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**APPLICATION DEVELOPMENT WITH VUFORIA AND UNITY 3D**

**Thesis**

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**ABSTRACT**

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<p>Application Development is the process to develop a program which performs certain tasks for the end-user. Thus, Augmented Reality has built a vast impact in modern software development process.</p> <p>Vuforia is a platform for augmented reality software development kit for mobile devices to create augmented reality applications. It uses computer tracking technology to recognize and track planar images and 3D images. This project directs towards the use of Vuforia and Unity, creating a final application using both platforms. For the final part of this project, a sample application was built for Android device to show the mobility of Unity 3D. Vuforia version used for this project is 7 and Unity's version is 5.3.4.</p> <p>Unity 3D is a software platform used to develop games and applications for mobile devices, computers, Xbox and Ps4. This project will go through the process of developing an application using Vuforia and Unity 3D.</p>		

<p><b>Key words</b> AR, Vuforia, Unity 3D.</p>
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## CONCEPT DEFINITIONS

AR	Augmented Reality
IOS	iPhone Operating System
GPS	Global Positioning System
PTC	Parametric Technology Corporation
SDK	Software Development Kit
PNG	Portable Network Graphic
JPEG	Joint Photo Expert Groups
RGB	Red Green Blue
XML	Extensible Markup Language

**ABSTRACT**

**CONCEPT DEFINITIONS**

**CONTENTS**

<b>1 INTRODUCTION</b> .....	<b>1</b>
<b>2 AUGUMENTED REALITY</b> .....	<b>2</b>
2.1 Overview .....	2
2.2 Hardware .....	3
2.3 Toolkits and libraries .....	3
2.4 Video Games .....	4
2.5 Tracking, Calibration, and Registration.....	5
<b>3 VUFORIA AUGMENTED REALITY SDK</b> .....	<b>7</b>
3.1 Overview .....	7
3.2 Architecture.....	8
3.2.1 ARCamera .....	8
3.2.3 Target Image .....	8
3.2.4 Video Background Renderer and Frame Marker .....	9
3.2.5 Virtual Buttons.....	10
<b>4 VUFORIA TARGET USAGE</b> .....	<b>11</b>
4.1 Wall Targets .....	11
4.2 Floor Targets .....	12
4.3 Handheld Targets .....	12
4.4 Retail Shelf Targets .....	13
<b>5 APPLICATION DEVELOPMENT</b> .....	<b>14</b>
5.1 Software Requirements .....	14
5.1.1 Unity 3D .....	14
5.1.2 Vuforia Library .....	15
5.2 Application Creation Process .....	18
5.2.1 Project Scenes.....	19
5.2.2 Vuforia Set-Up .....	20
5.2.3 Animations.....	21
5.2.4 Virtual Buttons.....	23
5.2.5 Adding Scripts.....	24
5.2.6 Debugging and Testing .....	26
5.3 Compiling Cross Platform .....	27
5.3.1 Build Setting .....	27
5.3.2 Android SDK/NDK Set-up.....	28
<b>6 TESTS AND RESULTS</b> .....	<b>30</b>
6.1 Target Recognition .....	30
6.2 Trackability .....	31
<b>7 CONCLUSIONS</b> .....	<b>32</b>
<b>REFERENCES</b> .....	<b>33</b>

## 1 INTRODUCTION

The following thesis is the presentation of application development with Vuforia 7 and Unity 3D. The main objective of Vuforia is to move the augmented applications into the reality using the camera of mobile devices. This software uses the capability of Computer Vision Technology to recognize and track individual coordinates of images.

The initial objective of this project was to go through the basic elements required to develop the final application along with the basic architecture of Vuforia and Unity 3D. Another objective of this project was to show the application development process in Unity 3D, and the basic architecture of the software. The cross-platform mobility of Unity 3D will be covered in the final stage. Starting from Unity 5.3, Vuforia is integrated by default in Unity 3D, so downloading the separate integration file is not necessary. Unity 3D is a fully integrated game engine software that reduces development time and costs. Unity also supports easy deployment to Android and iOS.

The main goal of this thesis is not to develop a full application, but a demo application is built and covered at the end of this project. The application is based on the Vuforia library and Unity 3D because of its simplicity. Application is improvised by adding the scripts.

Blogs and forums were the general supports that were available during the development and documentation process. There were few problems like setting up the SDK, NDK and Java for Unity 3D which was time consuming and frustrating. Setting up the SDK for Unity is explained at the end of the thesis. It was easy to go through the documentation of Vuforia and Unity to create a sample application because of the availability of the support from different forums and YouTube videos.

## 2 AUGMENTED REALITY

Augmented Reality is the real time direction of the existing reality and physical objects to trigger the enhancements over the reality, like images or 3D objects. AR is closer to the real-world objects. Basically, AR generates user selected images, videos, 3D objects and information into the real environment which can be viewed through the camera of the devices. The best-known example includes Snapchat and Pokemon Go. For example, in Snapchat users can use filters to personalize the self-portrait images, and nowadays with few updates, also real-time animation transformation with secondary camera is also available. AR enhances the user's perception of interaction with the real world. AR augments the user defined image target alongside the co-ordinates where next images, videos or objects can be transformed. The following chapters covers the basic of augmented reality and image tracking. (Schmalstieg & Höllerer 2016, 4-12.) The objective is to familiarize with the basic concept of augmented reality.

### 2.1 Overview

The first AR device was developed by Sutherland in 1968. He created the first head mounted display. Because of its weight, it had to be hanged on the ceiling and was named "Sword of Damocies" (Figure 1). Later, around 1993 Feiner introduced KARMA, a system that incorporated knowledge-based AR. AR has been useful for different aspects from late 90's to till date. US Naval Research Laboratory engaged on a decade long research program called Battlefield Augmented Reality System to prototype some of the wearable systems for soldiers operating in urban environment for situation awareness and training. The most recent development in AR has been by Niantic with a game called Pokemon-Go for iOS and Android, where players must go around real environment to find targeted objects. It became the most popular smartphone application and spiked in the augmented reality games. (Schmalstieg & Höllerer 2016, 4-12.)

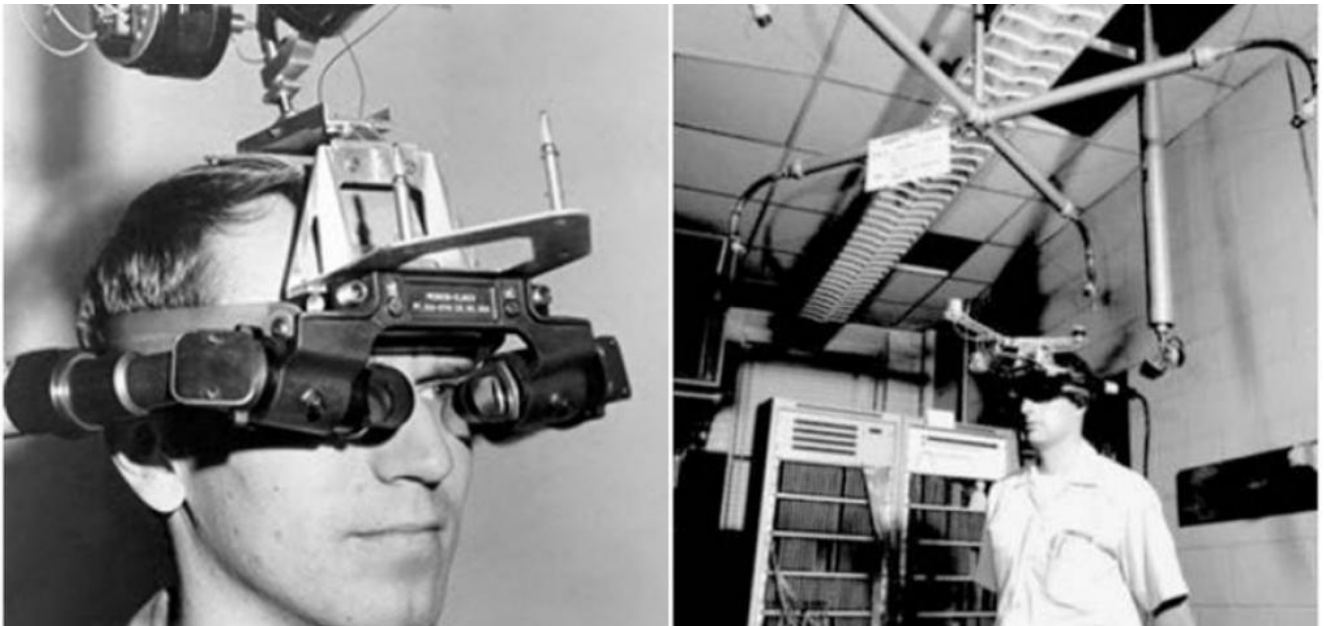


FIGURE 1 The Sword of Damocies was the nickname for the world's first head-mounted display, built in 1968 (Schmalstieg & Höllerer 2016).

## 2.2 Hardware

Google glasses, Microsoft HoloLens and smart phones are the sample hardware devices to access the AR functionality. Hardware components required are display, processor, camera, sensors and input devices. Modern smart phones contain all these elements and also GPS, accelerometer and compass which makes them compatible for AR. Head-up display, eye glasses, contact lens, and smart phone's camera are primitive display elements required for displaying purpose. Inputting the instructions is also very important to make AR applications realistic and interactive. Voice recognition, keyboards or touch controls can be used for data inputting. (Ingraham 2016.)

## 2.3 Toolkits and libraries

The fundamental part of AR is how well it can combine with the real-world entities. The system must bring the real-world image coordinates separated from the camera image coordinates. Researchers and developers have innovated many tools, SDK and development kits to develop augmented reality-based applications. The method uses tracking, graphic adaptation and interactions. AR applications normally use existing graphic libraries and 3D engines for rendering. The first library to create AR applications

was ARToolkit (ARToolkit 1999). This is the most complete library to develop AR based applications. It has been active since 2006, so development libraries have been extended to the possibilities such as standalone desktop applications, mobile applications and web applications. (Siltanen 2012, 36.)

Similarly, Vuforia which is used in this project is also a toolkit used to develop AR applications. The reason behind choosing Vuforia rather than ARToolkit or other development kits was the simplicity and the efficiency of the software. Vuforia 7 which is the latest version of the application comes alongside with Unity 3.1 recombined which is easier to use and saves time. Augmented reality generally means displaying objects to the real world which can be anything, but in Vuforia it is different. It does not augment any elements in the real world, rather it augments only the target image. Generally, end users are more concerned about the performance of the application rather than the approach used for its development. It is hard to distinguish which toolkit is the most preferable for the development because it differs according to the needs, levels, and functionalities. Therefore, there are many AR toolkits depending on the needs of an application. (Siltanen 2012, 36.)

## **2.4 Video Games**

The first commercial application developed by AR technology was “The Edge of Judgment”, an interactive card trading game for Sony PlayStation 3. The game uses overhead camera which is used to pick up the cards and transfers to the matches. Video games are the most essential part of the entertainment in the technological generation. The nature of video games has changed dramatically. Video games has advanced graphically, performance wise and categorically. The most important feature of AR games is its tangible nature. Kids can turn their entire room into a playground with the help of AR technology. AR can bring virtual games into the reality. For example, Vuforia’s MekaMon (Figure 2) delivers game with 3D objects to a target sheet of paper. (Siltanen 2012, 36.)





FIGURE 2 Vuforia MekaMon (Vuforia, 2017)

## 2.5 Tracking, Calibration, and Registration

In the context of AR, there are three most important elements which are the main reasons behind its functionality- tracking, calibration and registration. (Figure 3) During the tracking process, it is responsible for dynamic registration. Objects are registered in AR and are aligned to the coordinate system. The aim of the AR system is to register the virtual information exactly how it looks for the system. Calibration reads the sensor's accuracy and it is responsible for the static registration for the tracking system. (Siltanen 2012, 36.)



FIGURE 3 An AR system addressing three important things (Siltanen 2012, 36.)

Tracking is a term used to describe the sensing and measuring the values in the AR system. To transform the 3D position of virtual objects into the system, the relative positions, orientations are required. AR operates in real time, so passing the value from real environment should be in real time and should be updated continuously. Tracking two-dimensional objects is common in the computer system, so tracking is rather unique technology in AR which is different because it passes the three-dimensional coordinates of any objects abased of their nature. (Siltanen 2012, 36.)

Calibration is the process of comparing the value between two devices. One which is the reference device and the device which needs to be calibrated. Then the reference device can be replaced with the known coordinates from the real environment. Unlike tracking which needs to be done continuously, calibration works between discrete times. Calibration is done just once in one device unless the device is completely restored. AR application works flawlessly if the device is calibrated properly. (Siltanen 2012, 36.)

Registration refers to the alignment of coordinates between virtual and real objects. More specifically, the AR display should show or align the virtual object into the real world perfectly. This requires the tracking of user's camera providing the background. Static registration happens during the non-movement of the camera to establish the common coordinate between real and virtual objects while dynamic registration is when camera is moving, which requires tracking. (Siltanen 2012, 36.)

### 3 VUFORIA AUGMENTED REALITY SDK

Augmented reality and its basic elements and functionalities were covered in the previous chapters. So, moving on with the main tools of the project which is Vuforia. It is an Augmented Reality Software Development Kit for mobile devices to create AR applications. This SDK is offered by Qualcomm which has boosted its market share in augmented reality industry. (Vuforia 2017.)

#### 3.1 Overview

Vuforia previously started by Qualcomm in 2006 is now owned by PTC since November 2015. It uses camera vision to recognize and track images and 3D objects in real time. According to the benchmark tests, this has been proven to be the fastest tracking algorithm, and with more image stability. The user interface and functionalities are easy to use, which makes even the beginners comfortable with the new tool. Most important feature for amateur developers is the cost of the development tools. Open source projects have made big change in the number of participants in application development. Similarly, Vuforia is also free to use with limited features. (Vuforia 2017.)

In modern application development, the most helpful thing is the Internet and more specifically forums and communities. There are threads and forums in different websites and in the official website of Vuforia where developers can discuss and share problems during development. Vuforia 7 which is the latest version of the SDK comes combined with Unity 3.1, through which it is easier to deploy into multiple devices to test the applications. This tool is helpful for amateurs but is also useful for robust development of applications. Some applications developed with Vuforia are Lego Nexo King, Meka-Mon, Qualcomm Insights, RAV4 T.I.G and many more. (Vuforia 2017.)

Vuforia offers easy interaction between end user and the real environment. It uses the ARCamera components to give live video feedback from the real environment with also trackable coordinates from the targeted image and object. The ARCamera also tracks the orientation of the devices and objects to get the precise value which simplifies the experience of augmented reality. Vuforia provides API with Java, C++ and .Net programming languages through the extension of Unity 3D engine. This engine supports the development of 3D and 2D applications and games which supports both iOS and Android platforms. (Figure 4) (Vuforia 2017.)

Development Options					
	Unity		Native SDK		
	Android	iOS	Android		iOS
			Java API	Java & C++	
Windows	✓		✓	✓	
OSX	✓	✓	✓	✓	✓
Linux			✓	✓	

FIGURE 4 Development Options in Vuforia 7 (Vuforia 2017).

## 3.2 Architecture

Vuforia includes several components to make it smooth and realistic in application development. It offers different tracking solutions to cover different situations. The following components are the basic features available in the SDK. There are also many other components available as a plugin which is found in the Vuforia's store. (Vuforia 2017.)

### 3.2.1 ARCamera

The initial approach towards modern development was the portability of the devices along with its performance and capabilities. The first prototype of the augmented reality-based method was back in 1969. It used the eye lens to augment reality but with the recent development in camera technology, camera can be used to track the objects behind it and give live coordinates accordingly. Similarly, ARCamera means it uses the live feed from the real environment through the device's camera and offers real time values to the toolkit for further processing. The pixel formatter singleton converts the image target into the suitable OpenGL rendering and tracking. (Vuforia 2017.)

### 3.2.3 Target Image

The target image is the most essential part of this SDK and without which it does not function at all. Apart from other toolkits the specialty of this tool is its target image, which increases the stability of

objects. Using this component, which can detect any target image and shows AR contents. The AR content will overlay over the targeted image and in some cases like moving characters, which can move around whole space even though the target image is small. This generally explains that the target image is only required to target the object to augment. (Vuforia 2017.)

Supported image targets are JPEG or PNG images in RGB or gray scale. Vuforia Target Manager which is available in Vuforia's website is also useful to create custom target images. Admiringly to the low light target image detection capability of Vuforia, the application works smooth in low light. And also using virtual buttons alongside target image is possible. The following image shows a sample virtual object augmented to the target image. (Vuforia 2017.) (Figure 5)



FIGURE 5 Sample object placed in real target image (Vuforia 2017.)

### 3.2.4 Video Background Renderer and Frame Marker

The video background renderer renders the captured image to the state object. The background video rendering is optimized for specific devices. The frame markers are the square shaped frames embedded in the internal edges. There are 100 markers that Vuforia offers that lets detect the objects and display AR contents on top of it. Any target images uploaded will be automatically sorted by Vuforia and it displays small brackets around each object inside the target image which helps to smooth the stability of virtual objects in the target image. Frame markers are usually smaller than the target image. The following image shows the sample frame marker. (Vuforia 2017.) (Figure 6)

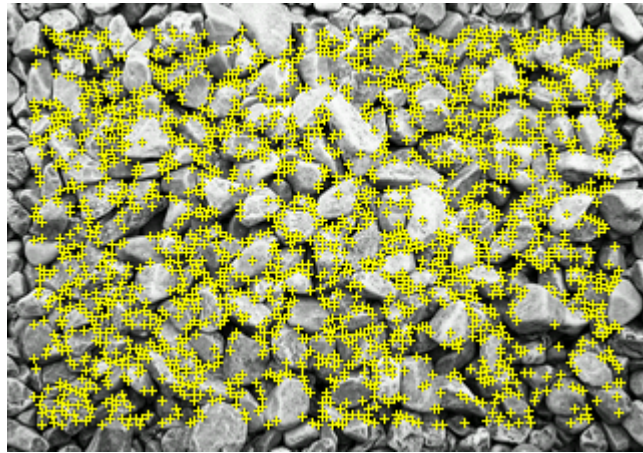


FIGURE 6 Frame markers in target image (Vuforia 2017.)

### 3.2.5 Virtual Buttons

The virtual button is the whole new concept in AR experience brought by Unity and Vuforia combined. This extends the capabilities of the augmented reality by giving the user square buttons in the screen to interact with the virtual objects in the real environment. There can be more than one virtual button in an application which interacts and triggers specific events. Virtual buttons can also be created in Vuforia itself by defining as dataset configuration XML file to the property of image targets. The following image shows the virtual button to navigate the functions. (Vuforia 2017.) (Figure 7)



FIGURE 7 Demonstrating the virtual buttons (Vuforia 2017)

## 4 VUFORIA TARGET USAGE

Reaching the real world with less confusing and easy applications are the main targets of Vuforia. AR applications can be quite confusing for the new users for this platform. Appropriate guidelines are required along with the equipment. Target image needed beforehand to use the application. The target where objects will be augmented should be properly defined according to the usage. One fact which must be considered is, the end user has two hands and one hand is already occupied holding the device, so the controls should be a blind interaction. Another important target usage can be the real-time interaction to make it more intuitive. (Vuforia 2017.) Different types of target usages are explained below.

### 4.1 Wall Targets

Recent development and progress has shown that augmented reality can not only be done in the floors or horizontal areas as well as the 3D objects and vertical areas. Wall targets are another important field where augmented reality has prospered. Wall posters or billboards, where videos or information can pop out when targeted. This might help in museums to show history and for painter to show the depth of the photography. Tangible interaction is not impossible but continuous interaction might be tiring for the end user. Wall targets can also help different departments to see the blueprint of something like the pipe system. And, customers can try from home how the specific lighting system or different equipment suits the house remotely. So, there are many fields of applications of augmented reality based on vertical alignments also (ThinkMobile, 2016).

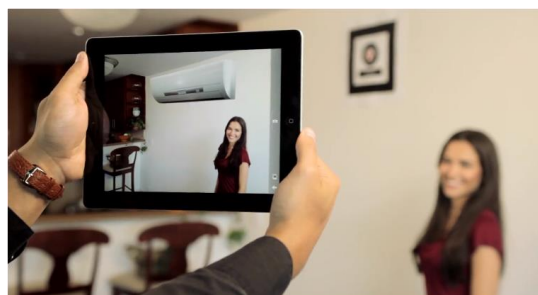


FIGURE 8 Wall targets (ThinkMobile, 2016.)

## 4.2 Floor Targets

This is the most common usage of augmented reality. This includes tables or any objects pointing horizontally to the ground. It is easier to hold the device and the interaction with the device is also easier. With this, children can make their entire room a playing ground. The most recent advancement in the floor target is buying online furniture. The first company to make use of this is Ikea, where the customer can select various items from the product list and try it at home or office with different rotations before buying. This might also help the engineers to show the sketch of the house to the customers before building. This helps also to show emergency instructions to guide people to safety (Wired 2017).

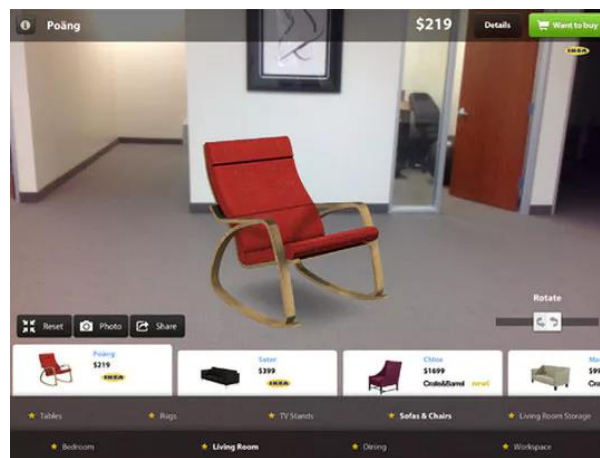


FIGURE 9 Floor Targets (Wired, 2017.)

## 4.3 Handheld Targets

Handheld targets generally mean small business cards or beer mats which is easy to augment. This generally refers to any object held by hand. This makes it simple to use and allows quick movement and portability. Simple menu can be built to pop up, which can also be used as a controller. Small business cards can also be used as a tangible object to show the interactive results. (Wired, 2017.)





FIGURE 10 Handheld Target showing in beer mat. (Wired, 2017.)

#### 4.4 Retail Shelf Targets

This is another big aspect of augmented reality. Generally, there are many fields of usage for augmented reality, but this might just be the most anticipated and beneficial field. Store's shelves are filled with different products, there are many customers viewing the store daily and a television screen can only bring advertisements for single product at a time. Augmented reality helps here by displaying advertisements or information where the targeted product is viewed through camera. It is easy to go through the store with the path shown and displays the current offers in each item in the shelf. This changes the shopping experience and acknowledges customers through the products. (ThinkMobile, 2016.)



FIGURE 11 Guiding path to the product (ThinkMobile, 2016.)

## **5 APPLICATION DEVELOPMENT**

Application development is a lengthy process. It consists of heavy brainstorming, designing the plan, creating a prototype, debugging and the final release. There is many software available in the market to ease this process. (Unity 2018.) The initial objective of the following chapters is to guide through the basic setup for the development and exploration of new version of Unity which comes with Vuforia plugin. To make the final application more interactive, few scripts have been added to its functionality.

### **5.1 Software Requirements**

Development part usually consists of the use of various software to make the final application. Usually going through the final applications, it might not look like there has been usage of multiple software in the creation process, but all the remarks goes to the simplicity of small software which makes it happen. Similarly, Vuforia is also useless without a development kit, but it also has different options than Unity engine like Android studio and XCode. Previously, Vuforia did not have internal plugin with Unity which was the reason why developers had to download separate Unity compatible file and open it with Unity package manager. With the latest update of Unity, which is Unity 3.1, comes recombined Vuforia plugin which can be selected with the few steps. As mentioned before, different elements can be augmented images, videos, 3D objects and information. (Unity 2018.) For the instance of this project, a free open source object from Unity asset store was used. Unity also gives access to model one's 3D object, but this project only covers the basis of augmenting, not modeling.

#### **5.1.1 Unity 3D**

Unity is a cross-platform application development tool developed by Unity Technologies, which develops two dimensional and three-dimensional video games and simulations for mobile devices, consoles and computers. The first version released was Unity 1.0 back in 2005. Programming languages supported are C++ and C#. (Unity 2018.)

The reason to choose Unity to develop the AR application for this project over several other software was the simplicity and extendibility of the software. The use of Vuforia plugin is easy, it is easy to de-

bug at runtime and the deployment of the application for the test purpose is easy. The installation part of Unity 3D is easy and skipped for this project. The application was produced in the Windows machine and for the test purpose of the deployment, Samsung Galaxy's Android phone was used. Supported platforms are: iOS, Android, Tizen, Windows, Universal Windows Platform, Mac, Linux, WebGL, PlayStation 4, PlayStation Vita, Xbox One, Wii U, 3DS, Oculus Rift, Google Cardboard, Steam VR, PlayStation VR, Gear VR, Windows Mixed Reality, Daydream, Android TV, Samsung Smart TV, tvOS, Nintendo Switch, Fire OS, Facebook Gameroom, Apple ARKit, Google ARCore, and Vuforia . (Unity 2018.)

### 5.1.2 Vuforia Library

The most important part of this project is the Vuforia library which must be imported to Unity after creating a new project in Unity. As mentioned before, Vuforia itself is not a development tool, it requires a development platform where its capabilities can be explored. Vuforia's latest release has separate development targets for Android, iOS and Windows independently but with its Unity plugin it is easy to achieve all the features from one software. To pass targets from Vuforia online to Unity, Vuforia requires developers to have a developer portal which can be found at its official website. (Figure 12)

vuforia™ Developer Portal

Home Pricing Downloads Library Develop Support

## Login

Login with your Vuforia developer account to download software, get license keys, and participate in the Vuforia community.

Email Address  
chapsrijan@gmail.com

Not Registered? [Create account now](#)

Password  
●●●●●●●●

[Forgot password?](#)

Login

FIGURE 12 Vuforia Login Portal (Vuforia 2017.)

After that the developers need to create a free development license key which later must be inserted to Unity to access to the account and its contents. (Figure 13) The use of the license key is to ensure the activeness of the developer and project. It also helps to retrieve the contents from the developer's database portal. The license key is unique to each developer. Name of the project can be edited at any time and license key can also be deleted with the developer's request. (Vuforia 2017.)

The screenshot displays the Vuforia Basic AR license key creation process. On the left, the 'Add a free Development License Key' form includes an 'App Name' field (Vuforia Sample Test), a 'License Key' section with details (Develop, No Charge, 1,000 Reco Usage, 1,000 Cloud Targets, 1 active VuMark Template, 100 VuMarks), and a checkbox for terms and conditions. On the right, the 'Vuforia Basic AR' section shows the generated license key, its type (Develop), status (Active), creation date (Feb 10, 2018 19:03), and a history entry (License Created - Feb 10, 2018 19:03).

FIGURE 13 Development License Key (Vuforia 2017.)

Sample license key looks like as shown above which should be copied to Unity which will be mentioned later in this project. (Figure 13) These were the basic steps to create the development identity and moving on the image targets also needs to be managed in the same developer's portal which will be automatically updated later in Unity. In the next step, developers need to switch to the target manager and add the database target. By clicking on the add database button the users are redirected to the next step to add the image target of their own choice. (Figure 14)

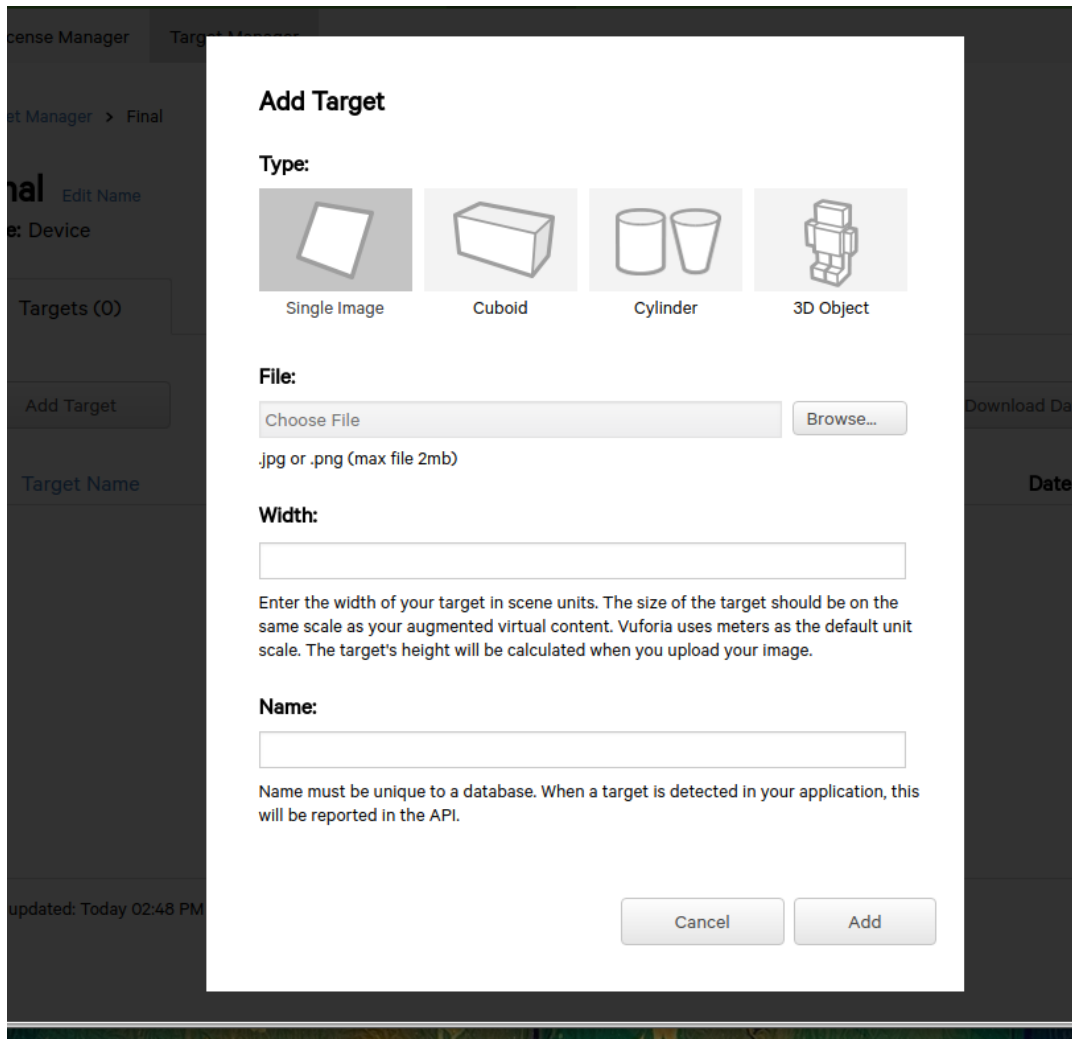


FIGURE 14 Add Target (Vuforia 2017.)

Sample target images can also be found in Vuforia's official websites which can be used for test purposes. Vuforia kit automatically detects the coordinates from the target image and shows if it is possible to augment to specific image target. For instance, if the target image is with complete white background or black with no coordinates in reference, it is not possible to augment the objects. Beneath, it is shown how the feature points look like on an image target. (Figure 2.4)

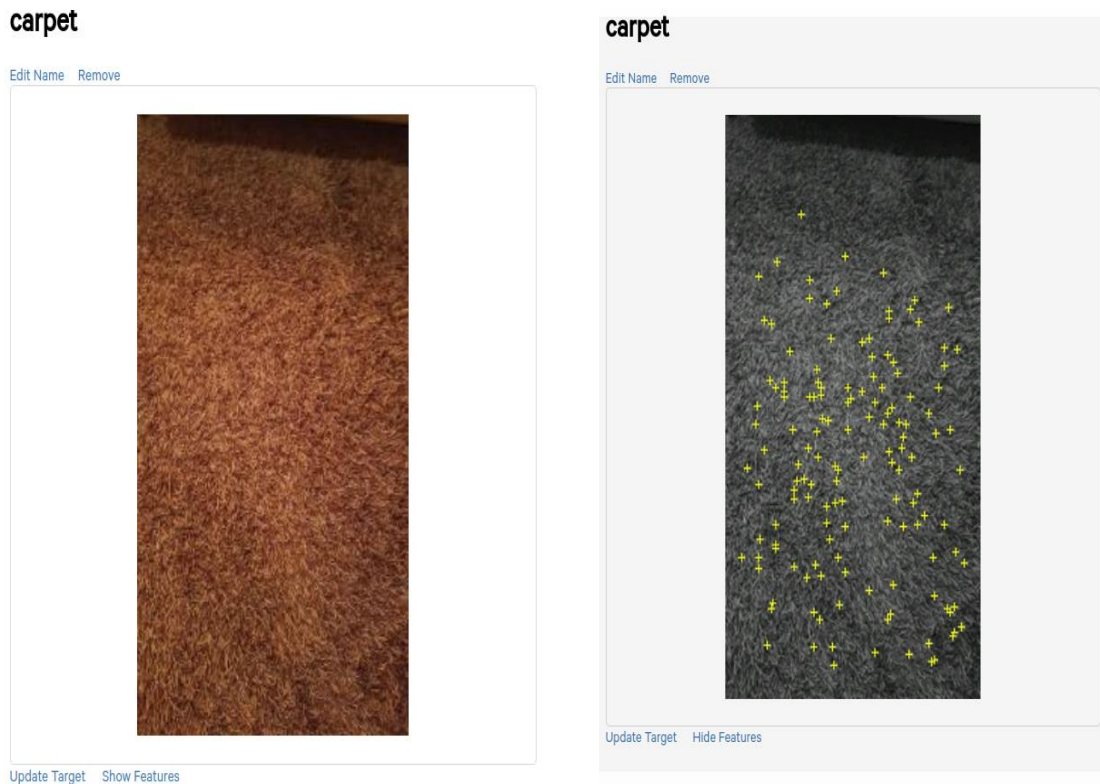


FIGURE 15 Show features button showing the image target coordinates (Vuforia 2017.)

## 5.2 Application Creation Process

Application creation process consists of various elements. The efficient application development process consists of planning, analysis, design, construction, testing, implementation and support. As mentioned before the software used to develop the AR application is Unity 3.1. With the latest release of Unity, Vuforia plugins is available from within the menus and can be used with simple steps. (Unity 2018.) The various elements for this project are configuring the Vuforia developer's portal which was covered in chapter 5.1.2, blending or extracting open source characters for augmentation, debugging and final release. The following chapters will also cover similar aspects of the application creation process. The application created will be working but with no functionalities because the aim of this project is to showcase the only usage of Unity and Vuforia combined to develop a sample application.

### 5.2.1 Project Scenes

The simplest way of creating a sample application in Unity is by clicking on the new project from the opening windows of Unity. For this project the option selected should be 3D which makes the camera angle possible for 3D objects. (Figure 16) Animations, Assets, GameObject, rendering everything happens in the project scene. The only method which occurs outside of the project scene is scripting which is compiled by Visual Studio's external code editor.

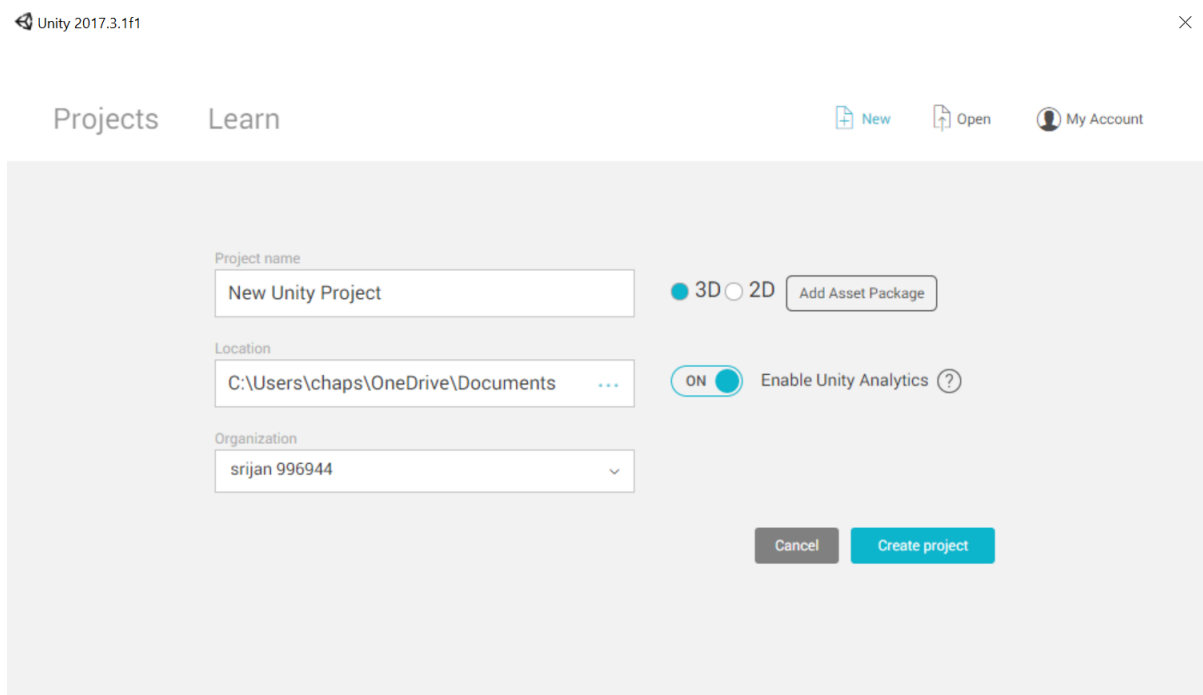


FIGURE 16 New Project Selection Mode

This is the first page which opens while opening Unity. Here, developers can select the project name, location, and asset package. The newly created project will have default camera and scene which should be replaced with the Vuforia's AR camera. Everything that will be seen by the end user is through the AR camera. The easiest option to import the Vuforia AR camera is by clicking the GameObject menu and then Vuforia and AR camera. After placing the AR camera, the main camera must be deleted to switch focus to the AR camera. (Figure 17)

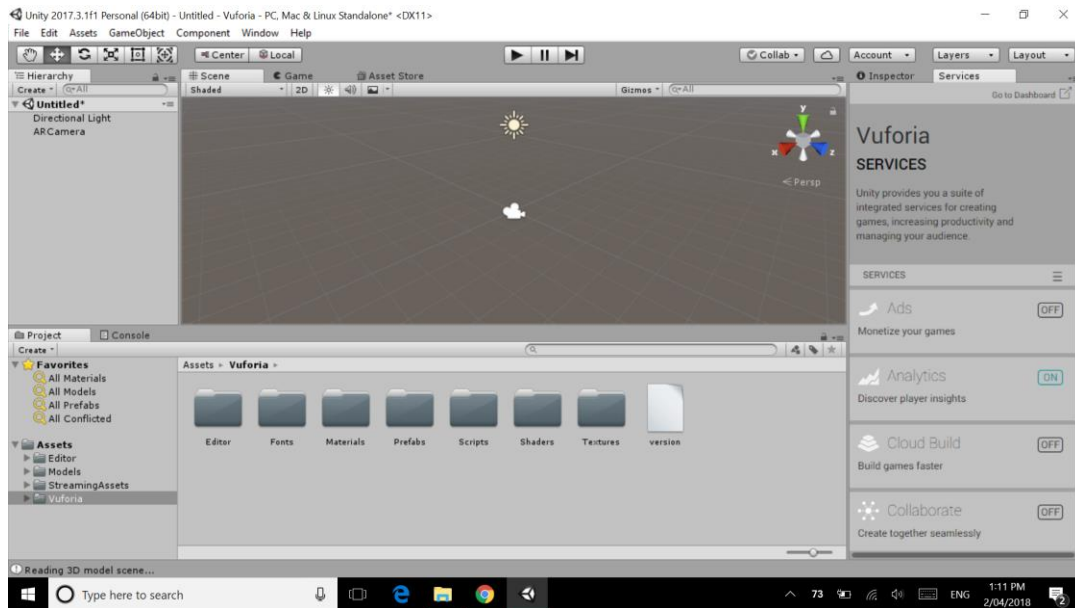


FIGURE 17 Default project with ARCamera

## 5.2.2 Vuforia Set-Up

The very first step of creating the application was shown in the previous chapter and the basic way to import the AR camera was mentioned. As a reminder, in chapter 5.1.2 Vuforia license key was created which was due to import in this new project's scene. The easiest way to paste the application license key is by clicking in the window tab from the project scene which pops out the sub menu with Vuforia configuration. The license key is added to the App license key field. (Figure 18) The next step is that the project needs to have image target to target the image for augmentation. Image target can be dragged from the prefabs from the assets folder or from the Vuforia menu from GameObject tab. Selecting Image Target from hierarchy will pop out the properties and image target and the database can be selected respectively.

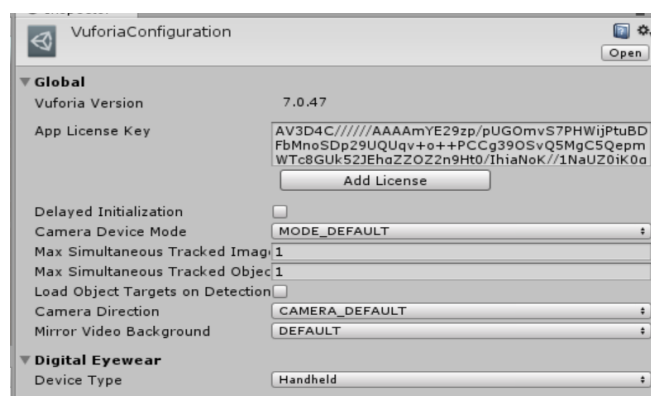


FIGURE 18 Vuforia Configuration window



The above-mentioned steps were the basic configuration of Vuforia for AR applications. Carrying it forward, the aim of the project is to show a sample object augmented to the target image. The target image should already be uploaded to Vuforia's developer portal before continuing with the project. Next part required is the target object. For this instance, a sample object is chosen from Unity's Asset Store which is free to use. To make this object pop out in the image target which is very simple in Unity, just drag the object from resource folder and drop it to the Image Target which makes object its child object. According to the size and position required, the object can later be configured from its properties. (Figure 19) The figure 18 shows the basic configuration of Vuforia in Unity. In that window, developer paste their license key and choose the device's camera mode. The next step for the developer is to select the image target. There needs to be at least one Database and one Image target. Developers can also twist different behaviours of objects through the properties menu.

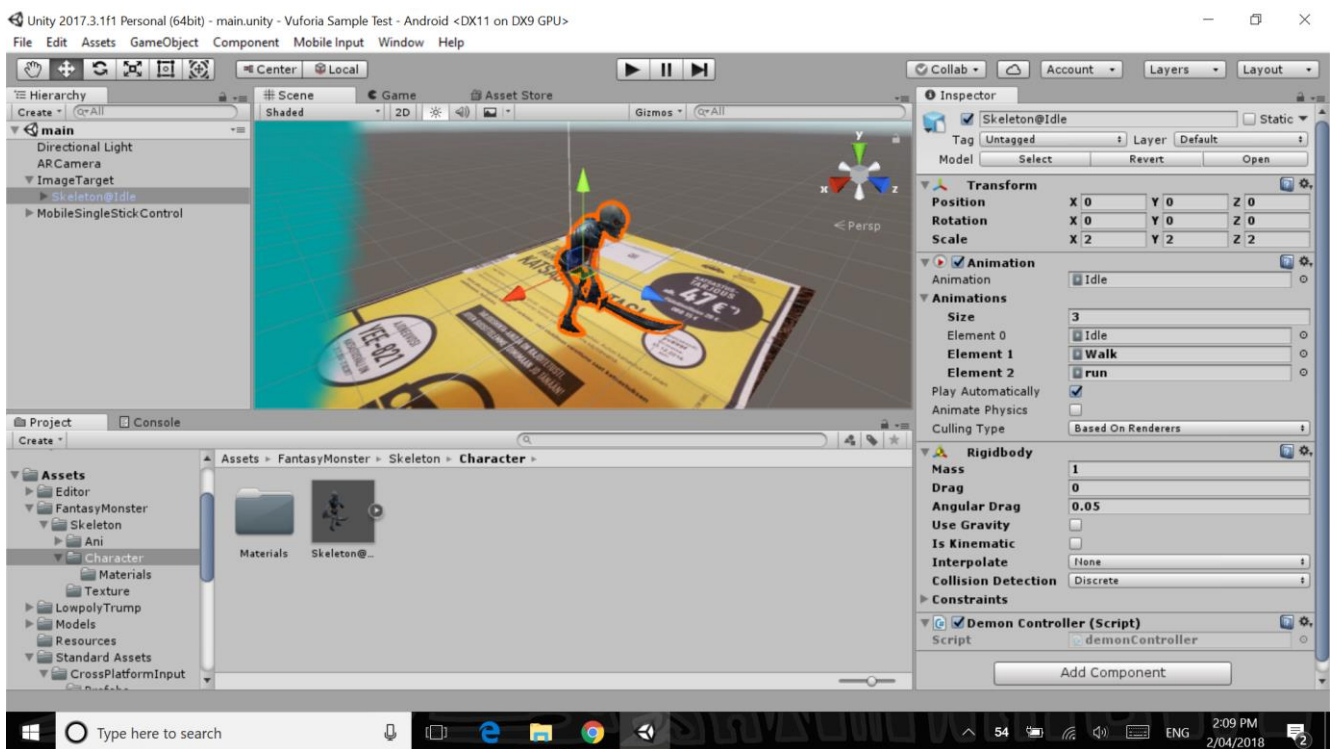


FIGURE 19 Adding object to Image Target

### 5.2.3 Animations

The important aspect of 3D object are the free-flowing shape and animation which makes it more realistic. There are several ways to put animation in the objects. The easy method is to get the free objects from asset store with embedded animation. The next method is to have the all possible stereotype of the object and creating custom animation with Unity. The object which is needed to be animated must

be selected and an Animator Controller must be attached to it. After attaching the animation controller, new animation clip must be created for the object, if the object does not have any animations, then the 'Create' button appears. Clicking it prompts to save the animation clip with appropriate name. (Figure 20)

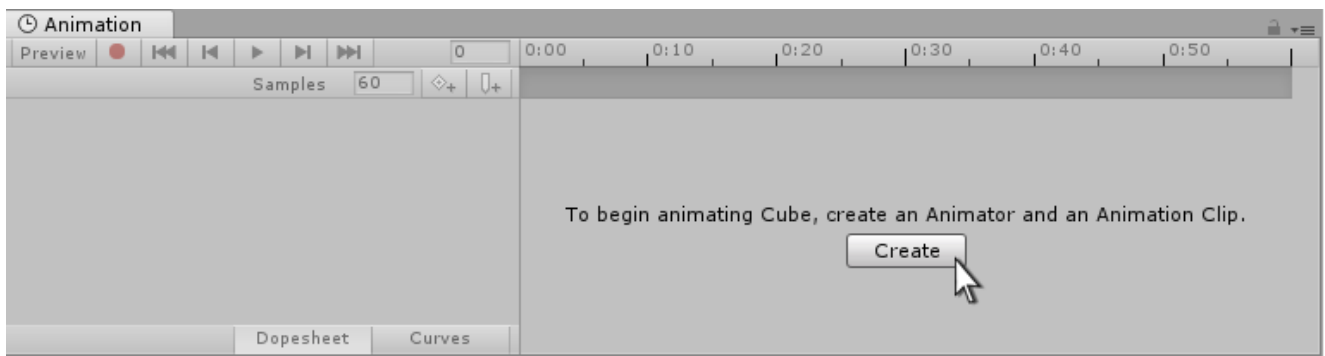


FIGURE 20 Animation Creation Window

New animation can be created with 'create' button. This will prompt users to save the animation first. Then the users can create the animations with layover and movements of object. Animation is just the positioning and scaling of the object to different coordinates in fixed speed to make its movement. This differs from objects to objects for example, to animate a cube, only its position can be changed which is easier compared to animating a human object where the body portion should also be scaled for the movement. A GameObject must have the Animator component, where animator component must have an animator controller and an animation clip must be assigned to the Animator controller. (Figure 21)

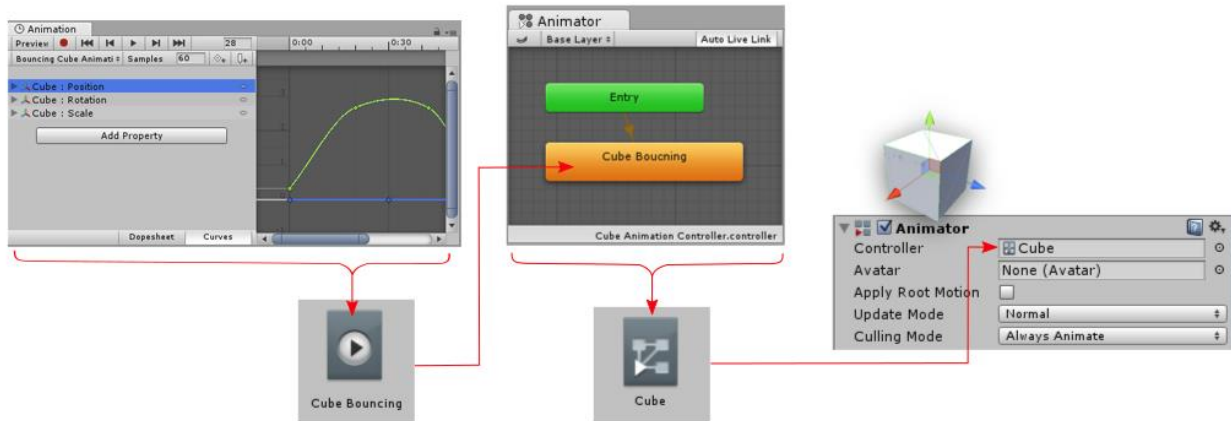


FIGURE 21 Relationship between different components of Animation

#### 5.2.4 Virtual Buttons

There are many elements which make an application or game complete. Similarly, depending upon the situation of the game there can be different controllers like motion controllers, virtual buttons, and interactive objects. All the mentioned simulation is possible in Unity. In regard of this project, the virtual button was the primitive way to move the augmented object around the real environment. Designing custom virtual button and programming it to function is also a possibility but there is also another possibility to get the sample virtual button from Unity's official asset store which can also be customised to function in a user-defined way. Scripting is needed for an object to move according to the movement of the buttons which will be covered in chapter 5.2.5.

The easiest way to get the mobile joystick for this project which acts as a virtual button is by clicking in the assets menu then import package and then the CrossPlatformInput (Figure 22). This will import all the cross-platform packages, so to add mobile single joystick to the scene, click in assets in project resource directory then standard assets and CrossPlatformInput and then prefabs and drag MobileSingleJoystick to the main scene. To input the mobile joysticks controller to the project, the users can select import packages and CrossPlatformInput. There are several small packages included in this package. Developers can only drag and drop mobile joysticks to the project.

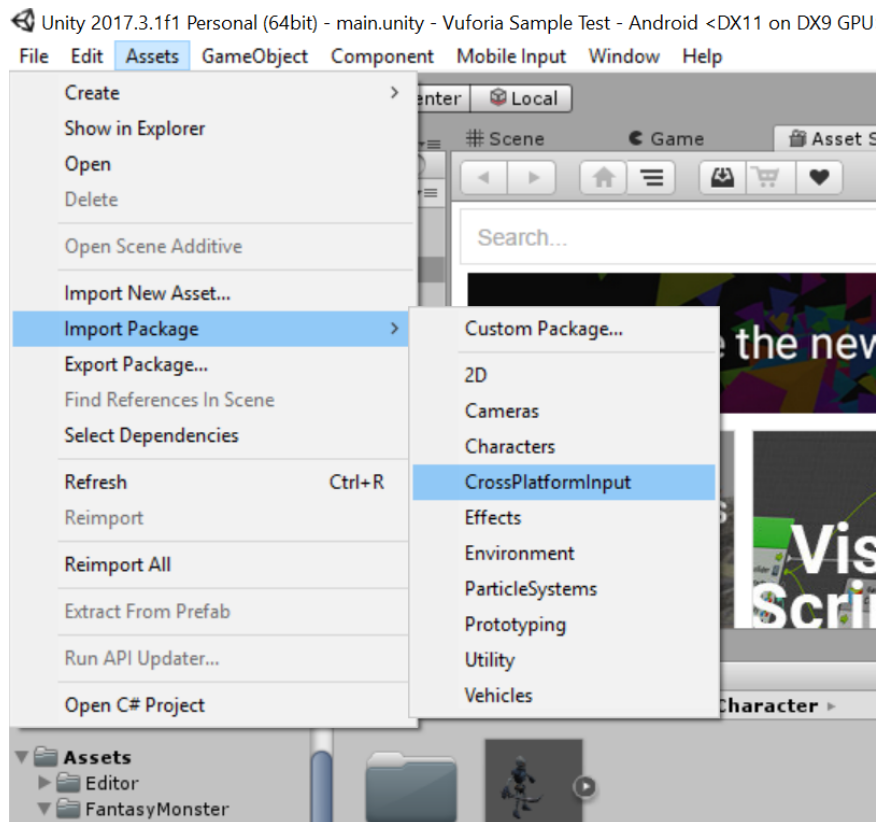


FIGURE 22 Importing CrossPlatformInput

### 5.2.5 Adding Scripts

Any applications without functionalities are dull. Applications must be interactive with the user to make it more realistic. Scripting in Unity means adding programming codes to make the objects or scenes interactive. This helps to trigger the game objects, modify component's properties over time and respond to user input. Scripting is compiled with Visual studio's external code editor which means the system must have pre-installed latest version of Visual Studio also. All the coding is written in C# programming language. Adding script to the object is easy, which can be set by selecting the target object which needs to be programmed and from the inspector Add Component must be selected, which pops out the option with New Script and custom name. (Figure 23)

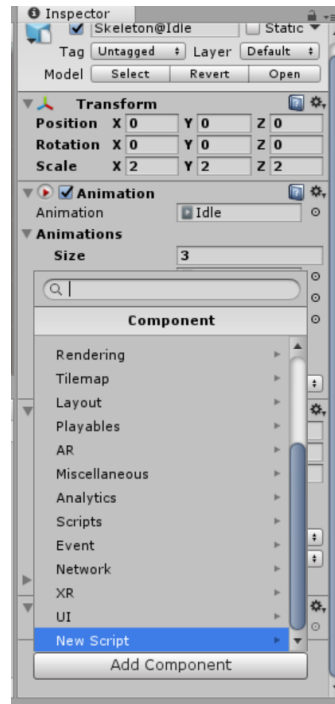


FIGURE 23 Adding Script to the GameObject

After adding a new script to the GameObject, necessary code can be added to the script by double clicking the added script which opens new windows with Visual studio external editor. (Figure 24) The only part needed to be programmed here is the GameObject which must move according to the MobileJoyStick and the animations according to the movement. In Unity, to move a GameObject, the easiest method is to get the Vector of the object and transform it adding velocity to its movement. The figure below shows the method to switch the animation for the object using programming method. (Figure 24) Animation can also be switched from the animation controller.

```

1  using System.Collections;
2  using System.Collections.Generic;
3  using UnityEngine;
4  using UnityStandardAssets.CrossPlatformInput;
5
6  0 references
7  public class demonController : MonoBehaviour {
8      private Rigidbody rb;
9      private Animation anim;
10
11     // Use this for initialization
12     0 references
13     void Start () {
14         rb = GetComponent<Rigidbody>();
15         anim = GetComponent<Animation>();
16     }
17
18     // Update is called once per frame
19     0 references
20     void Update () {
21         float x = CrossPlatformInputManager.GetAxis("Horizontal"); // Get Horizontal Axis
22         float y = CrossPlatformInputManager.GetAxis("Vertical"); // Get Vertical Axis
23
24         Vector3 movement = new Vector3(x, 0, y);
25
26         rb.velocity = movement * 4f;
27
28         if (x != 0 && y != 0)
29         {
30             transform.eulerAngles = new Vector3(transform.eulerAngles.x, Mathf.Atan2(x, y)
31                 * Mathf.Rad2Deg, transform.eulerAngles.z); // TO move if controller is moved
32         }
33         if (x != 0 || y != 0)
34         {
35             anim.Play("Walk"); // animation to start
36         }
37         else {
38             anim.Play("Idle"); // Idle animation is switched
39         }
40     }
41 }
42
43
44
45

```

FIGURE 24 Script for the movement of GameObject with MobileJoyStick and animation control

### 5.2.6 Debugging and Testing

Applications developed must be tested and debugged before the final release. Testing is required in every phase of development like designing, programming, animating. Applications can be tested in user's own device by compiling cross platform or within the developing system. The most important

hardware device required for testing for this project is the camera. External camera or in-built webcam is required to test the augmented application. (Unity 2018.)

Visual studio shows if the written code has some errors which are highlighted with red marks. Code must be attached to unity for testing. Testing the code in every phase of programming is a good way to program large applications. In Unity, there is an option with play button which gives developers a chance to test the application if the program has no external errors. Errors are displayed in the console directory. (Figure 25)

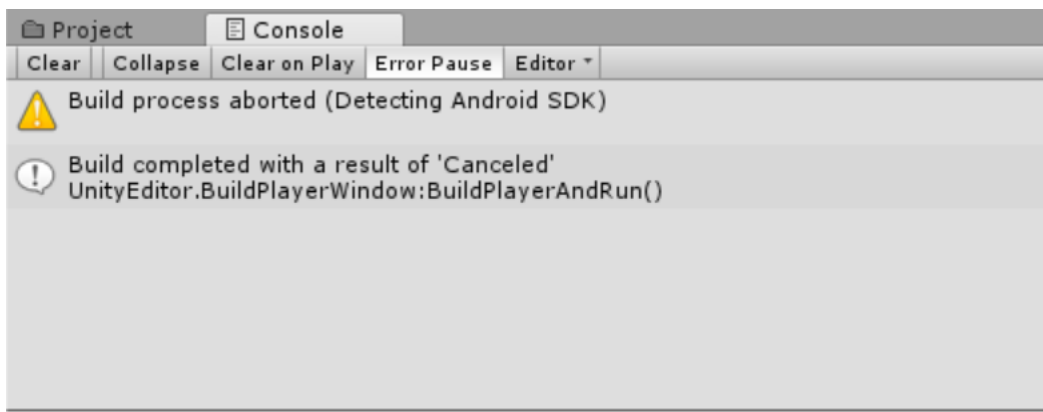


FIGURE 25 Console directory to show errors

### 5.3 Compiling Cross Platform

There are many devices in the market with different platforms which means the development kit used must deliver to as many platforms as possible. The most used platforms are Android, iOS, Windows, Xbox, and PlayStation. For this project, and Android device is used to show how Unity combines different platforms to work with few simple steps. Rest of the devices can also be configured with similar process with little or no changes. There are few things needed to be added before building the final applications which are covered in the following chapters.

#### 5.3.1 Build Setting

The very first step is to download the module for the platform required to deploy. From the main scene of the project, clicking in the file from menu and selecting build setting will give the user to select the deployment platform. If no modules are loaded, then it can be downloaded with an opportunity to open

download page button otherwise the developer can start by clicking the player setting and defining appropriate settings. (Figure 26) In the player setting, unique application name, icons must be defined according to the developer, otherwise a default unity logo will be loaded. The most important option to be selected in player setting is the Vuforia Augmented Reality which should be checked in XR settings.

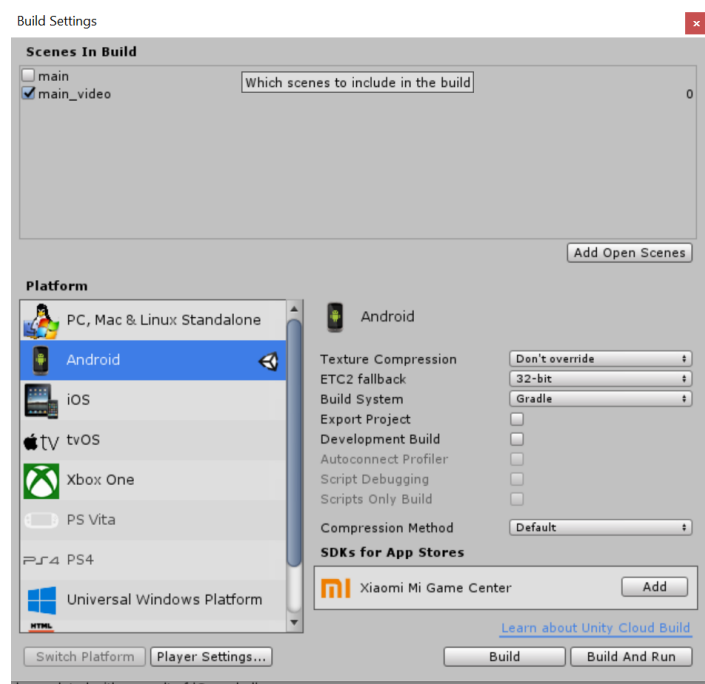


FIGURE 26 Build Setting

### 5.3.2 Android SDK/NDK Set-up

Android SDK/NDK is required to be download and installed before building the application for Android devices. SDK is the main development kit for Android, it contains tools for java for compiling, packaging to an APK file, debugging and emulators. NDK is a set of tools to compile C code to share the library which are used in the application. NDK also helps to access the device's hardware components like camera, sensor, and touch. NDK tools can be download within the SDK application. NDK helps to reuse other developers or own C or C++ libraries. In Unity appropriate installed path of SDK and NDK must be given after installing (Figure 27). This can be achieved by selecting edit option from main menu and then preferences and External Tools. To download the SDK and NDK, the download buttons can be used. (Figure 27)



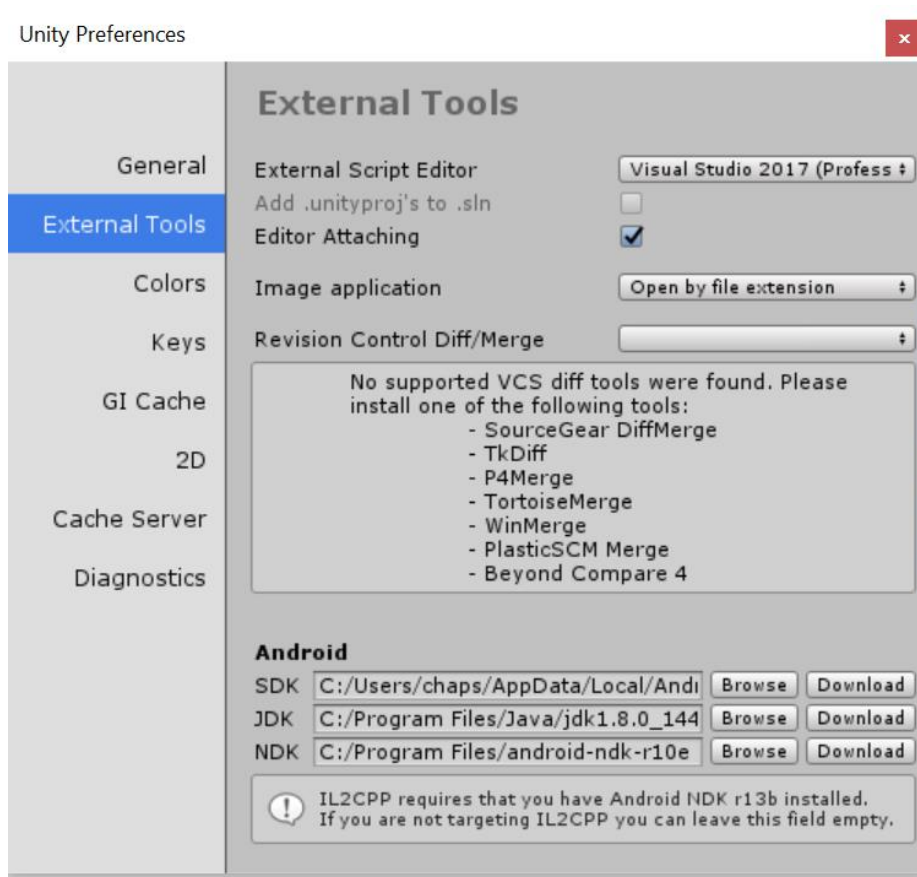


FIGURE 27 SDK and NDK Set up

## 6 TESTS AND RESULTS

Testing enhances the quality of the products. There are various types of testing in an application development process. Good practice of testing is to engage someone from outside the development to test the application. Gathering the test result and creating a report that benefits developers to excel the quality of the product. In AR applications there are few different steps to test either the application is functioning precisely or not. The following chapters will cover the methods of testing an AR application's functionality.

### 6.1 Target Recognition

In Vuforia, target images with enough feature points are easily targeted by the camera. Features points were discussed in chapter 5.1.2 and Figure 15 shows the image with enough feature points to track the target image. The development system itself was used for the first test purpose, and the result was quite satisfying but all the functions were not feasible with computer. Therefore, application was deployed to Samsung's Android device with latest version of Android software. The MobileJoystick function was working smoothly, and image target was recognised with no lags. The only problem found was if the image target was folded or if the image target was pointed in wrong direction to the camera, the target image was detected poorly, and the augmented object was coming in and going out all the time. During the development process few different types of target objects were chosen, one with blank white paper, image of carpet with shredded lines, top of a simple brown furniture and a yellow paper with pictures and a lot of letters. The only successful result was acquired with the yellow paper because of its feature points, all the pictures edge and letters edge can act as a feature points for Vuforia's target images while rest of the chosen image objects did not have enough feature points with similar patterns (Figure 28).



FIGURE 28 Target Detection

## 6.2 Trackability

Trackability test is another most important part of testing in this project. As this is a different type of application which works based on augmentation. The main test required is the distance of Trackability and maximum movement of the object around the environment. Samsung Galaxy s7 was used to test the application and during the test process it was found that the maximum distance of 278 cm was augmented smoothly. The good feature of Vuforia is the object can even be augmented to normal surface if the part of target image is in the surrounding. This means the bigger the device used for tracking the wider the object can cover in the surrounding. The object can even move freely outside the target image if the target image is around the environment. Theoretically, the Trackability of the object only depends on the contrast of the target image and the angle of incidence.

## 7 CONCLUSIONS

The aim of this thesis was to demonstrate the basic usage of Vuforia and Unity 3D to make an application. There is no limitation in development of the quality of the application with these platforms but because of the short time frame, focus was switched to the background and basic usage of the software. The application was also developed from the scratch but with help of open source objects.

During random meetings with the research department, this topic came to the list. There were many topics to choose for the thesis, but the reason to choose this topic among all other was the uniqueness of the topic and robustness of the augmented reality in the current situation. The sample application development process took around three weeks because Vuforia was totally unknown platform. There are many blogs and official community of Vuforia and Unity to help for the beginners.

During the beginning of the research process for the thesis, the older version of Vuforia 6 was used which was not integrated with Unity. The development process was moreover similar but the configuring method alongside Unity was different. But, during the documentation process of the thesis, new version of Vuforia was released which was Vuforia 7 integrated with Unity 3.0. So, the configuration process in this project was also shown according to the latest version of Vuforia and Unity.

In conclusion, the trend towards the use of augmented reality is growing rapidly in various sectors. With the general concept of augmentation, Vuforia or any other software can be useful depending on the user requirements. There are few setbacks using Vuforia which were already discussed before. Moreover, during the few months of this project, a lot of interest from developers towards Vuforia was seen.

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