DEVELOPING AUGMENTED REALITY MOBILE APPLICATION: NEU CAMPUS GUIDE

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
SAGIR TAMBUWAL MUHAMMAD

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Computer Information Systems

NICOSIA, 2019.

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Approval of Director of Graduate School of Applied Sciences

Prof. Dr. Nadire CAVUS

We certify that this thesis is satisfactory for the award of the degree of Masters of Science in Computer Information Systems

Examining Committee in Charge

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my late parents…

ABSTRACT

Augmented Reality (AR) seemed like a wild, modern idea, yet the innovation has been around for a considerable length of time. AR is generally involved with superimposing computer produced graphics over human perspective of the real world making a composite view that augment the present reality. Augmented Reality mobile applications today are one of the most patronised in the field of mobile computing. This is because they span across variety of aspect of life including health, telecommunication, gaming, shopping, interactive learning solutions, tourism and so on. In this study, a user-friendly AR mobile application in the form of a campus guide was developed to enable students to locate and recognise buildings around the institution as well as the offices, classes, cafeterias and halls in those buildings. The application works in such a way that user can scan around his immediate environment within the campus to find information about the buildings. The application was developed for Android operating system only. To develop the application, Unity 3D development environment was used in conjunction with Vuforia, ARCore and MapBox. The adopted software development life cycle is Rapid Application Development (RAD). Considering the usability test carried out on the developed application in this study, combining both marker based AR and GPS based AR experiences in one application brings about a better awareness of the users' immediate environment, thereby making life easier and more efficient specifically within the geographical scope of the study. Moreover, the usability test that was carried out has shown that the application has high usability and therefore it is very efficient and useful.

Keywords: *Augmented reality; campus guide; AR campus tour; marker based AR; GPS based AR; AR SDK; ARCore; Unity 3D; Vuforia; MapBox*

ÖZET

Artırılmış Gerçeklik çılgın bir modern fikir gibi görünsede uzun süredir mevcut olan bir teknolojidir. Genel olarak insanın gerçek dünyaya bakış açısı üzerine yapay grafikler ekleyerek mevcut gerçekliği artıran bir birleşik görüntü oluşturmada kullanılır. Bu günlerde artırılmış gerçeklik içeren mobil uygulamalar mobil programlama alanında en fazla tercih edilen türler arasındadır. Bunun sebebi ise hayatın sağlık, telekomünikasyon, oyun, alışveriş, etkileşimli öğrenme çözümleri ve turizm de dahil olmak üzere birçok farklı alanına yayılmalarıdır. Bu çalışmada öğrencilerin kampüs içerisindeki binaları bulabilmeleri ve tanıyabilmeleri amacı ile kampüs kılavuzu görevi üstlenen, kullanımı kolay bir mobil artırılmış gerçeklik uygulaması geliştirilmiştir. Uygulama kampüs dahilindeki bir kullanıcının yakın çevresini tarayıp, binalar hakkında bilgi edinmesini sağlayacak şekilde çalışır. Uygulama yalnızca android işletim sistemi kullanan cihazlar için geliştirilmiştir. Uygulamanın geliştirilmesinde Unity 3D, ARCore ve MapBox kullanılmıştır. Benimsenen yazılım geliştirme yaşam döngüsü Hızlı Uygulama Geliştirme'dir (RAD). Çalışma esnasında geliştirilen uygulamanın kullanılabilirlik testlerini göz önünde bulundurduğumuzda, hem marker hem de GPS tabanlı artırılmış gerçeklik deneyimlerinin tek bir uygulamada birleştirilmesinin kullanıcılarda yakın çevreleri hakkında daha iyi bir farkındalık oluşturduğu gözlemlenmiş, böylece bu durumun çalışmanın coğrafi kapsamı dahilinde hayatı daha kolay ve de verimli kılacağı öngörülmüştür. Üstelik, gerçekleştirilen kullanılabilirlik testi sonucunda uygulamanın yüksek kullanılabilirliğe sahip olduğu kanaatine varılmıştır.

Anahtar Kelimeler**:** *Artırılmış gerçeklik; kampüs rehberi; marker-tabanlı artırılmış gerçeklik; GPS-tabanlı artırılmış gerçeklik; AR SDK; ARCore; Unity 3D; Vuforia; MapBox*

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LIST OF ABBREVIATIONS

AR:	Augmented Reality
GPS:	Geographic Positioning System
ASR:	Augmented Sound Reality
POI:	Point of Interest/ Place of Interest
OS:	Operating System
MAR:	Mobile Augmented Reality / Mixed Augmented Reality
QR Code:	Quick Response Code
LBS:	Location Based Service
UX:	User Experience
UI:	User Interface
UTAUT:	Unified Theory of Acceptance and Use of Technology
RAD:	Rapid Application Development
GIS:	Geographic Information System
SDK:	Software Development Kit
RFID:	Radio Frequency Identification
GPM:	Graphic Processing Module
MPN:	Mobile Pedestrian Navigation
6-DOF:	Six Degree of Freedom
HMD:	Head Mounted Device
IDE:	Integrated Development Environment
NFC:	Near Field Communication
SLAM:	Simultaneous Location and Mapping
UWP:	Universal Windows Platform

CHAPTER ONE

INTRODUCTION

Augmented Reality (AR) still remains a developing technology in this modern era. AR is defined as involvement of virtual environment into the real world to enrich the view, the sound, sense of taste, feel or touch and scent or smell. The AR technology timeline originated from a cinematographer, Morton Heiling who perceived that cinema should allow interaction between the humans and the real world environment putting into consideration all the senses (Daponte et al., 2014). Augmented Reality is the augmentation or superimposing of graphical elements that are generated by computer such as audio, video, GPS data or graphical images on top of the real world environment. It could be understood more specifically by a notion called mediated reality through which artificial information can be added or subtracted or manipulated or overlaid on the real world (Agarwal et al., 2014).

In more formal terms, Capece et al. (2016) defined AR as the superimposing of graphical components produced by computer against the pictorial view of the physical reality through a camera. AR permits users to perceive the real world augmented with virtual objects (Hincapié et al., 2011). Simply, AR allow for the coexistence of virtual and real objects in one environment.

Moreover, AR is could not be associated with sight only; it might extend across all human senses. Hitherto, numerous research in the area only emphasised on the augmentation of graphics. Though, augmentation of sound is also possible. This could be experienced through a microphone-enabled headsets. The environmental sound is sensed by the microphone, while the headsets enhance artificial 3-D sounds. The artificial sound from the headset is then augmented with the environment sounds by the system. Some AR applications that works with sound are MusicAR and Augmented Sound Reality (ASR) (Mahadik et al., 2016).

The appearance of smartphones has projected a prospective market share for AR applications. A typical smartphone having a camera and sensor features such as GPS, gyroscopes and accelerometer could exhibit high AR potentials. Currently, AR is one of the principal technologies in health and surgeries, collaborative newspapers, virtual gaming, as well as shopping and collaborative learning services and solutions as described by (Khan and Khusro, 2015).

1.1 Problem Statement

By tradition, the university surroundings orientations are given via road signs and printed tour guides on books or in some cases on the walls of some buildings. Yet they are not sufficient, because new students or even visitors may end up asking people all around the university in order to locate a building. Moreover, these traditional approaches cannot build good context and location awareness for the people that dwell within the campus environment. Pawade et al. (2018) in their study suggested that a mobile augmented reality application that can allow a user to navigate by randomly scanning his immediate environment can be developed. Thus, with the recent development of AR and mobile devices, campus touring that enhance context and location awareness becomes easy and with no boundaries.

1.2 Aim of the Study

The aim of the study is to develop a user-friendly Augmented Reality mobile application that would enable students (especially new intakes) to locate and recognise buildings around the institution as well as the offices, classes, cafeterias and halls in those buildings.

1.3 Importance of the Study

The growing interest of the market for AR mobile applications makes the development of the proposed application very important. It is also important to develop such an incredibly helpful application because it is believed to have a significant impact on the context and location awareness of the students around the campus which has never been in existence before. The literature review showed that, very few or none of the related research works implemented both GPS and marker based AR functionality in a single application in the area of campus touring. In addition to the originality of this study, the “Map View” feature was also implemented.

1.4 Limitations of the Study

The limitation of the study is that it will present its content in English only, despite the fact that many of the students speaks Turkish which means that the application could not be properly used by all students. This limitations gives room for further research or development in the area of campus guide application development. Another limitation is that, due to time constraint, the application could not be developed to locate, recognise and describe all the buildings within the campus, but only those selected for this study. Also, the application is developed for Android mobile devices only.

1.5 Overview of Thesis

Here in this section of this chapter, a general overview of the thesis report chapters is briefly presented.

The first chapter of the report introduces the concept of the study and stated clearly the problem which the application developed in this project solves. The aim of the study is also categorically stated as well as the importance limitations posed by the study.

The second chapter presents a related research where the literaure is thoroughly reviewed by the author. The author compared in a summary table between the works reviewed and that of this project based on the features that could be offered by the AR technology.

The third chaper presents the theoretical framework where the main concepts, ideas and technologies associated with the study are discussed in detail some of which includes the history of AR, AR systems, application of AR, types of mpbile applications, mobile operating systems, user interface design in AR and so on.

In the fourth chapter, the employed methodology is presented in details. It includes the system description, system architecture, system development technologies, the adopted development model, and the system test design.

The fifth chapter presents the result of the study which includes the screenshots of the interfaces of the developed application and the result of the analysis of the feedback gotten from the user based application evaluation survey carried out after engaging in the application testing activity.

Finally in the last and sixth chapter, the discussion, conclusion and recommendation is presented.

CHAPTER TWO

RELATED RESEARCH

The appearance of smartphones has projected a prospective market for AR applications. A typical smartphone with camera and sensors like GPS, accelerometer and gyroscopes can unleash full potential of augmented reality. Presently, AR is one of the principal technologies in health and surgeries, collaborative newspapers, gaming in virtual environments, shopping and collaborative learning solutions. AR is a technology that enriches the sensorial perception of a person by adding virtual contents directly on the user's surrounding environment. The modern AR platforms, such as smartphones and head-mounted displays, are moving the application fields of this technology from research centers to a wide range of application domains.

2.1 Related Research in the Area of Tourist Guidance

Augmented Reality applications seem to be having high acceptance in the area of tourism. Numerous researches have been carried out under this umbrella, which turns out to give positive result towards the usage of AR applications in tourism. Moreover, some researchers even went further to come up with useful models for developing AR applications.

Geiger et al. (2014) focused on the employment of a robust mobile AR engine that could offer location based functionality and a mobile business application with regards to the implemented AR engine. Generally, the research work is to portray the development of the location based mobile AR engine for iOS 5.1 (or higher) and Android 4.0 (or higher) operating systems. The researchers identified their engine as AREA1. A business application called LiveGuide was successfully developed on the AREA engine but unfortunately some challenges were encountered. In the Android OS, an issue came up when they had to embark on an upgrade, which was later solved by making some changes to the application where some constants were changed. Same to the iOS, some customized user interface elements were hidden in different situations and some not even reacting to user interactions anymore due to the release of iOS7 as an update.

In another research, Muchtar et al. (2017) developed a GPS based tracking AR application called Medan KulinAR. The application presents information in real world view which can be more interactive and also easily understandable by users. The application is developed in such a way that it tries to find the coordinate of the user's mobile device as a marker in order to help dynamically find the location of potential assets in the nearest area in Medan, through presentation of existent, interactive and detailed information with the use of the GPS based tracking. The system was implemented based on two-tier architecture framework i.e. client-server architecture.

Aloqily (2016) presented a work in which an application was developed and called JoGuide which stands for Jordan Guide. The application was designed in such a way that it can help users by locating and providing information about their local surrounding sites. It was designed to support the users in urban areas or tourism destination in order to locate places of interest (POI) around them by simply moving the camera of their phones in all possible directions. The information about the buildings of interest are superimposed on the real view of the area through the camera. Places captured by the phone camera are indicated by adding graphical bins displaying the name of those places as defined by foursquare.com database. JoGuide is expected to be very helpful for those users who will be visiting places they have never been to (e.g. tourists). Without obstructing the view in the camera, the application displays details about sites including landmarks, stores, eateries etc. The application was developed only for android OS running on mobile phones and tablets of different screen resolution and computational capabilities.

Kourouthanassis et al. (2015) reported from their work in which they developed an MAR travel guide called CorfuAR. They presented a process of the development of a theoretical model that shows the adoption of MAR based on their emotional influence. The application was made available in two versions of Android OS; one personalized and the other non-personalized. The application allows users to view information about different points of interest (POI). The user may even make suggestion of POIs to their peers in the personalized version of the application only. In addition, the two applications can also give directions to specific locations or POIs. A sample of 105 users participated in the filed study of the two versions of the application where it was found that the functional features of the application bring to the minds of the users a sense of pleasure and arousal (emotion), which stimulate their behavioral intention of making use of the application.

Oleksy and Wnuk (2016) reported from their research in which they tried to study the opportunities in using AR application to induce positive emotional feelings towards places with dispossessed historical traces in order to bring their historical value back to life. The researchers selected the former Jewish district located at Warsaw, Poland and the study was carried out by participants, some of which used an AR application that can help display historical images superimposed on the real environment as they walk around the site and some watched images on computers. Based on the result from their analysis, they arrived at a conclusion that AR applications have influence on users positive attitudes towards places, brings about reduction in ethnic biasness and improve the meaning of multi-ethnic places.

Jung et al. (2015) in their research work tried to measure user's satisfaction and willingness to commend marker-based AR applications to others through the use a quality model. They also tried to examine the difference between high and low innovativeness groups that visited a theme park in Jeju Island of South Korea. Based on the result from the questionnaires given to 241 visitor of the park, they found that the content, custom-made services and the quality of the system have emotional impact shown users' contentment and willingness to recommend to others AR applications. Their study has shown that content, system and personalized service qualities influenced visitors' contentment in a positive manner. The study has also discovered that both content and personalized service qualities had more influence on user satisfaction than the system quality.

Fino et al. (2013) presented in their work, an outline and a way of putting into practice a tourist guide by combining three technologies. The technologies are web 2.0, AR and Quick Response (QR) code. The application was meant for visitation of the two historically significant routes in a world heritage city. Videos and 3D animations augmented to the real environment are displayed to the user as he walks in the route across the town showing all the historic buildings. Upon arrival at each historic building, the AR application guides the user on how to access information about the building by scanning the QR code. Another part of the project was carried out in such a way that a tourist map of the city holds the images of historical buildings one can visit in the two proposed routes of the world heritage city. Separate QR codes were assigned to each image of the buildings which when scanned can give a user access to detailed information in multimedia and text format kept in a website specifically designed for this purpose. However, they also suggested that an AR application of this kind with functionalities like augmented audio and interactive games related to the town's history and culture could be developed in future studies.

tom Dieck and Jung (2018) reported that current research examined improvement of user experience through the advantages of employing augmented reality despite the fact that limited research has been carried out on users' approval of AR in the context of tourism. Their work tries to suggest an AR acceptance framework in the urban heritage tourism environment. Youthful British tourist ladies coming to Dublin in a category of five focus groups experiencing the AR application participated in conducting the study. Schematic analysis was used to analyze the data which shows that seven dimensions could be integrated into AR acceptance studies. They include the quality of information, the quality of system, usage cost, recommendations, personal innovativeness and risk along with facilitating circumstances. They recommended that in a future research, male sample should also be considered to have a better representation of the tourist market visiting Dublin.

Ajay (2017) presented a work with the aim of studying an MAR game called Pokémon GO to find out the features of the game that influenced tourists and also to identify the features that engage them in terms of memory of visited places like a tour guide and as well as influence their experience as they are using the application and even after using it. The study is precisely trying to investigate the behavioural intentions to make use of the application as a tour guide in the future. The sample that participated in the study were mobile phone users who had experience of the Pokémon GO application. Based on their analysis, they revealed that the application presented four realms of experiences namely, entertainment, educational, aesthetical and escapist. They also revealed that the app improves the general user experience. Moreover, they revealed also that majority of the respondents mentioned their interest of using an MAR game as a travel guide. Also, it was found in their research that MAR games brings people together.

Tsai et al. (2017) carried out a study to develop a museum tour guide application based on AR and beacons. The application was meant to provide a highly interactive details of historic items, guidance services, educational and entertainment functions based on media richness theory. This study tries to examine the usability of the application through a mobile-specific heuristic evaluation. The usability evaluation was carried out by experts who confirmed that the app conforms to usability standards and it can good user experience. However, they revealed that it will be necessary to carry out the evaluation with audiences.

Kadi et al. (2018) in their research tried to combine Location Based Service (LBS) and AR to develop a tourist guide application. The application displays augmented information to the user on the screen of his mobile device with regards to the tourist object scanned. The information displayed includes the scanned objects location, its description, distance and the route to the tourists' location.

Fenu and Pittarello (2018) presented in their research work, the design and evaluation of an AR experience for a museum and city tour through story telling methods. The application developed in order to increase accessibility to the collections of the museum which was dedicated towards the popular novelist Italo Svevo and also to improve the user experience, who are mostly adults. They revealed in their study that the results has shown that visitors have significant interest in the use of AR technology which led to further extension of AR experience in the museum. Moreover, it was revealed that there was a mutual relationship between new media and the environmental context.

2.2 Related Research in the Area of Campus Guide

Dirin and Laine (2018) in their study tried to assess the User Experience (UX) of a commercial mobile augmented reality and a developed Virtual Campus Tour mobile augmented reality application with the aim of drawing deductions as to what prospects, challenges and best practices are related to Mobile Augmented Reality (MAR) applications development with regards to the UX viewpoint. The two case studies presented were evaluated from the UX perceptions with emphasis on user feelings while using the applications. The identified best practices from their study was used to present a fine-tuned or upgraded version of the developed Virtual Campus Tour application to make it more emotionally engaging. The conclusion drawn from their evaluations of the two applications shows that the users value the applications with regards to their functionalities, effectiveness and usability.

Pawade et al. (2018) presented an MAR application called "ARCampusGo" and tried to explain how it was implemented. To make use of the application, a user has to scan or capture a structure to have its information displayed on the screen of the mobile device. The application also gives the name of neighboring buildings to the scanned one. When a user selects any of the neighboring buildings, the application renders the route to the selected building from the current location in a gorgeous and interactive manner. Users from different age groups were considered for evaluating the performance of the application. They were directed to make use of the application in the day time and also at night. The users had different smartphone models and were said to be using different service providers also. Based on the result of the evaluation, they found that the speed of the internet is the only constraint concerning the performance of the application. Moreover, they suggested that the application can in the future be upgraded to present navigation by randomly scanning the environment and not only specific buildings. They added that a functionality like information about current and upcoming events could be delivered as notifications.

Alqahtani and Kavakli (2017) developed an AR application called “iMapCampUS” that can help students in locating surrounding buildings at Macquarie University. The application works in such a way that information about buildings within the institution is augmented on the real view of the environment through the mobile phone’s camera without obstructing the view. The application was developed for both Android OS and iOS devices. They also revealed that it is a GPS-based AR application that can use the Google maps to provide details about places of interest. However, they suggested that the application be upgraded in different ways such as covering the entire campus, saving visited sites, indoor navigation and lots more. The researchers revealed their plan to test the application in order to validate the interface design approach of the AR app. Also, they mentioned their plan to analyse and inspect the factors affecting the user acceptance of the application using the Unified Theory of Acceptance and Use of Technology (UTAUT).

Ramos et al. (2018) developed locator map in the form of a campus guide to help student in locating places around the campus using the shortest route technique. The application also includes a lot of information about places around the campus. Their study adopted Rapid Application Development (RAD) model. They employed the ISO9126 standard to evaluate the quality of the application. Based on the result from their survey, the application got an average score of 4.36 “Excellent” in terms of functionality, reliability, usability, efficiency, maintainability and portability. However, they found that the campus map layout was not very effective. The researchers recommended that features like voice command could be added and also the application could be developed for iOS platforms since their work was designed for Android only.

2.3 Related Research in Learning and other Relevant Areas

Kysela and Štorková (2015) presented a work with the sole aim of defining how AR could be used as a channel for teaching history and tourism. In a bid to achieve this, the researchers tried to compare between paper-based tourist guide and mobile applications for tourist guide and were able to deduct new opportunities and developments in the teaching of history. They also reported that, AR is a powerful medium of underlining interesting features and reviving history to life through the use of multimedia content in smartphone devices. They added that different from old-fashioned tourist information channels, AR can provide users the opportunity to study whenever they feel like.

Chin et al. (2017) developed an AR application for Mackay culture in Danshui to widen the learners' horizon of historic places which was found to improve the general interest in architecture and history. To get information about a building using the Walking Tour APP, a user is required to press an AR button and scan the desired building or point of interest. Information about the scanned target could be presented in 3D model or video. Map and GPS are another feature of the application such that the GPS could allow the users to locate themselves on the maps. To carry out a usability survey of the application, five students were selected to make use of the AR app using both questionnaire and interview methods. Regarding the analysis made by the researchers, they recommended an improvement of the app by adding English and Korean version of places description, video contents and 3D models to allow tourist from all around the world to make use of the application.

Musliman et al. (2015) research work made emphases on the combination of Augmented Reality and Geographic Information System (GIS) to enhance the context and location awareness learning in mobile environment. The research work presented an AR application that makes it easy for a user to identify nearby features with their contextual information instantaneously. The information is user location oriented in order to increase the user's awareness of the locality with regards to ongoing and future events. They claim that the application increases the level of self-tour guide experience. The application is a client-server based type which was developed mainly for android OS. Their work tries to tackle the issue of objects having different distances form the mobile device overlapping in augmented views of AR applications which can result to inaccurate positioning of AR objects. The researchers recommended that in the future, AR can be combined with 3D GIS databases so as to allow for picturing of the underground or behind concrete walls utilities.

Joo-Nagata et al. (2017) in their research, presented an evaluation of an AR Mobile Pedestrian Navigation (MPN) application in an educational, qualitative and quantitative context. The application was developed basically for mobile learning in an educational environment with the aim of examining how useful or efficient it will be when adopted as a tool for teaching. It was designed with the intention of offering mobile learning process for cultural heritage subjects that are being taught. A sample of n=143 primary school students from Chile was selected. The sample was divided into two; a control group that worked within an e-learning environment and an experimental group which used the application to carry out a field activity. A pre-test and a post-test was conducted to study their levels of learning. Also they carried out a user satisfaction survey as well as interviews with many of the students and their teachers regarding the use of the employed technologies. Based on the results from the pre-test-post-test, it was shown that the experimental group performed better than the control group. The interview conducted has revealed that an increase in the effectiveness of the teaching-learning process is due to the combination of the technologies to fieldwork. However, they recommended that such work is reproduced at levels of tertiary institutions or informal educational settings.

Capece et al. (2016) presented a framework that guides in the creation of Augmented Reality (AR) mobile applications for geolocation data visualization which could permit users of an AR application to successfully comprehend and respond to the setting or environment of the application deployment. The researchers made provision for an architecture that is easily accessible and dynamic design, creation and management of both the client and the server together with the data used by the application. To implement the developed architecture for AR application development, two applications were developed for two different case studies. One of the applications is for the supervision of failures in electricity power lines putting into consideration the ideology of providing useful information that could be used in locating high-voltage Pylons in need of maintenance, and the second one is for supporting hydrogeological monitoring which includes water level data collection and analysis and also showing stations and their current hydrometric levels.

2.4 Summary of Related Research

Regarding the literature search carried out, the table below gives a summary of the different research works that were reviewed. The table tries to show the authors of the article, name of the application developed or adopted for the purpose of the research, the operating systems the developed or adopted application is meant to target, the purpose or area of usage of the application, and the kind of approach that was used in testing the application. It also shows whether the application being developed or adopted by the researchers is GPS-based, marker-based or both. And it also presented whether the applications has “Map” features.

The author have found that none of the related research works reviewed uses both GPS and marker based AR in the area of campus tour. And in general, he has found that none of the related research works implemented both GPS and marker based AR functionality together with Map feature in a single application in the area of campus touring. To close the found knowledge gap, this study implemented all the features in one application.

Table 2.1: Related research summary table

Authors/References	AR App	OS	Area of Use	Testing Approach	GPS Based	Marker Based	Map Feature
Ajay (2017)	Pokémon GO (Adopted)	Android and iOS	Tourism	Survey method was used for a sample of 488 users.	YES	NO	YES
Aloqily (2016)	JoGuide (Developed)	Android	Tourism	Application was experimented at two cities in the day time and at night.	YES	NO	NO
Alqahtani and Kavakli (2017).	iMapCampUS (Developed)	Android and iOS	Campus	App was used within the Campus to see AR view and the Map view	YES	NO	NO
Capece et al. (2016).	Two Apps were developed	Android	Electric power line and Hydrogeological monitoring	Experiment was carried out to view the augmented view of the two subjects	YES	NO	NO
Chin et al. (2017).	Walking Tour App	Not Mentioned	Tourism and History	5 students were interviewed and questionnaire was also used.	YES	YES	NO
Dirin and Laine (2018).	Commercial MAR (Adopted) and Virtual Campus Tour (Developed)	Android	Business and Campus	Two case studies, questionnaire and interview was used	NO	YES	NO
Fenu and Pittarello (2018).	Svevo Tour (Developed)	Not Mentioned	Tourism and History	Two separate studies were carried out using survey	NO	YES	NO
Fino et al. (2013).	Website (Developed)	Not Mentioned	Tourism	No testing indicated	NO	YES	NO

	and QR codes generated to serve as links to site content						
Geiger et al. (2014).	LiveGuide (Developed) and AR engine AREA (proposed)	Android and iOS	Implementation of AR engine	App was developed for Android and iOS and tested. Examples, challenges and lessons learned were highlighted	YES	NO	NO
Joo-Nagata et al. (2017).	AR Mobile Pedestrian Navigation (MPN) and Desktop App (Developed)	Not Mentioned	Cultural Heritage Mobile Learning	A sample of n=143 primary school students was selected and divided into two; a control group and an experimental group. Survey and Interview was used.	YES	NO	NO
Jung et al. (2015).	Marker-based AR App	Not Mentioned	Tourism	Questionnaires were given to 241 visitor of the park.	NO	YES	NO
Kadi et al. (2018).	AR_SBDApps	Android	Tourism	Comparative analysis was carried out between developed App and other Apps that works almost similar to it.	YES	NO	NO
Kourouthanassis et al. (2015).	CorfuAR (Developed)	Android	Tourism	A sample of 105 users participated. App was developed in two versions; personalised and non-personalised	YES	NO	NO
Kysela and Štorková (2015).	Prototype App (Developed)	Not Mentioned	Education and History	Compared paper tourist guide and mobile applications to outline new opportunities.	YES	NO	NO

Muchtar et al. (2017).	Medan KulinAR (Developed)	Android	Tourism	Testing was conducted based on different POIs; ATM, Culinary and so on.	YES	NO	NO
Musliman et al. (2015).	Prototype App (Develope)	Android	Self-tour/ Campus Guide	The application was experimented by categorising it	YES	NO	NO
Oleksy and Wnuk (2016).	GeoTracker (Adopted)	Not Mentioned	Tourism and History/ Campus	The study included 45 Warsaw students divided into two groups. Questionnaire was used.	YES	NO	NO
Pawade et al. (2018).	ARCampusGo	Android	Campus	Users from different age groups were considered for evaluating the App	YES	NO	NO
Ramos et al. (2018).	E-Vision (Developed)	Android	Campus	346 respondents participated in the survey. Interview was also carried out	YES	NO	NO
Tom Dieck and Jung (2018).	Dublin AR (Developed)	Not Mentioned	Urban Heritage Tourism	5 focus groups with 44 participants were conducted	YES	YES	NO
Tsai et al. (2017).	FPGM Pocket Navigator (Developed)	Android	Museum	mobile-specific heuristic usability evaluation	YES	NO	NO
Author	NEU Campus Guide (Developed)	Android	Campus	12 users (new students) were selected randomly and given a task to test for the usability of the application. A questionnaire was filled by the users after completing the task	YES	YES	YES

CHAPTER THREE

THEORETICAL FRAMEWORK

This chapter introduces the concept of AR. It will also discuss briefly, the history of AR, Augmented Reality systems, the importance and applications of AR as well as the challenges of the AR technology as at the current time of this research. In addition, the chapter presents a list of AR Software Development Kits (SDKs). Also, the chapter will discuss about mobile applications development and mobile devices operating systems.

3.1 Augmented Reality

AR is a technology that enriches an individual's sensory perception through the addition of virtual or graphical elements directly on the immediate environment. Mobile devices and HMDs are modern platforms which are gearing forward, the areas where the technology could be utilised from research centres to a wide range of application domains. (Daponte et al., 2014). Since early 2000, AR has increasingly turned out to be a vital area of advancement in numerous industries. This is obviously because of the fact that it is among the promising areas of digital media which has offered an extended option of interaction between individuals and applications (Han, 2016).

The most vital components required in an AR system are depicted in Figure 3.1 below. It comprises of a camera which is utilized in capturing the actual images of the environment. It also comprise of a Tracking Module, a Graphic Processing Module (GPM), and a graphical display. The real time location and position of the camera tracking is processed by the tracking module, which provides the six Degree-Of-Freedom (6-DOF) values which are the x, y and z coordinates together with orientation angles: pitch, roll and yow. These values allows for the accurate orientation of the intended virtual objects on the physical scene. The tracking module is employable using numerous kind of available sensors like 9D IMU, ultrasonic sensors, video cameras, GPS modules, and RFID devices. The GPM expands the images captured from the video camera and augment on them the virtual objects. Then the computationally processed images are rendered to the user through the display (Daponte et al., 2014).

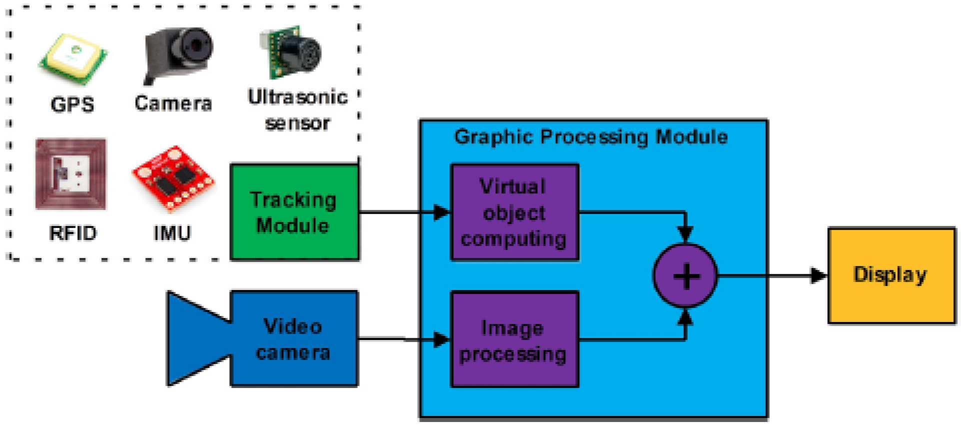

Figure 3.1: Architecture of an AR system (Daponte et al., 2014)

AR in some sense is mostly about context and location awareness. The root of context awareness could be associated to ubiquitous computing or as it is otherwise called pervasive computing, which sought to handle the linking variations in the environment using computer systems, which otherwise are seen to be static. Context aware systems are associated with getting hold of context (for example, application of sensors to observe a condition or situation), the notion and understanding of context (for instance, corresponding a perceived sensory stimulus to a context), and behaviour of the application with regards to the recognized context (for example, prompting actions with regards to the context). As the user's activities and geographical location are crucial for numerous applications, context awareness has been fixated more profoundly in the research fields of location awareness and activity recognition.

The advantage of context-aware system is to increase the awareness among the users, especially for mobile users. Location or location awareness is a part of location based services (LBS) since it provides location-aware application. LBS can be defined as "any service or application that extends location information processing, or GIS capabilities, to end users via the Internet and/or wireless network". The location-aware technology is a term that refers to the technology that can identify and define its own geographical location. The identification of the location of users together with the equipment is a prerequisite for context-aware applications support. Locating physical objects is itself a divergent research area which encompasses the development of location hardware devices, software storage structures, and mechanisms to enable location-based querying (Daponte et al., 2014).

The utilization of AR applications on mobile devices seem to be ever growing due to the improvement in the computational capacity and declining prices of the devices. Smartphones consists of position and orientation sensors, and cameras that ease the development of mobile AR applications. Mobile Augmented Reality (MAR) extends the capabilities of AR to contain a broad range of scenarios to be used in mobile environments (Pence, 2010). The provision of context-related information in real time is the key advantage of an MAR application. The enormous advantages of using AR technology in educational environments, have been widely acknowledged. AR technology has been utilized in numerous mobile devices in various universities as self-guided tours all over the world.

3.1.1 Brief History of Augmented Reality

The emergence of AR began around the year 1950, when Morton Heilig envisioned the concept of cinema as a kind activity that has the potential of creating a kind of emersion of the viewers into the activities portrayed onscreen putting all the senses into consideration. Heilig developed a model of his envisioned idea "The Cinema of the Future" in 1962, which was titled Sensorama. This originated even before digital computing. In 1966, Ivan Sutherland developed the Head Mounted Display (HMD). Also, in 1968 he was able to develop an AR system which uses an optical see-through HMD being the first of its kind (Carmigniani and Furht, 2011).

In 1975, Videoplace was developed by Myron Krueger, which was a room that permits the users to have interactions with the virtual objects. It is the first of its kind. Tom Caudell and David Mizell devised the catchphrase Augmented Reality during a period they were assisting workers to carry out the assemblage of wires and cables for an aircraft. Within that same year, L.B Rosenberg built “Virtual Fixtures”, which is among the early implemented AR systems. He described the benefits of the system on human performance (Turner, 2009).

In 1994, the Reality-Virtuality continuum was defined by Paul Milgram and Fumio Kishino which extends from the physical to the virtual environments. The continuum can be seen in the figure below.

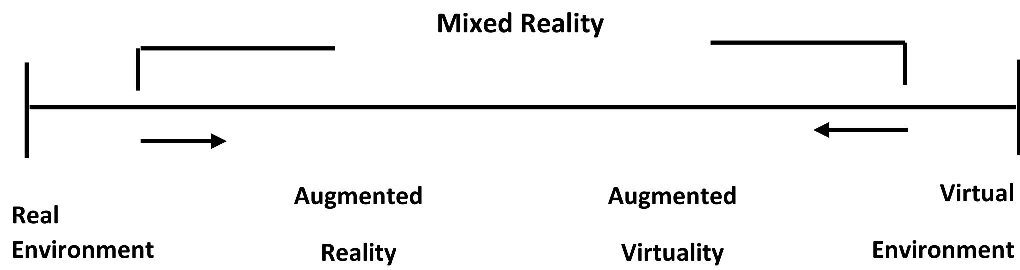

Figure 3.2: Milgram’s Reality-Virtuality continuum (Carmigniani and Furht, 2011)

Three years later, Ronald Azuma carried out the first survey in AR where he presented a generally accepted definition of AR by recognizing the concept as “combining real and virtual environment while being both registered in 3D and interactive in real time”. Bruce Thomas created the first outdoor mobile augmented reality game in the year 2000, which he presented in the International Symposium on Wearable Computers. As time moves on, many more AR apps were built. At the present time, with the innovative technologies, there is an increase in the number of AR systems that is being developed (Carmigniani and Furht, 2011).

3.2 Augmented Reality Systems

As the creation and deployment of AR systems turned out to be progressively plausible, researchers have endeavored to create real-world solutions in accordance with the settings of putting the technology into practice. Concerning contemporary innovative advancements, the AR systems are categorized into 'Mobile/Portable AR' and 'Wearable AR'. It is discovered that the two systems are applicable in their particular manner and could be used in various settings (Haller et al., 2007).

3.2.1 Wearable Augmented Reality Systems

The utilization of wearable devices as the next stage of AR gadgets has been progressively reviewed in the industry and the scholarly world. Based on some educational findings which tries to examine the pilot reactions, it was discovered that HMDs decreased the need for reorientation and lead to the completion of tasks within shorter periods of time. In other words, it was discovered that simple tasks could be executed without facing difficulties.

Chapman et al. (2009) imagined wearable devices that could be utilized for regular daily activities in the form of wearable glasses with a steady display to blend with any open physical space condition. Two sorts of wearable systems were recognized by exploring early improvements of HMD. They are; “video-see-through” and “optical-see-through” displays.

- **The Video-see-through displays:** this displays totally shut out the user's sight of the external environment and subsequently expose his vision to that of the video camera appended to the glasses which displays the physical location in real time. Being examined after some time, these kinds of HMDs are known as virtual reality headsets, for example, Facebook's Oculus Rift, and the Samsung Gear VR headset, which is additionally fueled by Oculus Rift.
- **The Optical-see-through displays**: conversely, intelligent reflective mirrors are embedded in these displays, which allow the user to directly have a sight of the real world. Despite that, graphic elements could not be superimposed appropriately on the physical world situation. A promising option of hybrid technique between VR and AR is presented by Microsoft's HoloLens (Chapman et al., 2009).

3.2.2 Mobile Augmented Reality Systems

On the other hand, utilizing MAR allow a user to identify and concentrate on a target, which could be associated with the task, giving more opportunity in including the real world environment.

Regardless, hand-held devices could be considered as the most appropriate gadget, as these form of devices have been produced adequately as far as access and day-to-day usage is concerned. Furthermore, GPS systems and electronic compasses are currently embedded in a very large proportion of mobile devices. Thus, since mobile devices have turned out to be an ever increasing aspect of life, it is foreseen that AR applications will be utilized more in the nearest future (Han, 2016). Mobile AR systems are further grouped into marker based and GPS based systems.

- **Mobile Marker Based AR System:** Despite the fact that mobile AR is still considered to be at its birth stage of development, there has been a huge concern and discussion about marker-based AR since it is considered among the most reliable forms of AR systems. Quick Response (QR) Code that is two dimensional were used in building marker-based systems at the early stage. The QR code mostly serves as a link to a website holding more information about the object which it represents. To access the information, the QR code is scanned. It was initially built in Japan at a vehicle producing industry to help car building procedure, it has rapidly turned out to be prominent in different ventures, for example, the tourism industry (Han, 2016). Siltanen, (2012) asserted that marker-based AR includes an "easily detectable predefined sign in the environment and uses computer vision techniques to detect it". Due to this reason, marker-based systems are usually made for indoor purposes.

- **Mobile GPS Based AR System:** Another type of mobile AR system is the GPS- based systems, which functions based on the foundation that the device incorporates a GPS functionality. However, a few researchers contended that this sort of AR is not suitable for indoor application because of the constrained GPS range, as it differs with its potential in the outdoor usage, making it especially intriguing for the purpose of tourism. Regardless, it should be recognized that marker-based AR are being built and enhanced consistently and progressively, while GPS based AR has been recognized to present a greater challenge that needs to be solved (Han, 2016).

3.4 Augmented Reality Software Development Kits

Usually, it is exceptionally troublesome for an enthusiast to build up an AR application since it fundamentally incorporates technologies like pattern recognition, image processing, object rendering, GPS positioning in some cases, interaction ability etc. To have a successful AR experience, all or some of the aforementioned technological processes must be put together to be able to present a graphical element on the physical environment. As a result, developing AR apps in a customized fashion can be laborious and troublesome (Alex, 2018). However, many AR companies have developed AR SDK which enable AR application to be developed effectively some of which do not essentially require any programming skills. Some of the AR SDKs are discussed in brief in this chapter.

Wikitude SDK: is an SDK that is always being enhanced in order to progressively include an ever-increasing number of features in every release. Wikitude has more than one billion application installs and thus regarded amongst the quickest developing AR community. It supported platforms are namely Android, iOS, Windows for tablets, and smart glasses. It also supports some frameworks for mobile AR development such as Native API, JavaScript API, Unity3D, Xamarin, Titanium, and Cordova. Currently, in addition to the very useful features of its SDK 7, the new SDK 8 presents even more features (Alex, 2018):

- Augmentation of large objects for the purpose of outdoor gaming and so on. The feature is referred to as "Scene recognition".
- Another feature allows a user to view augmented objects even beyond the markers after performing a scan over the marker area.
- The SDK 8 allows for instant targeting i.e. it saves instantly superimposed object and allow for sharing.
- It also include an AR-view functionality that allows for testing of the SDK features in Unity editor (i.e. Unity live preview).

ARKit SDK: support AR development in iOS only, which is amongst the largest or top platforms for mobile devices of the recent time. The SDK is meant for application developers to build AR and gaming experience for Apple products. However, it only supports the iOS 11 and 12 versions. In other words, it supports iPhone 6/iPhone 6 plus and above. And for the iPad, it supports the iPad Pro models. ARKit provides 2-D image detection and tracking i.e. it possess the capability of embedding objects into augmented reality experiences.

ARKit 2 was launched by Apple in June 2018, which is an updated version of the preceding one. A gigantic improvement of the SDK is that it comes with the feature that allows sharing of AR experiences with others in multiplayer gaming. In other words, the SDK support building of games that, for example, could be played between two iPads by two distinct individuals (Alex, 2018).

ARCore: is the Google's reaction in competitive response to ARKit. ARCore is a platform that support developers in designing and implementing AR experiences. The ARCore SDK makes it possible to detect the surrounding physical environment through the use of a mobile device. The supported mobile device platforms for the SDK are Android and iOS running devices. To be more specific, it supports Android 7.0 or higher versions and iOS 11 or higher versions. ARCore presents three extremely important functionalities that support in the superimposition of the virtual objects on the physical or real environment. They are:

- Motion tracking: tracing of the device’s position relative to the physical environment.
- Environmental understanding: detection of the size or location of surfaces, whether horizontal or vertical or even angle surfaces.
- Light estimation: estimation of the environmental lighting conditions in real-life (Alex, 2018).

Vuforia: is one of the outstanding platforms whose SDK enable developers to build augmented reality applications. Vuforia allows for the implementation of very important features like recognizing a variety of objects, text, and recognition of the physical environment, VuMark (consisting of images and QR-code). Additionally, a user may scan and create object targets by utilizing the Vuforia Object Scanner. The recognition procedure can be actualized utilizing the database in a local or distributed storage. It is very easy to incorporate Vuforia SDK with Unity to make powerful applications. All the plugins and features of the SDK are for free but they include watermarks. The paid version of Vuforia however, does not have the watermark, and it has some additional advantages. Vuforia supports Android, iOS, UWP and Unity Editor.

Recently, Vuforia launched an updated version that offers new functionalities for augmented reality experiences. They are:

- Vuforia Model Targets: this feature renders object recognition based on shape, unlike in visual print media designs.
- Vuforia Ground Plane: this functionality makes it possible to superimpose the virtual objects on the ground or surfaces using the Unity engine.
- Vuforia Fusion: is a feature that is meant for solving fragmentation, and to enable cameras, sensors, as well as external frameworks (Alex, 2018).

MaxST SDK: presents two distinct features that allow for image and environments recognition. Database creation is done through an online Tracking Manager, and the scanning of 3D objects is done using 3D scan applications for Android and iOS mobile platforms. However, Maxst SDK only integrates into the 32-bit version of the Unity environment. The mobile device platforms it supports are Android, iOS, Windows, and Mac OS. The only difference between the free version and the paid version is the watermark that comes with the free one. It has a very simple and easily utilizable library and it is simple to integrate into other platforms. Moreover, it has a complete and self-explanatory documentation (Alex, 2018).

DeepAR: is an incredible software development kit from the US-based organization of engineers, 3D creators, and animators which has been in existence in the market for 20 years, whose works includes the popularly known Candy Crush, Hailo application, NASA and the Russian Space Agency. It is accompanied by four types of effects, which are rigid objects, deformable masks, morph masks, and post-processing effects. This shows that AR developers can use this AR SDK for reliable face lenses, just like the ones that come with Facebook and Snapchat, and other different masks and effects for smartphone devices as well as desktop application.

This Augmented Reality pack is fit for detection of faces and facial features in real time, in view of protected data models and machine learning procedures. It is very quick, and it can it can detect about seventy facial points at sixty frames per second. Moreover, it supports Android, iOS, Windows, and WebGL devices (Alex, 2018).

EasyAR: EasyAR: is an unpaid simple to utilize SDK which is mostly viewed as an alternative for Vuforia SDK. It renders support for Android, iOS, UWP, Windows, Mac and Unity Editor Platforms. The most recent released version of EasyAR allows for image recognition only. However, the next version to be released is said to offer the below functionalities (Alex, 2018) :

- 3D Object Recognition
- Environment perception
- Cloud Recognition
- Smart Glass Solution
- App Cloud Packaging

To begin working with EasyAR, a developer is required to only signup/create an account via which they can generate the unique key for their various bundle IDs. It is very simple to integrate and the provided examples and documentation are instinctively reasonable.

ARToolKit: this is an AR open source tracking/detection library which supports Android, iOS, Linux, Windows, Mac OS as well as Smart Glasses to make augmented reality experience a reality. It allows for the implementation of features such as Single-camera/Stereo-camera position or orientation tracking, simple black square tracking, planar images tracking, camera and optical stereo calibration, Unity and OpenSceneGraph plugins, support for optical HMD, and it is suitable for real time augmented reality apps. However, the numerous features offered makes incorporating the library a bit challenging and consumes longer time to examine all options and settings (Alex, 2018).

Xzimg: is a Hong Kong made SDK that makes available a variety of AR features for face tracking in real-time and building of augmented reality applications particularly. The SDK supports desktop apps, mobile apps and web browsers through a Unity plugin. The devices supported by the SDK are Android, iOS and Windows. Xzimg comes along with three distinct features contained by its SDK. They are:

- Augmented Vision: it enables or make possible features for computer vision, detection and tracking of marker that AR developers can implement on mobile devices and other AR supported Windows platforms.
- Augmented Face: it allows for recognition of human faces, and it comes as an exceptional Unity plugin.
- Magic Face: this feature of the SDK is for non-rigid tracking of the face, refactoring from Augmented Face and enhancing with other features, like face replacement, face detection/tracking (Alex, 2018).

Other very useful SDKs worth mentioning are Metaio SDK, LAYAR SDK, SLARToolkit, D'Fusion, and ARmedia which also presents a lot of significant features for the development of AR applications and experiences. The table below presents feature comparison of the briefly discussed SDKs in this section.

Table 3.1: SDK features comparison table (Alex, 2018)

	Wikitude	ARKit	ARcore	Vuforia	MaxST	DeepAR	EasyAR	ARToolKit	Xzimg
Maximum distance capture (m)	2.4 / 5	1.5 / 5	1.0 / 3	1.2 / 3.7	0.5 / 0.9	0.7 / 5	0.9 / 2.7	3 / 3	0.5 / 1
Recognition stability of immovable marker	6	9	9	10	7	8	7	8	4
Recognition stability of movable marker	6	7	6	6	2	7	3	6	3
Minimum angle recognition	10	30	50	30	50	35	35	10	45
Minimum visibility for recognition overlapped marker	100%	50%	75%	20%	50%	10%	10%	100%	25%
2D Recognition	✓	✓	✓	✓	✓	✓	✓	✓	✓
3D Recognition	✓	✓	✓	✓	✓	–	–	–	✓
Geo-Location	✓	✓	✓	–	–	–	–	–	–
Cloud Recognition	✓	✓	✓	✓	–	–	–	–	–
SLAM	✓	✓	✓	✓	✓	–	–	–	–
Total	**8.0**	**7.5**	**7.7**	**7.7**	**5.2**	**4.7**	**4.4**	**2.8**	**3.1**

3.5 The Importance and Applications of AR

It has been discovered that AR gives numerous advantages for different industrial utilization because of its blended environment or digital improvement of the physical world setting. In any case, AR benefits have been relied upon to produce greater returns contrasted with VR because of the idea of the idea of superimposing graphical object on the real environment and in some cases in interacting with them. Today, Augmented Reality has gained a lot of momentum around the consumer market. Rossi (2016) believes that AR will have an essential effect on businesses in the years to come, especially as wearable devices tend to offer more conceivable opportunities.

Current development in freely accessible mobile augmented reality platforms like Wikitude, ARCore, ARKit and many more affirm the development enthusiasm and implementation support for AR systems and services. In concurrence with industry, the scholarly community predicts a gigantic potential for mobile augmented innovations; many researchers have recognized that the mix of portable devices and AR functionalities present one of a kind opportunity for the implementation of novel applications in diversified settings. Nowadays, MAR has been utilized to help in providing learning support, university/campus touring and guidance, library administration, architecture, smart home, and treatment of phobias among many others (Kourouthanassis, 2015).

Currently, the advancement of AR applications can be credited to arrangements that enable individual customers to preview items and envision how it is going to feel to possess such products or examine the quality of service before buying it. The high interest and investment in AR will rise due to the recent sophistication and cost-effectiveness as well as the expansion of business applications using AR technology. It is anticipated that there is going to be about one billion AR users by the year 2020 (Bernard, 2018). This segment will examine early use instances of AR in the different industries, accompanied by the present application of AR for public utilization.

- **Advertising and commercial:** AR applications are frequently deployed by marketers to convince customers to buy their products. Most of the methods adopted the use of marker based AR in which the users presents a marker in front of their web camera using specified software or by basically visiting the company's website to make the preview of the AR experience (Carmigniani and Furht, 2011).

- **Entertainment and education:** There is a lot of AR applications that are developed for the purpose of entertainment and education which include applications that presents cultures via provision of sightseeing and museum tour functionalities, gaming applications that uses augmented reality interfaces as well as mobile applications that employs AR to entertain or otherwise educate people (Carmigniani and Furht, 2011).
- **Aviation Sector:** A couple of recognitions has been won by the Gatwick Airport passenger application due to its imaginative adoption of augmented reality technology. Over 2,000 beacons were placed all around the two terminals in the airport, through which passengers may utilize the AR maps installed on their mobile devices for navigation around the airport. It is expected that the application will assist in increasing traffic flow into the airport (Bernard, 2018).
- **Interior Design:** in this area of application of AR, it seems like there have been a lot of cool productive applications deployed by some highly recognized companies. For example, the Ikea Place AR app was designed to help customers in the purchase of accurately-fitting furniture sets for their rooms. It was developed using the Apple's ARKit technology. Another area of interior design that employs the use of AR application is painting. The Dulux Company developed an app called Dulux Visualizer. Their application allow users to apply a paint color and design of their choices before proceeding to purchase it. With the application, a customer just scan his room and paint it as he wishes by picking from the rainbow colors. Many other applications of this kind are in existence (Bernard, 2018).
- **Cosmetics and Jewelries:** in the area of cosmetics, a cosmetic company called Sephora deployed an AR app that enable their customers to sample out variety of their products on their digitally presented faces, eyes, lips and cheeks before deciding to purchase a product. It turns out to be fun and a very influential tool to increase sales. Another company that adopted the use of AR technology in this area is Rolex. They built a virtual try-on AR experience for customers to try out their watches and see how it fits them before purchasing it (Bernard, 2018).
- **AR in Healthcare:** Exceptionally thrilling AR applications exist in the area of healthcare whose purpose ranges from enabling medical students to learn a lot within an AR environment, to the application of AR functionalities in telemedicine which could allow professionals in the field to interact with different patients in real-time. In life-threatening

conditions, AR apps can provide information in real-time to the part of the body that requires treatment in order to help in diagnosis, carrying out surgery and executing treatment plans. An example of a device that uses AR in this area is the AccuVein which could be used in scanning a patient's vein network. The device could be employed in developing a model for a tumor or a disease condition before surgeons carry out the first cut.

Moreover, AR in other cases is not used for inspiring customers to purchase more products, rather it could also be built just for the sake of deriving fun or engaging the customers. Also, it is very important that we know that AR applications are currently being built at a very speedy rate so as to improve numerous industries (Bernard, 2018).

3.6 Types of Mobile Applications

The majority of mobile devices of these days are believed to be made for Android, iOS and Windows operating platforms. These operating platforms are what we popularly know as operating systems (OS) of mobile devices (Mallikarjun, 2017). Moreover, mobile applications could be categorized into three types, with regards to the recent technological advancements and frameworks. These three categories are briefly explained as below:

- **Native applications:** the native applications are built specifically to work on a selected operating system, i.e. not a cross-operating system built application. A local or native application built for one selected OS cannot work for another, for example, an application developed to work for Android running devices cannot work on either iOS or Windows running devices, and the reverse may also be the case. If the need to develop a similar application for another platform arises, the application has to be redeveloped from the scratch for the newly intended platform. The development of native apps is supported by a variety of Integrated Development Environments (IDEs) and programming languages. The building of iOS native apps is popularly known to be supported by Swift and Objective-C, Android apps supported by Java and ADT, and Windows apps supported by .NET (C#). However, in the case of augmented reality, the likes of ARKit for iOS and ARCore for Android platform could be said to have fallen into this category.

- **Mobile web applications:** Any application that allows for the display of web pages on the browser of a mobile device is simply called a mobile web application. These applications are a cross-operating system running type of apps, that is to say, that they could run on all the variety of operating systems since they do not rely on them, but rather, they rely on the browsers on the devices. In addition, mobile web apps could easily be run even on a desktop computer's web browser. The creation of such applications is supported by programming and scripting languages such as HTML and CSS, JavaScript, jQuery and many more. However, in the case of augmented reality, such category of applications could be related to the marker based AR apps that can fetch information mostly from a website by scanning for example a QR Code.
- **Hybrid applications:** the hybrid applications put together the features of native and mobile web applications together as its own. It is the type of mobile application that stands in between the two. Hybrid applications are compatible with all operating platforms. Generally, these powerful applications are developed by utilizing technologies like Cordova/PhoneGap, Ionic framework etc. which adopts the usage of HTML, CSS, JavaScript and so on. However, in augmented reality, the development of cross-platform applications is supported in a different manner. This feature is offered by some AR SDKs like the Wikitude, Vuforia, and others.

3.7 Mobile Operating Systems

Mobile OS is the one that runs on mobile devices such as tablets, smartphones, smart watches, wearable devices and so on. The operating system in the mobile devices manage all the features and functionalities of the devices ranging from remote or wireless network administration, Bluetooth connectivity, GPS positioning, camera, and lots more. Also, the OS gives the users an opportunity to access and interact with all the managed features and functionalities of the devices (Ballagas et al., 2006).

This segment presents a brief discussion about the most popularly used operating platforms as at the period of this study.

3.7.1 Android, iOS and Windows Operating Systems

Android OS: it was launched on September 23rd in the year 2008. It is a powerful and open source mobile operating platform developed by Google. The operating platfrom was developed with the objective of enhancing technological development in the area of mobile computing and at the same time providing users with a more efficient and cost effective mobile experiences (Butler, 2011). Since the release of Android, there has been numerous upgrade to the operating system in order to add some functionalities and fix errors that exist in preceeding earlier versions. For each new upgraded version they release, they identify it with a name of a desert in an alphabetically ordered manner. For example, Cupcake, Donut, Eclair, Froyo and so on and so forth (Lazareska and Jakimoski, 2017).

The Android mobile operating system has many advantages some of which are listed below:

- Android is open source.
- It gives free acces to download and install applicatons from the Google Play store or as an executable (APK) file.
- It is an intelligent multi-tasking system that can simultaneously run applications.
- It grossly increase user experience because of it's high customisability.

Nonetheless, Android also has some disadvantages as listed below:

- Android has the issue of battery consumption due to its ability to allow multiple open apps.
- It is somewhat vulnerable due to the openness of the platform, which might give room for cyber crime attacks.
- Some applications might still be running in the background even when a user does not want them to (Thomas, 2017).

iOS: The iOS was built by Apple Inc. to run principally on mobile devices. It was initially launched on June 29^{th} in the year 2007. Unlike the Android operating system, iOS was developed to be a closed source platform. That is to say that no source code was released publicly for the usage of developers or manufacturers (Padhya et al., 2016). Devices running on iOS are one of the most purchased product today. According to one of the reports published in 2017, 1.2 billion devices were sold by Apple (Lazareska and Jakimoski, 2017).

Below are some of the advantages attributed to the iOS mobile operating platform:

- Devices running on iOS are known to be very powerful due to its high performance.
- Its devices does not generate as much heat as the Android running devices.
- The gaming experience of iOS is excellent.
- It is less vulnerable to cyber attacks because of its high security.
- Just like Android, it enables multi-tasking.

However, despite the quality of iOS, it also pose some drawbacks which are listed below:

- It only support Apple devices since it is closed source.
- Apple devices running iOS are very expensive and so also some of their applications.
- When compared to Android, iOS is seen to have less customisability.
- Its battery performance when on 4G is very poor.
- It does not allow for Near Field Connection (NFC) or Radio support.

Windows OS: Microsoft Corporation first launched the Windows mobile OS on November 8th, in the year 2010. It was built to be running on touch screen mobile devices. Over the years, they have released a number of upgrades which comes in variety of versions. Interestingly, the Windows mobile operating system is also closed source. But however, it varies with the iOS in so many ways. This type of mobile operating system also has its advantages and disadvantages.

Some advantages of this OS is that:

- In the updated version, side loading is permited.
- Updates could be easily carried out due to the high control over applications by Microsoft.
- The security is almost unbreachable. They are the most difficult to crack.
- Its accuracy in terms of location querying is the most commendable (Padhya et al., 2016).

Some of its disadvantages are as briefly listed below:

- One of its major disadvantages is that their are fewer available applications for users when compared to Android and iOS.
- Its applications are said to be facing the challenge of lower quality development.
- In terms of usability and aesthetics, the Microsoft Store seem to be performing poorly.
- It does not allow for high customization (Murali, 2016).

3.8 Augmented Reality User Interface Design

Augmented reality user interface design employs the same principles as in other various interface design. However, the rudimentary objective is to map the user input and the output of the computer through a suitable metaphor of interaction. Three important components are to be put into concern when designing an AR interface; physical elements for input on the interface, virtual and auditory display, and lastly the metaphor of interaction which connects the first two elements together.

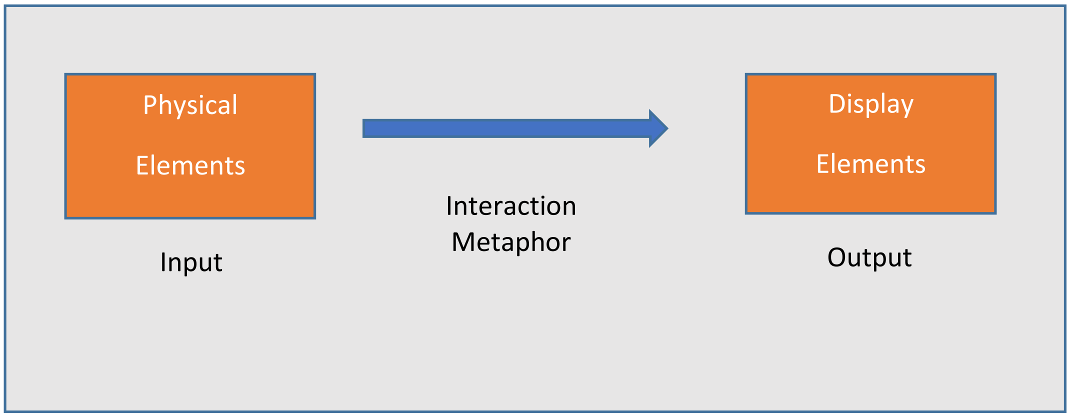

Figure 3.3: The key interface elements (Billinghurst et al., 2005)

In AR interface design, there exist a numerous variety of devices and techniques used for input/output mapping. During the design of a fresh user interface in augmented reality, certain stages are progressively passed. The stages are:

1. Demonstration of the application model (prototype).
2. The interaction methods of other interface metaphor is embraced or adopted.
3. New interface metaphor that is suitable to the medium is built.
4. Models for prediction of user interactions are then built.

Billinghurst et al. (2005) referred to their method of augmented reality interface design as "tangible augmented reality" (tangible AR). Highly efficient and user-friendly AR interfaces are attainable when you adopt the principles of tangible AR. It could also be referred to as Tangible User Interface (TUI). Basic TUI principles are:

- Using physical controllers to manipulate virtual content.
- Spatial 3D interaction methods support

- Time and space multiplexed interaction support
- Multi-handed interaction support
- Matching the interface object affordances to the task requirements
- Parallel activity supporting in a case where manipulation of multiple objects exist
- Multiple participants collaboration

CHAPTER FOUR

SYSTEM ANALYSIS AND DESIGN

In this section, the system architecture is clearly presented in detail and a clear description of the system is also given. The development technologies adopted for this project will be stated with reasons why they are employed. The software development methodology as well as the interface design will be discussed. Also, the technique for testing the usability of the application is presented.

4.1 System Description

The application developed has a beautiful and user-friendly splash screen which serves as a welcome screen, after which it presents the home screen to the user. On the home screen, it presents all the features of the application through which the use can interact with the system. The developed application has the following distinct features:

- **About:** This feature of the application presents to the users the basic information about the application, which includes a brief introduction and also the names of the author and the supervisor. The page allows the user to go back to the main menu in order to proceed with the other functionalities.
- **Scan Building:** This feature allows a user to scan the entrance of any building in order to retrieve information about them. Information to be displayed to the user includes name of the building or the faculty name assigned to the building, list of departments and their names, staff offices, halls and cafeterias. In addition, it will be able to display video/audio related to the buildings that are historical within the campus.
- **Locate Building:** The developed application is designed to be able to locate the buildings within the campus via GPS positioning and show the user the point of interest (POI) around the campus augmented on the physical environment as he scans around him. As a user approaches the POI, the description augmented above the building becomes bigger and clearer.

The application is developed for mobile devices that support Android operating system. These category of devices was selected because reports has shown that there are more Android users than any other devices running on different operating systems. According to a recent report by International Data Corporation (IDC), the Android running mobile devices market share is about 85% and expected to rise as indicated in their forecast. Moreover, it was projected that there would be a 1.7% growth rate and the number of android running mobile devices will be about 1.36 billion by 2022 (Chau and Ryan, 2017).

4.2 The System Architecture

The architecture presents how the system carries out its functionalities from the main menu interface to render AR view for rich immersive user experience. It presented in the above figure that the initial activity begins from the physical device (mobile device in this case) through the user interface. The user interface presents selectable options to the user; the options are either to scan or locate a building via GPS, or search option to find desired buildings within the physical environment (campus).

The system then sends track points to the ARCore engine after a building is scanned by a user through the AR camera on the device. The engine then queries the database in the ARCore Target Recognition System. The Target Management System then retrieve a corresponding target image and send feedback to the AR engine which will then render the specified media graphics on the scanned physical area to form a complete AR view.

The architecture also presents that a user can locate a building in the physical environment using the GPS. The system retrieves all the coordinates of the buildings in the Point of Interest (POI) storage and augment a marker (an indicator) with the name of the building (faculty) above the real building which is seen in the generated AR view.

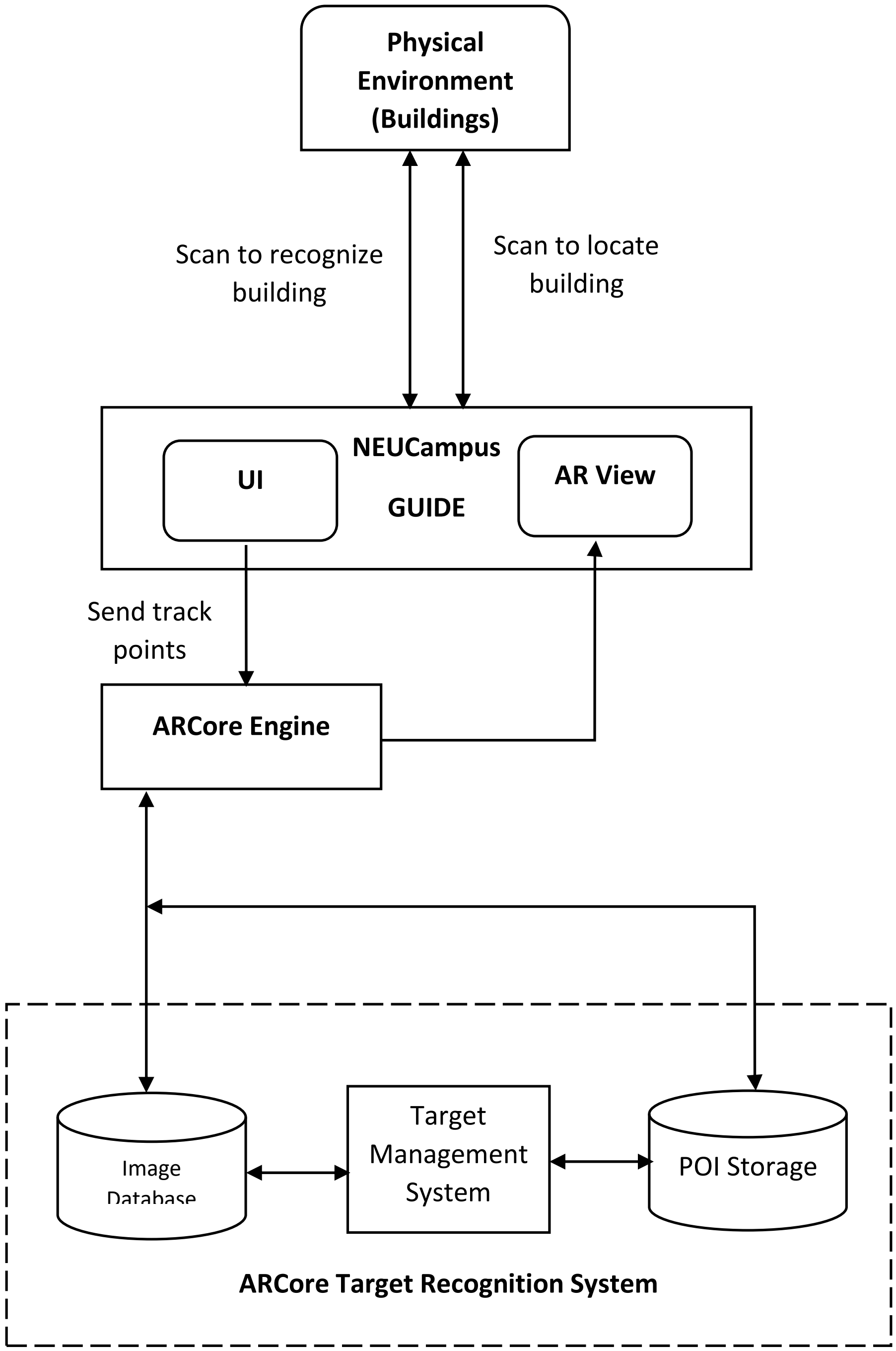

Figure 4.1: The developed application architecture

4.3 System Development Technologies

The developed system is a fully functional prototype that was implemented using some trending technologies in the area of Augmented Reality. The different technologies will be used for different features of the application. The technologies are briefly discussed below as to what function they were adopted for, in the development of this system:

- **Adobe Photoshop:** this technology was employed in the design of user friendly interfaces of the application. The designed items are logo, buttons, icons, background image and many others.
- **Unity 3D:** this is the Integrated Development Environment (IDE) that was used in developing the application. The IDE enable integration of Software Development Kits and Application Programming Interfaces (APIs) that support variety of operating systems for AR applications.
- **Google ARCore SDK:** this SDK was utilized in the development of the application in the Unity 3D environment. It was used because it fits this project since the developed application is running on Android OS which the SDK supports.
- **MapBox AR Engine:** this technology was utilized to provide for the GPS service. MapBox is the geographic data environment that support mobile and web applications. The platform offers the building blocks for incorporating geographic location features into many experiences created by individuals, businesses or organizations.

A combination of the features and or functionalities provided by the above mentioned technologies supported in the successful implementation of the system. However, more development technologies could be adopted if there is any need to add more features to the application.

4.4 System Development Methodology

Numerous software development methodologies or techniques are available today. Each and every methodology has its advantages and disadvantages. Therefore, the different methodologies fit into different projects for some alternating reasons. The most commonly utilized methodologies are Waterfall, Incremental, Spiral, Agile, Rapid Application Development (RAD) and few others.

The Rapid Application Development methodology is used to achieve this project because it is the best methodology that suits the application. This is because the project satisfies the below situations where RAD is the best fit as asserted by (Anderson, 2017):

- RAD should be used in a situation where the project needs to be completed quickly.

- It should be used when there is availability of users who can dependably test the prototypes.
- It should be used when there is an adequate financial budget for it.

He also claimed that using RAD in a situation that satisfies the assertions above can lead to some beneficial advantages. These advantages are as below:

- The project could be broken into smaller and more feasible pieces.
- A working system is delivered earlier rather than at the end of the development process.
- User feedback is gotten directly and regularly

When using the RAD methodology, the project is expected to pass through some stages or phases. The Figure 4.2 below represent all the phases of RAD which are briefly discussed afterwards.

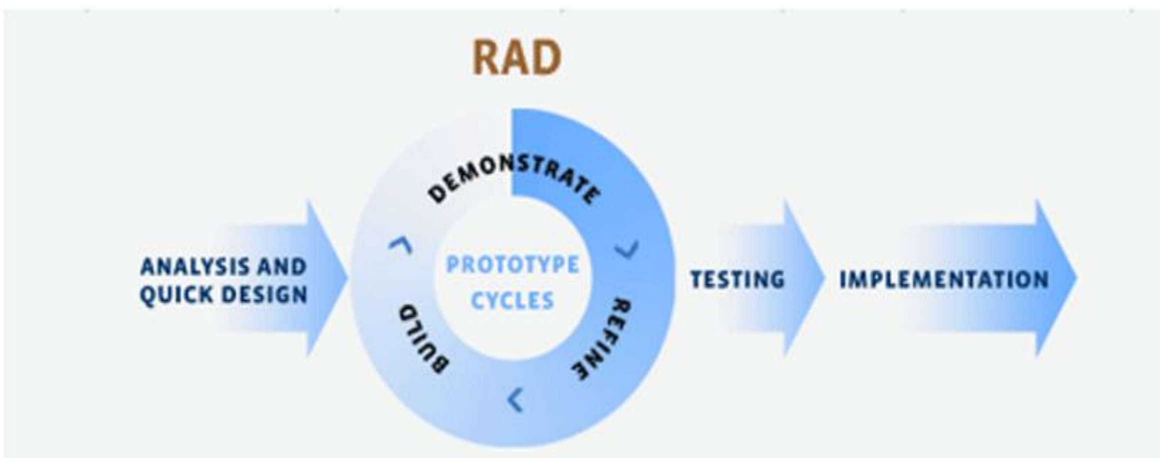

Figure 4.2: Rapid application development methodology (Anderson, 2017)

Analysis and Quick Design Phase: Each and every application is developed for a reason or to solve a problem. The RAD methodology begins by trying to find out what a project aims to accomplish. That is to find out the requirements. After figuring out the requirements, the project timeframe is set and then you presume how to build the system within the set budget.

In this phase of the development of the augmented reality mobile application, two consecutive brainstorming sessions were held to put down the requirements of the application. The brainstorming sessions included the author (developer) and five fresher students. The interface of the system was also designed during the analysis phase. Moreover, the interface was designed based on the Tangible User Interface (TUI) principles as stated in (Billinghurst et al., 2005). The Table 4.1 presents the AR interface elements of the application.

Table 4.1: The developed system interface elements

Physical Element	Virtual Element	Interaction Metaphor
Mobile device	Video, audio, text, POI names and display icons	The user holds a mobile device and scan the frontage of a building to view augmented videos, images or audio
Buildings to be scanned	Virtual dataset	

The different cells in the Table 4.1 describe how the interface was implemented in the developed application showing the physical elements, the virtual elements and the connecting interface metaphor of the device. Moreover, other generally known interface design principles were put into consideration since AR interface design does not go against adoption of general principles.

Prototype Cycles Phase: The second phase of RAD comprises of three distinct steps which are carried out repetitively. This is why this phase is called the Prototype Cycles. The three steps are building, demonstrating and refining of the application. At this phase, the developer or development team begin working on developing a functional prototype immediately (*Build*). Then the system is tried by the five fresher students in order get feedback (*Demonstrate*). However, to get feedback from the users, there is a continuous collaboration between the developer(s) and the users which in turn give room for developing a highly efficient system. The first built system is then updated based on the feedback gotten from the users (*Refine*). It is required that the prototype cycle is repeated multiple times until one is convinced that the project is complete after integrating all the modularized parts of the system together.

Testing Phase: In the testing phase, the application is tried in different numerous circumstances to be clear of doubt that the system meets the desired requirements. Furthermore, the testing phase will include extra user testing in addition to that of the developer.

Nielsen and Landauer, (1993) asserted that a usability testing that involves too many testers is regarded as misusage of resources, and that the best result of a usability test is gotten from not more than five participants carrying out as many test as possible. Therefore, this study used five fresher students as the participants of the final test session. However, the author was present at the venue of the test to serve as a guide and also get feedback thereafter. The usability testing was carried out based on the ten general heuristics of Jakob Nielsen. The Appendix B shows the usability testing form that was created.

Implementation Phase: Finally, the application is being deployed for the general users after passing the test phase. The application is enjoyed by the users as developers continue to update the system when necessary. This phase of RAD is called the Implementation phase (Anderson, 2017). With regards to this study, the application will be upgraded on regular basis to provide maximum satisfaction to the users.

4.5 Project Schedule

The Figure 4.3 below presents the schedule of the project from the beginning to the end. The schedule of the project is represented in a Gantt chart. It shows the number of days assigned to each section of the project. Each task has a start date and end date to show when it was started and when it was concluded. Each task is represented in block letters and the sub-tasks are represented in small letters.

Figure 4.3: Project schedule

CHAPTER FIVE

SYSTEM IMPLEMENTATION

In this section, the functional features and user interfaces of the NEUCampus Guide mobile AR application developed is discussed. Each screen from the start of the application is snapped in real environment to show how the application works. Also, each snapshot is accompanied by a brief explanation of what it entails

5.1 Snapshots of the Developed Application

Figure 5.1: Icon view of the developed application

The Figure 5.1 above shows the initial state of the application where a user can launch it.

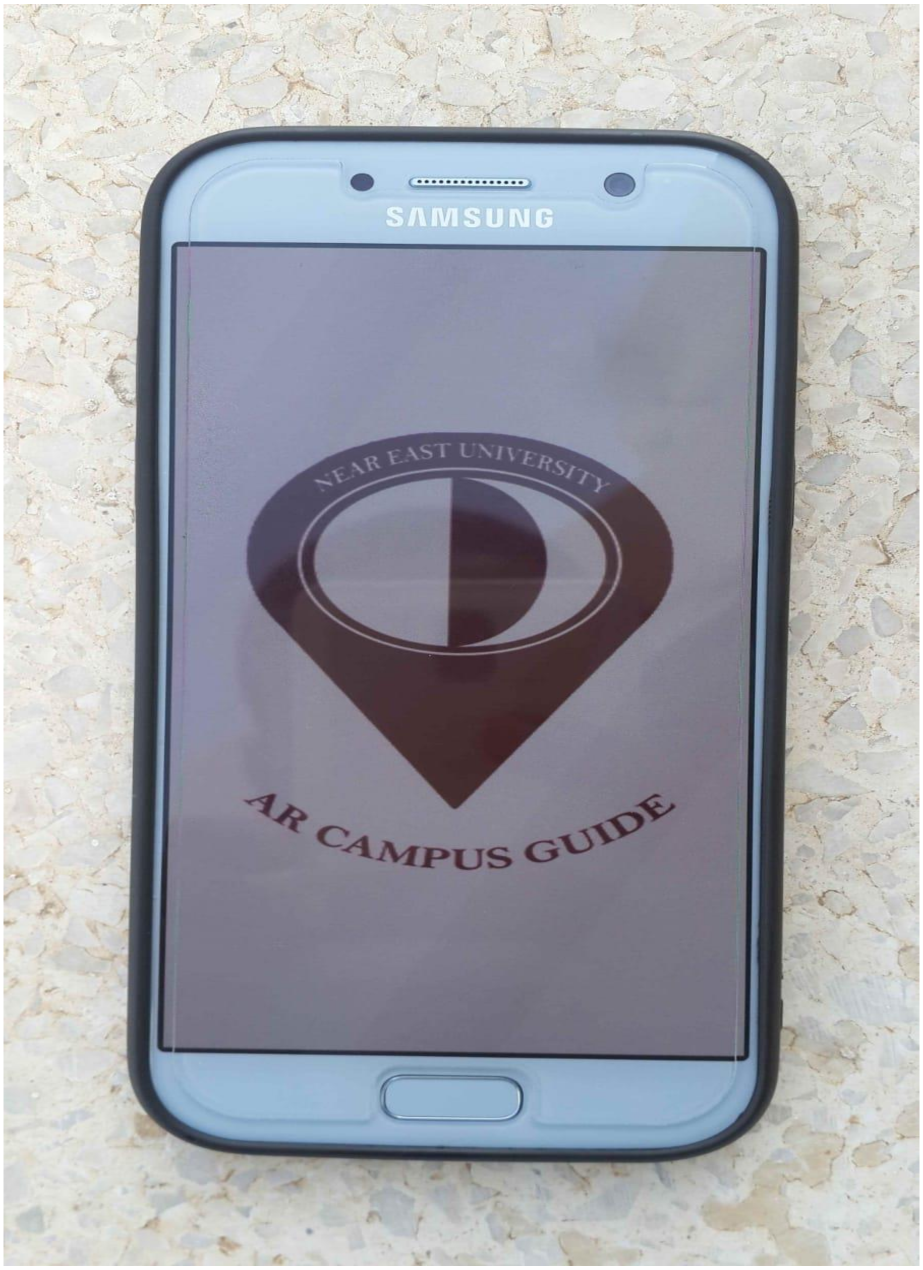

Figure 5.2: Splash screen of the developed application

The Figure 5.2 above shows the first screen a user will see when he opens the application.

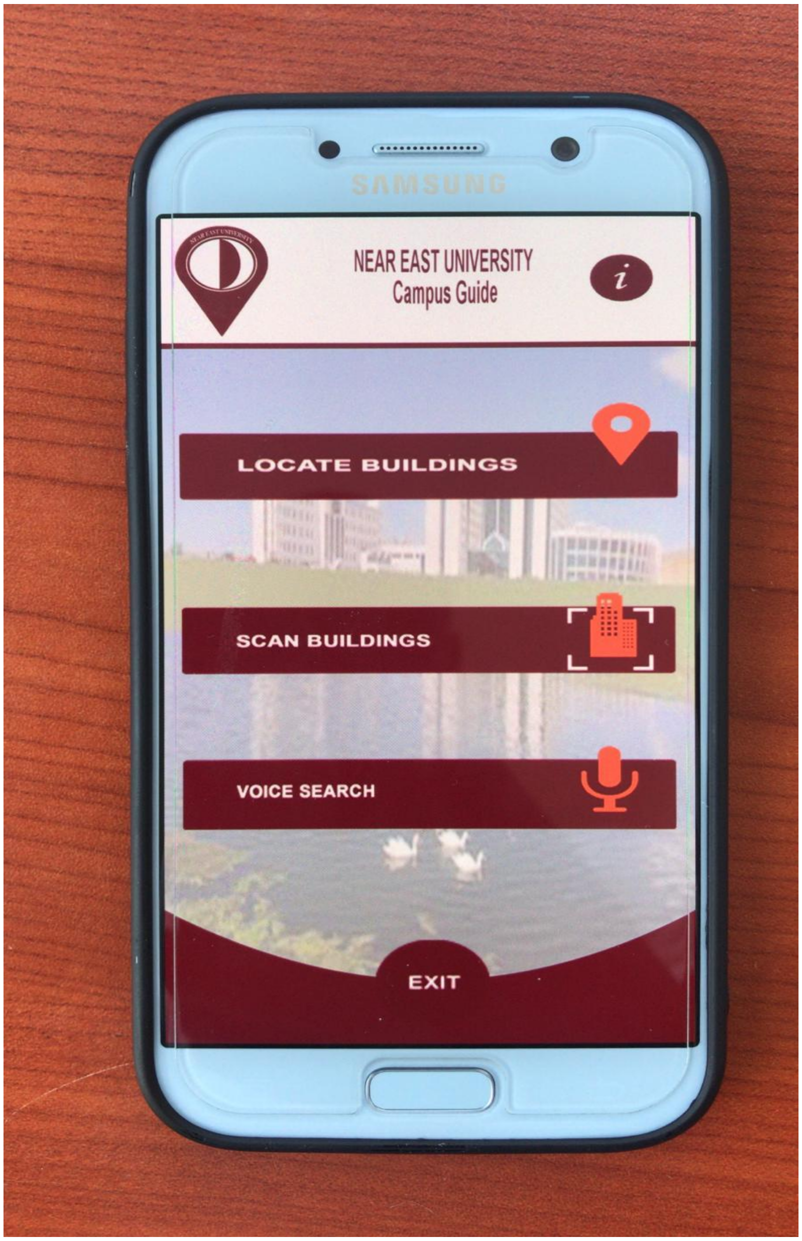

Figure 5.3: Main menu page of the developed application

The Figure 5.3 presents all the features of the application. From the menu page, a user can view the information about the application or select the option to scan a building to find information about it or locate buildings in real-time using GPS or even use the voice command to search for a building.

Figure 5.4: Information page

Information about the application is presented as shown in the Figure 5.4 above. A user is allowed to go back to the Main Menu page after viewing the general information.

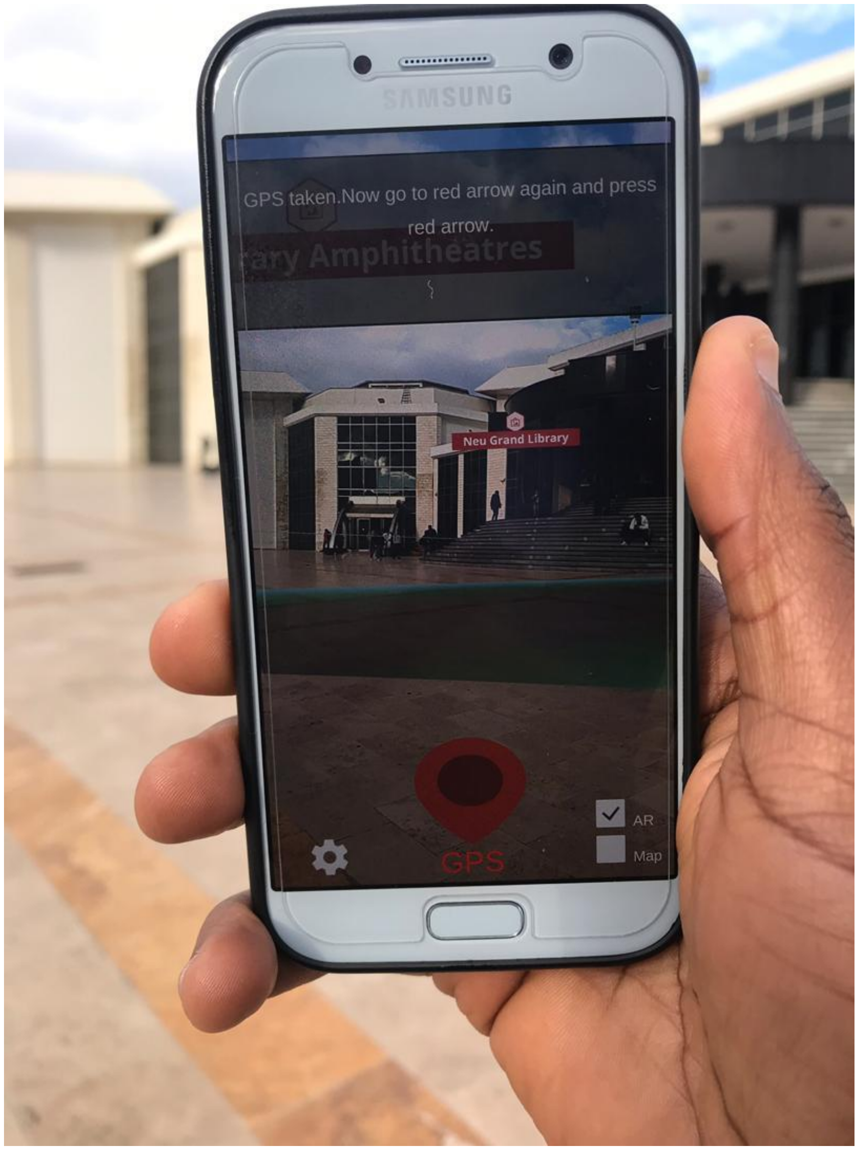

Figure 5.5: Screenshot of an augmented view for locating a building

The Figure 5.5 shows a screenshot made while trying the Locate Building feature of the application. This feature allows a user to use his mobile devices camera to scan the immediate environment in order to view the names of the buildings superimposed above them in the physical environment. This makes it easy for students to locate buildings for students without struggling to find a signpost that can guide them to a building they want to visit.

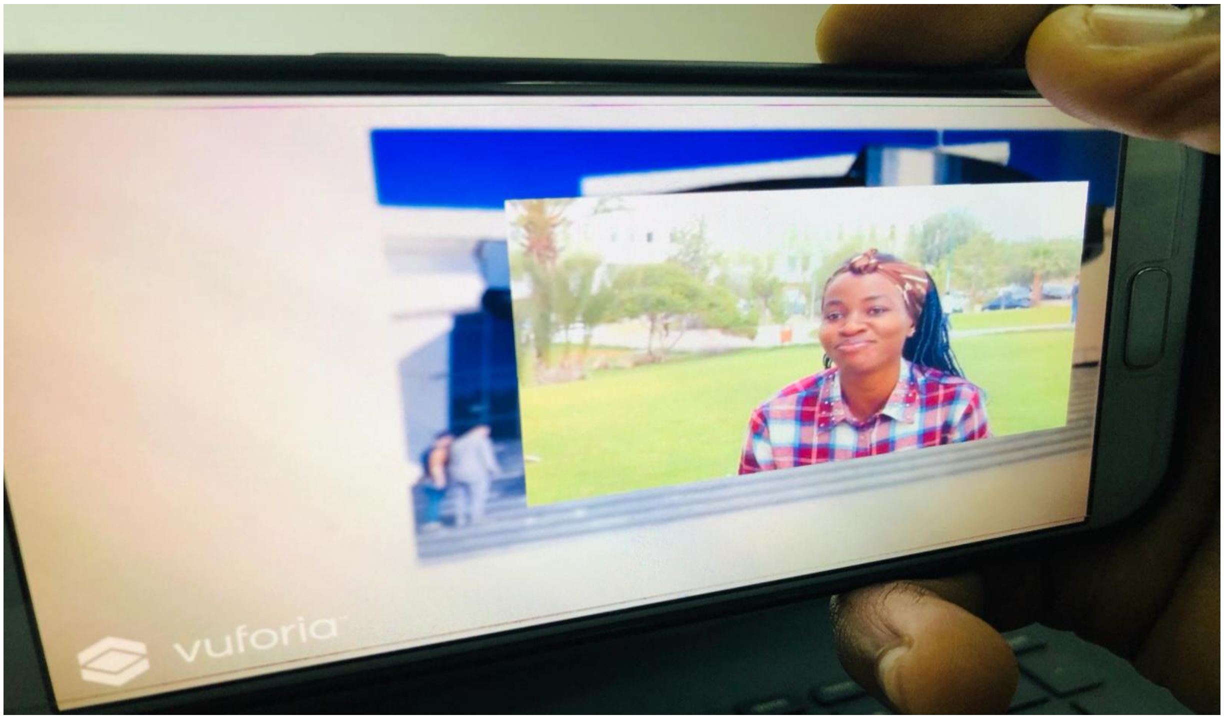

Figure 5.6: Screenshot of an augmented view for scanning a building

The Figure 5.6 shows a screenshot of how the developed application can augment information about a building by just scanning the entrance of the building. Information displayed could be in the form of a video, audio or text depending on the information intended to be given to the user.

5.2 Test Result of the Developed Application

This section presents the results of the usability test carried out by the five users. The test was conducted to verify that the application has implemented the required features and also examine whether the system is efficiently usable or not. The main features considered for the testing are the user interface, ease of performing task, relevance of information provided by the application and other related heuristics. The Table 5.1 below presents the result of the test as carried out by the users.

Table 5.1: Usability test result

Heuristic	User A	User B	User C	User D	User E
Visibility of system status	4	4	3	4	3
Match between system and the real world	5	5	5	5	5
User control and freedom	4	4	3	4	4
Consistency and standards	4	5	5	4	4
Recognition rather than recall	5	4	4	4	4
Flexibility and efficiency of use	4	4	4	3	3
Aesthetic and minimalist design	3	3	4	5	4
Help and documentation	4	5	4	4	5
Average	**4.13**	**4.25**	**4.00**	**4.13**	**4.00**
Overall average	**4.10**				

Based on the result above, the average score of the usability of the application is calculated. To arrive at the final conclusion, the overall average was taken. It turned out that the application scored 4.10 out of 5.00 which is equivalent to 82.04%. This result indicated that the application has a high usability. However, only eight of the ten Nielson heuristic were considered due to some factors.

Moreover, it was discovered during the testing that the GPS based feature of the system is not affected by weather condition while the Marker based is highly affected. For example the GPS based functions efficiently at night or even when it is raining, but the marker based only works in the day time. Also, the distance between the building and the user holding the mobile device has effect on the marker based feature.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Augmented reality technology is at the stage of high spread and growth, and it is being widely accepted and adopted in various aspect of everyday life. Thus, campus guidance and touring is constantly evolving at the same pace with the AR technology, and providing enhanced experiences. Considering the usability test carried out on the developed application in this study, combining both marker based AR and GPS based AR experiences in one application brings about a better awareness of the users' immediate environment, thereby making life easier and more efficient specifically within the geographical scope of the study. Moreover, the usability test that was carried out has shown that the application has high usability and therefore it is very efficient and useful.

6.2 Recommendations

The developed application in this study proved to be very efficient and usable. The application offers functionalities that can make life very easy for any new student, since finding a building within the huge campus is not a problem anymore. However, the application does not still offer some features for one reason or the other. In the future, it is recommended that:

- The iOS version of the application should be developed since the current one supports only Android. This will allow more users to have access to the AR campus tour experience.
- The application can be developed to support multiple languages.
- The application should have an augmented news feed.
- Voice command should be integrated to allow students to vocally interact with the application.

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APPENDICES

Appendix A: Usability Test Form

Heuristic	Test element	1	2	3	4	5
Visibility of system status	Giving feedback when necessary					
Match between system and the real world	Does the app present information in a familiar language?					
User control and freedom	Support for undoing unintended actions					
Consistency and standards	Consistency of the style of the interface of the app					
Error prevention	Receiving error message when necessary					
Recognition rather than recall	Objects and options visibility in the app					
Flexibility and efficiency of use	Ease of interaction with the system					
Aesthetic and minimalist design	System dialog information relevance					
Help users recognize, diagnose, and recover from errors	Error message expression					
Help and documentation	Help feature efficiency					

Appendix B: Program Source Code

The source code presented here is not for all the application, rather, it is the source code of some important features of the application. The source code of each feature is indicated with a comment at the beginning before the first line of code and another closing comment after the last line of code.

```
// This is the code for Main Menu Page
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class menumain : MonoBehaviour {

	// Use this for initialization
	void Start () {

	}

	// Update is called once per frame
	void Update () {

	}
	public void AboutApp(){
		SceneManager.LoadScene("about");
	}
	public void LocateBuilding(){
		SceneManager.LoadScene("locate");
	}
	public void ScanBuilding(){
		SceneManager.LoadScene("scan");
	}
	public void VoiceCommand(){
		SceneManager.LoadScene("command");
	}
	public void QuitApplication(){
		Application.Quit();
	}
}
// This is the end of the code for Main Menu Page
```

```
// This is the Code for Information Page
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class aboutApp : MonoBehaviour {

	// Use this for initialization
	void Start () {

	}

	// Update is called once per frame
	void Update () {

	}
	public void BacktoMenu(){
		SceneManager.LoadScene("MainScene");
	}
}
//This is the end of the code for Information Page.

//This is the code for the Scan Building feature.
//It includes the code for the Image Controller and the Image Visualizer
//Code for Image Controller
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class AugmentedImageController : MonoBehaviour
{
   [SerializeField] private AugmentedImageVisualizer _augmentedImageVisualizer;

	private readonly Dictionary<int, AugmentedImageVisualizer> _visualizers =
		new Dictionary<int, AugmentedImageVisualizer> ();

		private readonly List<AugmentedImage> _images = new
List<AugmentedImage>();
```

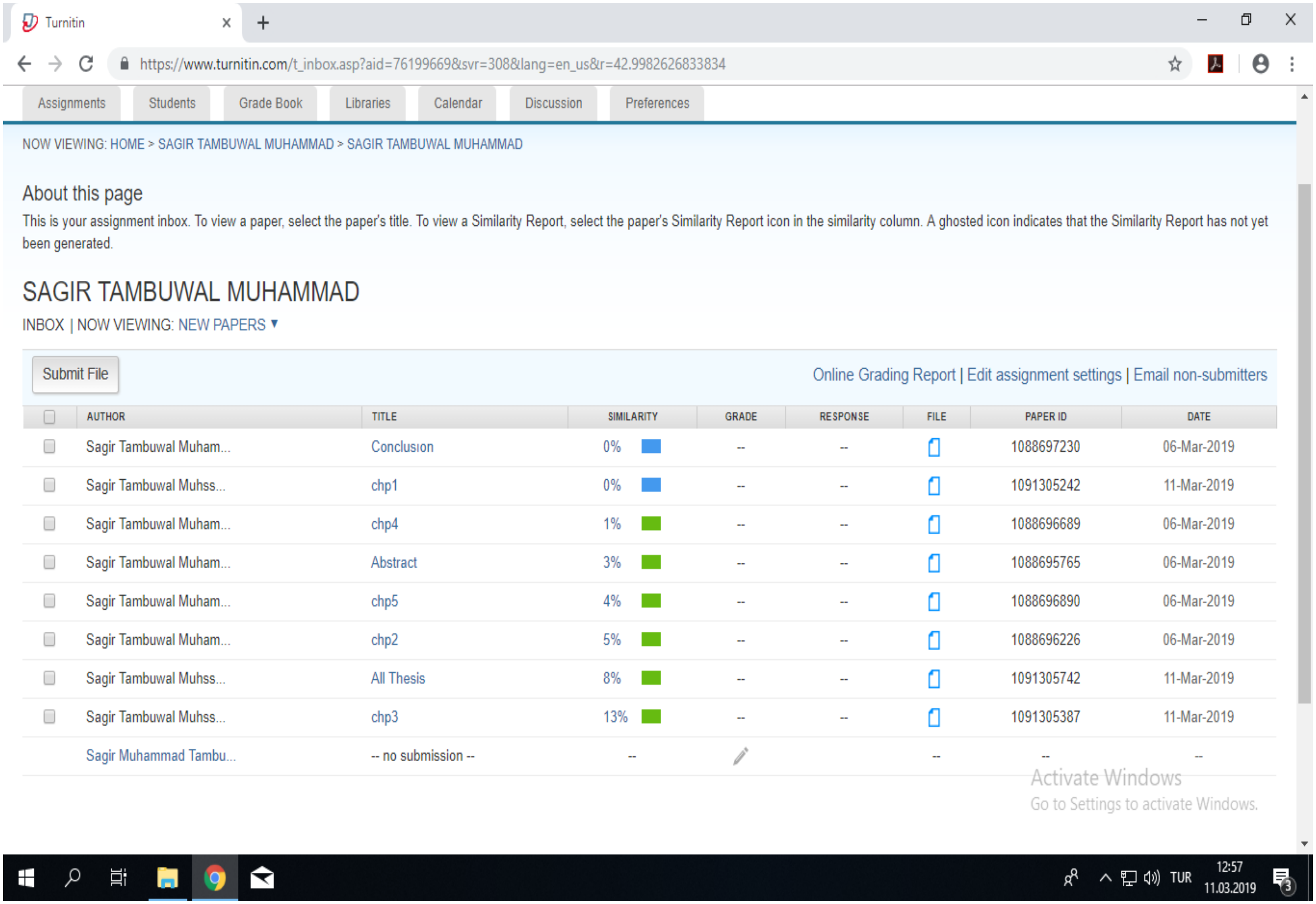
```
		private void Update()
		{
			if (Session.Status != SessionStatus.Tracking)
			{
				return;
			}
			Session.GetTrackables(_images, TrackableQueryFilter.Updated);
			VisualizeTrackables();
		}

		private void VisualizeTrackables()
		{
			foreach(var image in _images)
			{
				var visualizer = GetVisualizer(image);
				if (image.TrackingState == TrackingState.Tracking && visualizer
== null)
				{
					addVisualizer(image);
				}
				else if (image.TrackingState == TrackingState.Stopped &&
visualizer != null)
				{
					RemoveVisualizer(image, visualizer);
				}
			}
		}
		private void RemoveVisualizer(AugmentedImage image,
AugmentedImageVisualizer visualizer)
		{
			_visualizers.Remove(image.DatabaseIndex);
			Destroy(visualizer.gameObject);
		}
		private void AddVisualizer(AugmentedImage image)
		{
			var anchor = image.CreateAnchor(image.CenterPose);
			var visualizer = Instantiate(_augmentedImageVisualizer,
anchor.transform);
			visualizer.Image = image;
```

```
                        _visualizers.Add(image.DatabaseIndex, visualizer);
                }


                private AugmentedImageVisualizer GetVisualizer(AugmentedImage image)
                {
                        AugmentedImageVisualizer visualizer;
                        _visualizers.TryGetValue(image.DatabaseIndex, out visualizer);
                        return visualizer;
                }
}

//Code for Image Visualizer
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Video;

public class AugmentedImageVisualizer : MonoBehaviour
{
    [SerializeField] private VideoClip[] _videoClips;
        public AugmentedImage Image;
        private VideoPlayer _videoPlayer;

    void Start()
    {
        _videoPlayer = GetComponent<VideoPlayer>();
                _videoPlayer.loopPointReached += OnStop;
    }

        private void OnStop(VideoPlayer source)
        {
                gameObject.SetActive(false);
        }

    void Update()
    {
        if (Image == null || Image.TrackingState != TrackingState.Tracking)
                {
                        return;
```

```
		}

		if(!_videoPlayer.isPlaying)
		{
			_videoPlayer.clip = _videoClips[Image.DatabaseIndex];
			_videoPlayer.Play();
		}

		tranform.localScale = new Vector3(Image.ExtentX, Image.ExtentZ, 1);
    }
}
//This is the end of the code for the Scan Building Feature

//This is the code for the Locate Building Feature
//This is the code for Instruction UXCanvas
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Events;
using UnityEngine.UI;

public class InstructionUXCanvas : MonoBehaviour
{
    public Text instructionText;
    public Button closeButton;
    public static InstructionUXCanvas Instance = null;
    // Use this for initialization
    private void Awake()
    {
        Instance = this;
        closeButton.gameObject.SetActive(false);
    }

    public void SetInstruction(InstructionObject I)
    {
        instructionText.text = I.InstructionText;
        closeButton.onClick.RemoveAllListeners();
        closeButton.onClick.AddListener(I.canvasEvent.Invoke);
    }
```

```
    public void SetButtonActive()
    {
        closeButton.gameObject.SetActive(true);
    }

    // Update is called once per frame
    void Update()
    {

    }
}

[System.Serializable]
public class InstructionObject
{
    public string InstructionText;
    public UnityEvent canvasEvent;
}
//This is the end of the code for Instruction UXCanvas

//This is the code for Manual Calibration Canvas
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ManualCalibrationCanvas : MonoBehaviour {

    public static ManualCalibrationCanvas Instance = null;
            // Use this for initialization
            void Start () {
        Instance = this;
        Instance.gameObject.SetActive(false);
            }

            // Update is called once per frame
            void Update () {

            }
}
//This is the end of the code for Manual Calibration Canvas
```

```
//This is the code for the Moving Roads Script
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class MovingRoadsScript : MonoBehaviour {

    public Material roadMat;
    private GameObject[] gameObject;
    public float ScrollX = 0.5f;
    public float ScrollY = 0.5f;
    public bool stopped = false;
    public float offsetSpeed = 0.5f;
    public bool reverse = false;
    private float timePassed = 0;

    void Start()
    {

    }
    // Update is called once per frame
    void Update()
    {
        //float OffsetX = Time.time * ScrollX;
        //float OffsetY = Time.time * ScrollY;

        float offset = Time.time * offsetSpeed % 1;
        if (reverse)
        {
            offset = -offset;
        }
        roadMat.mainTextureOffset = new Vector2(0, offset);

    }
}
//This is the end of the code for the Moving Roads Scripts
```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