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Development and Evaluation of an Augmented Reality Tourist Map Application Case Study: Berlin

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A dissertation presented in partial fulfillment of the requirements for the degree of Master of Science in the Department of Geomatics, Computer Science and Mathematics, Stuttgart University of Applied Sciences

Declaration

The following Master thesis was prepared in my own words without any additional help. All used sources of literature are listed at the end of the thesis.

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Stuttgart, 20.09.2012 Yasmin Dadas

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Approved by: Prof. Dr.-Ing. Volker Coors

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ABSTRACT

Augmented Reality is a technology supplementing reality with virtual 3D data in real time. It is becoming a part of everyday life, as the developments in smartphone industry are drastically increasing, making smartphones a common technology. Mobile phones are not anymore used only for communication, but also provide services in music, Internet, navigation, games and tourism fields. One of the trending uses of smartphones is the mobile tourist guides. These applications provide vast amount of information in a compact form, visualizing it using alternative modes of display like multimedia, visual aids. Moreover these applications offer navigation functions, which traditional maps fail to provide. Although these applications have certain advantages over traditional modes, there have been studies implying that they still fail to completely replace paper maps. The main inconvenience of smartphones is the limited screen size, which makes it difficult to visualize large amount of information in an understandable manner and makes map applications unclear to understand.

This study aims to develop a sample tourist guide application that overlays paper maps with digital applications, combining the advantages of both. Moreover a survey is conducted in order to examine the feasibility of such applications.

Keywords: Augmented Reality, Paper Maps, Mobile Applications, Tourism

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ABBREVIATIONS

ADT	Android Development Tools
Android NDK	Android Native Development Kit
Android SDK	Android Software Development Kit
API	Application Programming Interface
AR	Augmented Reality
CityGML	City Geography Markup Language
DoF	Degrees of Freedom
DVM	Dalvik Virtual Machine
Eclipse IDE	Eclipse Integrated Development Environment
GPL	General Public License
GPS	Global Positioning System
HMD	Head Mounted Display
LoD	Level of Detail
MAR	Mobile Augmented Reality
XML	Extensible Markup Language

CHAPTER 1

1 INTRODUCTION

Developments in recent years have greatly broadened the usage of Augmented Reality. There are increasing number of AR projects in medicine, games, entertainment, tourism, interior decorating, industry, military, architecture and urban planning sectors. However, some of these fields require mobility and availability of the tools anywhere and anytime. Emergence of smartphones and advancements in their operating powers and integrated tools such as cameras, GPS sensors, acceleration, compass and gyroscopes have greatly influenced Mobile Augmented Reality applications and AR became part of daily life.

Mobile Augmented Reality is considered to be one of the fastest growing research areas for AR applications. Although still facing with technical difficulties, MAR applications are being used broadly in number of fields. One of the most promising application areas of MAR is tourism. Digital tourist guides offer various attractions in terms of presentation, quality and amount of information. These applications can employ videos, images, texts or symbols to visualize related information such as tourist attractions, restaurants, transportation network, weather, ATMs, etc.

There are plenty of theoretical and empirical studies regarding whether electronic maps are completely replacing paper maps or not. Even though digital maps have become commonplace in many fields, there is still a valid argument suggesting that map applications on mobile devices are not one of them. Studies investigating the efficiency of using digital map applications in mobile devices propose that the small display screen of smartphones is causing inconveniences to users in terms of map clarity and limited size for information display. A research conducted by Ishikawa et al. (2008) suggest that larger displays provide a better tool for people to orient themselves, locate their destinations and plan a route to their destinations.

In light of this information, this study focuses on developing a system that combines the best of paper plans and digital applications. A tourist guide application is developed that uses paper maps as base map and overlays digital information, which is accessed through a mobile device. Moreover, evaluation is done via a survey to measure the feasibility of an integrated approach and to discover preferences of tourists in tourism activities.

In this case, a sample tourist guide that overlays 3D models of landmarks in Berlin over a paper map is developed in Android platform using ARToolKit framework. Afterwards a target group is selected and a questionnaire is conducted to measure the public response. Finally results were evaluated and some inferences were made.

1.1 Problem Statement

There have been various projects developed to bring alternative approaches to tourist experience. Extents of what these projects offer are increasing as smartphones become commonplace. Mobile tourist guides are broadly used by lot of tourists due to the wide range of information they offer. Peres at al (2011) state that the mobile tourist guides have been regarded as one of the most promising technology while they provide mobility and access to variety of interactive information. On one hand, mobile tourist guides are enhancing the tourist experience by providing dynamic information in compact form with alternative display options and modes of services. On the other hand, traditional paper maps and guidebooks are providing convenient, easy to understand information. Both systems have advantages and disadvantages over the other one. A valid argument discussed by Pauschert et al. (2010) state that even though mobile tourist guides contain greater amount of information and provide better services than traditional paper maps, these applications can be insufficient in terms of map and information display due to the limited display size of smartphones.

Pauschert et al. (2010) examine the advantages and disadvantages of using analogue maps and digital maps as follows:

Analogue Maps		**Digital Maps**	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Provide a better overview/ orientation of the area of interest	Not dynamic	Provide access to larger amount of information in a compact form	Limited to battery, network connection
Easily accessible	Difficult to improve	Provide access to alternative modes of display (multimedia, visual aids)	Small display size
Clear	Limited information	Provide access to alternative modes of services (navigation, route guiding)	Difficult to get an overview of the area of interest
Easy to understand	No feedback	Provide access to dynamic information	More complex to use
Better resolution		Possible to get feedback	Unclear
Cheap		Provide internet access	Expensive

Table 1: Affordances of paper maps and electronic devices (Pauschert et al., 2010)

Moreover, Brown and Chalmers (2003), draw attention to the fact that tourists often travel with groups, collaborate around maps and guidebooks. Smartphones with small displays however, would not be a convenient tool to gather around.

It should also be considered that reaching to certain destinations is not always the main concern. Learning cities and discovering some districts is a common wish of tourists. Brown and Chalmers (2003) also state that paper maps are optimal for tourists to walk around in the city providing directional information, without having a specific target to reach. This is an important benefit of paper maps, since a part of the tourism activities is to discover the city districts. Moreover, educational aspect of paper maps should also be considered. Paper maps are often used as a learning tool to memorize the places by looking at the street names, landmarks and after a point having enough information to walk around without maps. When people want to measure or estimate distances between places, it is likely that small display size of smartphones will not be able to display the positions in question in the same view. This decreases the clarity of the map, and the accuracy of estimations. Paper maps however, provides a good overview of the areas, resulting in better estimations of distances and directions. (Dillemuth, 2009)

However, mobile applications provide variety of services in more comprehensive manner. Yovcheva et al. discusses services that are provided by mobile AR applications as follows:

- *“provide access to location based information, relevant to the immediate surroundings of tourists*
- *enable access to variable content, which is timely and updated*
- *flexible in terms of delivering text, video, or images and provide interactive annotations which are integrated with map-based services and additional information”*

There have been alternative approaches to overcome these deficiencies. A significant strategy that this study also embraces is an integrated approach of paper maps and mobile tourist applications. Combining the advantages of paper maps and mobile applications and eliminating the disadvantages could be the answer of an optimal system. This study investigates the feasibility of such combined approach by developing an application which projects 3D models of points of interests via mobile device over a paper map. Feasibility of this approach is measured by investigating the public response.

1.2 Significance of the Research

It is essential to understand how tourists organize their activities in order to be able to develop an optimal approach to enhance their travels. This study investigates tourist activities from various aspects, providing a comprehensive analysis.

Although there have been studies regarding a collaborative use paper maps with digital applications, there is currently a significant gap between high-tech and low-tech tourism in practice. Tourists have been forced to choose either one of the systems or they try to combine advantageous tools of both systems manually.

This study aims to develop a system that would not only provide a more enjoyable and convenient tourist experience, but also would provide a more sustainable system that could be updated and used in the long run.

Moreover, the comprehensive evaluation provides a better understanding on people's opinion about an integrated approach. It is essential to spot the inadequacies in state of art in tourism tools in order to answer to the needs of tourists.

1.3 Objectives

The overall aim of this study is to develop and evaluate a sample tourist guide application that integrates paper plans with digital information. The project is a development and an evaluation project, which gives equal importance both to the sample project and the questionnaire.

The sample tourist guide is projecting 3D models of attraction points over the markers on paper maps via mobile devices. This could be considered as the first step of the project, which will be improved and will consist of additional functionalities. The project is bringing a new approach to mobile tourist guides by showing 3D models of attraction points over paper maps. Due to time limitations additional functionalities could not be developed in the scope of this master thesis.

The survey is conducted in order to measure the attractiveness of the project and feasibility of a collaborative use of traditional analogue maps with digital applications. A guided questionnaire is chosen as the survey method and small groups of tourists have been interviewed. The questionnaire aims at questioning people's preferences regarding paper map and smartphone usage during travels, opinions about the sample project and the additional functionalities that can be integrated.

Following objectives are set to achieve the overall aim of the study:

- To develop an alternative tourist guide application combining the advantages of paper plans and mobile applications. The project is a sample project not an end product, which requires further developments
- To examine the feasibility of an integrated approach of paper maps and digital information
- To evaluate the public response to the application
- To find out the opinions about additional functionalities that would be integrated in the application

1.4 Area of the Study

Berlin is chosen as the study area, which is located in northeastern Germany. The capital city of Germany; Berlin has witnessed many historical milestones, which altered the city in a unique manner. The urban-form, architecture and the social life of the city have a distinct character, making the city a highlight for tourism throughout the world. As a result, Berlin provides an optimal test case in the scope of this study.

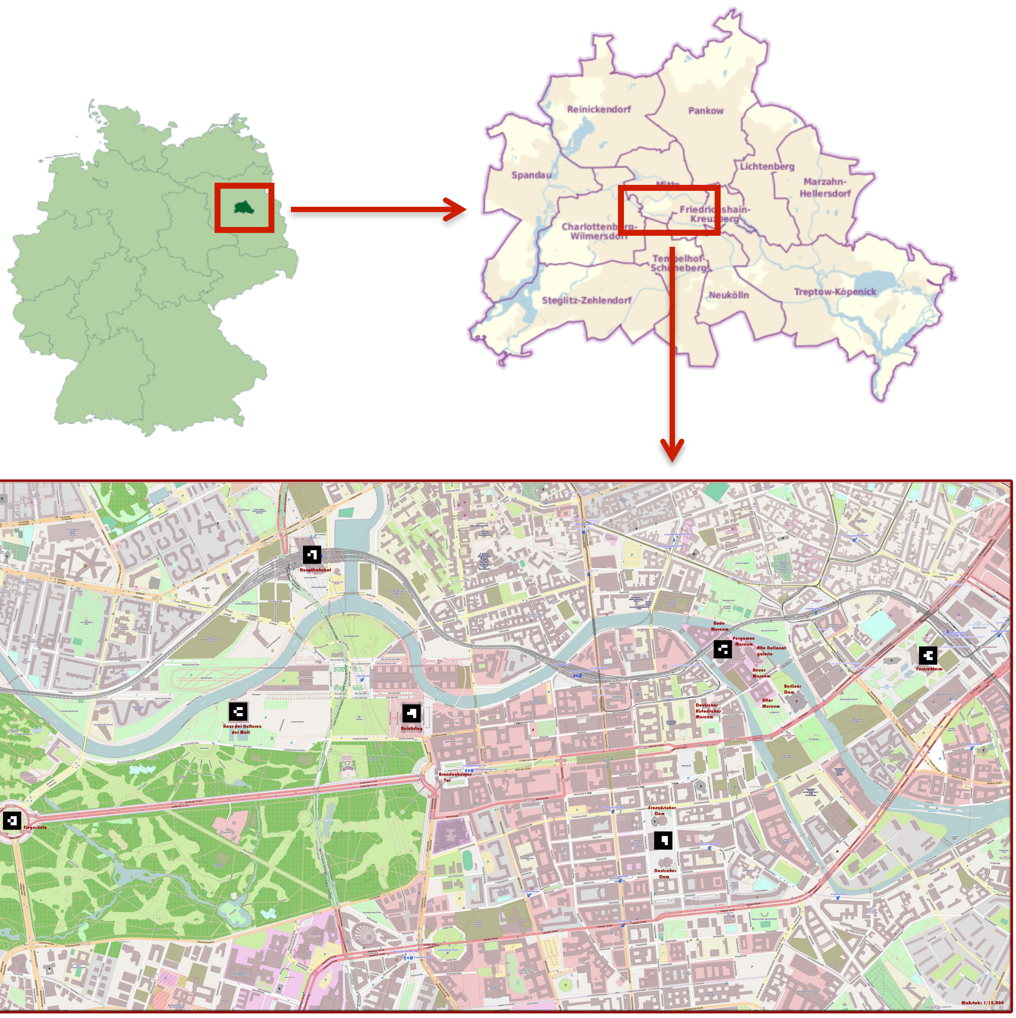


Figure 1: Area of Study, (Wikipedia)

1.5 Data, Software and Hardware

The main data source that is used for this project is the ARToolKit framework, which is broadly used for marker based Augmented Reality applications. The framework also provides 2D barcode markers, which has high compatibility with the application resulting in high accuracy detection. ARToolKit library is consisting of both Java based and native libraries, sample applications showing various functionalities.

3D models of landmarks of Berlin are downloaded from Google Warehouse. The models were downloaded in Sketchup format (.skp) and then corrected and exported into Alias Wavefront Obj (.obj) format.

The base map that is used for the project is an OpenStreetMap map for Berlin historical city center.

Data	Source
ARToolKit for Android	ARToolWorks Inc
3D Models	Trimble Warehouse
2D Barcode Markers	ARToolWorks 2D barcode marker generator
Paper plan	OpenStreetMap

Table 2: Data used in the study

The project uses Android platform with Android SDK, on Eclipse development environment with Android ADK and Java Development Kit (JDK), Android NDK. ARToolKit framework is used in order to develop the sample application; Berlin3dAR.

Google SketchUpPro is used in order to correct and export the 3D models of landmarks. A custom 3D model of the application is also designed in SketchUpPro.

Moreover the logo of the application and its marker is designed and drawn in Adobe Photoshop and Adobe Illustrator.

The paper map is obtained from OpenStreetMaps and corrected and designed in Adobe Photoshop.

The questionnaire results were analyzed in IBM SPSS, which provides various tools for analysis.

Software	**Purpose**
Eclipse IDE with Android ADK and JDK	Developing the application
Sketchup Pro	Editing models and converting to obj format
Autodesk Maya	Editing obj models
Adobe Illustrator	Designing and editing markers
Adobe Photoshop	Designing the application logo and the paper map
IBM SPSS Statistics	Analyzing questionnaires, visualizing results

Table 3: Software used in the study

Mobile device that is used to develop the sample application is Motorola XOOM MZ606 Tablet, with 1 GB RAM, 5 MP camera, Dual-core 1 GHz Cortex-A9-CPU, Android OS v3.1, sensors such as accelerometer, gyro, barometer, compass and GPS.

1.6 Thesis Structure

This study is organized in eight main chapters.

Chapter 1 provides an overview of the thesis starting with problem statement, significance of the research and objectives of the study. Moreover, brief information about the study area and, data and software employed in the study are also presented.

Chapter 2 describes the background information of the study area, including Augmented Reality, and its' fundamentals.

Chapter 3 reviews existing research and the survey in the study area.

Chapter 4 focuses on providing an overview of the fundamental tools that are employed for the application development.

Chapter 5 provides a methodology of the study that is divided into two sections, application development and evaluation.

Chapter 6 describes the process of developing the application, challenges faced during the process; and provides conclusions.

Chapter 7 explains the process of creating the questionnaire, implementation of the questionnaire. Then it elaborately evaluates the results of the survey.

Chapter 8 combines the inferences derived from application and questionnaire and provides and overall evaluation.

Chapter 9 returns the initial research questions and interprets the findings. It sums up the results of application and survey, and presents conclusions derived. An overall summary of the research and recommendations are provided in this chapter.

CHAPTER 2

2 BACKGROUND

This chapter focuses on providing background information regarding Augmented Reality technologies. In order to fully understand the context of this study, explanations regarding the tools and systems employed in Augmented Reality should be explained.

2.1 Definition and Basic Principles

Augmented Reality is an extension of virtual reality, which is supplementing the reality by adding a new layer of virtual information. A common definition of Augmented Reality put forth by Ronald Azuma (1997) as:

"AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it."

Moreover Ronald Azuma states that there are three essential characteristics that needed to be fulfilled in order to consider a system an AR system. These characteristics are:

- Combining real and virtual world: New layer of virtual information, which can also be referred as artificially generated graphics is overlaid with reality to enrich the reality. In order to overlay virtual data over real world, several display alternatives can be selected

- Interactive in real time: The artificial information that is presented to the user should be generated and presented in real time and is affected from the changes in environment

- Registered in 3D: The graphical information that is to be presented should be combined in 3D, which means it should have an exact correspondence between virtual and real environments. This is achieved through tracking, which calculates the position of the user relative to his environment

Milgram et. al (1994) propose the concept of “Reality-Virtuality Continuum”, which represents on one side the real environment, on the other a virtual environment. In between there is a continuous spectrum where either virtual data is supplementing the real world, like in AR, or where real world data is supplementing a virtual environment, like with physically interactive gaming consoles such as the Nintendo Wii. While virtual reality is replacing the world; AR enhances the world, giving a great opportunity to create a new version of reality interacting with superimposed graphics, audio and other sense enhancements.

Figure 2: Milgram’s Reality-Virtuality Continuum, Milgram et. al (1994)

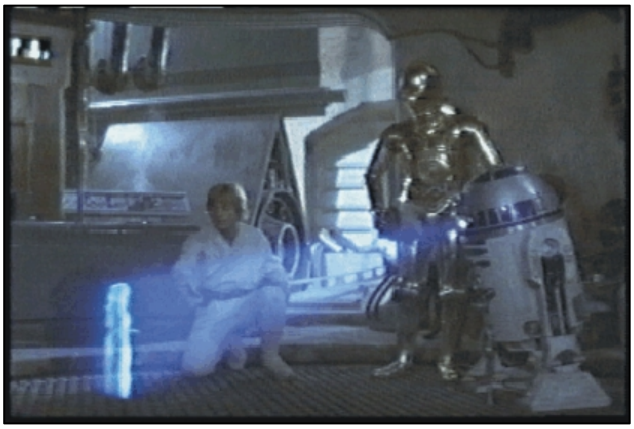


Figure 3: Representation of an AR system

An example of combining virtual information with real world data would be from Star Wars movie; R2-D2’s spatial projection of Princess Leia. Although the idea represents an AR example, the implementation in the movie is just an illusion. (Bimber and Raskar, 2005) Holographic projection to visualize the virtual information might be realized in the future for AR applications, but for now display systems need to be employed. These systems will be explained in the following section.

2.2 Display

In order to visualize the Augmented Reality systems, there are three display categories available, namely optical see-through, video see-through systems, projection based systems.

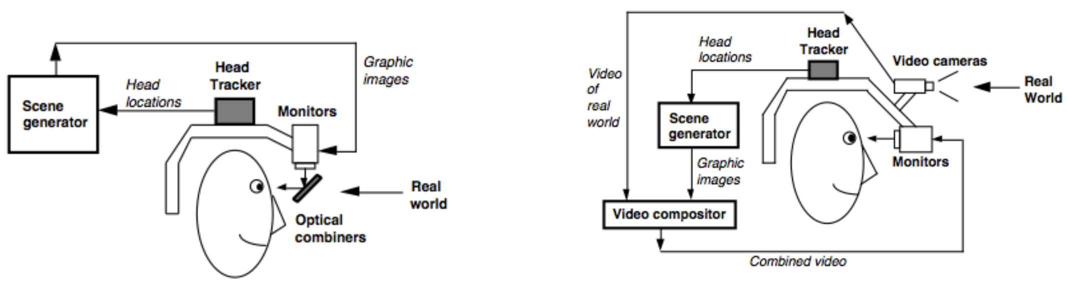
Optical see-through systems uses semi transparent mirrors as optical combiners that projects virtual data over real worldview. The real worldview is obtained via looking through the semi transparent glasses. Optical see through systems provide the advantage of showing high resolution of real world directly. Moreover, user can still see the real world in case of a power cut. On the other hand the semi-transparent display reduces the amount of light transmitted from real world to user's eyes. (Azuma, 1997, Henrysson, 2007)

Video see-through systems work with closed viewed displays and one or two video cameras. It first blends the real world data and virtual data and then projects it through the display to the user. Video see-through system, superimpose the real world images with graphical augmentations through a video display, resulting in a delay in the view. The amount of light transmitted is not reduced in video see-through systems. Moreover brightness and contrast of virtual objects blends with real environment. Since the reality is visualized through a display, the resolution decreases. (Henrysson, 2007, Azuma, 1997, van Krevelen and Poelman, 2010)

Third option to visualize AR applications is to use projection based systems. These systems projects graphics over real world using calibrated projectors. They are able to provide large field of view. However they require low brightness and contrast and a special background to project the graphics on it. These conditions can be realized mostly in indoor environments. (Henrysson, 2007, van Krevelen and Poelman, 2010)

In order to visualize AR systems using either optical or video see-through or projection based systems, there are three display categories; Head Mounted Displays (HMD), hand-held displays and stationary displays.

Head Mounted Displays requires users to carry a display system in front of the eyes like glasses. These systems are broadly used in AR applications and can either be optical or video see-through systems. Due to the limitations of the display screen the resolution of the view and field of view are limited in these systems. (Bimber, Raskar, 2005)



(a) Optical see-through HMD *(b) Video see-through HMD*

Figure 4: Working principle of Optical and Video see-through HMD (Azuma, 1997)

Another display option for AR is hand-held systems, which are tablet PCs, personal digital assistants (PDAs), and smartphones. The use of hand-held systems are getting broader as the computational power of mobile devices increases, making it possible to operate mobile AR applications. These systems mostly use video see-through displays, in which the virtual information is combined with live video streams of the environment prior to the projection. However, it is still challenging to operate applications that require high computational power in smartphones. Moreover the limited screen size of most hand-held devices restricts the field of view. (Bimber, Raskar, 2005)

Finally, stationary display can be used to project AR applications. These systems use PC monitors, or advanced 3D spatial displays fixed in space, which does not support portability. As a result they cannot be used in mobile applications. However, they provide higher quality and more realism compared to HDMs or hand-held systems. This is due to the fact that they are operated in controlled environments and have higher computational powers. Moreover projectors can be used for display purposes for larger areas. (Henrysson, 2007)

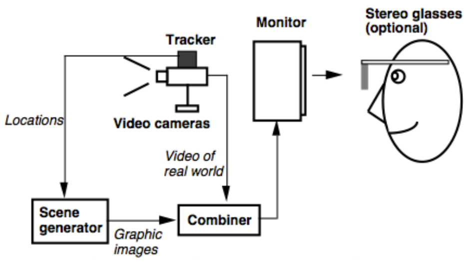


Figure 5: Working principle of stationary display (Azuma, 1997)

2.3 Tracking Techniques

Augmented Reality systems project virtual information over real world objects. In order to position the virtual information aligned with a specific real world object; the exact position of the real world object, and/or its relative position to the camera needs to be known. This process is called tracking and there are several tracking methods to calculate the position of the camera relative to the real world object.

These tracking methods; namely sensor-based, marker-based and feature-based tracking systems, will be explained in this section.

These systems can either require inside-out tracking or outside-in tracking. Inside-out tracking means that the sensor is attached to the user and the signal emitters to fixed points in the environment. Inside-out tracking is most commonly used method, which is employed in mobile Augmented Reality applications. Outside-in tracking is working other way around meaning the user is wearing/carrying the emitters and the sensors are attached to the environment. Outside-in tracking is mostly applied in human motion capturing applications. (Mehling, 2006)

2.3.1 Sensor Based Tracking

There are various sensors like GPS, ultrasound, accelerometers, etc. that can be used for tracking. Although each system is using different kind of sensor, these tracking systems have something in common (Strickland, 2007):

- They detect six degrees of freedom (DoF), which are the object positions in x, y, z and object's orientation; yaw, pitch, roll
- Every tracking system generates a signal which is detected by a sensor, processed by CPU and transmitted to the display screen

There are alternative tracking systems like; mechanical tracking which rely on a physical connection between the target and a fixed reference point, acoustic tracking which uses transmitters to send ultrasonic waves and receivers to determine target's position and orientation, optical tracking which uses light to measure the position and orientation of the target, electromagnetic tracking which is based on electromagnetic coils generated by a transmitter and received by a receiver. (Poguntke, 2005)

These systems require special equipment as a result not used in common Augmented Reality applications. GPS systems integrated with digital compasses however, does not require any additional equipment than a smartphone, which contains both of the tools integrated inside. This results in widespread use of GPS systems in Augmented Reality applications. GPS systems will be explained more comprehensively in this section.

GPS + Compass Systems

These systems use the geographic (absolute) location of user, compass and accelerometer to determine position and the direction view of the mobile device. However, in most cases the accuracy of GPS is limited, resulting in imprecise measurements. It is beneficial in terms of accuracy, computational costs and processing time to combine several methods such as GPS system combined with feature tracking method. Using this integrated approach virtual data can be projected. It provides a direct view of reality, providing additional information to the objects that are shown on the screen. (Brauer, 2010), (Siltanen, 2012)

However, GPS reception is only available in outdoor environments. As a result an alternative solution is developed to use in indoor environments. The indoor systems are making use of either Bluetooth, WLAN positioning or inertial trackers such as gyroscopes and compasses, which provide local position of the user instead of global position. (Siltanen, 2012)

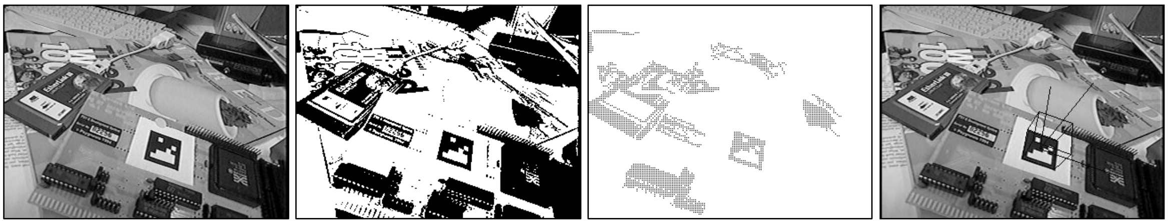
There is variety of mobile applications using these systems. An example would be “Wikitude”, a mobile AR application, which supplements the camera view of the mobile device by projecting information about the surrounding. It projects information about hotels, buildings, restaurants around users’ location, search for places or events, etc. It is using GPS, compass and accelerometer of the mobile device to find out the location and the line of sight of the camera, and then projects the related information. (Herdina M., 2012)

Morisson et al. (2011) uses an feature-based tracking approach combined with GPS in their study. It is a map-based project called MapLens, which operates on mobile platform. The project is described in detail in Chapter 3. This approach of combining GPS with feature based tracking is a promising approach since it reduces the processing need, which facilitates its’ use on mobile devices.

2.3.2 Marker-Based Tracking

Another option to determine the location of the user relative to the real world object is to use marker based tracking. Marker based tracking is widely used in AR applications due to low computational requirements, low costs and robust results. In marker base tracking, virtual objects are superimposed on top of fiducial markers. Fiducial markers are predefined in the system. They are easily recognized objects, which are placed in the real world and used as a point of reference. (Henrysson 2007)

Jun Rekimoto (1998) introduced a 2D matrix marker; square-shaped black and white markers using camera based 6 DoF tracking. Large number of objects can be tagged by encoding unique identifiers in 2D markers. The distortion of the marker is calculated in order to estimate the distance, rotation and tilt of the marker to the camera. With this information objects can be positioned relative to the marker so that they appear three-dimensionally on the screen.



(a)Original image (b)Binarization (c)Connected components analysis (d)Coordinate system estimation

Figure 6: The matrix code recognition process, (Rekimoto, 1998)

A similar approach has been used by ARToolKit framework, which is employed in this study. The key functionality of ARToolKit is that it calculates 3D pose position and orientation of the mobile device relative to the markers via video tracking capabilities. Then a virtual camera is positioned at the real camera location and the code of the markers is tracked. Finally 3D models are drawn over the markers. (ARToolKit Support Library)

The coordinate system used by ARToolKit is given as follows;

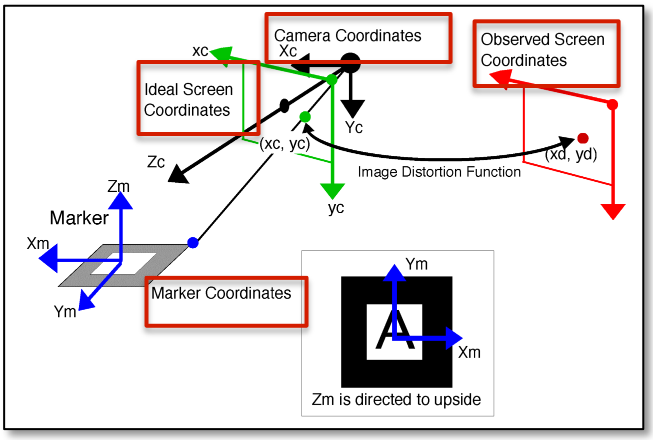


Figure 7: Graphical representation of relationships between the coordinate systems (Kato H., 2006)

There are three significant connections in the diagram that needs to be calculated. First one is the relationship between the camera and the marker coordinates (both in 3D), which is calculated via image analysis. The other two relationships are calculated via two-step camera calibration. They depend on the camera parameters and vary between different cameras. First one is the relationship between the camera coordinates (in 3D) and the ideal screen coordinates (in 2D) which is calculated via perspective projection. The second one is the relationship between the observed screen coordinates and the ideal screen coordinates calculated via image processing. (Kato and Billinghurst, 1999)

Furthermore there are other alternative markers used by different systems. Some examples to alternative square shaped markers would be ARTag, IGD (Institut Graphische Datenverarbeitung), SCR (Siemens Corporate Reaseach) and HOM (Hoffman marker) marker systems. (Zhang et al., 2002)

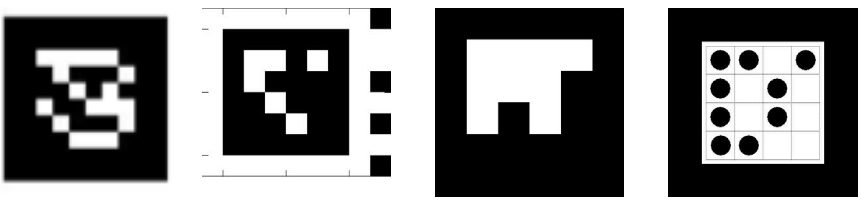


Figure 8: Sample markers, Left to right: ARTag ID Marker, HOM marker, IGD marker, SCR marker (Zhang et al., 2002)

Moreover, Wagner et al. (2008) introduce Studierstube Tracker, which is a marker tracking library that is developed to run on mobile devices. It supports 6 different marker types. The first three; namely template markers, ID markers and data matrix markers have similar principle to the above markers.

Figure 9: Sample markers, Left: Template marker, Middle: ID marker, Right: Data matrix marker (Studierstube Tracking Library Website)

However the other three; frame markers, split markers and dot markers define a new approach by aiming at reducing the size of the artificial features. Frame markers do not require any interior space and therefore can be filled with application specific artwork. The code is arranged in clockwise order, which allows determining the correct orientation of the marker. Split markers consist of two separate barcodes, which reduces the occupied area. Similar to frame markers, interior is not required for tracking. Dot markers consist of two-dimensional grid of black dots with white surroundings. They are well suited for tracking larger areas, such as maps. The texture inside of each four dots composing a grid cell is pre-computed. At runtime by using template matching, grid cells are detected and the camera pose relative to the grid is estimated. (Wagner et al., 2008)

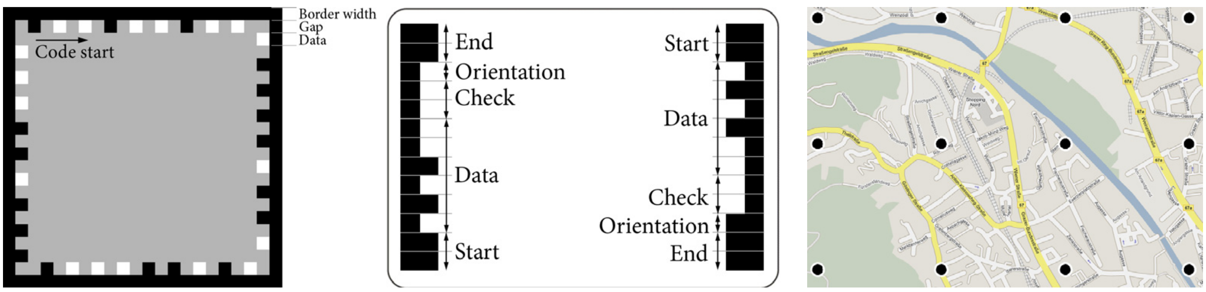


Figure 10: Sample markers, Left: Frame marker, Middle: Split marker, Right: DOT marker, (Wagner et al., 2008)

There are various projects, that are based on marker based tracking in Mobile Augmented Reality applications due to its' low computational requirements. An example study that is using ARToolKit markers would be AndAR project developed by Domhan (2010). It is a student project that visualizes 3D models over ARToolKit markers.

Billinghurst et al. (2001) propose a MagicBook application, which augments a child book with virtual information over ARToolKit markers. Project is using a handheld display, and is one of the pioneers of such a project designed for children. Similar projects can be observed more often nowadays, since the smartphones that are equipped with necessary tools are very common.

A similar approach can be seen in MusicAR student project, developed by Hauser in 2002. The project is an AR music game for children, enhancing their learning experience via projecting 3D models of different musicians playing instruments. It is developed on a desktop platform, but could easily be adopted in mobile platform. (Haller M., 2002)

Hecht et al. (2007) (Chapter 3) proposes a project called WikEye, which makes use of the DOT markers from Studierstube Tracking library in their map based mobile application. It is a promising approach since the more common markers are replaced with DOT markers, which is optimally designed for maps.

2.3.3 Feature Based Tracking

Instead of using markers, real objects can be used as “artificial markers” for tracking purposes. This system basically works like a marker system, but instead of markers real world objects, which are predefined on the database, are used. Also called markerless tracking, the system recognizes the registered objects when captured and overlays the corresponding digital data or object on it. Image matching, edge detection, finding interesting points methods are used to identify the images. Due to complex calculations, feature based tracking requires higher computational costs, compared to marker based tracking. (Brauer, 2010)

Model based tracking method is used broadly in feature-based tracking. Model based tracking is matching the 3D models in the database with the images captured by the camera. The main workflow can be summarized as follows; the system renders the 3D model, extracts the edges and then matches with the captured images. Moreover some systems use points, shapes or texture in addition to the edges for matching. (Reitmayr and Drummond, 2006)

Furthermore, tracking can also be done via matching with 2D images rather than 3D models, which requires rather less computational power. However, because of various lighting conditions and occlusions in the view, the robustness of the process is affected negatively in outdoor environments. In order to improve the results, the system is combined with a sensor providing gyroscope and accelerometer. Due to high computational power requirements, and high video capturing capabilities, which are not supported by mobile phones, these systems are mostly combined with other tracking methods such as GPS, magnetic tracking etc. It still remains the most challenging and yet most promising tracking method for Augmented Reality. (Bimber and Raskar, 2005)

Korah et al. (2011) develop a project, which uses simplified natural tracking methods on a Nokia phone. Project is aiming at detecting and estimating the stars on Hollywood Walk of Fame. The project is using natural outdoor urban features; stars of celebrities as markers and develops a recognition algorithm making use of image processing methods. The challenges of the project are mostly due to the changing lighting conditions, deformations and occlusions. Moreover, the system succeeds to be robust and efficient, which allows it to operate on mobile devices with limited processing power.

2.4 Application Areas

Augmented Reality technologies have been broadly used in variety of fields. Over years, more and more areas benefited from Augmented Reality. Fields such as military, medicine and industry are the first to implement AR technologies. A major benefit of AR is that it encourages collaborative environments by providing interactive visualization. This section provides brief information about some of the application areas of AR.

Medicine

One of the most important application areas of AR is medical diagnostics, support and therapy. There are many AR projects that overlays ultrasound, CT, and MR scans. AR provides an additional layer of graphical information directly projected over the patient, which provide a real time support in planning process of a surgery or in surgery trainings, which results in faster and safer procedures. Since medical applications require high degree of accuracy, AR is used more in planning process than during surgeries. (Fischer, 2006)

Military

AR is used in number of areas in military. It is employed for training purposes to generate cost-effective, realistic simulations, for navigation of vehicles in hostile areas, for provision of tactical information such as augmented maps, and for training purposes. (Tegtmeier, 2006)

Industry

AR provides great opportunities while planning, producing or repairing large, complex machines. It can guide the process of bringing the pieces together. Companies like Volkswagen, BMW are using AR technologies for simulations, construction and analyzing purposes. Moreover, complex machinery can be viewed with “x-ray vision” to assist the maintenance and restoration of the machines. (van Krevelen and Poelman, 2010)

Urban Planning, Architecture and Interior Design

Visualizing buildings with AR technologies is very advantageous while it allows architects or urban designers to present their designs three dimensionally, customers to see the product in the construction site. It enables discussing the plans and progress the data through a common visualization. Moreover it increases public participation by providing 3D realistic visualizations in construction sites, providing a better understanding of the projects. (Azuma, 1997)

AR can also be used in designing interior rooms, via superimposing virtual furniture. There are a number of companies, which allow the customers to choose furniture from digital catalogs and project it in their home. (Tegtmeier, 2006)

Entertainment

Entertainment sector is also benefited from AR technology. It is very common to see live sport broadcastings augmented with virtual information, to highlight hard-to-see details. Besides increasing number of projects are developed, which use AR systems enabling interactive games and new forms of advertising. AR games are more attractive while they augment gaming experience, allowing user to interact with the environment. Entertainment and theme parks are also using AR to create alternative attractions. (Siltanen, 2012)

Tourism

Another application area that uses AR broadly is tourism. Since mobility is really important in tourism activities, AR applications in tourism become more common with the broader use of smartphones. There are various kinds of tourist applications aiming at providing travelers useful information. Currently number of tourist guidebook companies provide guidance in digital form. Besides museum and art galleries are also using digital technologies to provide their visitors alternative exploration possibilities. Furthermore, virtual reconstruction of destroyed historic sites is gaining a great importance. These “Time Travel Tourism” applications visualize how the ancient ruins used to look like, making the visit a unique experience. (Brown and Chalmers, 2003, Fritz et al., 2005, FormFunction Digital Consultants)

CHAPTER 3

3 REVIEW ON RELATED RESEARCH

To understand the state of art in the study area, related projects and surveys about integrating MAR systems with analogue systems for tourism applications should be investigated. Considerable amount of projects and research have been published regarding the collaborative use of paper maps and mobile applications. Firstly, several projects that embrace an integrated approach are explained. Then some of the research in this field is expanded. The studies that are chosen to be explained either inspired the study or provide ideas about further development possibilities.

- **NavAD** (navigation and support through linkage of analogue and digital maps) project is developed as a joint project of Hochschule München and Hochschule für Technik Stuttgart and attracts the attention at the technological gap between analogue paper maps and electronic domain. (NavAD homepage)
  The project has the similar objectives as this study, meaning it also aims at combining the advantages of paper maps and mobile devices. It is using digitally enhanced paper maps, technology developed by Swedish company Anoto. A special pattern called Anoto pattern is printed on a common paper. It is a dot pattern using carbonaceous black ink making every position on the map unique, and giving every unique position a coordinate. An electronic pen, which has a Bluetooth connection with a mobile device, reads this pattern, in this case a Blackberry smartphone. Electronic pen reads the pattern and transfers the relative paper coordinates to the mobile device, which then sends it to the server. Server sends back the coordinates to the mobile device. Finally mobile device shows the virtual information to the user on the display window. There have been two scenarios developed to test the project, one of which is a sample tourist guide application. The tourist guide has been developed for Munich center, using a map taken from OpenStreetMaps. Design of the map is then adjusted to the needs of the pattern (no dark colors) in order to prevent interference of the dot pattern with map features. Small symbols have been placed on the map to access functions like “New route, “Where am I”. New route function uses GPS receiver of the mobile device to locate the user, the destination point given by the user via electronic pen and calculates a route, which is then shown on the display of the mobile device superimposed on the paper map. Where am I function is using a similar approach to show the current location of the user. Further functions include local searches for attraction points, hotels, restaurants, bars for a certain area selected with the electronic pen. (Pauschert et al., 2010)
  The project is still on an early stage and facing with some limitations such as high costs of electronic pen and Anoto paper pattern, making it difficult to be used broadly.

Still, the project provides an alternative approach to combine paper maps with digital applications, which is a very promising development.

- **MapLens** is an Augmented Reality application providing a collaborative use of maps and mobile applications. It is developed for Nokia smartphones using Symbian OS S60. Application uses camera and the display of the phone and combines it with a paper map. GPS of the mobile device is used to determine the location of the user. Then a tracking technology with sub pixel accuracy is used to determine the geographical coordinates of the visible portion of the paper map. This georeferencing process is implemented through a natural tracking method and pursues the following steps: Prior to the tracking a database with distinct feature points in a representative template image of the paper map is created. During tracking firstly these feature points are found in the live image captured by the camera. Then the distance, rotation and tilt of the phone with respect to the map are calculated using the comparison between live image feature points and the feature points in the database. Finally the data (photos and their metadata) is transferred from the database to the display window of the mobile phone overlaid with the paper map. Similar to NavAD, "You are here function" is also included. (Morrison et al., 2011)
  This project employs image-processing tools that can be similarly used in order to further develop the sample project that will be developed in this thesis.

- In their article **Mobile Map Interaction for Local News**, Janowicz and Schöning (2007) propose a system that provides local news of an area projected over paper maps. They argue that the combination of local scale high-resolution maps with mobile devices with adjustable information displays would be an optimal tool for tourists to obtain current news of a certain area. Moreover the proposed system also allows tourists to post news either in text form or images. Users can adjust their settings to get information about topics they are interested in or define a time frame to select recent news only. Physical maps are used as the background layer and the local news filtered by the selected criteria are projected through mobile device on map. The user can move the device over the map to get news about other areas.

- **WikEye**, Hecht et al. (2007) suggest a mobile tourist guide application integrating paper maps with Wikipedia content. They study Berlin as case study and develop the test application. When the user is moving the display screen over the map, Wikipedia content of the spatial objects in the area are visualized. The user can reach the information simply by clicking the Wikipedia symbol. Moreover the system allows users to get information about different time periods by rotating the device on camera axis. The system provides dynamic information via a transparent screen over a physical map, which is subdivided by grid of dots. These grids are replacing markers with less obvious signs for tracking, introducing more appealing, easy to read maps. Furthermore it is also stated that the next step would be replacing the grid dots with even less obvious signs such as horizontal and vertical lines, which is already present in most of the maps.

- Schöning et al. (2007) propose another project called **WikEar** based on WikEye study, which overlays paper maps with dynamic Wikipedia information in audio form. They argue that update costs of tourist guidebooks and mobile tourist guides can be really high and that they are only available for certain places and not for everywhere. Wikipedia content is however regularly updated and provides wide range of information for almost everywhere. Similarly to WikEye, WikEar also works with paper maps with grid dots. It provides a guided audio, narrative based tour between a start point and a destination point entered by the user. It is also possible not to use the tour functionality and get information about places only. It has the advantage of being flexible, meaning its not limited to prescribed tour paths. Both WikEye and WikEar projects are tested in Nokia phones. These projects provide great examples on how paper maps and mobile applications can be combined using alternative display options.

- Based on the importance of sustainable urban tourism, Isabel Micheel (2012) proposes a project called **eCOpenhagen**. The system is composed of a reusable city map (with a special reusable material) and a mobile guidebook application that communicates with the map via NFC (Near Field Communication) tags. The study differs from its counterparts in two aspects; the motivation of the study attracts the attention to the importance of sustainability in every aspect of life including tourism. Secondly the NFC technology that is employed in this study provides an alternative to markers. Broll and Hausen (2010) describe NFC technology as a radio-based technology, for short-range data exchange between reading devices. NFC tags that are used in the study are small microchips, which can store a small amount of information to transfer to another NFC-enabled device in this case an Android smartphone. The tags are placed on the back of the map and the device could read the information when its in 10 cm range to the chip.

- Norrie and Signer (2005), attract the attention to importance of paper maps during travels, in terms of their portable, cheap, robust, foldable structure. Moreover, paper maps do not depend on electric power, and allow travelling groups to collaborate around a map or a guidebook. However, authors also state that the digital maps and guides are enhancing the tourist experience by providing dynamic information in addition to static information. They propose an alternative system that provides a link between high-tech and low-tech tourism, retaining both systems working together. In order to realize digital augmented paper maps; and test this approach, they propose an algorithm, which is similar to the NavAD project. The project uses Anoto paper pattern for map, a digital pen and an earpiece for voice interaction. It is tested during Edinburgh Festivals in 2005. In addition to measuring the response to an integrated approach providing familiar tools such as navigation, locator, proximity or event tasks; this study also measures the public response to an alternative mode of data acquisition; namely the voice interaction. The project does not use any additional visual interface such as mobile devices. Authors state the overall response to the interactive map was positive even though many challenges remain in terms of the design and the sustaining technology. They also mention that the response was less positive about the voice interaction, but the authors depends this to the problems on voice interface and believe that the level of acceptance would increase when the system is improved.

- Julie Dillemuth (2009) investigates the impacts of having small display screens to visualize maps. The study is based on the hypothesis that viewing a section of a map at a time would have negative impact on peoples understanding of the area. In order to measure that, a survey is conducted with 80 people. Participants are divided into four groups. The first group had only 10% of a map visible at a time, second 25%, third 40% and the last 100%. Groups with small map extend needed to move the map within a bounding box in order to view the rest of the subject area. Each group had to answer series of questions about navigation and landmarks of a fictional city. The results revealed that the users with smaller display windows (10%, 25%) showed significantly worse accuracy on spatial relationships of landmarks to one another or in distance estimations. However, the difference between the 40% and 100% is not significant. The writer relates this to the fact that points of interests are not visible in the same view in small displays, which makes it difficult to relate them to each other. Moreover, participants who used bigger screens needed less time to answer the questions.

- Ishikawa et al. (2008), evaluate the way finding behavior of people to investigate the effectiveness of each system namely; paper maps, mobile devices equipped with GPS and direct experience of routes. The first group used a mobile device with small screen showing a map of the area with user's current position and a route to the destination, which is updated dynamically. The second group used a paper map showing the starting point and the destination point. The third group walked the route once prior to the research with a person who is explaining the way. Each participant needed to walk the route alone in an unknown area, with the help of the tool they are given and their performance on way finding tasks and accuracy of their knowledge about the route is measured. The results of the study showed that the participants using GPS were less effective in terms of speed, error, overall understanding of the area, while people using analogue maps showed significantly better results. The study suggests that having a larger display makes it easier for people to orient themselves, locate their destinations and plan a route to their destinations.

CHAPTER 4

4 FUNDEMENTALS

This chapter focuses on explaining the fundamentals of the study in terms of software, framework and data employed.

4.1 Mobile Augmented Reality

As explained in the previous sections, Augmented Reality applications can employ alternative tools for display and tracking purposes in variety of fields. This study focuses on Mobile Augmented Reality in tourism sector, using hand-held video see-through systems and marker based tracking.

Throughout years, there have been drastic improvements in Augmented Reality in desktop PC environments. However, introducing mobility to Augmented Reality applications greatly broadened its usage. There are various fields that require utilization of information at anytime and anywhere. Mobile Augmented Reality (MAR) allows users to use their mobile instrument as an interaction device.

As the mobile processing speed and battery power increase, using smartphones for AR applications became more feasible. They combine the capabilities that AR applications need such as GPS, compass, accelerometer, cameras, and Internet connection, so that there is no need to purchase special independent equipment. However, computing power of the mobile devices is still limited, which restricts the applications that can be adjusted in MAR field. In order to increase the usability, alternative methods are implemented. An example would be using tracking methods that require low processing power. As described in Section 2.3.2 marker based tracking requires low computational requirements, which results in its’ broad use in mobile applications. Moreover combined systems such as GPS and feature based tracking also helps to overcome computational challenges. (Schmalstieg D. and Wagner D., 2007)

Despite the inadequacies that MAR industry is facing right now, mobile applications offers a lot of possibilities in various fields such as games, entertainment sector, interior decorating, architecture and urban planning. Mobile Augmented Reality is still in its early development period. There is still a large gap between conceptual applications and those already developed, which means there are a lot of opportunities for future developments.

4.2 Development Environment

There are a number of operating systems to define the development possibilities for Mobile Augmented Reality applications. These operating systems are namely Android, iOS for Apple, Symbian, Research in Motion (RIM) for Blackberry, Microsoft's Windows Mobile. A survey conducted by Gartner (2012), shows the market shares of these operating systems as follows;

Figure 11: Worldwide Smartphone Sales to End Users by Operating System, Gartner (2012)

Right now the majority of the mobile AR applications are written in Android, which is mostly open source and not restricted to certain hardware, or in iOS, which is proprietary software for Apple's iPhone and iPad devices.

Android development environment is employed in this study. In order to understand the basic structure of Android, brief information will be given.

Android

Android is a Linux based operating system, developed by Open Handset Alliance; a consortium led by Google Inc. The majority of the Android software is licensed under Apache Software License, 2.0, allowing developers to access the framework APIs of the core applications. (*XDA Developers Portal*)

In order to develop Android applications, Android Software Development Kit (SDK), which contains the required utilities to develop applications, needs to be downloaded. Android SDK includes the tools and API's such as sample projects with source codes, debugger, libraries, device emulator, a virtual machine and tutorials that are needed to build Android applications.

Moreover, Eclipse IDE (Integrated Development Environment) with Android Development Tools (ADT) plug-in provides a user-friendly environment to build Android applications, which is also employed in this study. ADT plug-in allows the user to have access to SDK tools within Eclipse interface. *(Android Developer Homepage)*

Furthermore Android Native Development Kit (NDK) provides necessary tools to compile native codes in C/C++ into JNI-compatible native shared or static libraries. If the application is not using native codes, it is NDK does not need to be downloaded. *(Android NDK Documentation)* The framework that this study employs is a C/C++ based software, which uses native codes and uses JNI interface to reach the native codes. NDK tools are used to compile native codes into shared libraries.

4.3 Application Framework: ARToolKit

4.3.1 General Information

ARToolKit is the base of the AR framework that has been used for this study. It is a C/C++ based software library, which has been developed by the University of Washington. ARToolKit framework provides tracking functionality, allowing users to overlay virtual objects on the real world. In order to do so, the real camera position and orientation relative to the marker needed to be calculated. ARToolKit library uses computer vision algorithms to overcome this challenge *(ARToolWorks Support Library)*.

ARToolKit has an open source and commercial packages. Open source library for Augmented Reality applications are designed for computers, not for mobile devices and distributed under General Public License (GPL). Open source library was developed until May 2007.

The commercial license for ARToolKit on the other hand, provides up to date professional libraries, which gives higher level of support and customized libraries for desktop, web and mobile platforms.

In order to develop applications based on ARToolKit framework it is important to understand how it works. ARToolKit is using tracking functionality in order to calculate the position of the camera relative to the marker and then to overlay virtual objects onto the markers.

When the software is operated, firstly the camera records the video of the environment and converts each frame to black and white. Then the software identifies the square shapes on the frame in order to detect the marker. Once the outline of the marker is identified, the software looks for the pattern inside and matches it with the pre-defined pattern templates. When a match is found, the distance, rotation and tilt of the real video camera relative to the marker are calculated using the known square size and distortion of the marker and camera calibration. After calculating the real world coordinates and the orientation of the camera; the virtual object is rendered and drawn on top of the marker. *(ARToolKit Documentation)* The Figure 12 below is visualizing this process:

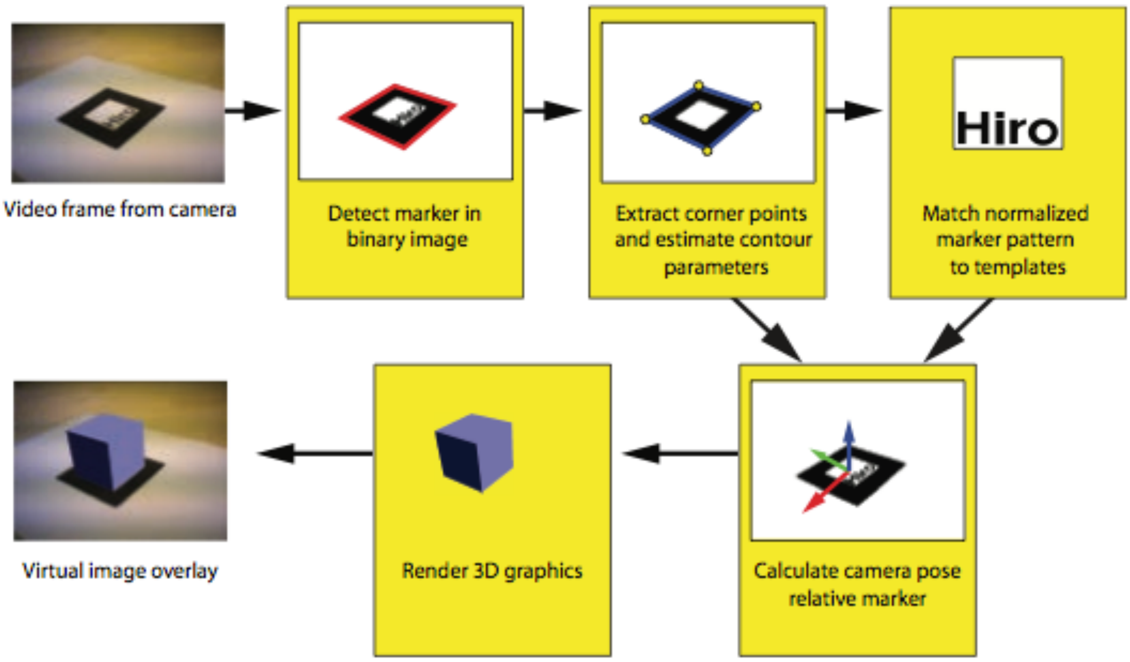


Figure 12: ARToolKit tracking workflow based on ARToolKit Documentation (Henrysson, 2007)

However, there are several limitations of ARToolKit software, which needed to be taken into account in the development process. *(ARToolKit Documentation)*

Firstly the marker needs to be completely visible in the display of the camera since the edges are being used to detect the camera coordinates and the pattern inside is used to find a match from the database. When a part of the marker is not visible to the camera, no virtual objects can be drawn. The orientation of the marker also affects the process. As the marker is becoming more horizontal, the pattern in the middle is becoming less visible, making the recognition more difficult.

Secondly, the distance of the camera from the marker is another important factor. If the marker is too far away from the camera, it will not have sufficient details to be recognized. The complexity of the marker plays an important role in this process. The more complex the marker is, the closer it should be located to the marker. Tracking ranges of the markers in relation to their sizes are given in the ARToolWorks support library as follows:

Pattern size (inch)	**Usable Range (inch)**
2,75 (7 cm)	16 (40,6 cm)
3,50 (8,9 cm)	25 (63,5 cm)
4,25 (86,4 cm)	34 (86,4 cm)
7,37 (127 cm)	50 (127 cm)

Table 4: Tracking range for different sized patterns (ARToolKit Project Homepage, How does ARToolKit Work?)

Finally the lighting conditions have a significant role in the recognition process. When there is a strong and direct light source in the environment creating shadows or reflections, or the marker is printed on a glossy paper, the software is having difficulties to recognize the markers. In order to reduce this negative effect, the paper should be matte, non-reflective. Moreover diffused lighting provides the optimal environment for more accurate recognition.

4.3.2 ARToolKit for Android

There are various products being developed by ARToolWorks, which are available for desktop, web and mobile platforms. The application built in this project is developed in Android platform. ARToolKit for Android is used in the context of this study.

In its core ARToolKit is based on C/C++, and consists of native shared or static libraries. In order to create ARToolKit applications on Android however, a Java interface is needed which loads the native libraries and links them to Java methods. As a result ARToolKit for Android is developed as a combination of both Java and C/C++. The SDK components of ARToolKit for Android are be explained in *ARToolKit Support Library* as follows:

ARToolKit core modules are native static libraries (.a files) providing greater control over the ARToolKit functions and contain five static libraries; libar (core AR functions), libarcip (Iterative Closest Point functions), libarmulti (multi-marker support), libeden (additional math and rendering functions), libgl (OpenGL functions for video texturing) These core libraries can be used to build shared libraries (.so files).

ARToolKitWrapper is a native C++ shared library consisting of a set of ARToolKit functions for initializing, adding markers, getting the projection matrix, querying transformations, and cleaning up at the end. It has a jni interface that is referencing the shared library to a java based android library, "ARBaseLib". That way ARToolKitWrapper can be called from Java and used within Android applications. ARToolKitWrapper classes are listed below in a hierarchical order:

AR Marker	Base class for supported marker types
MultiARMarker	Multiple marker type of ARMarker
SingleARMarker	Single marker type of ARMarker
AR Pattern	Information about a specific pattern
ARToolKit	Wrapper for ARToolKit functionality – initialization, maintenance of markers, adding and removing them and cleanup
Color	Simple color representation using four float values
VideoSource	Base class for different video source implementations
Android Video Source	Video input implementation for Android
ARToolKitVideoSource	Video source implementation using the ARToolKit arVideo module

Table 5: ARToolKitWrapper classes (ARToolKitWrapper Documentation)

ARBaseLib is a Java library, which is linking to ARToolKitWrapper, allowing the Android application to access the native libraries.

The most important classes of the ARBaseLib for this study are ARActivity and ARRenderer subclasses.

ARActivity subclass, organizes the view hierarchy that is to be displayed. It is explained in the ARBaseLib documentation that; "*ARActivity creates a camera preview surface and an OpenGL surface view, and arranges them in the user interface. It uses a FrameLayout to hold the Camera SurfaceView and GLSurfaceView and projects them on top of each other*."

ARRenderer subclass is explained in ARBaseLib documentation that; "*ARRenderer renders the AR scenes, checks to see if the marker detection is up and running before calling draw to ensure that the ARToolKit projection matrix and markers are ready to be used during rendering pass*."

The sample application is using ARToolKitWraper library for all the functions needed to run the application from initializing the application to deleting it at the end. However, the customizations in the application such as the markers and the models used, was made using custom made native library called Berlin3dARWrapper, which is explained in detail in Section 6.1.1.

ARBaseLib library is also used in the sample application to provide a link between native libraries and Java interface.

The relationship between ARBaseLib, ARToolKitWrapper and the android applications can be summarized with the following diagram. It represents a java development environment working together with ARBaseLib and ARToolKitWrapper libraries. Berlin3dAR application is using this schema.

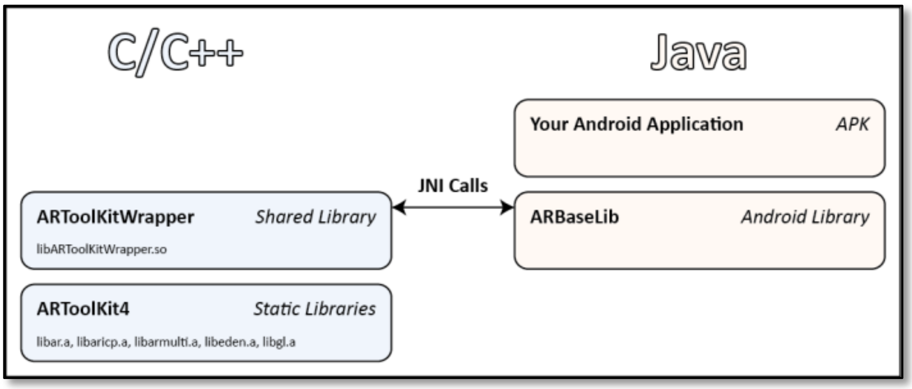


*Figure 13: Relationship between native libraries and Java interface of the application (*ARToolWorks Support Library)

4.4 Markers

As explained in the previous section, ARToolKit framework is using markers in order to identify the position of the user.

ARToolKit provides markers in square shaped patterns that are recognized and tracked by the application. The framework supports a great variety of markers as long as it follows certain rules: *(ARToolKit Support Library)*

Markers must be square shaped and must have continuous borders, which is by default 25% of the length. Borders are typically black or white. For better recognition; the marker should have contrast with the background. The area inside of the marker, which is called marker image, must look different and asymmetric from different angles, to allow the software to project the 3D model correctly on top of the marker.

Figure 14: Hiro sample marker provided by ARToolKit

An example of a marker provided by the framework can be seen in Figure 14. The sample pattern looks different from each side, therefore provides good results. However, the complexity of the marker causes problems in recognition, when the markers are used in small sizes. Colored marker images are supported as well as black and white image. However, it should be noted that recognition of colored markers are slower than black-white markers. ARToolKit provides a number of marker images but also allows users to design their own marker images.

Markers are used with pattern files, which can be defined as representation of the image, which usually has 16x16 grid in the interior, allowing 256 different intensities. These pattern files are used to distinguish different markers form each other. Inside of a pattern file four pre-rotated versions of the marker is stored, in order to ease detection from different angles. (Fiala, 2004) The orientation of the marker is also calculated using pattern files. As a result, 3D models can be projected correctly on the markers. For the markers employed in this study, pattern files needed to be generated using a tool provided by ARToolKit.

Even though various patterns are supported for the marker image, complex patterns result in higher computational costs, which slow down the process. When the application starts, the marker image of the captured marker is compared with all of the markers loaded in the system. As the size of the marker gets smaller, or the number of markers loaded in the application gets larger, it would become more difficult to detect the details and recognize the marker.

A certain set of markers created by ARToolKit, which has a special two-dimensional grid of black and white squares, provides faster tracking when the size of the markers are small or there are too many markers in the image. These markers are called 2D barcode markers and have simple, geometric patterns, which makes them easier to recognize.

Figure 15: 2D barcode markers, (ARToolWorks Support Library)
https://www.artoolworks.com/support/app/marker.php, [Accessed 16.08.2012]

Fiala (2004) investigates the effectiveness of ARToolKit markers. Author states that ARToolKit marker system has very successful and robust performance. However, he also mentions that inter-marker confusion, false positive detections, and false negative detections are often observed with ARToolKit markers, especially with small marker sizes. These problems are also observed in this study. Some alternatives to overcome this problem are presented in Section 6.3 and **Fehler! Verweisquelle konnte nicht gefunden werden.**.

4.5 3D Models

There is great variety of 3D model extensions, which are broadly used in 3D Graphics. Three of them are explained in the context of this project since they offer important functionalities in the scope of this study. These data models are namely; CityGML data based on XML, .obj - Alias / Wavefront Obj, and .skp - Sketchup Model.

4.5.1 CityGML

CityGML is an open XML-based, geospatial information model, which is commonly used for the representation of virtual 3D urban models. It is realized as an application schema for the Geography Markup Language. It aims at providing a cost-effective common standard model that defines the basic entities, attributes and relations of a 3D city model, therefore goes beyond just representing the 3D data. Digital Terrain Models, buildings, bridges, water bodies, transportation facilities and city furniture are represented in a CityGML dataset. This allows employment of 3D urban models for complex tasks in different application areas like city planning, architectural design, touristic and leisure activities, etc. (Stadler et al., 2009)

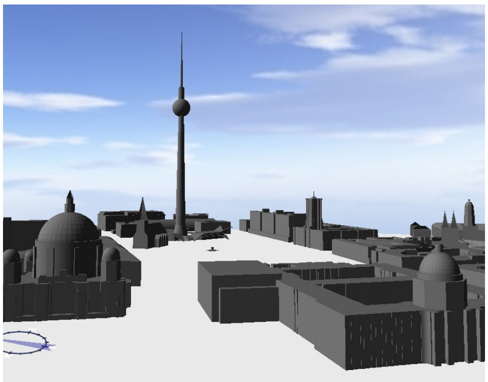


Figure 16: LoD2 representation of Alexander Platz, Berlin without textures http://www.citygml.org/index.php?id=1532, Accessed [12.08.2012]

Moreover, the data can be represented in five different levels of details (LoD), which also allows virtual 3D objects to have simultaneously different visualizations for different LoDs. LoD0 is two and a half dimensional Digital Terrain Model with or without an aerial image. LoD1 is prismatic buildings without roofs, while with LoD2 roof information is also included. Vegetation objects may also be included. LoD3 visualize vegetation and transportation components and buildings even more detailed with high-resolution textures. LoD4 includes interior space of buildings. The models can be visualized in one view with different levels of detail. (*OGC Inc., Candidate OpenGIS CityGML Implementation Specification*)

Data, which is stored in XML schema, can be exported into various file formats.

A citywide model of Berlin is available in LoD2. Moreover around 200 selected buildings are available in LoD3 and 5 buildings in LoD4. *(Berlin Business Location Center)* Berlin virtual 3D city model developed to provide efficient storage and fast processing. It is also possible to export the dataset into other formats. (Stadler et al., 2009)

These characteristics of CityGML make the dataset very beneficial for this study. Due to the limitations in the processing power of mobile devices, simple 3D models (LoD2) with fast processing were needed to obtain optimal results. However, the dataset is provided as a commercial product. Since it cannot be obtained free, it was not possible to use it for the sample project although it would have provided great opportunities.

4.5.2 Sketchup Models

Previously owned by Google and now by Trimble; Sketchup is a 3D modeling software optimized for architecture, city planning, mechanics, video game design fields. The file extension .skp is mostly used for intermediary purposes; meaning program provides a functionality to convert the 3D models into various data formats. There are free and professional versions of Sketchup, which are differentiated by the file formats they support. Free version of Sketchup supports to export models into .dae and .kmz file formats while Professional version supports .3ds, .dwg, .dxf, .fbx, .obj, .xsi and .wrl. *(http://en.wikipedia.org/wiki/SketchUp, Accessed [16.08.2012])*

An important functionality that Sketchup provides is that it is working together with the Trimble 3D Warehouse, which is a website that enables users to upload or download free 3D models. Therefore there is a large collection of 3D models, which can be downloaded by any user. However, since different users prepare the models, each model has its own style, which is not always matching with the others.

The framework that is used in this project is compatible with 3D models in obj format. Therefore, SketchupPro needed to be employed to convert skp models into obj file format. When exporting the models to .obj from Sketchup, .mtl file and texture data is automatically created.

4.5.3 Alias / Wavefront Obj

The obj file format initially developed by Wavefront Technologies and has become a universally accepted data format that represents 3D geometry. It supports lines, polygons, free-form curves and surfaces. Obj data have a companion file format called MTL (material libraries), which holds material descriptions inside. OBJ file can be stored in ASCII (.obj extension) or in binary format (.mod extension). Mtl file format is stored in ASCII format. The position of each vertex is stored by default counterclockwise. *(Clemson School of Computing, Lecture Notes, http://www.cs.clemson.edu/~dhouse/courses/405/docs/brief-obj-file-format.html [Accessed 18.08.2012])*

Components of an ".obj" file can be represented as follows;

(*http://www.fileformat.info/format/wavefrontobj/egff.htm, Accessed [12.08.2012]*)

- *Vertex data:* Geometric vertices (v), Texture vertices (vt), Vertex normal (vn)
- *Elements:* Point (p), Line (l), Face (f)
- *Grouping:* Group name (g), Object name (o)
- *Display / render attributes:* Color interpolation (c_interp), Dissolve interpolation (d_interp), Material name (usemtl), Material library (mtllib)

Components of a .mtl file: (*http://www.fileformat.info/format/material/, Accessed [12.08.2012]*)

- *Material color and illumination:* Ambient reflectivity (Ka), Diffuse reflectivity (Kd), Specular reflectivity (Ks), Transparency (d, Ty)

The Figure 17 and Figure 18 below demonstrates the structure of "Brandenburgertor" obj file and mtl file.

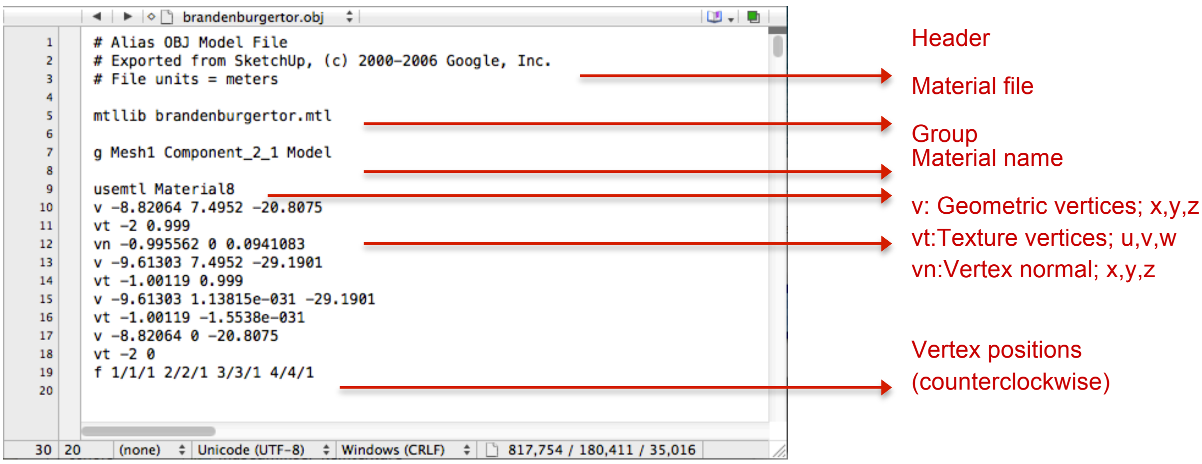


Figure 17: Example ".obj" file, Brandenburger Tor

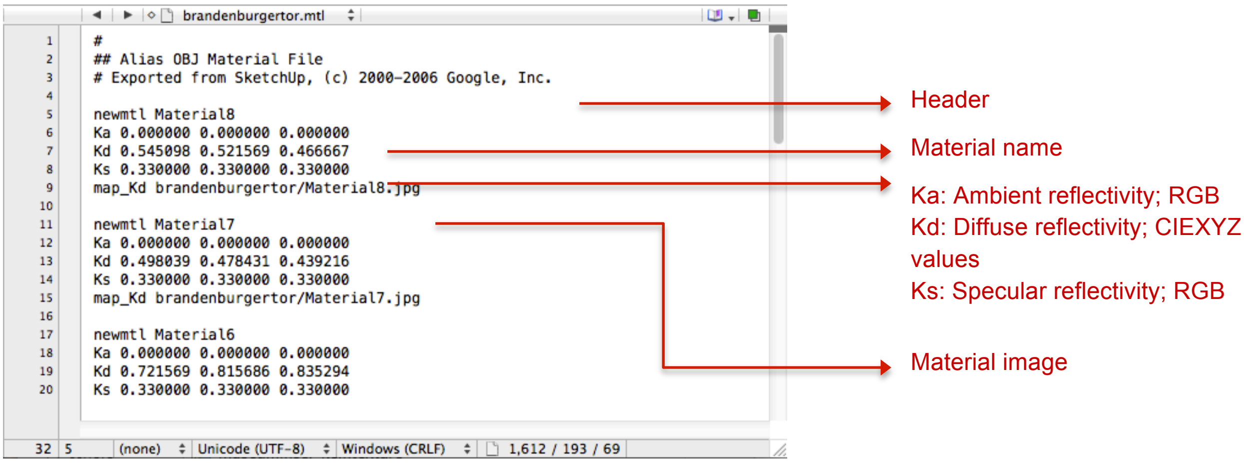


Figure 18: Example ".mtl" file, Brandenburger Tor

CHAPTER 5

5 METHODOLOGY

This chapter explains the workflow that was followed in the study. It covers the sequence of activities that were undertaken in two sections, first being for the application development and the second for the survey. However these two sections collaborate and complement each other. Procedural steps, actors involved, the required input, the tools needed in the process and the evaluation is described.

The study aims at developing and evaluating combined use of paper maps and smartphones in tourism activities. Furthermore it is intended to combine the advantages of both systems. For this purpose a prototype application is developed which overlays 3D models of attraction points with paper maps using markers. Afterwards a survey is conducted to evaluate the public response.

Overall the study seeks to address the following questions:

- Would it be feasible to develop a mobile tourist application that integrates 2D paper maps with smartphones?
- What is the current attitude of people towards paper maps and mobile tourist applications?
- What are the advantages and disadvantages of paper maps and mobile tourist applications?
- Would people find it interesting to have 3D visualization of landmarks?
- What kind of attributes would people want to have in such an application?
- What would be the advantages and disadvantages of a combined application?

The application is used as an intermediary tool to investigate the answers to these questions through a questionnaire.

Figure 19 below visualizes the general workflow that was followed. Each step uses the output of the previous step as an input.

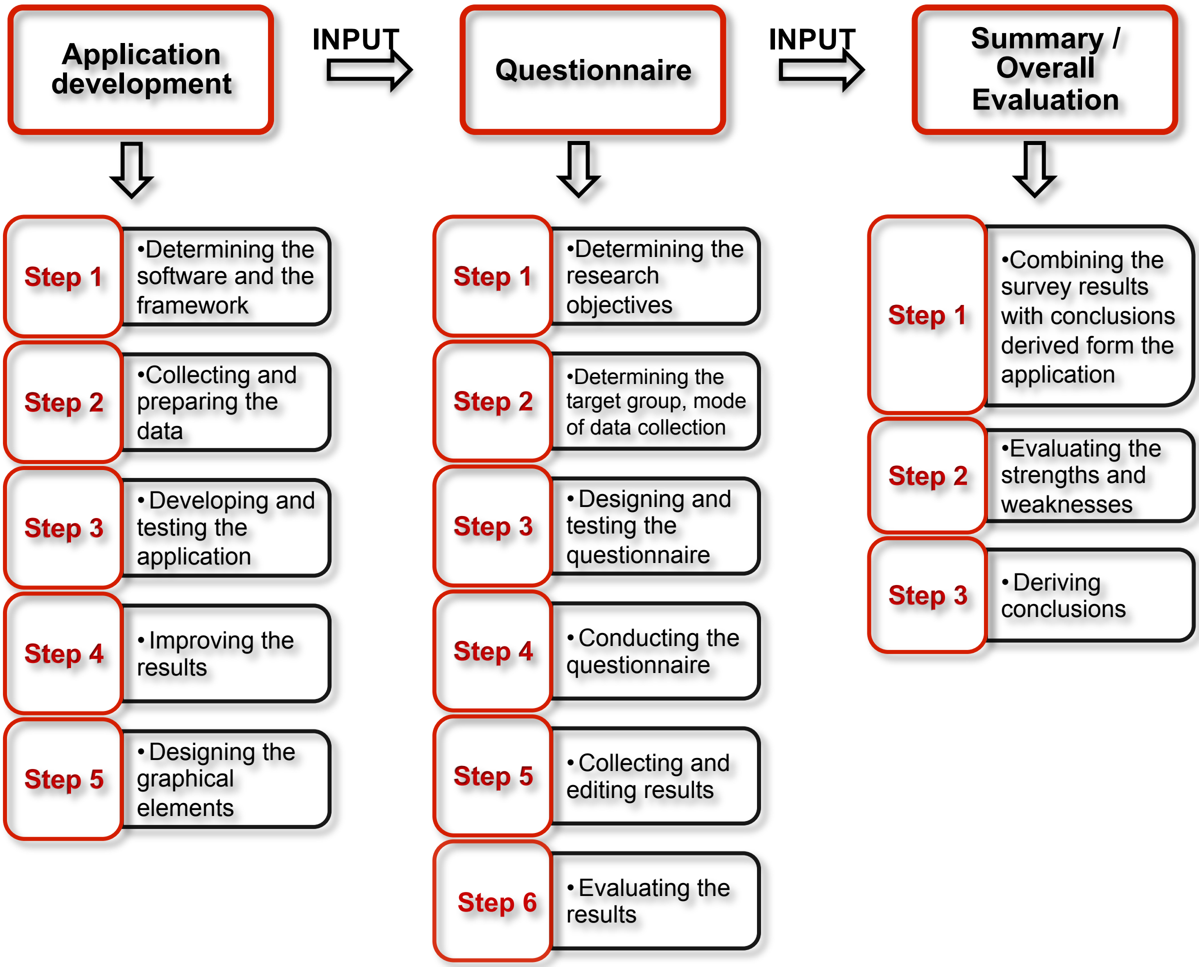


Figure 19: Overall workflow

The phases followed for the application development are described below:

- Determining and familiarizing with the software and, finding the appropriate framework

The application is developed in Android platform, which uses Eclipse with Android plug-ins. Prior to the application development process; it was essential to get familiar with the software. Moreover several frameworks were tested and ARToolKit was found the most efficient framework since it satisfies the objectives of the study, provides an up-to-date dataset and has an active support team.

- Collecting and preparing the data

Secondly the data needed is determined and collected. The most important input is the ARToolKit framework. Then the 3D models of landmarks needed to be obtained. The most convenient solution was to get the City-GML dataset for Berlin, which is a commercial product and cannot be obtained free of charge. As a result models are downloaded from Trimble Warehouse in .skp format and edited. Markers to be used are downloaded from ARToolWorks Support Library and prepared. Moreover, the map of Berlin is downloaded from OpenStreetMap.

- Developing and testing the application

After preparing the data needed, the application is developed and tested iteratively. The application was first tested with the sample models that are provided by the ARToolKit framework. Afterwards models of landmarks and markers are integrated into the code.

- Improving the results

Once the application was functioning, results are improved and some additional attributes are added. One important issue was regarding the size and the frequency of the markers. The aim is to use minimum number of markers and the size of the markers should be as small as possible. It was also observed that the size of the models affected the speed of the application. As a result, complex models are simplified. Furthermore, a custom marker and a 3D model are designed and integrated to the application.

- Designing the graphical elements

The last step was to design an application logo and the paper map design.

The phases followed for the survey are described below:

- Determining the research objectives

The questionnaire aims at measuring the feasibility of developing a project combining analogue maps with digital applications. In order to achieve this information a questionnaire is conducted. Prior to the questionnaire, the sample application is presented to the applicants to provide an overview about the topic

- Determining the target population and the mode of data collection

After determining the target population to conduct the questionnaire, the most efficient way to reach that group is evaluated. The target group is determined mainly as tourists in Berlin and also inhabitants of Berlin. Eighty people were interviewed during the process. The most effective alternative to conduct the survey is determined as guided street survey, which required one-to-one contact to attendants.

- Designing and testing the questionnaire

The questionnaire is prepared in English and German, and divided into three sections written in a simple, clear form. Firstly general information about people's travel habits is asked. Then their opinion about paper maps and mobile tourist guides is questioned. Finally a series of questions are asked regarding the application that is developed in this study. Since the errors can be caused by the poorly explained questions, preparation and pretesting stage is included to achieve reliable results.

- Conducting the questionnaire

Investigation is made through a street survey in several key tourist attraction points and university campuses. In order to provide a better overview of the study, a demonstration of the sample application is made and assistance is provided during the process.

- Collecting and editing results

Before analyzing the results incomplete or faulty questionnaires are eliminated. In order to detect and remove the errors, the questionnaires with extreme results were double-checked.

- Evaluating the results

Finally the results are transferred into SPSS; a data analysis program and evaluated elaborately.

In order to evaluate the results of the overall study, inferences derived from both application development and survey processes need to be combined. First inferences from the application development process regarding the utilization of the application are explained. While conducting the questionnaire, the prototype application was presented to the respondents. As a result, the application was tested in various environments; outdoors, indoors, sunny, cloudy etc. Besides inferences from the conversations with people provides an important opportunity to improve the application.

Furthermore, the questionnaire investigates the opinion of people regarding the application in depth. The results provide an overview of people’s preferences during tourism activities, their remarks on the application and wishes on how to improve the application.

By combining the results of the questionnaire with personal and technical inferences of the application, some further strategies are developed.

6 APPLICATION DEVELOPMENT

The main structure of the framework and data employed for the study is explained in the Chapter 4. This chapter focuses on the implementation of the application and explains tasks that are carried out to prepare the application. Firstly the application components such as the modifications on the framework, the preparation of markers, 3D models and paper plan are covered. Then visualizations of the application, challenges faced in the period and the conclusions are provided.

6.1 Application Components

6.1.1 Berlin3dAR Framework

As explained, this study employs Android Platform and ARToolKit framework to prepare the sample application. ARToolKit framework provides sample applications to provide guidance while developing applications. While developing Berlin3dAR, a sample application ARSimpleNativeCars, which uses native OBJ model loader is used for assistance. Figure 20 below, visualizes the steps followed to develop the Berlin3dAR application.

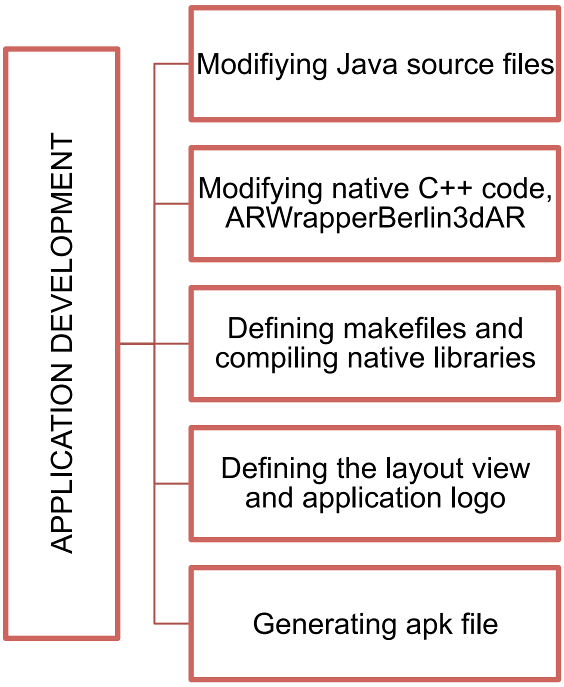


Figure 20: Workflow of the application development

The application is based on native libraries ARToolKitWrapper, ARWrapperBerlin3dAR and contains an obj loader. It connects to ARBaseLib library as the mediator between the native libraries and the Java interface and built in Android version 3.1.

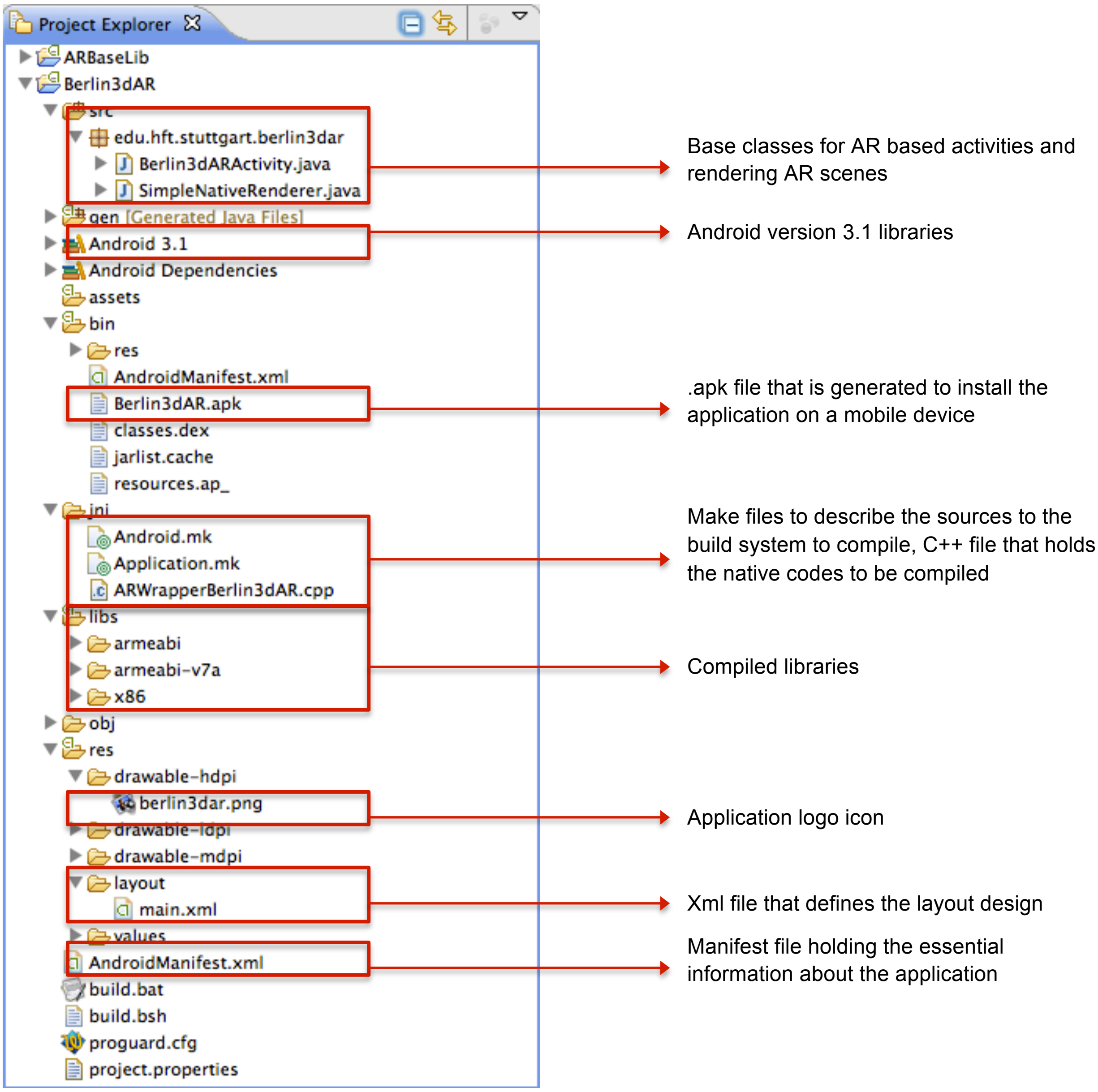


Figure 21: Main structure of the Berlin3dAR project

Source files

The Berlin3dAR application is consisting of two main classes: an Activity class and a Renderer Class. While the main activities are defined in ARBaseLib library that is provided by the framework, Berlin3dARActivity and SimpleNativeRenderer classes are used to reference to ARBaseLib library to have access to key java classes to run the application.

These two classes Berlin3dARActivity and SimpleNativeRenderer are created manually based on the SimpleNativeCars sample application. No major alterations were necessary. The only important change required was to include “ARWrapperBerlin3dAR” native library to the SimpleNativeRenderer class.

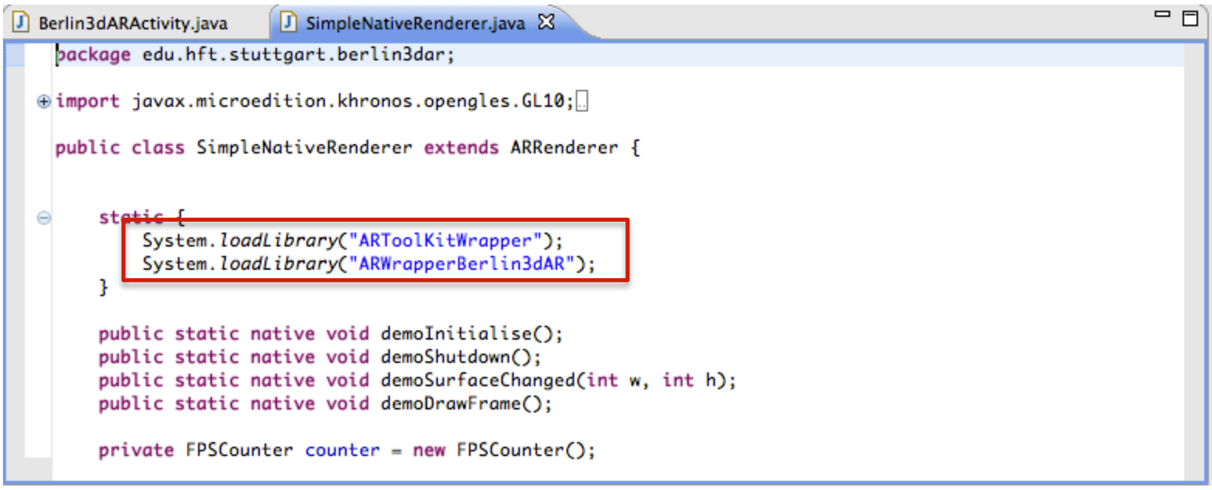


Figure 22: SimpleNativeRenderer java class

Native Codes

The ARToolKitWrapper is the core native library, which defines the functionalities from initialization of the application to cleaning up at the end. As it is explained in Section 4.3.2, the main workflow of the application is defined here. The library is used without any modifications for the project.

The major alterations are made in the native code **ARWrapperBerlin3dAR**, which defines more specific parts of the project.

Firstly the properties of the virtual light are set. Ambient and Diffuse lighting values and the position of the light were determined. The optimal lighting conditions were found after several try-outs as following:

```
static float lightAmbient[4] = {1.0f, 1.0f, 1.0f, 1.0f};
static float lightDiffuse[4] = {1.0f, 1.0f, 1.0f, 1.0f};
static float lightPosition[4] = {2.0f, 1.0f, 1.0f, 0.0f};
```

Secondly, 3D models to be loaded were defined manually inside of the native code. For each 3D model, a specific marker is assigned.

An array from 0 to 7 is created in order to define the paths, pattern files, scale and rotation for all of the eight models. The path of the models and the pattern files are defined in the array that is created for the models.

"single; Path to pattern file; Pattern width in mm"

```
models[1].patternID = arwAddMarker("single;/sdcard/AR/Data/patt.02;80");
models[1].obj = glmReadOBJ("/sdcard/AR/Data/models/tvturm.obj", 0);
glmScale(models[1].obj, 0.020f);
glmRotate(models[1].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
glmCreateArrays(models[1].obj, GLM_SMOOTH | GLM_MATERIAL | GLM_TEXTURE);
        models[1].visible = false;
```

Figure 23: Loading the models with markers, Native code, C++ file; ARWrapperBerlin3dAR

After loading the models, before shutting down the application, the models needs to be erased. This is done by defining the following array:

```
JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoShutdown(JNIEnv* env, jobject object)) {
        glmDelete(models[0].obj, 0);
        glmDelete(models[1].obj, 0);
        glmDelete(models[2].obj, 0);
        glmDelete(models[3].obj, 0);
        glmDelete(models[4].obj, 0);
        glmDelete(models[5].obj, 0);
        glmDelete(models[6].obj, 0);
        glmDelete(models[7].obj, 0);
}
```

Figure 24: Deleting the models, Native code, C++ file, ARWrapperBerlin3dAR

Native Libraries

After the native codes are edited, they are compiled using ndk-build function into shared libraries. The shared libraries are automatically created in three versions, "armeabi", "armeabi-v7a" and "x86", which are different versions of the same library. The device is selecting the supported version automatically at runtime. *(Android NDK Documentation)*

In order to generate shared libraries, following line in Figure 25 is written in to the "Terminal" window. The first part is the path to the ndk-build function and the second part is the path to the Berlin3dAR application file.

Documents/android/android-ndk-r8b/ndk-build -C Desktop/ARToolKit4Android-release6-2012-07-20/EclipseProjects/Berlin3dAR

Figure 25: The command in "Terminal" window to compile the native codes to shared libraries

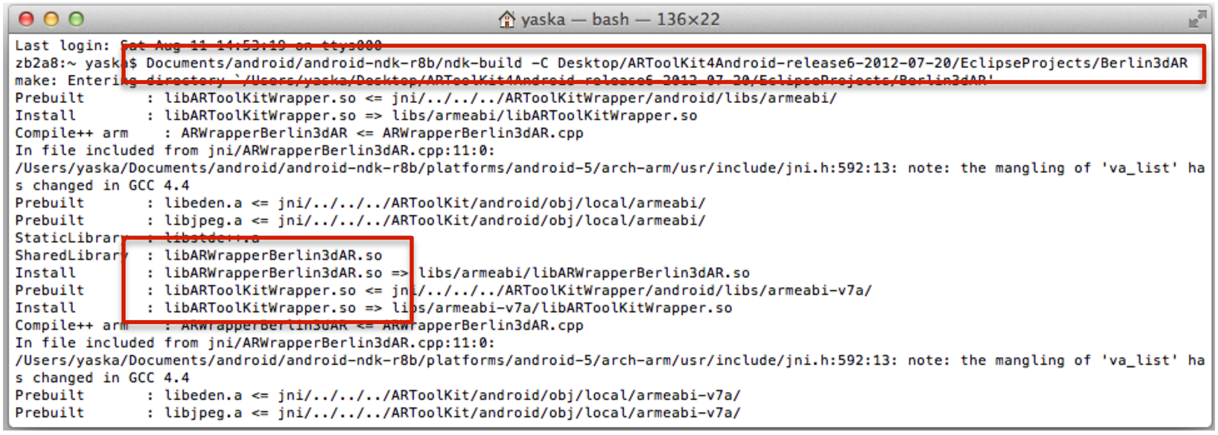


Figure 26: Terminal window showing the ndk-build function to compile source files to shared libraries

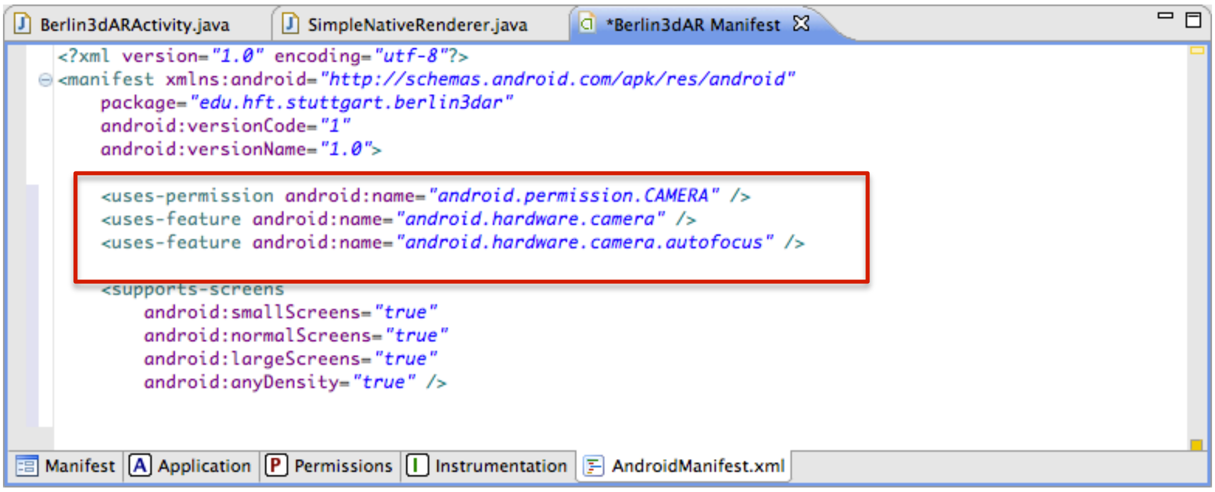
The ndk-build function compiles the native codes automatically using "Android.mk" and "Application.mk" files which defines the versions of compilation ("armeabi", "armeabi-v7a" and "x86"), and the location where they will be saved.

"Android.mk" and "Application.mk" files are provided by the framework. Only the name of the native codes to be compiled needed to be given manually.

Figure 27: "Android.mk" file

Permissions

The application requires permission to access camera and using its functionalities. This permission must be specified in application manifest file as follows:



Finally, when all modifications are made, and the libraries are created, the application is compiled and the apk file is loaded into the mobile device.

The Berlin3dAR application is compiled in two versions. The first version is with an integrated asset loader, which automatically saves the data into the mobile device and run the application. The second version does not have asset loader integrated. The user needs save the needed data manually into the mobile device and then run the Berlin3dAR application. The first version checks the availability of data in mobile device each time before the application starts and this process takes time. The second version however, runs the application directly and as a result is faster. Because of that, the second version is preferred.

6.1.2 Markers

As explained in Section 4.4, barcode markers are used in this study to attain more effective results. Moreover a colored marker is designed in Adobe Illustrator for the 3D model of the application logo.

The framework detects the markers via pattern files that are generated from the markers. These pattern files needed to be generated both for the markers downloaded and for the custom marker. The pattern files with file extension ".patt", can be generated from the following webpage, which is also supported by ARToolKit;

"http://flash.tarotaro.org/blog/2009/07/12/mgo2/"

When selected markers are loaded into a toolbox on this webpage, pattern files are automatically created and saved to users computer.

The markers provide rather good results in small sizes. However, in some cases marker confusion is also observed. In order to overcome this problem some possible strategies are discussed in Sections 6.3 and 6.4.

6.1.3 3D Models

Initially CityGML dataset for Berlin's landmarks planned to be used in the application. Using CityGML data would bring advantages to the project in several aspects. Firstly, because the dataset contains several levels of details, rather simple level of detail (LOD 2) could be chosen which would save some computational time while loading the models. The models would have had the same properties and quality with a functioning texture data. Due to difficulties to obtain CityGML dataset, this plan could not be realized.

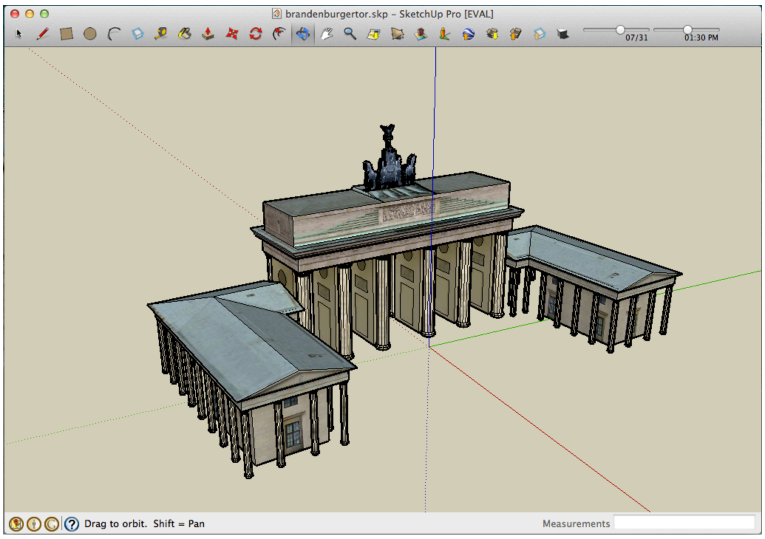


Figure 28: Visualization of Brandenburger Tor in Sketchup

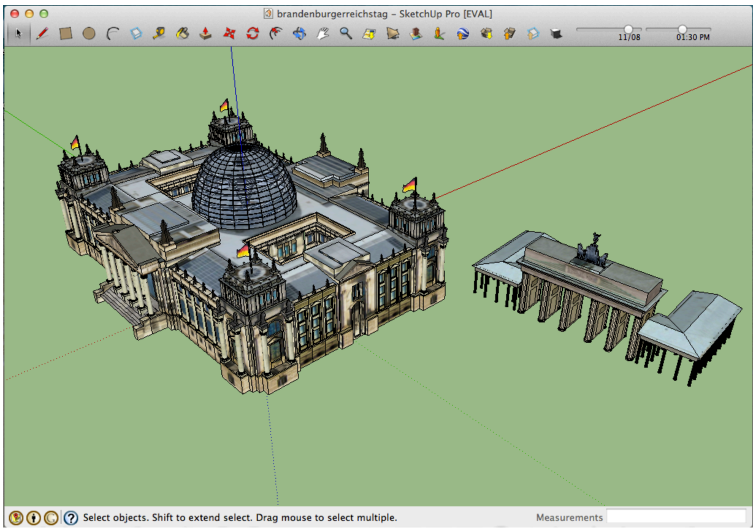
Instead, 3D models that are used for this study are downloaded from Trimble 3D Warehouse, corrected in SketchupPro and exported into ".obj" file format. However, using Sketchup models brings some disadvantages. Firstly, Trimble Warehouse allows everyone to prepare 3D models, which sometimes results in faulty models or significant style and texture differences.

As explained in Section 4.5, when exporting 3D models into ".obj" file format, material files with ".mtl" file extension are generated automatically. These files define the textures of the models, both as images or colors. However, when the models were exported, it was observed that there were too many texture files generated for each, making it impossible for the application to load them. This problem is explained more in detail in Section 6.3.

Moreover, to test the utilization of a custom made model, an application logo is designed in 3D in Sketchup and exported as obj model. It is integrated with the custom marker that is designed.

F
Figure 29: Visualization of custom-made 3D Model for Berlin3dAR

The number of markers on the paper map was an important issue that needed to be considered to make it easier to read the paper map. As a result, for the 3D models that are located close to each other, one marker could be used.



To achieve this, models are combined in Sketchup before being converted to ".obj". Afterwards the models were exported together. An example to that would be Reichstag and Brandenburger Tor, which are located close enough to each other that using one marker would be sufficient.

Figure 30: Visualization of Brandenburger Tor and Reichstag in Sketchup

6.1.4 City plan

In order to test and demonstrate the application, a paper plan of the city center of Berlin is needed. The data is obtained from OpenStreetMap, which is an open source project to create a free, editable map of the world.

The map is designed in 1:15,000 scale, with names of the landmarks and the public transportation stations marked on it. The design of the map is a sample layout. It should contain more information depending on the requirements of the end-application.

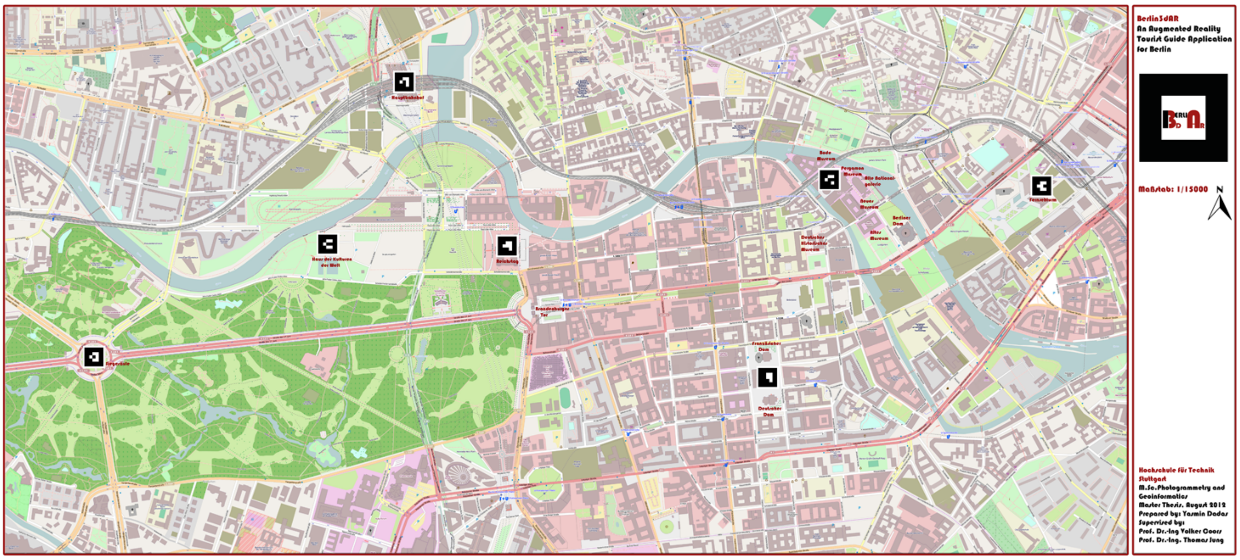


Figure 31: Paper map designed for the application using OpenStreetMaps plan

6.1.5 Application Logo

An icon is designed for the application to visualize it on the Android device. The icon is also used as the logo of the application and designed in Adobe Illustrator. The name of the sample application; Berlin3dAR is written over the borders of the city. The icon is loaded into the project in Eclipse, before compiling it.

Moreover, a 3D model is generated from the logo in Sketchup.

Figure 32: Application Logo icon

6.2 Visualization

Below, some photos of the application are presented to provide an overview of the prototype that is created. The sample application projects 3D models of landmarks over specific markers that are assigned to them. This prototype is presented to the respondents of the questionnaire in order to provide an overview to the application. Currently, the application is only showing the 3D models, some suggestions for further iterations would be to have the possibility to click on the markers to connect on the Wikipedia page, or to listen an audio record about it.

Figure 33 visualizes Reichstag and Brandenburger Gate. It can be seen that they are located close to each other. Since these two models were located close enough to each other, only one marker is used to project the two models. The same method was applied to Museum Island and Berliner Dom (Figure 35), and Deutscher and Französicher Dom (Figure 37).

Figure 33: Reichstag, Brandenburg Gate

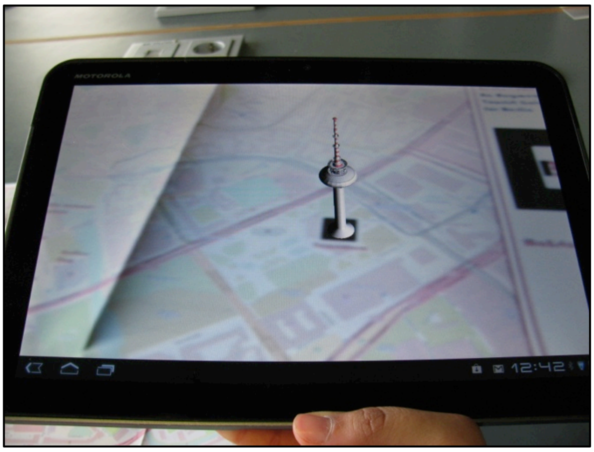


Figure 34: TV Tower

Figure 35: Siegessäule

Figure 36: Museum Island, Berliner Dom

Figure 37: Deutscher, Französicher Dom

Figure 38: Central Train Station

In Figure 39, multiple models using multiple models are visualized. The application fails to visualize all of the models at the same time because of the tracking range. It is explained in Section 4.3.1 that tracking range decreases as the size of the marker decreases. As a result, when the device is far enough to have the whole view of the map, the distance between the camera and the map exceeds the limit. It would be possible to overcome this limitation, simply by increasing the marker size. However priority of this application is to keep the marker sizes as small as possible. Moreover, it is still possible visualize several markers within the tracking range as in Figure 39.

The application logo is visualized in Figure 39 using the custom application marker located on the top right corner of the map.

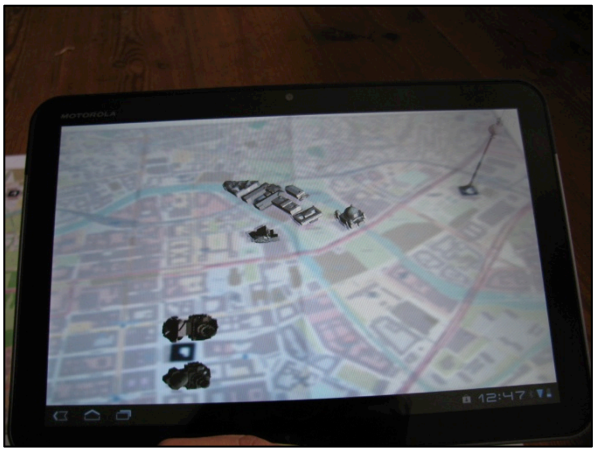


Figure 39: Multiple models visualization

Figure 40: Model of the application logo

6.3 Challenges

A number of challenges that were experienced during the study process are presented in the following section.

Firstly, when the application is loaded several times, models do not appear on marker. In order to fix this, the device needs to be restarted. This problem is occurring due to a bug on the native applications, resulting in the camera preview surface appearing in front of the OpenGL drawing. *(ARToolWorks Community Support Forum)* Although the reason of this problem is known, it was not possible to fix it.

Camera calibration file plays an important role, during the process of projecting models on markers. However, ARToolKit framework does not support on-device calibration utility for Android devices. Therefore, the camera calibration file that was included into the framework need to be used. However, the difference between two cameras causes continuous shaking of the models. This is a restriction set by the framework that is being used, and cannot be overcome.

When the application is first started it takes up to a minute till the models are projected on to the markers. Both the complexity of the models and the small size of the markers are playing an important role here. Fiala (2004) draws attention to the inter-marker confusion, false positive detections, and false negative detections problems of ARToolKit. These problems are also faced in this study. He introduces a system called ARTag, which is based on ARToolKit and has very low error rate.

As explained in Section 4.4, ARToolKit usually samples (also in this study) 16x16 grid of interior points with 256 grey levels. ARTag only sample 6x6 grid with binary colors, black and white. Moreover, ARToolKit requires more processing time when the number of markers increases, while the time remains the same or ARTag. However, the author compares ARToolKit pattern markers (such as Hiro) with ARTag ID markers, which shows significantly worse results than the barcode markers employed in this study. Nonetheless, ARTag could still be considered as an alternative to reduce the false-positive detection and inter-marker confusion problems. (Fiala, 2004)

Another solution would be using less complex models to increase the quality of the results. Theoretically, the CityGML dataset with LoD2 would be ideal, but since the dataset was not available, it could not be tested.

As it is explained in Section 4.5.2, the models were downloaded from Trimble Warehouse, and then converted to .obj file format with textures. However, texture files are generated automatically. As a result, the textures generated for each model were either too big in pixel size (supported texture sizes are limited to a maximum of 2048 pixels) or there were too many texture files generated which makes it too difficult for the program to load all the models. Moreover dimensions of the textures should be power of two. In order to overcome this problem, texture atlas could be created. Texture atlas is a large image consisting of smaller texture images, which belong to a 3D object. It is more efficient in CPU usage, since less rendering should be done. (*http://en.wikipedia.org/wiki/Texture_atlas*) Due to time limitations, it was not possible to generate texture maps for the models, as many of them consist of dozens or even hundreds of textures. As a result, the 3D models that are visualized in the sample project are without textures.

6.4 Inferences

In this section, evaluations, observations and personal experiences from the study process of developing the application and the conclusions derived are explained.

Firstly the inferences of the application development process will be stated. ARToolKit framework is chosen because it provides a large number of possibilities regarding the Augmented Reality applications. Furthermore it is updated regularly and a comprehensive documentation is provided. Support is also provided when needed by the ARToolKit Support Forum. As a result the experiences with the framework can be described as positive.

As described in detail in the previous section, there were some challenges during the process that could not be solved.

The set of markers that are chosen to be used in the study provides convenient results, with small sizes. The size and the frequency of the markers were set to be as minimum as possible. One approach was to use one marker on the top of the plan and load all the models inside of this marker. Although this approach would solve the problem of markers making the map unclear, it would not be a convenient solution since then the user would have had the marker on the screen of the mobile device all the time and cannot look closer to the models. However, the models that are located close to each other are loaded into the same marker in several locations like Museum Island, Brandenburg Gate and Reichstag, Deutscher Dom and Französicher Dom.

Nonetheless, it should be considered that the current version of the application is only showing models of landmarks. For future iterations, it is planned to include additional points of interests such as restaurants, bars, ATMs and etc. In this case alternative scenarios should be considered to prevent the map to be covered with markers. Some alternatives would be replacing markers with “DOT markers” (Wagner et al., 2008, Hecht et al., 2007), which seems as an optimal marker system for map applications. Introducing a grid of black dots to reference the map would eliminate the need to assign a marker to each object/place. Another possibility would be using NFC tags that are employed by Isabel Micheel (2012) in her study, which replaces the need for the markers with NFC microchips attached to the back of the map. NFC chips allows data transfer between NFC-enabled device. Furthermore introducing feature based tracking integrated with GPS (Morrison et al., 2011) and making use of methods such as image matching, edged detection etc. is another alternative. However, the higher computational costs that this method requires need to be taken into account. Nonetheless in state of art, it may be more convenient to replace the markers with DOT markers or introducing NFC tags. In order to reach some conclusion on which system would be more convenient in the scope of this study, further investigations should be made in this area.

As explained in Section 6.1.3, the models that were used were not ideally the best solution. There were some inconveniences in the application caused by the models, like the application running in low-speed or problems with the texture. In order to solve this problem, some complex models (Reichstag, TV Tower) were simplified to decrease the overall size. Although a solution (Section 6.3: Texture Atlas) could be found to the texture problem, due to time limitations it cannot be realized.

While all these deficiencies can be solved in time, there is one major disadvantage of the project that cannot be solved, which is its sensitivity to lighting conditions. The application fails to recognize the markers when there is not enough light in the environment or when the sunlight is creating shadows over the markers. Since the application will be used during travel, the lighting conditions will not always be ideal. The users of the application need to pay attention to the lighting conditions in the environment to overcome this problem.

Although not ideal, the sample application succeeds to provide an overview about the concept of the study. However, more time and experience are needed to overcome the problems and improve the application.

7 QUESTIONNAIRE

This chapter provides the workflow carried out in order to evaluate the study. First the preparation process of the questionnaire is described, and then the results are elaborately discussed. Finally, observations of the process and conclusions derived are explained.

7.1 Aim of the Questionnaire

This study aims at combining the advantages of paper maps and mobile applications. As a result the main objective of this questionnaire is to find out the public response to an integrated approach of paper maps and mobile applications.

7.2 Mode of data collection

There are alternative modes of data collection, which can be applicable to different types of studies. For certain studies, internet questionnaire could be sufficient, while for others door to door questionnaire or street questionnaire will provide more accurate results. In this study target group is chosen as inhabitants of Berlin and the tourists visiting Berlin. It was important to find out the most appropriate mode to reach to the target group.

After an evaluation, street survey is chosen as the main mode of data collection while it provides an opportunity to observe the participants and have a personal contact with them as a result achieving clearer and more accurate results. Via street survey it is also easier to identify the appropriate target people to complete the questionnaire.

In addition a guided questionnaire is preferred because it requires face-to-face contact with the respondents, making it easier to prevent errors due to misunderstandings, or poor explanations. Small groups of people are selected at a time in order to be able to respond to the questions of attendants and control the responses. Prior to the questionnaire, a demonstration of the sample project is presented in order to give a clear idea about the topic.

7.3 Target Population

As the area of interest for sample application is chosen as Berlin, main target group is selected to be the inhabitants of Berlin and the tourists visiting Berlin. The questionnaire is conducted in several touristic sights in the city, namely Brandenburg Gate and Siegesäule. These locations are selected in order to address domestic and international tourist groups of various ages. Moreover, a part of the questionnaire is administered in a language school and in university campuses.

7.4 Design of Questionnaire

The quality of the analysis depends on how well the questionnaire is designed. A questionnaire should consist of clear, understandable questions without any redundancy. It is important to analyze the questions before conducting the questionnaire in order to be sure that all key questions are asked to achieve reliable results. It is also essential not to ask any redundant questions, which will not only scare possible respondents away but also will have no contribution to the study. (*Loughborough University Library, Questionnaire Design Advice Sheet)*

The questionnaire is conducted in two languages; German and English and written in a simple, clear form with a mix of closed questions where people choose an answer and open-ended questions where people can provide reasons.

At the first part of the questionnaire gender, age, and country of residence information of the respondents are asked in order to be able to categorize the respondents to their individual characteristics, find out correlations and analyze more specifically. Afterwards general questions about the kind of information participants would like to know prior to and during their tourism activities and also the types of means they are using to acquire this information is asked. This part aims at understanding people's preferences and possible expectations from an alternative mean of tourist guide, which is developed in this study.

Since this study is aiming to combine the advantages of paper maps and mobile applications, it is essential to investigate people's preferences regarding paper map and smartphone usage. Another point that is crucial to the study is people's opinions about the advantages and disadvantages of paper maps and smartphones. In light of this information, an application that is responsive to people's needs could be developed.

Afterwards, a detailed list of alternative functionalities that could be integrated in the previously demonstrated application, are listed and people were asked to assign a level of importance to each of the functionalities. This part aims at providing a greater perspective to improve and further develop the prototype application.

Finally people were asked to state their opinion about an end product, which would be developed from the demonstrated prototype and will have the additional functionalities like internet connection, search functions and navigation tools. The final part of the questionnaire is focusing on the advantages and disadvantages of such a combined approach and the general response to the additional functionality that this project is providing, namely 3D Models.

7.5 Implementation

As previously mentioned, the sample project was planned to be demonstrated before conducting the questionnaire. A 1:10,000 scale paper map of Berlin historical center, with markers on it is designed and printed for this purpose. Before conducting the actual survey, a pilot survey is made in order to prevent any mistakes that could affect the results. During this pilot survey, some unclear statements are corrected and some suggestions regarding the scale of the paper map are made. The scale of the paper plan was 1:10,000, which was found too big and not functional to use during movement. Afterwards the scale is changed to 1:15,000, which would be easier to walk with and some deficiencies in the questionnaire are corrected.

The questionnaire is conducted in several tourist attraction points in Berlin. Small groups of people were chosen, and the questions were explained. Questionnaire and the guidance are provided in both German and English to make sure that the people feel comfortable answering the questions. Furthermore, in some cases discussions about the application were made, which contributed to the survey in a unique manner. Due to time constraints, it was aimed to conduct 80 questionnaires for evaluation. Considering the fact that there could be some inaccurate, false or incomplete questionnaires; in order to have to option to eliminate the defective ones, some extra questionnaires were conducted.

7.6 Data Analysis

Even though the respondents were observed and guided during the process, there were some questionnaires, where some pages were missing or others that the respondent was not showing any interest and marking some random answers resulting in contradictory results. After the questionnaire was carried out, the answers were inspected and faulty questionnaires were eliminated.

Since the analysis to be made is relatively complex (multiple answers vs. age intervals etc.), software called SPSS (Statistical Package for the Social Sciences), which is considered to be an optimal statistical analysis tool for such projects, is used. (*UCLA Academic Technology Services)*

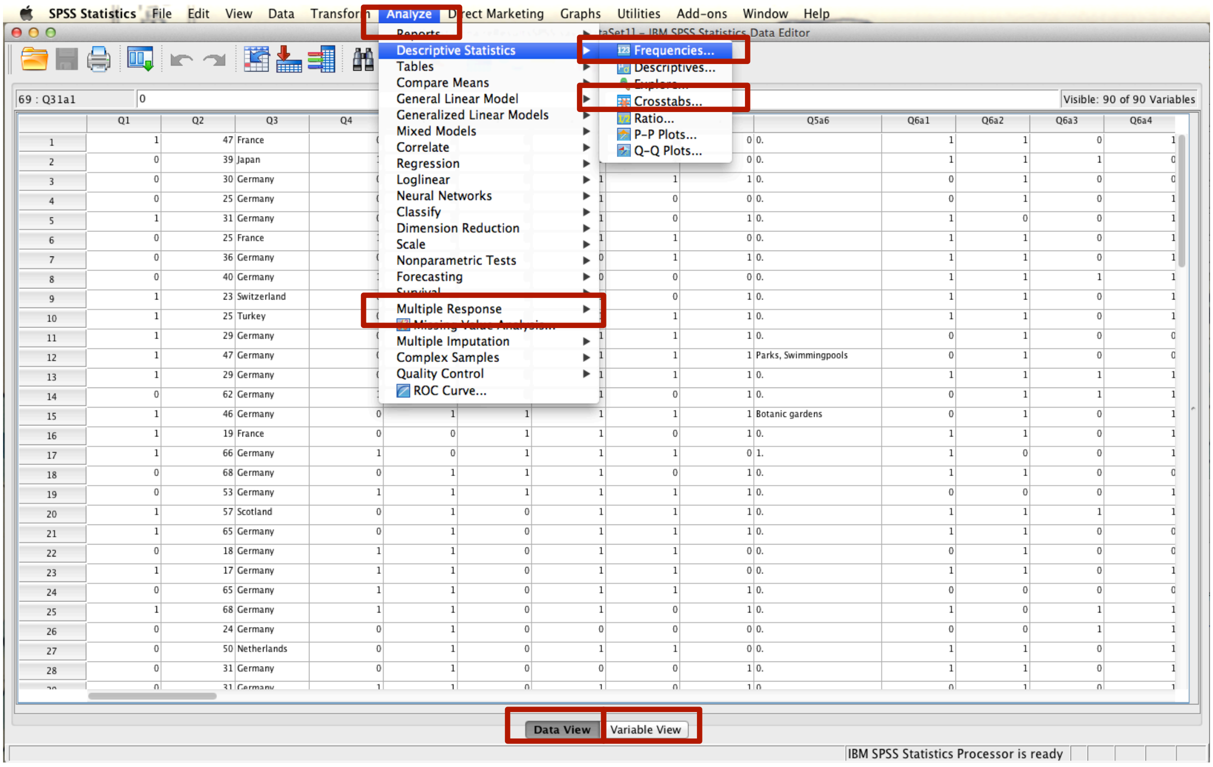


Figure 41: *SPSS overview*

SPSS has two different views; “Data View” in which the data is entered and visualized and a “Variable View” in which the names and types of the data are defined. Firstly the data is entered in a coded style in “Data View” and then coded variables were defined in “Variable View”. Afterwards tools in “Analyze” caption are used for analyzing the data. The most used tools for this study were “Frequencies” to visualize the number of occurrence of the answers, “Crosstabs” to see the correlation between two variables and “Multiple Response” to define and analyze the multiple response questions. The visualization type (table, histogram, chart etc.) could be defined during the process. Finally there is an “Output” window showing the desired visualizations, which could then be exported into the desired format.

7.6.1 Evaluation of General Information

A homogeneous distribution of age and gender was important and tried to be achieved, in order to investigate whether there is a correlation between the results and age or not. Even though the number of people responding to the survey is not enough to make such inferences, it would still make sense to look for some indicators.

Among the eighty people interviewed for the study, 51% were male and 49% were female. The age is varied between 14 and 72. A relatively homogeneous distribution was achieved but there were some slight increases in some age groups.

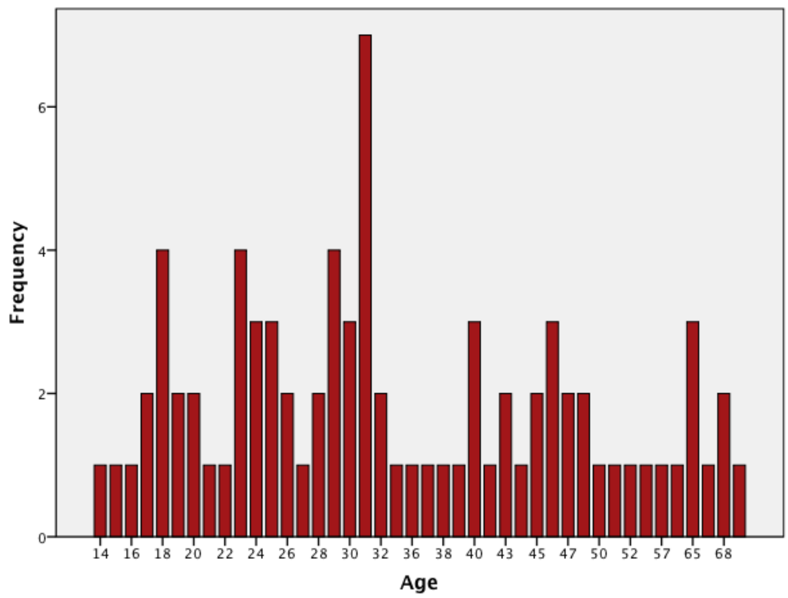


Figure 42: Age distribution chart

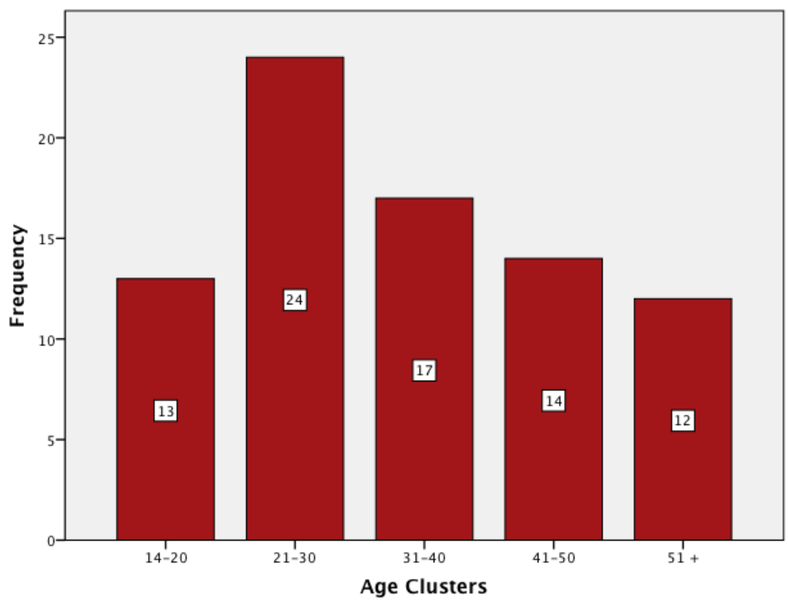


Figure 43: Age distribution chart in clusters

Only 33% of the people said they are familiar with Augmented Reality technologies, while 67% of them are not familiar with it. If we investigate further and look at the correlation between smartphone ownership and the familiarity with AR technologies; 38% percent of people who have smartphones are familiar with AR technologies, while 62% are not. Moreover 23% of the people who do not have smartphones are familiar with AR technologies, while 77% are not. This information indicates that the familiarity with AR technologies is correlated with smartphone ownership, which can also mean that smartphones have a positive impact in introducing AR technologies.

Tourism Activities

In order to be able to develop an application that is responding to people's needs, their habits to acquire information in tourism activities needed to be investigated. It was also important to identify the differences between before and during the stay.

Prior to visit

	Responses (Frequency)	Percent of Cases
Landmarks	57	71.2%
Restaurants	22	27.5%
Accommodation	65	81.2%
Transportation	48	60.0%
Cultural activities	49	61.3%

Table 6: Information acquired prior to visit

As it can be seen from the Table 6, before visiting a place most people tend to look for information about landmarks (71%), and accommodation (81%). Transportation and cultural activities follows with 60% and finally small percentage (%28) of people looks for restaurants. In addition, it was stated that parks, sport facilities, botanical gardens, shopping centers, bars & clubs, popular places among local people are also investigated.

	Responses (Frequency)	Percent of Cases
Internet	73	93.6%
Tourist guidebooks	51	65.4%
Mobile tourist apps	11	14.1%
Paper maps	31	39.7%

Table 7: Means used to acquire information prior to visit

Internet is the main tool, which is preferred by 94% of people. Tourist guidebooks follow it with %65 percent. Paper maps also have a significant share with 40% while the majority of the people do not prefer mobile tourist guides. Moreover when people are asked if they use any additional tool to obtain information, 14% answered that they are asking for tips from their friends.

This information gives a brief idea about the travel preparation process.

During Visit

People's preferences during their stay in a foreign city for travel purposes have greater importance in the scope of this project since the application aims at providing guidance during the stay. As a result knowing the information that is investigated and the tools people are using would provide ideas to improve the project.

	Responses (Frequency)	Percent of Cases
Landmarks	45	56.2%
Restaurants	58	72.5%
Accommodation	18	22.5%
Transportation	52	65.0%
Cultural Activities	57	71.2%

Table 8: Information acquired during visit

Comparing the results with the previous part, we can observe that the previously less significant elements like restaurants, transportation and cultural activities gained importance, while previously significant elements like landmarks and accommodation lose their importance. This change is remarkable especially for restaurants, which increased from 28% to 73% and for accommodation, which decreased from 81% to 23%. These are understandable changes, implying that the application should give less importance to providing information about accommodation facilities and more to cultural activities, restaurants, transportation and finally landmarks. Moreover it is stated that hospitals, embassies, parks, open markets, shopping centers, bar & clubs, and local's preferences are also investigated.

	Responses (Frequency)	Percent of Cases
Internet	42	53.8%
Tourist guidebooks	48	61.5%
Mobile tourist apps	19	24.4%
Paper maps	54	69.2%
Tourist information centers	34	43.6%

Table 9: Means used to acquire information during visit

The main tool that is being used during the travel is with 69% paper plans. Tourist guidebooks follow / supplement it with 62%. Even though there is a significant decrease in Internet usage compared with prior to the travel, it still maintains a large share of 54%. Tourist information centers follow it with 44% and finally mobile tourist applications are used by 24% of the respondents. Low usage of mobile tourist applications could indicate either that these applications are not yet well known or they fail to answer people's needs. These possibilities will be investigated in the following sections.

7.6.2 Evaluation of Paper Maps and Mobile Applications Usage

Paper Map Usage

When people were asked whether they use paper maps in their daily life or not, 73% of them replied that they use it sometimes, 17% always and 10% never.

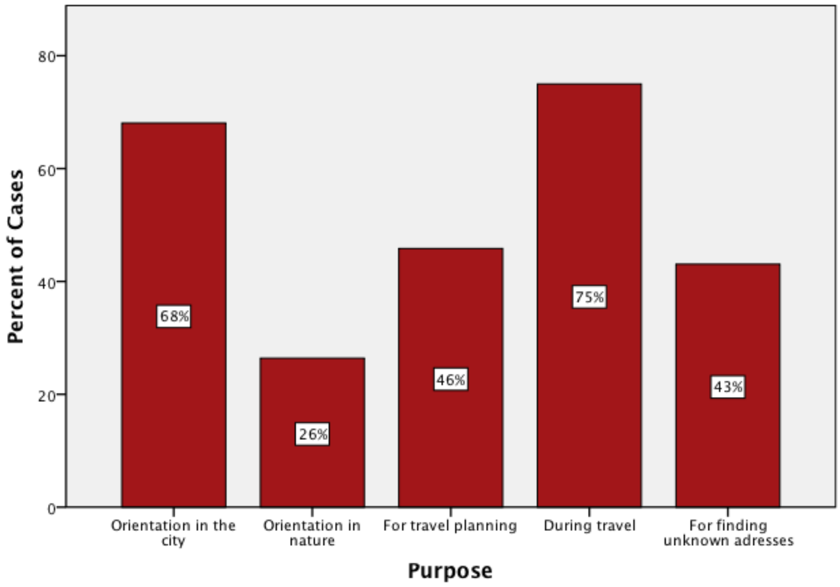


Figure 44: Purpose of using paper maps

Among the people using paper maps; 75% of them said that they use them during their travels, 68% people said they are using them to orient themselves in the city they are living in. Travel planning also has a significant share with 46%. 43% of people use them for finding unknown addresses and lastly 26% for orientation in nature.

	Responses (Frequency)	Percent of Cases
Provides good overview / orientation of the area	59	73.8%
Easily accessible	24	30.0%
Easy to understand	40	50.0%
Cheap	21	26.3%

Table 10: Reasons for choosing paper maps / Advantages

Overall paper maps are found advantageous mainly because they provide good overview and orientation of the area (74%) and it is easy to understand them (50%). Another significant reason mentioned by the respondents is that paper maps are always available and does not depend on batteries.

	Responses (Frequency)	Percent of Cases
Difficult to understand	5	11.1%
Limited information	28	62.2%
No navigation / route planning functions	25	55.6%
I prefer other means (mobile tourist applications)	7	15.6%

Table 11: Reasons for not choosing paper maps / Disadvantages

44% of the attendants do not think paper maps have any disadvantages. Among the people who think paper maps have disadvantages, 62% of them think the main disadvantage is that paper maps provide limited information, and 56% think that they have no navigation / route planning functions. It is also stated that they are impractical to use and do not provide dynamic, up-to-date information.

14% of the people do not use any other supplementary tool to paper maps, while 64% uses tourist guidebooks. 30% of people are using mobile tourist guide applications in order to supplement paper maps. Other tools that are being used are Internet or navigation functions of smartphones. This implies that people are using paper maps even though they have disadvantages. By employing additional tools they are overcoming the inadequacies. This also suggests that a collaborative system between paper maps and smartphones would be a promising improvement.

Mobile Application & Navigation Usage

63% of people who filled out the questionnaire are using smartphones. The distribution however, tends to be even with respect to age.

		Smartphone ownership		Total
		No	Yes	
Age Clusters	14-20	3	10	13
	21-30	10	14	24
	31-40	5	12	17
	41-50	5	9	14
	51 +	7	5	12
Total		30	50	80

Table 12: Smartphone ownership with respect to age

Additional to the common purposes to use smartphones like Internet, navigation, games & entertainment, photo and music; 43% of the people who own a smartphone are using their smartphones for tourism. This does not necessarily mean that they are using mobile tourist guides, so a further question has been asked to find out the rate of mobile tourist guide usage. 18% of the people who have smartphones answered that they use mobile tourist guides always, 34% of the respondents use smartphones sometimes.

		Mobile Tourist Guide Usage			Total
		Always	Sometimes	Never	
Age Clusters	14-20	1	5	7	13
	21-30	2	5	17	24
	31-40	2	4	11	17
	41-50	1	3	10	14
	51 +	3	0	9	12
Total		9	17	54	80

Table 13: Mobile Tourist Guide Usage with respect to age

Table 13 suggest that there could be a correlation between mobile tourist guide usage and age, which tends to address more people's attention between 14-20, 21-30, and 31-40 age groups. For 41-50 and 51 and above age groups usage rate is rather low. However, this can only be considered more as a hypothesis.

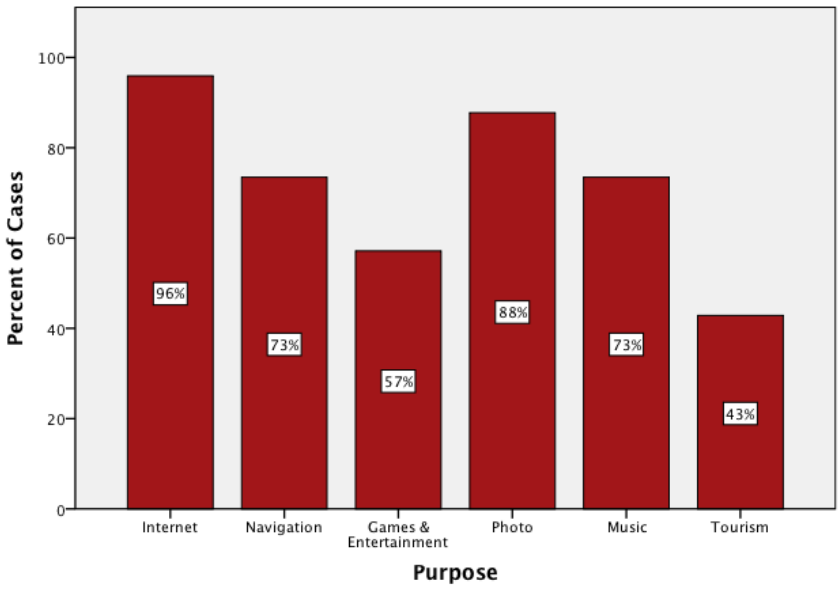


Figure 45: Purposes of smartphone usage

Moreover, 14% of people who own smartphone said that they are using Internet always when they are visiting foreign countries. 58% said they are using it sometimes and 28% said never because of the high connection costs abroad. They also mentioned that an application that requires Internet connection all the time would not be preferable.

	Responses (Frequency)	Percent of Cases
Large amount of information in compact form	27	54%
Several display options (multimedia, visual aids)	8	16%
Alternative modes of services (navigation, route planning)	28	56%
Internet access	12	24%

Table 14: Advantages of Mobile Tourist Guides

The most selected functionality of mobile tourist guides is with 56% availability of alternative modes of services like navigation and route planning and with 54% the large amount of information they provide in a compact form. It is noted that absence of these functionalities are stated as disadvantages of paper maps. In addition 24% think allowing Internet connection within the application framework is an important advantage. 16% think that availability of several display options like multimedia or visual aids are another reason they prefer mobile tourist guides.

	Responses (Frequency)	Percent of Cases
Complex to use	12	21.8%
Limited / expensive network connection	32	58.2%
Small display size for maps	22	40.0%
Expensive applications	23	41.8%

Table 15: Disadvantages of Mobile Tourist Guides

Despite the advantages mobile tourist guides have, there are also disadvantages of these systems in terms of cost and efficiency issues. Among 55 people who think mobile tourist guides have disadvantages, the most rated subject was with 58% of the votes, limited / expensive network connection abroad. Then the prices of the applications are found too expensive by 42% of the people. With 40% of the votes, small display size for maps and with 22% complex usages of the applications were found disadvantageous. However it should be noted that the display size would not anymore be an issue when using tablets that have bigger screens than smartphones. It is also essential to mention that although it is not asked in the questionnaire, the observations during the questionnaire suggested that respondents more commonly use smartphones than tablets during travels. Moreover, an important advantage stated about smartphones was the small size of the smartphones that makes is practical to carry around all the time, which is not so much applicable for tablets.

Nevertheless more comprehensive research should be done in order to reach some conclusions.

It should be noted that for some people, the reason not using mobile applications is their expensive prices. They said they would use the application if the price would be reasonable. However the amount that people are willing to pay is another research issue that could be investigated only after the application is improved.

Besides, there were also some complaints about the outdated or mainstream databases and unreliable user reviews. During conversations with people, it was implied that the provided data should not be too mainstream but should provide some alternative information and insider tips.

After analyzing the results, the main task is to improve the effectiveness of the mobile tourist guide that is developed for this study by combining the advantages of both systems in an effective manner. It can be observed from the results that both systems have their advantages, which cannot be replaced by the other system. For example paper maps are found to provide good overview of the area, while mobile applications fail to provide such service due to the limited display size. However, there are also functionalities that paper maps fail to provide such as large amount of detailed information in a compact form or the navigation and route planning functions. These are promising indicators for a system that combines paper maps and mobile applications. More detailed questions about these functionalities in a combined system are asked in the following section.

7.6.3 Evaluation of Berlin3dAR

It is explained to participants that this project is a pilot project, which should be further developed in order to provide full functionality. The end product aims at providing guidance during the stay.

A Likert scale of five importance degrees is used to state the level of agreement of the respondents. Likert scales are commonly used to measure attitudes towards a particular statement. It is mostly consisting of five or seven points on a continuous scale bar, allowing the respondents to express how much they agree or disagree with the statement. *(http://www.simplypsychology.org/likert-scale.html, [Accessed 14.08.2012])*

A number of functionalities were given that could be integrated to the application and participants were asked to circle the number indicating their level of agreement.

1-Very important	2-Important	3-Moderately Important	4-Of Little Importance	5-Not at all important

Internet connection

1	2	3	4	5
65%	18%	11%	0%	6%

Internet connection was found very important by 65% of the participants. However, during the discussions it was also stated that it should be a functionality that could be activated when needed instead of being used all the time. Moreover static information that is valid for longer period should be stored in the application database and be validated so that it would not be outdated. For the dynamic data like events, exhibitions, reviews, etc., Internet connection could be activated. There is no correlation observed between age and Internet connection variable.

Connection to social networks / receiving feedback from other users

1	2	3	4	5
%14	%20	%20	%22	%24

There is a relative even distribution of votes regarding the connection to social networks. When the votes are cross tabulated with age variable, it is observed that the 14-20 age group tend to give more importance, 21-30 age group has a relatively even distribution and 31-40, 41-50 and 51 and above clusters tend to give less importance to this attribute.

		Connection to social networks / receiving feedback					
		Very Important	Important	Moderately Important	Of Little Importance	Not at all Important	Total
Age Clusters	14 - 20	6	5	1	1	0	13
	21 - 30	4	2	9	4	5	24
	31 - 40	1	2	3	6	5	17
	41 - 50	0	4	1	4	5	14
	50 +	0	3	2	3	4	12
Total		11	16	16	18	19	80

Table 16: Importance distribution of connection to social networks with respect to age

This suggests that the availability of connection to social networks would have in overall a positive impact, but still would not be a vital attribute that needs to be integrated.

Search functions showing;

Landmarks

1	2	3	4	5
47%	35%	14%	4%	0%

Almost all of the participants found it important to have search functions showing the location of landmarks and providing information about them. This attribute does not have a correlation with age or gender attributes.

Cultural activities (Museums, Exhibitions)

1	2	3	4	5
45%	24%	28%	2%	1%

Respondents' attitude towards a function showing cultural activities is highly positive, making this attribute an important input for the application.

Restaurant, Bars

1	2	3	4	5
36%	33%	24%	7%	0%

As discovered in the first part of the questionnaire, people tend to gather information about restaurants and bars during their visit. It can also be observed here that the votes are concentrated on the left side of the scale bar, implying that the attribute has a significant role for the application regardless of the age.

Clubs

1	2	3	4	5
25%	23%	24%	16%	12%

Votes for clubs have a relative even distribution slightly in favor of the left side of the interval. As expected most of the positive votes are coming from the 14 – 40 age groups. In fact almost no negative answer is observed from this age interval.

		Search functions for Clubs					
		Very Important	Important	Moderately Important	Of Little Importance	Not at all Important	Total
Age Clusters	14 - 20	3	5	5	0	0	13
	21 - 30	10	6	4	3	1	24
	31 - 40	5	5	5	2	0	17
	41 - 50	1	1	4	3	5	14
	50 +	1	1	1	5	4	12
Total		20	18	19	15	10	80

Table 17: Correlation between "Search funtions for Clubs" and "Age"

It would be reasonable to provide this functionality to answer the needs of a broader age group. However it is not crucial to integrate this functionality.

Accommodation facilities

1	2	3	4	5
36%	30%	24%	7%	3%

Although it was assumed that people would not be so interested in knowing the accommodation facilities once they arrive to the city, votes tends to be concentrated on the left hand side of the interval. When attendants were asked about it, they replied that it would be preferable to have the option to get information in case there is a problem with their accommodation.

Navigation tools

“Where am I?” function, showing the current location of the user

1	2	3	4	5
69%	21%	8%	1%	1%

With 69% of the votes, “Where am I?” function appears to be a must for the application. As it was already implied previously, that a significant disadvantage of regular paper maps is the fact that they do not have navigation or route planning function, this was a predictable result.

“Route planning” function, providing a route from the current location of the user to a destination

1	2	3	4	5
55%	27%	14%	0%	4%

“Route planning” function also collects high number of votes and should be integrated into the application.

Predefined city tours (a day tour, 3 days tour) according to the criteria entered by the user

1	2	3	4	5
11%	27%	31%	19%	11%

Even though votes slightly tend to be in favor of predefined city tours, the even distribution implies that the function is more a nice-to-have than a need-to-have. However it would bring advantages to have it integrated.

Additional functionalities: Besides given possibilities, attendants were asked to state their ideas about alternative functionalities. There were a number of proposals made by applicants:

- Transportation network with bicycle roads, gas and repair stations
- Shopping centers
- Sport facilities
- Hospitals, emergencies and pharmacies
- Information about local people's preferences, insider tips
- A multi-language user interface
- Weather information

The final part of the survey is consisting of questions that investigate the opinion of the people about a hypothetical end product that is to be developed from the sample project. People were asked to mark the statement that indicates their level of agreement for the following questions.

1-Strongly Agree	2-Agree	3-Neutral	4-Disagree	5-Strongly Disagree

Combining paper maps with mobile applications will bring advantages in my travels

1-Strongly Agree	2-Agree	3-Neutral	4-Disagree	5-Strongly Disagree
24%	36%	25%	11%	4%

When people were asked whether they find a collaborative use of paper maps and smartphones useful during their travels, answers were concentrated rather on the positive side of the scale bar with 60% of the votes. However there were also a significant number of people (15%) who implied that the combination of these two systems is not useful.

		Combining paper maps with mobile applications					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
Age Clusters	14 - 20	1	6	4	2	0	13
	21 - 30	5	10	8	1	0	24
	31 - 40	3	5	4	2	3	17
	41 - 50	4	3	4	3	0	14
	50 +	6	5	0	1	0	12
Total		19	29	20	9	3	80

Table 18: Correlation between "Combination of two systems" and "Age"

When the answers are cross-tabulated with the age data, it can be seen from the Table 18 that the distribution of the votes are on the positive side of the scale bar for 14-20, 21-30 and above 50 age clusters. This distribution is rather even for 31-40 and 41-50 age groups. However this information does not imply any significant inferences. It is still interesting to observe so many positive votes from people in 50 and above age group. Moreover no correlation between gender data and the attribute is observed.

As expected, smartphone ownership and paper map usage data show some correlation with this attribute. However this correlation tends to be more remarkable for paper map users. 52% of the smartphone users gave positive feedback about a combined system, while 30% remained neutral. 73% of people who do not have smartphone stated that the combination of two systems will bring advantages and 17% remained neutral.

67% of the people who are using paper maps during their travels tend to be in favor of an application combining paper maps with mobile applications.

Moreover, there are some positive responses from people who are not using smartphones or paper maps. This indicates that it is still possible to attract people who are not using paper maps or smartphones by providing a strong, original application.

		Combining paper maps with mobile applications					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
Smartphone ownership	Yes	14	12	15	7	2	50
	No	5	17	5	2	1	30
Total		19	29	20	9	3	80

Table 19: Correlation between "Combination of two systems" and "Smartphone ownership"

		Combining paper maps with mobile applications					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
Paper map usage during travel	Yes	12	24	13	4	1	54
	No	7	5	7	5	2	26
Total		19	29	20	9	3	80

Table 20: Correlation between "Combination of two systems" and "Paper map usage"

Using an application that is combining 3D models with 2D paper maps is interesting

1-Strongly Agree	2-Agree	3-Neutral	4-Disagree	5-Strongly Disagree
27%	31%	30%	8%	4%

58% of the people found it interesting to have the functionality to look at the 3D models of the landmarks. 30% said it is rather interesting but not essential to have the functionality. However 12% of the people found it useless to look at the 3D models. Neither age, nor smartphone ownership or gender data showed any significant correlation with this attribute.

I would use the application during my travel

1-Strongly Agree	2-Agree	3-Neutral	4-Disagree	5-Strongly Disagree
21%	44%	15%	14%	6%

Overall the application received positive response. 65% of the participants implied that they would use this application during their travels as long as it provides the essential functions that are mentioned in the previous section, while 15% remained neutral about it. Yet there is 20%, who said they would not use the application.

		Using the application					Total
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	
Age Clusters	14 - 20	5	5	1	2	0	13
	21 - 30	4	10	7	2	1	24
	31 - 40	0	9	3	3	2	17
	41 - 50	4	5	0	3	2	14
	50 +	4	6	1	1	0	12
Total		17	35	12	11	5	80

Table 21: Correlation between "Application usage" and "Age"

Looking at the Table 21, it can be seen that almost all people in 14-20, 41-50 and 50 and above age groups respond positively to the attribute, while the answers are rather positive to neutral for 21-30 and 31-40 age groups. It was rather unexpected to get more positive results from people in 50+ age group than people in 21-30, 31-40 age groups. This indicates that the application should not prioritize any age group but should address to everyone.

		Using the application					Total
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	
Smartphone ownership	Yes	12	22	6	7	3	50
	No	5	13	6	4	2	30
Total		17	35	12	11	5	80

Table 22: Correlation between “Application usage” and “Smartphone ownership”

60% of the respondents who do not have smartphones said they would use the application, while 20% said they would not use it. Furthermore 68% of the respondents who have smartphones said that they would use the application, while 20% said they would not. Comparing the two results, it could be seen that the percentages are quite similar, implying that the smartphone ownership does not play a significant role on this attribute.

The reasons for using the application or not using it are explained in following part.

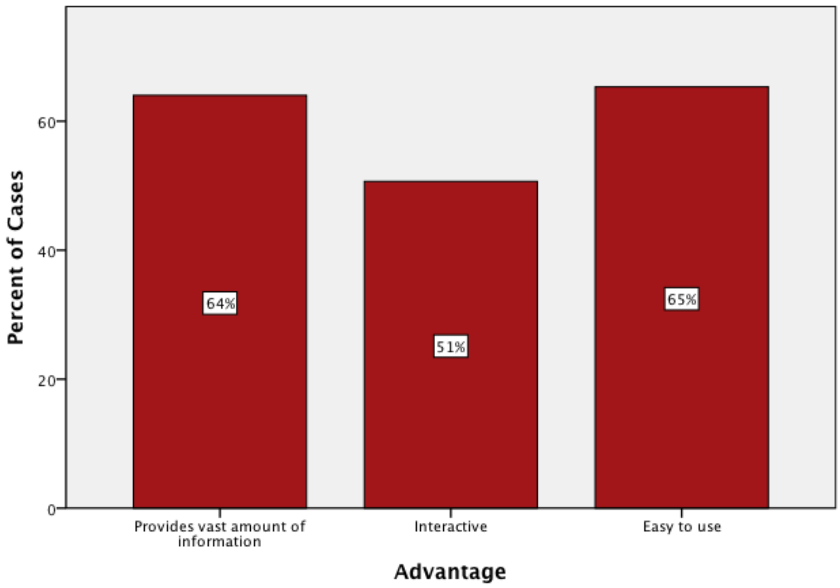


Figure 46: Advantages of the Berlin3dAR application

One of the most rated advantages of the application is that it provides vast amount of information in combined/compact form. Then it is also found to be easy to use, which however should not be taken into consideration while the application as it is now is just the prototype and does not provide any further functionality than showing the 3D models. 51% of the attendants stated that it is convenient that the application would have an interactive user interface.

Moreover it is also stated that using the application would provide an exciting, alternative approach to discover the cities. The direct visualization of the information would save the time to look up for the information from various tools.

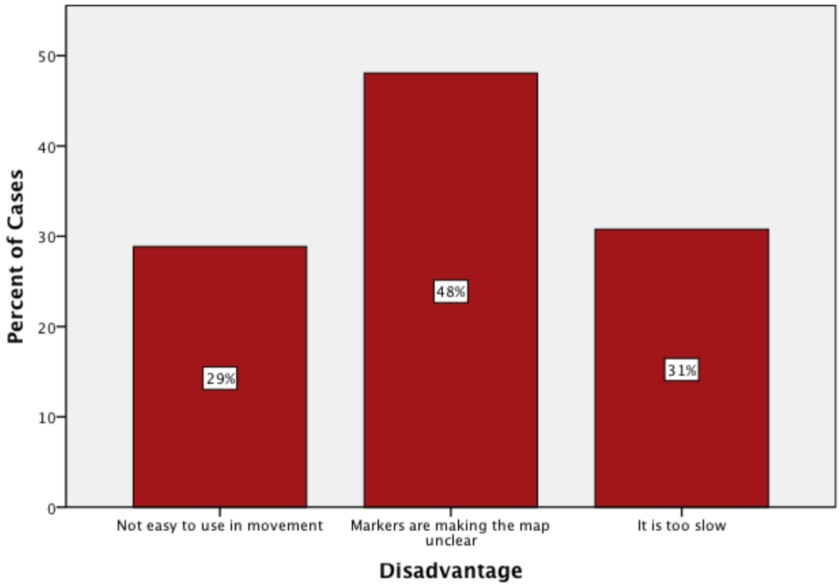


Figure 47: Disdvantages of the Berlin3dAR application

Among 52 people who said that the application has disadvantages, 48% thinks that the markers are making the map unclear. Moreover 31% think that the application is running too slow. 29% of participants indicated that it is not easy to use the application while moving.

Another important criticism was that combination of paper maps and smartphones are not practical and that some of the respondents would prefer to use either one of these systems during their travels but not the combination.

Some people expressed their concern about the fact that it could be complicated to use the application when all the functions are integrated. It is also said that the price of the application could be also a disadvantage in case it is too expensive. During conversations even people who were positive about the application stated that whether they would use the application or not is highly correlated with its price. Furthermore, a significant number of people answered the question why they are not using mobile applications stating that the prices of these kinds of applications are too expensive.

7.7 Evaluation of the Process / Observations

Strengths	A detailed research and a pilot survey was made prior to the actual questionnaire to eliminate flaws Small groups of people were interviewed, which made it possible to control and guide the process resulting in a higher validity of the results People had the opportunity to choose the language of the survey (German or English), which resulted in more comfortable environment for exchanging ideas People from every age group are interviewed which provides a greater number of viewpoints Since the survey is mostly consisting of close ended questions, it is rather time saving to code the questions for a easy analysis
Weaknesses	The questionnaire was relatively long, so it was difficult to find people willing to complete it Because of the time constraints, only 80 people could be interviewed There was still some unclear points in the questionnaire needed to be explained to the participants Some of the participants left the open ended parts empty It was challenging to talk about a hypothetical product, to provide people the realistic overview so that they understand the end product
Opportunities	Overall impact of the project on people was positive It was possible to talk about the project and discuss it in detail which provided a greater perspective about the participants' internal meanings and ways of thinking
Threats	Although guidance was provided and the project was explained there could be some people who are not familiar with such technologies at all and didn't understand the application correctly. An important problem that is noticed during the questionnaire was that the marker detection process is highly correlated with the light; when there was not enough light or when the sunlight is creating shadows on the paper map, detection process is not working. This is the biggest problem that needed to be overcome and which currently does not have any solution.

7.8 Inferences

In this section, inferences from the conversations with the participants and the conclusions derived are explained.

Since the goal of the application is to combine the advantages of paper maps with mobile applications, it was important to find out what people find advantageous and disadvantageous about paper maps and smartphones. Overall, advantages of paper maps were that they provide good overview / orientation of the area, they are easily understandable, accessible and always available. Nevertheless they can only provide limited information and do not have navigation or route planning functions, which are present in mobile applications. Besides, smartphones can present information using various modes like visual aids or multimedia, which is a useful detail that should be used in the application. However mobile applications also have disadvantages like the limited or expensive network connection, small display size for the maps and complex usage. In light of this information, it can be seen that an application combining both systems could overcome the disadvantages of both systems.

Both positive and negative criticisms and/or suggestions were made during the discussions. Firstly it was stated that the size of the paper map should not be too big so that it is possible to hold the plan and use the smartphone at the same time. It was frequently stated that it would make sense to use the application at the hotel to look up for information the day before the trip or during a break in a café where there is Internet connection, and then use only the paper map during the travel. It was a common idea that it is not easy to walk around and use paper maps with smartphones. Moreover some people said that it provides a better alternative than looking up for places from the guidebook then looking it up from the map, which can be frustrating after a point. The fact that the application provides direct information on the map was found practical. It could be an interesting alternative to integrate mobile functionality to the maps on guidebooks, instead of only paper maps. In that way, there will not be any inconveniences to look up for information from the map and guidebook consecutively. Moreover, alternative tools to visualize information would enrich guidebooks and bring a dynamic aspect to it.

It is often stated that the amount and the quality of the information and how it is visualized play an important role. Respondents would like to have access to local people's preferences. Furthermore the information should be up-to-date and the application should be easy to use.

Some people said it is enough to have the mobile application to obtain information and the paper map is a redundant detail that slows down the trip. Although there were significant amount of people who found the collaborative use of paper maps and mobile applications interesting, it would still make sense to intensify roles of both systems in such an integrated approach. That way none of the elements would be redundant, but essential for the application. This can be achieved through emphasizing the advantages of both systems.

The functions that are found most important to be included into the application were; Internet connection, search functions showing landmarks, cultural activities, restaurants and bars, navigation functions like "Where am I?" and route planning. Moreover the younger participants found the search function for clubs very important while it was not so important for the older participants. Other frequently mentioned functionalities were having the transportation network with bicycle roads, search functions for hospitals and pharmacies. Attributes like connection to social networks, accommodation, and predefined city tours were found interesting but did not receive as much attention as the other functionalities. It would still be beneficial to have them integrated but they should not be one of the priorities. An alternative to the function “connection to social networks” would be to provide an interface to communicate with local people. By this way people could also get insider tips from people living in the city. Moreover it should also be taken into consideration that the application should only require Internet connection for dynamic information like events, festivals, etc., and should be able to operate without Internet connection, since the network connection is expensive abroad.

Another important point is that, people think that there are already lots of mobile tourist guides that provide mainstream information and it is essential to present the information in an alternative, unusual form. As Peres et al. (2011) also states in their paper; presentation of services and attractions should be made in a creative, intelligent manner, using alternative modes of technologies. Therefore it is significant to employ alternative functionalities of smartphones to present the information. At this point it might be interesting to consider developing game interface to the application, giving users tasks from one location to another, explaining facts about the places using multimedia, visual aids. However, designing such an application requires broader search on this area. Nevertheless, it could be considered as an alternative that can be integrated into the application as an additional functionality. It would be reasonable to develop an approach that would make the use of the paper map crucial and entertaining. That way the criticisms implying that the paper maps are redundant when the information can be obtained through mobile devices would be outdated.

For more detailed evaluation correlations between attributes and age, gender, smartphone ownership information were investigated. These results are provided in depth in Section 7.6. These findings enhance our understanding on how certain age groups react to certain attributes or how smartphone ownership affects people’s opinion about the application, etc. The most significant finding is the answer of different age groups to the question whether they would use the application or not. Most positive answers came from 41-50 and 51+ age groups, indicating that the application would in fact address to people in every age group.

The overall reaction to the application was positive and participants found the collaborative use of paper maps and mobile applications advantageous. However, there were people who were not in favor of using paper maps with mobile applications. The additional attribute that this thesis offers which is the presence of 3D model of landmarks was also found an interesting tool by most of the people, but considered as nice-to-have rather than need-to-have service. Even though there were some negative comments, in general there were a significant number of people who said that they would be interested in using such an application.

8 EVALUATION

Inferences of the application and the questionnaire are covered in depth in Section 6.4 and Section 7.8. This chapter provides an overall evaluation of the study, combining the findings of both application and questionnaire, and sums up the findings.

The application is developed in order to provide an impression on what this thesis aims to investigate, which is evaluating a system that integrates digital systems with analogue maps. In order to come up with some conclusions, a prototype was needed to test the usability of the approach and to provide a demonstration during the questionnaires. The prototype presented at the end of this study fulfills these requirements. However, there were some challenges faced, during this process. Some of these challenges were able to be solved, while some remained unsolved such as textures and shaking of the models. These challenges are explained in depth in Section 6.3.

In terms of usability of the application, there were some inferences derived while conducting the questionnaires. A significant weakness of the application is the affect of direct sunlight. The marker detection process is negatively affected by direct sunlight, and in some cases the application fails to recognize the markers. Moreover the screen of the mobile device is also not visible due to the reflections on the screen caused by sunlight. To a certain extend this problem is valid in all digital applications, due to visibility matters and could not be overcome. Users need to pay attention when using the application.

Secondly, the size of the paper map is also an important factor. It is essential to provide an optimal sized map, so that the mobility is not restricted while using the map and mobile device.

Another important issue is the utilization of the markers. Research has shown that the black barcode marker that are used in this study, are not favored and found disturbing by significant number of people. This implies that in further iterations of the prototype, alternative solutions should be developed. Furthermore, the results of the markers are not very convincing in several aspects. The small size of the markers causes in some cases marker confusion, which means visualizing the wrong model for a certain marker. Also, the smaller the size of the marker get, the more the visualized models are shaking on the display screen. Moreover, when new functions are integrated to the application, increasing number of markers will be needed. Some alternatives to replace current markers are presented in Section 6.4, which are namely, DOT markers, NFC tags or feature based tracking systems.

Questionnaire aims to investigate the public response to an integrated approach. Therefore it uses the pilot application to provide an overview. Afterwards set of questions are asked via a questionnaire to the respondents.

Based on the results from the survey, some functions that could be integrated to the application in further iterations can be derived. These functions are Internet connection, search functions showing landmarks, cultural activities, restaurants and bars, navigation functions like "Where am I?" and route planning.

It is possible to summarize the findings of the questionnaire as follows:

- The quality and quantity of information and how it is visualized plays an important role. Alternative display modes provided by smartphone should be employed
- The information should be up-to-date and not be mainstream, but alternative such as providing insider tips
- The application should have an easy user interface.
- The information should be presented in a comprehensible manner. In order limit the display content to increase the legibility of the information, one thematic layer of information should be viewed at a time
- The application should not be expensive
- The paper plan should have an ergonomic size, which allows users to walk around with it and a smartphone together

Results of the evaluation imply that an integrated system would be favored by significant amount of people. However, it is important to take into account the findings of the questionnaire. In light of this information, it is possible to develop a strategy for further iterations of the application.

9 CONCLUSION

This chapter provides a summary of the overall process and the findings of the study. Recommendations for future work are also given.

9.1 Summary

Although mobile tourism embraces lots of innovations, it falls behind to respond the needs of the tourists in several matters. The small display size of the smartphones fails to provide a good overview of the area. Besides, it is also not convenient to project the map with its' corresponding information due to the limited space. However, traditional paper maps are still favored by many tourists, due to its' easy to use, legible structure.

The motivation of this study is to investigate an alternative approach that combines the advantages of analogue and digital systems in tourism activities by designing a mobile application in which virtual information achieved through a mobile device is projected over paper plans. The application can be described as a sample application that overlays 3D models of attraction points over the markers printed on the 2D paper maps. Furthermore, feasibility of the project and public response is examined via a survey, in which the sample application is demonstrated to the participants prior to conducting the questionnaire.

Firstly inferences and the conclusions from the application development section will be summarized. As described in depth in Chapter 6, the application is using ARToolKit framework, and developed through series of modifications in the framework. The project is using native libraries via a Java interface. 3D models that were used in the study were taken from Trimble Warehouse in ".skp" file format, and exported into ".obj" format. 2D barcode markers were used due to their fast and accurate tracking performance. Finally, the paper map is downloaded from OpenStreetMap and prepared.

The application succeeds to visualize the 3D models over markers, but due to the time limitations some challenges remained unsolved, such as textures and shaking of the models etc. These challenges could be overcome with more time and experience with the framework.

As explained in Section 7.2, the questionnaire is conducted through a street survey to the tourists and inhabitants of Berlin. 80 questionnaires are made in several key locations in Berlin. Findings of the questionnaire are summarized in following part. The questionnaire is consisting of three sections. First two sections provide general information about the state of art regarding tourism activities, paper map and smartphone usage. Section three is focusing on the sample application, public response to the application and suggestions to improve it.

Research has shown that the overall reaction to the application was positive and people are enthusiastic about an integrated approach of paper maps and digital applications, which provides an interactive, alternative approach to discover cities. Furthermore people found it interesting to have the functionality to visualize 3D models of landmarks. However, this additional attribute that this study proposes was not found vital for the application. Overall, significant amount of respondents in various age groups found the application interesting and useful to employ during their travels.

The purpose of the study was to provide a mediatory approach to low-tech, high-tech tourism tools, namely paper plans and mobile applications instead of choosing one among the two. Returning to the hypothesis posed at the beginning of this study; it is now possible to state that developing a tourist guide application that collaborates paper maps with mobile applications would be feasible depending on the content and the presentation of the application.

9.2 Recommendations

This research has thrown up many questions in need of further investigation. There were some critics made, regarding the application. An important critique was that markers decrease the legibility of the map. Considering the fact that the current version of the application is only visualizing the landmarks; when additional functionalities are integrated such as restaurants, bars, hotels etc.; the map would be covered with markers. Future research should therefore concentrate on the investigation of removing the markers. Some possibilities would be to replace markers with “DOT markers” (Hecht et al., 2007), or with NFC tags (Micheel, 2012) or introducing feature based tracking integrated with GPS (Morrison et al., 2011). In order to reach some conclusion on which system would be more convenient in the scope of this study, further investigations should be made in this area.

Furthermore, challenges faced in application development process and could not be overcome due to limited time and experience, should be solved. The first step would be replacing 3D models with the CityGML dataset of Berlin, which is a commercial product, providing number of advantages (Section 4.5.1).

An important limitation of the project lies in the fact that the sample size of the respondents to the questionnaire was relatively small. As a result, looking for correlations between some attributes and age, gender, paper map and smartphone ownership would not necessarily project the truth. Although correlations were investigated in the study it was only interpreted as indicators but not as definite conclusions. Further research needs to be done to examine these correlations.

The findings of this study suggests that the information should be presented using alternative approaches such as visual aids or multimedia in order to attract people. It should be taken into consideration when improving the sample application. Moreover, the functionalities that are found most important (Section 7.6.3), should be integrated to the application.

One of the findings of the research was people’s wish to get insider tips. Therefore it might be interesting to develop an interface, which allows users to communicate with local people and obtain information and ask questions in a more direct, personal way.

One of the main advantages of this project was the fact that it provides direct information. Some people stated that it is a convenient alternative to using guidebooks and paper maps consecutively. These findings provide the following insights for future research: integrating the mobile interface to a guidebook instead of an independent paper map. This would enhance the content of a guidebook, making it more interactive and dynamic. Furthermore it would eliminate the inconveniences by providing direct information.

Another interesting possibility would be designing a game interface to deliver information. Paper map and mobile application could be designed to supplement each other by giving tasks to users from one location to another and explaining some interesting facts. However, game design is a new research topic that needs to be investigated before any implementations could be done.

Finally, it is observed that Mobile Augmented Reality can still be considered as a new technology and there are lots of possible investigation areas and developments to be made. As more powerful devices being developed, limitations will be overcome, more accurate, cheaper applications will be developed. This study has revealed that linking digital technologies and analogue systems offers great possibilities to enhance the tourist experience.

ANNEX A: QUESTIONNAIRE, *IN ENGLISH*

This questionnaire is conducted as a part of the master project "Development and Evaluation of an Augmented Reality Tourist Map Application - Berlin", in University of Applied Sciences - Stuttgart. It aims at measuring the public response to a mobile tourist guide application working together with paper maps.

Augmented Reality Tourist Map Application for Berlin

Gender: ☐ F ☐ M
Date:_________________

Age: ____________

Country of residence: ____________

General Information

Are you familiar with Augmented Reality technologies? ☐ Yes ☐ No

Tourism Activities

What kind of information do you like to know when visiting cities for the first time?

Before you arrive	During your stay
1-☐ Where the landmarks are? 2-☐ Where the restaurants are? (Price, location, availability) 3-☐ Where are the accommodation possibilities? (Price, location, availability) 4-☐ Transportation network 5-☐ Cultural activities (Festivals, concerts, theaters) 6-☐ Others:_________________________	1-☐ Where the landmarks are? 2-☐ Where the restaurants are? (Price, location, availability) 3-☐ Where are the accommodation possibilities? (Price, location, availability) 4-☐ Transportation network 5-☐ Cultural activities (Festivals, concerts, theaters) 6-☐ Others:_________________________

What types of means are you using to achieve this information?

Before you arrive	During your stay
1-☐Internet 2-☐Tourist guides – books 3-☐Mobile tourist applications 4-☐Paper maps 5-☐ Others:_________________________	1-☐Internet 2-☐Tourist guides – books 3-☐Mobile tourist applications 4-☐Paper maps 5-☐Tourist information centers 6-☐ Others:_________________________

A- Paper Maps and Mobile Applications

Paper Map Usage

1-Are you using paper maps in your daily life?

☐Never ☐Sometimes ☐Always

2-For which purpose are you using paper maps?

☐ Orientation in the city you are living
☐ Orientation in nature
☐ For travel planning
☐ During the travel in a foreign city
☐ For finding unknown addresses (for an appointment)

3-What are the reasons for choosing paper maps for tourism activities? (advantages)

☐Provides a good overview/ orientation of the area
☐ Easily accessible
☐ Easy to understand
☐ Cheap
☐ Other: ________________________________

4-What are the reasons for not using paper maps? (disadvantages)

☐ Difficult to understand
☐ Limited information
☐ No navigation / route planning functions
☐ I prefer other means (mobile tourist applications)
☐ Other: ________________________________

5-Are you using any additional tool to supplement paper maps while travelling?

☐ Mobile tourist guides
☐ Tourist guide books
☐ Nothing
☐ Other: ________________________________

Mobile Applications & Navigation Usage

1-Do you own a smart phone?

☐ Yes ☐ No

2-For which purpose are you using your smart phone?

☐ Internet
☐ Navigation
☐ Games & Entertainment
☐ Photo
☐ Music
☐ Tourism
☐ Other: ________________________________

3-Are you using internet functions of your smart phone during your visit to foreign countries?

☐ Never ☐ Sometimes ☐ Always

4-Have you ever used a mobile tourist guide application?

☐ Never ☐ Sometimes ☐ Always

5-If yes, how would you describe your experience?

____

6-What are the reasons for choosing mobile tourist applications? (advantages)

☐ Provides large amount of information in a compact form
☐ Provides several display options (multimedia, visual aids)
☐ Provides alternative modes of services (navigation, route planning)
☐ Allows internet access
☐ Other: ________________________________

7-Are you using navigation functions of mobile tourist guide applications?

☐ Never ☐ Sometimes ☐ Always

8- What are the reasons for not using mobile tourist applications? (disadvantages)

☐ Complex to use
☐ Limited/expensive network connection
☐ Small display size for maps
☐ Expensive applications
☐ Other: ________________________________

Berlin3dAR – An Augmented Reality Tourist Guide Application for Berlin

After each statement, circle a number indicating your level of agreement. Mark "1" if you strongly agree with the statement, "5" if you strongly disagree and "3" if you are neutral.

1-Very important	2-Important	3-Moderately Important	4-Of Little Importance	5-Not at all important

This application is a prototype application, which is to be further developed to provide full functionality. It aims at providing guidance during the stay.

What kind of features would you want to be included into the mobile application?

1-Internet connection

Very Important - 1 2 3 4 5 - Unimportant

2-Connection to social networks / receiving feedback from other users

Very Important - 1 2 3 4 5 - Unimportant

3-Search functions showing:

a- Landmarks

Very Important - 1 2 3 4 5 - Unimportant

b- Cultural Activities (museums, exhibitions)

Very Important - 1 2 3 4 5 - Unimportant

c- Restaurants, Bars

Very Important - 1 2 3 4 5 - Unimportant

d- Clubs

Very Important - 1 2 3 4 5 - Unimportant

e- Accommodation facilities

Very Important - 1 2 3 4 5 - Unimportant

4-Navigation tools;

a- "Where am I?" function, showing the current location of the user

Very Important - 1 2 3 4 5 - Unimportant

b- "Route planning" function, providing a route from the location of the user to the destination

Very Important - 1 2 3 4 5 - Unimportant

5-Predefined city tours (1day tour, 3 day tour) according to the criteria entered by the user

Very Important - 1 2 3 4 5 - Unimportant

What other functionalities do you think can be added to the application?

____

____

After each statement, circle a number indicating your level of agreement. Mark "1" if you strongly agree with the statement, "5" if you strongly disagree and "3" if you are neutral.

1-Strongly agree	2-Agree	3-Neutral	4-Disagree	5-Strongly Disagree

Previously demonstrated application is a prototype application; final product will have additional functionalities like internet connection, search functions, navigation tools. Following questions should be answered for the final application.

1-Combining paper maps with mobile applications will bring advantages in my travels

Strongly Agree - 1 2 3 4 5 - Strongly Disagree

2-Using an application that is combining 3D models with 2D paper maps is interesting

Strongly Agree - 1 2 3 4 5 - Strongly Disagree

3-I would use the application during my travel

Strongly Agree - 1 2 3 4 5 - Strongly Disagree

4-What do you think are the strengths/ advantages of the project?

☐ Vast amount of information
☐ Interactive
☐ Easy to use
☐ Other: __________________________________

5-What do you think are the weaknesses/ disadvantages of the project?

☐ Many functions are not available
☐ Markers are making the map unclear
☐ It is too slow
☐ Other: __________________________________

ANNEX B: QUESTIONNAIRE, *IN GERMAN*

Dieser Fragebogen ist Teil einer Masterarbeit mit dem Titel "Entwicklung und Auswertung einer 'Augmented Reality Tourist Map Application for Berlin'", die an der Hochschule für Technik – Stuttgart entsteht. Er dient der Erfassung eines allgemeinen Meinungsbildes bezüglich des kombinierten Einsatzes von mobilen Reiseführer-Applikationen und Stadtplänen.

Augmented Reality Tourist Map Application for Berlin

Geschlecht: ☐ W ☐ M
Datum:_________________

Alter: ____________

Wohnort: ____________

Allgemeine Informationen

Sind Sie vertraut mit Augmented Reality Technologien? ☐ Ja ☐ Nein

Touristische Aktivitäten

Welche Art von Informationen holen Sie für einen erstmaligen Städtebesuch ein?

Vor Ihrer Reise	Während Ihres Aufenthaltes
1-☐ Wo sich Sehenswürdigkeiten befinden 2-☐ Wo Restaurants zu finden sind (Preis, Ort, etc.) 3-☐ Wo Unterkünfte zu finden sind (Preis, Ort, etc.) 4-☐ Verkehrsnetz und/oder öffentliche Verkehrsmittel 5-☐ Kulturelle Aktivitäten (Festivals, Konzerte, Theater, etc.) 6-☐ Anderes:________________________	1-☐ Wo sich Sehenswürdigkeiten befinden 2-☐ Wo Restaurants zu finden sind (Preis, Ort, etc.) 3-☐ Wo Unterkünfte zu finden sind (Preis, Ort, etc.) 4-☐ Verkehrsnetz und/oder öffentliche Verkehrsmittel 5-☐ Kulturelle Aktivitäten (Festivals, Konzerte, Theater, etc.) 6-☐ Anderes:________________________

Von welchen Möglichkeiten machen Sie Gebrauch, um an diese Informationen zu gelangen?

Vor Ihrer Reise	Während Ihres Aufenthaltes
1-☐Internet 2-☐Reiseführer 3-☐Mobile Reiseführer Apps 4-☐Stadtpläne (in Papierform) 5-☐ Anderes:________________________	1-☐Internet 2-☐Reiseführer 3-☐Mobile Reiseführer Apps 4-☐Stadtpläne (in Papierform) 5-☐Touristeninformationszentren 6-☐ Anderes:________________________

B- Stadtpläne und Mobile Apps

Gebrauch von Stadtplänen

1-Benutzen Sie Stadtpläne (in Papierform) in Ihrem Alltag?

☐ Nie ☐ Gelegentlich ☐ Immer

2-Zu welchem Zweck verwenden Sie Stadtpläne?

☐ Zur Orientierung in der Stadt
☐ Zur Orientierung in der Natur, beim Wandern oder Radfahren
☐ Zur Reiseplanung, Reisevorbereitung
☐ Während einer Reise
☐ Um unbekannte Adressen ausfindig zu machen (z.B. für Termine und Verabredungen)

3-Aus welchen Gründen wählen Sie Stadtpläne für Ihre touristischen Aktivitäten?

☐ Sie bieten eine gute Übersicht über das gesamte Gebiet
☐ Sie sind einfach zu erwerben
☐ Sie sind leicht zu verstehen/zugänglich
☐ Sie sind günstig
☐ Anderes: ________________________________

4-Aus welchen Gründen benutzen Sie keine Stadtpläne?

☐ Sie sind schwierig zu verstehen
☐ Sie liefern nur begrenzt Informationen
☐ Sie bieten nicht die Möglichkeit, Routen zu planen
☐ Ich bevorzuge alternative Mittel (mobile Touristen-Apps)
☐ Anderes: ________________________________

5-Benutzen Sie zusätzliche Mittel, um Stadtpläne während Ihrer Reise zu ergänzen?

☐ Mobile Reiseführer
☐ Reiseführer (in Buchform)
☐ Nichts
☐ Anderes: ________________________________

Mobile Apps & Gebrauch von mobilen Endgeräten zur Navigation

1-Haben Sie ein smartphone?

☐ Ja ☐ Nein

2-Wozu nutzen Sie Ihr smartphone?

☐ Internet
☐ Navigation
☐ Spiele & Entertainment
☐ Photo
☐ Musik
☐ Tourismus
☐ Anderes: ___________________________________

3-Verwendgen Sie Internet-Funktionen Ihres Smartphones während eines Aufenthaltes im Ausland?

☐ Nie ☐ Gelegentlich ☐ Immer

4-Verwenden Sie mobile Reiseführer-Apps?

☐ Nie ☐ Gelegentlich ☐ Immer

5-Wenn ja, beschreiben Sie Ihre Erfahrungen?

____

6-Aus welchen Gründen verwenden Sie mobile Reiseführer-Apps?

☐ Sie liefern viele Informationen in kompakter Form
☐ Sie weisen verschiedene Darstellungsformen auf (visuell, auditiv, etc.)
☐ Sie bieten Zusatzleistungen (Navigation, Routenplanung)
☐ Sie ermöglichen einen Zugang zum Internet
☐ Anderes: ___________________________________

7-Nutzen Sie mobile Reiseführer-Apps zur Navigation?

☐ Nie ☐ Gelegentlich ☐ Immer

8- Aus welchen Gründen verwenden Sie keine mobile Reiseführer-Apps?

☐ zu komplizierter Gebrauch
☐ begrenzte/teure Netzwerkverbindung
☐ zu kleine Kartendarstellung auf dem Display
☐ zu teuer
☐ Anderes: ___________________________________

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Bitte geben Sie an, wie wichtig für Sie folgende Funktionen einer Reiseführer-App sind, '1' steht hierbei für 'sehr wichtig', '5' für 'überhaupt nicht wichtig'.

1-Äußerst wichtig	2-Wichtig	3-Maßig wichtig	4-Weniger Wichtig	5-Nicht wichtig

Bei der vorgeführten App handelt es sich um einen Prototyp, der in seiner Funktionalität weiterentwickelt wird. Sie zielt ab auf einen Einsatz während des Reiseaufenthaltes.

Welche Möglichkeiten/Features sollte eine mobile App Ihrer Meinung nach bieten?

1-Internetverbindung

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

2-Verbindung zu sozialen Netzwerken / die Möglichkeit, Feedback von anderen Nutzern zu erhalten

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

3-Suchfunktionen für folgende Informationen:

f- Sehenswürdigkeiten

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

g- Kulturelle Aktivitäten (Museen, Ausstellungen, etc.)

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

h- Restaurants, Bars

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

i- Diskotheken

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

j- Unterkünfte

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

4-Navigationsfunktionen;

c- "Wo befinde ich mich?"-Funktion, die den Standpunkt des Nutzers lokalisiert

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

a- "Routenplaner"-Funktion vom Standpunkt des Nutzers zu einer Zieladresse

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

5-Vorschläge für Stadttouren (Eintagestouren, Dreitagestouren) nach den eingegeben Kriterien des Nutzers

Äußerst wichtig - 1 2 3 4 5 - Nicht wichtig

Welche weiteren Funktionen wären Ihrer Meinung nach sinnvoll für eine Reiseführer-App?

____

____

Bitten geben Sie im Folgenden an, wie sehr Sie mit den Aussagen übereinstimmen. '1' steht für 'Ich stimme voll und ganz überein', '5' für 'Ich stimme überhaupt nicht überein'.

1-Stimme voll und ganz überein	2-Stimme überein	3-Neutral	4-Stimme nicht überein	5-Stimme überhaupt nicht überein

Die zuvor demonstrierte App ist ein Prototyp. Die Endfassung wird zusätzliche Funktionen bieten wie eine Internetverbindung, Suchfunktionen und Navigationshilfen. Die Antworten dienen einer verbesserten Entwicklung des Endprodukts.

1-Die <u>Kombination</u> von mobile Apps mit Stadtplänen (in Papierform) ist bei meinen Reisen von Vorteil.

Stimme voll und ganz überein - 1 2 3 4 5 - Stimme überhaupt nicht überein

2-Die Verwendung einer App, die 3D-Modelle mit 2D-Karten verbindet, ist interessant.

Stimme voll und ganz überein - 1 2 3 4 5 - Stimme überhaupt nicht überein

3-Ich würde die App während meiner Reise verwenden.

Stimme voll und ganz überein - 1 2 3 4 5 - Stimme überhaupt nicht überein

4-Was sind Ihrer Meinung nach die Vorteile dieses Projekts?

- ☐ Es bietet viele Informationen
- ☐ Es ist interaktiv
- ☐ Es ist einfach im Gebrauch
- ☐ Anderes: ____________________________________

5-Was sind Ihrer Meinung nach die Nachteile dieses Projekts?

- ☐ Viele Funktionen sind nicht verfügbar.
- ☐ Die Marker machen die Karte unübersichtlich.
- ☐ Es ist zu langsam
- ☐ Anderes: ____________________________________

ANNEX C: APPLICATION CODES

Berlin3dARActivity.java

```
package edu.hft.stuttgart.berlin3dar;

import com.artoolworks.ar.base.ARActivity;
import com.artoolworks.ar.base.rendering.ARRenderer;
import android.os.Bundle;
import android.widget.FrameLayout;

public class Berlin3dARActivity extends ARActivity {

         private SimpleNativeRenderer simpleNativeRenderer = new
SimpleNativeRenderer();

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.main);
    }

    public void onStop() {

         SimpleNativeRenderer.demoShutdown();

         super.onStop();

    }

    @Override
    protected ARRenderer supplyRenderer() {
         return simpleNativeRenderer;
    }

    @Override
    protected FrameLayout supplyFrameLayout() {
         return (FrameLayout)this.findViewById(R.id.mainLayout);

    }

}
```

SimpleNativeRenderer.java

```
package edu.hft.stuttgart.berlin3dar;

import javax.microedition.khronos.opengles.GL10;
import com.artoolworks.ar.base.FPSCounter;
import com.artoolworks.ar.base.rendering.ARRenderer;
import android.util.Log;

public class SimpleNativeRenderer extends ARRenderer {


    static {
          System.loadLibrary("ARToolKitWrapper");
          System.loadLibrary("ARWrapperBerlin3dAR");
    }

    public static native void demoInitialise();
    public static native void demoShutdown();
    public static native void demoSurfaceChanged(int w, int h);
    public static native void demoDrawFrame();

    private FPSCounter counter = new FPSCounter();

@Override
          public boolean configureARScene() {
          SimpleNativeRenderer.demoInitialise();
          return true;
    }

    public void onSurfaceChanged(GL10 gl, int w, int h) {
          SimpleNativeRenderer.demoSurfaceChanged(w, h);
    }

    public void draw(GL10 gl) {

          SimpleNativeRenderer.demoDrawFrame();

          if (counter.frame()) Log.i("demo", counter.toString());

    }

}
```

ARWrapperBerlin3dAR.cpp

```
extern "C" {
	#include <AR/gsub_es.h>
	#include <Eden/glm.h>
};

#include <jni.h>
#include "ARToolKitWrapperExportedAPI.h"

#define JNIFUNCTION_DEMO(sig)
Java_edu_hft_stuttgart_berlin3dar_SimpleNativeRenderer_##sig

extern "C" {
	JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoInitialise(JNIEnv*
env, jobject object));
	JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoShutdown(JNIEnv*
env, jobject object));
	JNIEXPORT void JNICALL
JNIFUNCTION_DEMO(demoSurfaceChanged(JNIEnv* env, jobject object, jint w,
jint h));
	JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoDrawFrame(JNIEnv*
env, jobject obj));
};

typedef struct ARModel {
	int patternID;
	ARdouble transformationMatrix[16];
	bool visible;
	GLMmodel* obj;
} ARModel;

static ARModel models[8];

static float lightAmbient[4] = {1.0f, 1.0f, 1.0f, 1.0f};
static float lightDiffuse[4] = {1.0f, 1.0f, 1.0f, 1.0f};
static float lightPosition[4] = {2.0f, 1.0f, 1.0f, 0.0f};

JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoInitialise(JNIEnv* env,
jobject object)) {

	models[0].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.01;80");
	models[0].obj =
glmReadOBJ("/sdcard/AR/Data/models/brandenburgerreichstag.obj", 0);
	glmScale(models[0].obj, 1.900f);
	glmRotate(models[0].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
	glmCreateArrays(models[0].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
	models[0].visible = false;
```

```
        models[1].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.02;80");
        models[1].obj = glmReadOBJ("/sdcard/AR/Data/models/tvturm.obj",
0);
        glmScale(models[1].obj, 0.020f);
        glmRotate(models[1].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[1].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[1].visible = false;


        models[2].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.04;80");
        models[2].obj =
glmReadOBJ("/sdcard/AR/Data/models/siegesaule.obj", 0);
        glmScale(models[2].obj, 0.070f);
        glmRotate(models[2].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[2].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[2].visible = false;

        models[3].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.05;80");
        models[3].obj =
glmReadOBJ("/sdcard/AR/Data/models/hauptbahnhof.obj", 0);
        glmScale(models[3].obj, 0.015f);
        glmRotate(models[3].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[3].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[3].visible = false;

        models[4].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.06;80");
        models[4].obj =
glmReadOBJ("/sdcard/AR/Data/models/kongresshalle.obj", 0);
        glmScale(models[4].obj, 0.025f);
        glmRotate(models[4].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[4].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[4].visible = false;

        models[5].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.07;80");
        models[5].obj =
glmReadOBJ("/sdcard/AR/Data/models/museuminseldeutsches.obj", 0);
        glmScale(models[5].obj, 1.200f);
        glmRotate(models[5].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[5].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[5].visible = false;
```

```
        models[6].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.09;80");
        models[6].obj =
glmReadOBJ("/sdcard/AR/Data/models/deutschfranzdom.obj", 0);
        glmScale(models[6].obj, 0.025f);
        glmRotate(models[6].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[6].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[6].visible = false;

        models[7].patternID =
arwAddMarker("single;/sdcard/AR/Data/patt.berlin;80");
        models[7].obj = glmReadOBJ("/sdcard/AR/Data/models/berlin3d.obj",
0);
        glmScale(models[7].obj, 0.900f);
        glmRotate(models[7].obj, 3.14159f / 2.0f, 1.0f, 0.0f, 0.0f);
        glmCreateArrays(models[7].obj, GLM_SMOOTH | GLM_MATERIAL |
GLM_TEXTURE);
        models[7].visible = false;

}

JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoShutdown(JNIEnv* env, jobject
object)) {
        glmDelete(models[0].obj, 0);
        glmDelete(models[1].obj, 0);
        glmDelete(models[2].obj, 0);
        glmDelete(models[3].obj, 0);
        glmDelete(models[4].obj, 0);
        glmDelete(models[5].obj, 0);
        glmDelete(models[6].obj, 0);
        glmDelete(models[7].obj, 0);
}

JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoSurfaceChanged(JNIEnv* env,
jobject object, jint w, jint h)) {
        glViewport(0, 0, w, h);
}

JNIEXPORT void JNICALL JNIFUNCTION_DEMO(demoDrawFrame(JNIEnv* env, jobject
obj)) {


        glEnable(GL_DEPTH_TEST);
        glEnable(GL_TEXTURE_2D);

        glDepthFunc(GL_LESS);
        glClearDepthf(1.0f);
        glShadeModel(GL_SMOOTH);
        glHint(GL_PERSPECTIVE_CORRECTION_HINT, GL_NICEST);
```

```
        glEnable(GL_LIGHTING);

        glFrontFace(GL_CCW);

        glClearColor(0.0f, 0.0f, 0.0f, 0.0f);
        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);

        float proj[16];
        arwGetProjectionMatrix(proj);
        glMatrixMode(GL_PROJECTION);
        glLoadMatrixf(proj);

        glMatrixMode(GL_MODELVIEW);

        glStateCacheEnableDepthTest();
        glStateCacheEnableLighting();
        glEnable(GL_LIGHT0);

        for (int i = 0; i < 8; i++) {
                models[i].visible =
arwQueryMarkerTransformation(models[i].patternID,
models[i].transformationMatrix);

                if (models[i].visible) {

                        glLoadMatrixf(models[i].transformationMatrix);

        glLightfv(GL_LIGHT0, GL_AMBIENT, lightAmbient);
        glLightfv(GL_LIGHT0, GL_DIFFUSE, lightDiffuse);
        glLightfv(GL_LIGHT0, GL_POSITION, lightPosition);

        glmDrawArrays(models[i].obj, 0);
                }
        }
}
```

Main.xml

```xml
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:id="@+id/topLayout"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:orientation="horizontal" >

   <FrameLayout
       android:id="@+id/mainLayout"
       android:layout_width="match_parent"
       android:layout_height="match_parent"
       android:orientation="vertical" >

    </FrameLayout>

</LinearLayout>
```

AndroidManifest.xml

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="edu.hft.stuttgart.berlin3dar"
    android:versionCode="1"
    android:versionName="1.0">

        <uses-sdk
                android:minSdkVersion="7"
                android:targetSdkVersion="7" />

    <application
        android:icon="@drawable/berlin3dar"
android:label="@string/app_name" >
        <activity
            android:name=".Berlin3dARActivity"
            android:label="@string/app_name" >
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />
                <category android:name="android.intent.category.LAUNCHER"
/>
            </intent-filter>
        </activity>
    </application>

    <uses-permission android:name="android.permission.CAMERA" />
        <uses-feature android:name="android.hardware.camera" />
        <uses-feature android:name="android.hardware.camera.autofocus" />

        <supports-screens
                android:smallScreens="true"
                android:normalScreens="true"
                android:largeScreens="true"
                android:anyDensity="true" />

</manifest>
```

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