IMPLEMENTING A MARKER-LESS AR APPLICATION FOR KRISTKIRKEN USING VUFORIA SDK

By

AREZOO SOLATIAN

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To the Faculty of Bergen University & Western university of applied sciences(HVL):

The members of the Committee appointed to examine the master thesis of AREZOO SOLATIAN find it satisfactory and recommend that it be accepted

Atle Birger Geitung , Supervisor

Harald Soleim,Supervisor

Oyvind Fosse,Supervisor

Remy Andre Monsen,Supervisor

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Abstract

Background: In recent years, researching in the field of Augmented Reality (AR) regarding cultural heritage has immediately expanded due to the progression of technology and the availability of more affordable hardware. It is, amongst other things, being used as a tool to increase accessibility and capture the public's interest in cultural heritage.

Objectives: The goal of this master thesis was to create a marker-less augmented reality Android mobile application using Vuforia which is considered, the best software development tool(SDK). It also supports iOS perfectly. However, the iOS version hasn't been implemented yet and Hopefully, will be done in the future. During the analysis of 3 different software development tools such as ARCore, ARkit, and Vuforia, Vuforia was chosen to work with because of the broad range of capabilities. **Methods:** With the use of Unity3D and Vuforia, the AR application was implemented to display a historical site located in Bergen, Norway. A church by the name of Kristkirken pÃě Holmen, based on abstract models and inspiration of other churches that existed in a similar era. The program will get the users coordinates, compare it with the church's principal coordinates. If the user reaches a certain distance, it will display the church's four principal coordinates. If the user enters a specific range (for example 10 m from the church) **Results:** The applications were evaluated in a user study with 5 participants. Each participant was asked to perform a simple task of walking through different angles of the displayed church and then answer some questions based on usability of the app.The result of the study showed that the application was perceived as usable and well-performing, although it should be mentioned that the coordinates are not accurate. **Conclusions:** The participants felt that with just a few instructions, the applications were easy to use, even though all of them had no previous experience in utilizing AR. Possible further development of the app would be to complete the church-model by adding more details, materials, and lighting that are currently missing. Also the precise coordinates will be replaced.

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To my FAMILY...

Chapter One

INTRODUCTION

1.1 Motivation

1.1.1 Augmented Reality

Augmented reality is an intuitive encounter of a real-world environment where the computer-generated conceptual information magnifies the objects that live inside reality, over numerous modalities. For example, visuals, auditory...(R. Azuma et al., 2001)

1.1.2 Vuforia

Vuforia is, as of now, the most popular AR software development tool (SDK) available with more than 325000 enlisted engineers and over 35000 applications are using this innovation worldwide (Grahn, 2017). About 80 percent of these applications were created using Vuforia models and extensions. Qualcomm created Vuforia and later, it was purchased by PTC in late 2015. Regardless of being such a far-reaching apparatus, be that as it may, there use to be not much documentation about execution on the Vuforia/Unity stage and how it performs on various operating systems, for example, Android or iOS (Soussi, Spijkerman, and Jansen, 2016).

1.2 Aim

This thesis aims to create a marker-less AR application simulating Kristkirken using the Vuforia SDK which currently located in Bergenshus Fortress. The church used to be in front of Håkonshallen. The users will be able to use their devices; therefore, visualize the church through their desired positions. They could also be able to go inside the church and see the interiors. In order to create an AR-based application, developers have to consider what type of an AR apps they would use. To do so, different tools were analyzed, such as ARCore, ARkit, Vuforia, and some other appliances. Conclusively, Vuforia was chosen and has implemented for this project finally, exported from Unity3D.

1.3 Challenges

They were a few challenges faced with this thesis study:

- There is no building or structure in the church's current location. Placing the church at the exact position as it was in the past is quite difficult due to the lack of data; Therefore, specifying the coordinates are done by estimation. The accurate coordinates can be obtained from the history experts and replaced by the current ones.
- The exact model and architectural construction of the church is unknown, and we have very little information regarding the precise structure of the building. The modeling is inspired by Stavanger Cathedral which is a church that existed in the same era as Kristkirken.
- There are some bushes and trees covering some parts of the location where the church use to be, which will make it harder to use markers to be able to detect and see the church. To avoid this problem, a marker-less method was chosen for development.

- The structure of the church is humongous; The program should be able to present the whole church by holding the device in the right places and angles. In some apps, once you place the object and move towards a specific direction, it will disappear, misplace or shake constantly. By using Vuforia and testing with the right methods, these problems will be solved or reduced significantly.

1.4 Importance of the study

One of the most significant challenges regarding AR is educating the market or society. The reason being, many people are not exposed by AR consistently. Therefore, they haven't seen it's wide-attaining applications in their lives. On the contrary, they are a lot of simple AR application that needs a gentle introduction for showcasing. With better understanding and advancing by developing with an early introduction, AR will be more available and accessible.(Magaji, 2018) Developing an app for this church in vital due to 5 reasons:

- Accessibility: The church can be seen by anyone, at any time, and any stand point. The users stand on the field with their AR application and visualize the church.
- Marketing and History: Societies have long attempted to protect and preserve their cultural heritage, for the most important reasons from historical research to education to strengthen a sense of identity. In times of war and conflict, cultural heritage and cultural identity become all the more critical. Monuments, and symbols and buildings of culture that speak of shared roots importance acquire to be well preserved. Consequently, they can become victims of violent and suffocating action that seeks to destroy the symbols considered and appreciated by enemies or the iconography associated with alternative faiths and traditions. In case of Kristkirken, the building was destroyed in order to protect the castle from danish ship attacks.
- Guide: The application will serve as a tourist guide to all the visitors. Bergen is a touristic place; therefore, the application can bring awareness to the visitors regarding

it's rich historical background.

- Upgrade: The application will also uplift the standard of the church to meet world standards.
- Popularity: Because of the innovation in question while developing the application, it's uniqueness and showcasing will draw in more individuals. In this way making the app is increasingly conspicuous and outstanding.

1.5 Scope

1.5.1 Limitations

Although mobile applications using AR technology will fulfill all sorts of requirements, in any case, there were some limitations connected to it because of the impediments:

- The study only targets Kristkirken.
- The mobile application design and specifications are only limited to Android devices and not iOS.
- The timing of the project was limited; therefore, only the vital features have been deployed. The extra features will be added in the future.

1.6 Case description

Olav Kyrre built Kristkirken på Holman (Christ Church at Holmen) between 1066 and 1093. It was located on the northern side of Håkonshallen. Although the church was dedicated to the holy trinity, it was called the Christ church. There were originally two Christ churches, which were mainly fabricated in order of the coronation. The small Christ church was made out of wood; however, there are no traces of the small church now. The Big church, (built 1066-1093), is a Romanesque-style church, fabricated from wood to stone so that it made the bigger church more strategically important such as several buildings that are close in time, St. Mary's Church and Domkirken. The significant Christ church building process was not accomplished during the kingdom of Olav Kyrre. It turns out that the smaller church was serving as a temporary church to everyone until the full Completion of the big church. Historians believes that the English initially built the big Christian church that is influenced by Domkirken I Lund. The craftsmen and artists of Lund had worked on multiple churches during (1130 – 1170). The Great Church of Christ was decorated and manufactured in building styles used at that time. In the 13th century, Holmen and The Christ church were Norway's biggest political pole. The church had been used as court sites, Cemetery, and all kinds of royal tributes. It was also a place for kings' coronations and funerals.(*Bergenanno1350* 2019). In 1531 the church was destroyed by chief Eske Bille at Bergenhus fortress. It turns out that the church was a barrier and a blind spot when it comes to protecting the castle. Nowadays, the only remaining of the church is the ground plane, which has been marked with a planted hedged at Bergenhus moreover. The alter is also still standing in the memorial of st — Sunniva, who was the patron saint of Bergen and Bjorgvin Bishop.(*Bergenanno1350* 2019)(Rudrud, 2007)

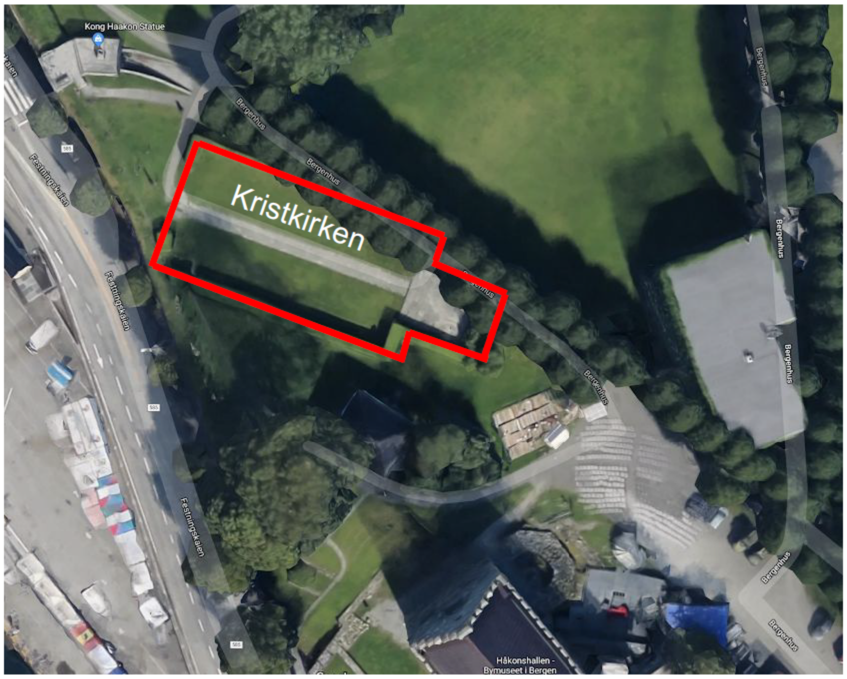


Figure 1.1 Approximate position of the church based on the current location. Map rendered from: (**www.googlemaps.com**)

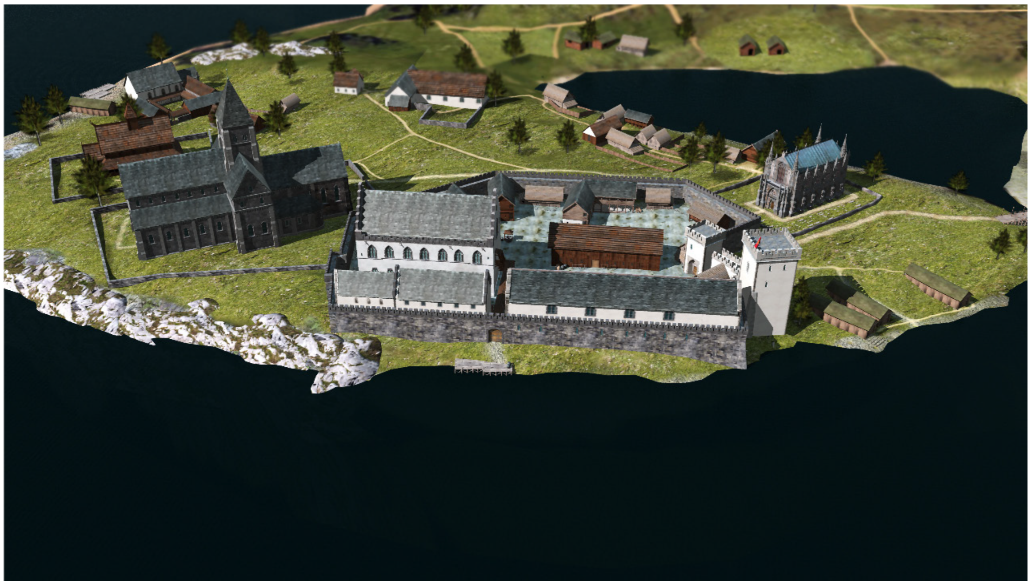


Figure 1.2 A rendered model of the approximate position of the church. The church is located on the left side and Håkonshallen on the right side which still stands today(*Bergenanno1350* 2019)

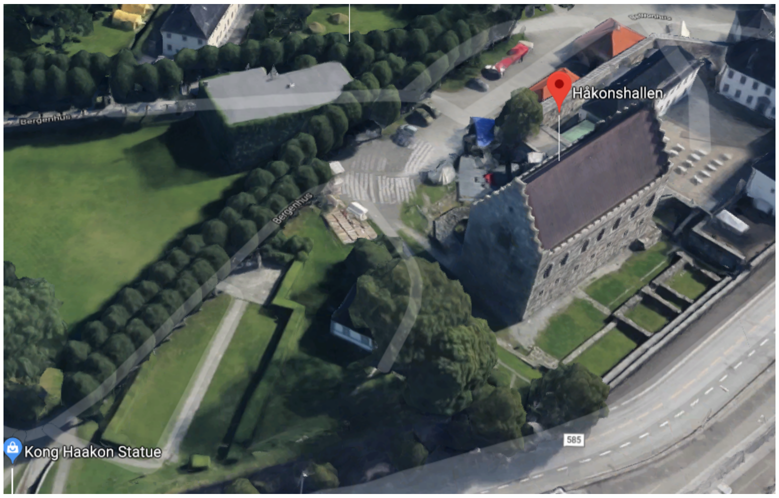


Figure 1.3 A 3D satellite photograph: The approximate location of the church which has been determined by bushes

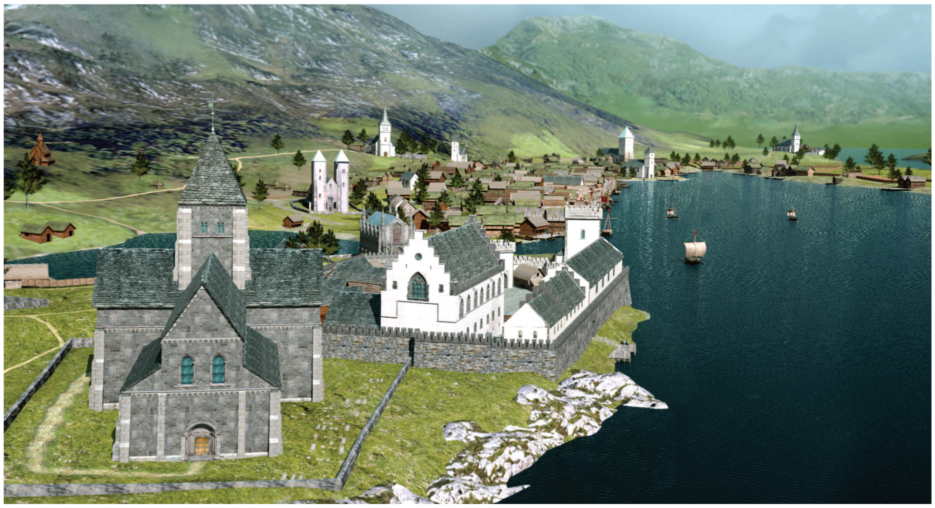


Figure 1.4 *Bergenanno1350* 2019

1.7 Overview of chapters

This thesis consists of 8 chapters:

- **Chapter 1** is the introductory part of the thesis that explains the Motivation, objectives, importance of the study, and the limitations.
- **Chapter 2** presents the related research done by other researchers in the same area

of interest in the AR application and Vuforia.

- **Chapter 3** manifests the theoretical structure utilized for the thesis, consequently clarifying Augmented reality, a brief history of AR, AR usage, components and different types of AR applications.
- **Chapter 4** also provides a theoretical background for Vuforia, main components and comparisons to other SDKs.
- **Chapter 5** explains in detail, the created Mobile Augmented Reality application for The church, framework necessities of the entire research, programming advancement cycle, Hardware, Software, engineering architecture, flowchart, and Operating framework that shows the plan of the created framework as visual.
- **Chapter 6** will give an exploration through the results and the testing process of the thesis.
- **Chapter 7** wraps up the study and includes recommendations and suggestions for future works.
- **Chapter 8** Provides Glossaries.

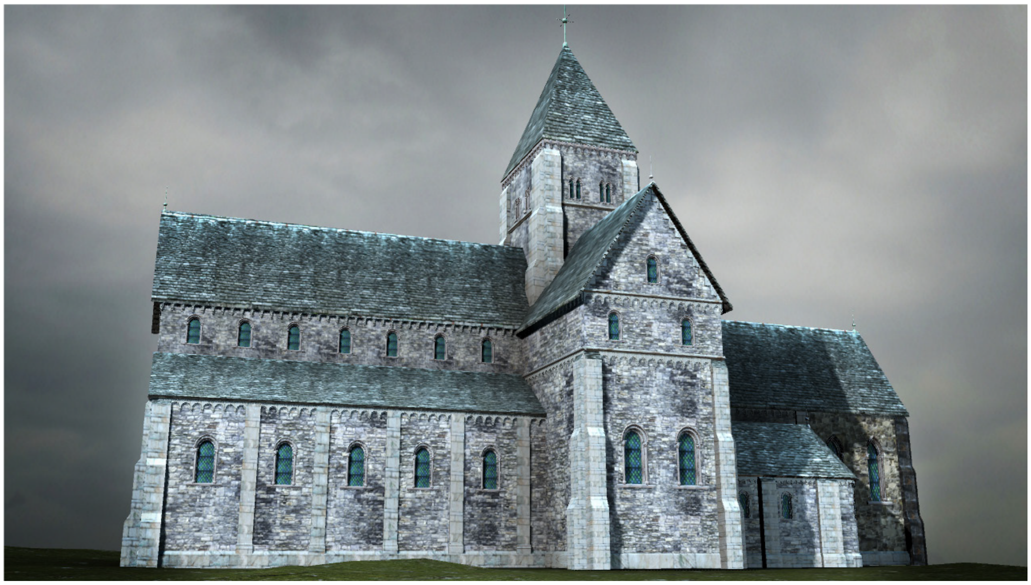


Figure 1.5 (*Bergenanno1350* 2019)

Chapter Two

RELATED WORK

Stridbar and Henriksson, 2019, created two AR applications using Vuforia and Unity3D. A marker-less and a marker-based application was developed. Both of the apps displayed a model of an 18th century Swedish warship. The model was based on a wooden ship, and it was created in Autodesk Maya to suite the AR application needs. Fourteen participants have tested the application. Each of the participants was asked to perform a single task while using the app; for example, walk around the site and answer some questions afterward. The same methods has been done for the second application. Finally, they compared the results based on functionality and performance. The result of the questionnaire-based survey showed that the applications were considered usable, with an average of 90.5 points for marker-based AR and 86.8 scores for marker-less AR(on a 0-100 point scale). Regarding performance, the marker-based method was perceived as better performing.

A study has been done by Magaji, 2018 at Near East University; he implemented an AR application for the NEU car museum located in Cyprus. The cars in the museum are costly and have historical values; therefore, they should be maintained well and remained untouched. This application will serve as a guide to visitors to obtain information about the cars in the NEU museum through using the image target view ability to see the objects in 3D views.It is tested by 35 students. The results in the case study showed that the application is user-friendly and interactable.

One of the most significant titles in the AR gaming industry currently is Pokémon Go (Gould, 2016), a mobile application where the goal is to catch Pokémon's by throwing Poké balls at them. The Pokémon appears on a depiction of a real-world map, their positions being semi-randomly set GPS coordinates, and the players must move to these positions in the real world to be able to capture them. When the player is close enough, a 3D model of the Pokémon is contextually superimposed on the phone's camera view using location-based AR and can then be caught by throwing poke balls on them through the phone display.

Chen, 2014 presented the design, implementation, and evaluation of a mobile AR application for historical Oslo that intends to bring history to life by providing historical pictures of a location, depending on which direction the camera is facing. The application can run offline and is designed as a nonexclusive framework where a related application for a new city can be generated by replacing the city-specific database. When a user enters the AR view, the latitude and longitude are automatically generated. A compass function identifies which way the user is pointing to. A query with the information accumulated is then sent to the database to retrieve the picture and supplementary information. The query returns the relevant picture and historical data.

Chapter Three

AUGMENTED REALITY

3.1 Introduction

The environment, which includes both reality and the elements of the real world, is called augmented reality (AR). In this environment, the user is capable of viewing the real world along with virtual objects superimposed on or combined with the real world. (R. T. Azuma, 1997) describes augmented reality as it:

- Merges the virtual and real
- Responsive in the real-time
- Ascribable in 3D

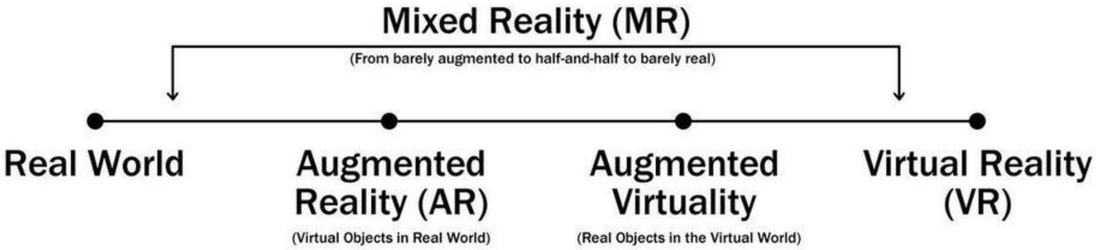

Mixed Reality (MR)
(From barely augmented to half-and-half to barely real)
Real World
Augmented Reality (AR)
(Virtual Objects in Real World)
Augmented Virtuality
(Real Objects in the Virtual World)
Virtual Reality (VR)

Figure 3.1 A simplified representation of a virtuality continuum, also know as Milgram & Kishino Mixed Reality ModelMilgram and Kishino, 1994

- **Real World:** The real and physical life around us, and it does not consist of any digital entity.
- **Augmented Reality:** The technology which overlays the real world with digital information.
- **Mixed reality:** This is the merging between the digital world and the real world.
- **Virtual Reality:** This is the user in an utterly digital world.

3.2 Overview

Sutherland built up the principal Augmented reality (AR) in 1968. He made the principal head-mounted display. As a result of its weight, it must be held tight to the roof and was named "Sword of Damocles". Afterward, around 1993, Feiner presented KARMA, a framework that fused knowledge-based AR. It has been valuable for various perspectives from the late '90s till this day(Feiner, Macintyre, and Seligmann, 1993. US Naval Research Laboratory worked on a 10 years in a length research program called Battlefield Augmented Reality System to model a portion of the wearable system for fighters and soldiers working in the urban conditions for awareness and preparing(R. Azuma et al., 2001). The latest advancement in AR has been by Niantic with a game called Pokémon-Go for iOS and Android, where players must circumvent the exact condition to discover focused on items. It turned into the most prominent cell phone application and spiked in augmented reality games(Serino et al., 2016).

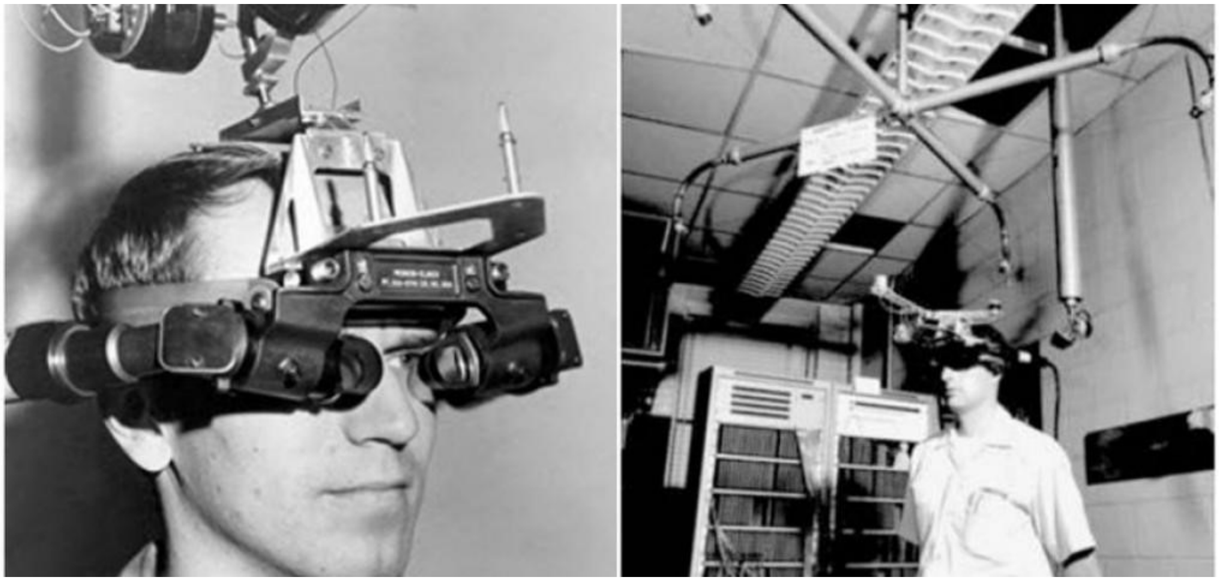


Figure 3.2 The sword of Damocies was built in 1968, the nickname for the world's first head-mounted display Boas, 2013

3.3 Hardware

Google glasses, Microsoft HoloLens and mobile devices are the example of equipment gadgets to get to the AR usefulness. Equipment parts required are: display, camera, sensors, processor, and input gadgets. Nowadays, Smartphones contain each of these components. GPS, accelerometer and compass makes them compatible with AR. Head-up displays, eyeglasses, contact lenses and advanced mobile phone cameras are crude display components required for display purposes. Contributing the directions is additionally critical to make AR applications reasonable and responsive. The input data is various tools such as keyboards and touch controls.(Siltanen, 2012)

3.4 Toolkits and Libraries

The principal portion of AR is how well it can join with the reality elements. It must bring this current real-world image coordinates isolated from the camera image coordinates. Scientists and engineers have advanced numerous apparatuses, SDKs, and improvement kits to create Augmented reality-based applications. ARToolkit, also is known as ARToolkit 1999(Piekarski and Thomas, 2002), was the first library to design AR applications. ARToolkit is the perfect library to create AR-based applications. It has been productive since 2006. Therefore, libraries have been reached out to potential outcomes, for example, portable applications and web applications. (Siltanen, 2012) Correspondingly, Vuforia, which is utilized in the thesis, is likewise a toolbox used to create AR applications. The purpose of choosing Vuforia instead of ARToolkit or any other kits was the effortlessness. Vuforia 8.5 is the most recent version, comes alongside Unity3D.

3.5 AR Components

With regards to AR, there are three most significant components, which are the fundamental explanations for it's Tracking, Registration and Calibration.(**Figure 3.3**). The Tracking process handles dynamic registration. The objects will first register in AR and align with the coordinate system afterwards. The objective of the AR system is; the virtual information must be registered precisely how they look for the system. The calibrations duty is to perform the static registration for the tracing system.

3.5.1 Tracking

Generally tracking objects in the real-world can be divided into two main categories: Marker-based tracking and marker-less tracking, for example, QR codes and bar-codes are the most common usage of marker-based tracking. Nowadays, a lot of AR applications dealing with image recognition are marker-based because the detection will be so much easier. The marker can be the image that is easy to identify and trackable. The marker-based applications do not require a lot of processing power. A marker-less AR, however, is much more complicated to implement. The application has to detect the colors, patterns that are not provided before.(Siltanen, 2012)

3.5.2 Calibration

Calibration is a vital process for the components in AR, especially the ones that serve as tracking devices. The process is to compare two devices. The first device will be the reference device. The second is the device that needs to be calibrated. The reference device replaces with the coordinate in the real environment. One of the pros of the calibration is that unlike Tracking, there will be no need to perform the process continuously.(Siltanen, 2012)

3.5.3 Registration

Registration applies to the alignment of coordinates between virtual and real objects. More particularly, the AR display should show or align the virtual object into the real world solely. This requires the tracking of the user's camera, providing the background. Static registration occurs during the non-movement of the camera to build the standard coordinate between real and virtual objects while dynamic registration is when the camera is moving, which will need tracking.(Siltanen, 2012)(**Figure 3.3**)

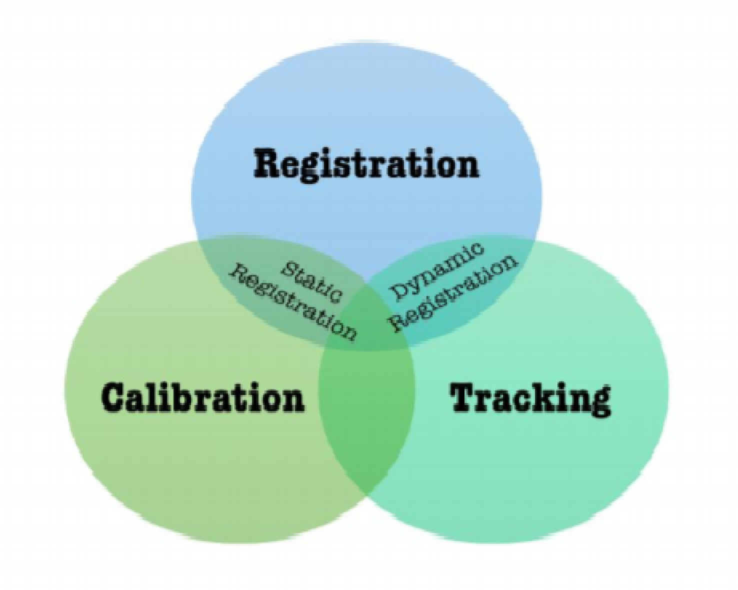


Figure 3.3 Three Vital Augmented reality components

3.6 Types of AR technologies

- **Marker-based AR:** When the camera spot a specific image or marker, the application triggers the augmented reality elements. The markers can be QR codes, Images, and signs.
- **Marker-less or location-based AR:** It reads the data from the GPS or any other positioning systems, and data can be collected from the phone's gyroscope.
- **Projection-based AR:** Different elements such as images and texts, can be projected on to physical objects.
- **Superimposition-based AR:** By using this ability, the users will be able to change the appearance of an element entirely or partially.

Chapter Four

VUFORIA SDK

4.1 Introduction

Nowadays, developers have deployed SDK and it's amplitude of advantages to develop plenty of applications for various purposes. One of the commonly used applications in Augmented reality SDKs has been done for developing mobile applications. The augmented reality SDKs include: Metaio, Vuforia, Wikitude, ARCore and ARKit.(Grahn, 2017) Augmented reality SDK is a collection of tools and libraries provided by the developers for developing augmented reality applications. It helps to comfort and simplify the components which is used in the AR application such as object recognition, object tracking, location-based AR, content rendering, visualization and marker-less applications.(Adrianto, Hidajat, and Yesmaya, 2016)

In this chapter the main tool of the project which is Vuforia SDK is discussed. Vuforia is one of the most popular Augmented reality SDK for mobile devices that enables the creation of Augmented reality applications.(Soussi, Spijkerman, and Jansen, 2016)

4.2 Overview

Qualcomm created Vuforia in 2006 which is presently owned by PTC since November 2015. It utilizes the camera vision to track and recognize the 3D objects and the images in real-time. By providing a simple user interface and functionalities, even beginners will be so satisfied using a new tool. One of the essential factors for the amateur developer is the cost of the development tools. The open-source projects and tools have made a massive change in the number of participants.furthermore, Vuforia is free; however, the usage of the features is limited.

4.3 Documentation

On the Vuforia website, an API can be found for each and every class. (*vuforia Documentation* 2019) The API also contains a detailed text on all the classes and methods. The texts are well-composed, which will make it so easy to have a good overview of the class structure. The website also contains a developer guide to assist in installing the tool-kits. The guidelines include various helpful information regarding how to set up the development environment for different platforms, how to compile and run the code inside the workflow.

4.4 License

Downloading and developing the applications using Vuforia is entirely free; moreover, it will not cost anything to publish the applications using Vuforia to application markets.(*vuforia Documentation* 2019)

4.5 Architecture

Vuforia includes several components to make it realistic in the development process. It offers different tracking solutions to meet different requirements. Components such as Camera, Trackers, Image converters and Video background renderer that are the basic features available in the SDK. Many other components can be found as a plugin in the Vuforia store.(Daraghmi, 2017)(*vuforia Documentation* 2019)

4.5.1 Application code

The developer has to perform 3 main steps for each proceeded frame(Daraghmi, 2017):

- Query the object for newly markers or updated states and detected targets
- The application logic has to update within the new input data
- Execute the augmented graphics coverage

4.6 Component of Vuforia platforms

Vuforia has three main parts:

- Tools
- Cloud recognition
- Engine

Figure 4.1 demonstrates the Vuforia Engine, and the target management system facilitated by the portal developer. A developer uploads the input image for the target that she intended to track. The mobile app, through the target resources, can then be accessed in two ways:

- Downloaded in a device target database to be a parcel with the mobile app.
- Accessed from a cloud target database using web services.

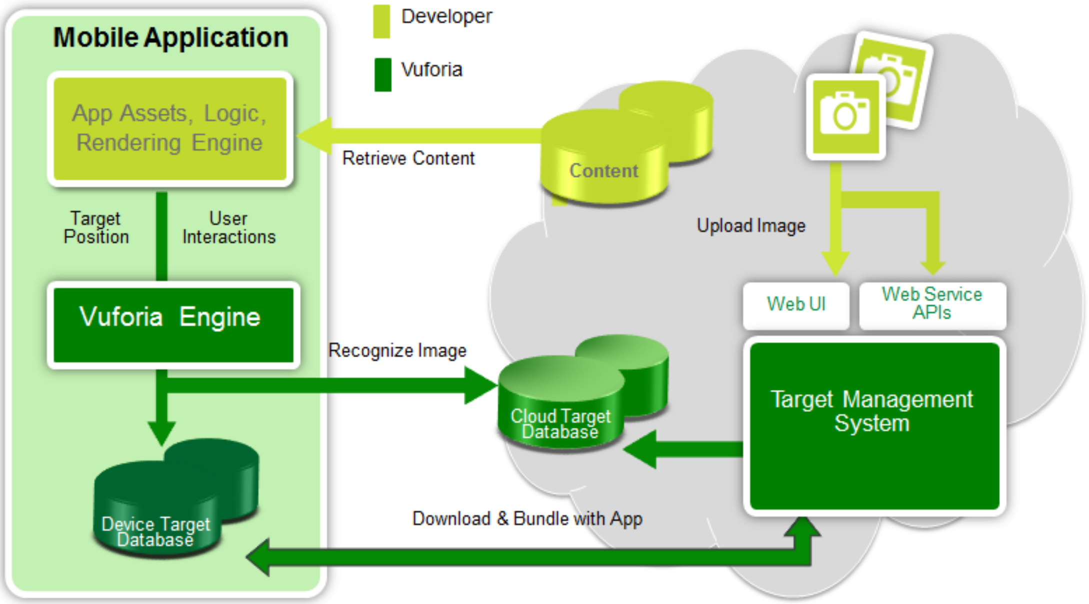


Figure 4.1 Vuforia's main Components(Ibañez and Figueras, 2013)

Target resources are generated using the on-line Target Management System. The downloaded dataset includes an XML11 configuration file that enables the developer to configure individual trackable characteristics and a binary file that carries the trackable database. These assets are compiled by the developer into the app installer package and used at run-time by the Vuforia SDK.(Ibañez and Figueras, 2013)

4.6.1 Vuforia's Capabilities

- **Vuforia Object Scanner:** This feature enables you to scan the object with an Android phone by creating a target. The application gives you a fixed visual input on the output advance and target quality and sets up the organizational framework so the user can build immersive encounters with accurately customized digital content. Additionally, the test mode enables you to access the acknowledgment and the following quality of the application before you begin any improvements. The finish directions are found in the guide. The Vuforia object scanner is just propped on the Samsung

Galaxy S6 model or higher models.

- **Vuforia Web Service:** These parts display how to utilize the Vuforia Web Services API. The JAVA and PHP tests show to superintend the cloud target from the user's own management system.
- **VuMark Designer:** By using this feature, the users will be able to create their VuMark using Adobe Illustrator. The Vumarks are incredibly customizable and easy to design. First, we must select the encoding type based on the data type, for example, a URL. Next, create a design around the desired image. Finally, we will upload the exported VuMark to the target manager.(*Natural Features and Image Ratings* 2019)
- **Software implementation usefulness of Vuforia:** Compliances different collections of visual objects such as box, cylinder, and plane. Texts and Environment, VuMark like QR-codes. Utilizing the VOS (Vuforia object scanner), filtered, and make object targets. The compliance procedure is executed using the use of database like local or cloud, which considers a incredibly powerful tool in the Unity plugin.

4.7 Target Usage

Coming to the real world with less confounding and simple applications are the most important targets of Vuforia. AR applications can be very befuddling for the modern clients at this stage. Appropriate guidelines are required in conjunction with the hardware. Target picture is also required in advance to utilize the application. The target where objects will be increased ought to be appropriately characterized concurring to the utilization. One reality which must be considered is,in conclusion client has two hands and one hand is as of now involved holding the gadget, so the controls should be a daze interaction. Another vital target usage can be the real-time interaction to form it more natural.(*Natural Features and Image Ratings* 2019) Diverse sorts of target usage examples are: Wall targets, Floor Targets, Handheld Targets and retail Shelf Targets.(Ibañez and Figueras, 2013)

4.8 Other SDKs

4.8.1 ARKit

Apple's framework for creating augmented reality applications. It was introduced with iOS 11.

ARKit Implementation Advantages

- Open source and free software
- Plugins for Unity
- Optical stereo camera Calibration
- Incredibly fast for AR applications
- tracking of planer image
- Tracking of Single Square

4.8.2 ARCore

Googles platform for creating AR applications. It uses various APIs; therefore, the phone will be able to sense its environment and surrounding and interact with it.(Linowes and Babilinski, 2017)

ARCore Components

ARCore has three capabilities to integrate virtual data with the real world and make them visible through the user's camera:

- Motion tracking: The phone can comprehend its position relative to the world.
- Light estimation: The phone will be able to estimate the lighting conditions.
- Environmental understanding: gives the phone the ability to detect the location and size of the surfaces.(Linowes and Babilinski, 2017)

4.8.3 ARCore and ARKit disadvantages and Vuforia's supremacy

Undoubtedly, ARCore and ARKit are immensely influential in the SDK world. Both of them offer a vast range of capabilities; however, they both have weaknesses, which makes them not suitable options for the applications.

Apple's ARKit is limited to iOS devices, and since its a relatively new technology, it will exclusively run on devices with iOS 11, while Google's ARCore will be restricted to Android 7.0 or higher. These limitations played an essential role in choosing the SDK of the application. Vuforia supports all kinds of operating systems and their versions.

Chapter Five

APPLICATION DEVELOPMENT

5.1 Introduction

The methods and techniques used during the design process were: Brainstorming, body storming, and the primary development process. The initial objective of the following chapters is to guide through the basic setups for the development. The chosen techniques helped to reduce and optimizing the code and ending up getting the best results.

5.2 Development Requirements

A variety of software was used in the thesis to make the final application. Previously, Vuforia did not have the internal plugin with Unity3d in the results. Accordingly, the developers had to download the separate Unity compatible file and finally open it with a Unity package manager. As mentioned before, different elements were used in the project; for example, videos 3D objects, and other information. (Unity 2019).

5.2.1 Jetbrains Rider:

A relatively new product that solves the problem of .Net core programming in different environments. In essence, Rider is a .NET programming IDE that has the power of Visual

Studio with Resharper and can be used in Windows, Linux, and Mac environments. Rider was used instead of Visual studio.

5.2.2 Minimum requirements for implementing marker-less grounds in Vuforia:

- IMU w Gyroscope Sensors
- Plugins for Unity
- Selective Image Stabilization (Ibañez and Figueras, 2013)

5.2.3 Smartphone requirements

This application is an Android-based. Although Vuforia features to support iOS, those features are not covered in this study. The project is developed using a Samsung Galaxy note 8 and tested with the same device also HTC ONE and Samsung Galaxy A7.

Smart phone features

- Display 6.30-inch (1440x2960)
- Processor Samsung Exynos 9 Octa 8895
- Front Camera 8MP
- Rear Camera 12MP + 12MP
- RAM 6GB
- Storage 64GB
- Battery Capacity 3300mAh
- OS Android 7.1.1

5.3 The 3D Model

In this thesis, a designed sketch 3D object was used. Unity3D also has the capability of modeling the objects; yet, this project covers the augmenting process, not modeling.

- The model requires to be materialized for better display
- Each 3D model has to have the light credentials otherwise the model will look rather dark and gray and the material will not show up in the best way possible. The model is painted in the application and will not look natural without proper lighting or material.

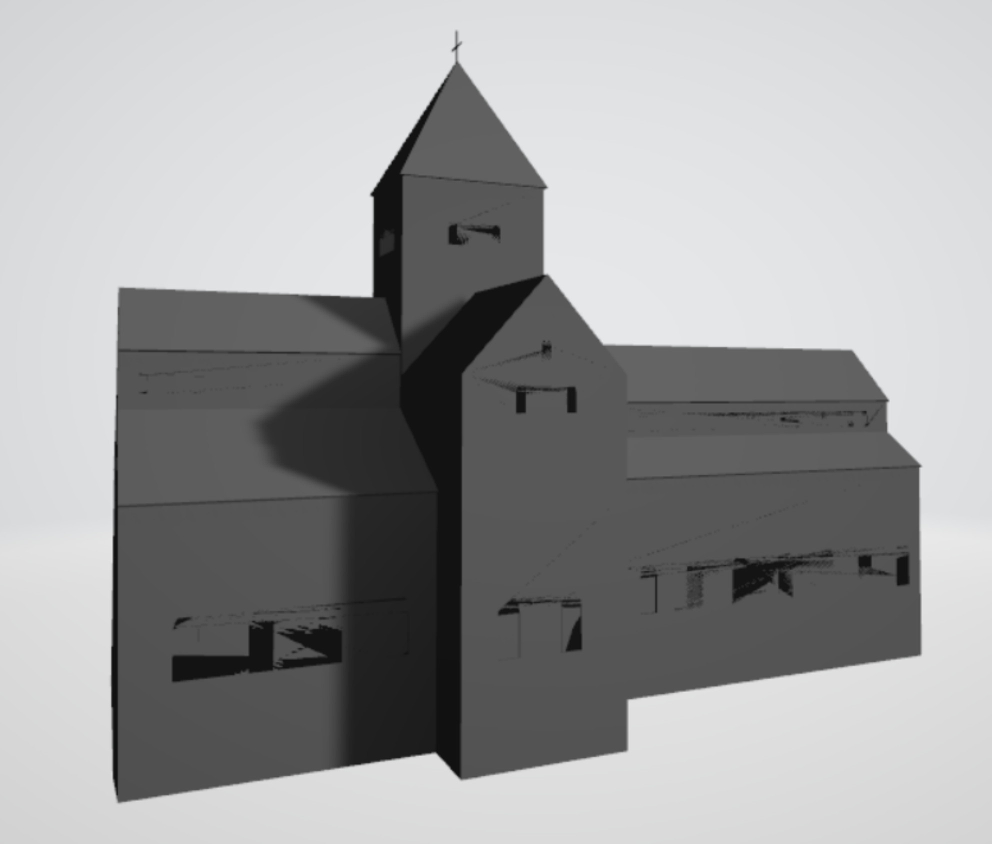


Figure 5.1 The first sketch of the 3D model used in the application

5.4 Brainstorming

Several brainstorming sessions with different topics were held during the design phase of the project. The first session was held at HVL with the supervisors. The subject of the meeting was, "How to develop the best application?" The discussed ideas include:

- IKEA Furniture: An application that helps the users to furnish their homes using different IKEA furniture. The user can select between the models and place them in the desired area. Therefor, they can test the furniture in the virtual world.
- The initial idea was to use the big signs shown in **Figure 5.2** that is located at the entrance of the property or to use a QR marker which had be situated in the center of the church or the suggested locations shown in **Figure 5.3**

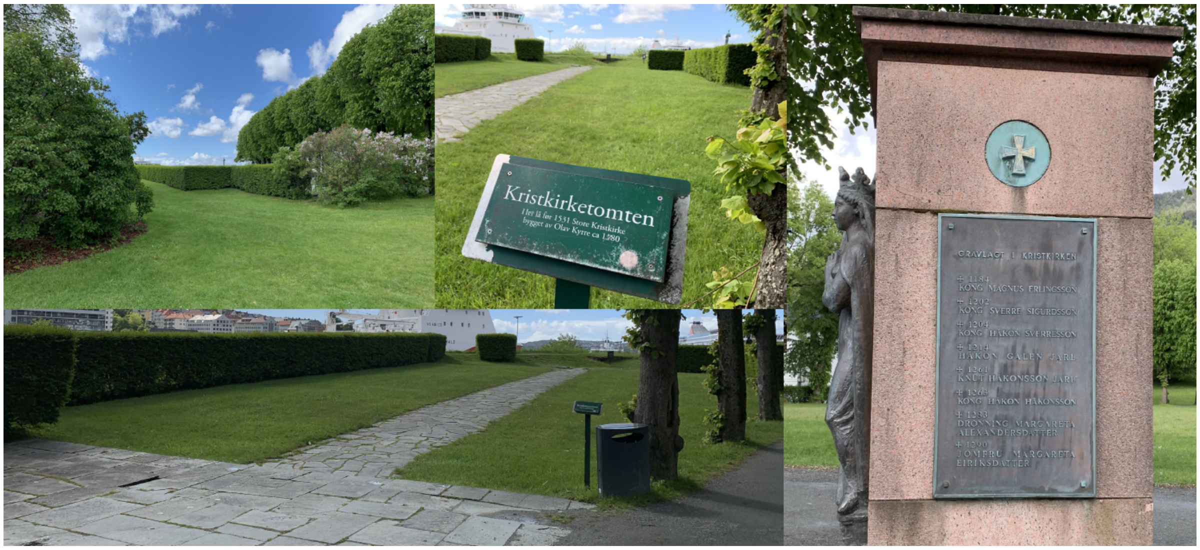


Figure 5.2 The possible areas to locate the markers discussed in the brainstorming session

Though none of the ideas discussed above were chosen, it resulted in a bodystorming session where the church is located at Bergen's Fortress.

5.5 Bodystorming

The first bodystorming session took place at the Bergen's Fortress. During the meeting, multiple points for locating the best marker was discussed. Also, some pictures were taken for a better comprehension of the location. During the second bodystorming session, we concluded that neither QR-code or markers could be used due to their inefficiency.The reason being, tourists have to wait for each person to use the marker. Each marker will present the same view every time and if you move from the markers range, it will disappear. The app has to give the tourist the ability to view the church from wherever perspectives they desire and not just limited markers and the church has to be presentable from each desirable standpoint. Also, some of the challenges were discussed, for example, the bushes currently in the location and how to delete them inside the project and the drafting problem, which means unexpected movements of the virtual building in the app.

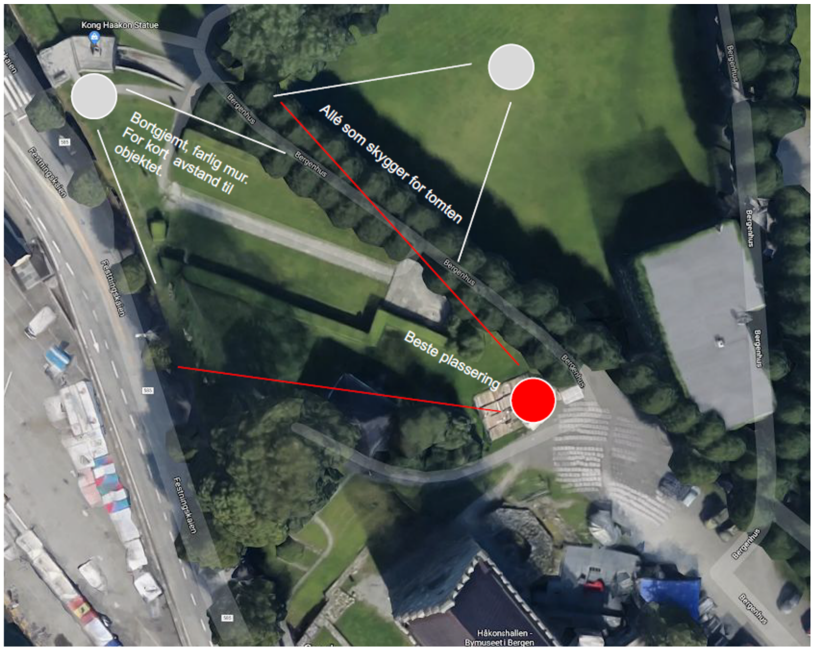


Figure 5.3 The best locations for placing the markers from a aerial photograph stand point discussed in both brain and bodystorming sessions

5.6 Flowchart of the system

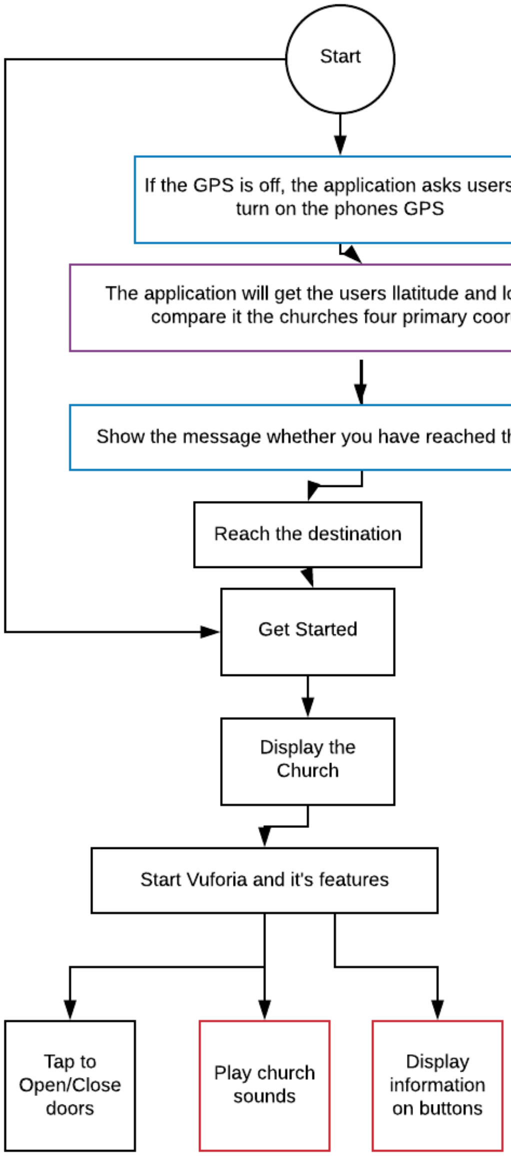
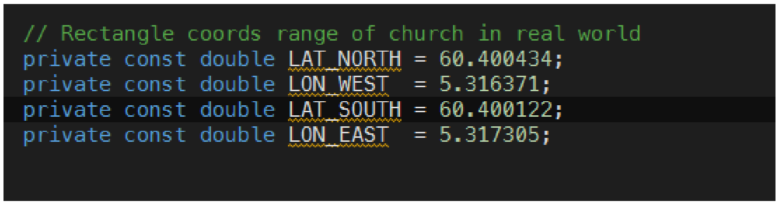

Start
If the GPS is off, the application asks users to turn on the phones GPS
The application will get the users llatitude and longitude and compare it the churches four primary coordinates
Show the message whether you have reached the area or not
Reach the destination
Get Started
Display the Church
Start Vuforia and it's features
Tap to Open/Close doors
Play church sounds
Display information on buttons

Diagram.png

Figure 5.4 The red features will be implemented in the future. The blue block are don by UI and the the purple blocks are done in the Church script. "Open/close" doors features is currently under implementation

5.7 Church Coordinates

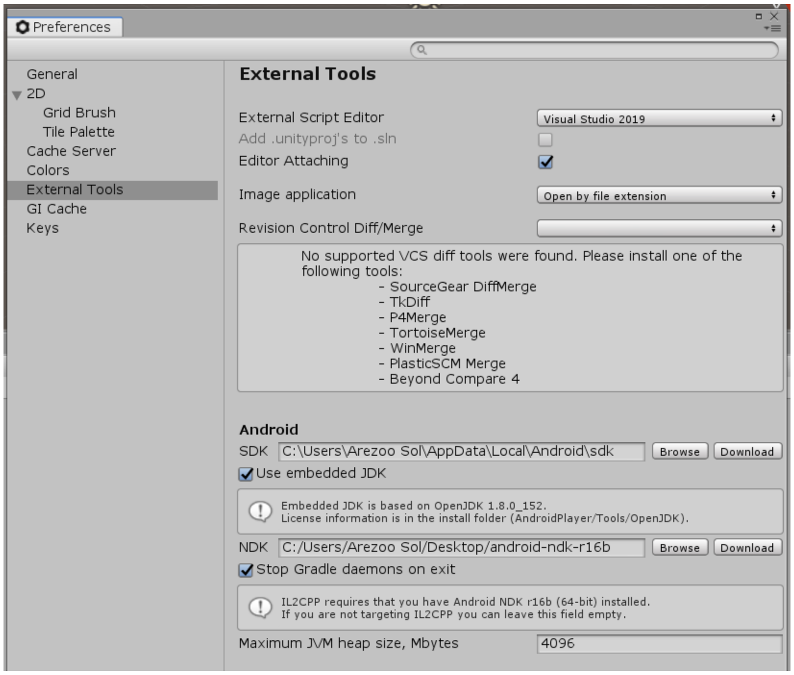


```
// Rectangle coords range of church in real world
private const double LAT_NORTH = 60.400434;
private const double LON_WEST  = 5.316371;
private const double LAT_SOUTH = 60.400122;
private const double LON_EAST  = 5.317305;
```

Figure 5.5 All of the coordinates have been fetched using google maps satellite mode.

5.7.1 Android SDK/NDK setups

Before building the application for any Android device, the SDK/NDK is obliged to be downloaded and installed. SDK is the principal development kit for Android; it contains tools for java to do compiling tasks, packaging to an APK file, debugging and emulators. NDK, on the other hand, is a collection of tools to compile C code to share the library, which is used in the application. NDK also assist in accessing the device's hardware components like the camera, sensors, and touch. NDK tools can also be downloaded within the SDK application. NDK helps to reuse other developers or own libraries. **Path: Edit>preferences>External tool tabs** By clicking on download for all three SDK,NDK, and JDK, the initial setups for building the Android app will be provided.(**Figure 5.6**)(*vuforia Documentation* 2019)



External Tools

External Script Editor: Visual Studio 2019

Add .unityproj's to .sln ☐

Editor Attaching ☑

Image application: Open by file extension

Revision Control Diff/Merge

No supported VCS diff tools were found. Please install one of the following tools:
- SourceGear DiffMerge
- TkDiff
- P4Merge
- TortoiseMerge
- WinMerge
- PlasticSCM Merge
- Beyond Compare 4

Android

SDK C:\Users\Arezoo Sol\AppData\Local\Android\sdk

☑ Use embedded JDK

Embedded JDK is based on OpenJDK 1.8.0_152.
License information is in the install folder (AndroidPlayer/Tools/OpenJDK).

NDK C:/Users/Arezoo Sol/Desktop/android-ndk-r16b

☑ Stop Gradle daemons on exit

IL2CPP requires that you have Android NDK r16b (64-bit) installed.
If you are not targeting IL2CPP you can leave this field empty.

Maximum JVM heap size, Mbytes 4096

Figure 5.6 Adding SDK/NDK to the Unity3D project

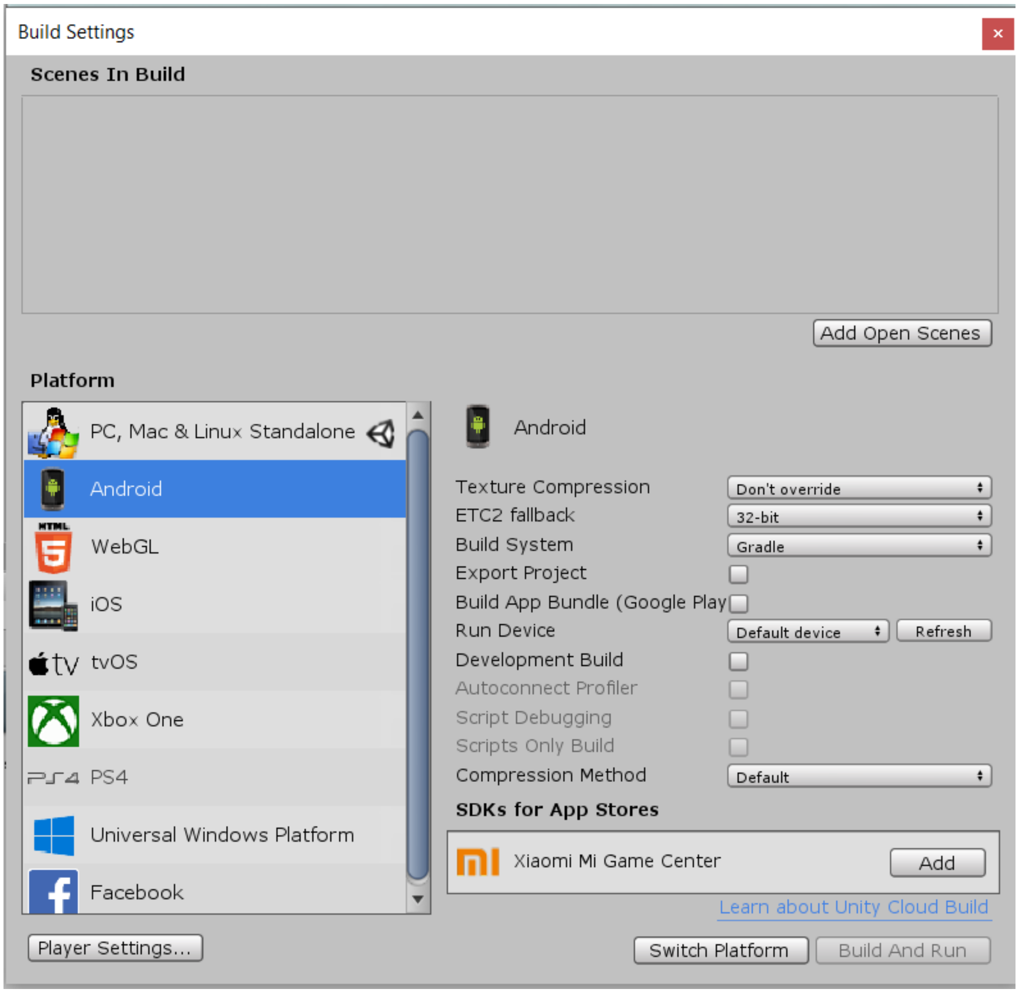
5.8 Application Implementation

5.8.1 Vuforia initial Setups

- Step 1: In the top left corner:**Path: File>Build settings and Select Android from the menu.**(**Figure 5.7**)
- Step 2: If the Vuforia Augmented reality is not yet been installed, the user would lead to a website where they can download the exe file and install it on their computers. Surely the blue link will turn black. Therefore the user can proceed. Once the file is installed, there will be a check file by the same name.(**Figure 5.8**)
- Step3: **Path Assets> Resources, a Vuforia configuration** appears, and by clicking the setting, the users will have access to the full configurations.(**Figure 5.9**)
- Step 4: Vuforia setup for each project will require an App License Key, which can be obtained on the developer website. By logging in or register, the users will have the ability to fetch the development key, and by naming their app, a list of all the projects

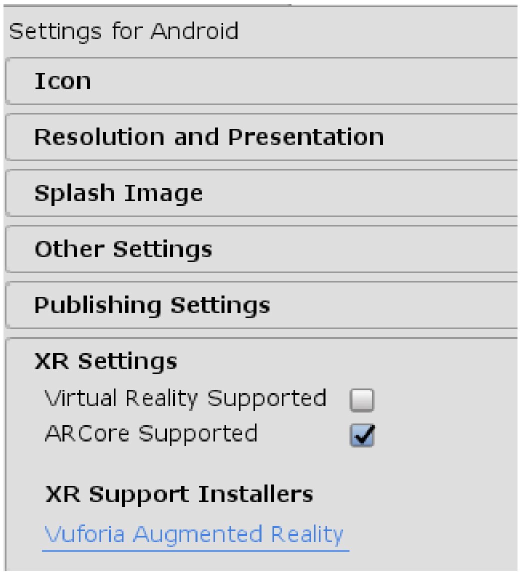
will appear. By selecting the desired project, the key can be fetched. The key has to be copied in the required field.(**Figure 5.11**)(*vuforia Documentation: License manager* 2019)

- Step 5: Select, copy and paste the key in the required field shown in (**Figure 5.10**)(*vuforia Documentation* 2019)



Texture Compression: Don't override
ETC2 fallback: 32-bit
Build System: Gradle
Export Project □
Build App Bundle (Google Play □
Run Device: Default device
Development Build □
Autoconnect Profiler □
Script Debugging □
Scripts Only Build □
Compression Method: Default

Figure 5.7 Switching the platform to Android Devices. Also checking the development build



Settings for Android

Icon

Resolution and Presentation

Splash Image

Other Settings

Publishing Settings

XR Settings

Virtual Reality Supported ☐

ARCore Supported ☑

XR Support Installers

Vuforia Augmented Reality

Figure 5.8 By clicking on the link the link the user will be transfer ed to the Vuforia website to download the Vuforia extension

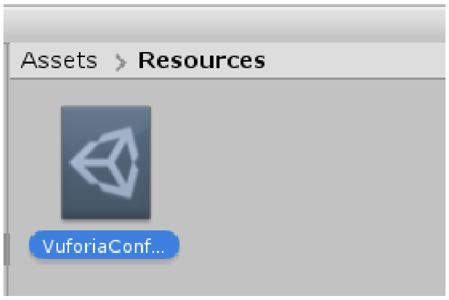
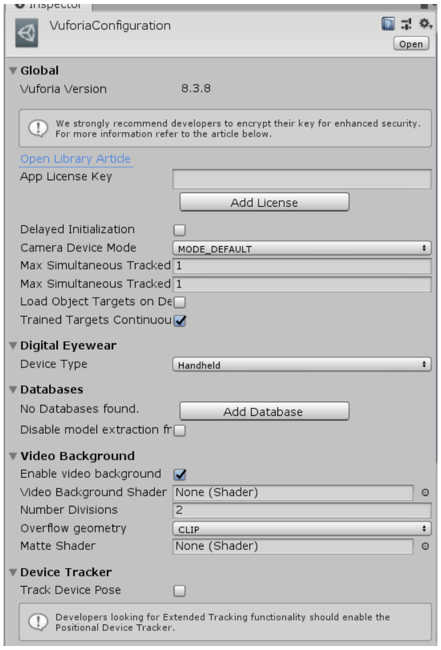


Figure 5.9 Right Click on the file will display multiple configurations

5.8.2 AR Camera settings

The project starts by creating a 3D project in Unity3D. The Vuforia configurations are active from the previous setups. The created project will have a default camera.Delete The current camera and replace it with the AR Camera.(**Figure 5.12**) **Path: GameObject>Vuforia Engine>AR Camera**

Import the model and drag it to the assets. The file can be either a .obj file or a fbx file extension. It's an Autodesk file extension and it can be open by any Autodesk product such as Maya, 3ds Max... (**Figure 5.13**) Click on the AR Camera to change the Vuforia Behaviour



Inspector

VuforiaConfiguration

Open

Global

Vuforia Version 8.3.8

We strongly recommend developers to encrypt their key for enhanced security. For more information refer to the article below.

Open Library Article

App License Key

Add License

Delayed Initialization □
Camera Device Mode MODE_DEFAULT
Max Simultaneous Tracked 1
Max Simultaneous Tracked 1
Load Object Targets on De □
Trained Targets Continuou ☑

Digital Eyewear

Device Type Handheld

Databases

No Databases found. Add Database
Disable model extraction fr □

Video Background

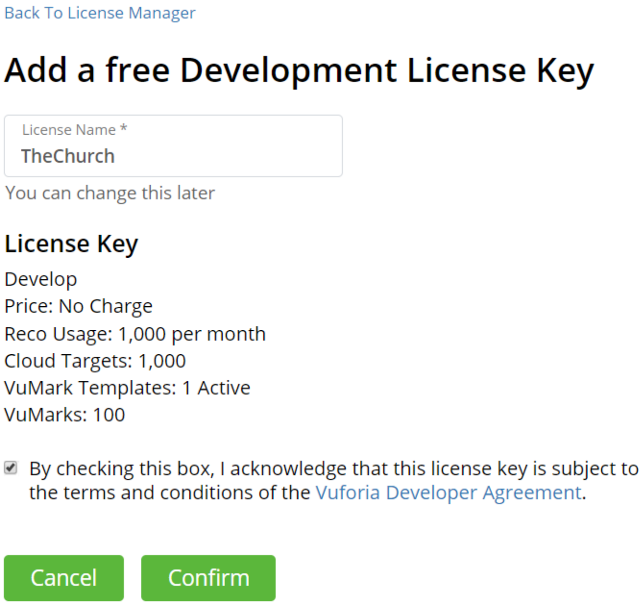
Enable video background ☑
Video Background Shader None (Shader)
Number Divisions 2
Overflow geometry CLIP
Matte Shader None (Shader)

Device Tracker

Track Device Pose □

Developers looking for Extended Tracking functionality should enable the Positional Device Tracker.

Figure 5.10 Configuration setup display



Back To License Manager

Add a free Development License Key

License Name *
TheChurch

You can change this later

License Key

Develop
Price: No Charge
Reco Usage: 1,000 per month
Cloud Targets: 1,000
VuMark Templates: 1 Active
VuMarks: 100

☑ By checking this box, I acknowledge that this license key is subject to the terms and conditions of the Vuforia Developer Agreement.

Cancel Confirm

Figure 5.11 Adding the License key *vuforia Documentation: License manager* 2019

also change the World Center Mode to Device tracking.(**Figure 5.14**) Afterward, in Vuforia configuration, check the Track Device Pose in the Device Tracker bar.(**Figure 5.15**)

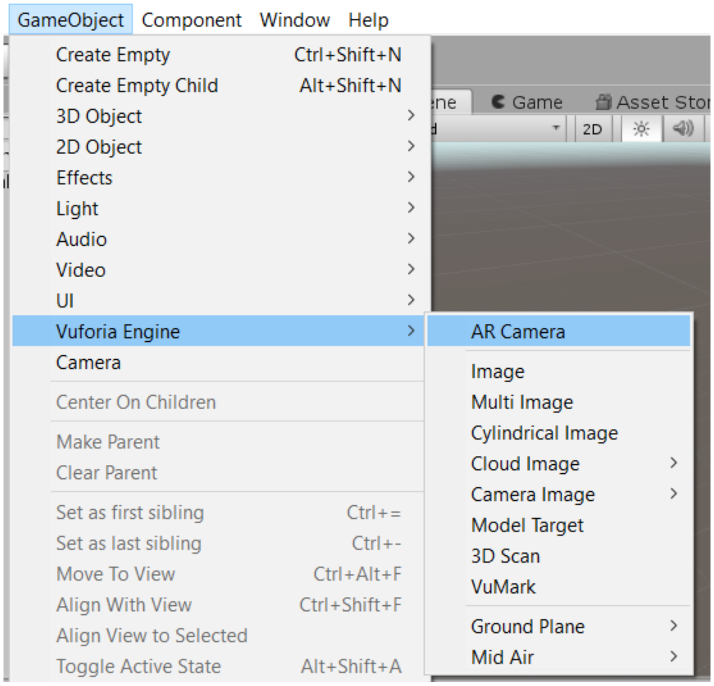


Figure 5.12

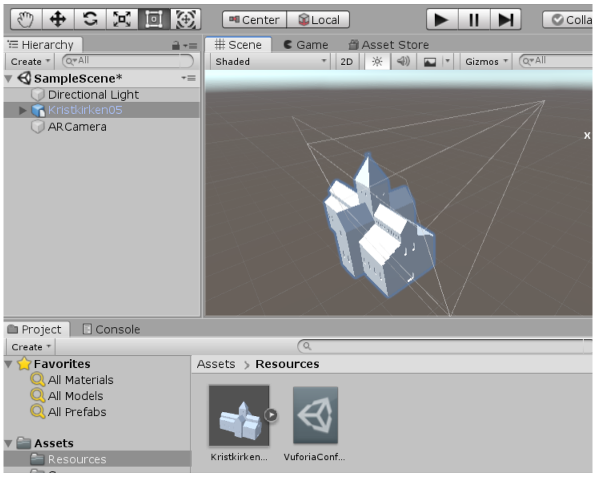
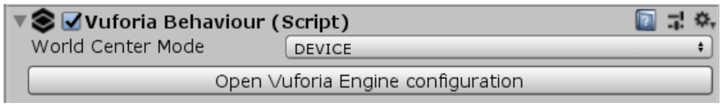


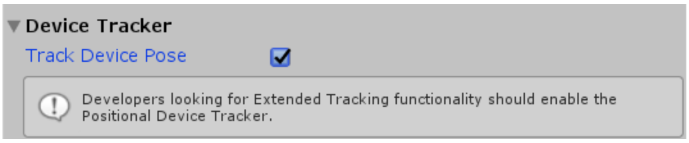
Figure 5.13 Importing the model into the scene


☑ Vuforia Behaviour (Script)

World Center Mode DEVICE

Open Vuforia Engine configuration

Figure 5.14 (*vuforia Documentation* 2019)



Device Tracker

Track Device Pose ☑

Developers looking for Extended Tracking functionality should enable the Positional Device Tracker.

Figure 5.15 (*vuforia Documentation* 2019)

5.8.3 Ground Plane Stage and Plane finder

The reason for adding these two is because we want to define a ground to avoid the drifting problem. Insert Ground Plane Stage and set church object(Kristkirken)as a child object.(**Figure 5.16**)

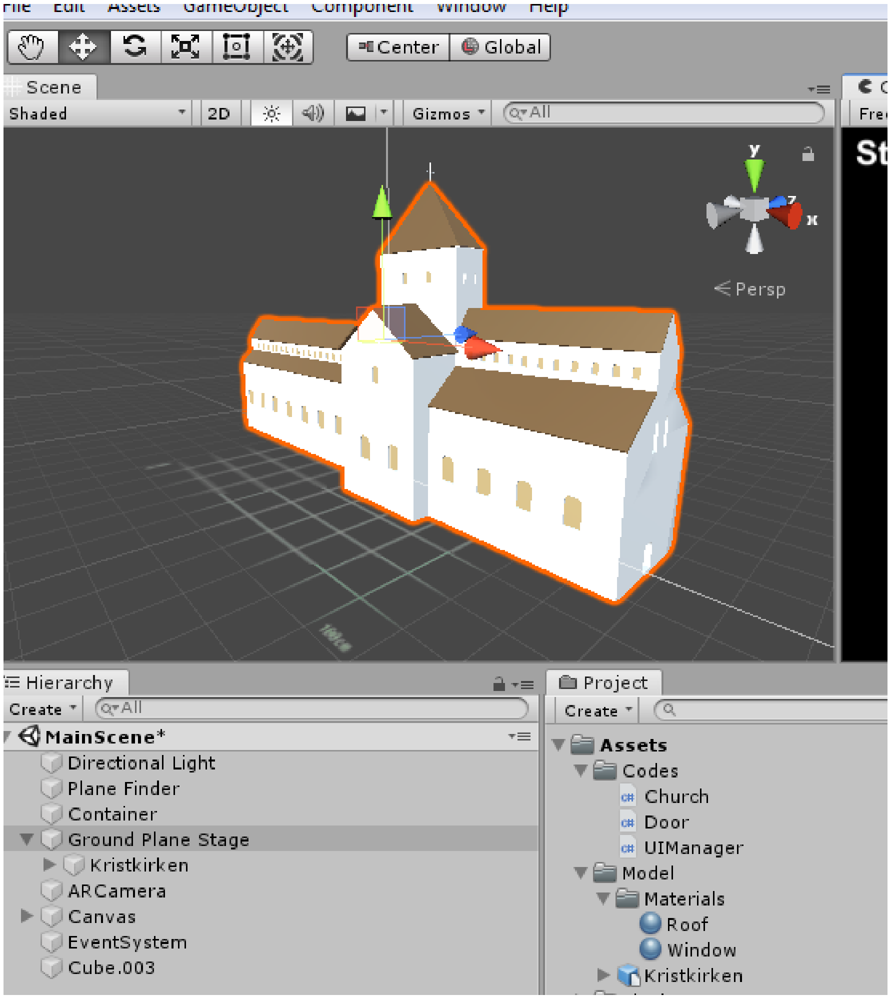
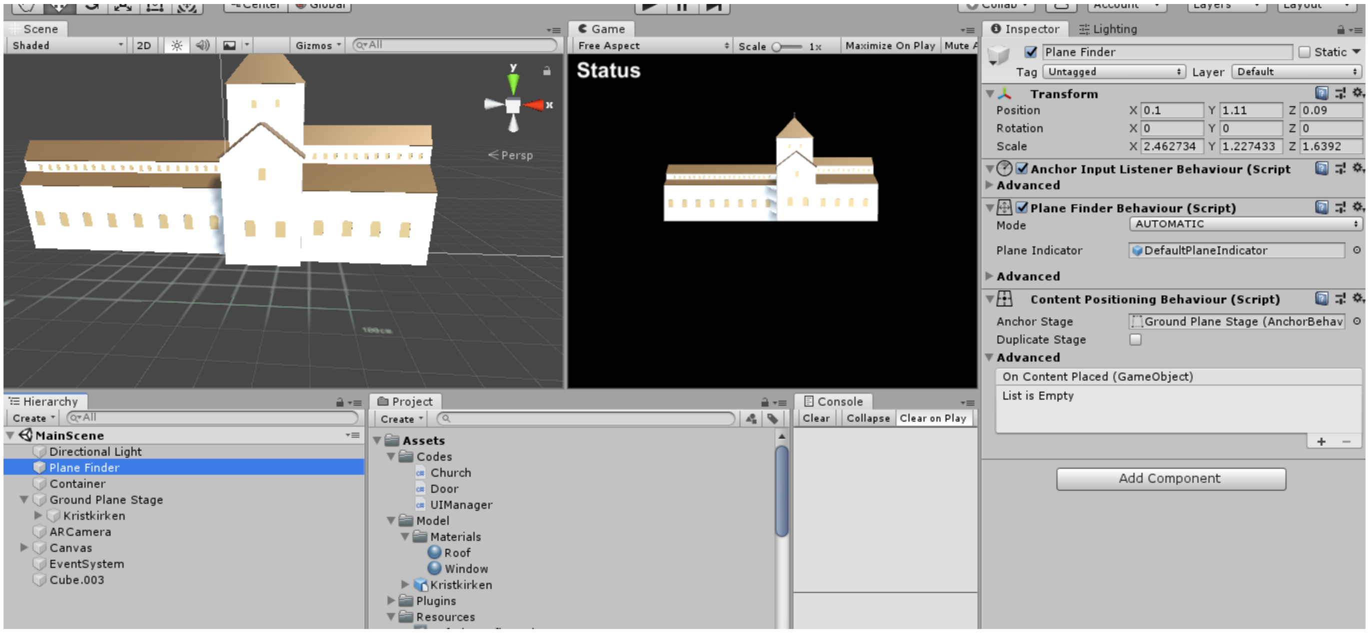


Figure 5.16 Creating Ground plane stage

Insert Vuforia "Plane Finder" prefeb to the scene and set Anchor Stage to "Ground Plane State" object to the scene.(**Figure 5.17**)



☑ Plane Finder ☐ Static

Tag Untagged Layer Default

Transform

Position	X	0.1	Y	1.11	Z	0.09
Rotation	X	0	Y	0	Z	0
Scale	X	2.462734	Y	1.227433	Z	1.6392

☑ Anchor Input Listener Behaviour (Script

Advanced

☑ Plane Finder Behaviour (Script)

Mode AUTOMATIC

Plane Indicator DefaultPlaneIndicator

Advanced

Content Positioning Behaviour (Script)

Anchor Stage Ground Plane Stage (AnchorBehav

Duplicate Stage ☐

Advanced

On Content Placed (GameObject)

List is Empty

Figure 5.17 Creating Plane Finder

5.8.4 UI Manager

Anything related to the user interface (UI) is inside this script. It handles the messaging between the application and the user and shows whether the GPS is enabled or not? If not, it will display a popup message back to the user, also get the user's consent while pressing the Back button.(**Figure 5.18**)

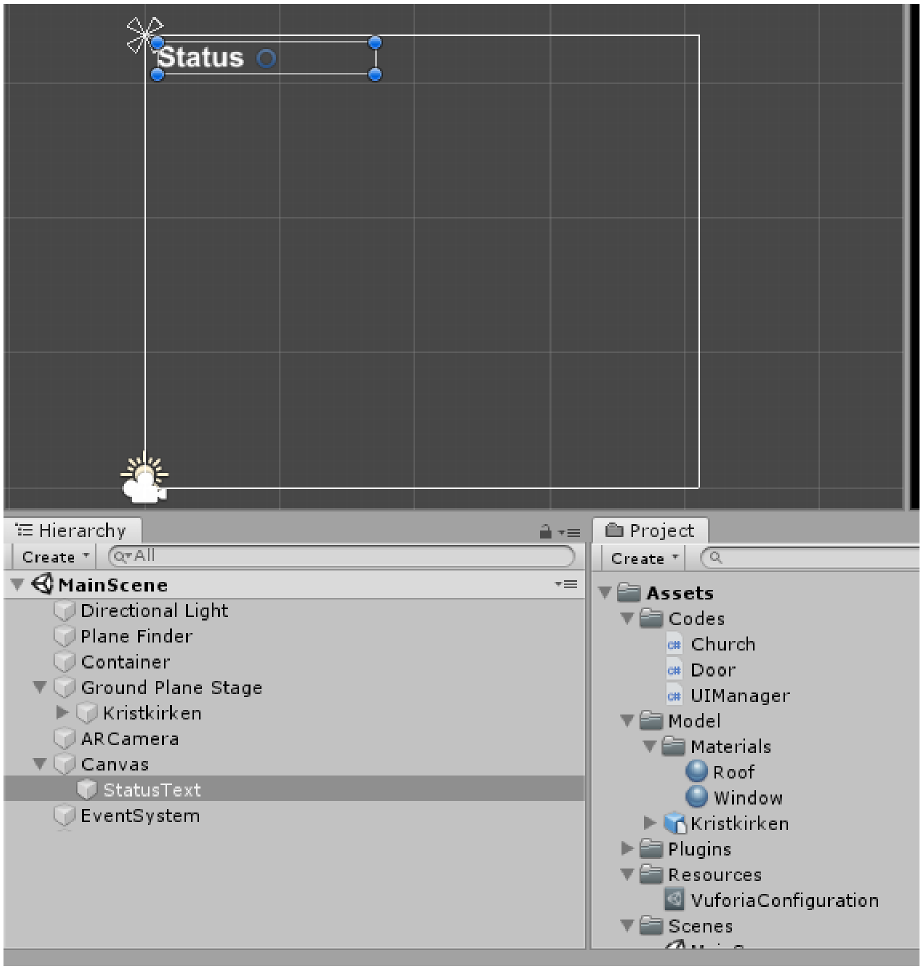


Figure 5.18 Creating a UI for the application

5.9 Application scripts

There are three scripts in the application:

- **Church.cs:** is the main Core of app and control all events which Consist of GPS coordinates, latitudes,...
- **UIManager.cs:** Shows the status of users GPS State and Tracking
- **Door.cs:** The script for opening and closing the doors

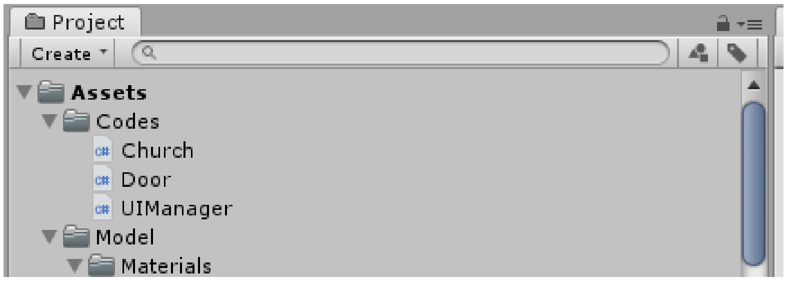


Figure 5.19 Application Scripts

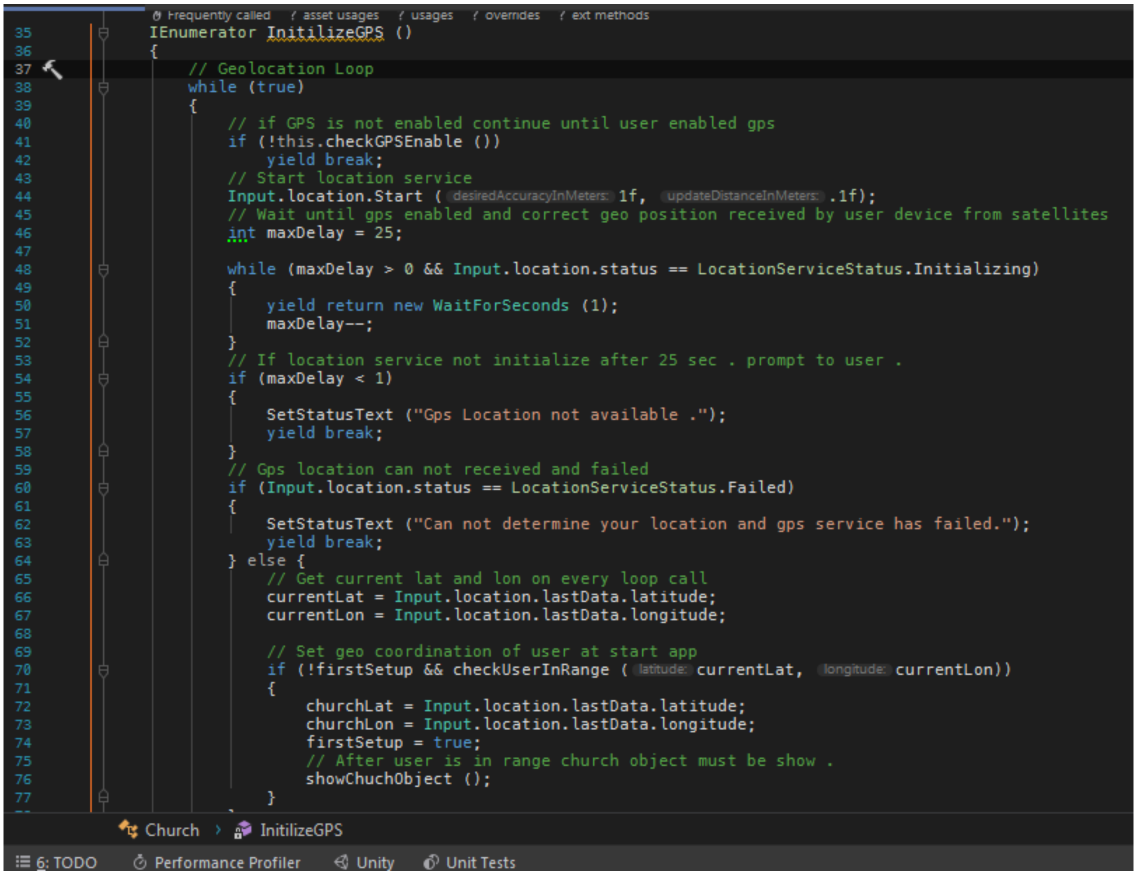
5.9.1 Church.cs

If the GPS was not enabled due to any reason (after 25 seconds), the program would display a timeout error. After that, The process of getting the coordinates from the satellite will begin. The user's coordinates will be collected and processed based on the church's four principal coordinates; If she gets to a church visibility distance (The distance is determined by the program), the church will be displayed.Figure 5.20)

The **checkUserInRange** function checks whether the geographical coordinates of the user captured by the GPS at any given moment (in the main loop of the application) are within the range of these points, and enables the church building display once the user enters this area. When the user is in the geographical range of the church, the church will be displayed in the correct place.(**Figure 5.21)**

GPS Coordinates

The church has four main coordinates.North, South, East and West so the user's coordinates will always be compared with these primary coordinates.(**Figure 5.22**)(**Figure 5.23**)

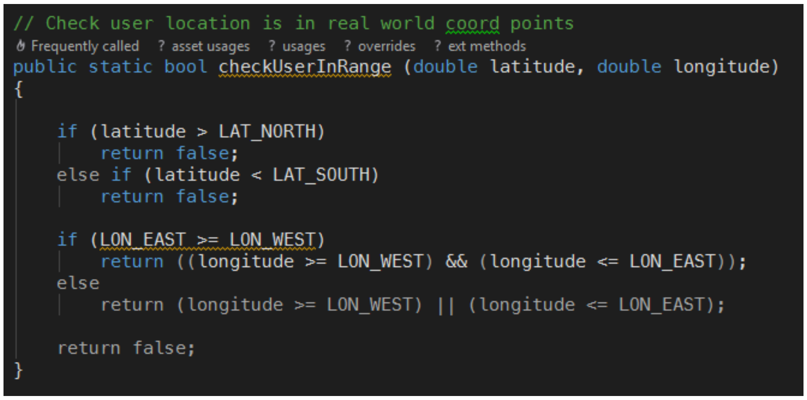


```
IEnumerator InitilizeGPS ()
{
    // Geolocation Loop
    while (true)
    {
        // if GPS is not enabled continue until user enabled gps
        if (!this.checkGPSEnable ())
            yield break;
        // Start location service
        Input.location.Start ( desiredAccuracyInMeters: 1f,  updateDistanceInMeters: .1f);
        // Wait until gps enabled and correct geo position received by user device from satellites
        int maxDelay = 25;

        while (maxDelay > 0 && Input.location.status == LocationServiceStatus.Initializing)
        {
            yield return new WaitForSeconds (1);
            maxDelay--;
        }
        // If location service not initialize after 25 sec . prompt to user .
        if (maxDelay < 1)
        {
            SetStatusText ("Gps Location not available .");
            yield break;
        }
        // Gps location can not received and failed
        if (Input.location.status == LocationServiceStatus.Failed)
        {
            SetStatusText ("Can not determine your location and gps service has failed.");
            yield break;
        } else {
            // Get current lat and lon on every loop call
            currentLat = Input.location.lastData.latitude;
            currentLon = Input.location.lastData.longitude;

            // Set geo coordination of user at start app
            if (!firstSetup && checkUserInRange ( latitude: currentLat,  longitude: currentLon))
            {
                churchLat = Input.location.lastData.latitude;
                churchLon = Input.location.lastData.longitude;
                firstSetup = true;
                // After user is in range church object must be show .
                showChuchObject ();
            }
```

Figure 5.20 Getting the user's coordinates based on the church four main coordinates



```
// Check user location is in real world coord points
public static bool checkUserInRange (double latitude, double longitude)
{

    if (latitude > LAT_NORTH)
        return false;
    else if (latitude < LAT_SOUTH)
        return false;

    if (LON_EAST >= LON_WEST)
        return ((longitude >= LON_WEST) && (longitude <= LON_EAST));
    else
        return (longitude >= LON_WEST) || (longitude <= LON_EAST);

    return false;
}
```

Figure 5.21 checkUserInRange function

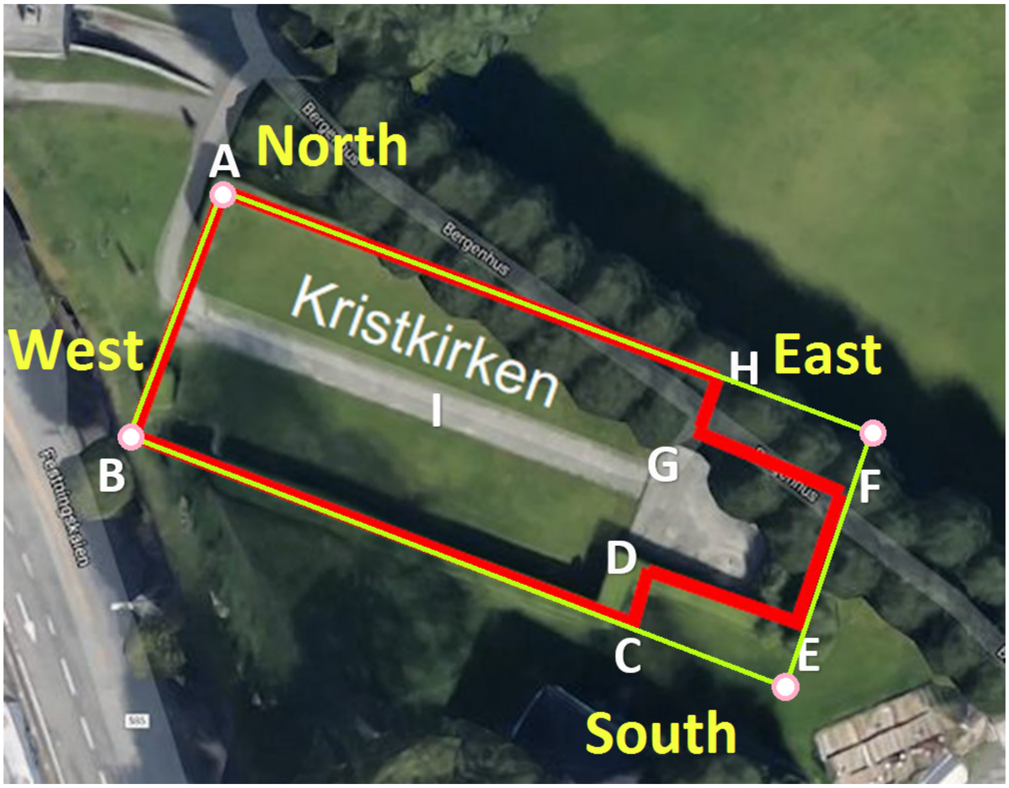
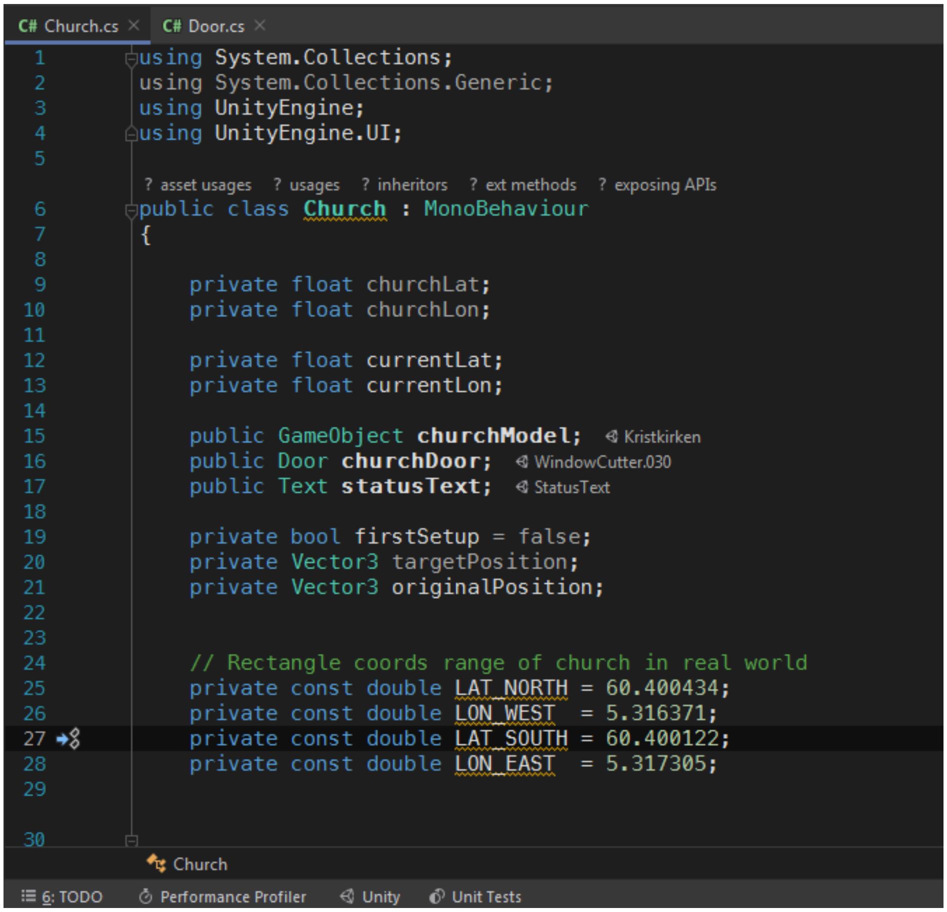


Figure 5.22 Four main coordinates of the church

5.9.2 Door.cs

Doors of the church are dynamic, and by tapping on the doors we can open/close them with using simple animation . By using this option users will be able to enter the church and view the interior, though the interior is not available yet.(**Figure 5.24**)

Door.cs is a script for door section of model and control event of the user tap for opening and closing the door.(**Figure 5.25**)



```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class Church : MonoBehaviour
{

    private float churchLat;
    private float churchLon;

    private float currentLat;
    private float currentLon;

    public GameObject churchModel;
    public Door churchDoor;
    public Text statusText;

    private bool firstSetup = false;
    private Vector3 targetPosition;
    private Vector3 originalPosition;


    // Rectangle coords range of church in real world
    private const double LAT_NORTH = 60.400434;
    private const double LON_WEST  = 5.316371;
    private const double LAT_SOUTH = 60.400122;
    private const double LON_EAST  = 5.317305;
```

Figure 5.23 Church's main points defined inside the application code. The users current latitude and longitude will be stored in currentLat and currentLon variables which will be compared with the churches coordinates latitude and longitude until the user reach to a distance where the church becomes visible.

5.10 Build the application

There are few steps prior to the building process. The Android device has to be on the developer mode:

- **Path: Settings>About phone>Software information> Continuously click on build number**

  The device will go to the developer mode.
- Turn on the USB Debugging

Go back to Unity3D:

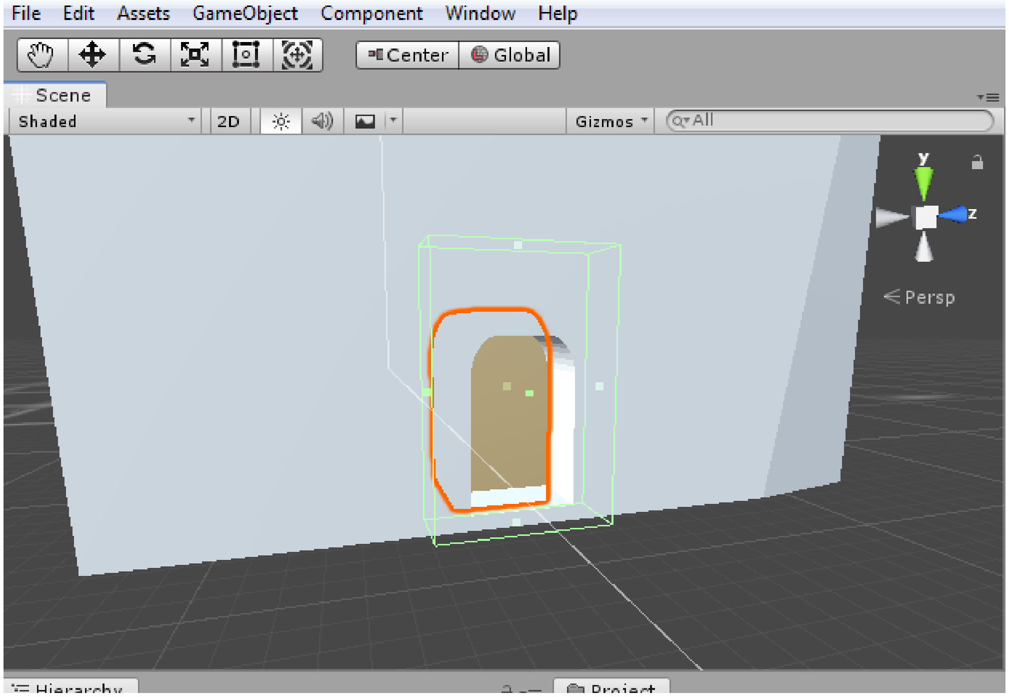
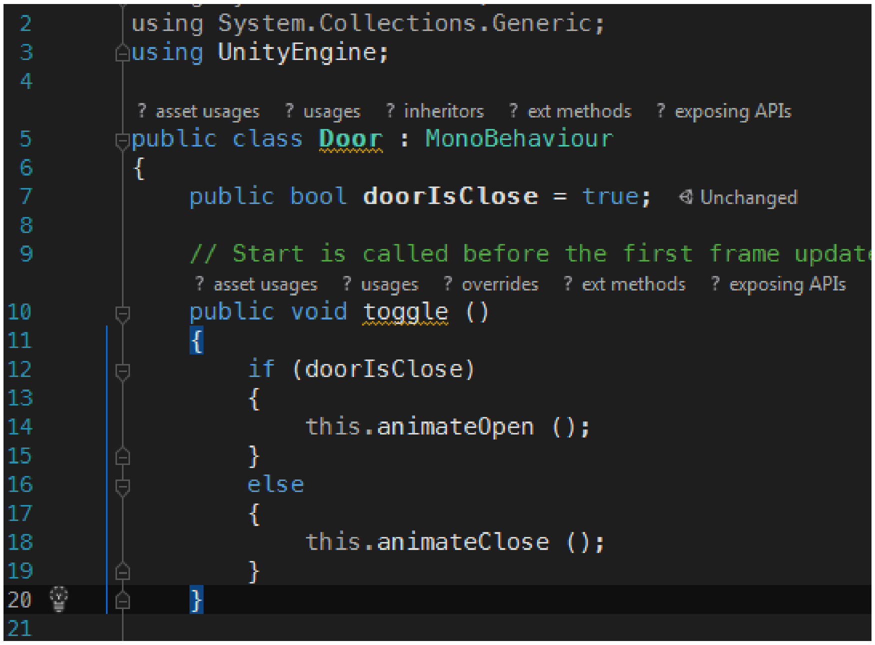


Figure 5.24



```
using System.Collections.Generic;
using UnityEngine;

public class Door : MonoBehaviour
{
    public bool doorIsClose = true;

    // Start is called before the first frame update
    public void toggle ()
    {
        if (doorIsClose)
        {
            this.animateOpen ();
        }
        else
        {
            this.animateClose ();
        }
    }
```

? asset usages ? usages ? inheritors ? ext methods ? exposing APIs
Unchanged
? asset usages ? usages ? overrides ? ext methods ? exposing APIs

Figure 5.25 Open/Close Door scripts

- Make sure the NDK/SDK setups are installed correctly otherwise the build won't run
- Use this naming format in the Identification: **com.Companyname.Productname** (*vuforia Documentation* 2019)

Chapter Six

Results

6.1 Testing

Testing enhances the quality of the products. There are multiple ways to test this application. One beneficial method of testing is to engage someone from outside the development process to test the application. By gathering feedback from several devices, we can excel in the quality of the application. Several tests were done by the primary device (Samsung Galaxy Note 8), and some others have done by HTC one.

6.1.1 User Tests:

The application has been tested by five different people with different Android devices. They were asked to go to the church's location and walk through the church. Two of the users experienced shaking and instability. The other user, however, had no problems utilizing the application. All users reported that the church was not placed in the right spot. This is because of the approximate coordinates used in the application, which will be solved by getting the accurate coordinates and replace them with the current ones. They also mentioned that the church is considerably smaller in the application.

6.1.2 Types of testing

Two types of testing have been performed on this application to determine the accuracy and pointing out the pros and cons of the functionalities:

- **Unit testing:** A testing method in which various parts of the application will be individually tested to see whether they are working correctly. The main target is to examine the functionality of the application, and the outcomes can be found in the experiments.
- **Integration testing:** This technique is done, regularly after unit testing. All of the individuals tested units of the application will be joined together, and the interface between them is tested. (Magaji, 2018)

6.1.3 Final render

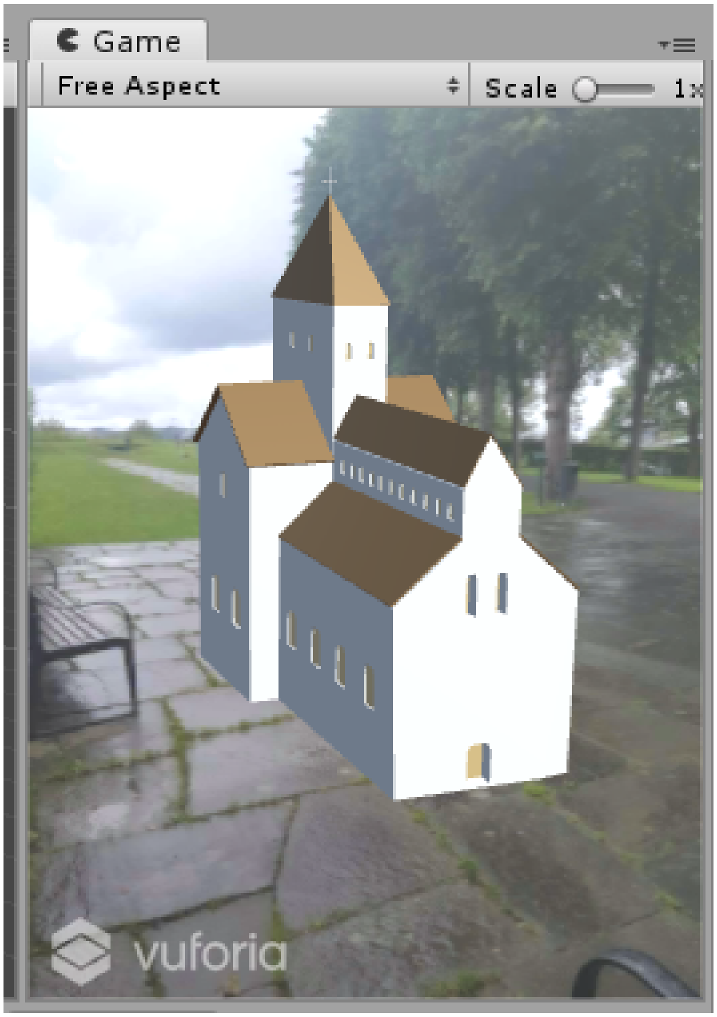


Figure 6.1 A final successful result with a smaller scale

Chapter Seven

CONCLUSION AND FUTURE WORK

7.1 Conclusions

This thesis aims to implement an Android-based app for Kristkirken på Holmen located in the northern side of Håkonshallen in Bergen's Fortress using Vuforia SDK and Unity Engine. The users will be able to hold their phone one the area where the church is situated. They will also be able to visualize the interior section of the church by opening the doors as well.

The idea of Augmented reality technology emerged in 1962 by a cinematographer who tried to create a Sensorama, which is a simulator with the virtual smell, sound, and vibration.(Peethambar, n.d.) The real world will not be replaced entirely with an artificial environment. However, it will expand the physical world and add digital information to it. There is a vast possibility of adding sound, videos and graphics. Looking through a physical real-world with the overlaid computer-generated images, which will lead to changing the perception of reality, is called AR.(R. Azuma et al., 2001)

Vuforia is an Augmented reality software development kit for mobile devices to create AR applications. It was offered by Qualcomm, which become famous in the market compared to its competitors. For the sake of choosing a satisfactory SDK for the project, a comparison was made mainly between 3 SDKs such as ARCore, ARKit, and Vuforia. Finally, Vuforia was chosen based on vast possibilities, availability and a selection of successful previous experiences. ARCore is only supported by iOS, which was not the case considering the fact that the used device is an Android-based device. ARKit is suited for Android devices; however, Only limited devices can use it due to its lack of Hardware and version support. Vuforia should, therefore, be considered as the best choice when using an SDK for augmented reality in mobile devices. The project is using the latest version of Vuforia(8.5). This study is using a marker-less method that stores four coordinates of the church from the satellite. The users can turn on their GPS. Their location coordination will be achieved by the devise's GPS and compared with church's coordinations. If the users enter a specific distance, the church will be shown. The users can also be informed by the apps UI, such as their distance from the church. They will be able to open the church's doors by tapping them. The application is tested by five people who do not have any developing knowledge. The app performed well on three devices, and they did not experience any interruptions. The other two, however, saw constant shaking and vibrations. All five mentioned the size, which is reasonable because the scale has been reduced.

7.2 Future Work

The fundamental requirements have been implemented for this thesis; however, it will be put out for more users to try out the app, and unquestionably, multiple changes will be implied based on their feedback.The application demands to be tested by more users to point out the weaknesses and strengths. Furthermore, a survey can be made for the users to get their feedback.

One of the vital future tasks for most accurate positioning is that the coordination has to be upgraded. The coordinates are based on approximate locations on the map; moreover, with the cooperation of history departments, the most precise coordinates have to be fetched and replaced with the current ones.

Meanwhile, the modeling process will proceed to a superior quality. For example, in order to have a better rendering quality in Vuforia, "Light Baking," that is a lighting technique feature in Autodesk softwares has to be done on the main church model. The modeling department also has to work on the interior of the church. Otherwise, it's a possibility that we can use interior models based on current old churches that still stand to simulate Kristkirken.

To enhance the usability and intractability, these additional features will be added:

- If the users enter the church, they can hear the ancient music, for example, the sound of the bells and the Norwegian chants and people's whispering.
- Special buttons for significantly important elements or areas. If the users touch those buttons, a drop down will be shown to educate them and give the user a suitable description of that specific object or area.
- The application has to be developed also for iOS to extend it's usability amongst users.
- The UI will be improved.

Chapter Eight

Glossaries

- SDK: Software Development Kit
- AR: Augmented Reality
- XML: Extensible Markup Language
- IMU: Inertial Measurement Unit
- VOS: Vuforia Object Scanner
- GPS: Global Positioning System
- UI: User Interface

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