Effective Learning Tool Using AR for Knee and Foot Anatomy Based on CT Images 3D Reconstruction

By

Liew Set Lee

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF COMPUTER SCIENCE (HONS)

Faculty of Information and Communication Technology

(Kampar Campus)

JANUARY 2020

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Date: 24/4/2020

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DECLARATION OF ORIGINALITY

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Signature : 

Name : Liew Set Lee

Date : 24/4/2020

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Finally, I must say thanks to my parents and my family for their love, support and continuous encouragement throughout the course.

ABSTRACT

Anatomy is the branch of biological science in medical education that focus on structured part of any living beings. While human body anatomy is an important chapter in any Biology subject for students of secondary and post-secondary education in Malaysia. Traditional methods and materials of learning human body anatomy usually available in the form of textbooks with pictures and photos and artificial anatomy mannequins. There are still not enough and hard to help students in understanding it with actual and accurate knowledge and images about our human body anatomy. This is because students are hard to imagine the reality structure of human anatomy body part and lack of interaction through the 2D images on the textbooks. Although there are artificial anatomy mannequins available and provided to access by the students in the school or university, it is limited in number of the mannequins due to its expensiveness and thus students need to queue to access the mannequins among the class. Besides, students are not able to access the artificial anatomy mannequins when they study and do revision out of the school time. Moreover, some of the students are facing difficulties in understanding 2D images on the textbooks as well, making them hard to understand and acquire the knowledge as fast as possible in learning the structure of human anatomy body part.

Therefore, a project titled “Effective Learning Tool Using AR for Knee and Foot Anatomy Based on CT Images 3D Reconstruction” will be study and develop to overcome those issues and problems. An AR learning knee and foot anatomy application will be developed through medical 3-dimensional(3D) reconstruction based on medical images. Incremental development model will be involved in this project. The purpose of this project is to provide an alternative learning method for student to study the complex structures of human body anatomy in more effective and more interactive way with the mobile computing platform.

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LIST OF ABBREVIATIONS

2D	2-dimensional
3D	3-dimensional
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
AR	Augmented Reality
VR	Virtual Reality
MITK	Medical Interaction ToolKit
FYP	Final Year Project
DCM	Dilated cardiomyopathy
GPS	Global Positioning System
UI	User Interface
GUI	Graphical User Interface
APK	Android Package Kit
STL	Standard Tessellation Language

CHAPTER 1 INTRODUCTION

1.1 Background Information

Human body anatomy is an important chapter in any Biology subject for students of secondary and post-secondary education in Malaysia. Traditional methods and materials of learning human body anatomy usually available in the form of textbooks with pictures and photos and artificial anatomy mannequins. There are still not enough to help students in understanding it with actual and accurate knowledge and images about our human body anatomy. This is because students are hard to imagine the reality human anatomy body part and lack of interaction with the 2D images on the textbooks. Although there are artificial anatomy mannequins available and provided to access by the students in the school or university, it is limited in number of the mannequins due to its expensiveness and thus students need to queue to access the mannequins among the class. Students are not able to access the artificial anatomy mannequins when they study and do revision out of the school time. Besides, human anatomy make students have less motivate to learn due to lack of interaction on its complexity of the anatomy structures on the textbooks with 2D images. Moreover, some of the students are facing difficulties in understanding 2D images on the textbooks as well, making them hard to understand and acquire the knowledge as fast as possible in learning human anatomy body part.

Figure 1.1.1 Anatomy Mannequin

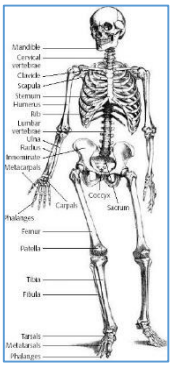


Figure 1.1.2 Anatomy on the book

Therefore, Augmented Reality (AR) is a technology which combines a 3D thing into real- time virtual environment interactively in order biology students easy to understand, acquire and remember the structure and the information of the human anatomy. Besides, apply AR in learning human anatomy can be more interaction between students and the real 3D objects so that student can self-learning without teachers or educators. With the AR-aided educational materials, students can learn even outside the classroom anywhere and anytime as well.

1.2 Problem Statement and Motivation

In this modern era with easy-access mobile technology, primary and secondary students are still using the traditional textbook method in learning complex human anatomy body part with 2D images and 3D human anatomy mannequin in the classroom. The motivation to develop this project is to solve the problems that are faced by the students who are learning the human anatomy body parts. The purpose of this project is to solve the problem for those students who facing difficulties in 2D learning human anatomy images on the textbooks and to provide an alternative and interactive method in learning human anatomy efficiently as well. Hence, an AR application for learning human anatomy with medical 3D visualization and segmentation through MRI and CT dataset. Several problems make this AR application of human anatomy with medical 3D visualization and segmentation more significant:

i. Difficulties in understanding human body anatomy structures, which are too complex and complicate to obverse through 2D images.

   Traditional material for learning human body anatomy with textbooks and anatomy mannequin is less interactive between students and the study materials. Learning complex human anatomy through 2D images in the textbooks is tricky. Although the 3D anatomy mannequin is available but students still need to refer to the textbooks mannequin to get the text information and knowledge at the same time using the mannequin. Besides, students need to queue for using the mannequin due to limitation in number and students only allow using the mannequin during school time under supervision of the teachers. Therefore, students are easy to access and more understand the complex human anatomy structures with this AR application educational material.

ii. Insufficient in sense of reality and accurateness of 3D human body anatomy in biology learning.

   The 3D images or objects display in AR are normally created by 3D graphic design software, so, it is not real and accurate compared from the real human body anatomy. Therefore, to display a high sense of reality of 3D human body anatomy rather than an artificial 3D drawing graphic by using graphic software. Hence, MRI and CT scan datasets are used in the process of medical 3D visualization and segmentation in order to get the most accurate and real 3D objects and apply in this AR application.

iii. The limitation of technology usage in AR in education system.

Most of the school in Malaysia are less access to and use AR technology in studying and learning process. Thus, students here are not familiar and used to the AR-based application in order to help in their study. With the aid of AR application, students can access the learning anywhere and anytime through the usage of the mobile devices.

1.3 Project Objectives

The main objective of this project is to propose and design a new application using AR technology to solve the problem in learning human body anatomy for students in Malaysia. The following sub- objectives are to support the main objective:

i. To enhance the acuteness of 3D human anatomy by replacing the 3D human anatomy, which made by graphic design software with the 3D visualization and segmentation of the medical data from magnetic resonance imaging and computed tomography gis applied to get the 3D visualization through segmentation method.

ii. To provide an alternative method or solution for students especially who have difficulty in understanding the 2D images of human body anatomy with the form of 3D practice. It enable students to fast understand and visualize the 3D views of the human anatomy in more interactive way.

iii. To enhance the interaction learning for the students with the 3D human body anatomy and the real-time environment using AR technology. Therefore, students can access and interact the 3D models anywhere and anytime.

1.4 Project Scope

The objective of this project is to develop an AR application for learning human anatomy from medical 3D visualization and segmentation. This application is mainly developed for students of secondary school who are taking biology subjects but normal students can use this application for acquiring basic anatomical knowledge as well. Human anatomy is one of the important topic in Biology subjects for our secondary school students and pre- university students. The structures of human anatomy are complex and difficult to fully understand and memorize by the students through the 2D images of human anatomy on the textbooks or anatomical mannequins. Besides, some of the students may have difficulties in visualizing 2D human anatomy structures from the textbooks and making them take much time to understand the subjects. Therefore, we need to think an alternative solution to solve the problem especially for those students who are learning human anatomy. The solution proposed in this project is using AR unity and Vuforia with 3D model human anatomy objects which are segmented and created through MITK from MRI and CT scan datasets.

First and foremost, before develop an AR application, the 3D model objects need to be create in order to be converted and applied with AR technology. In this project, MRI and CT scan dataset of human natural body anatomy are used in medical 3D visualization and segmentation processes in order to get the more accurate and more real 3D human anatomy model objects than using any graphic design software to draw and create a human anatomy part object from the sketch. For the 3D visualization and segmentation, we are using MITK (Medical Interaction ToolKit) technology with C++ programming language. Therefore, the 3D human anatomy body part will be more realistic and more accurate compare to the model that created with graphic design software.

After get all of the 3D human anatomy body parts from the medical 3D segmentation process, then AR technique is applied on those 3D model objects with AR unity and Vuforia. This application is developed with a feature that can view a 3D visualization of human anatomy structures. This function able to give a 360° angles and views of human anatomy body parts for fully visualizing and understanding to real structures.

Besides, the application is develop with Augmented Reality (AR) technology feature that can provide interactive function in learning the human anatomy. AR allow the views of virtual objects combined with the scenes from the real-time physical environments through the digital

devices with camera such as smartphones and tablets. This functions not only greater the interaction between the 3D visualization and the students but also enhance the motivation and interest of the students. For example, students can interact segmented anatomical structures by touching the screen and move the devices to see the 3D visualizations appear form different angles in the real-time. Besides, with the aid of the AR in the portable devices, students can learn thought this application anywhere and anytime.

Moreover, the 3D AR visualization must attach with a pop-up window with labels of anatomy part's name and details description information. This is much more convenient to the students from do not need to refer to the textbooks for details information and name of the part relatively. Finally, portable smartphone which including AR function is using in this project for the hardware parts.

The modules are included in this proposed application are:

Marker scan module

This module allows user to scan on the correct printed marker through the mobile device's camera and then AR human anatomy object will appear respectively on the screen of the mobile devices.

AR technology module

This module allows user to view the AR human anatomy model objects from 360° angles in real- time. Besides, user able to interact with the AR 3D anatomy model object with the fingertip gestures in order to fully visualize and understand the anatomy structures from different angles.

Labelling or pop out window module

This module allows user to know and view the parts of the human anatomy with respective biological naming and details description instantly. Therefore, user able to learn the anatomy part in more convenient and more clear without referring to the textbooks to Internet for the details description of anatomy parts.

1.5 Project Impact and Contribution

The innovation or contribution of this project is by making use of AR technology to implement the application in learning human anatomy for the secondary students and pre-university students who are taking biology subjects in Malaysia. Firstly, it can be an alternative method to enhance the motivation of the students in learning complex human anatomy rather than using 2D human anatomy images of traditional textbooks or anatomical mannequins. This is because learning with AR human anatomy object will stimulate and enhance students' intellectual curiosity and thus student have the sense of motivate and interest in keep learning and make the learning effective.

Besides that, learning human anatomy with AR application will provide more interaction for the students by using any mobile devices with AR features included. With the interactive study method, student not only have clear and better understanding of the complex human anatomy but also can increase sensory development of student. This is because AR providing more chance for student interacting by seeing, observing and feel the AR while learning the human anatomy.

Moreover, it also increases the interaction for students in learning 3D human anatomy at anytime and anywhere with the AR features using this application with mobile phones. This is providing convenience to the student who need to refer to the textbook or the anatomical mannequins. After applying this application, student able to study or revise the human anatomy anytime and anywhere without suffering in bringing the heavy textbook for refer or use the anatomical mannequins with permission in the school and limited time.

Last but not least, AR application is much more less cost than the educational materials such as textbooks and the anatomical mannequins. Students able to reduce the expense on buying repeated learning materials with just downloading the application.

1.6 Report Organization

In chapter 1, background information, problem statement and motivation to develop this AR application for learning human anatomy is discussed and stated. Then, the project objectives and scopes are identified based on the problem statement. Next, project impact, significance and contribution are discussed.

Chapter 2 will discuss about the literature review on the research paper or the existing system and the technologies in order to identify and analyse the strength, weakness and the recommendation for improving of each of the reviewed system. Besides that, a comparison table among the reviewed existing system is created and classified.

In chapter 3 the type of development model of system methodology is chosen, system requirement and functional requirement is stated. Besides that, system design including usecase, activity and sequence diagrams are drawn. Project timeline, expected challenges and expected system testing and performances are discussed in this chaper also.

Chapter 4 shows the preliminary work that I had done in this FYP, such as how to setup my own MITK software, using MITK to de segmentation for getting the 3D model object then applying 3D object with AR technology with Unity and Vuforia engine.

Chapter 5 show the System Implementation. How to make create an AR application using the 3D knee and ankle foot model and A APK file of this application is built and able to run on any mobile devices.

Chapter 6 show the result of this application, testing and last but not least the survey and questionnaires.

CHAPTER 2 LITERATURE REVIEW

2.1 Review of Technologies

2.1.1 MITK

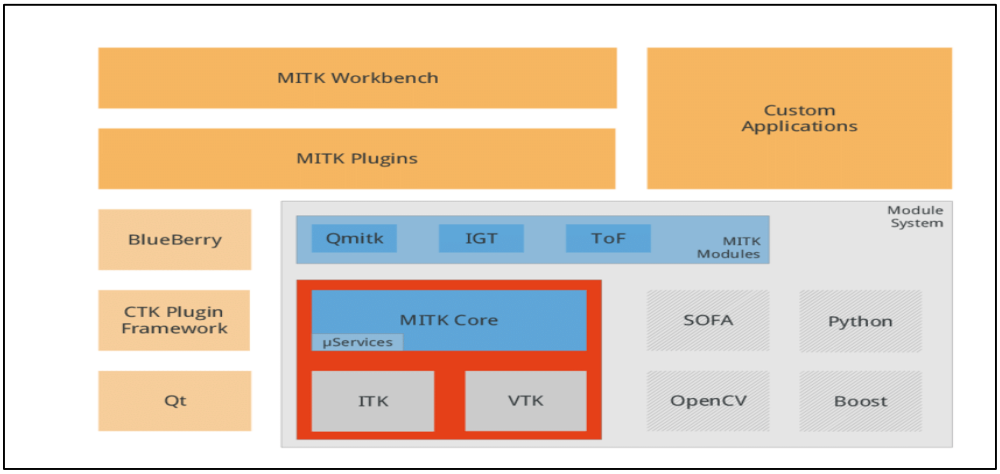


Figure 2.1.1.1: MITK architecture

Medical Imaging Interaction Toolkit is an open-source software for medical visualization and segmentation of human anatomy. The MITK Core extends ITK and VTK. For application level support, it provides Workbench which leveraged the BlueBerry application framework based on CTK Plugin Framework. It provides an easy to use superbuild for various of development scenarios and many customization of tools and plugin options. The core features of the MITK includes of multiple and consistent displays on the same data file, interaction mechanism with the toolkits, load and save of the application data in a datastorage including all item properties. The segmentation application in MITK providing underlying toolkit with mouse click and gestures; supporting 2D, 3D and 3D+t; 2D and 3D segmentation editing tools and interpolation functions. MITK using DICOM reader to supports file types such as DCM of MRI and CT scan.

2.1.2 Type of dataset

In this project, data from MRI and CT is taken to makes into 3D with the precise dimension. There are two type of scanning technologies to take imaging of human which are CT scan and MIRs.

2.1.2.1 MRI (Magnetic Resonance Imaging)

MRIs are using powerful radio waves and magnetic fields to produce detailed images of objects inside the body. Therefore, MRIs provide more detailed pictures of the inner organs such as organs of skeletal and reproductive system than CT scan. It is more suitable in helping doctor to determine different between the abnormal and normal tissues in the body. Both magnetic field and radio frequencies will bounce off water and fat molecules of body. MRIs take more time and noisy and cause user anxiety due to being enclosed in the machine. The body part that use MRIs are joints, bones, ankles and hearts.

2.1.2.2 CT (Computed Tomography)

CT scans are utilizing radiation(X-rays) to take cross-sectional images of body organ. It is a combination of a series of X-ray images what taken at various angles and then utilizes those X-ray to form a 3D image of the organ. Images produced by the CT scan are not as detailed as MRIs but it CT scan is more quick, painless and non-invasive to provide images of tissues, organs and skeletal structure. CT scan is more wisely used due to less expensive than MRIs but it may harm to unborn babies due to small dose of radiation is used. It used to captures detailed information of bones, eyes, neck and shoulder with the help of X-ray beam.

2.1.3 AR

AR (Augmented reality) is different from VR virtual reality which create an artificial environment to replace the real world and the user is needed to use of some equipment before engage the VR content such as VR spectacles, but AR are not. AR's goal is to enhance the user perception of the surrounding by displaying relevant information on the existing live real world environment at real time and location. The technology used in AR are recognition of image or object; tracking the real-time localization through the mobile device camera; superposition which mix the media AR objects on top of the image or the real-time location.

I. The camera will turn on and detect and capture the image by using image processing and recognition.
II. If valid and correct image detected then, the AR object will show on the virtual object or environment and display through the screen.

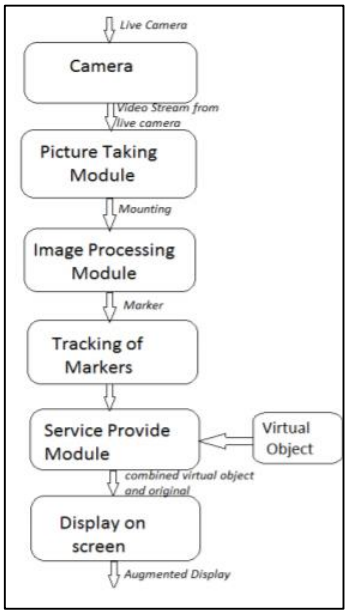


Figure 2.1.3.1: AR workflow

Type of AR

2.1.3.1 Marker-based

Marker-based AR/ image recognition uses the camera feature of mobile devices to detect, analyse and capture the unique visual marker from the real environment. This experiences is not spontaneous due to the marker-based AR is handled exclusively by requesting user to first download and print the marker then prompt user to scan and capture on the printed marker in

order to show the AR object in virtual environment. The example as a marker is QR code or 2D marker with more features on it so that the camera of mobile devices able to detect and recognize the marker easily. Therefore, it is used on the mobile devices to distinguish a visual marker with any other real world object.

2.1.3.2 Marker-less

Mark-less such as location-based, position-based or GPS AR by using phone sensors or features such as GPS, compass, accelerometer to provide data based on the location of the mobile devices. This type of AR usually used for direction mapping or finding the location application which are needed to interact with the real-time surrounding of the user. Besides, it performs active tracking and recognition of real world environment without using any placed markers. ARKit of Apple and ARCore of Google are the software development kits to implement markerless AR technology.

2.1.4 Unity

Unity is a cross-platform engine to develop game application for various of 27 platform such as IOS ,Android or websites. It provides many resources such as editing tools, ready-made assets which allow to download through the Unity assets store, clear documentation and tutorials to users. The features of Unity are rendering, asset tracking and adding script in order to reduce the time and the cost of development. The reason why Unity is chose to be used in my project is because it supports up to 27 platforms, its IDE editor supports JS and C# for scripting, the quality of the audio and visual effects is high, documentation is clear to understand and easy debug. On the other hands, it may have its weakness such as unity used up more memory storage, some of the features or actions need to be licensed with payment and the engine lacks of some advanced functionalities.

2.1.4.1 Vuforia Engine

It is an engine for creating augmented reality application. After downloaded the Vuforia Augmented Reality SDK, developer able to select Vuforia Augmented Reality Support in Unity software component selection when installing Unity in order to apply Vuforia engine in Unity. It able to recognize and track image target and show 3D objects in real-time by using computer vision technology. Its SDK supports both IOS and Android platforms for developing AR application in Unity.

2.1.5 Android Studio

Android Studio is a mobile operating system of Google and an official IDE (Integrated Development Environment) for developing application for Android platform. It used to design for the touchscreen-based application on the mobile devices. There are two languages Java, and Kotlin in which android native apps are developed. It has an editor tool for developing nice User Interface, many different version of emulators function as virtual machine for testing the application without having the actual Android devices. Application files (.apk) with different configuration is created and able to export then upload on PlayStore in order to deploy the application. Android is an open source platform and more easy to deploy an application than IOS platform. Therefore, Android is a good choice to implement an application or a system.

2.2 Review of the Exiting Application /System

2.2.1 An Interactive Augmented Reality System for Learning Anatomy Structure

Anatomy is most important courses in medical education. Due to the reduction of medical course hour, the anatomy education with 3D visualization technology has being brought into a new world.

Chien, C. et al. (2010) aim to utilize AR technology to create an interactive learning system. It helps medical students to more easy in memorizing and understanding the 3D anatomy structure with tangible AR support. In this study, they worked directly with 3D skull models with visual support AR. The examples of image technology are from magnetic resonance imaging (MRI) and computed tomography (CT) transform into 3D visualizations. For AR technology that offers an innovative learning environment by merging digital learning materials into the real physical space. Due to the complexity of the skull structure, this research used AR technology to create an interactive learning space, which allowing students to understand the 3D skull with visual support. It consists of a clear pop-up labelling information to the 3D model with 360° views which students not only do not need to check textbooks or other resource to get information but also can get different angle and position of the model. Besides, students can disassemble, assemble and manipulate the AR skull. For using this AR system, students need a computer with webcam and a marker. After the experiment on the student trial, this system able to enhance students' spatial memory by identifying the related position of skull, to help medical students to learn and interact the complex skull anatomy structure better and faster.

In my point of view, this system is providing more interaction AR technology in learning human skull anatomy with pop-up windows of related detail information. The system should be user-friendly, attractive with different colors and more sense of reality in order to improve the usability of the young students.

2.2.2 Segmented and Detailed Visualization of Anatomical Structures based on Augmented Reality for Health Education and Knowledge Discovery

The evolution of technology has changes the education system especially health field. The augmented reality (AR) and the interaction design techniques able to help in teaching for the medical training procedures and exposition of theoretical concepts. Besides, traditional teaching method for anatomy with real anatomical parts or 2D atlas is challenging than using 3D visualization with high resolution and AR.

Silva, I. C .S. da. et al. (2017) discuss solution about the use of AR and interaction design as a tool in teaching anatomy to visualize segmented anatomical structures for knowledge discovery based on mobile application. This AR application can display targeted parts with details of its parts for interaction with them in real time. This system helps students learn anatomical details and provides the enhancement of 3D structures which cannot be replicated by 2D atlas. With the aid of the AR technology, students learn the complex structure of anatomy in better and faster way than traditional way. This because AR with mobile devices allowing greater flexibility of interaction with virtual environment. This AR mobile application is using marker-based, intuitive and easy to use interface. For the 3D models were built in Blender software or obtained from public repositories, it consists of four main views: simple anterior and posterior views, detailed anterior and posterior views. However, it identified the response time of such tools that coupled with the quality of 3D models does not improve their use in the classroom by teachers. Besides, it is not found any solutions that allowing the combination of AR with the segmented imagery of 3D anatomical parts support for use in mobile application. Besides, there is not found a solution that allow combination of AR to the segmented visualization of 3D human body anatomy which support on mobile devices.

Through the validation experiment, this application is fulfilling its purpose of offering an intuitive interaction with 3D and AR representation of human bone. Besides, it is more efficient than traditional teaching method and user- friendly.

In my opinion, this AR mobile application is a good idea of providing 3D human anatomy for students to interact them in the real time. Besides of this function, it should have a detail information window or interface to describe the relative parts of the bone instead of just the name labelling. Therefore, students do not get distracted from referring the information through the textbooks for more details information.

2.2.3 Web based Augmented Reality for Human Body Anatomy Learning

Human body anatomy is an important topic in Biology subject for junior high school students. The ineffectiveness of learning materials such as in the form of textbooks and anatomy mannequin are not sufficient in helping student to understand human body in details.

Layona, R. et al. (2018) provide a solution by developing a web-based AR application for learning human body anatomy with 3D object features. This paper proposed the application in form of webpage which can be embedded on mobile application, using Google Sketchup and 3Ds Max 2011 for 3D object modelling, ActionScript 3.0, C# WFC template(Windows Presentation Foundation) for application development and Kinect XBOX 360 and AR marker are physical tools used.

To solve the visualization difficulties, AR application is displaying virtual 3D objects in real environment. Students can visualize the body anatomical in more reality through the 3D anatomical objects in the live environment. In this paper, web-based AR application is developed for learning of human body anatomy. This is because web-based is more easily accessible with computers, mobile phones and tablets. Besides, web-based is providing independent interface to billions of sources. It is means that various operating system of mobile platform can access the web application though online- devices. The software development method for this application is waterfall method. However, this AR application require to download and print the specific designed maker out before using the AR technology in order to display the 3D images in the real-time environment. Besides, the 3D anatomy models are created by using software instead of segmentation from real anatomy data.

In my perspective, this web-based AR application is good for young students who are taking basic biology subjects for improving the interactive in anatomy learning. Nevertheless, it should include the labels of relative parts of human body anatomy with details information. It can improve by providing interaction without maker.

2.2.4 Utilising Mobile-Augmented Reality for Learning Human Anatomy

Mobile-Augmented Reality (mAR) technology enhance the opportunity of student to gain improved access to the subjects. It facilitates students in learning complex human body anatomy. Besides, it can solve the problem of difficulty for student in recalling the subject matter after the practical session. mAR learning tools enable students easy access to the information through mobile devices and enhances the learning environment as well.

Jamali, S. S. *et al.* (2015) discuss the development of a prototype educational tablet application named with Human Anatomy in Mobile-Augmented Reality (HuMAR) that utilizes AR technology. This application is implemented as a learning tool which runs on Android tablet with a multimodal function which able to facilitate a better interaction with 3D objects. This prototype application is selected focus on learning the bones of the lower appendicular skeleton. It also runs similar to a courseware-based application or educational software as a learning and teaching material in the classroom. The features of HuMAR including navigation buttons, details information about the subject matter and hyperlinks. This prototype application enrich learning, foster motivation, improve the learning outcome in skeleton anatomy by creating interactivity with the system. Tablet's camera need to detect and recognizes an assigned marker in order to display the 3D AR objects using this HuMAR. 3D modelling techniques used in this HuMAR is transforming the bone photos in 3D with Studio Max, version 2013 software while for the AR extension is using Vuforia software platform and last all the functions of such as bone placements onto marker and finger interactions were designed with Unity3D.

In my opinion, this prototype HuMAR application easy and simple to access the 3D AR objects. It would be better that the 3D objects able to display when the camera capturing the human body parts instead of assigned marker. Besides, it should provide more details information with attractive interfaces in order to pleasant students to use it.

2.2.5 Human Anatomy Learning Systems Using Augmented Reality on Mobile Application

Learning human body anatomy with textbooks and plastic models are difficult to understand by the students. The AR technology is very useful for such learning field. It can be used as an replacement learning and teaching tool which helps to shape a 3D visualization. Besides, it provides mobility for students in learning so that they can learn anytime and anywhere.

Kurniawan, M. H. *et al.* (2018) proposes a solution using AR technology to help students in learning the 3D visualization of human body anatomy by utilizing the interactivity capability. They designed an android-based AR application as a tool for students to study human anatomy via 3D display on the assigned marker. The researchers used android studio with JAVA language. This is because android studio is designed specifically for the development of android platform and it is compatible to various AR engines. AR with the Unity and Vuforia AR frameworks are used to made for the mobile platform. This application showing 2 options of 3D visualization: outer layer of the skin and internal organ. Besides, the design interface of AR application is interactive and interesting in learning. The data descriptions used in this application are obtained from various books. This AR mobile application is creating a better interest in learning human anatomy visually and fulfilling student's desire to choose this as learning tools. It can help medical students and high schools student in learning human anatomy. However, the AR 3D display is not labelled relatively with name of the parts.

In my point of view, this application is easy to use and understand by the students for the basic biology knowledge but it is not suitable for high school or medical students. This is because the visualization of the human anatomy are not details enough and it is lack of labelling of the relative parts of the organs. It should be better and convenient to display the 3D images without detecting the marker.

2.2.6 Comparison of solution in learning human anatomy from different research

Authors/ researchers	Chien, C. et al.	Silva, I. C .S. da. et al.	Layona, R. et al.	Jamali, S. S. *et al.*	Kurniawan, M. H. *et al.*
Type of AR					
Marker-Based	/	/	/	/	/
Markerless					
Location based					
3D Modelling					
MRI and CT data	/				
Others graphic software		/	/	/	/
Parts of anatomy to display	Skull anatomy	Bone	Body anatomy	Lower appendicular skeleton	Body and heart
Application/ system	System	Mobile application	Web-based application	Mobile application	Mobile application

Table 2.2.6.1 Comparison of solution in learning human anatomy from different research

2.3 Concluding remark

This chapter had reviewed the technologies that I need to acquire in order to implement this project and the existing application which are done by other researchers. There are 4 type of applications and one system I have been reviewed with. Throughout the literature review, the advantages and disadvantages of the technologies used in this project and the existing application are found and identified. Besides, some of the opinion of recommendation of mine have stated at the end of each of the review. Therefore, it will be a direction and objective to implement and improve in my proposed application.

CHAPTER 3 PROPOSED METHOD / APPROACH

3.1 Incremental Development Model

Methodology that used in this project is incremental development model. This model is the most suitable software development approach in this project because of several functionalities in this system. Generally, the functionalities (requirements) of this system are firstly broken down into several parts that can be constructed and delivered incrementally. Therefore, it is easier to modify the several parts of the requirements incrementally. The core features of the system are first developed then, increase the levels of capabilities by adding new functions successively. Incremental development model consists phases of outline description (planning), specification (requirement), development, and validation. For the phases of specification, development and validation are carried out concurrently. These three phases are iterated until a final version of system is deployed. During the concurrent activities, the successive of system is constructed and delivered, at the same time, the feedback of the user is taken and these are then incorporated in the next iteration. Each iteration of the system have more additional features over the previous ones.

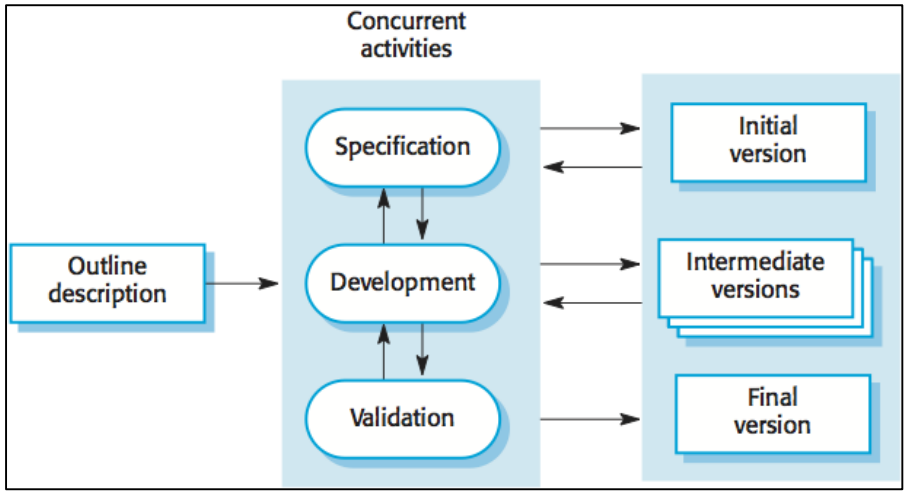


Figure 3.1.1: Incremental Development Model

Outline Description

The incremental development model begins with outline description phase or knowns as planning phase. The user requirement analysis and outlines are defined in this phase. Requirements for designing and developing an AR application for learning human anatomy are gathered through studying several journals or research papers and interviewing the user. After

that, collected requirements need to be defined and analyzed in order to have a mindset of what is the demand of the users towards this learning application.

Specification

Based on the selected features in this system, several system architecture patterns are chosen to design for this system in this phase.

Development

Each system increments are developed one by one through coding in this phase after choosing the suitable architecture patterns for each increment of the system. Thus, all the features and functionalities are included in the end of this phase and the application system are able to perform the requirements.

Validation

Validation of each system increments are done one by one iteratively. Then, the successful system increments are integrated together into a system and the final system is deployed at this phase. Final validation is done on the final system at the last step of incremental development model. After that, the final system is completed and can be deployed to the market. However, the maintenance of the system will be done in order to meet the user requirements in the future.

3.2 System Requirement

3.2.1 Hardware

The hardware involved in this project is computer and android mobile device. A computer is used for the process of 3D visualization and segmentation from MRI and CT datasets to obtain the 3D model objects, then it also used for applying AR technology on the 3D model objects. A mobile device is used for testing and deploying this AR application in learning human anatomy. The specification of each of the hardware used are shown in below:

Computer

Description	Requirements
Name	Asus A556U series
Processor	Intel CoreTM i5-6200U CPU @2.30 GHz 2.40GHz
Operating system	Windows 10
Graphic coprocessor	Intel HD Graphics 520
Ram	8.00GB
Hard Drive	1TB HDD 5400rpm
System type	64-bit Operating system, x64-based processor
Interface	2x USB 2.0 ports
Audio	Built-in 18W Stereo Speakers with Microphone

Table 3.2.1.1: Computer Specification

Mobile device

Description	**Requirements**
Name	Samsung Galaxy C9 Pro
Model number	SM-C900F
Processor	Qualcomm Snapdragon 653
Operating system	Android v6.0.1 (Marshmallow)
GPU	Adreno 510
Network	2G, 3G, 4G/LTE
Memory	64 GB
Sensors	Accelerometer, GyroSensor, Geomagnetic Sensor, Proximity Sensor, RGB Light Sensor
Battery capacity	4000mAh

Table 3.2.1.2: Mobile Device Specification

3.2.2 Software

The software include in this project is MITK (Medical Imaging Interaction Toolkit), Unity with Vuforia Augmented Reality SDK

3.2.2.1 MITK

In this project, MITK is used for importing DCM file of MRI and CT dataset to do visualization and segmentation in order to get the accurate and precise of 3D human anatomy part.

MITK GUI Overview

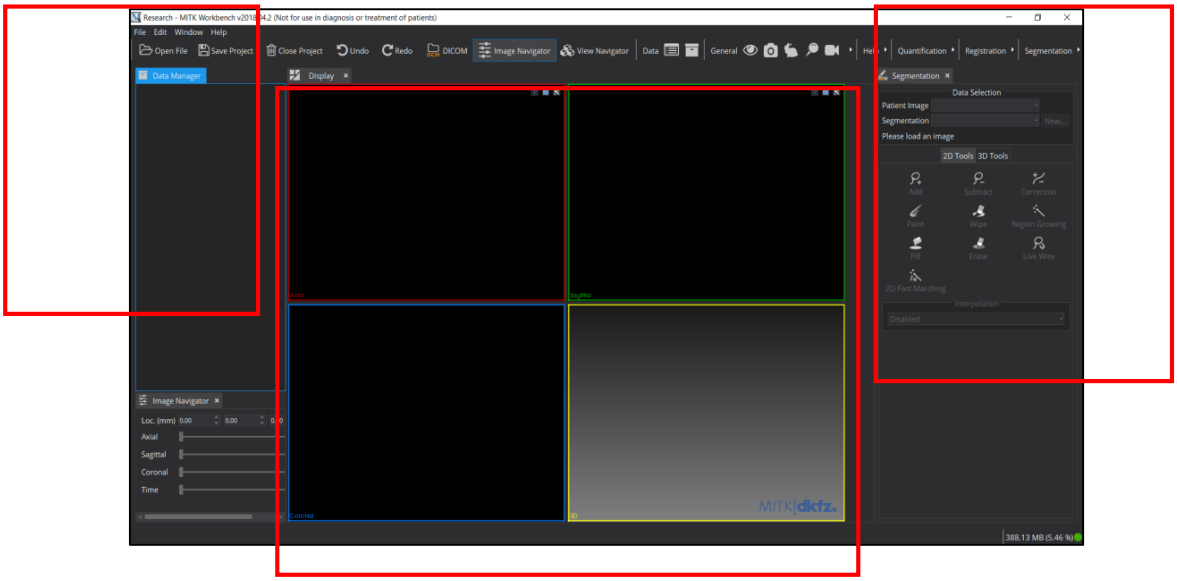


Figure 3.2.2.1.1: MitkWorkbench

The left red box area of Figure 3.0 is Data Manager is manage medical data which will show the file you imported or created such as DCM file and segmentation file in the 4-view windows. MITK supports lot of file formats: DCM, IMA, PIC, STL,VTK and MPS. Besides, you able to select the data file to display in the 4-view windows by clicking the checkbox. The file created allow to Reinit and adjust the opacity in order to ease process of segmentation and visualization.

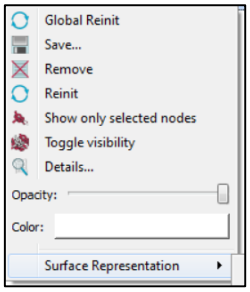


Figure 3.2.2.1.2: Properties of the data file (images, 3D model) in Data manager

he middle red box area of Figure 3.0 is four-view windows display. The 4 type of windows display consists of three 2D and one 3D window. Top left is 2D Axial window, top right is 2D Sagittal window, bottom left is 2D Coronal window and the bottom right is 3D window.

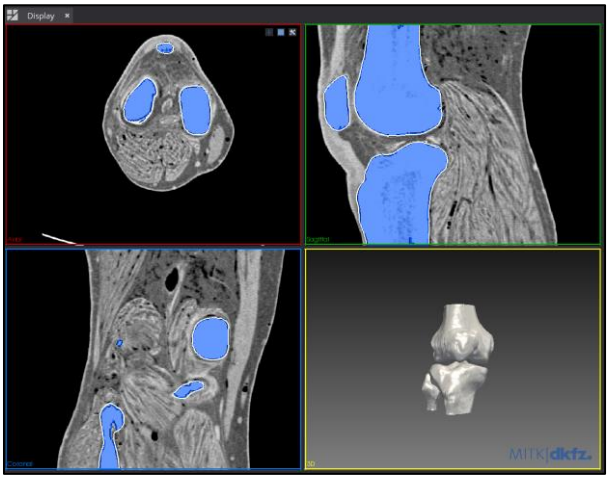


Figure 3.2.2.1.3: 4-view windows display

The right red box area of the Figure 3.0 is segmentation tools which consists of few 2D and 3D tools. The 3D tools used is UL threshold which segmentation according the pixel values within the interval of the threshold; 2D toold used are Add tool to add the segmentation part, substract tools to remove the inwanted or incorrect segmented part and fill tools to fillup the missing segementation part.

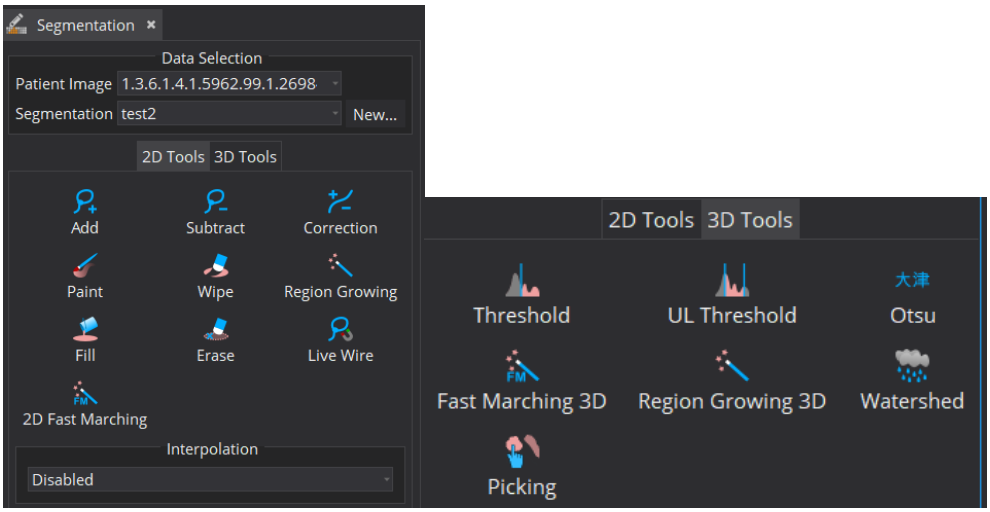


Figure 3.2.2.1.4: Segementation tools

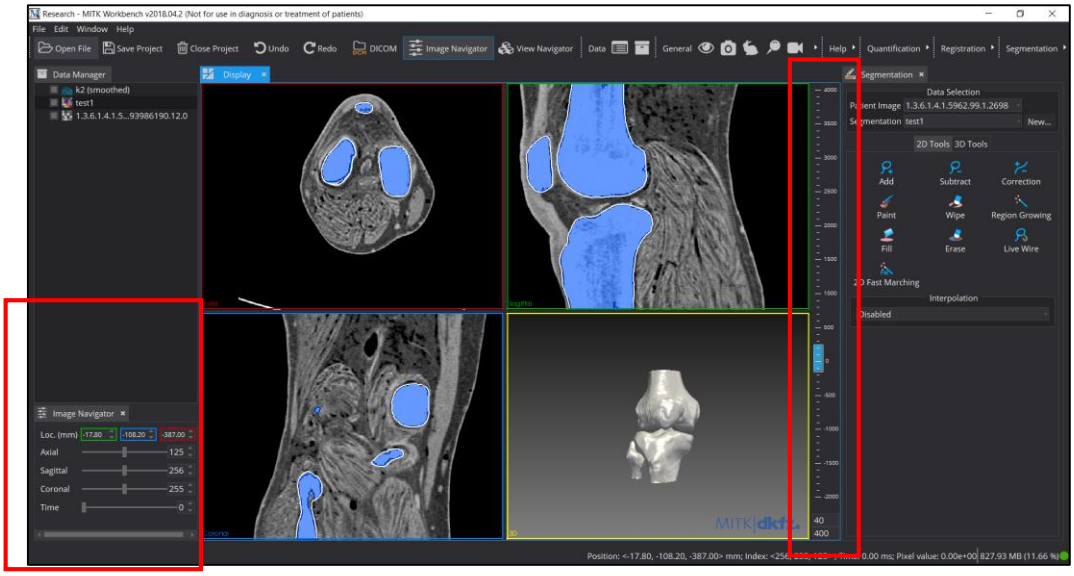


Figure 3.2.2.1.5: segmentation of knee anatomy

The red box on the left bottom of the Figure 3.4 is image navigator to control the view of the 4 windows display with Scrollbar of Axial, Coronal and Sagittal for all the slices of the DCM file.

The right red box of the Figure 3.4 is the level window to control the scale in order to see the part of the anatomy you wanted by controllin the grey value.

3.2.2.2 Anatomical Plane

There are three planes to indicate how to scan and capture the images of human body anatomy respectively.

Coronal (frontal) plane is vertical and dividing the body part into front and back sections.

Axial (horizontal/transverse) plane is horizontal and dividing the body part into top and bottom sections.

Sagittal (longitudinal) plane is vertical and dividing the body part into left and right sections.

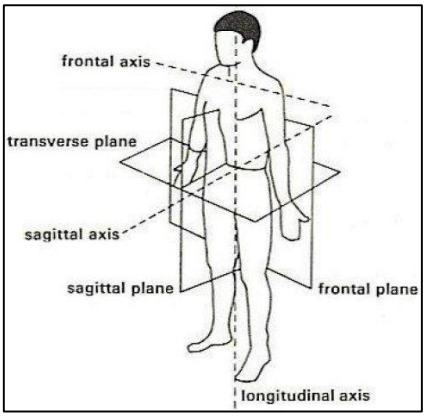


Figure 3.2.2.2.1: Anatomical Plane

3.2.2.3 Unity with Vuforia

In this project, Unity with Vuforia engine SDK is used to apply AR technology on the 3D model human anatomy in order to appear in virtual environment and enhance the interaction with AR object. In this project, I have done until displaying the AR body anatomy on Unity testing without any function yet. The process of applying AR are discussed in the chapter 4.

3.3 Functional Requirement

Marker scan module

- The application shall prompt user to capture the visual marker image.
- The application shall allow user to download the marker images.
- The application shall detect the marker image with mobile device's camera.

AR displaying module

- The application shall only response to the correct and unique visual marker image.
- The application shall only display the respective AR object on the respective correct marker image.
- The application shall allow user to interact with the AR object display on the mobile devices' screen after detected the marker with fingertip gestures.
- The application shall display AR object in the real-time existing environment which tracking by the camera of the mobile devices.
- The application shall show the 360 angles of the AR objects to the users with textures of the AR object.
- The application shall show the AR object which able to rotate itself to the user after the button clicked.

Labelling or pop out window module

- The application shall show the biologically naming labels of the anatomy part respectively to the user.
- The application shall show a details information of the anatomy part to explain and describe the respective part to the user with a pop out window.

3.4 Non- functional Requirement

Operational Requirement

- The application shall able to run on the mobile devices.
- The application shall able be access the camera features of the mobile devices.
- The application shall able to make use and access the sensor features of the mobile devices such as accelerometer.

Security Requirement

- The application shall not direct user to the dangerous and inappropriate existing real world locate on or environment in order to display the AR in the screen of the mobile device.

Usability Requirement

- The application shall be user- friendly, easy to learn and useful to the user.
- The application shall display the correct AR object with precise 3D body anatomy part according the correct valid visual marker image.

Performance Requirement

- The application shall able to navigate user in order to display the AR on the screen of the mobile device
- The application shall able to have redo function or reset function if user want to cancel the action.

3.5 System Design

3.5 Proposed System

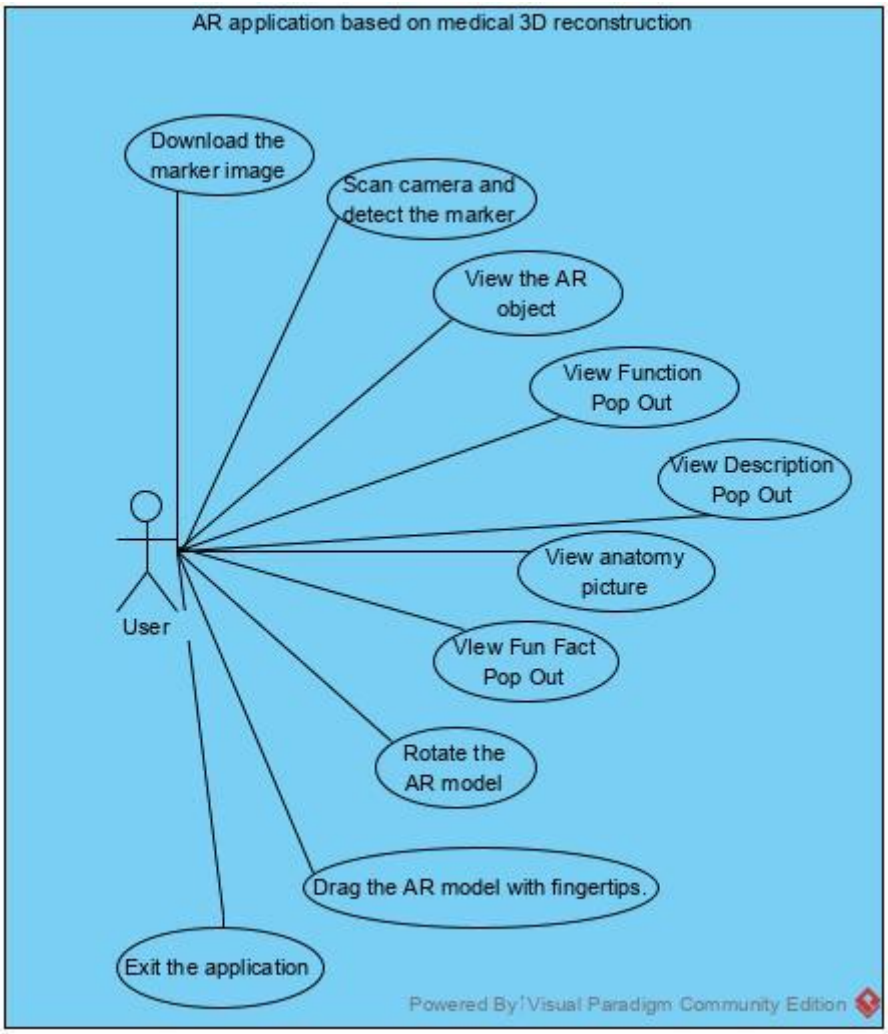


Figure 3.5.1: Use Case Diagram

The figure above shows that the use case diagram of this AR application system for learning human anatomy. The user able to download the marker image in order to scan and detect with the AR application along the camera of the mobile device. User able to get the AR object displayed on the screen if the marker image is detected correctly and successfully. After the AR object shown on the screen with the virtual environment successfully, user able to interact with AR object with fingertips gestures in order to fully view the structure of the 3D anatomy in various angles. Besides that, user also able to view the details information and explanation of the particular anatomy after user function button and the description button. Lastly, user also able to exit the application.

3.6 Functional Modules of the application

3.6.1 Activity Diagram

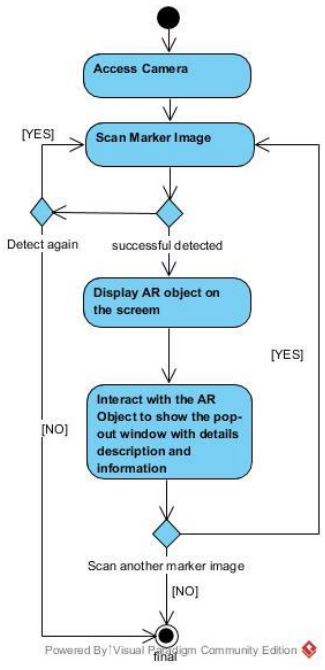


Figure 3.6.1.1: Activity Diagram of AR application for Learning Human Anatomy

Figure 3.8 shows that activity diagram of how AR Application for Learning Human Anatomy. After open the AR application with accessing the camera, user will scan on the printed marker image. If the marker is detected successfully then the AR object will display on the screen of the mobile devices. Then the user able to interact with the AR object shown and able to view the detailed information and explanation after clicked on the function icon button and description icon button. If the marker image is not detected successfully, user can choose to continue detect on the marker image or end of the process. After the user finished interacting and engaging with the AR object that successfully detected, he may scan on another marker image for displaying another AR object on the screen of mobile application, or else the user able to end of the process after interacted with the one AR object.

3.6.2 Sequence Diagram

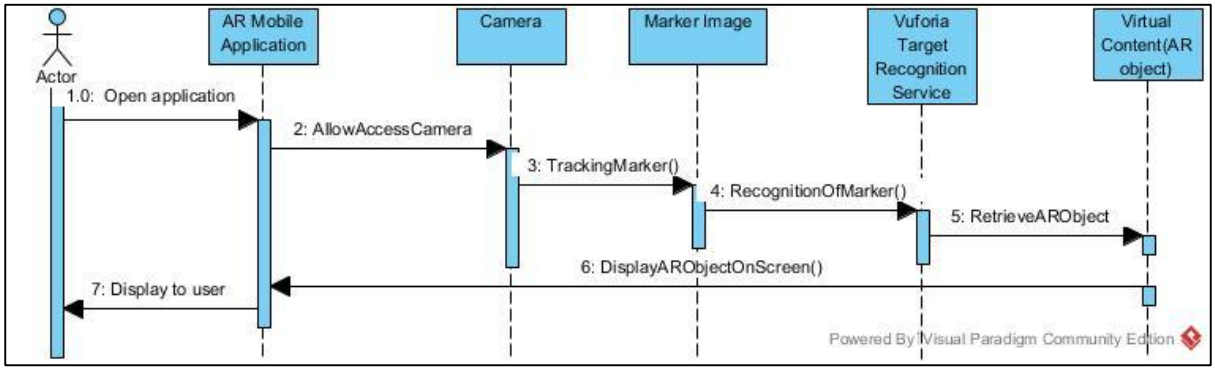


Figure 3.6.2.1: Sequence Diagram of AR Application for Learning Human Anatomy

Figure 3.9 shows the sequence diagram of AR application for Learning Human Anatomy. Firstly, user need to open the AR application on the mobile device then allow to access the camera feature of the mobile device. Next, user need to scan and detect the marker image correctly until the Vuforia target recognition service matched the correct and valid marker image and show the correct AR object on the screen respectively.

3.7 Expected System Testing and Performances

- The user should be able to download all of the marker images from the application successfully.
- User should able to interact with the AR object shown on the screen with his fingertips gestures.
- User should able to get the biologically naming of the part of the human anatomy through the point out labelling displayed along the AR object shown.
- User should able to know more about the human anatomy part through the pop-out windows with details information and descriptions of the anatomy.
- The application able to access and use the camera feature of the mobile device in order to detect and capture the visual markers images.
- The application able to detect and capture the marker images.
- The application able to display the AR object on the screen of the mobile devices after the camera the correct marker image is detected by the camera.
- The application should able to direct and navigate the user in order to show the AR objects the user wanted.

3.8 Expected Challenges

There are a few of challenges appeared in this project:

I. Difficulties in finding the accurate and clear MRI and CT scan data of human anatomy. MRIs and CT scan data are usually provided by hospital or Medical University with license. This is because the MRIs and CT scan dataset are patients' body scan data that are confidential and private to those hospital and University. Majority of the dataset re need to be paid for the license before allow to be downloaded. Therefore, finding the open sourced and clear MRIs and CT scan data are difficult.

II. GUI of the AR mobile application should be more easy to learn and easy to use.
GUI of the AR mobile application should be user-friendly and able to engage the curiosity of the user to use this application continuously. Besides, the images of the AR objects should be able to attract the attention of the user and high in resolution so that user will engage the sense of pleasant when viewing nice and clear AR object though

the screen. Therefore, the GUI design not only easy navigate user to obtain the correct AR object but also showing the precise and clear AR objects with high resolution.

III. Marked-based AR are not spontaneous, mark-less AR will be implement if possible. Marked-based AR is not so convenience due to the need of downloading the visual marker image before allow to engage with the AR content. User might lazy and not willing to download and print for the marker and give up using this application in the end. Therefore, mark-less AR better choice to overcome this problem but marker-less AR are more difficult to develop with ARCore.

3.9 Project Timeline

The tables below show the project timeline throughout the whole final year project. This FYP is planned to be completed within 24 weeks. This timeline is created to keep track the progress of each of the task which able to be completed within the planned period.

Project Task	Project Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Planing														
Dtermine FYP title and direction														
Collect and search for relevant information														
Determin project objective and scope														
Analysis														
Literatue review on technologies used														
Literatue review of existing system/ research paper														
Comparison and discussion on the literature review														
Design														
Identify the system framework														
Determine the system requirement														
Determine the system module														
Design system														
Implementation														
Validate and testing the modules														
Deliver initial system														
FYP1 documentation														
FYP1 presentation														

Table 3.9.1: Project Timeline for FYP1

Project Task	Project Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Refine and complete the report of Chapter 1 to 4														
Complete 50% of the application														
Complete 70% of the application														
Complete 90% of the application														
Writing the report of Chapter 5 & 6														
Writing the report of Chapter 7														
Complete 100% of the application														
Adding additional functionalities and features														
Validate and testing the application														
Deploy the application														
System testing														
Deliver final system														
FYP2 documentation														
FYP2 presentation														

Table 3.9.2: Project Timeline for FYP2

3.10 Concluding remark

In this chapter, the incremental development model of methodology is chosen to develop the application for the whole FYP. The system framework and architecture of this application are identified and explained. Besides, the system and functional requirement are defined in this chapter. Lastly, the project timeline is created to ensure the project able to be delivered on time.

CHAPTER 4 PRELIMINARY WORK

4.1 Setting up MITK

Before starting to develop the MITK, there are four softwares needed to be installed and downloaded in my laptop:

1. Visual Studio 2017 Enterprise Edition v15.9.14, SDK
2. Git:2.22.0(repositories which host MITK source code)
3. Qt: 5.11.1
4. CMake : 3.14.5

Firstly, set up source directory by ran my Git bash and get my MITK source code from Git repositories by using command and save in the folder named as MITK-file :

$git clone https://phabricator.mitk.org/source/mitk.git MITK

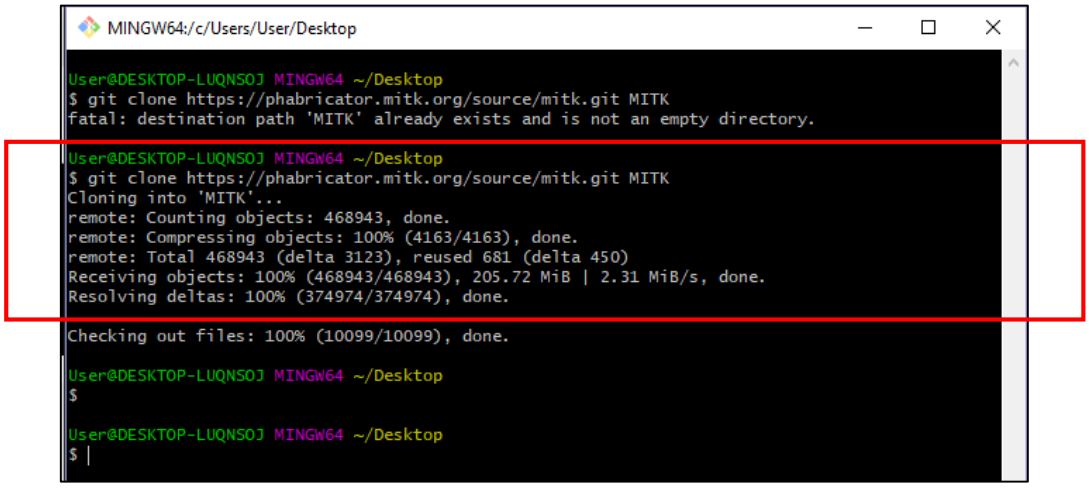


Figure 4.1.1: Get my MITK source code

Then, to generate the binary directory using CMake by opening the CMake to browse the MITK source code you have just downloaded and build the binaries in to the folder names as MITL-build. Then, start to configure it.

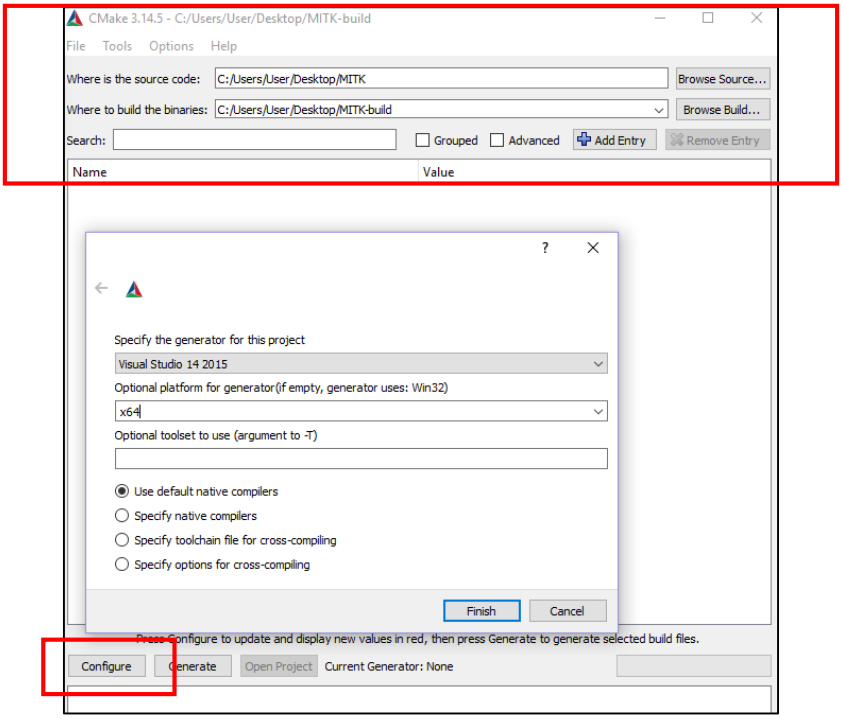
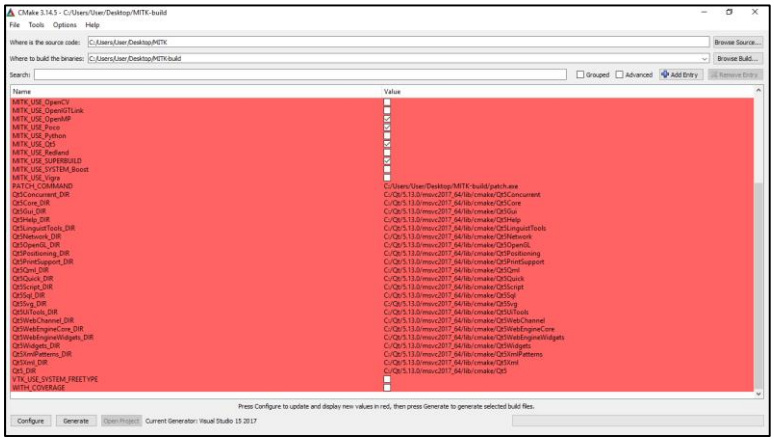
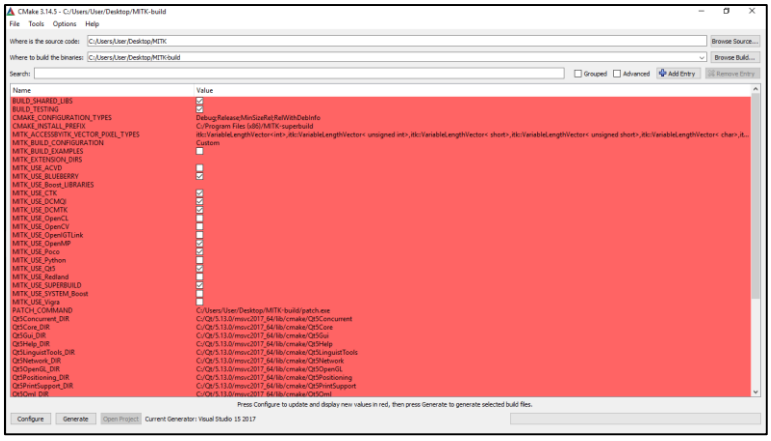


Figure 4.1.2: Build the binaries





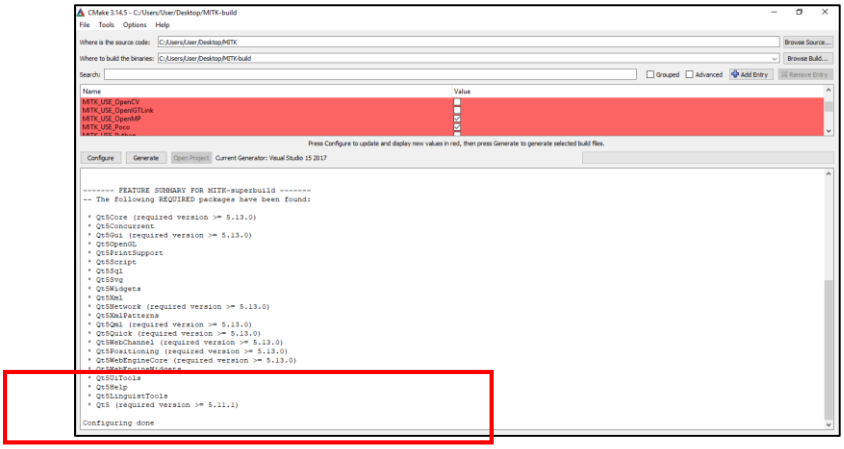


Figure 4.1.3: Configuring

After configure done successfully. Tick the MITK_ BUILD_EXAMPLE and configure again.

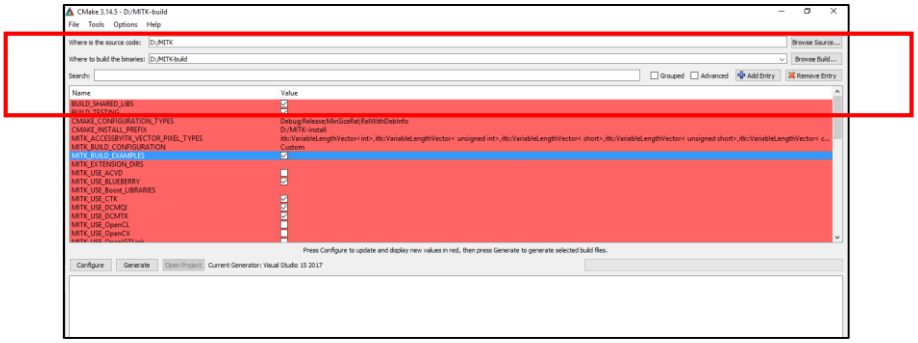


Figure 4.1.4: Tick the MITK_ BUILD_EXAMPLE

After the second configuring is done, generate it and open the project thought Visual Studio 2017 in order to build the installer for deployment

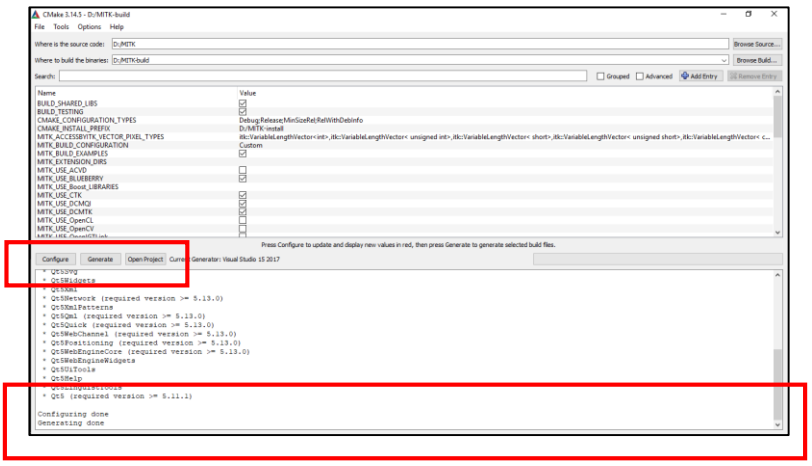


Figure 4.1.5: Configuring and generating

Then, run the program until all the warnings and errors are fixed in order to open the MITK successfully.

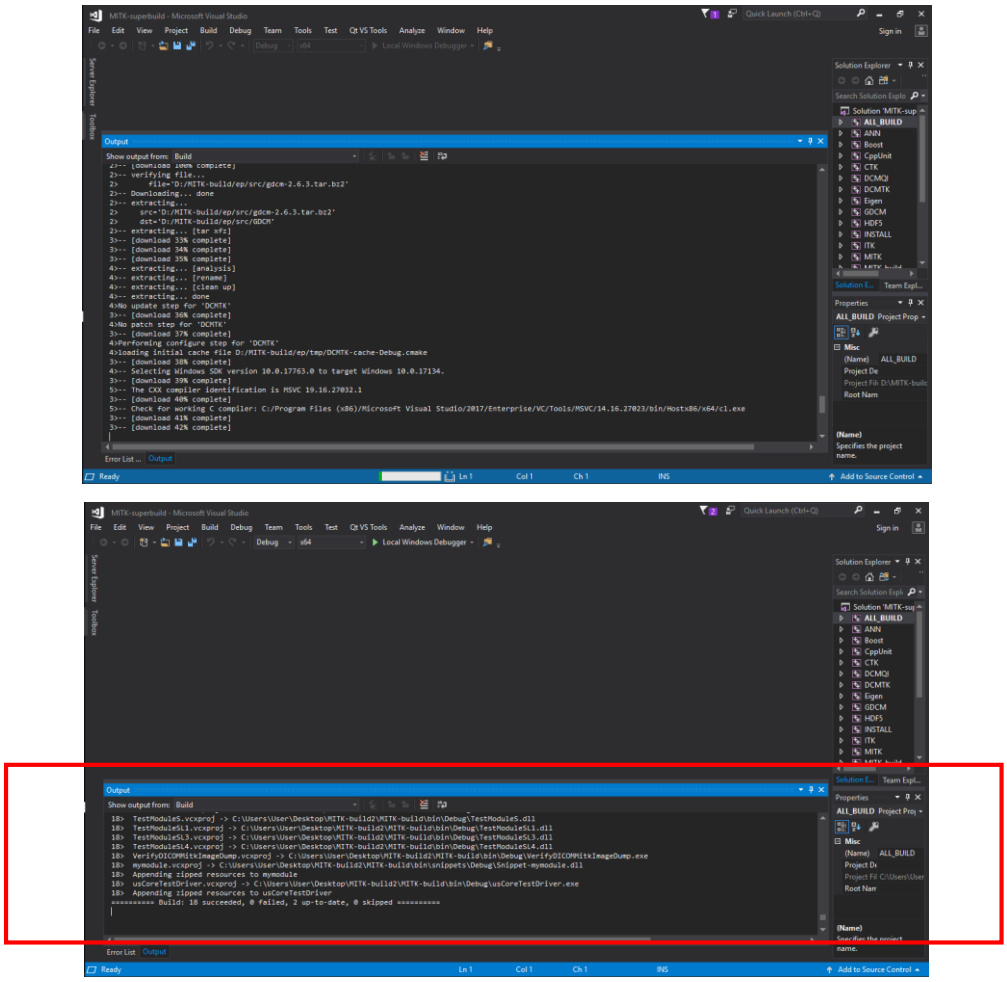


Figure 4.1.6: Open the Project and run until without any error

After the program are run successfully without any errors, open (installer startMitkWorkbench.debug file (installer) under Mitk-Build/MITK-build/bin . This file will open successfully if you run and debug the project correctly without any error.

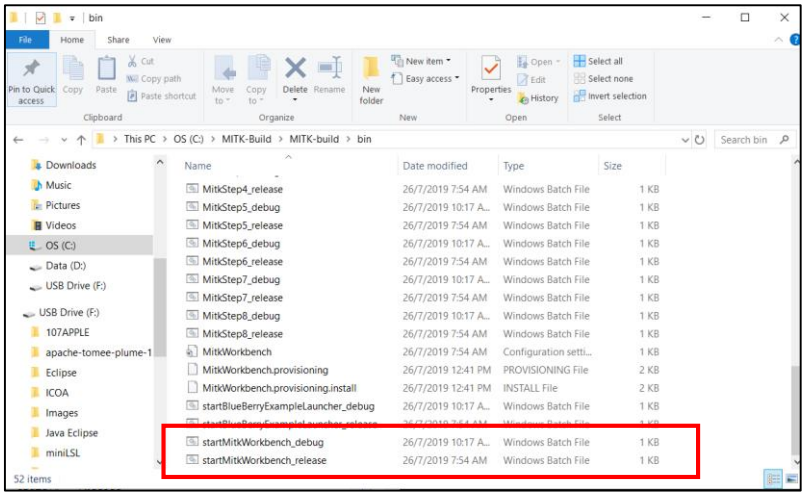


Figure 4.1.7: Open startMitkWorkbench.debug

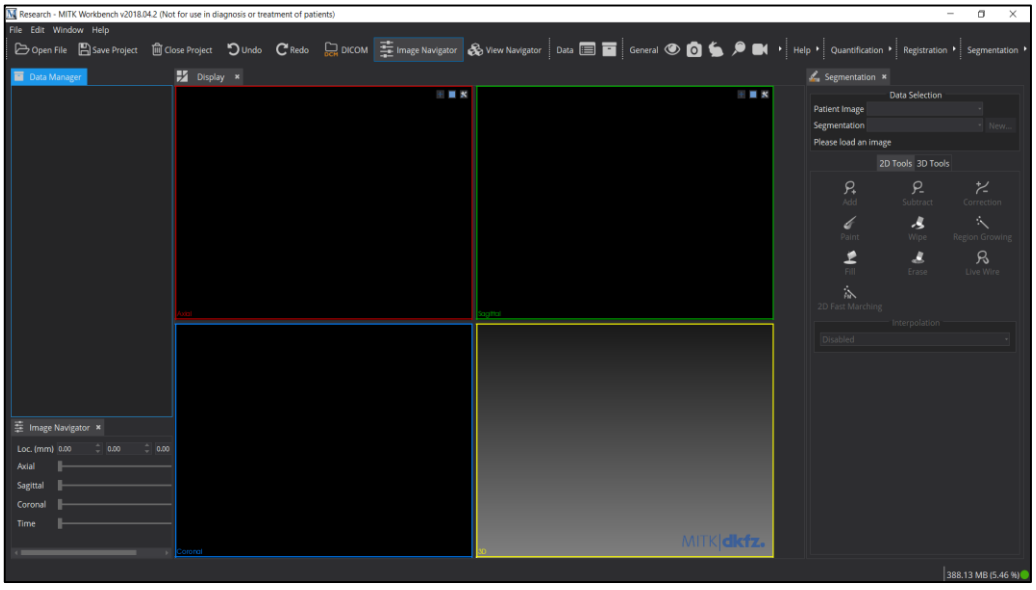


Figure 4.1.8: MitkWorkbench

4.2 Visualization and segmentation with MTIK

The following are the steps of segmentation process:

I. Import dcm file of the human anatomy
II. Create segmentation with file name and choose a color indicated the segmented part with a anatomy's part name.
III. Start segmentation process until you satisfy with it.
IV. Create the polygon model to get the 3D and save as STL file type.

4.2.1 Importing MRI or CT dataset file

There are two medical dataset used in this project. One MRI dataset of knee part which consists of 251 dcm files and another CT dataset of foot consists of 150 dcm file are used to segment and get the 3D object. The materials of datasets used in this project are:

I. Natural knee MRI data :
https://digitalcommons.du.edu/natural_knee_data/1/
Provided by: University of Denver Center for Orthopaedic Biomechanics
Image Acquisition Details: 251 slices; thickness: 0.6 mm; In-plane pixel spacing (mm): 0.390625 x 0.390625; In-plane resolution: 512 x 512; Tube Current: 186 mA; Peak kV: 120

II. Visible Female CT Foot data:
https://mri.radiology.uiowa.edu/visible_human_datasets.html
Provided by: University of Iowa Carver Collage of Medicine
Image Acquisition Details: 150 slices; thickness: 1.0 mm; In-plane pixel spacing (mm): 1.0 x 1.0; In-plane resolution: 512 x 512

4.2.2 Images Segmentation

In all image datasets, the anatomical knee and ankle foot anatomy structures are segmented using a semi-automatic approach and visualized in 3D by using surface rendering based on the Medical Imaging & Interaction Toolkit (MITK open-source framework). In this process, we segmented the knee and foot anatomy structures based on the "slice-based segmentation" with "3D-shape interpolation" approach. This method required the operator to trace the contours of

the target regions on some key 2D slices manually then the MITK estimated and reconstructed the whole 3D surface automatically.

Start Segmentation

After created the segmentation file with blue segmentation colour, I adjusted the scale of the level window in order to control the intensity of the grey so that I able to view the bone anatomy part that I want to segment with more clearly. Then I adjusted the Upper/Lower threshold of the 3D tools to segmentation the bone part according the pixels with values within the adjusted threshold intervals. After that, I modified it with the 2D tools such as Fill tool, Add and subtract tools in order to get the more precise 3D polygon model. The other reason needed to modify with 2D tools manually is because segmentation with threshold is not accurate as it is segmented according the pixels values of the threshold so some of the segmented part might not the part of the anatomy such as external objects or the part may no need to be segmented. Below show the pictures of the knee anatomy and foot anatomy segmentation:

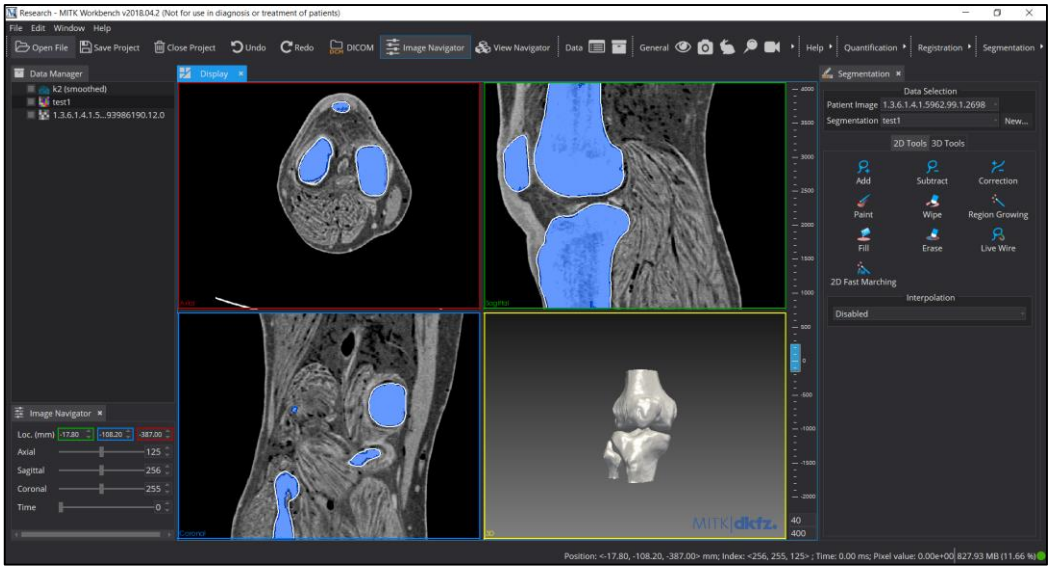


Figure 4.2.2.1: Segmentation of Knee bone

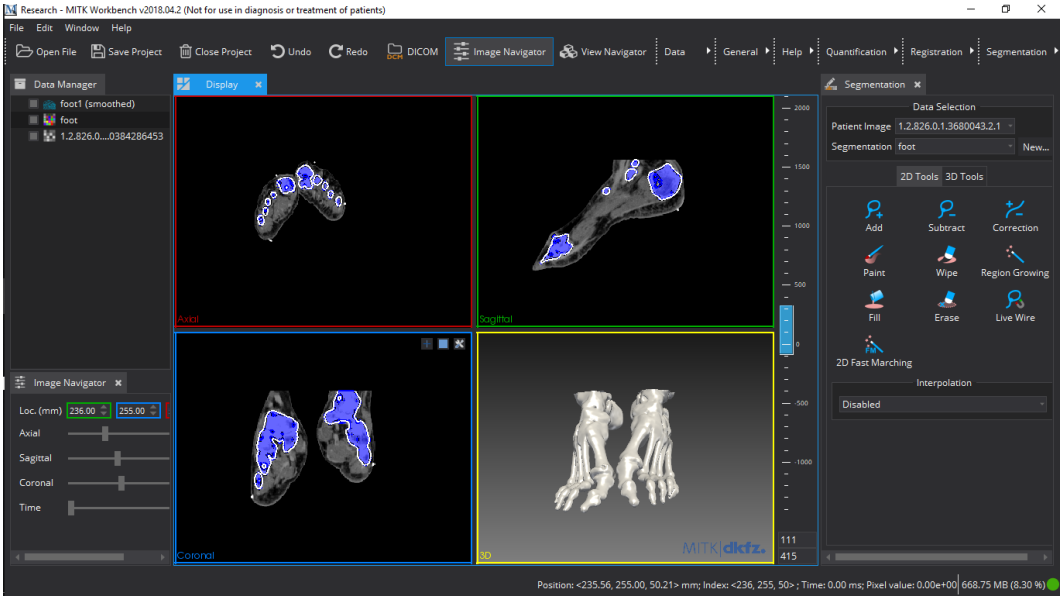


Figure 4.2.2.2: Segmentation of foot bone

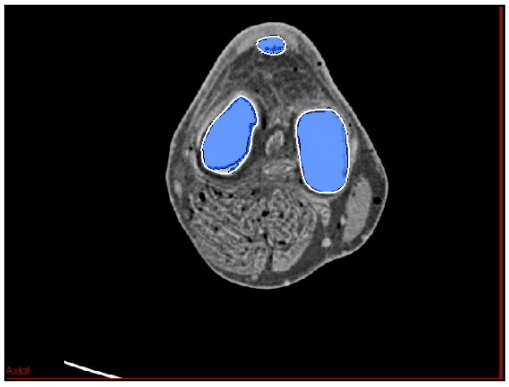


Figure 4.2.2.3 Axial view of segmented knee bone

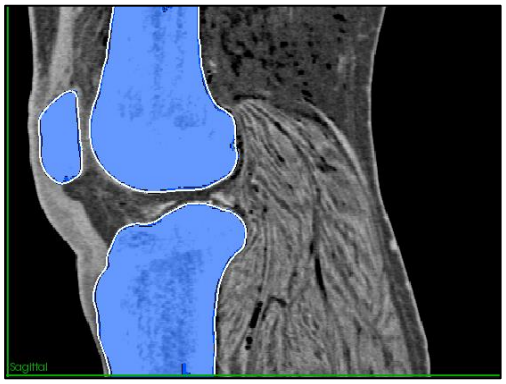


Figure 4.2.2.5 Sagittal view of segmented knee bone

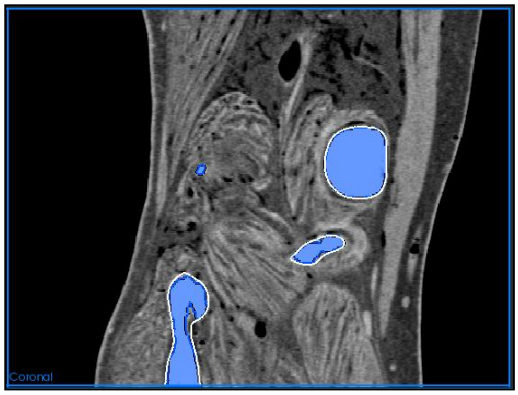


Figure 4.2.2.4 Coronal view of segmented knee bone

Figure 4.2.2.6 Axial view of segmented foot bone

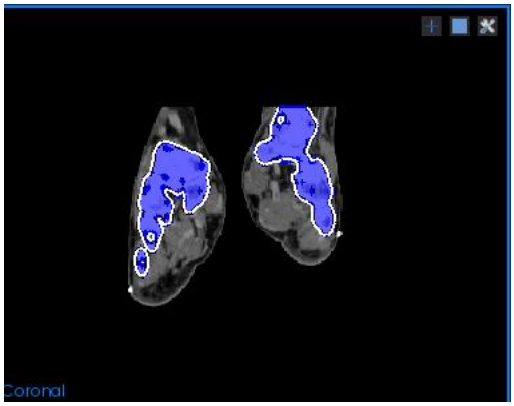


Figure 4.2.2.7 Coronal view of segmented foot bone

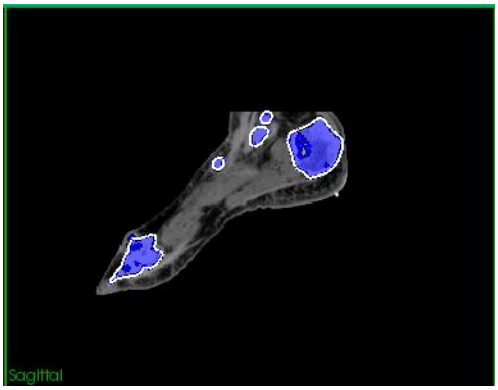


Figure 4.2.2.8 Sagittal view of segmented knee bone

4.2.3 3D visualization

After done and satisfied with the segmentation, the segmented model need to be visualized using surface rendering technique. This method used a marching cubes algorithm, which can produce extremely high-quality images by generating a polygonal mesh of the iso-surface from 3D voxels, with smoothing (Gaussian standard deviation and median filter) technique. Then, the smoothed polygon model is created and save in standard tessellation language (STL) file format. STL format is a triangular representation of a 3D object and it is a file format for 3D printing as well.

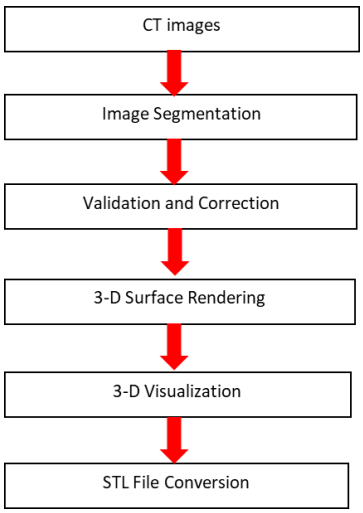


Figure 4.2.3.1: Image Processing Workflow

Below shown the smoothed polygon models of knee anatomy and foot anatomy created after segmentation:

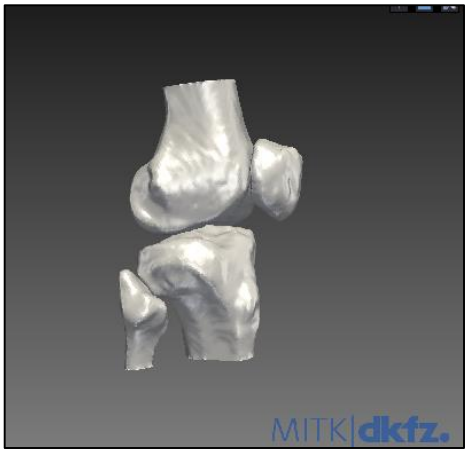


Figure 4.2.3.2: 3D knee

Figure 4.2.3.3: 3D foot

Chapter 5 System Implementation

5.1 Apply AR technology on the 3D model object with Unity Vofuria

Before the 3D .stl format file able to be imported into Unity with Vuforia. It need to be converted to OBJ file type. This is because Unity are not supporting STL file format but OBJ and FBX file format. Converting STL to OBJ using 3D builder software. Then, import the 3D model OBJ file into Unity to display in AR with respective marker. In this project, Marker-based AR is used. The following steps are how to convert 3D model object into AR:

I. Switch to the Android platform under build setting and activate Vuforia Augmented Reality on XR setting under player setting.
II. Import AR camera and image target as and AR marker image.
III. Create Vuforia license by logging with your Vuforia account, then copy the license and paste under “App License Key” section.
IV. Add target under “Image Target” (marker image) by making an Image Target Database in the Vuforia website. Under the database, you able to add few of target images as you can. The Target image file must be uploaded in jpg or png file type eith single image type.
V. Download the Image Target database and import into the Unity
VI. Select the target image you want to become the marker of the AR object respectively.
VII. Then, import the 3D model object under the asset/model folder.
VIII. Drag and position the AR you want to display on the marker

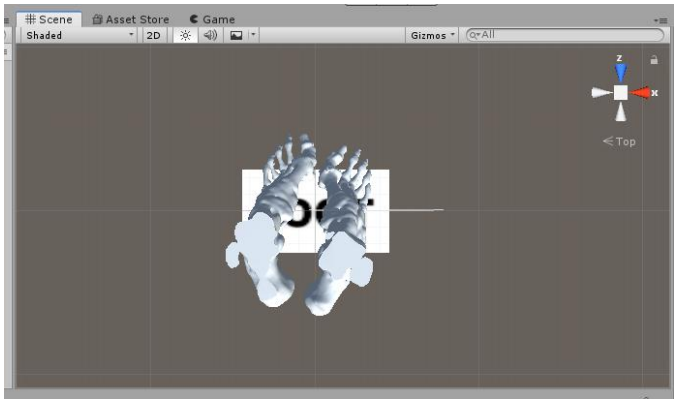


Figure5.1.1 Place the model on image target(marker).

IX. After satisfied with the AR display one the marker, canvas is added on each scene in order to create user interface for user to interact with.

X. On the Canvas, any UI such as panel, image or text able to be add as components under the respective canvas. In this application UI such images, textmeshpro, button, scrollbar, panel are used in this project.

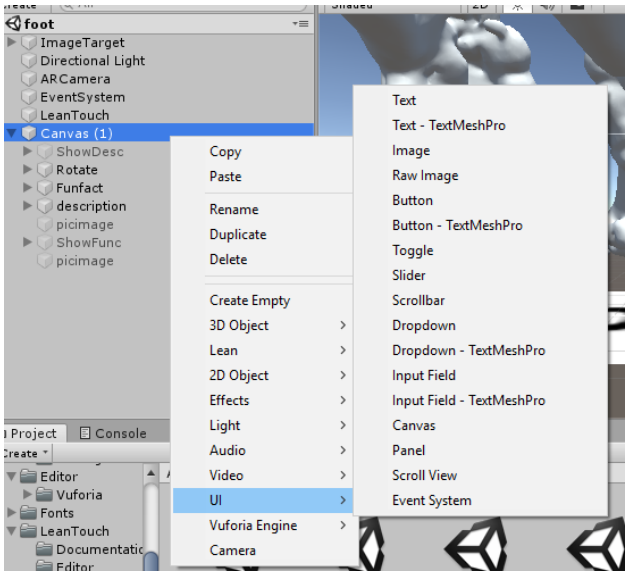


Figure 5.1.2 Canvas for GUI creation

XI. In order to perform some functions, some of the C# scripts needed to be created and imported.

XII. After you satisfy with each of the interface display, Scenes In Build under Build Setting need to be added, arranged and ticked before build and run this apk file of this application.

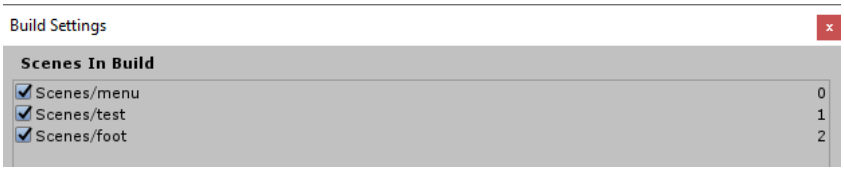


Figure 5.1.3 Build setting

XIII. Then, user able to testing this application before build the apk by the play testing button.

Figure 5.1.4: Testing button

XIV. If the testing run in the unity is satisfied, click “build and run” under build setting and an APK file of this application will be generated. the APK file can be save and

downloaded in the mobile device to show the AR in virtual environment with the correct markers respectively.

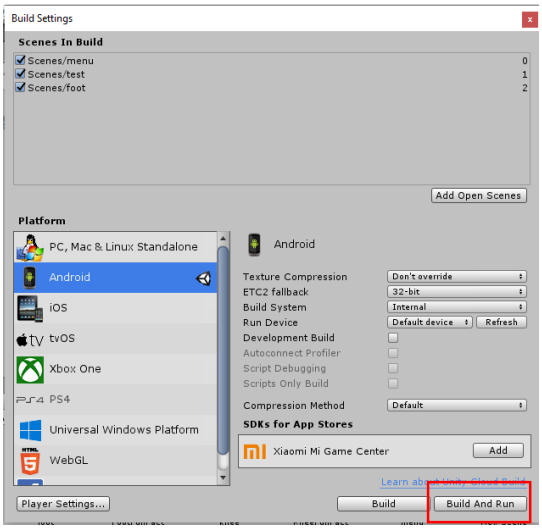


Figure 5.1.5 Build and Run the application

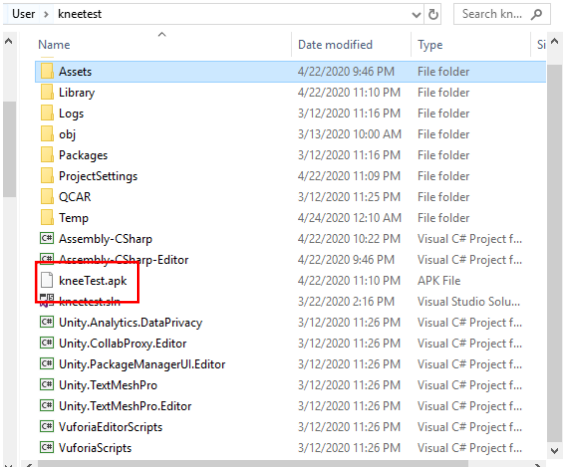


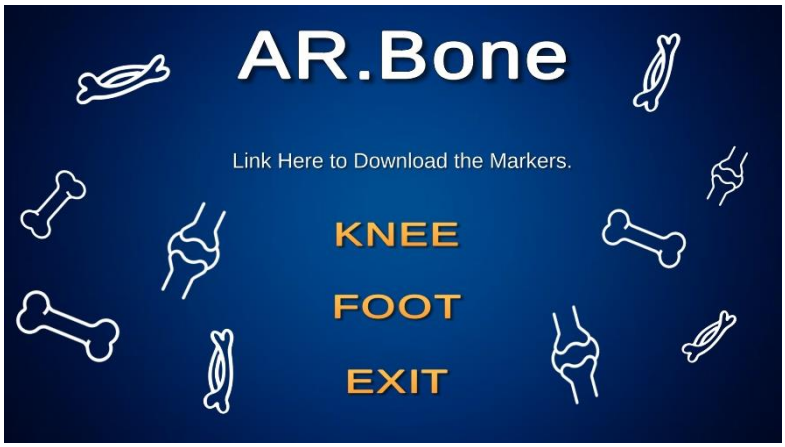
Figure 5.1.6 APK file named with KneeTest

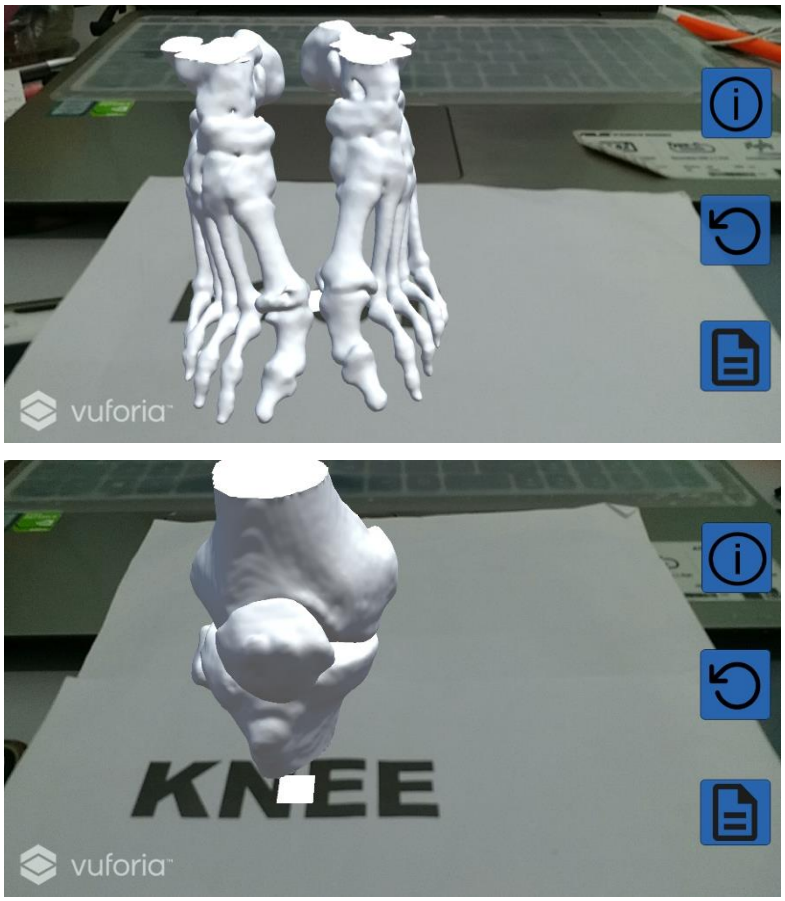
Below shown the markers used as Image Target: Left hand side is foot marker; Right hand side is knee marker.

Figure 5.1.7 Marker for AR knee

Figure 5.1.8 Marker for AR knee

This AR application not only gives a 360° angles and views of human anatomy body parts in order to enhance the interactivity by using fingertips of user, but also the pop out description windows are added to give user ease for learning the anatomy such as functions. Fun fact, picture and description by clicking on the buttons. I had imported few C# scripts for those features applied on the AR objects such as rotate script, drag script. Besides, I did create my own script on those 3 buttons feature: Function display and description display with pop out windows by OpenDesc.cs and rotate button with RotateObject.cs. Moreover, I created scripts to perform back function after done showing the AR with back button of the mobile device in order to make this application user- friendly. In this AR application consists of 3 scenes which are main menu, knee AR and foot AR. The Figure below are the user interfaces of this AR application which consists of main menu, and AR interface for each anatomy:





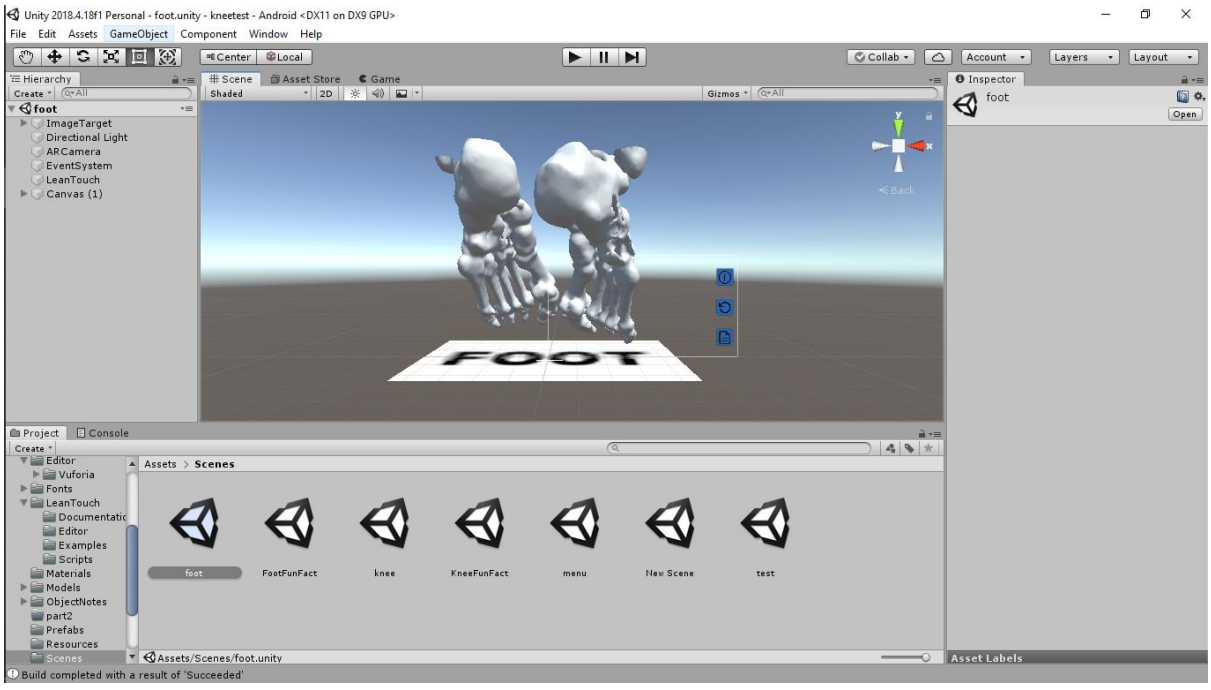


Figure 5.1.9 Ankle Foot AR unity

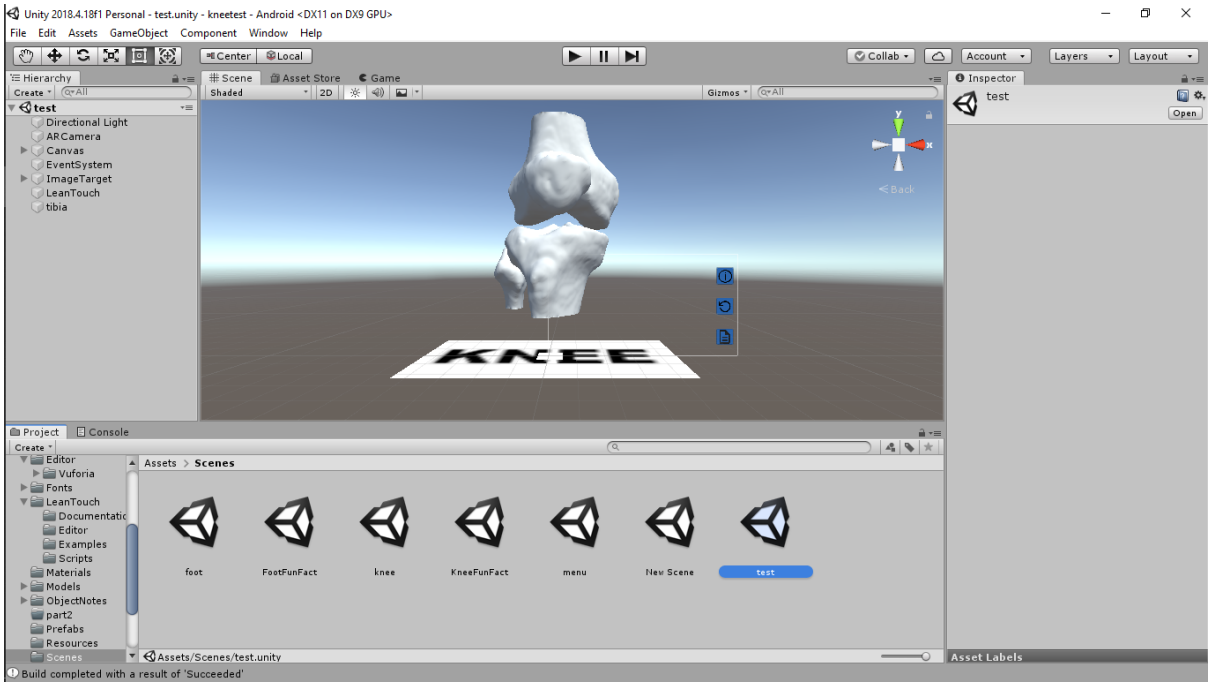


Figure 5.1.10 Knee AR unity

5.2 Augmented reality (AR) workflow

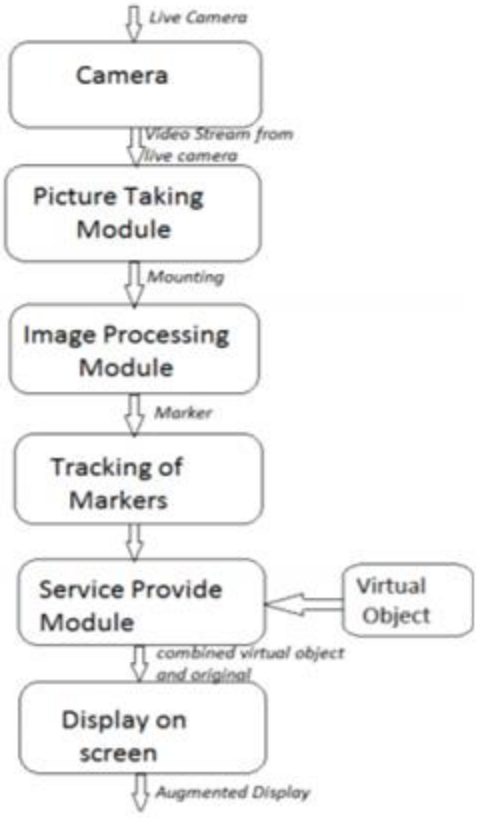


Figure 5.2.1 Augmented reality (AR) workflow

5.3 Summary the work done

In the implementation part, I had applied AR technology on the 3D model by creating GUI and C# scripts for performing some functions.

Chapter 6: Results and Testing

6.1 Graphical User Interface

6.1.1 Main Menu

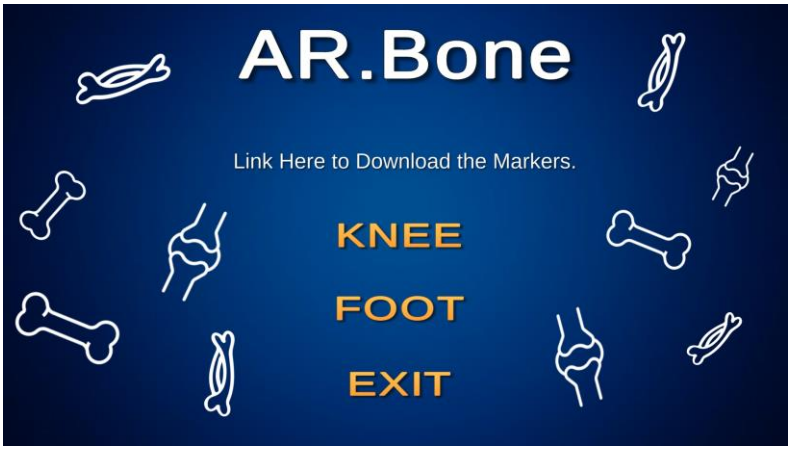


Figure 6.1.1.1 Main Menu

Upon launching the application, user will be shown a landscape main menu screen with 4 button. The “Link Here to Download the Markers” is for user to download the markers for the respective AR show on the devices. The user will direct user to a google drive in order to download and print the marker on a paper. Then, the “knee” and “foot” buttons are to show the AR and the “exit” is exit the application.

6.1.2 AR interface

Figure 6.1.2.1 AR interface

This is the GUI after clicked on the “KNEE” or the “FOOT” button at the main menu. In this scene, three blue icon button is sit on the right. Those 3 buttons are toggle button which user

need to open and close with pressed on the same buttons. User able to perform rotation of the AR structure with the second button after the respective marker is detected and 3D AR is shown in on the screen with real environment. The AR able to rotate vertically. The first blue button is to show pop out function windows of the respective anatomy structure while the third blue button is to show a pop out description box with details explanation of the respective anatomy structure.

Figure 6.1.2.2 Respective Marker detected and knee AR is shown.

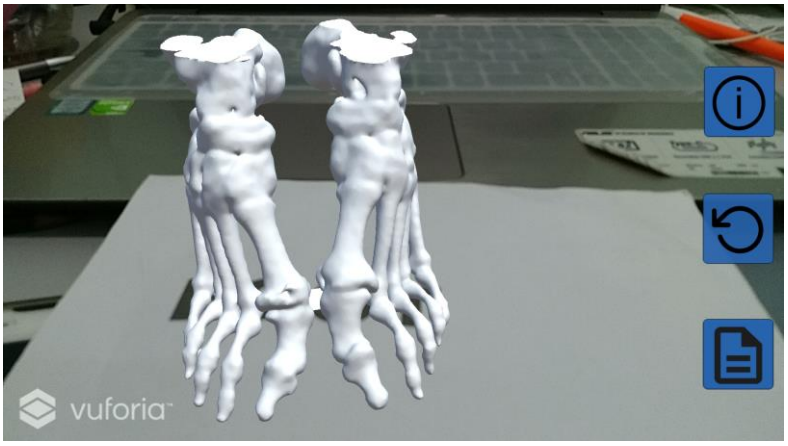


Figure 6.1.2.3 Respective Marker detected and ankle foot AR is shown.

Figure 6.1.2.4 Knee AR is scale bigger with fingertips movement

Figure 6.1.2.5 Knee AR is scale smaller with fingertips movement

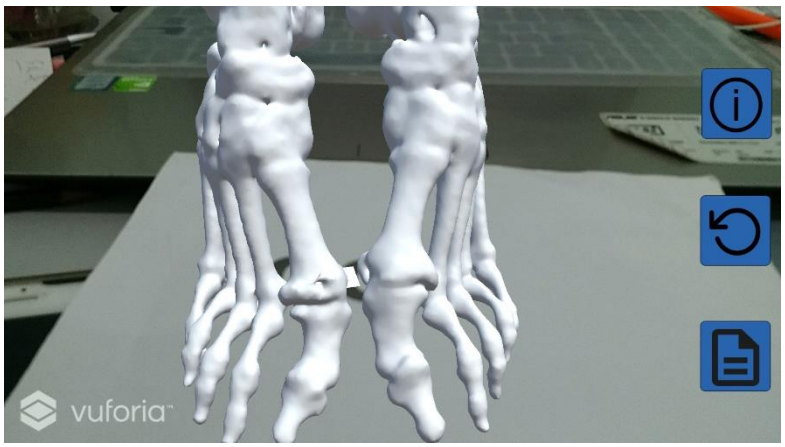


Figure 6.1.2.6 Ankle Foot AR is scale bigger with fingertips movement

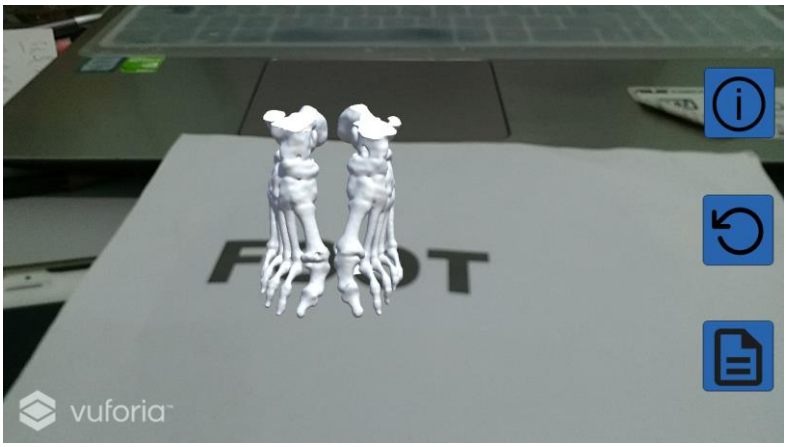


Figure 6.1.2.7 Ankle foot AR is scale smaller with fingertips movement

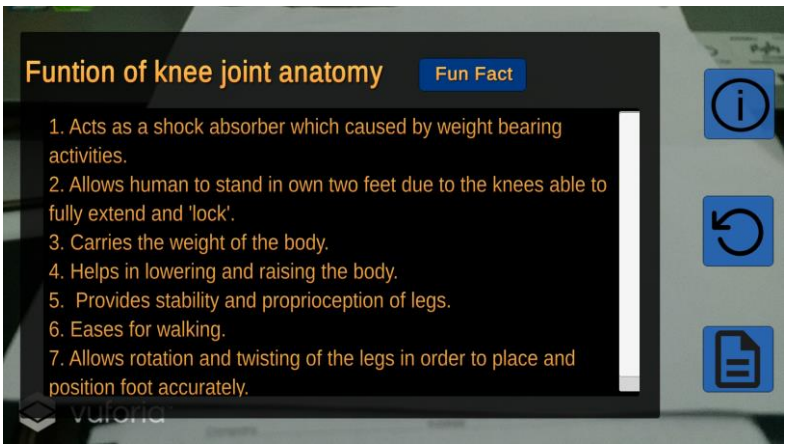


Figure 6.1.2.8 Pop out windows show the Function of the Knee Joint Anatomy after pressed the 1st blue button on the right.

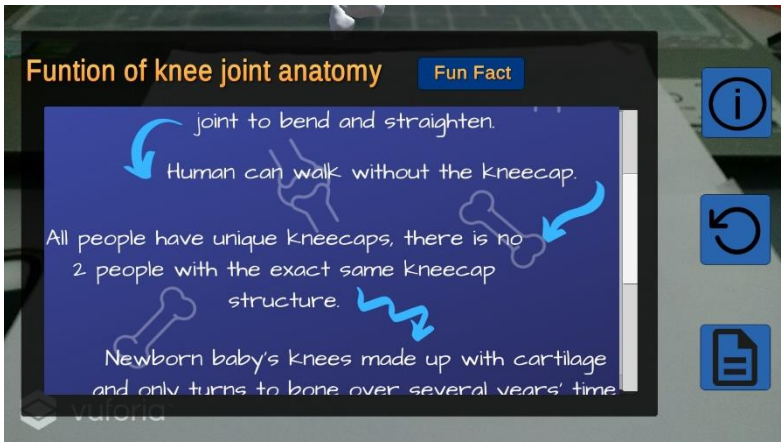


Figure 6.1.2.9 Fun fact windows is shown after pressed on the "Fun Fact" button on the screen of Figure6.1.2.8

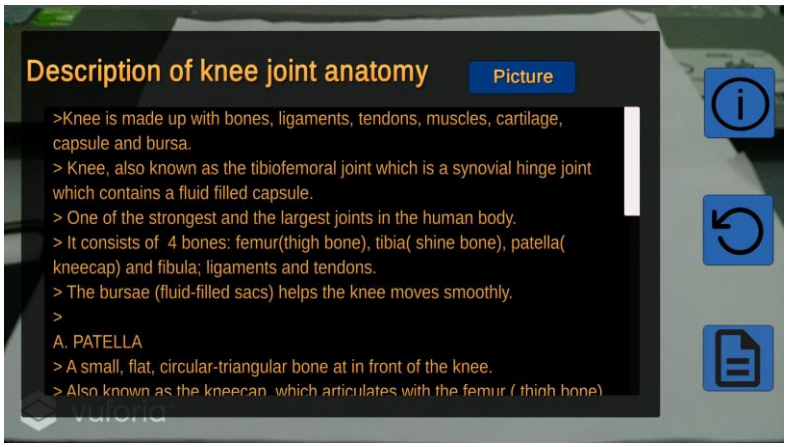


Figure 6.1.2. 10 Pop out windows show the Description of the Knee Joint Anatomy after pressed the 3rd blue button on the right.

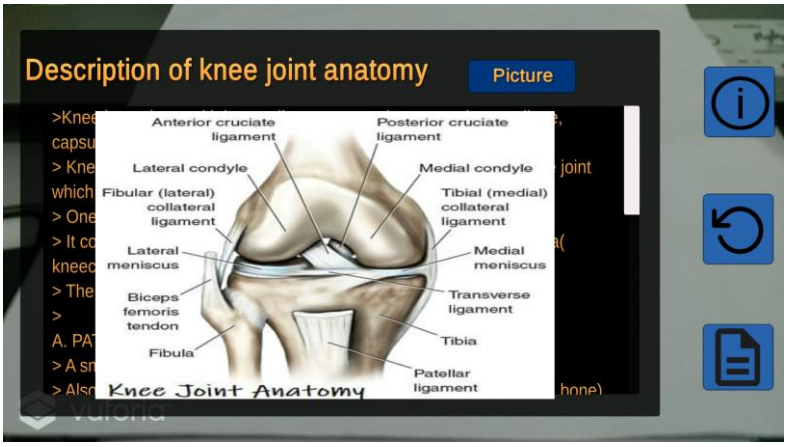


Figure 6.1.2.11 A 2D images of knee joint is shown after pressed on the “Picture” button on the scene of Figure 6.1.2.10

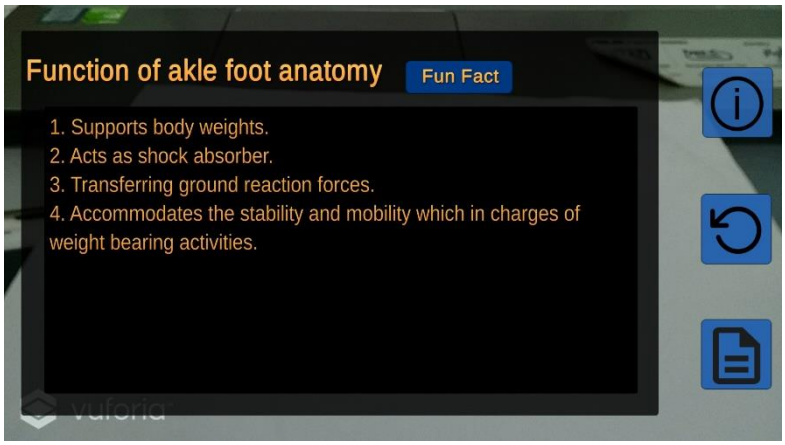


Figure 6.1.2.12 Pop out windows show the Function of the Ankle Foot Anatomy after pressed the 1st blue button on the right.

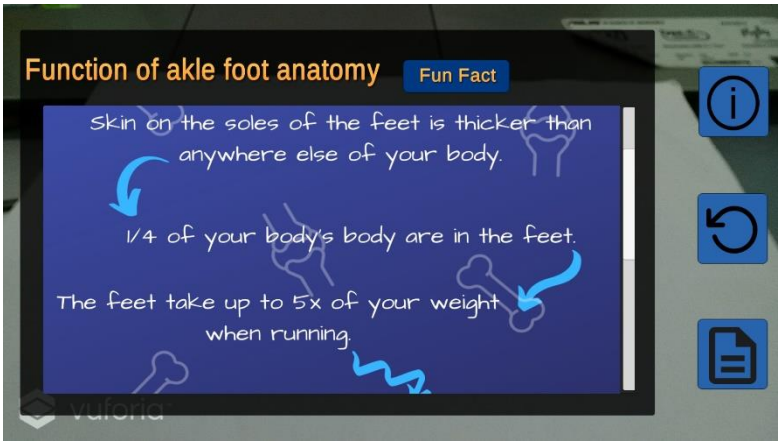


Figure 6.1.2.13 Fun fact windows is shown after pressed on the "Fun Fact" button on the screen of Figure 6.1.2.12

Figure 6.1.2.14 Pop out windows show the Description of the Ankle Foot Anatomy after pressed the 3rd blue button on the right

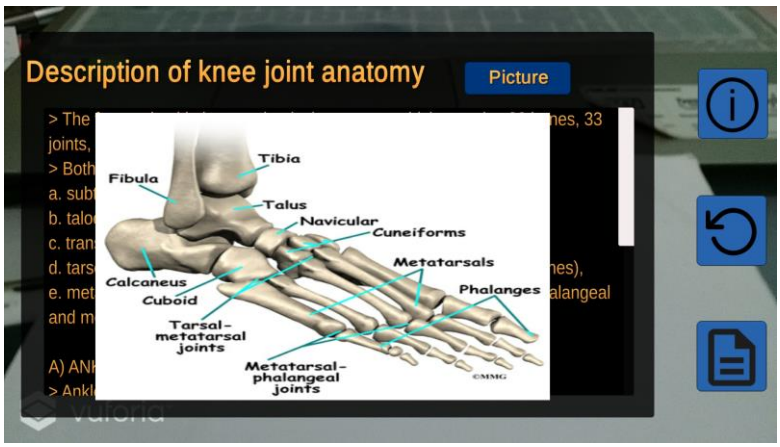


Figure 6.1.2.15 A 2D images of Ankle Foot is shown after pressed on the "Picture" button on the scene of Figure 6.1.2.14

6.2 System Testing

In this semester, I have completed the main function for this final year project of the proposed application which is AR anatomy structure shown on the screen when the marker is detected correctly, the AR interaction with fingertips and pop out windows with buttons.

6.2.1 Test objectives: The marker images able downloaded by user (refer Figure 6.1.1.1)

Situation	Expected Output	Actual Output
User pressed the "Link Here to Download the Markers" on the main menu.	The system will direct user to the google drive link in order to download and print on a paper.	The system directs user to a google drive link : "*https://drive.google.com/open?id=1MfNZ0xzBuspiZ-EnKWC5C2O4rtWPMkZk*"

Table 6.2.1: Test objective on the marker image download function.

6.2.2 Test Objective: knee AR anatomy structure appeared on the screen when the marker detected and able to interact it with dragging and scaling by user's fingertips. (refer to Figure 6.1.2., Figure 6.1.2.4, Figure 6.1.2.5)

Situation	Expected Output	Actual Output
User shows the device's camera toward the knee's marker. If the knee AR shown successfully, user drags and scales the AR with fingertips interaction.	The knee AR with label will show on the screen after the knee's marker is detected. Then the user able to resize the AR with two fingertips and able to drag the AR within the screen.	The knee AR is shown without label on the screen after the marker detected. Then the size of the AR is changeable with two user fingertips interaction but not easy to control. The AR shown will run out of the screen sometimes.

Table 6.2.2: Test objective on knee AR display function after the marker detected correctly and able to interact with fingertips(drag and scale function)

6.2.3 Test Objective: Ankle Foot AR anatomy structure appeared on the screen when the marker detected and able to interact it with dragging and scaling by user's fingertips. (refer to Figure 6.1.2.3, Figure 6.1.2.6, Figure 6.1.2.7)

Situation	Expected Output	Actual Output
User shows the device's camera toward the knee's marker. If the ankle foot AR shown successfully, user drags and scales the AR with fingertips interaction.	The ankle foot AR with label will show on the screen after the ankle foot's marker is detected. Then the user able to resize the AR with two fingertips and able to drag the AR within the screen.	The knee AR is shown without label on the screen after the marker detected. Then the user size of the AR is changeable with two user fingertips interaction but not easy to control. The AR shown will run out of the screen sometimes.

Table 6.2.3 : Test objective on ankle foot AR display function after the marker detected correctly and able to interact with fingertips(drag and scale function)

6.2.4 Test Objective: Function button (1st button on the AR display interface)with pop out windows of both GUI.(refer Figure 6.1.2.8 , Figure 6.1.2.12)

Situation	Expected Output	Actual Output
User able to pressed on the "Function Icon" button on both Knee and ankle foot AR display interface.	The pop out windows will show the function of the knee joint and the ankle foot anatomies with a top to bottom scrollbar.	The pop out windows able to function well as the user pressed and the scrollbar able to function with fingertip interaction.

Table 6.2.4: Test objective on the function button on both Knee and ankle foot(1st button on the right of the AR display interface)

6.2.5 Test Objective: Description button (3rd button on the AR display interface) with pop out windows of both knee and ankle foot AR display interface. (refer Figure 6.1.2.10 , Figure 6.1.2.14)

Situation	Expected Output	Actual Output
User able to pressed on the "Description Icon" button on both Knee and ankle foot AR display interface.	The pop out windows will show the description and details of the knee joint and the ankle foot anatomies with a top to bottom scrollbar.	The pop out windows able to function well as the user pressed and the scrollbar able to function with fingertip interaction.

Table 6.2.5: Test objective on the description button on both Knee and ankle foot(3rd button on the right of the AR display interface)

6.2.6 Test Objective: Picture button on Description interface (refer Figure 6.1.2.11, Figure 6.1.2.15)

Situation	Expected Output	Actual Output
User able to pressed on the "picture" button on the show description interface.	A picture of anatomy is appeared on respective interface.	A picture is appeared on respective interface.

Table 6.2.6: Test objective on the Picture button on description interface of both Knee and ankle foot

6.2.7 Test Objective: Fun Fact button on Functions interface (refer Figure 6.1.2.9, Figure 6.1.2.13)

Situation	Expected Output	Actual Output
User able to pressed on the "Fun Fact" button on the show Function interface.	A fun fact interface with scrollbar is appeared.	A colorful fun fact interface is appeared.

Table 6.2.7: Test objective on the Funfact button on description interface of both Knee and ankle foot

6.2.8 Test Objective: Rotate button(2nd button on both AR display interface

Situation	Expected Output	Actual Output
Once the AR is displayed	The AR object is rotated	The AR object is rotated

successfully on the screen, user able to pressed on the "Rotate icon" button.	horizontally itself.	horizontally itself until user pressed again on the same button.

Table 6.2.8 : Test objective on the Rotate button (2nd button on the AR display interface)

6.3 Survey and Questionnaire

A survey with 12 questions had been conducted to study the feedbacks on this AR application based on medical image 3D reconstruction. The target audiences are mostly university students. The first 4 questions are designed to survey whether the student notice about the medical images, augmented reality application and 3D reconstruction.

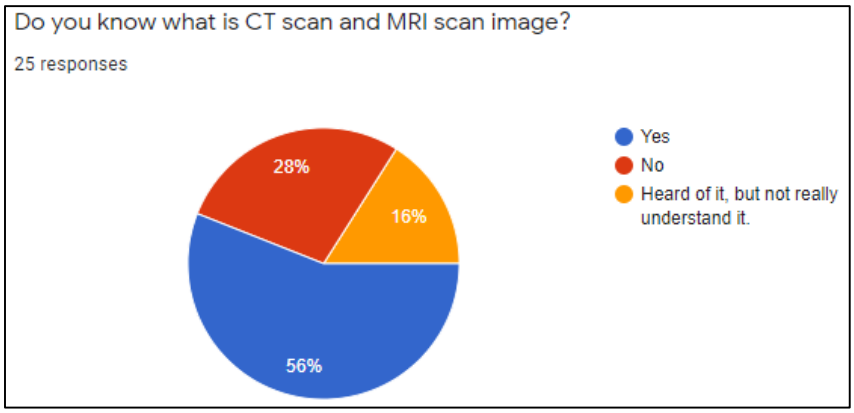


Figure 6.3.1: Question 1

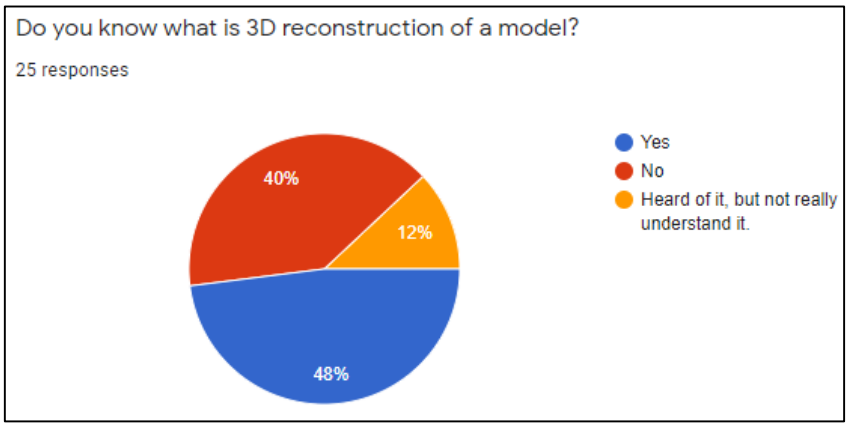


Figure 6.3.2: Question 2

Based on the Figure 6.3.1 and Figure 6.3.2, most of the respondents know about the medical CT scan and MRI images and the 3D reconstruction of a model. These both questions is to determine that most of the respondents have some medical knowledge.

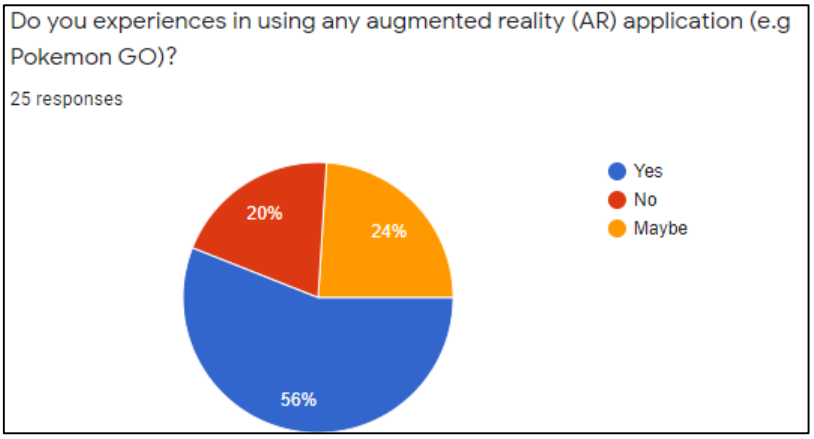


Figure 6.3.3: Question 3

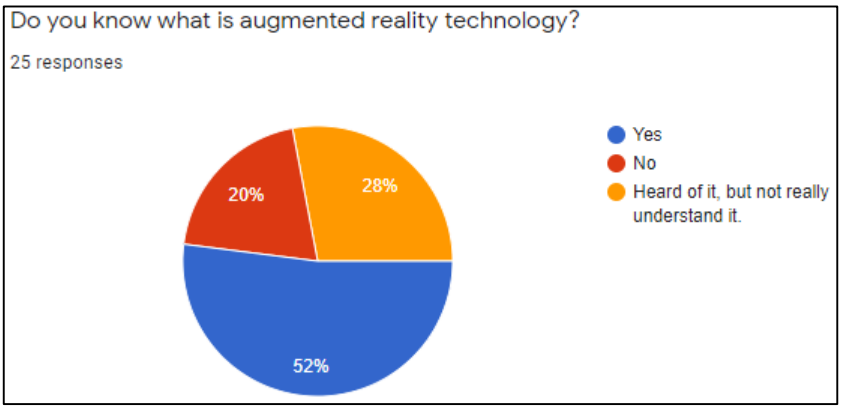


Figure 6.3.4: Question 4

Question 3 and Question 4 are about the AR technology. Based on Figure 6.3.3 Figure 6.3.4, more than half of the respondents do know about AR technology and did experience on AR application such as Pokemon Go. This shows that students now are aware of the IT technology of AR.

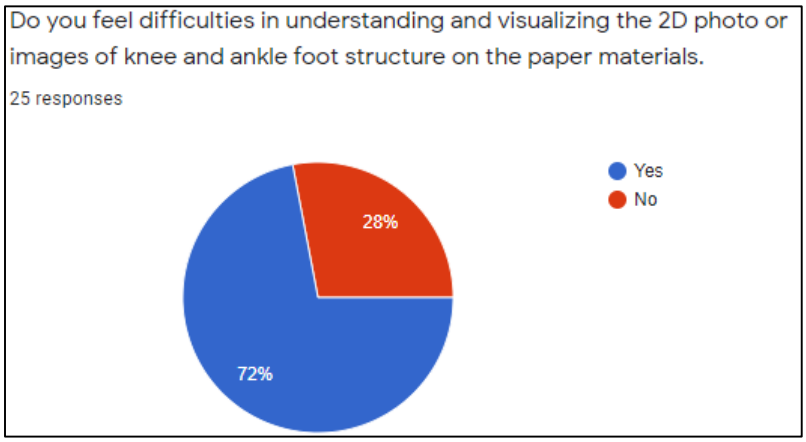


Figure 6.3.5 Question 5

Majority of respondent did feel hard in learning and visualizing the 2D pictures images of knee joint and ankle foot anatomy structures.

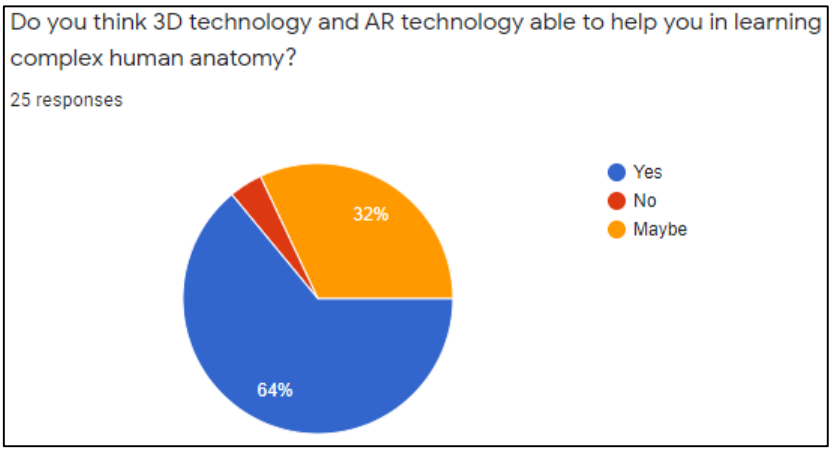


Figure 6.3.6: Question 6

64% of the those respondents do think that 3D image reconstruction and AR technology able to help them in learning the human anatomy structures due to their complexity. This is because 3D AR model not only able to show a clear and details structure to them but also provide interactivity while learning.

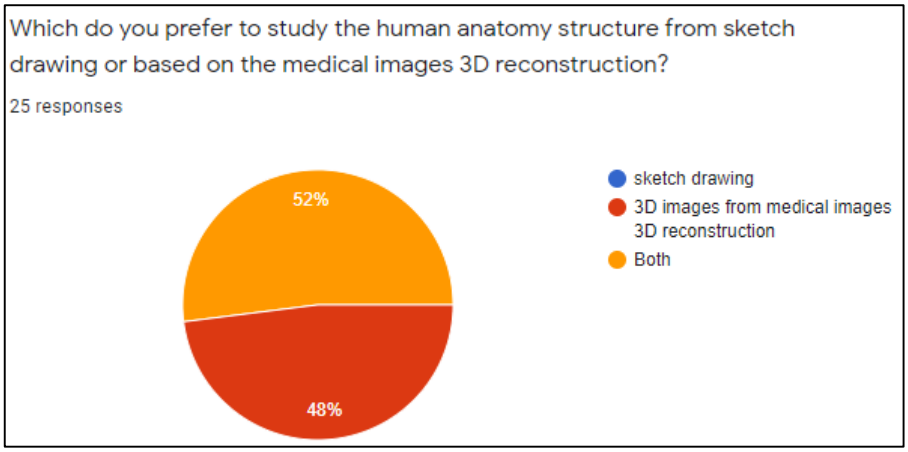


Figure 6.3.7: Question 7

According Figure 6.3.7, none of the student prefer to study the anatomy structure with only sketch drawing but most of them prefer 3D images from medical images 3D reconstruction and sketch drawing. I think giving both of the displays so that students able to refer alternatively in order to understand the complex structures.

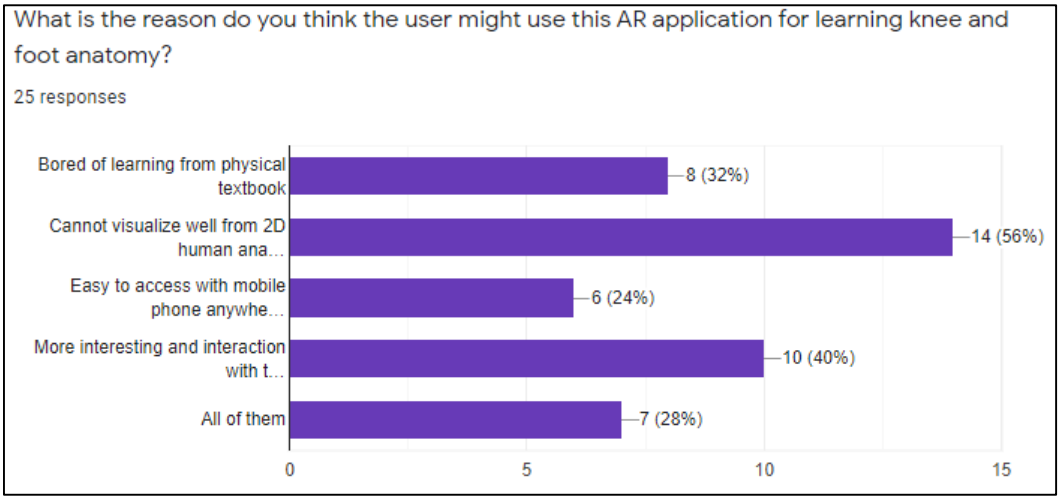


Figure 6.3.8: Question 8

Figure 6.3.8 shows the reasons of the user might choose to learn the anatomy structure with AR application instead of traditional materials. More than half of them agreed on unable to visualize well from the 2D anatomy structure. Secondly, the reason is AR application for learning anatomy is more interesting and interactivity than traditional way.

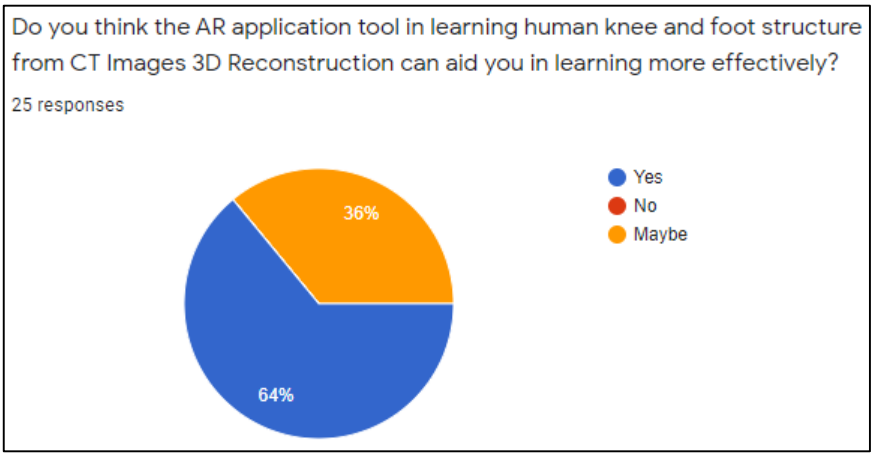


Figure 6.3.9: Question 9

Based on the Figure 6.3.9, 64% of the respondents agreed on this AR application in learning human anatomy structure from CT images 3D reconstruction helps them to learn more effectively.

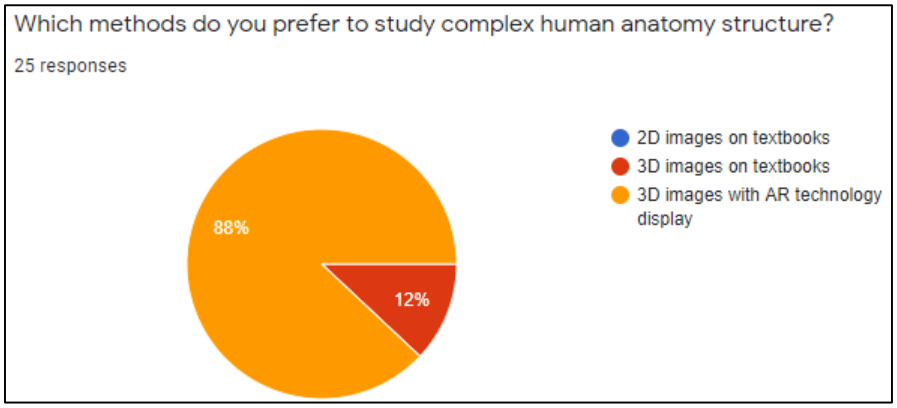


Figure 6.3.10: Question 10

Majority of the respondents prefer to study anatomy structure in 3D images but most of them (88%) prefer to learn with 3D and AR technology of model display. None of the student prefer 2D images in learning complex anatomy structures.

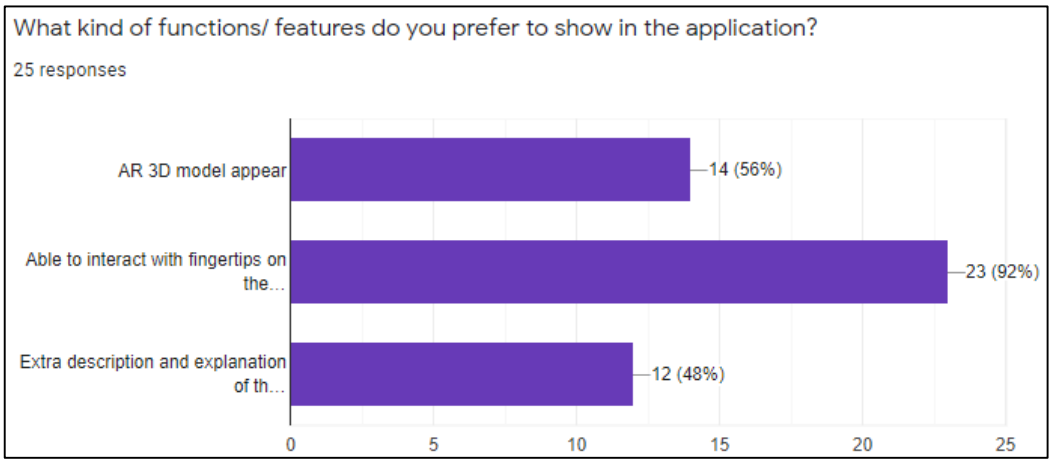


Figure 6.3.11: Question 11

Figure above shows few of the features such as AR 3D model appears, able to interact with fingertips on the AR model, extra description and explanation of the anatomy structure. Majority of them prefer to have not only AR model displays but also features of interacting with the fingertips movement on the AR.

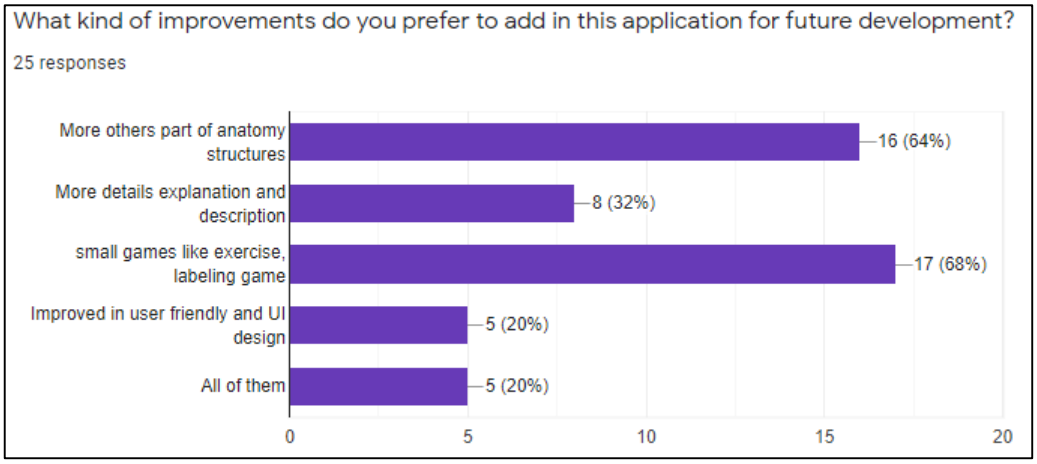


Figure 6.3.12: Question 12

After user did try to use on this application, most of them suggested to add more others part of anatomy structures and add small games in this application in future enhancements and improvement.

6.4 Summary the work done

In this chapter, the result of this application on the GUI is discussed, the system testing is implemented and come out with the expected outcome and actual outcome. A set of questionnaires with 12 questions is design in order to conduct a survey on the Utar student regarding this topic of FYP.

CHAPTER 7 Discussion and Conclusion

7.1 Future Work

This project is able to display 2 anatomy structures which are knee joint and ankle foot based on the medical image 3D reconstruction with marked- based AR. Besides, details description and function is able to display in this application with buttons and pop out UI. Therefore, the basic and fundamental functions objectives of this application is learning anatomy structures with 3D AR model with mobile devices. In order to enhance the user experiences for this application, it needs to add and enhance the functionality of the AR features on anatomy structures. It is considered challenging to get the medical images dataset of any others human anatomy part through online with clear and accurate CT scan or MRI scan images. Besides, due to the time constraints of the FYP, some of the features such as labelling annotation on the AR model is challenging to complete as well. Therefore, the future works of this project is to add more AR model to display; labelling features on the AR; the data store online with firebase instead of local storage; adding sound feature when marker detected and enhance the usability of this application such as user friendly.

7.2 Conclusion

Biology subjects is compulsory taken by all students of secondary school's science stream students and the complex structures of human anatomy is difficult and hard to fully understand by 2D images on the textbooks. Although the anatomical mannequins are providing for students to refer but it is limited to access in class time under teacher permission and student not able to refer when he student at home. Besides that, some of the student facing the difficulty in understanding the 2D images of the human anatomy. Moreover, lack of using the technology in educational method for study and teaching in Malaysia, therefore, students are still using the traditional method in acquiring the knowledge with texts on the papers.

In order to solve those issue, the proposed method is develop an AR application with 3D visualization and segmentation from MRIs and CTs scan dataset. Making use of modern technologies in this era such as AR or VR in implementing and replacing the traditional method of learning or studying for students. Learning with AR technology is not only providing an alternative method for learning but also helping student to learn effectively and efficiently. Learning complex human anatomy in AR is helping students for those who are hard to understand the 2D images of the human anatomy by giving more reality sense of 3D model

with details structures on it. Besides that, it also provide convenience for those who want to learn in anywhere and anytime with just a mobile device instead of carrying heavy textbooks if the student want to revise and study instantly. Besides AR technology is applying, the 3D model generated by the MITK software from MRIs and CT scan dataset is implemented in order to get the more precise and accurate models compare to the AR model which are created by graphical design software artificially. Therefore, in this proposed AR application for learning human anatomy, the AR model are generated from the medical 3D visualization and segmentation of MRIs and CTs dataset of body parts with MITK software.

In short, the aim of this proposed system is to providing an alternative method for learning human anatomy with AR technology and more precise 3D model from medical visualization and segmentation of MRIs and CT scan dataset. By implement this project, Malaysia student might realize and understand more about the advantage and benefit of AR technology in helping their learning process. Therefore, it will indirectly improve their sense and knowledge of modern technologies now. Lastly, student will get to know the more real and accurate anatomy AR due to the 3D are generated from real medical dataset.

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APPENDIX A: Weekly Report

FINAL YEAR PROJECT WEEKLY REPORT

Project II

Trimester, Year: January, 2019	**Study week no.: 6**
Student Name & ID: Liew Set LEE 17ACB03157	
Supervisor: Dr Sayed Ahmad Zikri Bin Sayed Aluwee	
Project Title: Effective Learning Tool Using AR for Knee and Foot Anatomy Based on CT Images 3D Reconstruction	

1. WORK DONE

The 3D reconstruction and AR display as the marker detected.

2. WORK TO BE DONE

Complete the AR application with description box, interaction activity and rotate features

Complete the chapter 5,6 and 7

3. PROBLEMS ENCOUNTERED

Take time in develop AR application

4. SELF EVALUATION OF THE PROGRESS

I need to be more handwork and should be start early before the semester started in order to complete. I should no drag until so late to start this project.

Sayed Ahmad Zikri

Supervisor's signature

Student's signature

Universiti Tunku Abdul Rahman			
Form Title: Supervisor's Comments on Originality Report Generated by Turnitin for Submission of Final Year Project Report (for Undergraduate Programmes)			
Form Number: FM-IAD-005	Rev No.: 0	Effective Date: 01/10/2013	Page No.: 1of 1

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

Full Name(s) of Candidate(s)	Liew Set Lee
ID Number(s)	17ACB03157
Programme / Course	BACHELOR OF COMPUTER SCIENCE (HONS)
Title of Final Year Project	Effective Learning Tool Using AR for Knee and Foot Anatomy Based on CT Images 3D Reconstruction

Similarity	**Supervisor's Comments (Compulsory if parameters of originality exceeds the limits approved by UTAR)**
Overall similarity index: 10 **%** **Similarity by source** Internet Sources: 3 % Publications: 6 % Student Papers: 5 %	
Number of individual sources listed of more than 3% similarity: 0	
Parameters of originality required and limits approved by UTAR are as Follows: **(i) Overall similarity index is 20% and below, and** **(ii) Matching of individual sources listed must be less than 3% each, and** **(iii) Matching texts in continuous block must not exceed 8 words** *Note: Parameters (i) – (ii) shall exclude quotes, bibliography and text matches which are less than 8 words.*	

Note Supervisor/Candidate(s) is/are required to provide softcopy of full set of the originality report to Faculty/Institute

Based on the above results, I hereby declare that I am satisfied with the originality of the Final Year Project Report submitted by my student(s) as named above.

SayedAhmadZikri

Signature of Supervisor

Name: SAYED AHMAD ZIKRI BIN SAYED ALUWEE

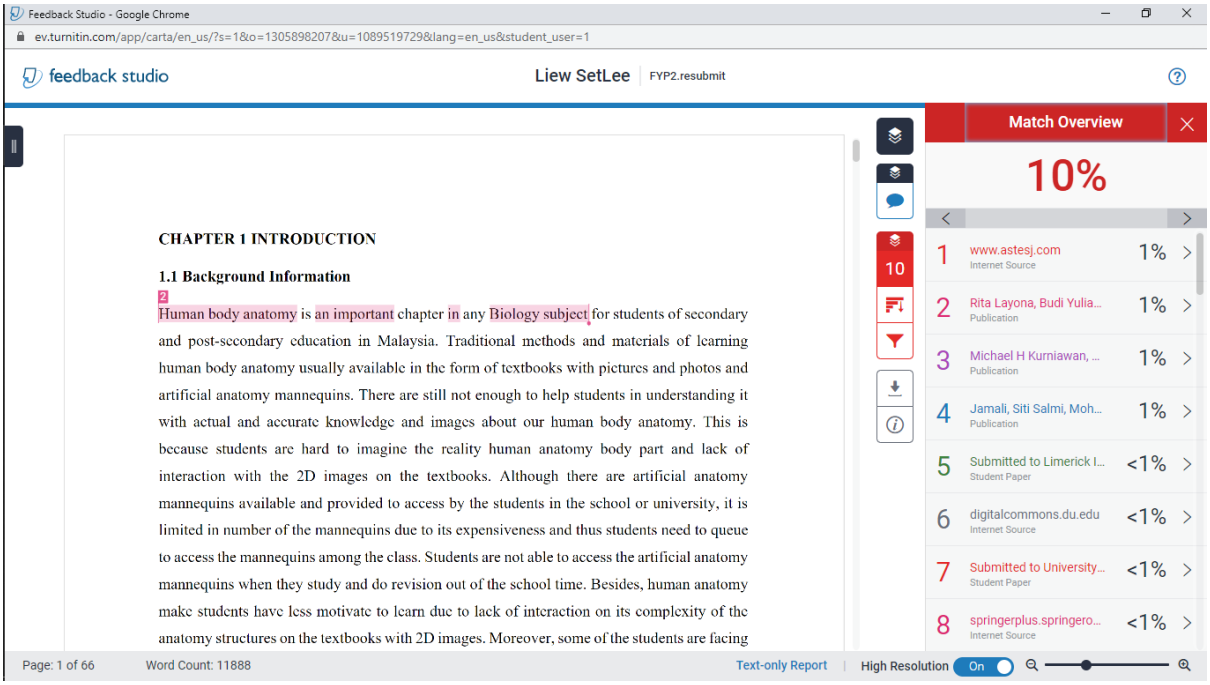
Date: 24/4/2020

Signature of Co-Supervisor

Name: _____

Date: _____

APPENDIX B: Plagiarism Check Summary



(Another version of Plagiarism Check Summary is attached at the last page)

Learning Tool Using AR for Knee and Foot Anatomy Based on CT Images 3D Reconstruction

BY: LIEW SET LEE | SUPERVISOR: DR. SAYED AHMAD ZIKRI BIN SAYED ALUWEE| MODERATOR: DR. TAN JOI SAN

Introduction

The human anatomy is a complex 3D structure which is details and the physical 2D images on traditional learning materials cannot easily to represent and visualize the anatomy features. Besides that, some of the students is experiencing difficulties in recognizing anatomy structure on the traditional method. Although there are several methods to learn anatomies through online but which are not interactive and easy to access. Moreover, most of the 3D anatomy learning model from the internet are created from the sketch drawing with software which are lack of accuracy and reality. Therefore, in this application the 3D reconstruction such as image segmentation and 3D visualization is applied on the medical datasets. Unfortunately, there is a limitation of obtaining the medical dataset of anatomy part as the data are mostly private and personal for the patients. In order to helps students to learn anatomy with more interaction, AR technology is applied in this projects.

Problem Statement

• Difficulties in visualizing and understanding complex anatomy structures through 2D images.

•Insufficient is sense of reality and accurateness of 3D anatomy structure in biology learning with 2D images.

•The limitation of technology usage in AR in education system .

Project Objective

- To enhance the acuteness of 3D modeling by replacing the 3D anatomy model from medical images 3D reconstruction instead of drawing with software.
- To provide an alternative learning method for study
- To enhance the interaction of learning for the students with 3D model in the real-time environment by AR technology

Datasets materials used

A) Knee
https://digitalcommons.du.edu/natural_knee_data/
B) Foot
https://mri.radiology.uiowa.edu/visible_human_datasets.html

System Implementation

1. Setting up MTIK
2. Images Segmentation from the medical images dataset file
3. 3D visualization to obtain the 3D polygon object
4. Apply AR technology on the 3D model with Unity Vofuria

Images segmentation process

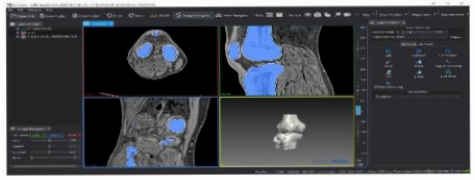
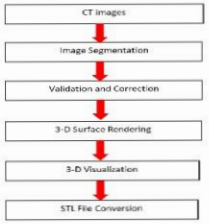
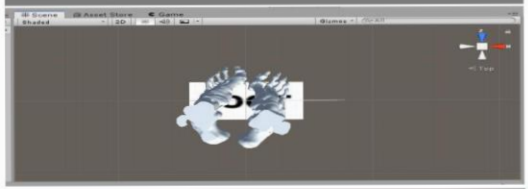


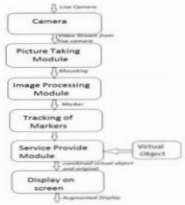
Image processing workflow



Unity vuforia



AR Workflow



Results

Conclusion

In conclusion, the aim of this proposed application is to provide an alternative learning method in study complex anatomy structures with 3D visualization and AR technology from medical images 3D reconstruction.

APPENDIX D: Questionnaire Sample

1. Do you know what is CT scan and MRI scan image?

A. Yes

B. No

C. Heard of it, but not really understand it.

2. Do you know what is 3D reconstruction of a model?

A. Yes

B. No

C. Heard of it, but not really understand it.

3. Do you experiences in using any augmented reality (AR) application (e.g Pokemon GO)?

A. Yes

B. No

C. Maybe

4. Do you know what is augmented reality technology?

A. Yes

B. No

C. Heard of it, but not really understand it.

5. Do you feel difficulties in understanding and visualizing the 2D photo or images of knee and ankle foot structure on the paper materials.

A. Yes

B. No

6. Do you think 3D technology and AR technology able to help you in learning complex human anatomy?

A. Yes

B. No

C. Maybe

7. Which do you prefer to study the human anatomy structure from sketch drawing or based on the medical images 3D reconstruction?

A. sketch drawing

B. 3D images from medical images 3D reconstruction

C. Both

8. What is the reason do you think the user might use this AR application for learning knee and foot anatomy?

A. Bored of learning from physical textbook

B. Cannot visualize well from 2D human anatomy structure

C. Easy to access with mobile phone anywhere and anytime

D. More interesting and interaction with the AR model while learning

E. All of them

9. Do you think the AR application tool in learning human knee and foot structure from CT Images 3D Reconstruction can aid you in learning more effectively?

A. Yes

B. No

C. Maybe

10. Which methods do you prefer to study complex human anatomy structure?

A. 2D images on textbooks

B. 3D images on textbooks

C. 3D images with AR technology display

11. What kind of functions/ features do you prefer to show in the application?

A. AR 3D model appear

B. Able to interact with fingertips on the AR model

C. Extra description and explanation of the anatomy structure

12. What kind of improvements do you prefer to add in this application for future development?

A. More others part of anatomy structures

B. More details explanation and description

C. Small games like exercise, labeling game

D. Improved in user friendly and UI designE. All of them

E. All of them

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Student Id	17ACB03157
Student Name	Liew Set Lee
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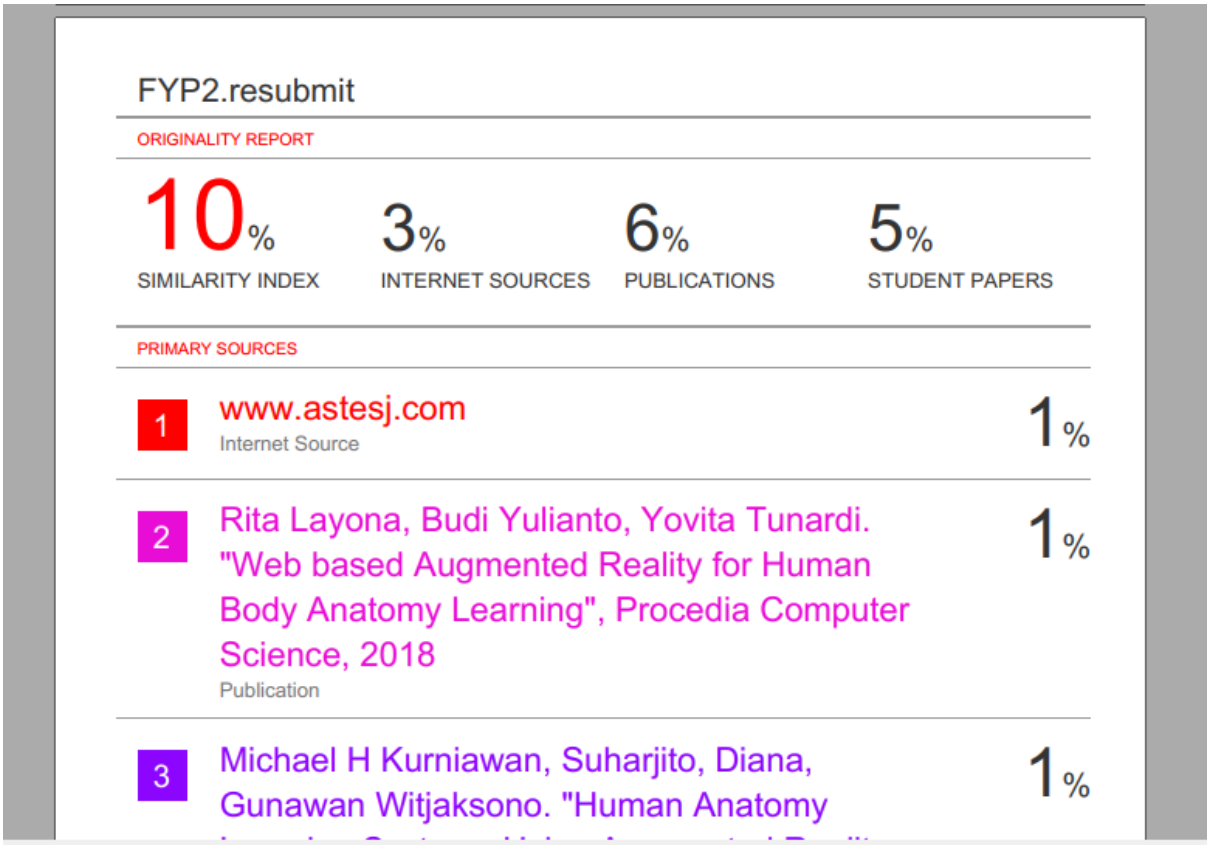
*Include this form (checklist) in the thesis (Bind together as the last page)

I, the author, have checked and confirmed all the items listed in the table are included in my report. (Signature of Student) Date: ~~24/5/2020~~ 24/4/2020	Supervisor verification. Report with incorrect format can get 5 mark (1 grade) reduction. (Signature of Supervisor) Date:~~24/5/2020~~ 24/4/2020

APPENDIX B: Plagiarism Check Summary



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3	Michael H Kurniawan, Suharjito, Diana, Gunawan Witjaksono. "Human Anatomy	1%