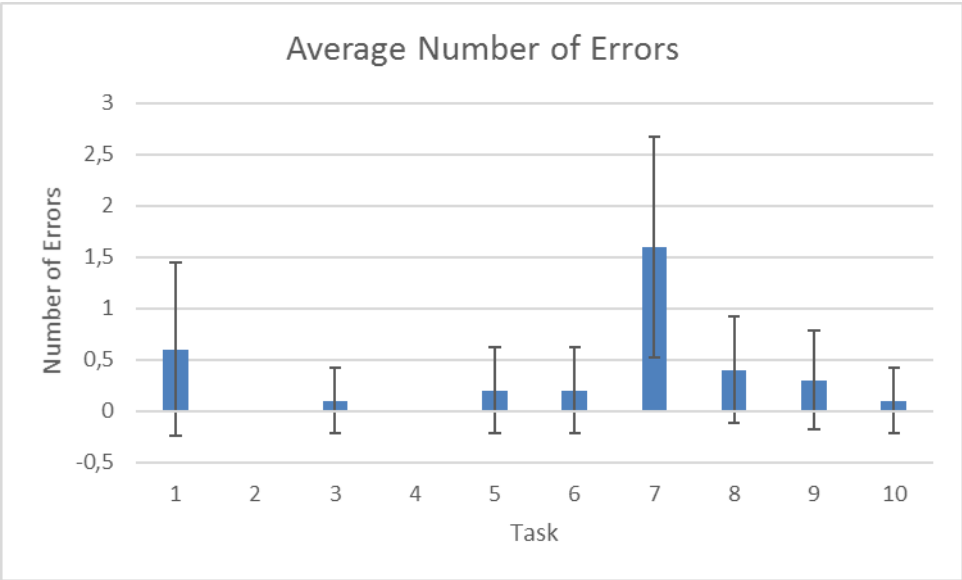



Figure 5.6: Average Number of Errors per Task

### 5.3.3 CSUQ Results

The following section presents the results pertaining to the four metrics measured by the CSUQ. Figure 5.7 indicates an overview of the percentages attained for each metric.

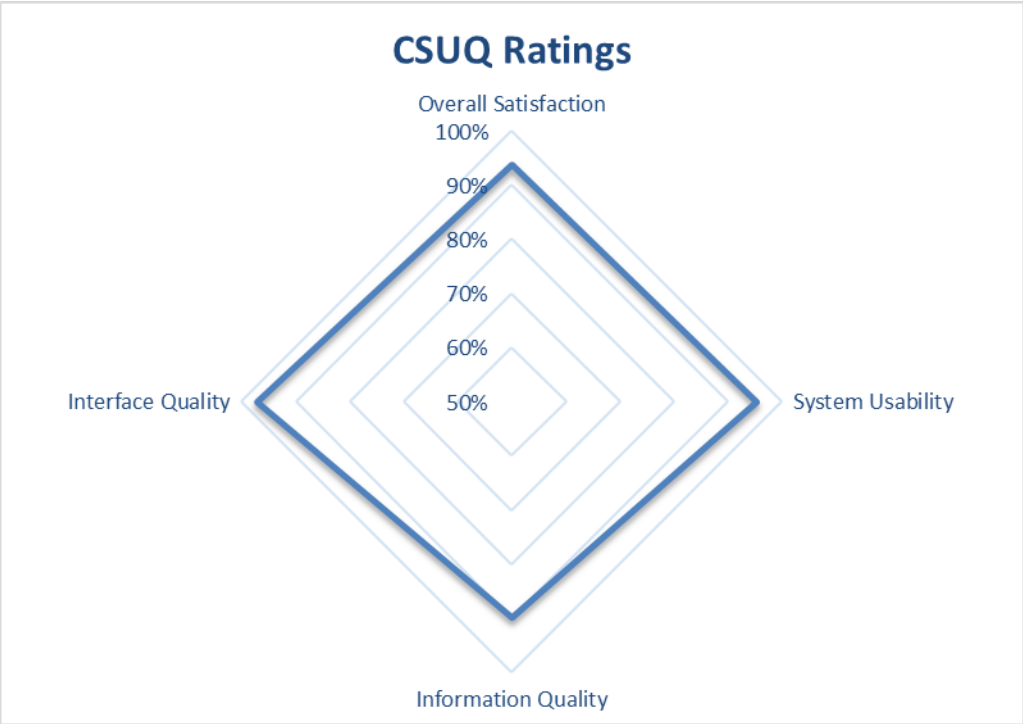



Figure 5.7: Percentage achieved per CSUQ Metric

#### Overall Satisfaction

Since the overall satisfaction corresponds to all 19 statements of the CSUQ, Figure 5.8 can be used to illustrate the results. It can seen in Figure 5.8 that the overall average for each statement was quite high. The average response for all 19 statements was 6.56, indicating that the overall satisfaction was 94% achieved. The response for statement 9 of the CSUQ has the lowest average rating of 4.67. The explanation for this will be covered when information quality is discussed, which is the metric group that statement 9 belongs to.

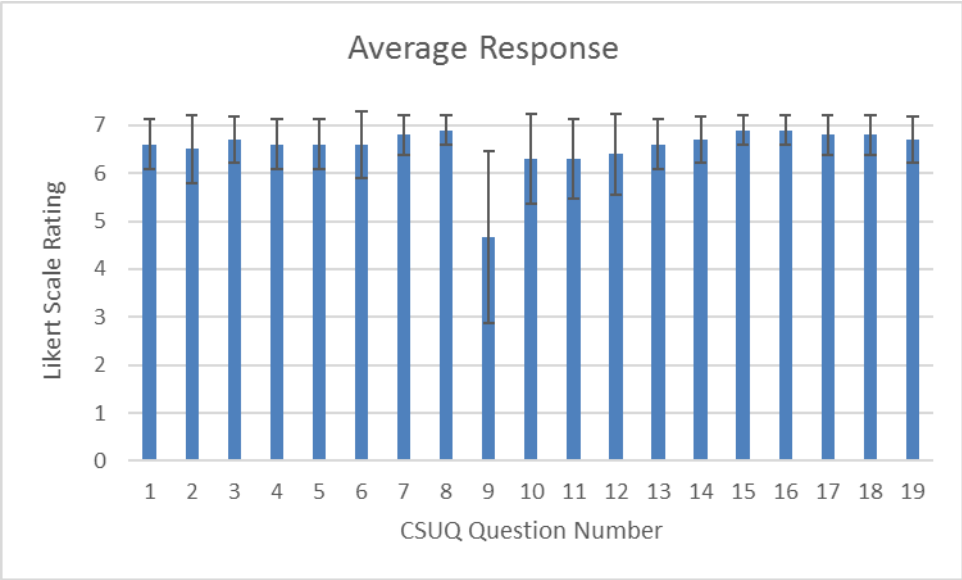



Figure 5.8: Average Response per CSUQ Question

### System Usability

The results for the CSUQ statements relating to system usability can be seen in Figure 5.9. The average response for the statements related to system usability was 6.66, which accounts for 95%. All statements, on average, received a rating above six. The low standard deviations of statements one to eight in Figure 5.8 indicate the the responses were very similar for all ten of the participants.

### Information Quality

The information quality category received the lowest percentage of 90% (Figure 5.7). The average response for all the information quality statements (Figure 5.10) was 6.28. The information quality metric contained statement number 9, the statement with the lowest average response. The cause of this negative response to the statement is due to little or no error messages being displayed during the usability study. The standard deviation of statement 9 (Figure 5.8) is extremely large, indicating the wide spread of responses. Most of the participants had mentioned whilst filling in the CSUQ that they felt that specific statement was not applicable.

### Interface Quality

The average responses for the statements relating to interface quality were all above 6.5, with an overall average of 6.8. This was the highest rated metric, receiving a percentage of 97%. The standard deviations of statements 16 through 19 are all low, indicating the responses for the ten participants were consistent.

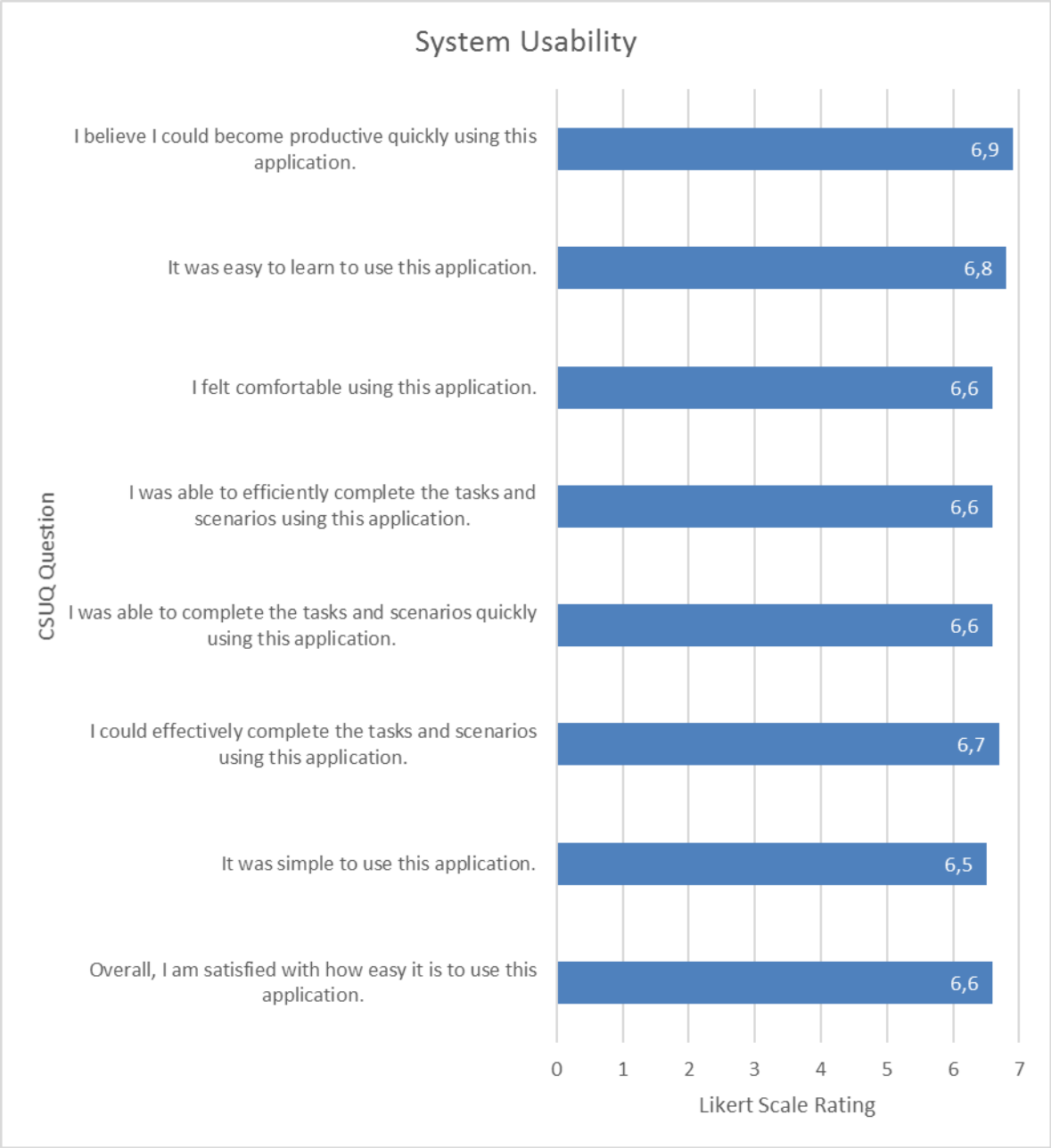



Figure 5.9: Average System Usability Response

Figure 5.10: Average Information Quality Response

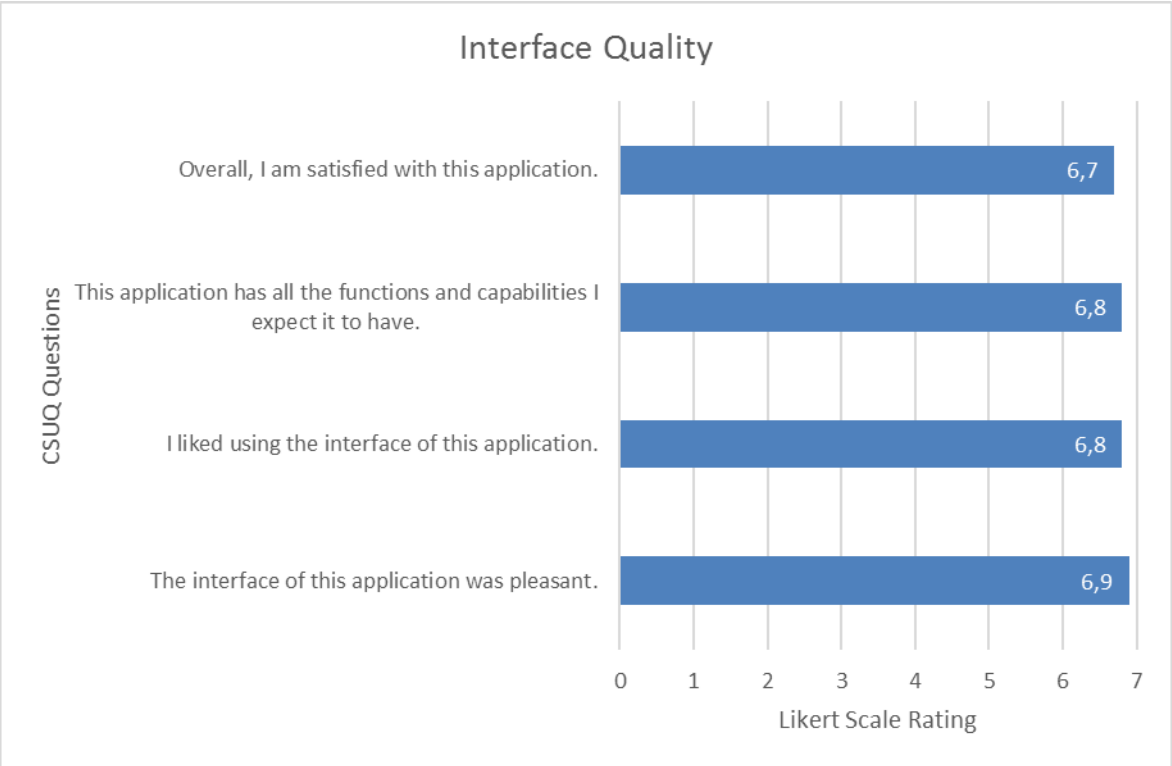



Figure 5.11: Average Interface Quality Response

### 5.3.4 Qualitative Results

The qualitative results were obtained from the last three questions in the questionnaire filled out by the participants (Appendix E). For each of the questions, only critical and recurring statements are presented as these statements will have the most impact on the prototype.

The positive aspects of the application, indicated by the participants are presented in Table 5.1. The comments are sorted in descending order of frequency. The User Interface (UI) of the prototype received the most response as a positive aspect, which confirms the results obtained from the CSUQ (Section 5.3.3). The participants also felt that the application was easy to use. The feature of changing the radii in order to view more or fewer POI's was mentioned by two of the participants, indicating that they felt it was a helpful feature to include. Lastly, two of the participants thought that the application was accurate in terms of the positioning of the POI's with their GPS coordinates.

| **Statement** | **Frequency** |
|---|---|
| Pleasant UI | 7 |
| Easy to use | 4 |
| Changing of Radii | 2 |
| Accurate Info (GPS) | 2 |

Table 5.1: Positive Qualitative Results

The negative aspect of the prototype, indicated by the participants are presented in Table 5.2. There were only two common negative aspects. The first negative aspect was the fact that the participants could not click on the Site marker to view the details. This aspect being mentioned three times, confirms that the participants expect this to be a feature and justifies the number of errors and time taken for Task 7 as discussed in Section 5.3.3. The only other common negative aspect evident in the qualitative results was that the application was not always accurate, causing the POI's to be displayed slightly off screen or be slightly unstable. This is an interesting result as in Table 5.1, there is evidence that some participants found it accurate. This is important as it indicates that either the participants have different ratings of accuracy or the application is not always consistent with regards to how accurately it performs.

| **Statement** | **Frequency** |
|---|---|
| Couldn't click Site marker | 3 |
| POI Moved off the screen / Slightly Jumpy | 2 |

Table 5.2: Negative Qualitative Results

The last qualitative data that was collected were suggestions from the participants to improve the prototype. The two main suggestions that would impact the usability of the application were:

- Be able to click a Site's marker
- Specify minimum length of the password

These suggestions could help the user's find the application easier to use as well as more intuitive, making them important to implement.

## 5.4 Changes Implemented

Due to the number of errors and the time taken for the participants to view the details of a Site (Section 5.3.2), as well as the negative aspects and suggestions form the participants (Section 5.3.2), an additional functionality was added to the prototype. The ability to tap on a Site's marker when the corresponding POI's are collated into their Site's marker was added. By tapping the Site marker, the description of the Site is displayed to the user. If this feature was present in the original application, it would have decreased both the number of errors as well as the length of time to complete Task 7. In order to try improve the information quality of the application, specifically regarding the error messages provided, the error dialogues in the login/create account screen were altered to be more descriptive. Additional hints were also provided to indicate the length of the password. No other changes were made directly to the prototype, however, future work for the prototype is proposed in Chapter 6.

## 5.5 Conclusion

This chapter provided the method and results of the evaluation conducted on the prototype outlined in Chapter 4, concluding the fourth activity and fifth activities of the DSR methodology (Section 1.7), demonstrating and evaluating the artefact, respectively. The prototype was evaluated by means of an observational usability study consisting of a convenience sample of ten participants. Four metrics were measured from the CSUQ as well as performance and qualitative metrics collected. The data was analysed, presented and discussed. It was concluded that overall, the participants were satisfied with the application as a whole and regarded the UI to be pleasant, the application easy to use and were satisfied with the functionality provided by the prototype. The changes made due to the results of the analysis and suggestions from the participants were also highlighted. The next Chapter serves as a concluding chapter and reviews the process followed and evaluates the goals set out in Section 1.4. Any future work pertaining to this project is also discussed.

# Chapter 6

# Conclusions and Recommendations

## 6.1 Introduction

The objective of this project was to develop a generic mobile Augmented Reality (AR) prototype as stated in Section 1.4. The database was to determine what information was to be displayed depending on where the user is. This chapter provides an overview of the process followed in the order depicted by the preceding chapters. The limitations of the prototype are then highlighted followed by suggestions for further development relating to the domain of the project.

## 6.2 Overview

The overview below discusses the phases of the project as presented in the preceding chapters. Each of the phases pertains to one or two activities of the Design Science Research (DSR) Methodology discussed in Section 1.7.

### 6.2.1 Literature Review

The literature review (Section 2.2) and extant systems review (Section 2.3) formed the relevance cycle in the DSR methodology as well as the first activity, explicating the problem. The purpose of the literature review was to gather information regarding the domain of the project. Methods and categories of AR were described which would serve as valuable knowledge when designing the proposed application in Chapter 3. Additionally, the review of extant systems helped get a better conceptual model of how AR applications function as well as identifying the different features of various applications. The literature and extant systems reviews further defined the scope of the prototype to be developed. The location based method was to be used to create an AR browser that would fall in the captioning category of AR.

### 6.2.2 Analysis and Design

The analysis and design of the application in Chapter 3 enters the Design Cycle of the DSR methodology as well as completes the second activity, outlining the artefact and defining the requirements. Requirements elicitation was performed by means of an interview and focus group (Section 3.2). The functional requirements for the proposed application were then outlined (Section 3.3). The chapter also initialised the third activity in the DSR methodology by providing a proposed design for the artefact (Section 3.4). The design of the proposed application provided the suggested application architecture (Section 3.4.1) as well as the initially proposed User Interface (UI) of the prototype (Section 3.4.2).

### 6.2.3 Implementation

The details of the implementation of the prototype provided in Chapter 4 completed the third activity of the DSR methodology. The implementation tools (Section 4.2) were discussed followed by a discussion on the implementation of the three components. The first being augmentation (Section 4.3.1), followed by data communication (Section 4.3.2) and ending off with the final user interface (Section 4.3.3).

### 6.2.4 Evaluation

The evaluation of the prototype developed, discussed in Chapter 5, completed the final two activities of the DSR methodology, demonstrating and evaluating the artefact. The evaluation plan was outlined (Section 5.2), indicating the method, tools, and metrics being evaluated. The observational usability study was then held and the results presented (Section 5.3). The results for performance (Section 5.3.2), the Computer Systems Usability Questionnaire (Section 5.3.3) and qualitative results (Section 5.3.4) were presented and discussed. It was concluded that overall, the participants were satisfied with the prototype and the features it supported and specifically thought the UI of the prototype was appealing. Based on the results, changes to the prototype were implemented (Section 5.4) in order to improve the usability of the prototype.

## 6.3 Limitations

Due to the nature of the project, there are two main limitations on the running of the prototype developed. The first limitation is that the prototype was developed for Android devices with a minimum version of 5.1.1. Some of the additional libraries used (Section 4.2.4) will not work for versions lower than 5.1.1. The other limitation of the prototype is that a connection to Nelson Mandela Metropolitan University's (NMMU) Virtual Private Network (VPN) is needed. The

need for the connection to the VPN is due to the database and web server (Section 4.3.2) being hosted on NMMU's server.

## 6.4 Future Development

Recommendations for future development related to the domain of this project are to use the other methods (Section 2.2.2) and categories (Section 2.2.3) of AR to compliment the features of the prototype developed. The implementation of the prototype made use of the location based method. Making use of image processing to determine the POI's in direct line of sight of a user could be investigated further and combined with the location based implementation in order to make use of the hybrid method. Currently the prototype falls under the captioning AR category and could be extended to the navigation category if augmented direction to a POI were implemented instead of the directions via Google Maps.

These recommendations could either extend the current prototype or be implemented and evaluated as separate prototypes serving a different purpose.

## 6.5 Conclusion

A generic mobile AR application was developed and evaluated that aided in displaying nearby POI's dependant on a users' geographical location. Users can view details of a POI by means of various media. The details of a POI are dependant on the Role the user takes on and can be changed by the user at will. The generic ability of the prototype is unique to AR applications and can be considered context aware. Due to the application solely relying on the data in the database, the prototype developed could easily be used in any scenario by simply adding the relevant data into the database. The prototype is scalable to any scenario and the generic nature ensures it could be used for in any setting. The objectives of the project were met and the evaluation indicated that the overall satisfaction, usability, information quality and interface quality were all of a high standard. For these reasons, the prototype can be considered successful.

**- The End -**

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# A Project Proposal



| | |
|---|---|
| **Proposer:** | Bradley van Tonder |
| **Project no:** | 2011/06 |
| **Title:** | **AUGMENTED REALITY MOBILE CAMPUS GUIDE** |
| **Supervisor(s):** | Janet Wesson, Dieter Vogts |
| **User(s):** | NMMU Students |
| **Pre-requisite(s):** | |
| **Best suited for degree** | ☑ BSc ☑ BCom ☐ BCom IS ☐ Not specific |
| **Implementation tool(s):** | Android or Apple iOS |
| **Priority:** | C |
| **Comments:** | |
| **Project Goal:** | The aim of this project is to develop a mobile campus guide application which provides users with an augmented reality view of the NMMU campus. |

**Description:**

An Augmented Reality (AR) system supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world (Azuma *et al.* 2001). Augmented reality systems typically overlay virtual objects or information on a real world visual display. AR applications have traditionally relied on computer vision algorithms to keep track of where the user is looking (see ARToolkit).

Mobile phones are increasingly equipped with the necessary sensors to enable mobile augmented reality applications to be implemented without the need for complicated computer vision algorithms. Mobile AR applications typically employ a combination of the phone's camera (to provide the real world view), GPS sensor (to determine location), digital compass (to determine what direction you are facing) and accelerometer and gyroscope (to determine orientation and field of view). Examples of currently available mobile AR applications include Wikitude and Layar (Figure 1), both of which overlay information on a real world display. Information about points of interest, restaurant reviews or Wikipedia articles are examples of information that has been overlaid on the camera display in mobile AR applications.

This project would involve the development of a prototype mobile AR application for the NMMU campus. The application would allow users to point their phone at university buildings and view information about the buildings (e.g. description, building number, which departments are in that building, links to department web pages and contact information). The application could also be extended to work indoors, although this would require the use of additional positioning methods (e.g. WiFi positioning), as GPS does not work well indoors.

Current research trends regarding mobile AR include investigating the best way to present information and to interact with this information (Mulloni *et al.* 2010; Schienke *et al.* 2010). This project will investigate different techniques for presenting information in a mobile augmented reality system. The final application would be evaluated in a user study to evaluate alternative information presentation techniques.

**Figure 1. Screenshot of Layar, a mobile augmented reality application**

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6. LAYAR, www.layar.com

# B Task List

## GenAR User Evaluation Task List

Task 1

**Create an Account.**

Task 2

**Find the Human Movement Science (HMS) building.**

Task 3

**View the details for Building 123.**

Task 4

**Find Route 67.**

Task 5

**Change detailed radius to 10km in the settings.**

Task 6

**Get directions to the Fish Bird Sculpture at Route 67.**

Task 7

**View a description of the Site 'Route 67'.**

Task 8

**Disable the site 'Route 67'.**

Task 9

**Change your role to a Technician at NMMU *[Access key = NMMUTech]*.**

Task 10

**View the details for Building 123.**

End of evaluation. Thank you for participating. Feel free to explore the application some more before completing the questionnaire.

# C Ethical Clearance

Nelson Mandela Metropolitan University

for tomorrow

**Faculty RTI Committee** (**Faculty of Science)**
Tel: +27 (0) 41 5042268
E-mail: lynette.roodt@nmmu.ac.za

**Ref: H15-SCI-CSS-003**

Contact person: Mrs L Roodt

Date: 1 April 2015

Dear Dr Vogts

**TITLE OF PROJECT: USABILITY EVALUATION OF HONOURS DEVELOPMENTAL AND NON-DEVELOPMENTAL (OR A COMBINATION THEREOF) PROJECTS - REFER TO APPENDIX 5 FOR LIST OF STUDENTS AND PROJECT TITLES**

**PRP**: Dr Vogts
**PI:** Honours Students

Your above-entitled application was considered and approved by the Sub-Committee for Ethics in the Faculty of Science on 1 April 2015

The Ethics clearance reference number is H15-SCI-CSS-003 and is valid for three years. Please inform the Committee, via your faculty officer, if any changes (particularly in the methodology) occur during this time.

*An annual affirmation to the effect that the protocols in use are still those, for which approval was granted, will be required from you. You will be reminded timeously of this responsibility, and will receive the necessary documentation well in advance of any deadline.*

We wish you well with the project. Please inform your co-investigators of the outcome, and convey our best wishes.

Yours sincerely

**Lynette Roodt**
**Manager: Faculty Administrator**
**Faculty of Science**

# D Participant Consent Form

## NELSON MANDELA METROPOLITAN UNIVERSITY

INFORMATION AND INFORMED CONSENT FORM REFERENCE: H15-SCICSS-003

| RESEARCHER'S DETAILS | |
|---|---|
| **Title of the research project** | **A Generic Mobile Augmented Reality Application** |
| **Principal investigator** | **Dean Gifford** |
| **Address** | **Department of Computing Sciences, University Way, Summerstrand** |
| **Postal Code** | **6031** |

| THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT: | | |
|---|---|---|
| 2.1 | **Aim:** | The aim of the project is to investigate the use of a mobile augmented reality application to help users identify nearby points of interest. |
| 2.2 | **Procedures:** | I understand that I am required to use the application to evaluate it by means of completing prescribed tasks, while the evaluator records my interaction (both audio and video) with the application. In addition, I will complete a post-test questionnaire. |
| 2.3 | **Risks:** | There are no risks attached to this project. |
| 2.4 | **Possible benefits:** | There are no benefits attached to this project. |
| 2.5 | **Confidentiality:** | My identity will not be revealed in any discussion, description or scientific publications by the investigators. |
| 2.6 | **Access to findings:** | Any new information or benefit that develops during the course of the study will be shared on request. |
| 2.7 | **Observation:** | Observations may be obtained through evaluator observation, and analysed to enhance the usability evaluation. |
| 2.8 | **Voluntary participation / refusal / discontinuation:** | My participation is entirely voluntary. My decision whether or not to participate will not affect me in any way. |
| 3. | The information above was explained to me/the participant by Dean Gifford in English and I am in command of this language. I was given the opportunity to ask questions and all these questions were answered satisfactorily. No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalisation. Participation in this study will not result in any additional cost to myself. | |

| **I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT**: | |
|---|---|
| Signed/confirmed at PORT ELIZABETH on 2015 | |
| *Signature of participant* | *Signature of witness:*<br><br>*Full name of witness:* |

# E Complete Questionnaire

## GenAR User Evaluation

User: _____

1. **Overall, I am satisfied with how easy it is to use this application.**
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

2. **It was simple to use this application.**
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

3. **I could effectively complete the tasks and scenarios using this application.**
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

4. **I was able to complete the tasks and scenarios quickly using this application.**
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

5. **I was able to efficiently complete the tasks and scenarios using this application.**
   *Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

6. **I felt comfortable using this application.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

7. **It was easy to learn to use this application.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

8. **I believe I could become productive quickly using this application.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

9. **The application gave error messages that clearly told me how to fix problems.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

10. **Whenever I made a mistake using the application, I could recover easily and quickly.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

11. **The information (such as online help, on-screen messages, and other documentation) provided with this application was clear.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

12. **It was easy to find the information I needed.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

13. **The information was effective in helping me complete the tasks and scenarios.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

14. **The information provided for the application was easy to understand.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

15. **The interface of this application was pleasant.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

16. **The organization of information on the application screens was clear.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

17. **I liked using the interface of this application.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

18. **This application has all the functions and capabilities I expect it to have.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

19. **Overall, I am satisfied with this application.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

20. **I feel the application was accurate.**
(In terms of the GPS)
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

21. **I am experienced with using mobile applications.**
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Strongly Disagree | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Strongly Agree |

22. **Pick the option that best describes your experience with the Andorid operating system**
*Mark only one oval.*

- ◯ No experience
- ◯ Somewhat Exerienced
- ◯ Very Experienced

23. **Select your gender**
*Mark only one oval.*

- ◯ Male
- ◯ Female

24. **Select your age group**
*Mark only one oval.*

- ◯ 18 - 21
- ◯ 22 - 25
- ◯ 25 - 30
- ◯ 31 +

25. **Comment on any aspects you liked about the application**

26. **Comment on any aspects you did not liked about the application**

27. **List any recommendations to improve the application**

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