Mobile Application for Augmented Reality Animal Dissection

By

Edwin Lee En Yueng

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONS)

COMPUTER SCIENCE

Faculty of Information and Communication Technology

(Kampar Campus)

MAY 2019

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I declare that this report entitled "**Mobile Application for Augmented Reality Animal Dissection**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

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Foremost, I would like to express my sincere gratitude to my advisor Mr. Tou Jing Yi for his guidance, motivations, suggestions and advices in the completion of my final year project.

I would also like to express my gratitude to my family for their support in my studies whether morally, financially or physically. Without their support, the completion of this project would not have been possible.

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ABSTRACT

For decades of years, animal dissection has been used as an educational tool for educators to teach anatomy. Educators find it difficult to find alternatives that is on par with traditional dissection. However, traditional animal dissection requires a lot of preparation for a single session of dissection. It is inefficient and not cost effective as an educational method. Educators feel that alternatives could not provide the same experience that actual dissection provides such as the quality of empathy and appreciation. This project aims to provide an alternative that could fulfil these requirements by developing a mobile application that utilizes augmented reality technology. It aims to provide a virtual dissection environment with virtual dissection tools through the use of gestures so that users could gain an insight into how dissection is done. The application will provide a multiplayer platform that can be used to assist educators in teaching dissection in a classroom environment which will help in coordinating multiple students.

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LIST OF ABBREVIATIONS

3D	3-Dimension
AR	Augmented Reality
CT	Computed Tomography
IDE	Integrated Development Environment
IK	Inverse Kinematics
LAN	Local Area Network
MRI	Magnetic Resonance Images
OR	Operating Room
PUN	Photon Unity Networking
SDK	Software Development Kit
SQL	Structured Query Language
VR	Virtual Reality

CHAPTER 1 : INTRODUCTION

1.1 Background

The teaching and practice of animal dissections are deeply rooted in the study of human anatomy and physiology. In order to learn more about how our bodies work, we have turned to the use of animal dissections as an alternative to learn how a complex living organism such as humans function. This practice have continued on to the modern day as a part of our educational system and has been considered to be one of the most effective method to learn about anatomies but has also raised many controversies.

Every year, millions of frogs and mice have been used as subjects of dissections for biological studies in class room environment whether in middle school, secondary or even college level. This practice have been thought of as a form of animal abuse from animal lovers and some students also find it uncomforting to dissect an animal. Even though dissections may have exponentially increase our understanding of the anatomies of living creatures, some has said that it is at the cost of our humanity.

Furthermore, to prepare the subjects such as mice and frogs for dissection in a classroom environment requires a huge amount of effort. This includes the process of acquiring the animals, putting it into sleep and the discarding it after the dissection. From this, it is obvious that it would have cost much time and generate a lot of waste just to conduct a single session of dissection. Besides that, the use of formalin to preserve the specimens might pose serious health issues to teachers and students who are constantly facing these chemicals. This is one of the concerns of educators who conducts dissection often.

Another problem that is faced by educator is that some students find that dissection is unethical and they find that rights should be given to students who do not wish to participate in the dissection. Nevertheless, this does not mean that students should opt out of studying anatomies entirely. Educators have always tried to provide a way to teach effectively to this group of students without compromising their learning experience. Forcing students to participate is definitely not an option as it will only create negative feelings towards biological studies. On the other hand, there is a lack of effective alternatives that could provide the same pedagogical value compared to traditional dissection.

Alternatives has always been viewed as lesser in pedagogical value as most alternative that are available lacks realism and information that can be gain through real dissections. Nonetheless, this is mainly because most alternatives that are available are outdated and was never developed with the full potential of the technology that is currently available. The main problem with alternative has always been the lack of interaction and sensation that traditional dissection allows users to experience. Therefore, a bias towards traditional dissection can be seen through various studies conducted regarding the use of alternative and traditional dissection as the main teaching method.

Undeniably, learning about anatomies through dissection has certainly played a huge role in the advancement of the biological field. Therefore, this project's aim is to solve these problems. The solution revolves around the use of the augmented reality technology and the availability of smart phones everywhere. Instead of using living breathing organisms, this project aims to create a mobile application that will produce a virtual environment for everyone to be able to experience the process of dissection and anatomies without physically doing it.

Hence, the need of preparation for living animals and the inhumane act of sacrificing animals for our own knowledge gain can be reduced or even eliminated completely if this application is used in every classroom. Furthermore, it will even reduce the learning curve of biological studies as everyone will be able to gain access to dissections where ever they are and at any time that is convenient. With this project, it is hoped that the alternative proposed by this project can change the biasness towards traditional dissection.

1.2 Problem Statement and Motivation

1.2.1 Problem Statement

Educational instructors and teachers who have conducted animal dissections are unable to find an alternative that is on par with actual dissections and the process of preserving specimens for dissection is hazardous if exposed to it frequently. There are many applications that act as an alternative but it does not satisfy the needs of those who uses dissection as a learning tool. Some applications and textbooks are very informative but it does not provide the same realism and experience of performing a dissection. There are existing applications out there that allow users to perform dissection but it still does not meet the expectations of those who has a high regard for dissection. Therefore, most instructors tend to rely on traditional dissection as the main educational tool.

- Lack of realism in existing alternatives
  - Alternatives do not provide realistic interactions of real dissections in terms of handling dissection tools and the environment that are illustrated in applications tend to be bland and unrealistic.
- Applications do not provide functionalities for group interactivity
  - Existing applications do not provide functionalities that can be used to interact as a group such as having multiple users dissecting on the same specimen.
- Applications do not provide the tools needed for educators to direct students
  - Existing applications are generally catered to solo usage which makes it difficult for educators to give directions to their students during dissection sessions.

1.2.2 Motivation

There are many applications and alternatives that are very informative in anatomies however it does not meet the requirements that educators need to use as an alternatives as an educational tool in dissection. This project aimed to develop an application as an alternative to dissection that will be able to serve the needs of educators that uses dissections as an educational tool.

1.3 Objectives

1. To develop a mobile application that simulates virtual dissection through marker based augmented reality.
2. To develop a mobile application for virtual dissection with dissection tools that utilizes touch gestures.
3. To develop a mobile application that provides a platform for multiplayer dissection environment through the internet.

1.4 Project Scope

The scope of the project will be to develop a mobile application for virtual dissection. There are existing applications that provide similar functions however improvements will be made to serve the need of educators.

- Marker based augmented reality of dissection environment
    - The dissection environment will be augmented with the real environment of users by using the camera to track an image that will be used as the marker to determine where the virtual objects will be placed on the scene.
- Virtual dissection tools that utilizes touch gestures
    - Three types of tools will be provided to perform the dissection which is a scalpel, pin, and forceps.
    - Gestures can be used to activate the tools without selecting the tools
    - The forceps can pick up virtual object with the pinch gesture.
    - The scalpel executes the cut function through the gesture of drawing a line on targeted areas.
    - The long press gesture activates the pin function.
- Multiplayer system
    - Users will be able to create a room that will be broadcasted on the internet.
    - Other users can create new room or join the rooms available.
    - The interactions on the virtual content will be synced with other users.

1.5 Proposed Approach

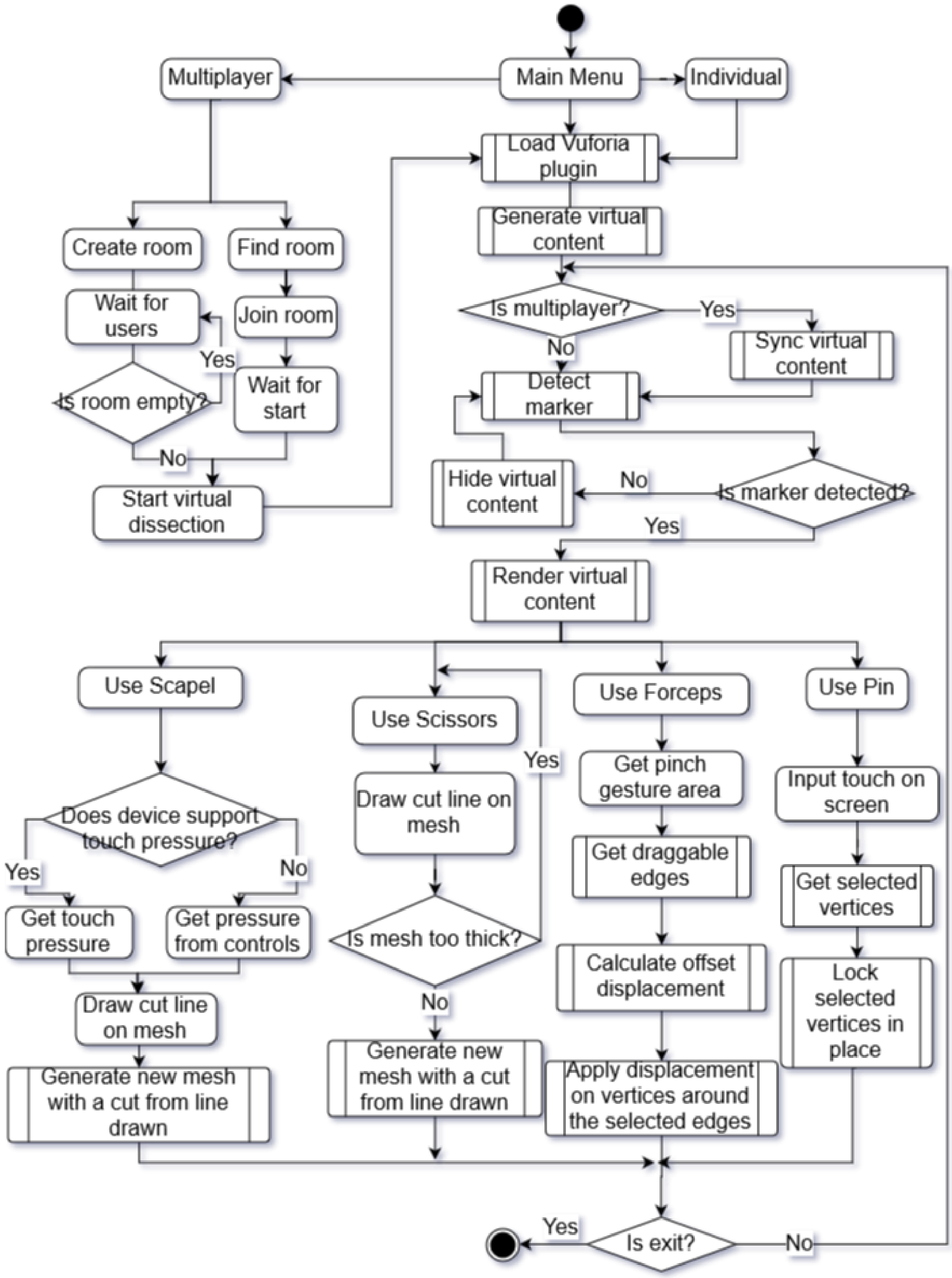

Figure 1-1 Propose System Flowchart

The proposed approach is made up of 6 modules that are integrated into one system. The modules are identified as the augmented reality module, scalpel tool module, scissors module, forceps tool module, pin module, and multiplayer system module. Each of this module will be integrated together to form a mobile application.

Augmented Reality Module

The augmented reality module works by first loading the Vuforia plugin which contains the libraries needed to perform image recognition to detect the marker and generating the virtual content and augment it onto the detected marker.

Scalpel Module

The scalpel module is activated when the user selects the scalpel tool. The tool is used to cut the 3D virtual specimen. The harder a user press on the screen the deeper the scalpel cuts.

Scissors Module

The scissors module is similar to the scalpel module. However, touch pressure is not taken into consideration as the tool will be able to cut through a single layer of mesh with a thickness that is lesser than or equal to a pre-defined thickness limit.

Forceps Module

The forceps module works by detecting the area afected by the pinch gesture. If there are edges in the selected area, the edges will be checked whether it is draggable.

Pin Module

The pin module is a simple tool that locks vertices in place so that part of the 3D virtual specimen can be hold in placed. The tool works by receiving touch input from user and the touch position will be used to determine an area of selected vertices.

Multiplayer System Module

The multiplayer system uses the host migration concept to connect multiple users in the virtual environment. However, instead of having a centralized server, the user that created (hosted) the room will be the server which will also be known as Master Client in the Unity's Photon plugin.

CHAPTER 2 : LITERATURE REVIEW

2.1 A Debate on Dissection and Alternatives

According to a survey done by Oakley (2012), it is shown that most of the teachers who have participated in the survey found that traditional dissection has unparalleled value compared to other substitutes. It was shown that "87.5% either agreed or strongly agreed with the statement, "Real animal dissection is important to the teaching of biology" and more than half (56.3%) agreed or strongly agreed that there are no substitutes for real animal dissection." (Oakley 2012). From the statement, it was clear that traditional dissection has played an important role in the biological studies. However, does this mean that a better alternative should not be considered?

Even though most teachers who participated in the survey prefers traditional dissections, some have also expressed concerns mostly regarding health and safety. Some of the concerns involves accidents from handling scalpels, pins and chemicals that might hurt the students, misbehaving students and classroom management issues. Prolong exposure to formalin solution is also one of the main concern as it could cause health issues. (Oakley 2012).

From the survey done by Oakley (2012), there were 125 participants who reported using alternatives out of the 153 teacher participants. The alternatives include "CD-ROMs or computer programs (80.0%); charts, posters, textbook diagrams, and/or overheads (76.8%); 3D anatomical models (67.2%); videos (56.8%); and "other alternatives" (21.6%). "Other alternatives" included written assignments, websites, field trips and virtual field trips, dissection picture cards, and other creative teaching strategies, such as asking students to build 3D models out of clay or asking them to create a board game illustrating their understanding of anatomy and physiology." (Oakley 2012). The report also states that 96 teachers used alternatives as supplementary aid or to prepare students to real dissections.

Some of the main concerns with alternatives was the lack of realism, diversity and do not gives a sense of wonder to the students as Oakley (2012) reported. Some students find that alternatives are good training tools but it is too boring for them and that there are no difference compared to a textbook. Sixty-four teachers indicated that most alternatives are outdated in their schools which it difficult to use while some considered it as more cost-effective.

Although some teachers have used alternatives, the study concluded that teachers do not see alternatives as adequate. Majority of the teachers found that the hands-on practice is the best way to learn as it increases student interest and shows the complexity of biological organisms. Oakley (2012) states that alternatives are not "the same" as traditional dissection but does it mean that it is less pedagogically effective and the question still remains as to whether dissection is ethically justified.

The research has shown clearly that almost none of the teachers find that alternatives can be compared to real dissection. It has states many of the benefits of hands-on practice and in general, students preferred it as well. The study pointed out that alternatives do not provide realism to the students and are not pedagogically effective. All this are definitely agreeable considering the alternatives that was used such as CD-ROMs and diagrams, are not as interactive as doing actual dissection.

However, this does not conclude that alternatives will never be pedagogically effective and should not be considered as the main learning source. As stated in the research, most teachers in school uses alternatives that are not interactive and outdated. The lack of interaction causes the use of alternatives to seem boring compared to real dissections. Therefore, this is one of the main reason that students find that alternatives are as boring as textbook and teachers find that alternatives are inadequate compared to conventional dissection.

2.2 Attitude towards Dissection

As cited by Osenkowski et al. (2015), Oakley (2012) stated that dissection is not practiced globally as countries such as Argentina, Israel, the Netherlands, Slovak Republic and Switzerland do not conduct dissections and even if practiced, it is very rare or gradually excluded in countries such as England, Germany, Sweden and India. Technological advancement have led to development of interactive virtual dissection alternatives that provide three-dimensional views of animal organs, information related to specimen being viewed and anatomical comparisons of animals and humans which are commercially available for tablets, laptop, desktops and interactive whiteboards (Osenkowskil et al. 2015).

How much do you agree or disagree with each of the following statements?	Agree	Disagree	Neutral
Dissection is the best way to teach anatomy and/or physiology.	70	12	18
Dissection is no longer necessary to teach the life sciences.	21	60	19
Alternatives are as good as dissection for teaching anatomy/physiology.	21	54	25
I have ethical concerns about animal dissection.	18	62	20
Technology will make animal dissection obsolete.	20	59	20
The use of dissection in biology education is an important tradition.	56	22	22
Students should be required to participate in animal dissection.	29	45	27
The science faculty at my school generally supports dissection alternatives.	48	13	38

Table 2-1 Shows percentage of educators who agreed or disagreed with the following statements regarding the use of dissection and dissection alternatives (Osenkowski et al. 2015:p341).

The research conducted by Osenkowski et al. (2015) shows that 84% of educators uses dissection as a teaching tool which is a figure that is slightly higher than other studies such as a research by Oakley (2012) as cited in the research. “Over half of educators (56%) viewed dissection as an important tradition in biology education. The majority of educators (70%) considered dissection the best way to teach anatomy and physiology. Most educators (60%) disagreed with the statement that dissection is no longer necessary to teach the life sciences. The majority of educators did not believe that alternatives were as good as dissection for teaching anatomy and physiology (54%) and did not believe that technology will make dissection obsolete (59%)” based on the table above (Osenkowski et al. 2015).

Another study that was done was on the subject of commonly used animals for dissection exercises. Teachers and students were asked about their use of dissection specimens. (Osenkowski et al. 2015). The result of the study was a report by teachers of frequent or occasional use of frogs (59%), fetal pigs (57%), and earthworms (47%), and other specimens for the past 2 years which is consistent to the top three animal specimen reported by King et al. (2004) (Figure 2-1A) (Osenkowski et al. 2015). Student however has reported of commonly dissected frogs (78%), earthworms (31%), and fetal pigs (24%) (Figure 2-1B). Figure 2-1 below shows “prevalence of animals commonly used as dissection specimens in precollege biology education. Table (A) shows the percentage of teachers who have regularly or occasionally used animal species for dissection specimens during the past 2 years, among the teachers who practice dissection (n = 986). Table (B) shows the percentage of students who have dissected animal species shown (n = 500).” (Osenkowski et al. 2015).

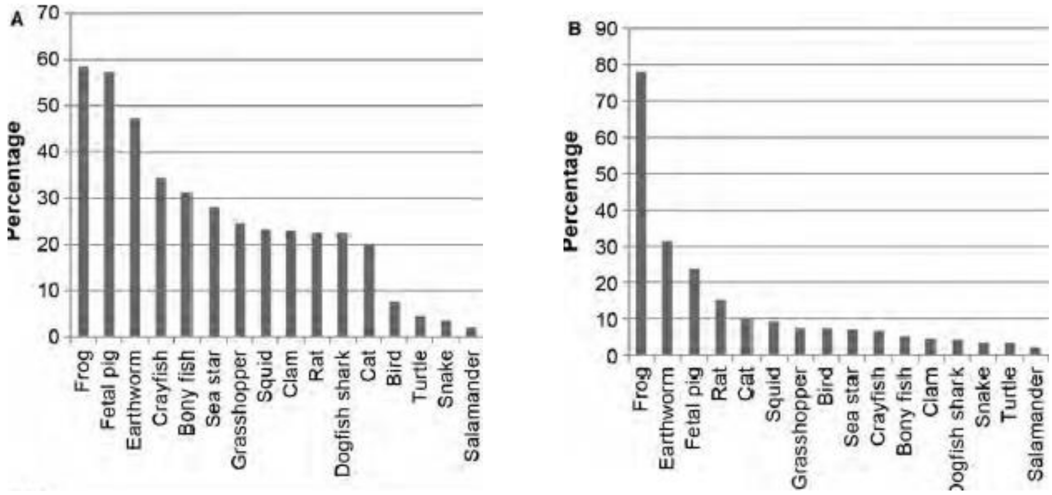

Figure 2-1 Shows prevalence of animals commonly used as dissection specimens in precollege biology education (Osenkowski et al. 2015:p342).

To better understand student preference toward animal dissection another study was conducted by Osekowski et al. About half of the students (48%) indicated that they do not prefer the use of alternatives while 37% did not know (2015, p. 343). The table below shows the result acquired from the study by Osenkowski et al. (2015).

How much do you agree or disagree with each of the following statements?	Agree	Disagree	Neutral
I have ethical concerns about animal dissection.	29	46	25
I am more interested in science because I dissected an animal.	30	45	25
Students should have a choice to opt out of dissecting animals.	68	17	15
I would like biology education to be more computer-based.	34	40	26
Dissection has been an important part of my education.	36	38	26
Students should be required to participate in animal dissection.	23	49	28
I am concerned about being exposed to toxic chemicals or sharp instruments.	32	44	24

Table 2-2 Shows percentage of students who agreed or disagreed with the following statements regarding the use of dissection and dissection alternatives (Osenkowski et al. 2015:p344).

The research has shown that many of the students and teachers prefer animal dissection instead of alternatives. Even though almost half of the students agreed that animal dissection is compulsory, more than half of the students finds that student should be given options to opt out of dissecting animals. According to Osenkowski et al. (2015), "it is possible that lack of awareness about dissection alternatives and their availability among the student population may be contributing to the low percentage of students requesting their use. Our survey revealed that 38% of students did not know whether dissection alternatives were available to them”.

2.3 Virtual Reality training in Neurosurgery

Observations has always been a method to learn in surgical education in the United States for more than a hundred years but it has been increasingly challenged recently regarding legal and ethical concerns for patient safety (Alaraj et al. 2011). The rising field of simulation and virtual training allows neurosurgical procedures to be practiced and taught outside of the operating room (OR) according to Alaraj et al. (2011). In this paper, the evolution of virtual reality (VR) simulators for neurosurgical training will be discussed.

Neurosurgery is a complex operation as it involves overlapping structures in the brain and spine which may be hard to visualize (Alaraj et al. 2011). However, with the aid of 3-dimensional visualization of the structure, surgeons are able to do pre-operative planning with the main focus of exploring the patient data as much as possible and evaluating possible intervention procedures against that data. “This is accomplished by first creating 3D images from the patient's own diagnostic images, such as computed tomography (CT) scans and magnetic resonance images (MRI).” (Alaraj et al. 2011).

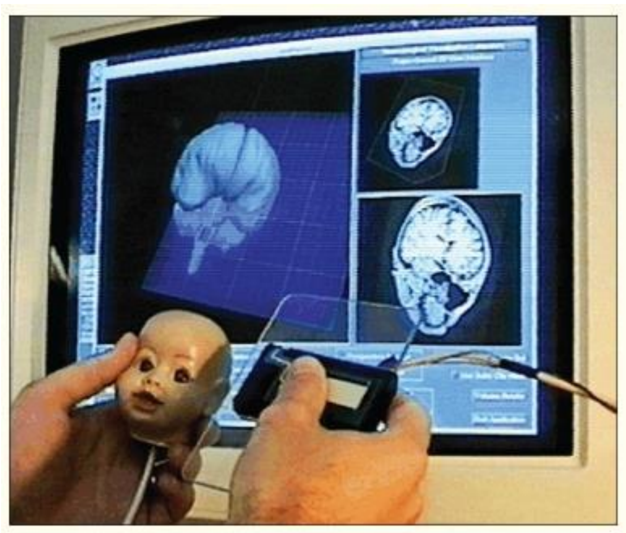

Figure 2-2 Shows a user selected a cutting plane of a mannequin head with the props interface showing the corresponding MRI image cuts part of preoperative surgical planning. (Alaraj et al. 2011).

This is only one of the virtual alternative that was researched on. There are more alternatives such as radio surgery, augmented reality surgery, Tele (remote) medicine, and augmented reality in intravascular neurosurgery. All of which could play a huge role in the advancement of neurosurgery without the need for observing an actual procedure in the OR.

Figure 2-3 Showing the ImmersiveTouch™ system in operation. (Alaraj et al. 2011).

From the research conducted, it can be concluded that virtual reality is becoming increasingly important in neurosurgery. Not only does virtual environments overcome the ethical issues, it also improves the performance of neurosurgeons drastically. However, some challenges and limitations still arise in the development of immersive and effective systems (Alaraj et al. 2011). According to Alaraj et al. (2011), "Open cranial operations provide a special challenge, since various tissue types may be concurrently present in the surgical field. These tissues are compacted in a three dimensional fashion, with a complex relationship to scalp, skull, and intracranial vessels".

The conducted research only applies to neurosurgery but if virtual reality could play such a huge role in the teaching and practice of neurosurgery which is considered to be a very complex field, why can't the same alternative be used for dissections in classrooms which is less complex compared to neurosurgery. The research has shown the potential of virtual environment in replacing traditional dissection in contrary to what most teachers and students have disagreed with regarding alternatives in dissections (Oakley 2012).

The statement "A group at the University of Tokyo, however, has recently established that an interactive visualization system and a virtual workstation offered significantly improved diagnostic value over traditional radiological images" as concluded by Alaraj et al. (2011) makes it even more compelling that alternative can certainly be considered as the main approach and even top traditional methods in biological studies.

The only reason such high end technologies are not available in schools for educational purposes are mainly due to the cost of the technologies (Oakley 2012). If a similar technology that is produced to cater to high school students with reasonable price or even free, it would definitely be able to change the view of dissection as the main approach to teaching about animal anatomies. Such ideal is not far from reality with the current technologies that is available now.

2.4 Dissection Lab Mobile Application Review

Dissection Lab is a mobile application available on the Android, iOS and PC that provides dissection process, facts and anatomy information of various animals to users. According to Navtek Solutions, creator of Dissection Lab, the application is created as an alternative to live animal dissection.

Figure 2-4 Promotional image of Dissection Lab from Navtek Solutions website

The application provides 7 types of species for users to explore which includes frog, rat, cockroach, earthworm, starfish, shark and pigeon. However, the only free to access species is the frog and all the other species require users to unlock by paying for approximately RM 4.99 with a 6 months validity duration. This means that after 6 months, users have to unlock the species again.

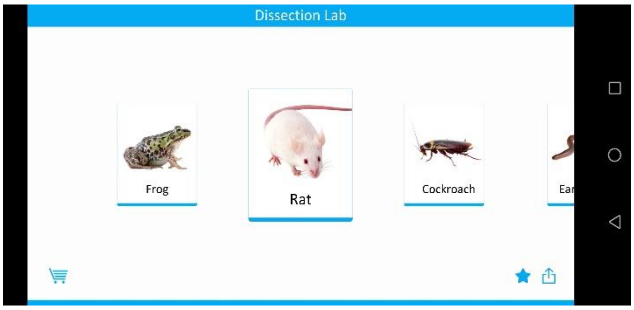

Figure 2-5 Main screen of Dissection Lab

Selecting the options above shown in Figure 2-5 directs users to 3 options or to the shop to unlock the locked species. The 3 options include Dissection process, about species, and external anatomy (Figure 2-6).

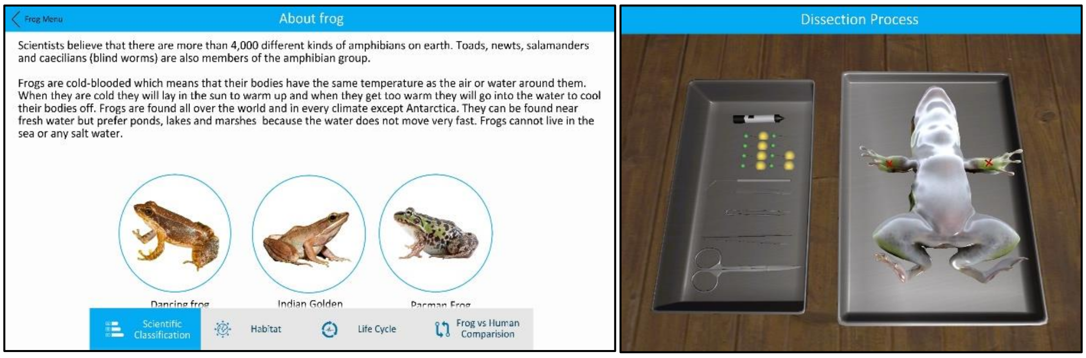

Figure 2-6 Learn about species screen (Left) and dissection process (right)

The dissection process screen uses texts and computer generated voice to direct users on the process of the dissection. The directions start from where to pin the frog to where to cut the frog. The users pin the frog by selecting the pins and tapping on the area marked with 'x's and the users can cut the frog by drawing a line that follows the guideline shown on the frog. Users can also open up the frog using the forceps by dragging on the spots that are drag able. However, users are able to use the tools' functions only when the directions are given.

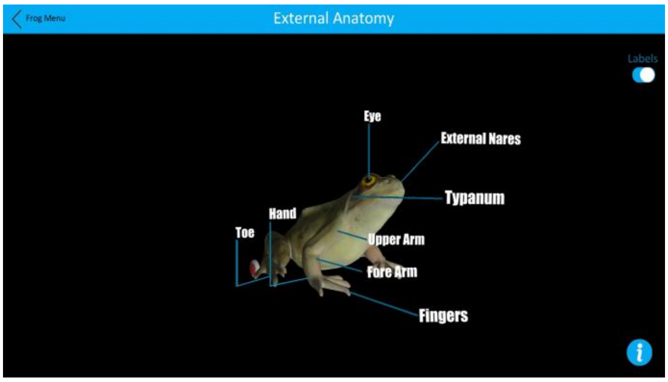

Figure 2-7 External anatomy screen

The external anatomy screen (Figure 2-7) shows a 3D model of a frog that have labels of the frog's anatomy. The labels will only appear when the users pressed on the area indicated to them. Once all the labels are shown, it will move on to showing deeper parts of the frog's anatomy. The functions of the 3 screens do not only apply to the frog but also to other animal species shown in the main screen (Figure 2-5).

2.5 Froggipedia iOS Application Review

Froggipedia is an application that is currently only available on iOS devices. It utilizes augmented reality and interactions with users to presents the life cycle and anatomical details of a frog. The application is solely focused on frog and it contains the life cycle, anatomical structures and the dissection process of a frog.

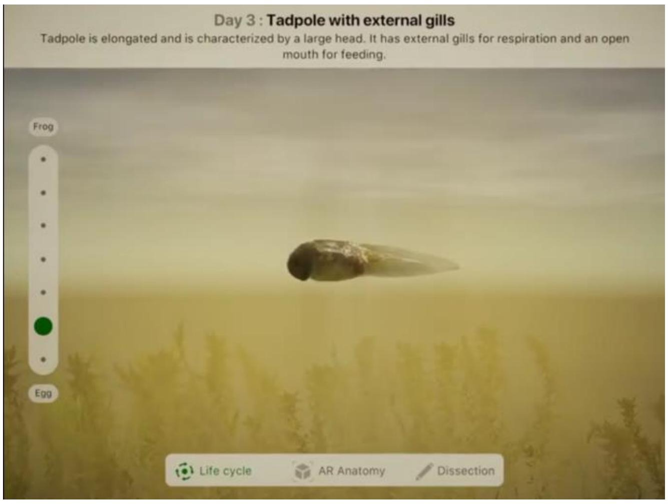

Figure 2-8 Life cycle screen

The main screen of the Froggipedia application is the life cycle screen. This screen allows users to navigate through the life cycle stages of the frog by selecting the dots on the left of the screen. There are 3 buttons located at the bottom of the screen that allows users to navigate to the other screens which is the AR anatomy screen and dissection screen. This 3 buttons remains at the bottom of the throughout all the screens.

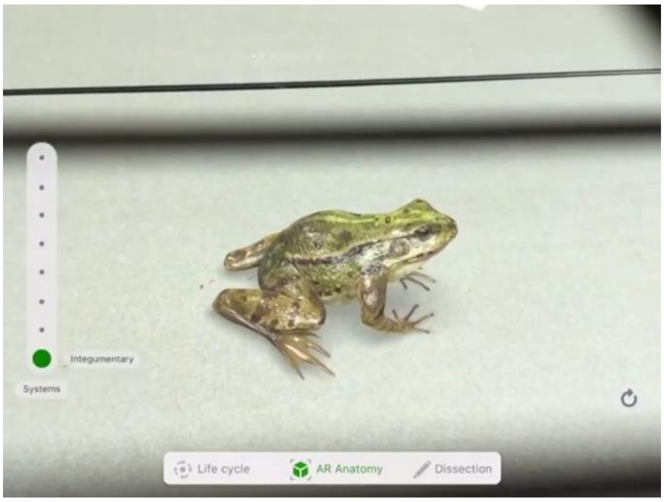

Figure 2-9 AR anatomy screen

The screen shown in Figure 2-9 uses augmented reality to present a life-like 3D frog model to users. On the left are buttons that allow users to navigate through the external anatomy to the internal anatomy of the frog.

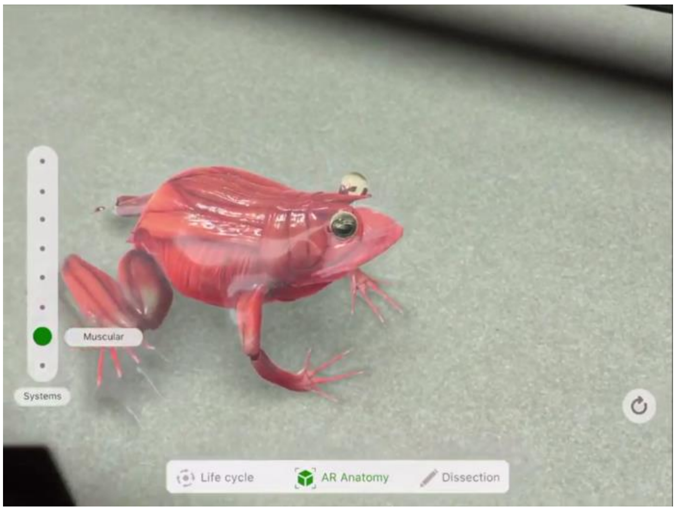

Figure 2-10 Muscular system of the frog in the AR anatomy screen

The figure above shows the muscular system of the frog. The screen allows users to view from the integumentary system to the digestive system of the frog. The 3D frog is constantly breathing and moving subtly and the inner systems actually mimics the breathing and movements of the frog.

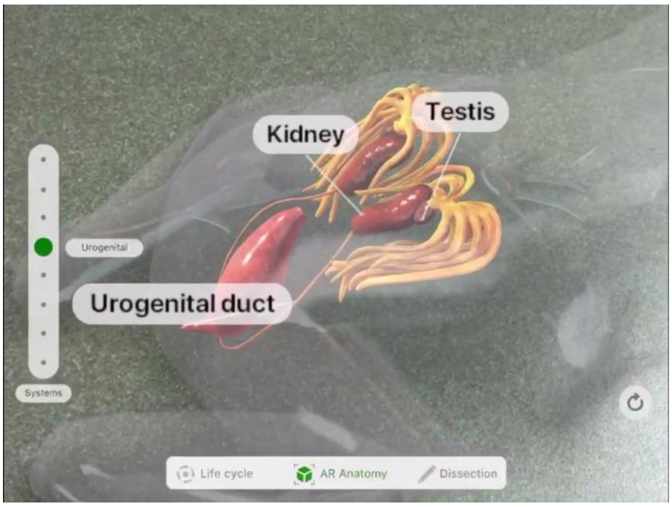

Figure 2-11 Muscular system of the frog in the AR anatomy screen

Whenever the user move closer to the frog, labels will appear to label the organs. It appears in a very neat and unintrusive manner.

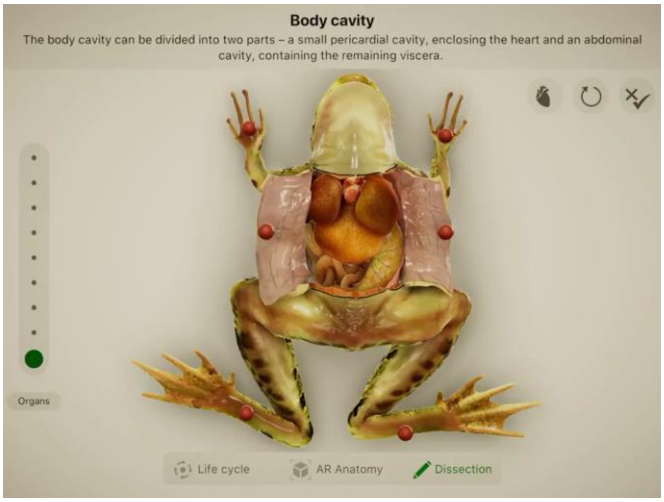

Figure 2-12 Dissection screen

The application also provides interactive dissection procedures to users. It will highlight the areas on the frog where users are supposed to perform certain actions and the textbox above the screen will provides instructions to the users. The users do not need to select any tools as the application will automatically display respective tools when the action such as tapping or drawing a line on the highlighted areas.

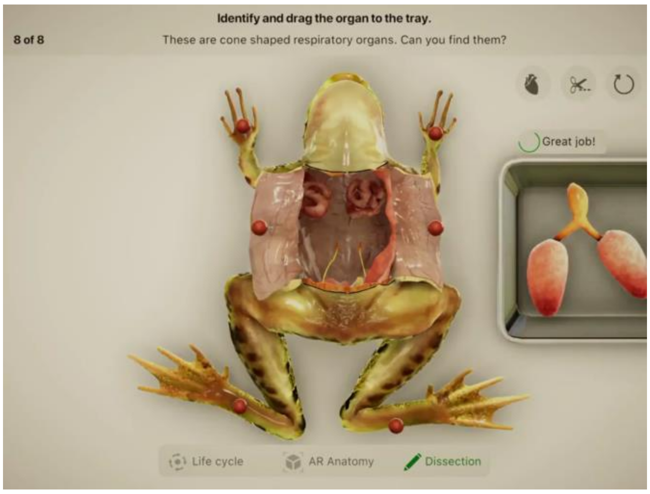

Figure 2-13 Organs identification

Once the frog is dissected, the texts above will start to ask users to identify the organs of the given characteristics. The users are required to drag the selected organs on to the tray on the right. If the selected organ is incorrect, the users will have to select again. Users will not be penalized for any wrong guesses.

CHAPTER 3 : METHODOLOGY

3.1 Software Development Methodology

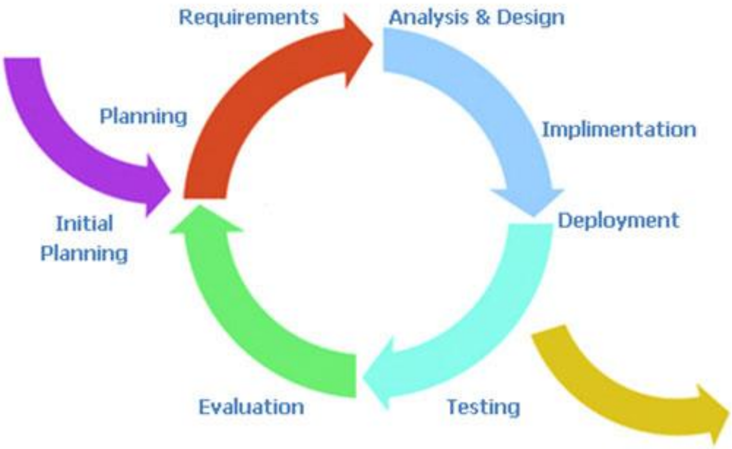

Figure 3-1 Incremental Development Model

The project will be based on incremental development where the application's features will be developed iteratively and incrementally. Each features will be added incrementally and iteratively during the whole development phase until all of the requirements are met. By using the incremental development method, useful versions of the application can be generated quickly to be used for testing and refining. Based on the system design in chapter 3, the functions and features of the application can be separated into phases where each phase will deliver a new version of the application.

In table 3-1 on the following page, shows the work breakdown structure of the project. The table shows how the modules are separated into phases to be develop incrementally. On each phase, tests are done for each module to ensure that it is functioning correctly before moving on to the next phase. Every completed phase delivers a version of the application. Every version should be functional without any dependencies to the next version. However, the next version will enhance the modules of the previous versions.

Once all the phases are completed, the objectives of the project should have been achieved. Since an incremental model is used, new phases with more modules can always be added to improve the delivered application. This allows future improvements for the application.

Phased/Activity	Description	Deliverable
Phase 1	• **Develop the first version of the application.**	**Application ver. 1**
Integrate augmented reality	• Integrate the augmented reality function with Vuforia using markers • Generating the virtual content	Augmented reality function
Develop Scalpel function	• Get the touch pressure function • Create control pressure function • Create function to draw line on mesh • Generate a new mesh with a cut based on the line drawn	Scalpel function
Phase 2	• **Develop the second version of the application by adding new tool functions into the first version**	**Application ver. 2**
Develop forceps function	• Create function to select an area of edges that will be affected • Create function to check if edges are drag-able • Calculate offset displacement on surrounding vertices • Apply the displacement on selected edges • Apply offset displacement on surround vertices	Forceps function
Develop pin function	• Create function to select affected area of vertices and lock vertices in place	Pin function
Phase 3	• **Develop the third version of the application by adding the multiplayer system into the second version**	**Application ver. 3**
Develop gestures handler for tools	• Implement gestures for the scalpel, forceps and pin	Gestures Handler
Develop multiplayer system	• Create function to create a room on the network using the device's IP address and the port number • Create function to discover created rooms on the network • Create function to join discovered rooms • Create function to assign role to users in the room • Create function to start the virtual dissection for every user in the same room • Create function to ensure the virtual dissection state is synced with all users in the same room	Multiplayer system

Table 3-1 Project work breakdown structure table

3.2 Tools Used

- Software Development Environment
    - **Unity** – Unity is a cross-platform game engine developed by Unity Technologies that allows application developed to be easily deployed to multiple platforms such as PC, web and mobile. The engine also provide ready-made assets, physics, intuitive tools and OpenGL based graphical rendering that greatly assist the development process.
- Integrated Development Environment (IDE)
    - **Microsoft Visual Studio Community 2017 –** Visual Studio Community 2017 is and IDE that is built on .NET framework which supports C# language that will be used as the main language for this project.
- Software Development Kit (SDK)
    - **Vuforia –** Vuforia is developed for integrating augmented reality into mobile applications. It is one of the most widely used platform for augmented reality applications. Vuforia utilizes ARCore and ARKit on devices that supports it otherwise, it will use its own technology which is on par with ARCore and ARKit. In addition to that, there is also a version that is baked into Unity.
    - **Photon –** Photon is a SDK that allows networking in Unity. It allows cross platform and contains pre-made scripts for network connectivity. This SDK contains a rich library for communications among devices.
- Programming Language
    - **C# -** C# was developed by Microsoft and is part of .NET and is commonly used for developing web and mobile application. It is a programming language that follows object-oriented and component-oriented programming disciplines.

3.3 System Design

3.3.1 System Overview

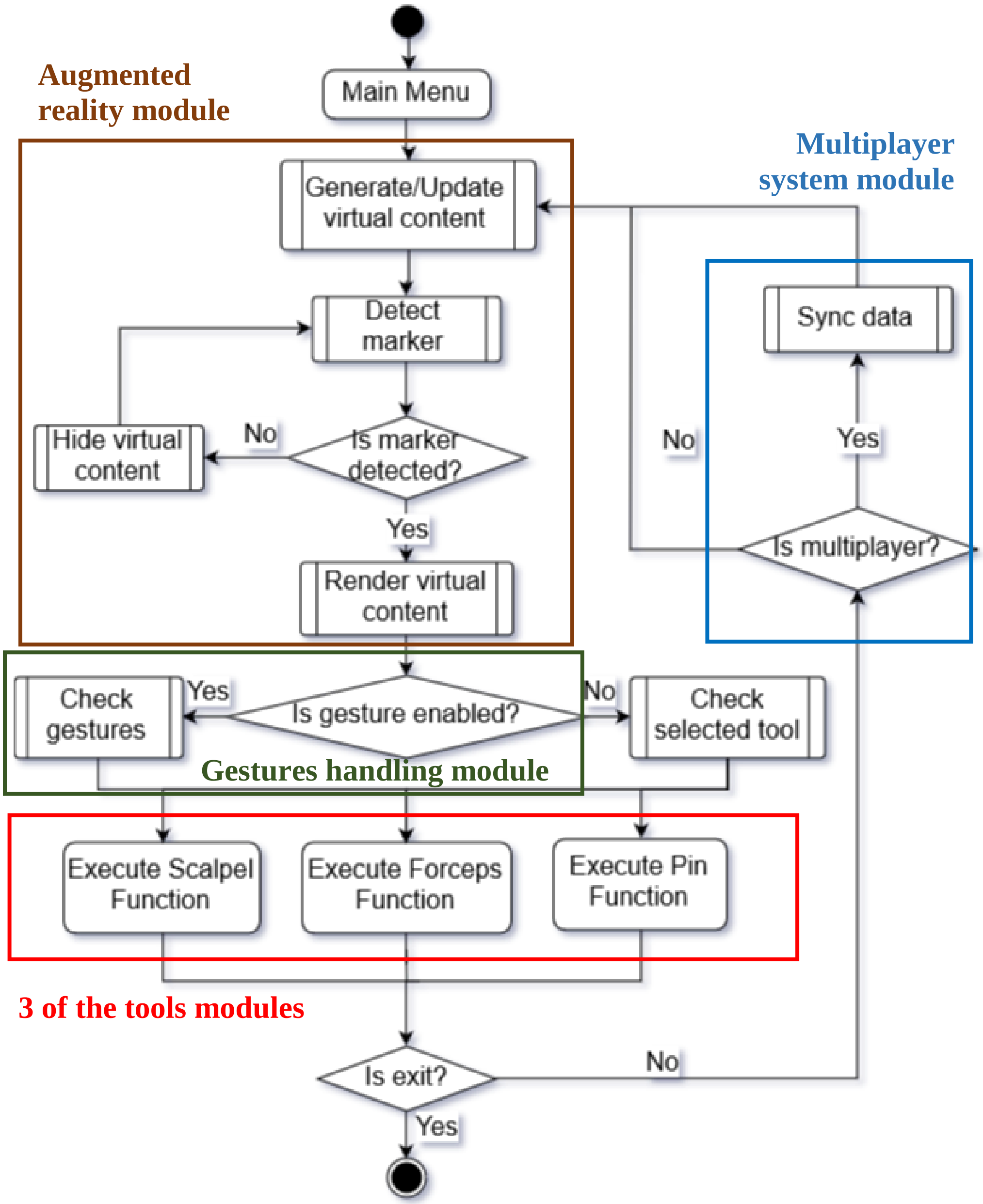

Figure 3-2 System Flowchart

The flowchart above is a simplified and improvised version of the flowchart shown in Figure 1-1 in section 1.5 of chapter 1. As described in section 1.5 of chapter 1, the system is made of 6 modules which is the augmented reality module, scalpel tool module, forceps tool module, pin too module, gestures handling module and the multiplayer system module. The sections highlighted above shows which module will handle which functions and processes. Each module will be explained in section 3.2.

3.3.2 Module Descriptions

3.3.2.1 Augmented Reality Module

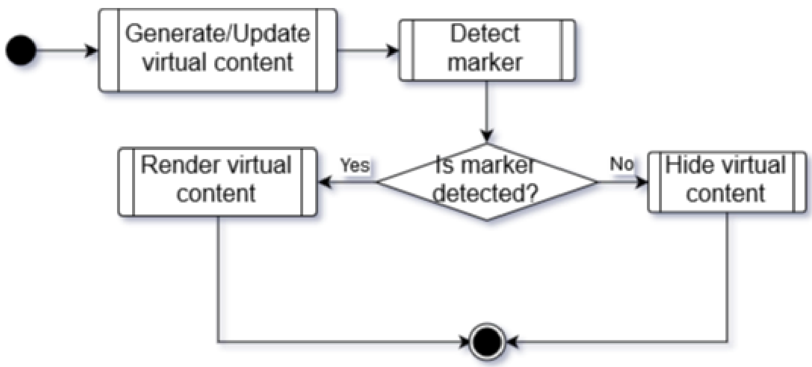

Figure 3-3 Augmented Reality Module

The augmented reality module works by performing image recognition to detect the marker and generating the virtual content and augment it onto the detected marker. This type of augmented reality is called marker-based augmented reality. The marker is detected by using the camera to capture the placement of marker and on every frame the marker will be compared to the target image that was set as the marker. The feature points of the target image will be used to identify whether the captured marker is the target image. If it is, the virtual content will be rendered and the placement of the virtual content will follow the placement of the marker. This creates an illusion of augmented reality. In this project, the processes desribed are handled by the Vuforia framework which contains the APIs and tools needed by the processes. The integration of the framework into the project will be described in chapter 5 section 5.3.1.

3.3.2.2 Scalpel Tool Module

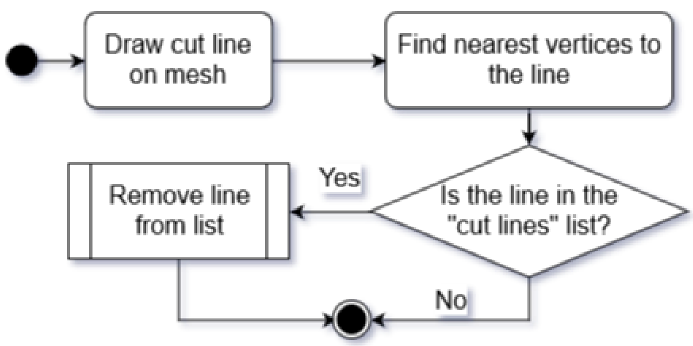

Figure 3-4 Scalpel Tool Module

The scalpel tool is a tool that enables users to perform the action of cutting the 3D model. The cutting mechanism does not perform any actual mesh deformation cuts on the mesh itself but instead unlocks the function to move the cut areas when the user has “cut” the pre-defined cut areas.

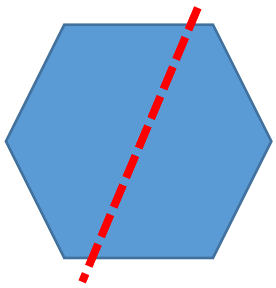

Figure 3-5 Illustration of a cut line on a 2D polygon

Based on the figure above, if the user draws a line outside of the dotted line, it will not be considered as a valid cut line and if the line is drawn on the dotted line, it will be considered as a valid cut and will unlock the respective cut areas to allow the user to manipulate it. For example, the ability to drag the skin of the cut area with the forceps.

The pre-defined cut method has been used in many applications especially applications that requires users to dissect objects. This method can be easily implemented by aligning the drawn line of the cursor which is in 2D space to the 3D object in the 3D space. However, the same cannot be done when augmented reality is applied to the 3D object as the angle and placement of the 3D object will constantly be changed due to movements of users.

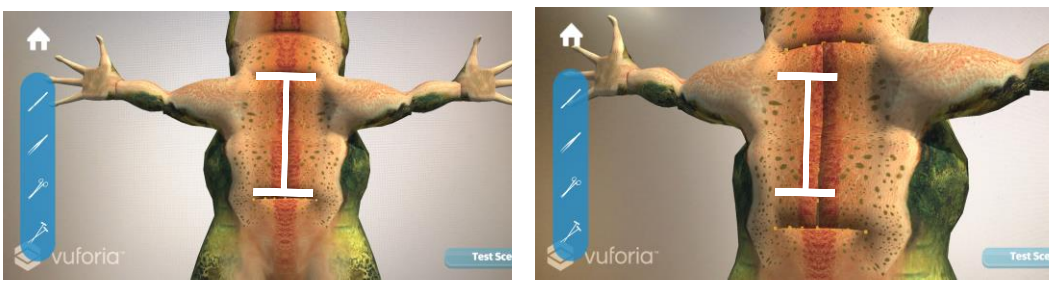

Figure 3-6 Front view of 3D model (left) and angled view of 3D model (right)

The figure above shows the 3D model of a frog with pre-defined cut lines. The white lines indicate the initial area of the pre-defined cut of the image on the left but when the angle and position of the 3D model is changed (as shown in the image on the right), it can be observed that the white lines are no longer aligned with the pre-defined cut.

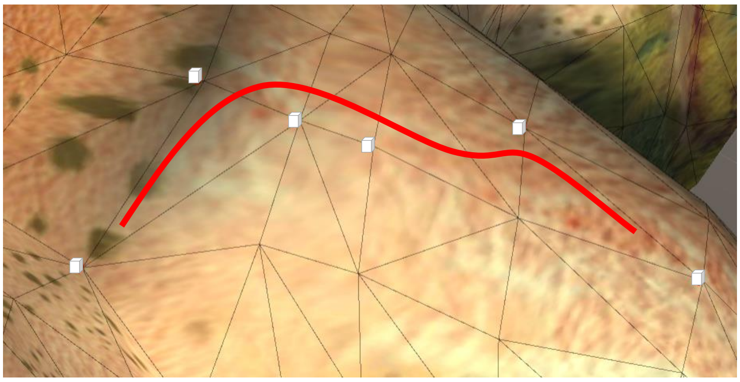

Figure 3-7 Drawn line on mesh with nearest vertices selected

Therefore, the method used in this project is to draw the line on the mesh itself instead. The line drawn is used to determined which vertices of the mesh are selected by finding the nearest vertices to the line. The vertices will then be compared to the vertices of the pre-defined cut line. If the vertices matches, then the cut will be considered as a valid cut.

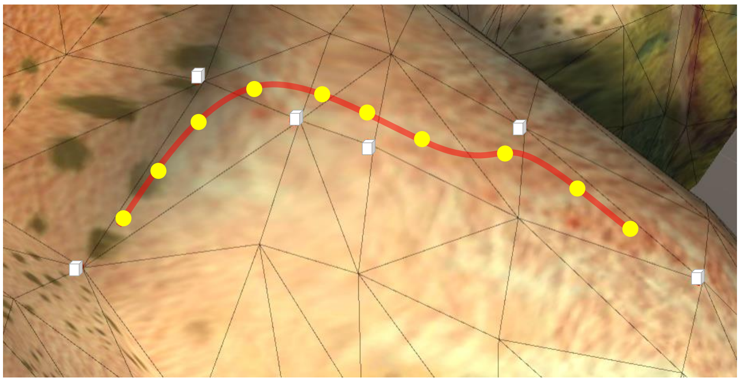

Figure 3-8 Points formed from drawn line on mesh with nearest vertices selected

In order to find the nearest vertex to the line, the line has to first be converted to points. The points can then be used to find the nearest vertex of each of the points. The points are formed at an interval to ensure that a limited amount of points are formed to save computational resources. Once the points are formed, the nearest vertex to each points can be determined by finding the smallest square magnitude of the vertex to the point. If the same vertex is selected by different points, the vertex will only be compared once during the comparison phase.

The setback of this method is that the time complexity of the operation will be O(n*m) which means the time required will increase quadractically depending on the number of vertices (n) and number of points (m). The solution to this is to first check which triangle the point is located at and compare the 3 vertices of the triangle instead. This will reduce the time complexity increase rate of the operation by 3 times as the number of triangles is 3 times lesser that the number of vertices.

3.3.2.3 Forceps Tool Module

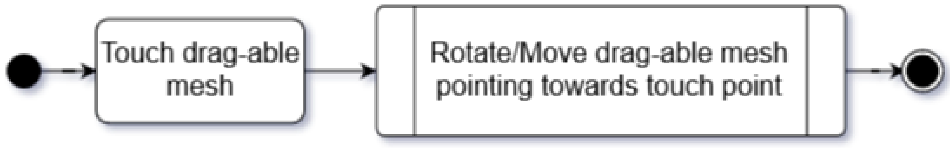

Figure 3-9 Forceps tool module flowchart

The forceps tool allows user to move and rotate parts of a 3D object in the scene. The forceps tool work by detecting the position of a touch on a drag-able mesh and then pointing the mesh towards the touch position or moving the mesh if it is moveable. The forceps tool does not deform the mesh directly but instead manipulates the "bone" that is associated with the mesh. Further implementation details on assigning the bones are described in chapter 5 section 5.2.2.

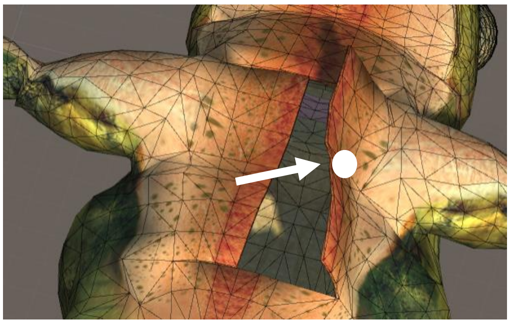

Figure 3-10 Frog skin flap dragged at touch point (white dot)

The figure above shows how the mesh if affected when the "bone" of the skin flap on the right rotate towards the touch point (white dot). This method contains 2 steps where the first step is to assign the mouse movements to the touch point and the second step is to calculate the rotation required for the mesh to rotate towards the touch point. The touch point is defined as the area where the mouse is supposed to be pointing on the mesh.

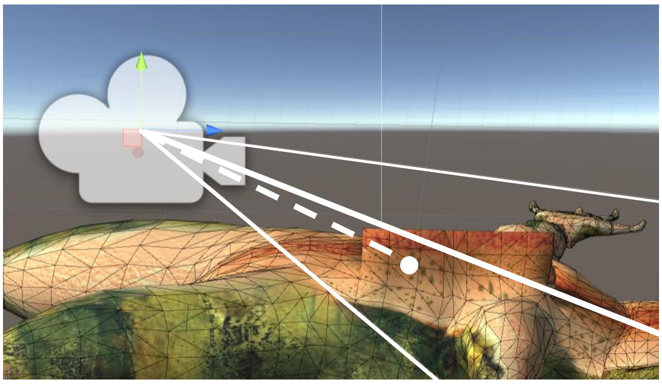

Figure 3-11 Mouse pointing direction (dotted line) to touch point (white dot)

The calculation to apply the mouse movement to the touch point is made up of 2 variables which is the mouse position in 3D space and the mouse offset from the touch point. The equation below shows the calculation of the mouse offset and touch point:

$$\vec{O} = \vec{I} - \vec{M}$$

$$\vec{T} = \vec{M} + \vec{O}$$

$$\vec{O} - mouse\ offset \quad \vec{M} - mouse\ position\ in\ 3D\ space$$
$$\vec{I} - initial\ touch\ point \quad \vec{T} - current\ touch\ point$$

Once the new touch point has been obtained, the rotation of the mesh can be calculated by calculating the amount of rotation required to rotate towards the touch point. For this project, the function Transform.LookAt() provided by Unity's API was used. However, there are cases where the rotation needs to be applied to one axis only. For example, when rotating the skin flap shown in Figure 3-10 , only the local Y axis was rotated (the axis pointing to the head). In this case, the calculation of the touch point has to take the axis into consideration. The formula below converts the touch point to the position where only one axis is needed to rotate:

$$\vec{T} = \vec{T} - \vec{A}[\vec{A} \cdot (\vec{T} - \vec{P})]$$
$$\vec{A} - axis\ taken\ into\ consideration$$
$$\vec{P} - target\ mesh\ position$$

The new touch point can then be applied to the look at rotation equation or in this case, the Transform.LookAt() function. When calculating the rotation, it is also important to take the axis as the world up axis. For example, in Figure 3-10, the world up axis (which is the Y axis (0, 1, 0)) is the Z axis (0, 0, 1) of the mesh. Therefore, it is important to specify the world up axis in the calculation according to the local axis of the mesh. Since the mouse position is relative to the camera in the 3D space, this method of moving the mesh works well with augmented reality implemented too.

3.3.2.4 Pin Tool Module

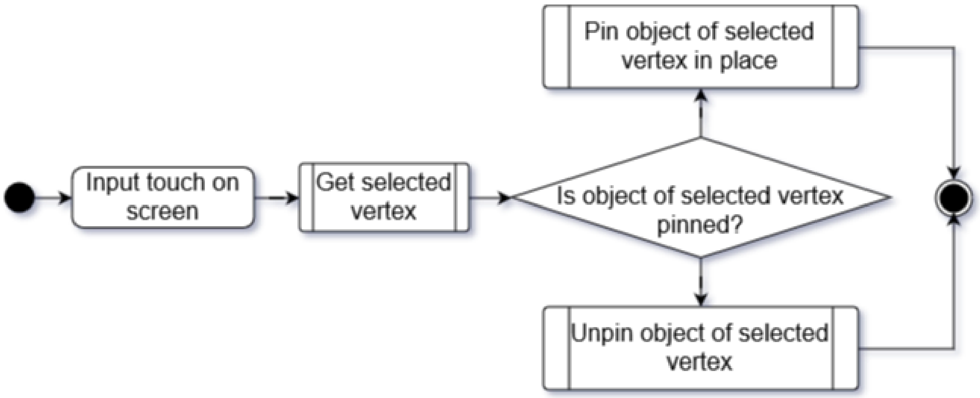

Figure 3-12 Pin Tool Module Flowchart

The concept of the pin tool module is to prevent interactions of the forceps tool with any interactable parts of the 3D model. The flow of the pin tool module start by receiving the touch input from the user. Once a touch is detected, it is then used to check whether the touch is on an interactable part of the 3D model. If it is, it will pin it and prevent any interaction from the forceps. However if the selected part is already pinned, it will remove the pin instead and allows interaction with the forceps once again.

3.3.2.5 Multiplayer System Module

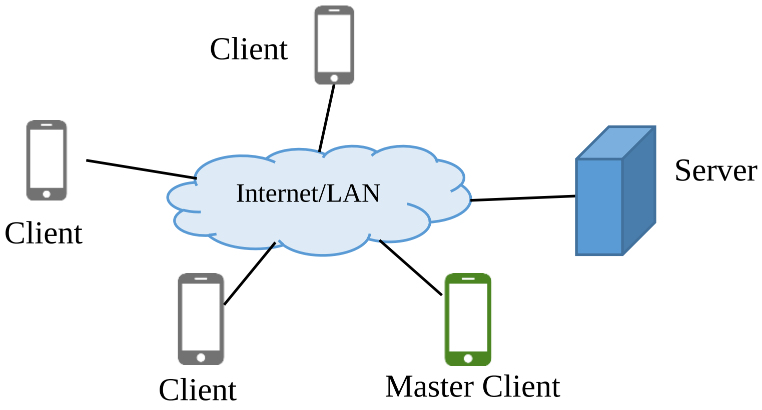

Figure 3-13 Host Migration Architecture

The multiplayer system uses the host migration concept to connect multiple users in the virtual environment. The user that created the room will be the master client. The master client is the client that other client sync to. However, all clients are connected to a centralized server. In this project, the Photon's Unity Networking server will be used.

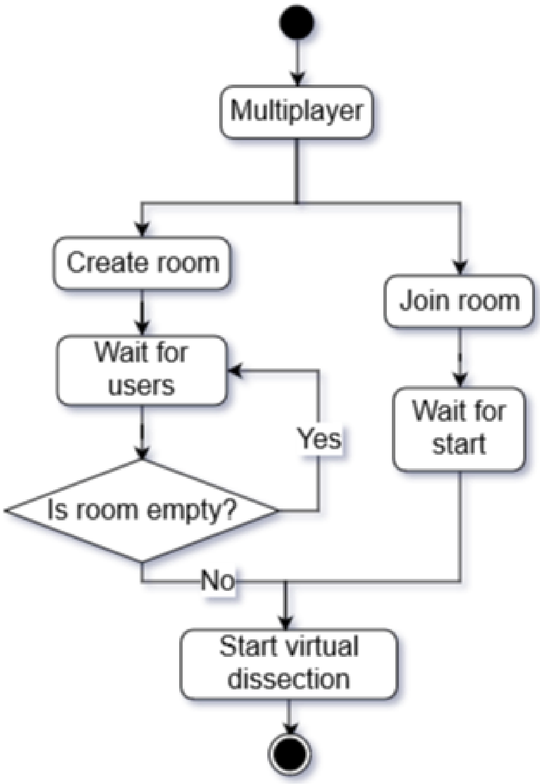

Figure 3-14 Multiplayer System Module Flowchart

In Figure 3-14, it shows how the clients (users) and the master client (host) are connected through the server. The architecture is similar to a client-server architecture. With host migration architecture, the system can switch Master Client to other users when the Master Client disconnects or when the Master Client initiates the switch function. There are two methods in Photon's library which supports this function which is a function called SetMasterClient() and its call back method called OnMasterClientSwitched(). The SetMasterClient() function allows the Master Client to be switched and the OnMasterClientSwitched() method is called when the Master Client is switched. This allows notification and state changes such as UI updates to be initiated when the Master Client is switched.

3.3.2.6 Gesture Handling Module

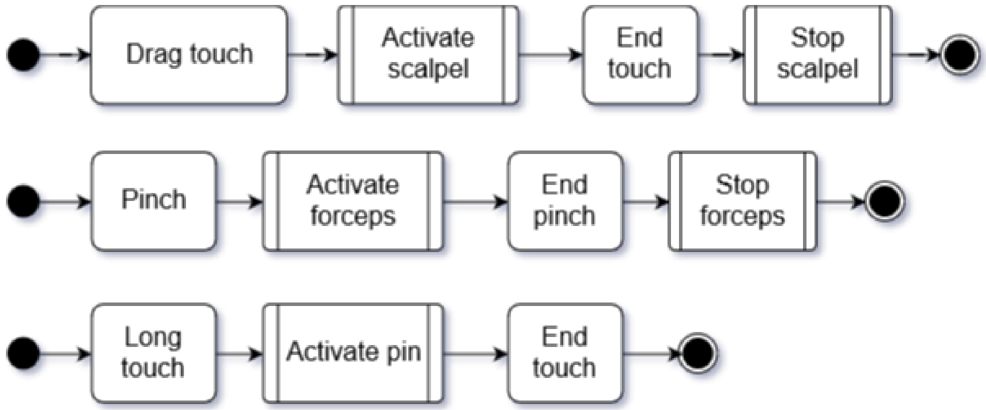

Figure 3-15 Gestures Flowcharts

The gesture handling module is used to assign gestures to activate the functions of the tools. This module allows users to interact with the 3D model using the tools without selecting it. For example, by using the pinching gesture, users can use the forceps tool without selecting it first. In this project, the dragging gesture performs the scalpel function, the pinching gesture performs the forceps function, and the long press gesture performs the pin function as shown in the figure above.

3.4 User Interface Design

The figures below shows the user interface design of the application. The following figures shows the placement of the buttons for every screen and the functions of the elements in the screen are described in this section.

Figure 3-16 Main screen with "Start Dissection button" and "Multiplayer" button

The main screen of the application contains the application title, a "Start Dissection" button that will load the dissection screen in Figure 3-16 and a "Multiplayer" button that will load the screen with the multiplayer lobby screen shown in Figure 3-18.

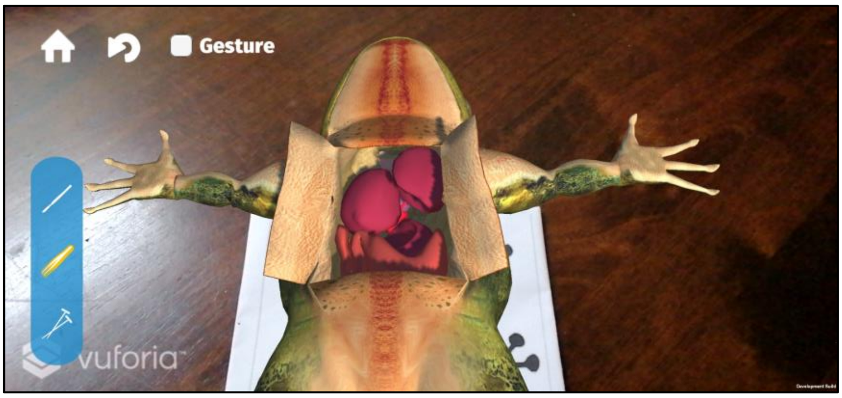

Figure 3-17 Dissection screen

The dissection screen shown in Figure 3-17 contains the list of tools available located on the left. The background will be the environment captured by the camera and the virtual specimen to be dissected will be augmented onto the captured environment.

Figure 3-18 Multiplayer lobby screen

The multiplayer lobby screen contains a list of rooms that is currently being broadcasted on the network. The list contains the room names and number of players currently in the room. A "Create Room" button located at the bottom of the screen to allow user to host a room and broadcast the rooms on the network connected by the device. When the button is pressed, the pop up shown in Figure 3-19 will be shown. Users can click on a room listed to join the room and the application will redirect users to the "Waiting screen" shown in Figure 3-21.

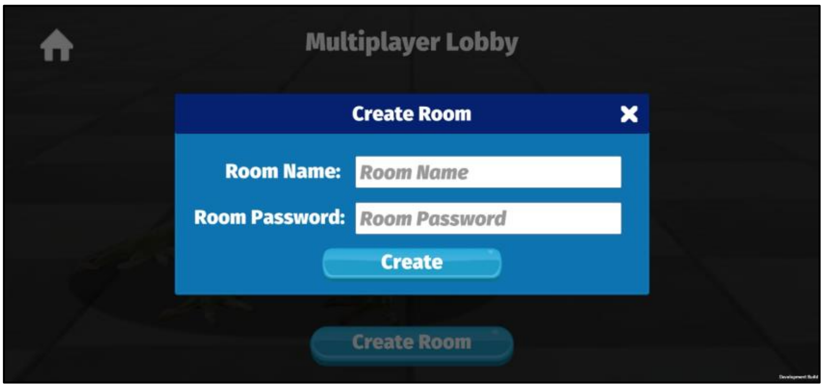

Figure 3-19 Create room popup

The figure above shows the popup that allows user to create a room. It contains an input field for the room name and another input field for the password. Users can leave the room name field and password field blank if they do not wish to set any room name and password. If the room name field is empty, a default name will be generated based on the room order (e.g. Room 1). The "Create" button will create a room and be broadcasted onto the network. When a room is created, users will be redirected to the "Waiting screen" shown in Figure 3-21.

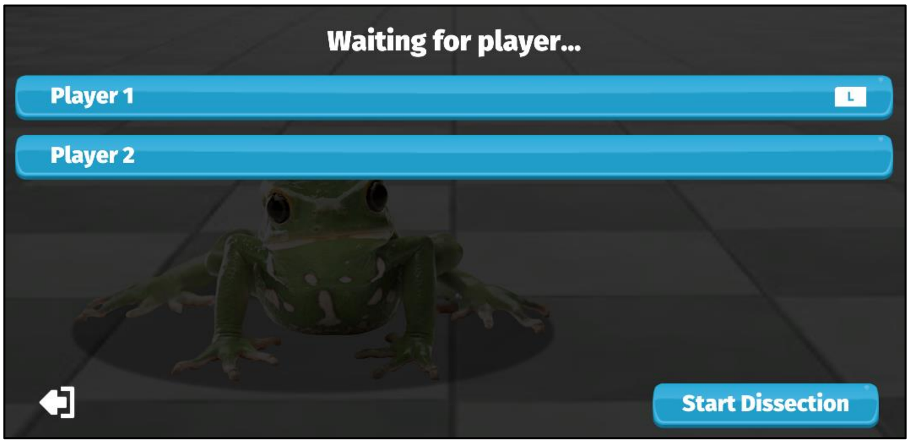

Figure 3-20 Waiting screen - Instructor view

The waiting screen of the Instructor's view shows a list of players in the room. Each player's name contains an "L" icon at the right used to indicate that the user is the instructor. There are two buttons at the bottom which is the "Exit Room" and "Start Dissection" button. The "Exit Room" button allows the user to exit the room and the "Start Dissection" button loads the dissection screen shown in Figure 3-17.

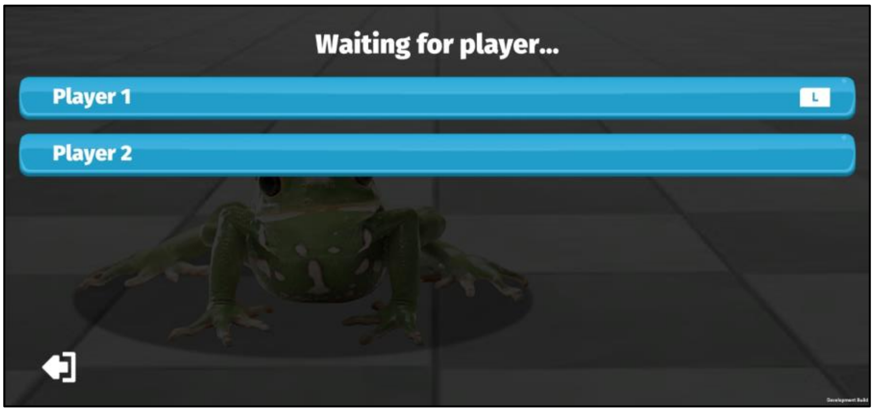

Figure 3-21 Waiting screen – Student view

The figure above shows the waiting screen of the Student's view. It contains a list of player's name and an "Exit Room" button at the left hand corner to exit the room. The instructor of the room will be indicated by the "L" icon placed on the right.

3.5 Implementations

3.5.1 Software Environment

The end product of this project is a mobile application that is integrated with augmented reality. To achieve that, Unity was used as the main engine for the development as it supports both ARCore and Vuforia framework. The mobile application is written in C# along with Vuforia as the main framework for the augmented reality module. Vuforia is cross-platform and is neatly integrated with Unity. As such, Vuforia’s APIs are easily called within Unity itself without any extra setups needed. Unity also uses OpenGL as its graphical rendering framework which allows Unity to render in 3D and perform mesh deformation related operations.

3.5.2 Pre-Implementation Processes

Before the implementing the modules, the 3D objects have to be created first. The 3D models used in this project are acquired from open source websites and was then edited using Blender which is an open source 3D modelling software. The aim of this process is not to create a realistic 3D model but instead to create a 3D model that can be used to demonstrate the functionalities of the modules in this project. Deforming meshes by code is very tedious and time consuming therefore this process is to ease the mesh deformation processes required by the modules of this project.

1. Predefining Cuts

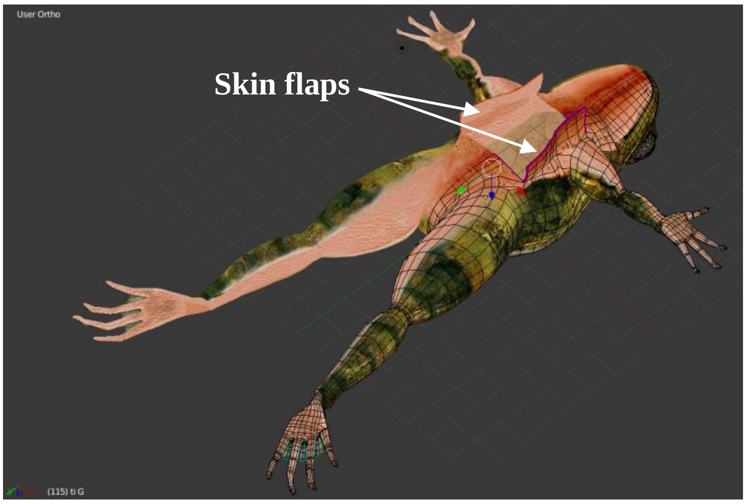

Figure 3-22 A cavity with 2 skin flaps in a 3D model of a frog

Since it is very rare that a dissectible 3D model can be found on the open source websites, modifications are required for the relevant 3D models found. In this case, a 3D model of a frog was found and it was modified to have a cavity around the chest area to allocate space for the organs of the frog. The 2 skin flaps were also remained to allow the cavity to be covered up again with the aim of hiding the cavity from being detected when covered up.

2. Assigning Bones

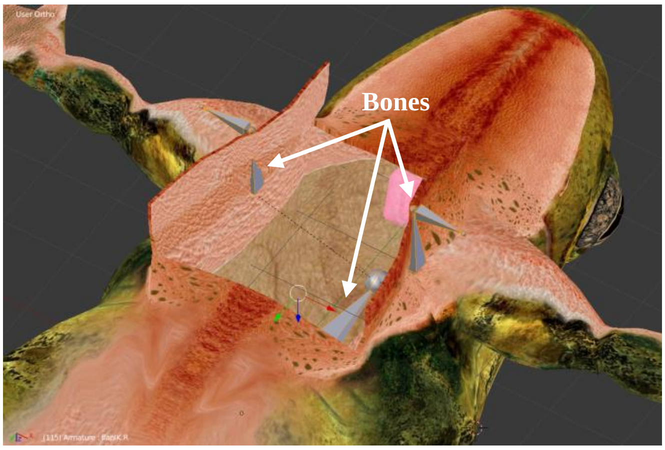

Figure 3-23 Simple bone rig for the skin flaps

In order to allow movement in different areas of the mesh, bone rigs have to be applied to the mesh. Each bones are assigned to separate groups of vertices that it will affect. For the purpose of this project, a simple rig is assigned to the flaps of the cavity described in the previous section. This allows the flaps to be opened and closed by rotating the bones on the Y axis (the axis parallel to the head and feet).

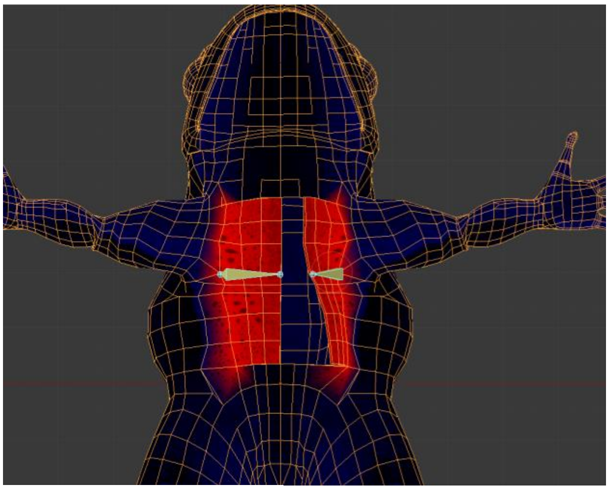

Figure 3-24 Bones weight relation with mesh (top view)

The figure above shows how the bones are associated to the mesh in terms of weightage. In blender, the weightage which range from 0 (dark blue) to 1 (red) indicates how much the bone will affect the areas of the mesh.

3. Creating the Anatomy

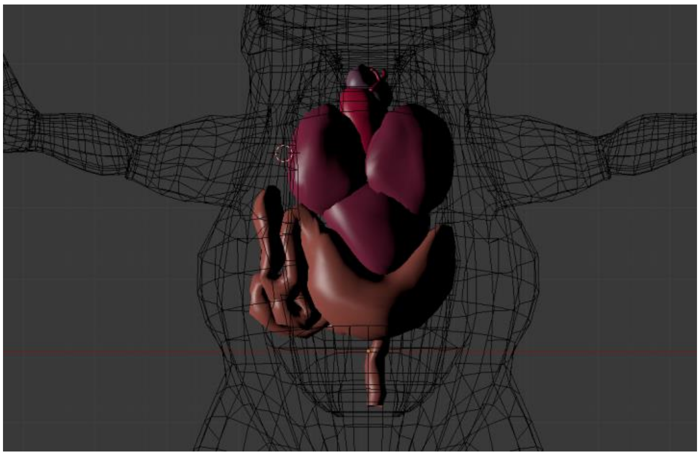

Figure 3-25 Mock up 3D models of the organs of a frog

The figure above shows the mock up 3D models of the organs that form the basic anatomy of a frog. The models created in this section is to allow the demonstration of how users can interact with the 3D model in the implementation of the following modules. The anatomy of the frog created may not be entirely accurate as it is only for demonstration purposes.

3.5.3 Implementation of Modules

3.5.3.1 Implementing the Augmented Reality Module

The augmented reality module is the module that allows the 3D object in the scene to be augmented to the users' surrounding through the device's camera. The framework that is used in this project is the Vuforia framework. The integration of Vuforia with Unity has eased the process of implementing this module.

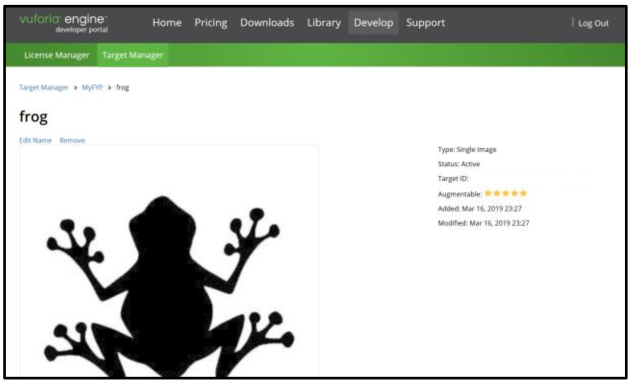

Figure 3-26 Image target created in Vuforia Developer Portal

The first step to implementing this module is to create a marker first. In Vuforia, the marker is known as an image target. The image target is created by using an image that as distinct shapes and is easily recognizable through image recognition. Then the image can be imported into the Vuforia Developer Portal Target Manager which will create a Unity package that can be imported into the Unity project. Once this is done, the image target can then be detected by Vuforia's augmented reality camera in Unity.

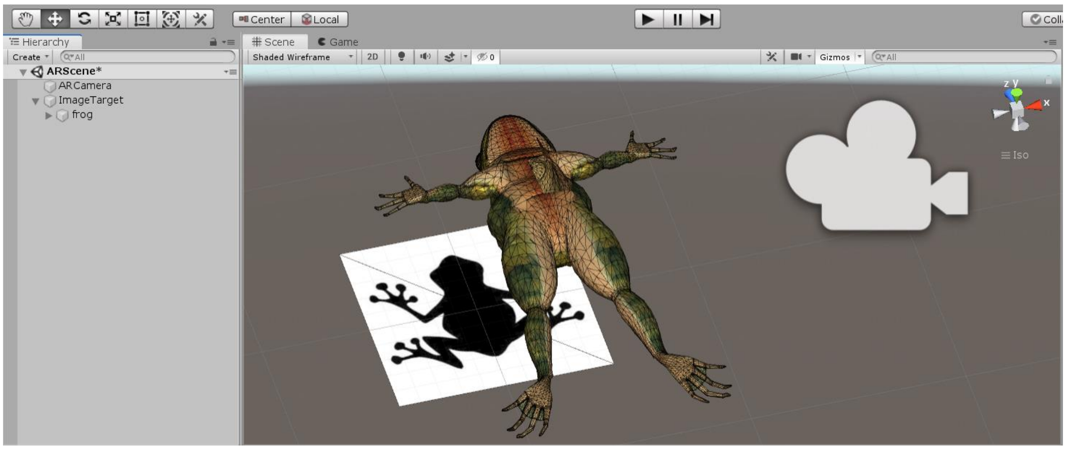

Figure 3-27 Unity scene with AR camera and image target with 3D frog model

The figure above shows the image target and AR camera in a Unity scene. The AR camera can be created from the GameObject > Vuforia Engine > AR Camera menu. The 3D model of the frog was also parented to the image target. It is important to parent the image target to the 3D model in order for the hiding and rendering of the augmented reality to work properly when the image target is detected or hidden.

3.5.3.2 Implementing the Scalpel Tool Module

1. Predefining Vertices of Cuts of a Mesh

The scalpel tool module works by selecting vertices of the 3D mesh and checking whether the selected vertices is part of a cut on the mesh. Since there are no way to check whether the vertices are part of a cut, the vertices of a cut need to be stored somewhere first. Then, when the user select a set of vertices, it can be compared to the stored vertices. Unity does not provide any API or tools to select vertices of a mesh in the editor nor during runtime. So, to select the vertices in the editor, a custom editor called VertexSelector was written. A custom editor is a script that enables the customization of the Unity editor. Once the vertices are selected, the vertices can then be added to an object called VertexLibrary, where all the vertices stored in a class object called CutVertices and the class object is stored in a list in the VertexLibrary. So, every set of vertices of a cut is an individual CutVertices object. For instance, if an object contains 3 cuts, there will be 3 CutVertices object in the list of the VertexLibrary.

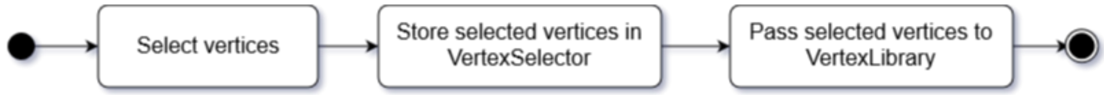

Figure 3-28 Selection of vertices flowchart

Once the vertex library has been populated with vertices of all the cuts in a mesh, the library can then be used to compare with the selected vertices during runtime.

2. Implementing vertex selection mechanism

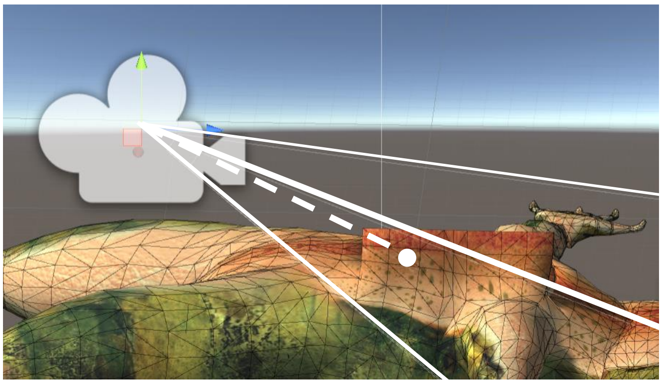

Figure 3-29 Casting a ray from mouse screen point to 3D mesh

To select the vertices of a mesh in Unity, the targeted mesh has to be defined first. In order to do this, the Unity's Raycast function can be used. The Raycast function works by casting a ray from one point to a specified direction. In this case, the ray will be cast from the mouse position on the screen to the forward direction as shown in Figure 3-29. The first object that the ray hits will be the targeted object. The point that the ray hits (the white dot in Figure 3-29) will be used to find the nearest vertex to it and that vertex will be considered as the selected vertex.

The following code snippet shows the code implemented in this project to select the vertex. In Unity, in order for the Physics.Raycast() function will only return true when the ray hits a collider and in this example, a mesh collider is used. The MeshTools.getNearestVertex() function is a function that finds the nearest vertex to the hit point by searching only the vertices of the triangle the hit point is in as described in chapter 3 section 3.2.2.

3. Checking if a cut is completed

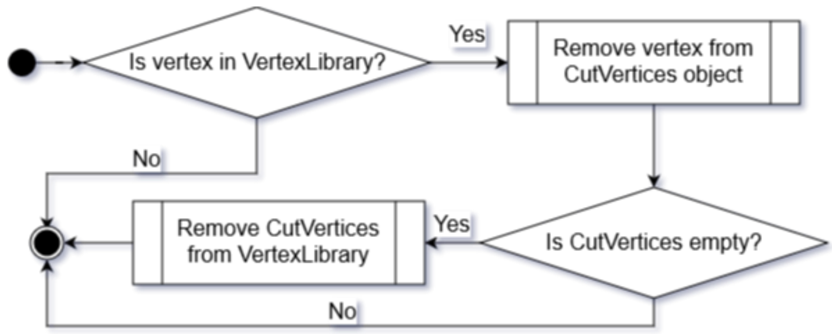

Figure 3-30 Checking selected vertex in VertexLibrary flowchart

Once a vertex is selected, the vertex is then used to check if it is in one of the CutVertices object of the list in VertexLibrary. If it is, it will be removed from the list. Once all the vertices are removed from the CutVertices object, the cut is considered completed and will be removed from the VertexLibrary list.

4. Improving cut interactions by implementing accuracy threshold

Since the chances of the users accurately selecting all the vertices of a cut is low, a threshold is implemented to ensure that the user is still able to perform a cut successfully without too many tries. The amount of vertices selected by the user are checked and compared to the initial amount of vertices. When the amount of vertices that were selected has reached a certain percentage, the CutVertices object will be removed from the VertexLibrary to signify that a cut has been successfully performed.

The code snippet above shows this implementation with the vertex selection code. It only requires a single else statement as the cutPercentage is calculated whenever a vertex is removed. The cutPercentageThreshold can be adjusted according to the interactivity of the cut operation.

3.5.3.3 Implementing the Forceps Tool Module

The forceps module can be separated into 3 procedures where the first procedure is to calculate the mouse offset from the touch point, the second procedure is to calculate the touch point position according to the mouse position and the third procedure is to calculate the placement or rotation of the mesh. In this project, these 3 procedures are handled by a C# class called PlayerInteractable. The script is then applied to whichever mesh that can be interacted with the forceps.

The mouse offset is calculated at when the mouse left button is pressed down. This is so that it is only calculated once on every mouse drag event. The position where the user clicked or touched is known as hitPoint. To find the hitPoint, the same Physics.Raycast() function was used. The position of the hit point is calculated every time the mouse is dragged along with the rotation of the mesh. The moveable part of the 3D model will be enabled when the cut vertices associated with the respective mesh collider have all been removed from the VertexLibrary as this signifies that the cut has been performed successfully by the user.

3.5.3.4 Implementing the Pin Tool Module

The pin tool module is implemented by using the Physics.Raycast() function to cast a ray to the 3D model. When the ray detects an interactable part, it will enable the flag that will prevent the forceps to interact with that part. However, if the ray hits on a pin object, it will remove the pin instead and unlocks the interactable part. In this project, multiple pin can be placed onto the same part. The pinned part will only be unlocked when all pins are removed.

3.5.3.5 Implementing the Multiplayer System Module

1. Setting up Photon Unity Networking

The multiplayer system's backbone is the Photon Unity Networking plugin (PUN). For the purpose of this project, the server that was used is a server provided by Photon. To use the server, an application has to be created in the Photon Cloud first.

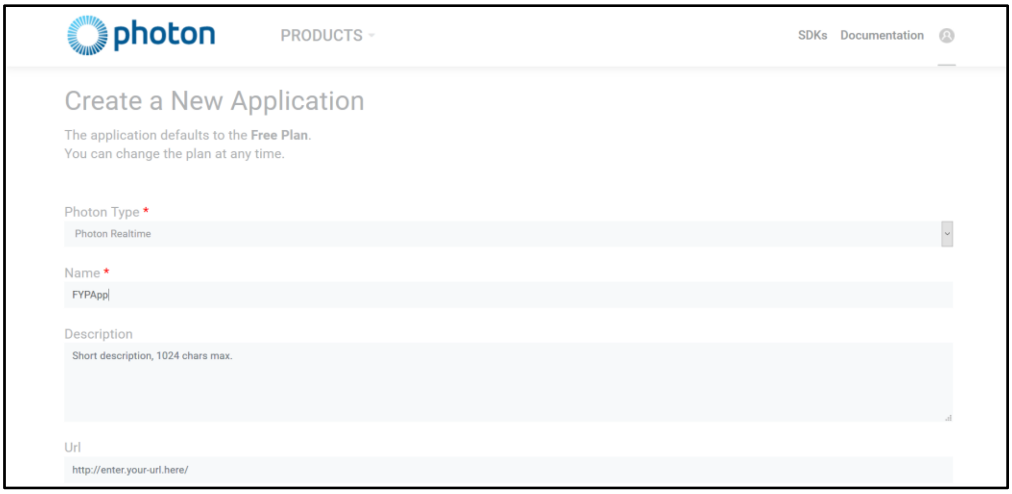

Figure 3-31 Create New Application page on Photon Cloud

Once the app is created, an app id will be provided which can be used in the Photon Server Settings in Unity to define the connection settings. Unchecking the "Use Name Server" checkbox allows other servers to be used instead of the Photon's default server.

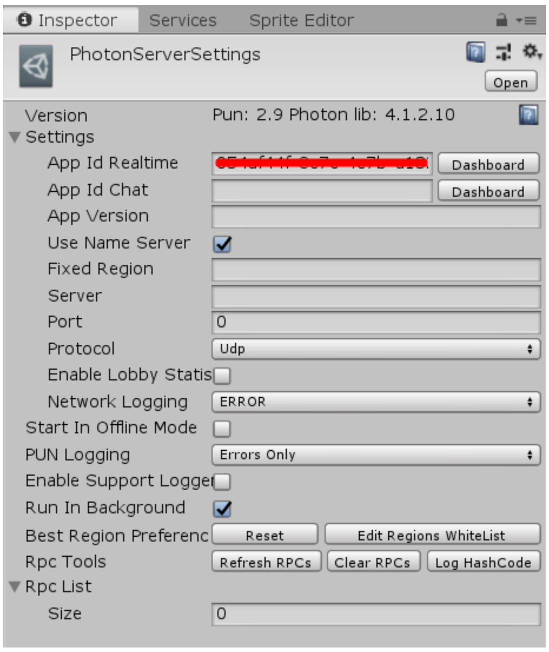

Figure 3-32 Photon Server Settings in Unity's inspector

2. Implementing the Photon's callbacks and multiplayer functions

Once the settings are set, the Photon's API can be used to connect the clients to the server. There are callbacks and function calls provided by Photon that can be used to communicate with the server and other clients. However, all communications will go through the server first.

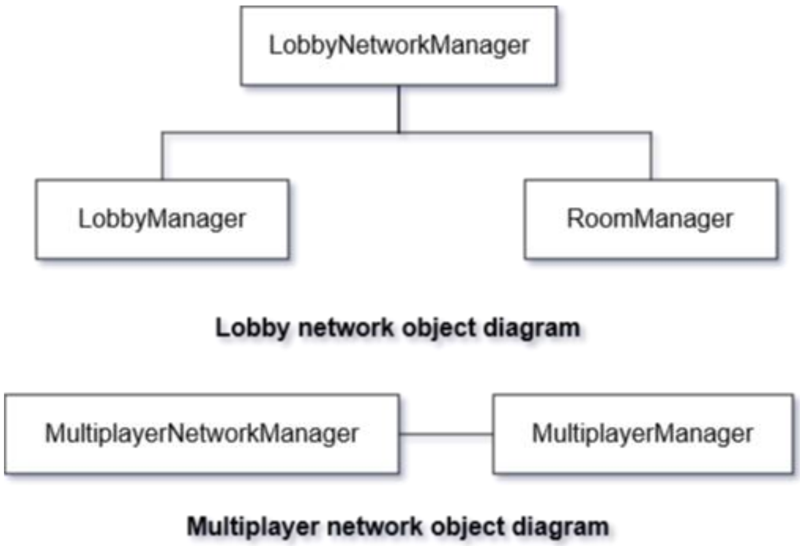

Figure 3-33 Network object diagram

The figure above shows the diagram of the relation of the objects that handles the multiplayer and networking behaviours. The LobbyNetworkManager contains the Photon's callbacks when changes (eg. room created, player disconnected, etc.) occur in the network. When changes occur, the LobbyNetworkManager will call functions in the LobbyManager and RoomManager accordingly. The LobbyManager handles the interfaces of the "Lobby" and the RoomManager handles the interfaces of the "Room". Once the multiplayer dissection session is started, the MultiplayerNetworkManager will be used instead. The MultiplayerNetworkManager handles the same functions and callbacks as LobbyNetworkManager but instead of calling to LobbyManager and RoomManager, it calls to the MultiplayerManager. The MultiplayerManager handles the interfaces of the multiplayer dissection screen.

3. Syncing the dissection screen with other clients using Photon View

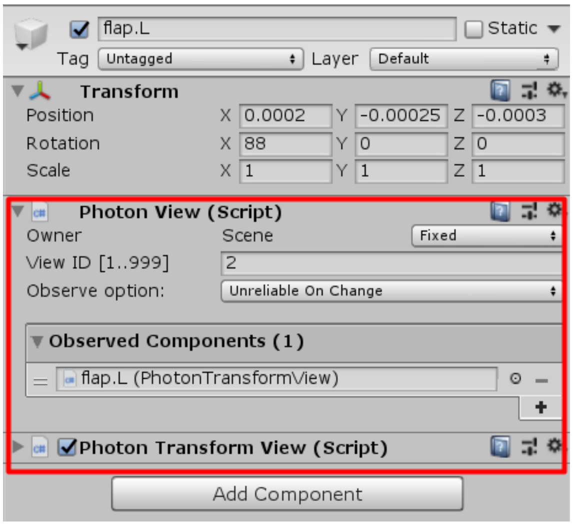

Figure 3-34 Photon View component applied to the left skin flap of the frog

The dissection screen is synced by using the Photon View component provided by Photon. Once the Photon View component is added to a game object (eg. the flap of the frog), it will start syncing the changes made on the game object with other clients. Specifications can be made to the Photon View component to sync only specific properties of the game object. In this project, the transformation properties of the frog, the skin flap, and the organs are synced.

3.5.3.6 Implementing the Gesture Handling Module

The gesture handling module is implemented by detecting touches instead of mouse input. The module starts by first checking if the running platform is an Android platform. This is done by calling the Unity's Application.RuntimePlatform API and checking whether the value is RuntimePlatform.Android. If it is not on Android, the gesture functions will not be executed.

Once the platform is checked, the module will check for the number of touches. It will call different functions depending on the number of touches. For the purpose of this project, only one and two touch counts are considered. If only one touch is detected, it will check if the touch has moved or if it is stationary. If the touch is moving, it will call the scalpel function. Otherwise, if it has been stationary for a specified amount of time (in this case 0.5s was used), it will call the pin function. Both the pin and the scalpel will cast a ray from the touch position instead of the mouse position. If two touches are detected, it will calculate the square magnitude between the two touches and compare it with a specified square magnitude. If the square magnitude is less than the specified square magnitude, it will call the forceps function. The forceps function will cast a ray from the center point of the two touches. When the touch ends (when user lifts up the finger from the screen), the execution of the tools will stop.

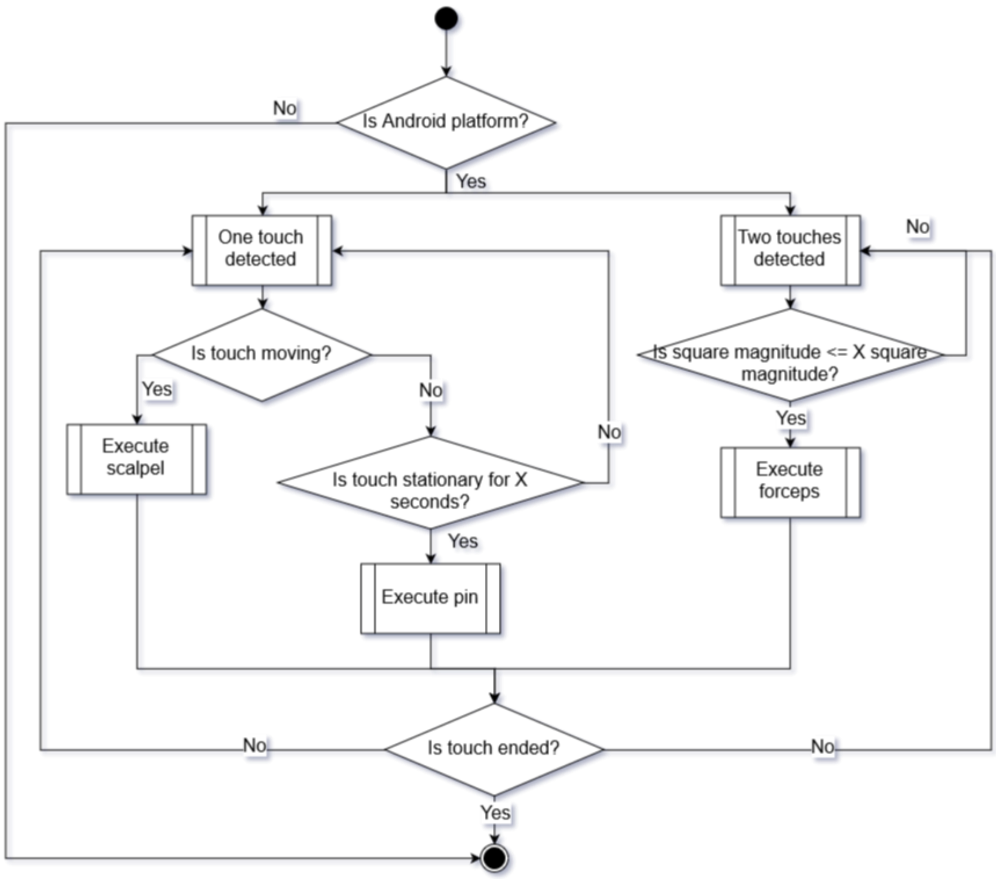

Figure 3-35 Gestures Handling module implementation flowchart

The figure above shows the implementation flow of the gesture handling module in this project as explained above. The module is linked to the scalpel, pin and forceps module as it needs to call their functions.

CHAPTER 4 : DISCUSSIONS AND VERIFICATION

4.1 Discussion on Implementation Techniques

4.1.1 Scalpel interactions

The technique used to create the interaction of cutting the 3D frog model is by selecting the vertices that are near to the cut lines. Once the correct vertices are selected, it triggers the respective cut lines to be unlocked (refer to Chapter 3 section 3.3.2.2). The meaning of the cut lines being unlocked means that the cuts can be interacted with the forceps to move the "skin" of the 3D frog model.

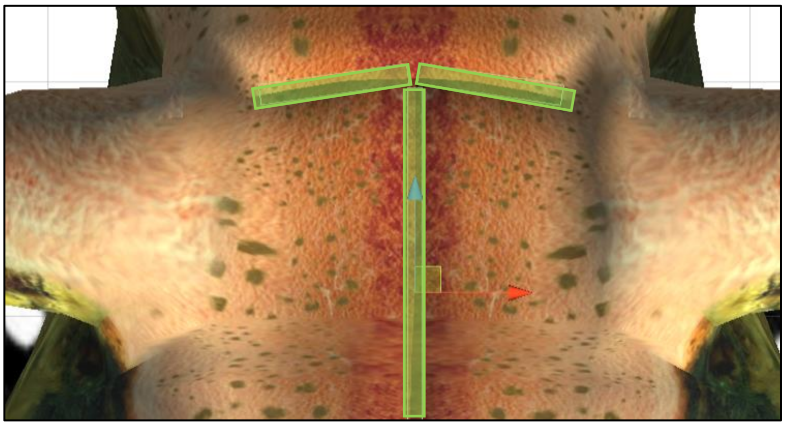

Figure 4-1 Colliders on cut lines

Another alternative to creating the scalpel cutting interaction is by placing colliders on the cut lines and using the colliders to trigger the unlock function when the mouse or a touch hits the colliders. Even though this way it is really simple to implement, it becomes more tedious when more precise cuts are needed to be implemented. This is because to create more precise cuts, more colliders need to be added according to cut line shape.

In addition, another way is to create actual mesh deforming cut lines on the mesh itself wherever the line is drawn using the scalpel. This technique requires advance mesh procedural generation techniques and geometry calculations. It is also very computationally costly as every cut that is made requires the entire 3D mesh to be regenerated. A more detailed discussion on this technique will be discussed in chapter 5 section 5.2.

4.1.2 Modelling of the dissected skin flaps

In this project, the cuts on the 3D frog model are pre-defined. This means that the 3D frog model has to be cut first during the modelling process. As shown in chapter 3 section 3.5.2, there are bones assigned to the dissected skin flaps which allows the skin flaps to be moved. In the Figure 3-23 in chapter 3 section 3.5.2, there are only one bone assigned to each flaps, the way the skin is modelled is too thick and the rims around the edge of the skin flaps are filled which pose a few issues that will be discussed in section 4.3.

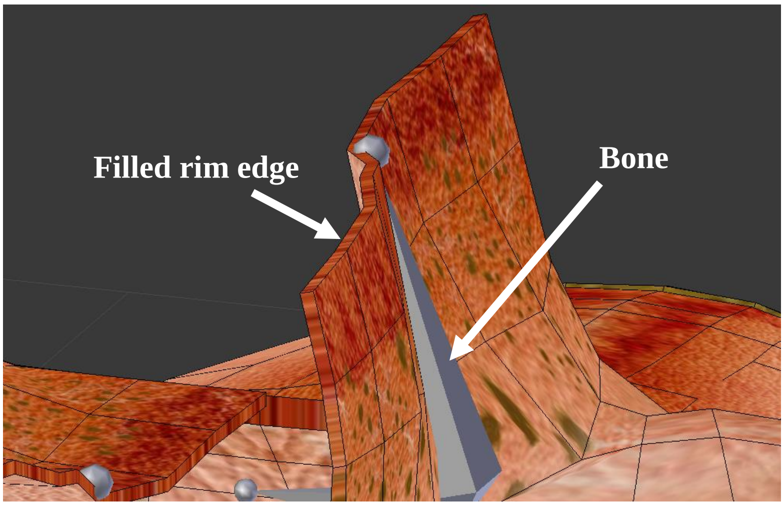

Figure 4-2 Skin flap of the 3D frog model with a single bone and filled rim

In order to create a more flexible and realistic skin flap, more bones can be added and the skin can be made thinner. Instead of assigning bones to the middle of the skin flap, bones can be assigned to multiple parts of the skin flap.

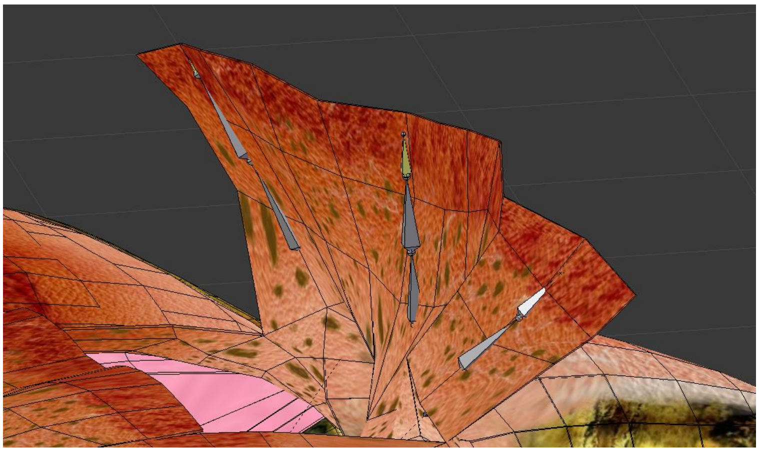

Figure 4-3 Thin skip flap with multiple bones assigned

In Figure 4-3, shows the implementation of a thinner skin flap with multiple bones assigned to it, this creates a more flexible and skin like interactivity. This also allows users to control multiple areas of the skin flap. The reason the skin flap has to have thickness is due to back face culling in Unity where the unseen side of the mesh is not rendered (usually opposite to where the normal is pointing). The thickness creates a double sided mesh which allows both sides to be rendered. Another reason for the double sided mesh is because each side might have different texture applied to it.

4.1.3 Forceps and bones interactions

The way the forceps interacts with the skin flaps is by rotating the selected skin flap bone towards the mouse pointer or touch area. However, this is only applicable to a single bone. This no longer works with multiple bones implemented. In order to solve this, inverse kinematics are introduced to the system.

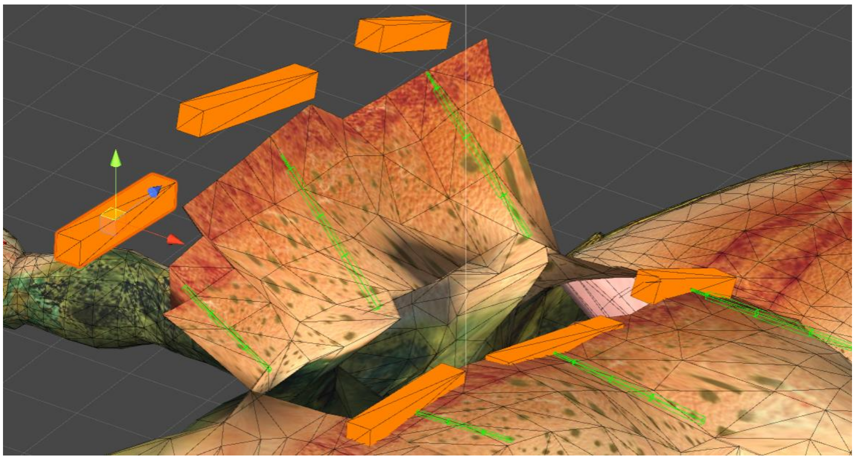

Figure 4-4 Inverse kinematics bones system in Unity

The figure above shows the inverse kinematics system assigned to the bones of the skin flap. The inverse kinematics system used here is the “FastIK” asset obtained in Unity’s asset store. The way the inverse kinematics works is by pointing the tip of the bone to the rectangular blocks which is the controllers for each sets of bones. The consecutive bones are oriented accordingly its parent bone. With this, the forceps can now interact with the rectangular controller blocks instead of the skin flaps.

4.2 System Verification Test Plan

<u>4.2.1 Unit Testing</u>

The main goal of unit testing is to verify that each module operates as intended. For this project, each module is considered as an individual unit and will be tested individually.

<u>Modules Testing</u>

1. Augmented Reality Module

Figure 4-5 Testing of Vuforia's target detection

A mock-up of the 3D model and image target is used to test that the 3D model appears when the image target is detected by the camera and disappears when the image target is undetected. The image on the right of the figure above shows the log that is shown it Unity's console log when the image target is detected and undetected.

2. Scalpel Tool Module

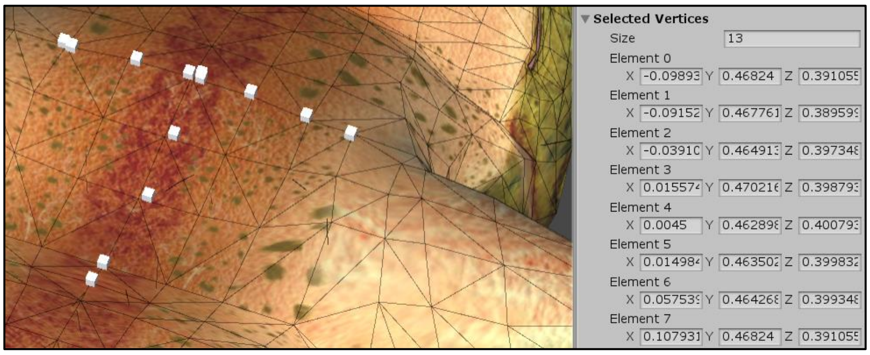

Figure 4-6 Selected vertices on mesh and the list of selected vertices

Different type of meshes are used to ensure that the scalpel tool is able to select the correct vertices where the mouse has pointed. The figure above shows the selected vertices indicated by the cubes on the mesh. Tests are done to ensure that the scalpel tool enables the interaction of forceps on the mesh when the correct vertices are selected.

3. Forceps Tool Module

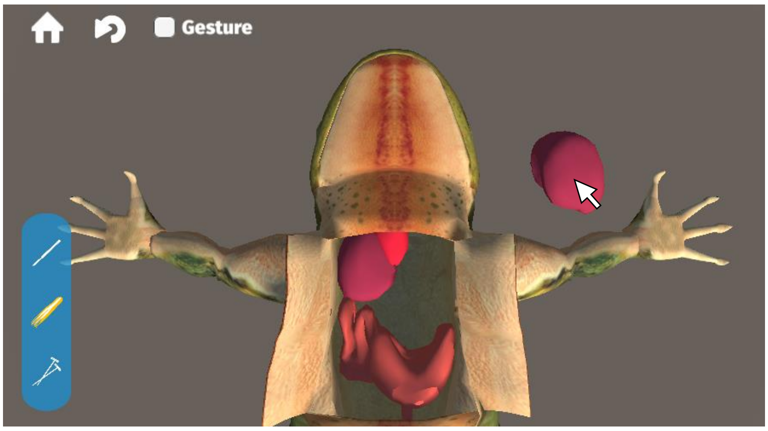

Figure 4-7 Mouse picking up the frog liver using the forceps tool

The forceps tool are tested to ensure that it is able to pick up only the interactable objects (e.g. the skin flap, organs). The figure above shows the forceps tool being tested without the augmented reality module loaded.

4. Pin Tool Module

The pin tool is tested for the function to pin the forceps interactable objects and it is also tested that it can unpin any pinned objects

5. Multiplayer System Module

The Create Room button is tested to ensure the functionality of creating a Room object with specified name and password. Clicking the one of the listed room is tested to be able to open the room list panel and close the lobby panel and the Start Dissection button is tested to load the multiplayer dissection scene.

6. Gesture Handling Module

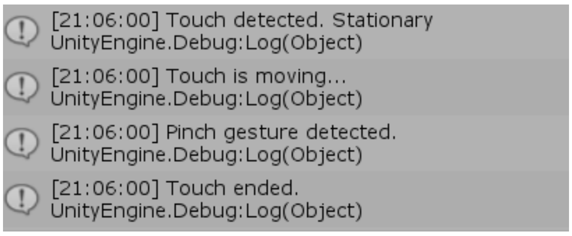

Figure 4-8 Sample touch gesture debug log

Each drawing line, pinch and long press gestures are tested by making sure that each gesture outputs a different log in the console.

4.2.2 Integration Testing

Once all the units' functions are tested, the integration testing are done to ensure that the specified functions operates as intended. The integration testing involves other modules and are used to test functions that cannot be tested in the unit tests.

Integration Tests

1. The augmented reality is tested to work in both the Dissection and Multiplayer Dissection screen.
2. All the dissection tools are tested be able to operate as intended with each other.
3. The multiplayer system is tested to check whether it syncs the dissection scene with all connected users.

4.2.3 System Testing

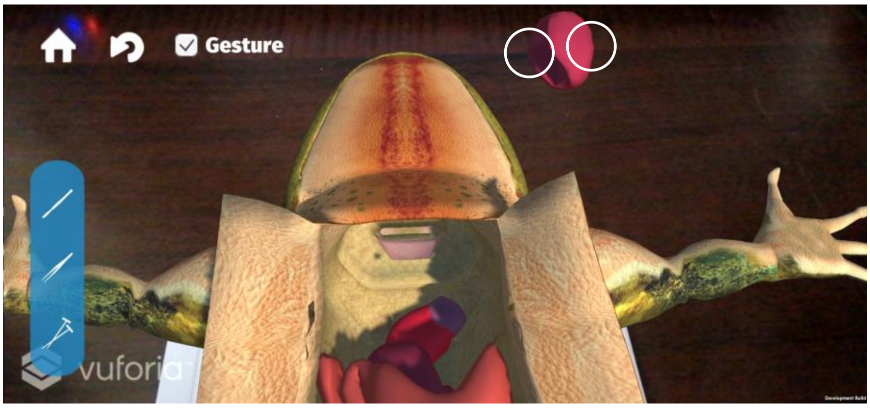

Figure 4-9 Picking up an organ with pinch gestures (shown as 2 circles) while in augmented reality environment on an Android device

System testing is done when all the units are tested and are working as intended. System testing is done by integrating all the units into the system to verify that every modules are able to operate together as intended. In this case, the system is deployed into Android mobile devices. The figure above shows a sample scenario of the deployed application. The circles indicates where the touches are located at.

System Test

1. All functions are tested in the Android environment.
2. The gestures are tested to ensure that it executes the tools functions according to specified gestures.

4.3 Implementation Issues and Challenges

1. Scalpel interactions precision issue

Selecting the cut line on the Android screen become less precise as the finger touch covers a large area and it becomes harder to select the cut line precisely compared to when using the scalpel with a mouse. This made it difficult to implement the scalpel interactions to have good user experience.

2. Difficulty of picking up objects in a cavity with the forceps

Due to only being able to move around the 2D space of the screen when using the forceps, it is difficult to pick up objects that are required to move in a certain axis. For example, the organs that are contained in the frog's abdominal cavity is hard to pick up (refer to Figure 4-7) because it is required to move up on the Z axis and out of the cavity but most of the time it is pick up from the top view and the touches can only move on the X and Y axis.

3. Issues in modelling the 3D models for dissection

A 3D model that can be dissected is uncommon, therefore it is required to be modelled. Modelling an accurate representation of a specimen is very tedious. When creating the pre-predefined cut lines, there were unexpected creases that were formed on the 3D model (Figure 4-10– left image).

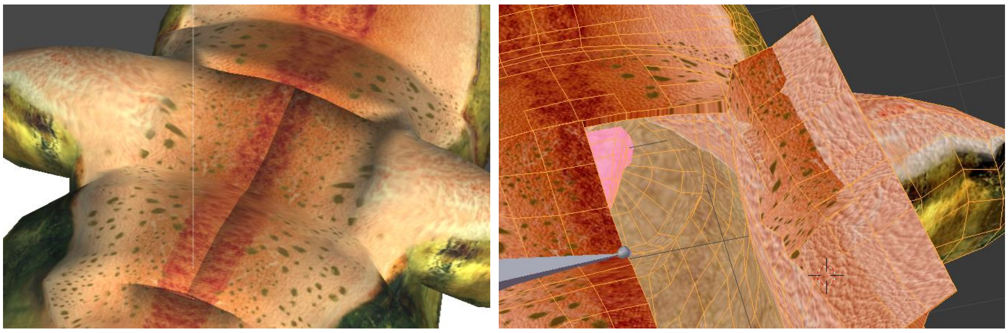

Figure 4-10 Creases formed due to pre-defined cut lines (left) and deformity of thin skin flaps (right)

In addition to that, the image on the right of Figure 4-10 shows the texture of one side of the skin flap peeks through to the other side of the skin flap. This occurs when the skin flaps are too thin.

CHAPTER 5 : CONCLUSION

5.1 Project Review

The objective of this project is to develop an alternative that is adequate to replace traditional dissection as an educational tool. Most educators prefer traditional dissection as an educational tool because they could not find any alternatives that could provide the same level insight and experience. It is said that alternatives could not provide the realism of dissection and not convenient to use as a teaching tool.

The solution proposed in this project is to create a mobile application that uses augmented reality to create a virtual environment for dissection. Users could use virtual tools provided to perform the dissection similar to real dissection. An image will be placed in the actual surroundings of the user to mark where the virtual object be located. The device's camera will be used to track where the image is and render a virtual object on top of the image that will be shown in the screen. This creates an illusion of a virtual object is placed in the actual surrounding. Besides that, the dissection tools will be programmed to be intuitive to use. The tools are aimed to imitate the capabilities of actual dissection tools. It also utilizes gestures to execute the dissection tools to provide better use experience. In addition to that, there is a multiplayer system that will sync the virtual content of multiple devices through a network. This provides a platform for users to learn about dissection in a group environment.

This project uses Unity as the main working environment to develop the application. The augmented reality module was implemented using the Vuforia plugin that is integrated into Unity. Blender was used to modify existing 3D model to suit the need of this project which is to demonstrate the ability to dissect a 3D model in augmented reality. The Photon Unity Networking (PUN) framework was used to connect users for the multiplayer system.

At the end of the project, the objectives are met as a mobile application with augmented reality was developed. The mobile application provides a set of dissection tools that utilizes gestures. In addition, the mobile application is also able to connect players and sync the virtual content of the dissection scene.

5.2 Future Implementations

Implementation of Dynamic Cutting

In the project, the scalpel tool uses pre-defined cuts to simulate the cutting interaction. However, this creates a limit to the application where users can only cut limited areas. This does not create a realistic interaction of the scalpel tool in a dissection environment. Future improvements to the project can be done by adding dynamic cutting as the interaction technique for the scalpel tool. This can be done by implementing and modifying existing mesh cutting algorithm.

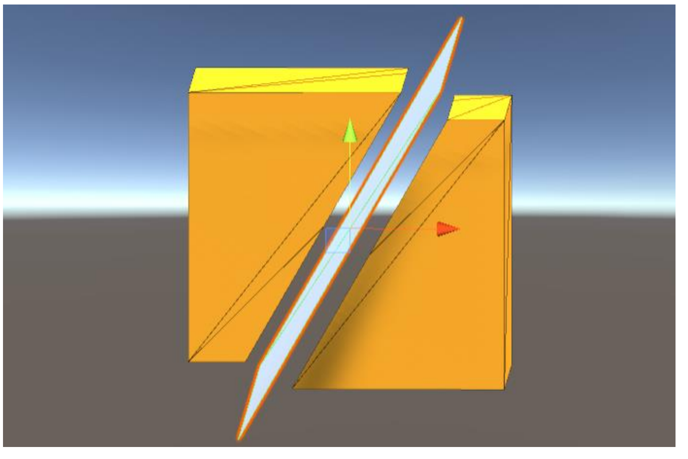

Figure 5-1 Mesh cutting implemented in Unity

The figure above shows the implementation of a mesh cutting algorithm implemented in Unity based on the paper written by Pregun (2017). The implementation shown above cuts the mesh using a plane but according to the paper, it is possible to also cut the mesh using different shapes as the formula of the mesh cutting algorithm utilizes the normal of the plane. With this technique, the scalpel tool can cut the mesh by cutting the mesh according to the normal of the lines created by drawing with the scalpel tool.

Utilizing Motion Detection

Currently, the interactions on the mobile devices are limited to only the 2D space which are converted to 3D positions. By utilizing motion detection, users can use gestures captured by the camera to interact with the virtual objects instead. An example of available framework for motion detection is Leap Motion which supports hand and finger motions as input. This enables users to move in all 3 axis of the virtual space.

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Mobile Application for
AR Animal Dissection
By: Edwin Lee En Yueng
Supervised by: Mr. Tou Jing Yi
INTRODUCTION
Animal dissections provides great insight into anatomies of living organisms
Huge amount of efforts are required to prepare and clean up for dissection
Not everyone is comfortable with animal dissections
This project aims to provide an alternative to traditional animal dissection
PROBLEM STATEMENT
Lack of realism in existing alternatives
Existing applications do not provide functionalities for group interactivity
Existing applications do not provide the tools needed for educators to direct students
OBJECTIVES
Develop a mobile application with augmented reality anima dissection
Develop virtual dissection tools for the mobile application that utilizes gestures
Integrate multiplayer animal disection environment into the mobile application
"...an Alternative to Traditional Animal Dissection"
METHODS and IMPLEMENTATIONS
Software Environment:
unity
vuforia
photon UNITY NETWORKING
blender
Methodology:
This project uses the Incremental Development model
Modules are developed in 3 phases where the final deliverable is the mobile application
Implementations:
An existing 3D model is used with some modifications done. (e.g. abdmominal cavity, organs, and etc.)
The implementations of this project utilizes the manipulations of the rigging of the 3D model
The project also utilizes a ray in the virtual space to calculate the position a touch on the screen is hitting on the 3D model
This converts the 2D interactions of a touch to a 3D input in the virtual environment
RESULTS
Gesture
Multiplayer Lobby
Room 1
1/50
Room 2
25/50
Room 3
10/50
Room 4
3/50
Create Room
The final deliverable of this project is a mobile application that allows users to use gestures to perform dissection on the 3D frog model.
The mobile application also allow the dissection to be synced with multiple users.
Try Now!
SCAN ME
CONCLUSIONS
At the end of the project, the objectives are met as a mobile application with augmented reality was developed.
The mobile application provides a set of dissection tools that utilizes gestures.
In addition, the mobile application is also able to connect players and sync the virtual content of the dissection scene.
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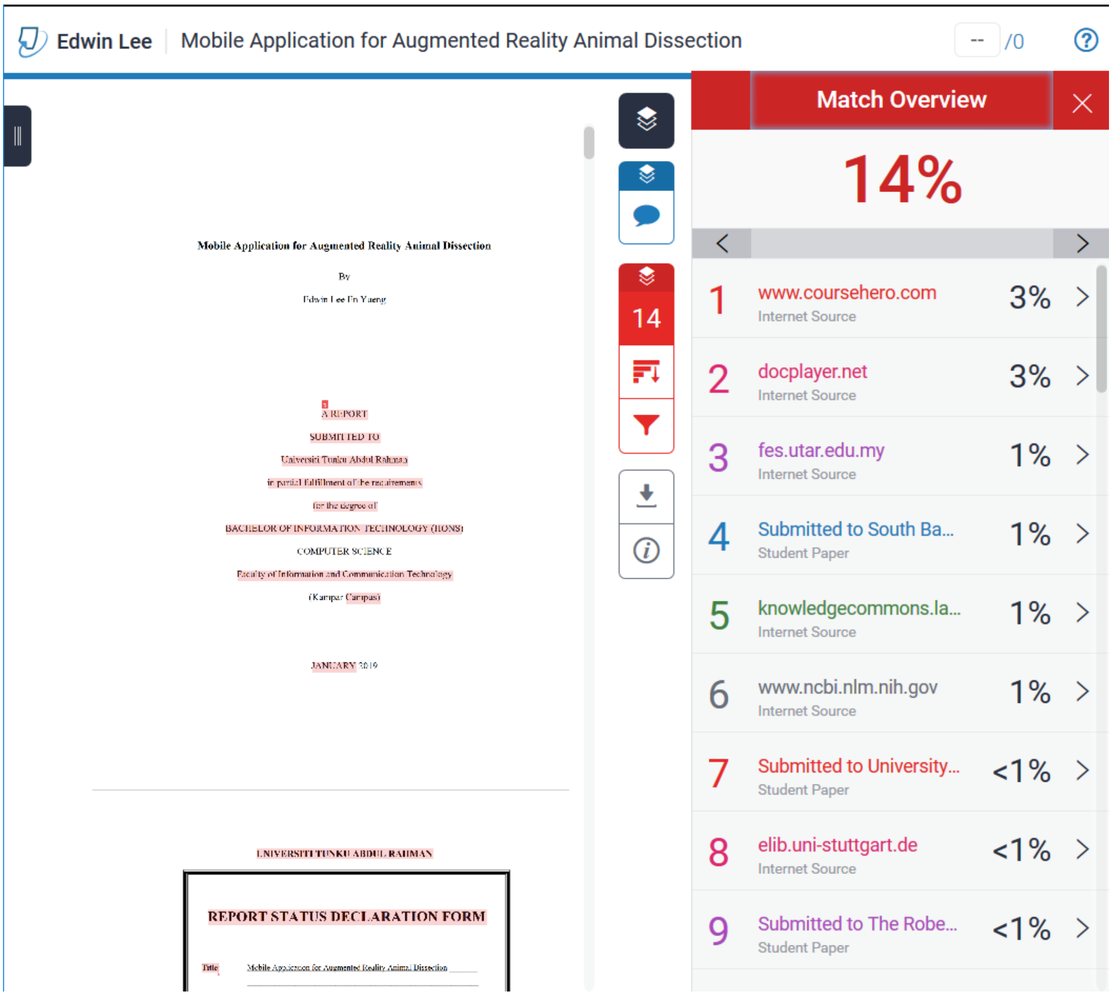

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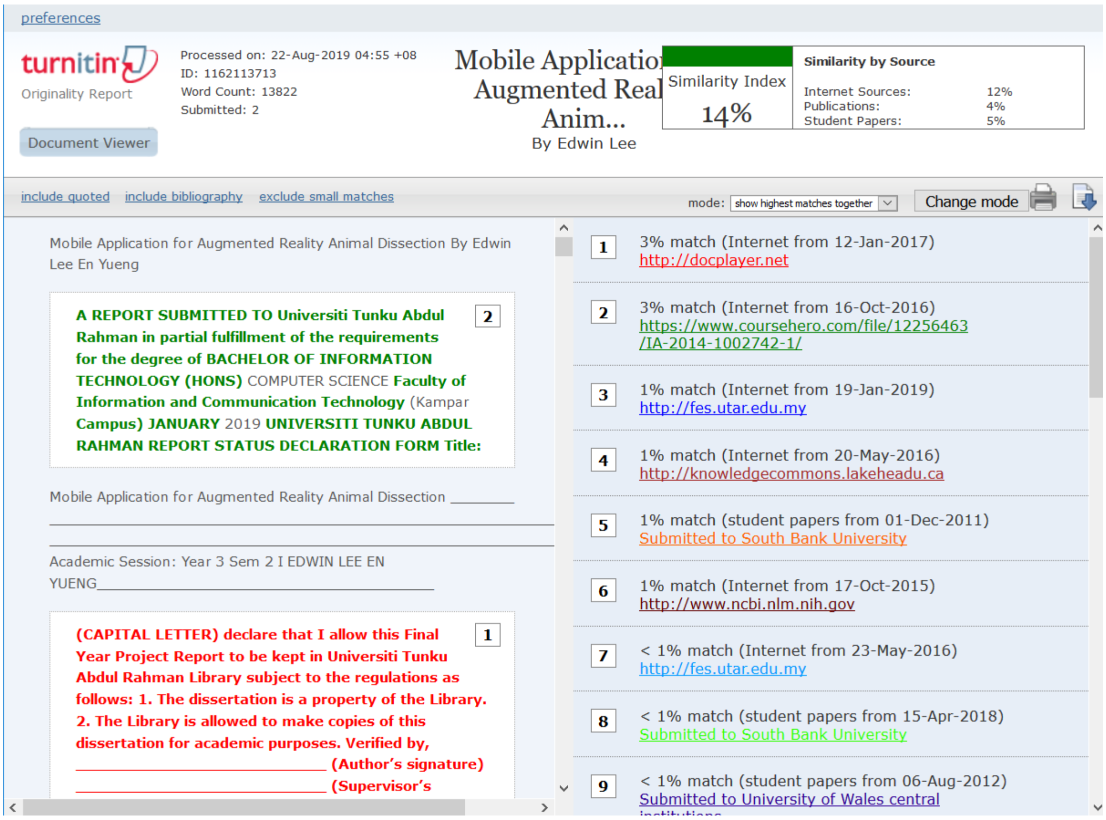

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