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Human Anatomy Learning Systems Using Augmented Reality on Mobile Application

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Abstract

Students generally experience difficulties in learning human body anatomy due to constraints to visualize the body anatomy from 2D into 3D image. This research aims to develop a human anatomy learning system using augmented reality technology. By using this system, it is expected that students can easily understand the anatomy of the human body using a 3D image visualization. The method used in this system is augmented reality marker on mobile computing platform. The marker is captured by taking a picture. Then, the captured image is divided into pieces and the pattern is matched with images stored in the database. In this research, we use Floating Euphoria Framework and combine it with the SQLite database. Augmented reality anatomy system of the human body has features that can interactively display the whole body or parts of the human organs. To evaluate the usefulness of the application, we tested the augmented reality anatomy system with high school students and medical students for learning the anatomy of the human body. The results show that the human anatomy learning system with interactive augmented reality visualization helps students learn human anatomy more easily.

Keywords: Augmented Reality; Human Anatomy Learning; Android Application

1. Introduction

Technology has been developing rapidly, especially in the area of information and computer technology (ICT). The development encompasses almost all aspects of life, including medical learning process. Currently, students who learn human anatomy use textbooks, text and picture media, and statue models.

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Medical students can also learn from cadaver surgery. However, these learning methods[1], especially using cadaver,could be costly while it is more challenging to use other media for visualizing the human anatomy. Learning using cadaver surgery in medical field is proved to be a good method for learninghuman anatomy. However, it is more complicated compared to the use of digital 3D model[2]. The current methodof learning human anatomy using text books and or plastic models poses difficulties for students in visualizing from 2D into 3D materials. To address such a problem, this research proposes the use of augmented reality (AR) to aid in learning human anatomy. This type of learning can help studentsuse both text media and 3D models, thus helping them gain a better understanding in learning. The primary goal of AR is to insert virtual 3D imaging into the real world. Therefore, it can represent an object into the real world and help the usersinteract with it. In education,AR will help students have a shorter learning curve because itcan motivate themto learn more about difficult subjects[3].

Previous research showed that information structure is very important in learning andthat the use of AR-based application can improve learning which needs visualization because AR can be usedinteractively[4]. Other research by Yeom which investigates the difficulties of learning anatomy also supported the above statement[5]. Considering sucha problem and previous research results, our research proposes a solution forlearning human anatomy using AR technology to help student in visualizing their learning materialsby utilizing the interactivity capability and make the learning process easier to understand[2].

2. Related Works

Augmented reality (AR) is a system that generates a real landscape by adding virtual objects created by computer including 3D objects[6] so that users can make the virtual objectsof the system as if the objects are real. Ideally, the objects must be able to interact with the user naturally[4].AR is an application that aims to add user experiences in the real world with virtual elements without losing the elements of the real world[7]. AR is also a tool to interact with digital objects in a physical sense[8]. Augmented reality has been widely used in various fields[7]. AR has an innovation factor and very interesting elements that match the modern technologies. AR can be used in various fields, for example AR in education, AR in business, and AR in the field of architecture. In education, the classroom AR can be useful for learning. AR can capture and store the teacher's movement. The movement can be added with digital information that can help the process of delivering teaching materials[2]. For example, when a teacher teaches physics, he can move the marker-covered ball to be smashed and showed it in 3D models using other markers to show the simulated movement during a collision between two objects[9].In business, the research done by Ekengren[7] with mobile JAR showed that AR can be used to enlarge business opportunities due to the technical functions of smartphones in human life so that companies that have a mobile strategy can obtain better results and are able to be ahead of the others in the formation of a new business model. In the field of architecture, AR is used for designing interiuor as mentioned by Domhan[8].AR application can be used to see if furniture fits to the need of ones' office before they buy the furniture. Another advantage of AR is that it can be used to adjust the position of the furniture. Users can preview the position before starting the arrangement.

Previous studies related to human anatomy learning system based on android platform using augmented reality technology describe the use of AR application for learning the anatomy of the human ear with a random group and control group[10]. A control group of students did not use the application for learning and the random group of students used the learning app with AR. We evaluated the quiz results of each group and generated difference in mean value of 18% with a confidence interval of 12% to 24% which was highly significant ($p < 0.001$). So, it is recommended to further examine the research on learning by utilizing 3D models [3]. Our study also uses AR system for learning the anatomy of the human skull[11]. The system uses an application on the desktop that is equipped with a webcam. The system was tested on 30 students who had not completed the anatomy class. The students were divided into 3 groups of 10 people in which group A used the book, Group B used the VR, and Group C used AR. All users responded tothe distributed questionnaires. The results show that the AR system can help students learn the complex anatomical structures.

The comparative study discusses augmented virtual reality method in learning the anatomy of the human spine[1]. The research created 3D models with 3D Maya as research objects of the virtual reality. Then,it used the 3D models into the application of AR in flash for augmented reality. The results of the observation are tabulated into a

comparative table. The study concludes that both VR and AR are very useful for learning the anatomy of the human body. The main application of AR technology can be applied for learning human anatomy. AR application is made using web-based application to simplifythe learning process[12]. It is easy for users to access web-based method because it does not require installation. The questionnaires,research evaluation, and feature comparison can be done automatically. The evaluation results indicate that application-based learning concept is easier to understand, more attractive and easier to use.AR can be used as an alternative learning and teaching tool that can help to shape a 3D visualization. Previous research describes thedesign of human heart anatomy learning system using mobile augmented reality[3,12]. The application was made with a technique dividing the development of AR applications into three important parts:Camera vision: at this stage, the camera serves as a tool to detect and assess the level of concordance marker; Capture, tracking and identify: this process determines the size of 3D objects by size marker. Then, the information obtained from the processes is analyzed in order to obtain the appropriate visualization.Visual display: the display information and 3D models on the user.

From the previous results as shown in[313], the authors conclude that the study of human anatomy can provide learning tools such as:providing assistance arrangement visualization of organs in the human body,having the ability to see different layers of the human body,providing a comprehensive description and in accordance with learning materialswhich are easy to understand, and providing mobility for students so that they can learn anywhere and anytime.These studies have concluded that the AR learning method can help students who need assistance in visualization of learning materials. The research results also indicate that the learning applications can complement and develop existing research results in order to meet the needs of teaching aids[14]. Researchers combined several methods in the existing research, and then implement it into a mobile-based application. In our proposed research, we design an android-based AR application that serves as a toolfor studying the human anatomy through a 3D display on the marker. We divide the anatomy of human body in two layers, namely the outer layer of the skin and the internal organs. Applications are designed to receive input on the touch screen as a command to select parts of the body. Information about the organs will appear when a user touches the organ models on 3D models displayed in the application.

3. Methodology

We initiated our work by conducting a literature study onthe development of augmented reality (AR) in various fields. Following this, we focus on the application of AR in education. With regard to the application of AR in education,weexamine how AR can assist students in learning materials that require visualization. One of the lessons is learning the anatomy of the human body. From the literature study,we look deeply into the learning of human anatomy using existing applicationsin which we found several weaknesses of the current research.

As shown in Fig 1, the next stage is designingand creating AR applications. According to Hazidar and Sulaiman [3], AR applications have important parts. The first part is camera (camera vision). The camera is a tool to capture a marker and measure the size and position of the marker. The second is capture and tracking (identifying the marker).The outputs from the camera are in the form of the position and size of images which will help to determine the initial size of the 3D model to be displayed. The third stage is identification (identifying) in which the applications will identify the marker, determine whether the marker can be used in accordance with the stored database, and determine which model will be displayed. The final stage is data appearance (visual display). The application displays the existing data in the form of 3D models and the coordinates of the part models. Appearance models use the marker as a position indicator for the 3D model that will be displayed. Based on the structure of the research,Hazidar and Sulaiman[3] and the stages of research conducted by Westerfield,[15] researchers developed applications of AR in this study using the stages starting from the camera capturing video, looking for markers that exist on the video and calculating the size, distance, and orientation marker. The application then identified markers visible form[16]. Researchers use the markers based AR on android smartphone, so that users of this app can use android smartphone camera to see the view from various perspectives. So, this application is expected to help students learn the position of each organ of the body and then observe them from various angles. Furthermore, researchers chose android studio with JAVA programming language because android studio is designed specifically for the development of android applications and is compatible with various AR engines. The AR engine used is the AndAR with the Unity and Vuforia AR frameworks that are made for the mobile platform.AR applications development started from designing the marker to be used. The ideal marker is a marker that is not symmetrical

horizontal or vertical. In this study, the marker is made at https://developer.vuforia.com/license-manager. On this website, users can create markers by registering on the website and then creating a license key. Then, the researchers upload the desired images to be processed as a marker and download the marker as a file with the extension .package for IDE unity. Then, the researchers use a license key and a file downloaded to add as markers on the application.

Data for the evaluation were collected using a survey of 30 medical students in Indonesia. The survey was conducted by delivering video application, testing the application,and distributing the questionnaires to the users after they used the application[5]. The Questionnaires were developed based on previous research[1718].The results obtained from the questionnaires will be used for the evaluation of the application.

The researchers evaluated the results of the survey which employedthe attitude questionnaire using Likert Scale. Attitude questionnaire was used to analyze the user's perceived of the system[17]. The questionnaire consisted of assessment of the various aspects of AR applications,such as the teaching materials that assess whether the teaching materials used in the application are in accordance with the education they receive.The interface design is to assess whether the design of the interface of the AR application is suitable for learning.The multimedia features are to assess whether the multimedia features provided are useful for learning.The interactive function assesses whether the function of interaction provided make the AR applications interesting and can assist visualization and interest in learning.Practicability assesses whether the overall application is useful in learning.Attitude questionnaire was selected because it provides an effective approach and save time to evaluate the satisfaction of users of the system[11].

The data used for learning materials are data descriptions of the anatomy of the human body. The data were obtained from various books, such asthe Atlas of Human Anatomy, the Interactive Atlas of Anatomy by Netter,the Atlas of Anatomy by Sobotta, the Atlas of Anatomy by Yokochi, Anatomy Physiology, World Book Encyclopedia Deluxe, and various education websites for students in the field of medical such as: http://www.adameducation.com/, and similar applications. Data for the evaluation were collected using a survey involving medical students in Indonesia and 30 people were taken as a sample. The survey was conducted by delivering video application and testing the application, then providing the user questionnaire application[19]. The users' answers to the questionnaires will be used as data input for the evaluation of this application.

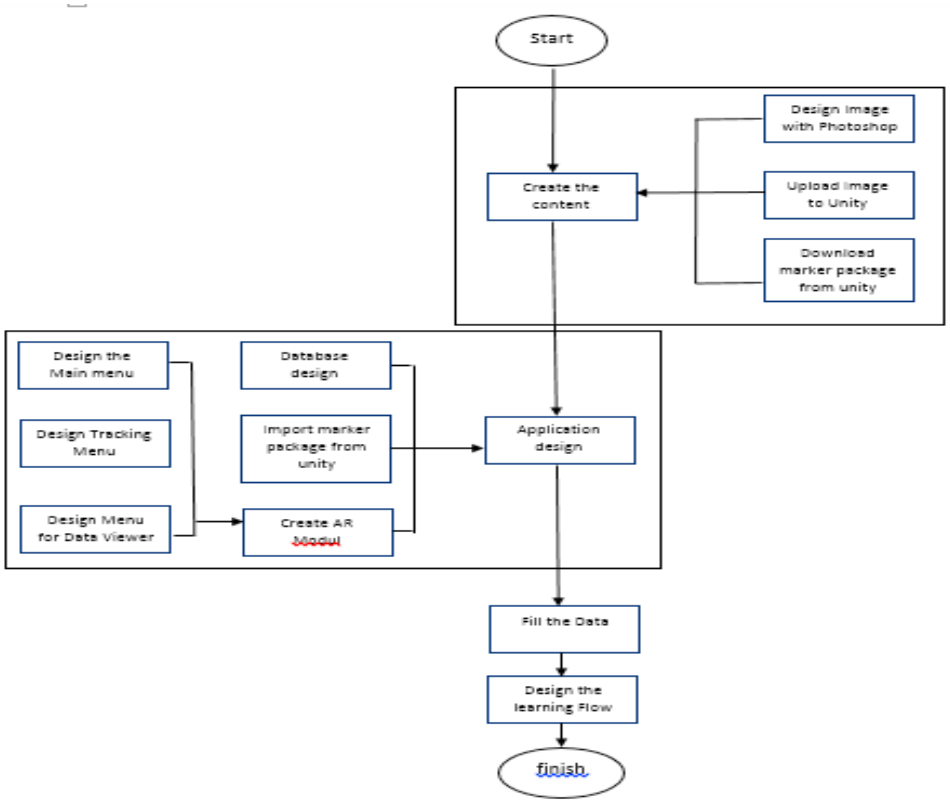

Fig. 1. Diagram of Application Development Structure

4. Results And Discussion

The application starts from the main menu Display as shown in Fig 2A. Here, the user can choose the desired learning mode. Furthermore, anatomy learning mode with AR begins withcapture marker. In this process, the application takes video stream from camera and takes a marker image to detect. Next, in the marker identification, the app detects markers and compares them to existing templates in the program (templates are files with .patt extensions). In the 3D model appearance process, the app displays a human 3D model with a position relative to the marker. In the user input process, the user provides input in the form of touch on the cell phone screen. Then,the app detects any touch interaction on the screen. If the touch is right on the section marked with details, then the next process continues. Next is the appearance of data. In this process, the application receives a touch coordinate value and the coordinates of the 3D model. From the coordinates of the application,the appropriate data on the part being touched are displayed.

4.1. Application Interface

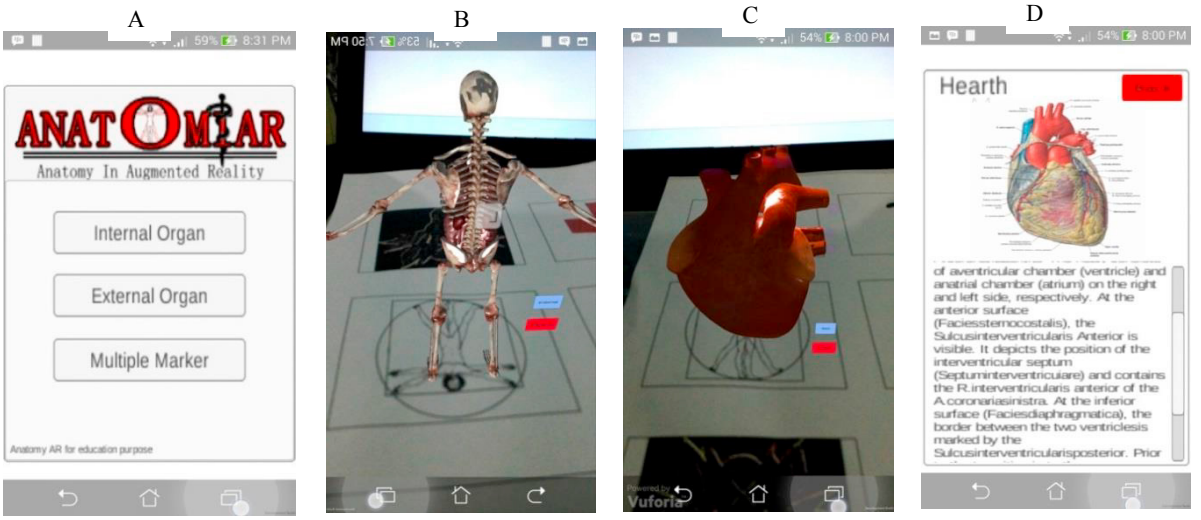

Fig. 2. Application Interface of AR Human Anatomy

The app displays the view obtained from the camera on the android device. Then,the camera will detect the presence of markers. When the marker is detected, it will display 3D models of the human body in accordance with the selected menu. Internal Organ menu displays 3D models of human organs as shown in Fig 2B, while the External Organ menu displays the 3D model. The 3D model shown has interaction touches on the parts of the body such as the heart, lungs, stomach, oesophagus, and brain. After a user interaction such as touching a body part of a 3D model which appears on the marker,the application will display a menu with a view as displayed in Fig 2C. As shown in Fig 2, 3D models of organs displayed can be touched on certain parts to show the detailed information, such as the name and description of the organs as shown in Fig 2D.In addition, 3D models displayed can be manipulated by rotation and model magnification. This is done by utilizing the touch screen input function on android. This function utilizes the android ability to recognize and determine the input position of touch on the screen. The app detects the user's touch coordinates on the mobile phone screen and then compares the coordinates of the displayed object. After obtaining a comparison of touch coordinates and 3D models, the app displays information that matches the data stored in the database. For example, when a user touches one of the organs, the application displaysa description of the organ. Users can also rotate the displayed organ by rotating markers. Zoom in and zoom out can be done by adjusting the distance marker with the camera.

4.2. Learning Model of human anatomy Using AR

The human anatomy learning model is a learning system that utilizes augmented reality technology applied to mobile device. The system is designed to be easy to use by teachers and students who study human anatomy. Student learning is done by pointing the camera at the marker device which is already determined. Users can interact by touching the screen or move the device to see 3D models that appear from different angles. The interaction will help students visualize the materials they learn through the 3D model of the human body anatomy.

The attitude questionnaire was used to measure the level of user satisfaction in using this application.This questionnaire used a likert scale ranging from 1 which means strongly disagree and 5 which means strongly agree. Questions on the questionnaire were divided into 5 categories with each category having 3 questions. Then, based on the results of the survey, the researchers calculated the average of each respondent's answer for each question then calculated the mean of the average for each predefined category. The questionnaire was distributed to 60 respondents; 30 respondents had a high school education background, especially from the science major and the other 30 respondents had a minimum education level of university of Tier 1 particularlyfrom majors which study the anatomy of the human body.

4.3. Survey Result Application evaluation

The results of the analysis are presentedin Fig 3and Table 1.

Table 1: Evaluation Result of AR Human Anatomy

Q	Teaching materials	Mean	Avg
1	I think the "anatomy learning application with AR" is very interesting	4.05	3.997
2	I think "anatomy learning application with AR" is very helpful in learning human anatomy materials	4.07	
3	In my opinion "anatomy learning application with AR" is very useable in other fields	3.87	
	User Interface	**Mean**	**Avg**
4	I think the design of "anatomy learning application with AR" is very interesting	3.95	3.983
5	I think the design of "anatomic learning applications with AR" with markers is more interesting to use than static images	4	
6	I think the design of "anatomy learning application with AR" with marker is able to show various application features	4	
Q	**Multimedia feature**	**Mean**	**Avg**
7	I think "anatomic learning applications with AR" with markers are more helpful in visualizing the anatomy of the human body	4.13	4.097
8	I think "anatomic learning applications with AR" with markers are more helpful in understanding more deeply about the anatomy of the human body	4.08	
9	I think the "anatomy learning application with AR" with marker is faster in understanding the anatomy of the human body	4.08	
Q	**Interactive function**	**Mean**	**Avg**
10	I think the function of "anatomy learning application with AR" to see the description of each organ is very helpful and interesting	4.08	4.163
11	I think the function of "anatomy learning application with AR" to rotate 3D model is very petrified anatomical observation	4.18	
12	I think the function of "anatomy learning application with AR" to enlarge 3D model is very petrified to see anatomy details	4.23	
Q	**Practicability**	**Mean**	**Avg**
13	I think learning by "anatomy learning application with AR" is very petrified in anatomy class	4.12	4.050
14	I am very interested in using "anatomy learning applications with AR" anytime	3.88	
15	Overall "anatomy learning applications with AR" greatly aided the learning process	4.15	
#	**The overall average**	4.058	

Q is the survey question, Mean refers to the average value of each question based on the respondents' answers and, Avg is the average of mean in each category.On the teaching materials category, as shown in Table 1, it can be seen that the value is 3.997 indicating that the respondents were quite satisfied with the materialsdisplayed on the application. Some participants also felt that the app could help if the data displayed could be more focused on 3D models for visualization than the written theoretical papers.The design of the user interface category shown in Table 1 has a value of 3.983. This indicates that the participants felt quite good about design but some participants felt that the font size is not big enough. So, it is a bit difficult to read. The multimedia features, as can be seen in the Table 1, has an average value of 4.097 indicating that the respondents perceived the 3D model and the displayed image as good.They just want more contents,showing that the users felt compelled to use this application further.The interactive functions category, as presented in Table 1, has a value of 4.163. The participants felt that the touch features and the ability to see the model from different angles are adequate and that there is no criticism with regard to this factor.The practicability, as can be seen in Table 1, has a value of 4.05. The respondents felt that

this application is quite useful although some participants mentioned that they were confused when using the application. Generally, the overall average as shown in Table 1is 4.058. This indicates that the majority of the respondents chose the option above 3 (agree or strongly agree).It indicates that all categories of evaluation meet the requirements of the users and that they are satisfied with this application in assisting the learning of human anatomy.

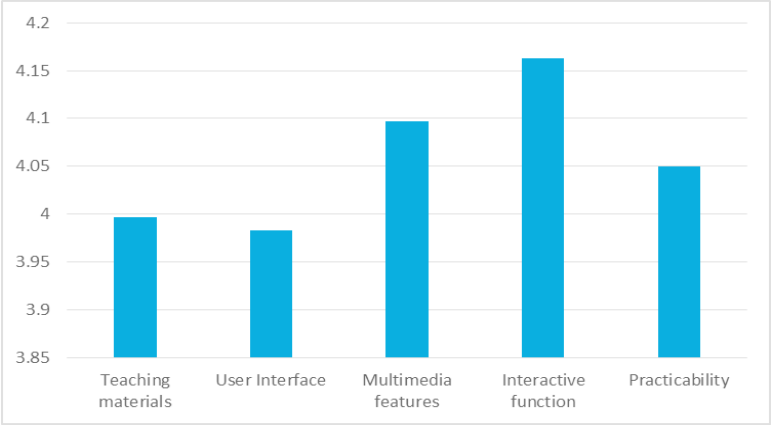

Fig. 3. The Comparison of the average value of categories

Fig. 3 shows the comparison of each category based on the user rating. As this figure indicates, the interactive function of the application has the highest value, followed by the multimedia features and practicality. This shows that AR applications of anatomical learning provide interactive and convenient multimedia features for students. Thus, students can interact with the application by obtaining detailed information from the desired anatomy model, and zooming or rotating for more detailed information. User interfaces and teaching materials are given low scores because the use of AR did not yet explain the use of the application. So, the respondents rated the user interface as rather confusing as the anatomical learning material is not yet completed. Therefore, this research is being developed to fully complement the learning materials of the 3D model of human body anatomy and to add an explanation of the use of the application. This will make it easier for the users to use it. In addition, the development of this application can be performed using speech to explain detailed information about anatomy and interaction features between the users and the application.

5. Conclusion

Based on the analysis of survey data and evaluation of mobile anatomy applications, anatomy learning applications using mobile augmented reality technology received positive feedback and received good feedback from the respondents. The application developed in this study using 3D models to visualize anatomy has many advantages such asclarity and easiness for understandingthe 3D anatomy model, giving different choices in visualizing 3D anatomy models from various organs of the human body, having interactive features of 3D anatomy models that can be displayed from various viewpoints and body layers, and meeting the requirements of learning quality materials for users.

This application is very useful in providing visualization of student learning materials and creating a better interest in learning anatomy material subjects. Mobile apps with augmented reality technology also create the desire of students to use this application higher as a complementary tool for learning and understanding human anatomy. Some improvements of the mobile app that can be done are to provide better guidance for beginner users, add visualization materials with more choices featured in multimedia platforms by using sound or video, easy-to-understand material annotation improvements with easier-to-understand language usage and user interface. Based on the results of this study, it can be concluded that applications using mobile augmented reality can help high school students and medical students in

learning the anatomy of the human body with an interactive learning[13].

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