UNIVERSITI PUTRA MALAYSIA

ENHANCEMENT OF INTERACTION FOR ANATOMY VISUAL LEARNING INTERFACES IN AUGMENTED REALITY LEARNING

CHE NUR SHAFAREEN AFERA BINTI CHE ANUAR

FSKTM 2020 22

ENHANCEMENT OF INTERACTION FOR ANATOMY VISUAL LEARNING INTERFACES IN AUGMENTED REALITY LEARNING

By

CHE NUR SHAFAREEN AFERA BINTI CHE ANUAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

February 2020

COPYRIGHT

DEDICATIONS

My respectable parents Che Anuar Ibrahim and Suriati Mohamad, who share their lives with me, who always give advice and encouragement
My dear husband, Abdul Mubin, whose infinite support, incredible understanding and ultimate kindness are immeasurable
To my supervisor Prof. Dr. Rahmita Wirza O.K. Rahmat and entire committee.
And thanks to the Trans-disciplinary Research Grant Scheme (TRGS) which sponsors this research study financially.
And, to all whom I love.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

ENHANCEMENT OF INTERACTION FOR ANATOMY VISUAL LEARNING INTERFACES IN AUGMENTED REALITY LEARNING

By

CHE NUR SHAFAREEN AFERA BINTI CHE ANUAR

February 2020

Chairperson: Rahmita Wirza O.K. Rahmat, PhD
Faculty: Computer Science and Information Technology

Mobile applications using Augmented Reality (AR) technology have been widely used in many fields, including education, computer games, advertising, tourism and more. AR is considered an exciting technology for users as they interact with 3D virtual models in the real world. AR is also widely used in medical education, as it helps medical students to see and understand the structure of human/animal anatomy more closely and this helps them visualize the model because their textbooks show only 2D images. Some existing AR applications are not widely used and are less user-friendly. The guidelines used in these existing application applications make it less attractive for users to continue using AR applications for long periods.

The main purpose of this study is to encourage medical students to fully utilize AR applications to assist in their self-study after taking the relevant classes. The main contribution of this research is to identify the challenges in interacting with AR applications in medical education. To identify the proposed guidelines, the Mobile AR Application called the Brain Anatomy Revision Application (BARA) was developed. BARA is developed in stages and each level will be tested by the user for feedback before advancing to the next level. Get started with BARA following the existing guidelines in the current AR application. Subsequently, several preliminary experiments were conducted according to the BARA phase and version, as well as User Evaluation by medical students from UPM. The final Acceptance Test was performed for UiTM Sg Buloh medical students on three different versions of BARA namely printed markers, digital markers, and object target markers.

All three versions of BARA have been applied using ten new guidelines, and medical students will choose which version makes it easier for them to use this

learning application, including issues of contents, ease of use of apps, and experience using AR in these applications as they can look at the entire AR 3D model view. Future work is to increase the level of details of the 3D model as if it were real texture to make it more interesting and real. Next, 3D models can be an interaction where the user can separate each part of the brain by pulling the parts together.

Abstrak tesis yang dikemukakan oleh Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

MENINGKATKAN INTERAKSI ANTARA MUKA UNTUK PEMBELAJARAN VISUAL DALAM PEMBELAJARAN ANATOMI MENGGUNAKAN REALITI IMBUHAN

Oleh

CHE NUR SHAFAREEN AFERA BINTI CHE ANUAR

Februari 2020

Pengerusi: Rahmita Wirza O.K. Rahmat, PhD
Fakulti: Sains Komputer dan Teknologi Maklumat

Aplikasi mudah alih yang menggunakan teknologi Augmented Reality (AR) telah banyak digunakan dalam banyak bidang, termasuk pendidikan, permainan komputer, periklanan, pelancongan dan banyak lagi. AR dianggap sebagai teknologi yang menarik bagi pengguna kerana mereka berinteraksi dengan model maya 3D di dunia nyata. AR juga digunakan secara meluas dalam pendidikan perubatan, kerana ia membantu pelajar perubatan untuk melihat dan memahami struktur anatomi manusia / haiwan dengan lebih dekat dan ini membantu mereka menggambarkan model kerana buku teks mereka hanya menunjukkan gambar 2D. Beberapa aplikasi AR yang sedia ada tidak digunakan dengan meluas dan kurang menarik minat pengguna. Guidelines yang digunakan dalam aplikasi aplikasi sedia ada ini menyebabkan ianya kurang menarik pengguna untuk terus mengguna AR aplikasi dalam jangka masa yang lama.

Tujuan utama kajian ini adalah untuk mendorong pelajar perubatan menggunakan sepenuhnya aplikasi AR untuk membantu kajian mereka sendiri setelah mengikuti kelas yang berkaitan. Sumbangan utama penyelidikan ini adalah menentukan cabaran dalam berinteraksi dengan aplikasi AR dalam pembelajaran perubatan. Untuk mengenal pasti atribut yang berkaitan dengan garis panduan cadangan, Aplikasi Mobile AR yang dinamakan sebagai Brain Anatomy Revision Application (BARA) telah dibangunkan. BARA dibangunkan mengikut peringkat dan setiap peringkat akan diuji oleh pengguna untuk

mendapatkan feedback sebelum dibaiki ke peringkat seterusnya. Bermula dengan BARA yang mengikut guideline sedia ada dalam aplikasi AR yang ada sekarang. Seterusnya beberapa preliminary experiment dilaksanakan mengikut fasa dan versi BARA, serta User Evaluation oleh pelajar medikal dari UPM. Final Acceptance Test dilaksanakan kepada pelajar medikal UiTM Sg Buloh ke atas tiga versi BARA yang berbeza iaitu printed marker, digital marker, dan object target marker. Ketiga-tiga versi BARA ini telah diaplikasi menggunakan sepuluh guideline yang baharu, dan pelajar medikal akan memilih versi yang mana paling memudahkan mereka untuk mengguna aplikasi pembelajaran ini termasuk menitikberatkan isu segi kandungan apps, kesenangan penggunaan apps, dan pengalaman menggunakan AR dalam aplikasi ini kerana boleh melihat keseluruhan pandangan AR 3D model. Cadangan kerja masa depan ialah meningkatkan level details of 3D model seakan akan real tekstur untuk lebih menjadikan ianya menarik dan real. Seterusnya, model 3D boleh menjadi interaksi di mana pengguna dapat memisahkan setiap bahagian otak dengan menarik bahagian-bahagian tersebut.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere thanks to Prof. Dr. Rahmita Wirza O.K. Rahmat, who patiently gives instruction, advises to strengthen the spirit. I am very grateful to have a supervisor who is very kind to me and to hope that God will always have mercy on her. I am also grateful to have a supervisory committee, Dr. Azrina Binti Kamaruddin from HCI Department, who gave a lot of good comments and helped to give some ideas on solving problems in this study. Also, to my supervisory committee, Dr. Rafidah Binti Hod and Dr. Siti Khadijah Binti Adam, from the Faculty of Medicine and Health Sciences, University Putra Malaysia (UPM), for helping me to meet up with medical students from the faculty in the course of conducting my master's degree study. May Allah bless them all. My study has also been greatly assisted by Trans- Disciplinary Grants Scheme (TRGS), and I am grateful to be able to serve this opportunity and hopefully this knowledge will also benefit others. I would like to express my gratefulness to my husband, Abdul Mubin, for his patience and support throughout my study. I also appreciate the patience and prayers of both of my parents Che Anuar Ibrahim and Suriati Mohamad, who always helped me when I need them. May my success be a source of pride and encouragement to my family.

I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of Che Nur Shafareen Afera Binti Che Anuar on her thesis entitled "Enhancing Interaction for Anatomy Visual Learning Interfaces in Augmented Reality Learning" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Degree of Master.
Members of the Thesis Examination Committee were as follows:

Prof. Madya Dr. Fatimah binti Khalid, PhD
Title: Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Chairman)

Prof. Madya Dr. Puteri Suhaiza binti Sulaiman, PhD
Title: Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Internal Examiner)

Prof. Madya Dr. Murni binti Mahmud, PhD
Title: Associate Professor
Information System Department
Kuliyyah of Information and Communication Technology
International Islamic University Malaysia (IIUM)
Jalan Gombak, 53100 Kuala Lumpur, Malaysia
(External Examiner)

_____
PROF. DR. ZALILAH MOHD SHARIFF, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Rahmita Wirza O.K. Rahmat, PhD
Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Chairman)

Azrina Kamaruddin, PhD
Senior Lecturer
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

Rafidah Hod, PhD
Senior Medical Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

Siti Khadijah Adam, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

_____
ZALILAH MOHD SHARIFF,PhD
Professor and Dean
School of GraduateStudies
Universiti Putra Malaysia

Date: 16 July 2020

Declaration by graduate student

I hereby confirm that:

- This thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of the thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceeding, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/ fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: _____

Signature: _____
Name of Member of Supervisory Committee: _____

Signature: _____
Name of Member of Supervisory Committee: _____

Signature: _____
Name of Member of Supervisory Committee: _____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
AR	Augmented Reality
BARA	Brain Anatomy Revision Application
VR Box	Virtual Reality Box
AI	Artificial Intelligence
MAR	Mobile Augmented Reality
Ai	Adobe Illustrator
Fl	Adobe Flash
Ps	Adobe Photoshop
UPM	Universiti Putra Malaysia

CHAPTER 1

INTRODUCTION

This chapter is the starting point for the entire thesis, which provides a general introduction to usage of Augmented Reality (AR) in anatomy medical learnings and AR user interfaces design guidelines. Next is brief explanation the background of this research, motivation to do this research and importance of this study. Moreover, this chapter clarifies the problem statements, objectives, and scope of the research.

1.1 Research Background

This section presents a brief of meaning and usage of Augmented Reality (AR). Then, some of the methods used by medical students in their study of human anatomy whether in lectures or self-study will also be discussed in this chapter. The guideline that used in current AR mobile apps for medical learning also will be discussed, hence the new guidelines were applied on Brain Anatomy Revision Apps (BARA) will be explained. Next, the use of AR in medical education will be explained in detail. The use of AR technologies in mobile applications, especially in anatomy medical learning and some examples of existing applications and the methods used in this application will be described in this chapter as well.

All AR applications use printed markers as AR markers, including flash cards, logo images, and printed image images. AR markers can be diversified not only using printed markers but also object targets have just been introduced. Objectives in this AR are still limited to a few areas, and this study will use this technique to ensure their suitability in education, in particular, in the medical field.

1.1.1.1 Augmented Reality

Augmented Reality is a technology that allows the physical real-world environment to be enriched with computer-generated information. AR can be divided into two which are marker detection and marker less detection also known as natural feature tracking. Marker can be physically held or a piece of paper that has been printed with a picture or icon on it. When the mobile phone pointed onto the paper, AR 3D model and environment will be displayed. The marker helps the camera to detect the position of the AR object. Figure 1.1 shows the AR application that was used a flash card as a marker from link (https://endinv.wordpress.com/2019/03/19/augmented-reality-dalam-dunia-pembelajaran/). The advantage of markers is to help users to go to the visual world more easily. On the other hand, a marker-less AR application recognizes things that were not directly provided to the application beforehand. This

scenario is much more difficult to implement because the recognition algorithm running in your AR application has to identify patterns, colours or some other features that may exist in camera frames. Figure 1.2 shows the example of AR application for interior designer that used marker-less from link website (https://www.marxentlabs.com/news/furniture-today-marxent-takes-huge-step-toward-future-markerless-augmented-reality/).

Augmented Reality is widely used in many fields, including education, health, games, securities, robotics, tourism, advertisement and more. Examples of use of AR in education have been used from children like AR with flash cards, where they use Apps AR and scans on the cards and display 3D models that are very attractive to them. The flash card for this child has been categories into several categories such as fruits, food, vehicles, and animals for the purpose of introducing basic objects. The next level are primary and secondary school, where AR apps are used only by scanning on textbooks and display 3D AR models to help them understand better by visualizing this visual AR, for example in the subjects of Science and Biology which are among the subjects that hard to understand by just reading.

Additionally, AR is also widely used in the world of gaming as the most popular example is Pokemon Go, where players will be able to see this Pokemon model in the real world. While in tourism it is usually the traditional way to use brochures to tourists to deliver interesting place info somewhere, but with this AR technology, travellers can scan this brochure and can see more about interesting places with audio, music, videos about the place. As an example of AR Art Book apps to promote traditional gameplay in Malaysian country, where only one piece of paper they can learn about the game with details include how to play and the tools used.

In the field of health, AR helps medical professionals in their work, for example they can see AR models that can help them during surgery for patients. Additionally, there are also medical doctors who use AR to describe the symptoms of the disease that their patients have and will make it easier for patients to better understand their illness. There are also Apps AR that are used by patients as an awareness of the patients they have and how to control the pain they experienced. With the use of AR that can display not only 3D models, but also audio, video, and animation as well as explanations in text form can help those in need in this field.

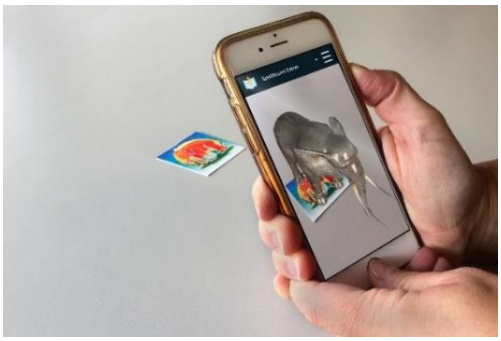

Figure 1.1: Example of Augmented Reality application using flash card as a marker

Figure 1.2: Example of Augmented Reality application using marker-less

1.1.2 Human Anatomy Learning Method to Medical Students

According to Tobias Blum et al. [1] Anatomy education ~~is~~ traditionally performed by the dissection of cadavers. This field is difficult to learnt because normally students learnt by memorizing through reading a textbook. According to him knowledge about human anatomy is an important part of education especially for medical professionals. Teaching anatomy is difficult, as there is a need an expended large amount of effort. Shahrul Badariah et al. [2] suggested Augmented Reality can be used in many other fields, such as physic and chemistry which are hard science subjects and required student's imagination to understand in depth.

1.1.2.1 Real Human Cadavers

The traditional way of medical students during the practical session is to dissect the real human body. The human body is used for learning is the corpse delivered by the hospital after not being claimed by family members for a certain period. This human anatomy specimen can last for a long time and can reach up to ten years if through a perfect curing process. If the human anatomy specimen is damaged or unusable, the remainder of this part will be planted for six months and will be excavated to be cleaned and drained into bone specimens. Medical students will undergo this anatomy learning process by holding each organ out of the body to see all the structure of each human body organ. Nevertheless, there will be several layers that may be damaged during the curing process. Figure 1.3 show how student learns human anatomy by using real cadaver.

Figure 1.3: Real Human Cadavers Lab Session
(https://humananatomy.uonbi.ac.ke/index.php?q=node/958)

1.1.2.2 Synthetic Human Cadavers

Apart from using real human cadaver in medical student learning, there are also other alternatives used such as synthetic cadaver or called SynDaver made of water, salt and other substances to produce such as human body tissues and other organs. Bones are made from 3D printed**.** The company that produces this synthetic cadaver has produced a cadaver that breathes, bleeds and employs hundreds to replace arteries, veins, bones, and muscles. The method of using this synthetic cadaver is to replace the old-fashioned way of using real human

cadaver, where this model will reduce costs over the old method, and most importantly this synthetic model can be used many times and the parts can be replaced. Figure 1.4 show the synthetic human cadavers used in anatomy lab session.

Figure 1.4: Synthetic Human Cadavers Lab Session
(https://syndaver.com/syndaver-news/)

1.1.2.3 3D Virtual Dissection Tables

Alternative approach from real physical dissection, there is a 3D Virtual Dissection Table, where the whole human anatomy will be displayed using a tool called 'Anatomage Table' as shown in Figure 1.5. Users can see the entire visual anatomy like real human cadavers. The table allows for exploration and learning of human anatomy beyond what cadaver could offer. This system allows students to focus on specific regions of body by rotating or zooming in and out. They believe this kind of technology is a good alternative compare to using an actual human cadaver. By simply interacting with this system, students can cut the part of the cadaver by slices to see the internal organ structure and can undo if incorrect cuts are done by simply pressing the undo button on the system, and this is an advantage compared to cutting true cadaver.

Figure 1.5: 3D Virtual Disecction Cadavers Lab Session
(https://steemit.com/steemhunt/@ememovic/anatomage-table-world-s-most-advanced-virtual-anatomy-visualization-system)

1.1.3 Augmented Reality in Medical Education

There are several mobile apps for learning anatomy that have been provided within Google Play or Apps Store. Some of these apps only use 3D models, and some also use AR technology. Furthermore, there are also applications that only display 2D images for the subject of human anatomy. However, there are still some shortcomings in this app application such as labels, misspellings, unrealistic 3D models, difficult interactions with applications, and so simple that they are not suitable for learning. Figure 1.6 shows the example of applications named Gray's Anatomy, which is used for medical learning using 2D images, and it can be downloaded from Play Store. Figure 1.7 shows Brain Anatomy Pro applications which used 3D model for medical learning mobile applications. Figure 1.8 was a medical learning apps using AR, this application is Human Brain Augmented Reality and can be downloaded with its marker through the Play Store.

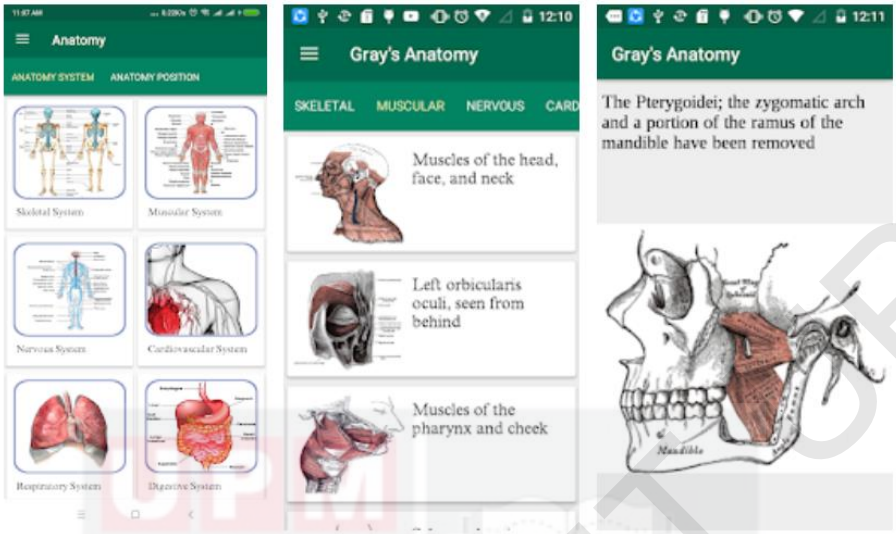

Figure 1.6: Gray's Anatomy: Mobile Apps of Human Anatomy in 2D Version
(https://play.google.com/store/apps/details?id=com.lyric.grays_anatomy)

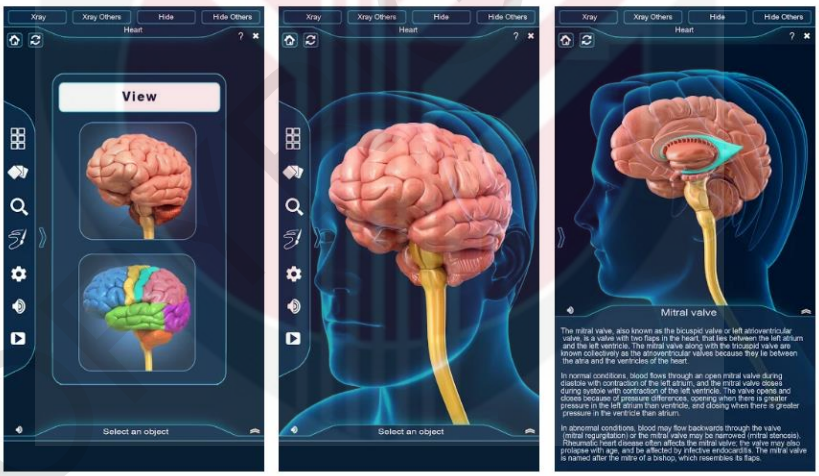

Figure 1.7: Brain Anatomy Pro: Mobile Apps of Human Anatomy in 3D Version
(https://play.google.com/store/apps/details?id=com.visual3dscience.brainpro)

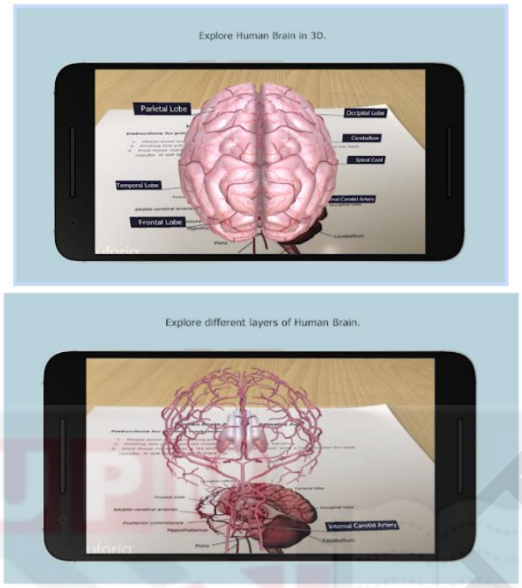

Figure 1.8: Human Brain Augmented Reality: Mobile Apps of Human Anatomy with Augmented Reality
(https://play.google.com/store/apps/details?id=com.magicsw.humanbrainar)

1.1.3.1 Guidelines in AR Medical Mobile Apps

Some of the following guideline lists are applicable to some AR Apps on the Play Store. For applications for medical subject learning also use between the list of guidelines. This study used this guideline early on to determine how well this guideline can be used in education especially in the medical field. And after being identified through several experiments, ten new guidelines have been added to develop BARA apps.

Item		Description
I.	Clear Textual Information	Make sure the text presented is clear. Type of font also should be readable.
II.	Contrast	Text and background should be contrast colour and sufficient. Need to know the environment of AR, so can decide the colour of text and background to be visible and readable.
III.	Grouping	When presenting the overlay of information, it is important to organize the information in grouping.
IV.	Placement	Important that the information presented should not obscured the item of interest.
V.	Alert/Attention Sensitivity	Alert when needed information is called, and the information presented should be able to identify the areas which are important and need immediate attention.
VI.	Interaction Methods	User will use many interactions and will switch the interaction anytime.
VII.	Distinct Icons	In augmented reality environment, the icons display should be known and recognize by user easily, or the labelling should be clear to be read.
VIII.	Visibility and Distance	In augmented information, especially in outdoor scene, it is important can to provide filter based on visibility and distance,

Guidelines	Definition
U1 Visual Design	Apps should follow standards of visual design that promote legibility, clarity of content, and user engagement without introducing unnecessary distraction. Apps that leverage user expectations in their design strategy shorten the learning curve and decrease user frustration
U2 Readability	Text used within the app must be readable, understandable, and adjustable to accommodate ease of operation for a variety of devices, users and use environments. Text size adjustments should not alter the screen layout in a manner that could confuse users or prohibit ease of use
U3 App Navigation	Users should be able to navigate quickly and easily between screens to complete tasks. Navigation should feel natural and familiar, and should not dominate the interface or draw focus away from content
U4 Onboarding	Apps should facilitate an intuitive process for launching, registering, entering personal information (if applicable), and preparing for first-time use. As the users' first introduction to the app, a simple and intuitive onboarding process is critical in instilling user confidence that the app will provide a satisfying overall user experience
U5 App Feedback	Apps should provide sufficient feedback to inform the user of the results of their actions and promote understanding of what is going on in the system. Feedback includes app reactions to user input, including providing messages to the user. Efficient and informative feedback ensures that users will be able to understand and perceive app actions without frustration. Guidelines associated with feedback related to notifications, alarms, and alerts can be found within Guideline U6
U6 Notifications, Alerts and Alarms	Notifications (general reminders or updates to the user), alerts (non-urgent indicators intended to capture user attention), and alarms (urgent indicators that may be safety-critical) must consider both safety and usability to inform users when attention is required
U7 Help Resources and Troubleshooting	Apps must incorporate help and troubleshooting features to guide the user when needed. Unavailable or unclear help features may lead to user confusion, frustration, and ultimately app abandonment
U8 Historical Data	Apps used to gather data should store historical data in a manner that is easy for users to access and understand
U9 Accessibility	Apps should be designed and built to accommodate a wide variety of users, including those with disabilities such as perceptual impairment (visual or auditory), cognitive impairment and learning disabilities, and motor impairment. Designs that are made to be adaptable will facilitate ease of use for all users, not just those with disabilities. Additionally, app design should aim to accommodate use with common assistive technologies (e.g., screen readers)
U10 Ongoing App Evaluation	Throughout the entire development lifecycle, apps should undergo robust, iterative evaluations that follow a user-centred design process. Understanding the user perspective and evaluating technology to test assumptions is critical in developing safe and usable products, and apps that do not meet user expectations or are cumbersome to use are unlikely to be adopted. Apps requiring review by the Food and Drug Administration (FDA) should undergo testing evaluation that follows the FDA's guidelines for applying human factors and usability engineering to medical device design

1.2 Motivation and Importance of Study

The motivation for this thesis arises from the following scenarios. It is nearly impossible for medical students to investigate in depth the layered anatomy structures and explore the complex structures from different angles. The text and visual representations of the anatomy in several manuscripts are inadequate to convey the complexity and the volume of the information related to the complex

region. Studying AR (Augmented Reality) in medical education could provide benefits for medical education and provide students a more personalized and exploration learning experience. We intend to propose a guideline for Augmented Reality user interfaces guidelines specially design for teaching and learning.

Anatomy education is traditionally performed by the dissection of cadavers. According to Carolien Kamphuis et al. [3], augmented reality (AR) technology could offer an additional teaching method for anatomy education, depending on how it is implemented. Augmented reality is a technology that adds virtual contents to the physical real world, thereby augmenting the perception of reality. The aim of this research is to develop an interactive visual learning of human brain anatomy using proper guidelines of Augmented Reality learning mobile application for medical students. Expected output of this research is constructing a guideline for AR user interfaces guidelines for anatomy visual learning for medical students with human brain anatomy as a case study. Ultimately there will be one best way and can help medical students use their own self-study AR Apps to review the lessons.

The significances for this research is to produce an interactive learning method for human brain anatomy visual learning using Augmented Reality. Next is implementing the appropriate for Augmented Reality user interfaces guidelines specially teaching and learning in medical educations. This study has highlighted the issue of using target image and object target in AR. The target object is new and has not been widely used in learning. There are several factors that can make this technique use object target markers beneficial to the user.

1.3 Problem Statements

The use of AR technology in learning has been highlighted several years ago, but still is not widely used among students, especially medical students. No doubt there are still a handful of people who do not know what AR is and the advantages of using AR in today's mobile app. The traditional way a medical student learns about this human anatomy by using human cadavers, Tobias Blum et al. [1], such as medical students from UPM. The cadavers of human beings sometimes have several layers that have been decayed and damaged, which at the same time give them little trouble during learning. With the help of AR technology, it can help them in this problem where 3D models will be built in detail by the actual human anatomy system.

Issues of AR usage techniques in this application also play an important role for users whether they like to use it or vice versa. The first issue for this study was that users did not use AR mobile apps even though there were several apps on Google Play or the Apps Store. This existing application could not help medical students as an additional reference material for several reasons. The guidelines used for these apps are all about the content and interface of those apps. There

are still students who are unfamiliar with the interface including the icons used in this application. AR 3D models are also not used in their learning. As we know, learning medical subjects especially about anatomy requires a virtual model as it is real because at the end of their lesson they will also work with real organs. There is no doubt that some students today do not know about AR and are very excited to see or use this app for the first time. Their fascination with these AR applications makes them want to interact with the AR model themselves, but these existing applications has a limit the interaction, such as not being able to turn or scale the 3D model to see it from another perspective. These are the existing AR limitation apps on the Play Store. Thus, the thesis study determines the difficulties and challenges of medical students using this AR application for their reference material in this subject, further developing a new guideline in prototype apps known as BARA gradually to be used by medical students.

The second problem is that the new guidelines applied in BARA are divided into different versions to ensure that the version method will enable them to continue using this kind of apps for a long time and to benefit them. By turning this BARA application into three versions: printed markers, digital markers, and object targets, which students choose the most to facilitate their use? Experiments will be conducted for each student using all versions of BARA and they will know the differences between each version.

1.4 Research Objectives

The main objective of this research is to establish a smooth interaction in Augmented Reality application in Education. To achieve the objectives of this research, this research must fulfil these objectives:

1) To determine the challenges in interacting with AR applications in medical learning.

2) To propose a guideline for the interaction with AR applications in medical learning.

1.5 Research Scope

In order to deliver successful of this research study, the scope is focusing on managing a few tasks as listed below:

I. This proposed study only focuses on the interface of human brain anatomy visual learning for medical students of Faculty of Medicine and Health Sciences, UPM to enhance their study method about this topic.
II. It will include a guideline of Augmented Reality user interfaces especially design for teaching and learning in Central Nervous System (Human Brain) topic.
III. This study will focus on design of interface guidelines of in Augmented Reality (AR) environments.

1.6 Outline of the Thesis Structure

The thesis is organized into six chapters. The first chapter is an introduction of this thesis, which provides a general introduction to use of Augmented Reality (AR) in anatomy medical learnings and AR user interfaces design guidelines. Next is brief explanation the background of this research, motivation to do this research and importance of this study. Moreover, this chapter clarifies the problem statements, objectives and scope of the research. Chapter two is a literature review of previous methods of medical learning application with AR. Some of these papers relate to method of using and not using AR in existence medical learning applications and interaction in mobile apps with AR. The current challenges in each of these issues are also described. Chapter three presents overall research methodology and discusses in detail each step that must be taken into consideration for development purposes. All the experiments set up in this research which is start with a few preliminary an experiment, User Acceptances Test (UAT) and Final Acceptances Test (FAT) will be discusses details in this chapter. Chapter four shows the first contribution of this research which is guideline for AR user interfaces guidelines specially designed for teaching and learning in medical education. Chapter five will discuss details the second contribution of this research which is evaluate the AR user guidelines. Chapter six contains conclusion of this research and summaries the research findings and suggest a potential of future works.

REFERENCES

[1] Blum, T., Kleeberger, V., Bichlmeier, C., & Navab, N. (2012). mirracle: An Augmented Reality Magic Mirror System for Anatomy Education. *IEEE Virtual Reality 2012*.

[2] B. Shahrul, T. C. Ng, H. Syariffanor. (2014). Interactive augmented reality art book to promote Malaysia traditional game, IEEE 2014 International Conference on Computer, Communication, and Control Technology (14CT 2014).

[3] Kamphuis, C., Barsom, E., Schijven, M., & Christoph, N. (2014). Augmented reality in medical education? *Perspective Medical Education*, *3*(4), 300–311.

[4] P. Siddhant, P. Chiquitha, N. Omkar, R. J. Abhijit, K. Neha. (2016). E-learning System using Augmented Reality.

[5] Billinghurst, M., & Duenser, A. (2012). Augmented Reality in the Classroom. *IEEE Computer Society Press Los Alamitos, CA, USA*, *45*(7), 56–63.

[6] Boyles, B. (2017). Virtual Reality and Augmented Reality in Education. *Semantic Scholar*.

[7] Pardo, C. R., Hernandez, S., Ángel Patricio, M., Berlanga, A., & Manuel Molina, J. (2015). An Augmented Reality Application for Learning Anatomy. *International Work-Conference on the Interplay Between Natural and Artificial Computation*, 359–368.

[8] Jain, N., Youngblood, P., Hasel, M., & Srivastava, S. (2018). An augmented reality tool for learning spatial anatomy on mobile devices. *Clinical Anatomy*, *30*, 736–741.

[9] L. K. Sung, J. S. Hae, H. K. Jeong, M. J Jun. (2014). Using Unity 3D to Facilitate Mobile Augmented Reality Game Development, IEEE World Forum on Internet of Things (WF-IoT).

[10] M. K. Zhaparov, U. Assanov. (2014). Augmented Reality based on Kazakh instrument 'Dombrya'.

[11] K. Hyejin, A. W. Elisabeth, I. H. Jae. (2015). Dynamic Hierarchical Virtual Button-based Hand Interaction for Wearable AR, IEEE Virtual Reality Conference 2015.

[12] A. Budi, S. Ade. (2017). Cultural Heritage Digitalization on Traditional Sundanese Music Instrument using Augmented Reality with Multiple Marker Method, Jurnal Teknologi dan Sistem Komputer, 101-105.

[13] Ganapathy, S. (2012). Design Guidelines for Mobile Augmented Reality: User Experience. *Human Factors in Augmented Reality Environments*, 165–180.

[14] De Sa, M., & F. Churchill, E. (2012). Mobile Augmented Reality: Exploring Design and Prototyping Techniques. *International Conference on Human-Computer Interaction with Mobile Devices and Services*, 221–230.

[15] A'isyah Ahmad Shukri, S., Arshad, H., & Zainal Abidin, Rimaniza. (2017). The design guidelines of mobile augmented reality for tourism in Malaysia. *AIP Conference Proceedings*, *1891*(1).

[16] Min Ko, S., Suk Chang, W., & Gu Ji, Y. (2013). Usability Principles for Augmented Reality Applications in a Smartphone

Environment. *International Journal of Human-Computer Interaction*, *29*(8), 501–515.

[17] Parhizkar, B., Khalid Obeidy, Waqas, Ahmad Chowdhury, Shahan, Mohana Gebril, Z., Ng Ah Ngan, M., & Habibi Lashkari, A. (2012). Android mobile augmented reality application based on different learning theories for primary school children. *International Conference on Multimedia Computing and Systems*.

[18] Lee, K. (2012). Augmented Reality in Education and Training. *TechTrends*, *56*(2), 13–21.

[19] Mekni, M., & Lemieux, A. (2014). Augmented Reality: Applications, Challenges and Future Trends. *International Conference; 13th, Applied Computer and Applied Computational Science*, 205–214.

[20] Contero, M., & Pérez López, D. (2013). Delivering Educational Multimedia Contents through an Augmented Reality Application: a Case Study on its Impact on Knowledge Acquisition and Retention. *Turkish Online Journal of Educational Technology*, *12*(4).

[21] F. L. Chi, S. P. Pai, S. F. Chiou. (2016). Mobile Application of Interactive Remote Toys with Augmented Reality.

[22] K. Hyejin, A. W. Elisabeth, I. H. Jae. (2015). Dynamic Hierarchical Virtual Button-based Hand Interaction for Wearable AR, IEEE Virtual Reality Conference 2015.

[23] J.G. Suryo, S. P. T. Arie, T. Radius. (2014). Aplikasi Gamelan Menggunakan Virtual Buttons pada Teknologi Augmented Reality Berbasis Android.

[24] Nainggolan, F. L., B. S., & F. F. (2016). Anatomy Learning System on Human Skeleton Using Leap Motion Controller. *2016 3rd International Conferences on Computer and Information Sciences (ICCOINS),* 465-470.

[25]] H. Steven, F. Steven. (2010). Opportunistic tangible user interfaces for augmented reality, IEEE transaction on visualisation and computer graphic, Vol. 16, No 1.

[26] Shane R.P, Michael R.M, Ross T.S, Joanne E.Z, Bruce H.T. (2010). Validating spatial augmented reality for interactive rapid prototyping, IEEE International Symposium in Mixed and Augmented Reality 2010 Science and Technology Proceedings.

[27] Leonardo B., Chia H. L, Ted S., (2005). Counterintelligence: Augmented Reality Kitchen.

[28] X. Cheng, L. Zhang. (2014). Implementation of Mobile Augmented Reality based on Vuforia and Rajawali.

[29] H.Taejin, L.Yougho, W. Woontack. (2011). Digilog book for temple bell tolling experience based on interactive augmented reality.

[30] P.Hyungjun, K.J Ho, J.P Sang. (2014). Tangible AR interaction based on fingertips touch using small sized non square markers, Journal Computational Design and Engineering, Volume 1, No. 4 (2014),289-297.

[31] M. Ma, F. Pascal, B. Tobias, E. Ulrich, S. Christian, W. Simon, W. Jens, N. Nassir. (2013). Kinect for Interactive AR Anatomy Learning, IEEE International Symposium in Mixed and Augmented Reality 2010 Science and Technology Proceedings.

[32] J.G. Suryo, S. P. T. Arie, T. Radius. (2014). Aplikasi Gamelan Menggunakan Virtual Buttons pada Teknologi Augmented Reality Berbasis Android

[33] Azad, R., Azad, B., Khalifa, N. B., & Jamali, S. (2014). Real time human computer interaction based on face and hand gesture recognition. *International Journal of Foundations of Computer Science & Technology (IJFCST), 4*(4), 37-47.

[34] Zhao, J., & Seah, H. S. (2016). Interaction in Marker Less Augmented Reality based on Hand Detection using Leap Motion. 147-149.

[35] Yowanda, A. G., Sunaryono, D., & Hariadi, R. R. (2014). Rancang Bangun Aplikasi Papan Tulis Virtual dengan menggunakan Leap Motion. *Jurnal Teknik Pomits,3*(2).

[36] Hurst, W., & Wezel, C. V. (2013). Gesture based Interaction via finger tracking for mobile augmented reality.

[37] Radkowski, R., & Stritzke, C. (2012). Interactive hand Gesture-based Assembly for Augmented Reality Application. *The Fifth International Conference on Advances in Computer Human Interactions,* 303-307.

[38] Liang, H., Yuan, J., Thalmann, D., & Thalmann, N. M. (2015). AR in Hand: Egocentric Palm Pose Tracking and Gesture Recognition for Augmented Reality Applicayions.

[39] Seixaz, M. C., Cardoso, J. C., & Galvao Dias, M. T. (2015). One Hand or Two Hands? 2D Selection Tasks with the Leap Motion Device. *ACHI 2015: The Eighth International Conference on*

[40] V. Meenakshi Sundaram, Shriram K. Vasudevan*, C. Santhosh, R. G. K. Barath Kumar and G. Deepak Kumar. (2015). An Augmented Reality Application with Leap and Android. *Indian Journal of Science and Technology, 8*(7), 678-682.

[41] Naidu, C., & Ghotkar, A. (2016). Hand Gesture Recognition Using Leap Motion Controller. *International Journal of Science and Research (IJSR), 5*(10), 436-441.

[42] Shao, L. (2015). Hand movement and gesture recognition using Leap Motion Controller.

[43] Sharma, R. P., & Verma, G. K. (2015). Human Computer Interaction using Hand Gesture. *Eleventh International Multi-Conference on Information Processing-2015 (IMCIP-2015),* 721-727.

[44] Seo, D. W., & Lee, J. Y. (2013). Direct hand touchable interactions in augmented reality environments for natural and intuitive user experiences. 3784-3793. Retrieved from www.elsevier.com/locate/eswa.

[45] Ng, K. P., Tan, G. Y., & Wong, Y. P. (2013). Vision Based Hand Detection for Registration of Virtual Objects in Augmented Reality. *International Journal of Future Computer and Communication, 2*(5), 423-427.

[46] McCartney, R., Yuan, J., & Bischof, H. P. (2015). Gesture Recognition with the Leap Motion Controller.

[47] UV, A., Schoofs K, Folta-, M, B., & Jan U, V. (2013). Effects of mobile augmented reality learning compared to textbook learning on medical students: randomized controlled pilot study. *Journal of Medical Internet Research*, *15*(8).

[48] H Kurniawan, M., Suharjito, S., Diana, D., & Witjaksono, G. (2018). Human Anatomy Learning Systems Using Augmented Reality on Mobile

Application. *3rd International Conference on Computer Science and Computational Intelligence 2018*, *135*, 80–88.

[49] Ma, M., Fallavollita, P., Seelbach, I., Von Der Heide, A. M., Euler, E., Waschke, J., & Navab, N. (2016). Personalized Augmented Reality for Anatomy Education. *Clinical Anatomy*, *29*, 446–453.

[50] Chen, L., W Day, T., Tang, W., & W John, N. (2017). Recent Developments and Future Challenges in Medical Mixed Reality. *2017 IEEE International Symposium on Mixed and Augmented Reality*.

[51] Salmi Jamali, S., Shiratuddin, M. F., Wai Wong, K., & L. Oskam, C. (2015). Utilising Mobile-Augmented Reality for Learning Human Anatomy. *7th World Conference on Educational Sciences*, *197*, 659–668.

[52] Layona, R., Yulianto, B., & Tunardi, Y. (2018). Web based Augmented Reality for Human Body Anatomy Learning. *3rd International Conference on Computer Science and Computational Intelligence 2018*, *135*, 457–464.

[53] Bidisha, R., Mark, C., & Natalie, Abts., Development of Usability Guidelines for Mobile Health Applications. (2019). *21st International Conference, HCII 2019 Orlando, FL, USA, July 26–31, 2019*, 500–506.

BIODATA OF STUDENT

Che Nur Shafareen Afera Binti Che Anuar was born in Kelantan, Malaysia, November 1992. She obtained her Matriculation Certificate in Physical Science in 2012, at Penang Matriculation College. She received the BSc in Degree in Computer Sciences majoring in Multimedia from Faculty of Computer Sciences and Information Technology, Universiti Putra Malaysia (UPM), Selangor, Malaysia, in 2016. In 2017, after she became a Research Assistant and developed applications using Augmented Reality for Heart Health, she is currently a full time Master in the same field at FSKTM, UPM. During her time as a postgraduate student, she also served as a demorator for lab sessions helping teach undergraduates students in the subject of Augmented Reality, Computer Graphics, and Rendering. She has also developed several Augmented Reality applications for exhibition and so on.

LIST OF PUBLICATION

Shafareen Afera, C. N., Wirza, R., Kamaruddin, A., Hod, R., & Adam, S. K. (2018). Virtual Buttons Interaction for Medical Learning Interfaces. *Journal of* Advance *Computer Science and Technology Research*, *8*(3).

Wirza, R., Shafareen Afera, C. N. & H. Khaleel, H., R.Hod., (2019). Medical Visual Learning with Interaction Through Cybergogy. *International Journal of Biomedical Nanoscience and Nanotechnology*. [Accepted waiting to be published]

UNIVERSITI PUTRA MALAYSIA
STATUS CONFIRMATION FOR THESIS / PROJECT REPORT AND COPYRIGHT

ACADEMIC SESSION : _____

TITLE OF THESIS / PROJECT REPORT :

_____

_____

_____

NAME OF STUDENT :

_____

I acknowledge that the copyright and other intellectual property in the thesis/project report belonged to Universiti Putra Malaysia and I agree to allow this thesis/project report to be placed at the library under the following terms:

1. This thesis/project report is the property of Universiti Putra Malaysia.
2. The library of Universiti Putra Malaysia has the right to make copies for educational purposes only.
3. The library of Universiti Putra Malaysia is allowed to make copies of this thesis for academic exchange.

I declare that this thesis is classified as:
*Please tick (√)

☐ **CONFIDENTIAL**	(Contain confidential information under Official Secret Act 1972).
☐ **RESTRICTED**	(Contains restricted information as specified by the organization/institution where research was done).
☐ **OPEN ACCESS**	I agree that my thesis/project report to be published as hard copy or online open access.

This thesis is submitted for:

☐ **PATENT** Embargo from _____ until _____
(date) (date)

Approved by:

_____
(Signature of Student)
New IC No/ Passport No.:

Date :

_____
(Signature of Chairman
of Supervisory Committee)
Name:

Date :

[Note : If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization/institution with period and reasons for confidentially or restricted.]