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Samia Loucif
Zayed University, samia.loucif@zu.ac.ae

Murad Al-Rajab
Alhosn University

Reem Salem
Alhosn University

Abdullah Hesham
Alhosn University

Doaa Mahely
Alhosn University

See next page for additional authors

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Learning Human Anatomy Using ARA Mobile Application

Samia Loucif[1], Murad Al-Rajab[2], Reem Salem[2], Abdullah Hesham[2], Doaa Mahely[2] and Mhd Alaa Ajlouni[2]

[1]College of Technological Innovation, Zayed University, Abu Dhabi, UAE
[2]Software Engineering Department, ALHOSN University, Abu Dhabi, UAE

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Abstract: Smartphones with mobile applications have become part of everyday life, as they transformed the ways people manage their tasks. Many fields and sectors are using mobile applications to facilitate their services. Education is an important field that can utilize the various features of mobile applications to assist students and educators. Students are learning several subjects and concepts in schools, including biology. With traditional teaching methods, students may face difficulties in grasping knowledge about human anatomy. This can affect the teaching effectiveness, students' learning process, their engagement in class, and their academic performance. To take full advantage of the technological tools available in the market and to improve teaching effectiveness in the biology field, this paper proposes an Augmented Reality Anatomy mobile application (ARA for short). With ARA, students can learn about human anatomy and organs using augmented reality technology. Among the interesting features of ARA are: visualizing human anatomy as 3D models, examining the different human organs, controlling their visibility, recognizing drawings of organs, learning about each organ structure, function, and how to keep it healthy, and taking pictures and sharing them using social media platforms. More importantly, the proposed application enables the visualization of human anatomy without resorting to the marker tracking method. To evaluate the usefulness and the usability of the proposed application, the latter has been tested with students at the Genius Kids Center in Abu Dhabi, UAE. Positive feedback has been received from students who have enjoyed learning and interacting with human anatomy.

Keywords: Smartphones, Augmented Reality, Biology, Anatomy, Education, Apps

1. INTRODUCTION

Advance in technology has led to the emergence of smart devices including smartphones, tablets, and mobile applications. A huge number of mobile applications have been developed targeting almost all sectors such as finance, entertainment, healthcare, and education. The latter is an important sector which can take full advantage of the benefits of smart devices and mobile applications and deploy them for effective teaching. In fact, several schools and educational institutions have already started using technology in the teaching process. In the UAE, for instance, some schools are shifting to the use of tablets in the classroom [1]. Using technological tools in classrooms not only results in supporting teaching and learning, expanding course offerings and learning materials, and increasing student engagement and motivation but they also keep students studying and practicing outside class time [2].

Augmented Reality (AR) is one of the important technologies which have been integrated with mobile applications. Instead of creating an entirely artificial world, AR seeks to supplement the real world by superimposing 3D objects upon it [3]. It comes in two flavors; marker-based or marker-less AR. The former requires the usage of markers/targets to visualize the 3D model of a target object, while marker-less AR users have the freedom to place the 3D objects wherever they want in the application without necessitating markers/targets.

Students spend the majority of their time learning about different kinds of subjects and concepts in schools. Studying human anatomy, for example, is an important subject in biology. Traditional teaching methods depend mostly on teachers explaining and showing static images of the human body and its organs. This can be very difficult for students to understand and remember. Studies have shown that 65% of the US population consists of visual learners [4]. Another study showed that visual aids

E-mail: s.loucif@zu.ac.ae, m.alrajab@alhosnu.ae, r.mohamed@alhosnu.ae, ahawad02@students.alhosnu.ae ,daali01@students.alhosnu.ae, maajlouni01@students.alhosnu.ae

in the classroom improve learning by up to 80% [5]. These statistics indicate that the immense majority of students find it easier to learn and memorize knowledge using visual cues. All these findings have been recently supported in [6] [7][8] where it has been shown that 90% of the information transmitted to the brain is visual and images help to store information longer.

The purpose of this research paper is to facilitate teaching/learning biology and to improve students' learning outcomes through mobile technologies. Instead of reverting to traditional methods of teaching, the proposed application, ARA, allows teachers to use a tablet or smartphone camera to visualize the teacher's or any human-like model organs, which makes the lesson more fun and increases interaction in the class. The application saves teachers' time by engaging students and helping them learn on their own. As mentioned before, the majority of students learn better when they are shown visual cues. Learning human anatomy in a fun way will motivate students to comprehend biological concepts better. It also encourages them to learn outside of class, which will have a positive impact on their academic performance.

The rest of the paper is organized as follows. Section 2 discusses related applications in the field. Section 3 describes the proposed mobile application, ARA, with its features, provides an illustrative example showing how ARA works, and presents results of the ARA usability test conducted in an educational center. Finally, Section 4 concludes this paper.

2. RELATED WORK

Several applications based on AR have been proposed in the fields of biology and medicine. The authors in [9] confirmed the importance of studying biology for high school students. They argued that traditional materials available in books are insufficient to help students understand the human body anatomy. They proposed an AR application which enables students to learn the human body easily with 3D objects through scanning paper markers, and learners can get more details about organs using a web application. Another contribution was done by [10], who developed a human anatomy learning system using AR. The method implemented in their system is an augmented reality marker which is captured by taking a picture, then the captured image is divided into pieces and each pattern is matched with different images stored in a database. The authors in this system had used Floating Euphoria Framework in addition to SQLite database. Their system had been tested with high school students and medical students. An augmented reality magic mirror application for teaching anatomy is presented by the authors in [11]. Their idea is based on a depth camera to track the pose of a user who stands in front of a large display monitor. The system depends on using a volume of visualization of a CT dataset which can be augmented into the user's body using a gesture which selects the different slices from the CT and the dataset. The system can display a set of 3D models of the organs, information text, and anatomy images.

Curiscope Virtuali-tee [12] is an AR-based mobile application which includes a virtual reality 360° experience on the human body. It allows users to examine the entire system and isolate individual organs. However, to fully examine the human body, the user must wear a special t-shirt that can be bought from their website. The Brain AR App [13] allows users to explore the head anatomy from the skin layer, muscle, and skull down to the inner areas of the brain. It uses virtual reality to experience and navigate the inner brain structure. The application requires the usage of specific printable targets on a surface so that users can visualize the parts of the human brain. Anatomy Next [14] is also an AR-based mobile application that is specially advertised for medical students and healthcare professionals. The app focuses on visualizing the head and brain of the human body. It offers a virtual reality experience for interactive learning. Similarly, this application requires placing the printable targets on a surface.

Mastering Biology AR [15] has been developed for teaching biological concepts. It applies AR technology to display 3D models of the images found in New Senior Secondary Mastering Biology book (Second Edition). The main drawback of this application is that it requires to purchase a specific book. Moreover, there exists another application known as Arloon Anatomy [16]. It is a comprehensive learning experience suggested for students. It offers curricular content with 3D models and exercises to test the student's knowledge. It also requires printable targets in order to use AR technology. Humanoid 4D+ [17] offers an insight into various parts of the human body systems. The 3D models are interactive and can be zoomed and rotated based on the user's needs. In addition, the application provides information related to each part of the human body. The main drawback of this application is the need for a printable target to be placed on a human body in order to use AR technology.

All the above-mentioned applications have several interesting features for students and learners in general. However, they all share a common feature which requires the need for a target/marker to visualize 3D objects, either as t-shirts, which can be costly for some people, or a printable target which tightens people to a specific book or marker. The latter can have a negative impact on the environment.

Our proposed mobile application, ARA, represents an interesting and useful educational tool for users who are interested to learn about human anatomy. ARA does not need the usage of any marker tracker; thus, students can visualize the human anatomy by pointing the camera to their face and then the application shows the human organs in their 3D models. Moreover, the application allows users to focus on each organ and learn about the

functioning of the organ and the appropriate food to keep it healthy. Users can also utilize the features of recognizing organ drawings and capturing pictures that can be saved or shared directly from the application using any social media platform.

3. THE PROPOSED APPLICATION - ARA

The application uses the cutting-edge technologies of Augmented Reality and face detection software to enhance the students' educational experience. The face detection technology utilizes algorithms that normally start by looking for human eyes, since they are considered an easy feature to detect. When eyes are successfully detected, these algorithms try to detect other facial features like the mouth, nose, and eyebrows [18]. ARA works by detecting the user through his/her smartphone or tablet's camera and superimposing the various body organs on the user's body. Moreover, the ARA app is developed using Unity software [19] to allow the application running on both Android and iOS platforms and enable it being used by several smartphones and tablets. For the face detection, we use OpenCV (Open Source Computer Vision Library) [20] along with Unity. It can also be connected to a smartwatch for added functionalities. The key feature of this application is that it can be used without requiring any fixed marker tracking, since the target is considered to be the body of any user.

A. ARA Features

ARA has the following features: human body detection, organ drawing recognition, organ examination and visibility control, and sharing the captured pictures using social media platforms. The main menu of the ARA app provides three main options to the user which are viewing organs, drawing organs, and using a smartwatch. These features are summarized in Figure 1.

1. The Human Body Detection is an important feature that allows users to visualize 3D images of the human anatomy as if users are seeing it in real life. The Face Detection feature makes use of a deep learning face detector model shipped with the OpenCV library. This facet of OpenCV depends on a huge number of positive and negative images that have been used to train the model to recognize a human face. Once the device's augmented reality camera is turned on, the user can target the device camera to any human face. After that, ARA will detect the user's face then visualize a 3D image of the human organs over the user's body.
2. The Organ Visibility Control and Organ Examination features give the user the ability to isolate each organ in the human anatomy's 3D image and display more information about each organ independently. The user has the ability to view the organ from different angles. In addition, the user can learn about the organ structure, how the organ works, and further important information in order to keep the organ healthy in both forms text and audio.
3. For fun, ARA users can take selfie photos with the 3D organs and share them through social media platforms.
4. Moreover, ARA takes into account the principles of usability support to make it more universal by offering text and audio explanation. More importantly, ARA comes with the support of two languages Arabic and English.

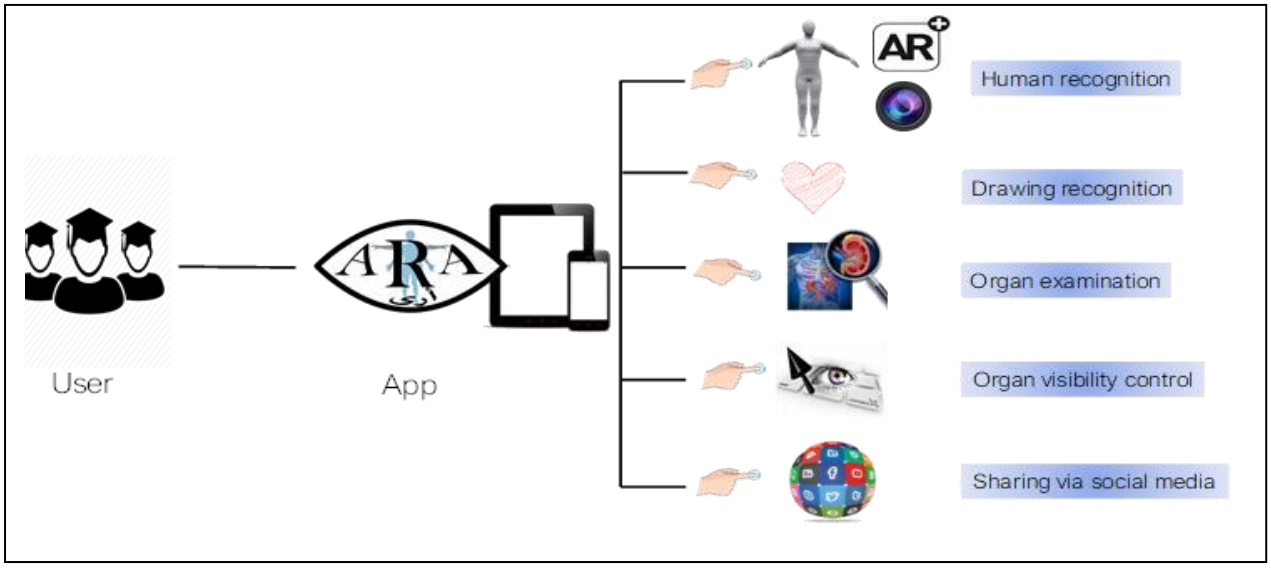

Figure 1. ARA features

5. The Drawing feature allows the user to manually draw simple organ shapes, like a heart shape for example, on a board or a piece of paper. Then, ARA displays the corresponding organ as a 3D model.

B. An Illustrative Example

An illustrative example of how to use the proposed application is shown in this section. By launching the application, the user will be offered the following options as shown in Figure 2.

- The language button: allowing the user to switch between Arabic and English languages. In case of selecting a language, all following application features will be in that language.
- The information button: provides details and contact information about the application developers.
- The sound button: enables the user listening to music while exploring the application, with the possibility to turn it off as well.
- The start button: takes the user to the three main options of the application, and the user can exit the application pressing the quit button.

By clicking the start button, the user will be directed to the application tutorial guiding how to use it, and the user can skip the tutorial by clicking the skip button. As shown in Figure 2. The same figure depicts the main menu of ARA: View Organs, Draw and Learn, and Connect to Smartwatch. The "View Organs" triggers the AR device camera to detect the face and virtualize the human organs on the user's body. In our case, the internal human body consists of five organs: heart, lungs, liver, stomach, and kidneys. The user can control the visibility of the 3D organs by showing/hiding the organs through the visibility menu, as illustrated in Figure 3.

Figure 2. "View Organs" screen

Figure 3. ARA home and main menu screens.

In addition, ARA allows the user to explore in more details each of the aforementioned internal organs by selecting any desired organ. For instance, to know more about the heart, the user can click the heart organ from the "View Organs" screen. Then, the user will be directed to a new screen that contains more information about the heart, as shown in Figure 4(a). The latter will exhibit the organ's parts in details with other four different preferences which provide more learning materials about the organ. These preferences include "Organ Structure", "Organ Functions", "Keep Organ Healthy", and "Play a Video" related to the organ.

The "Organ Structure", Figure 4(b), illustrates the heart structure. It provides additional information about what the organ consists of. The "Organ Functions" provides information about how the organ works and its main function, Figure 4(c). To learn and to be aware of the healthy food and beneficial vitamins for the organ, the user can select the "Keep Organ Healthy" preference, as illustrated in Figure 4(d). This preference can act as a guide to avoid any bad habits that may negatively affect the organ. Lastly, the user can enjoy learning more about how each organ works and how the interactions happen with the other organs of the human body by watching related videos, Figure 4(e). All of the above options are provided in text and audio.

Selection of the "Draw and Learn" option, results in directing the user to the screen shown in Figure 5. For example, after drawing a heart shape, ARA detects the drawn shape and displays an animated 3D heart. It can be rotated to visualize it from different angles.

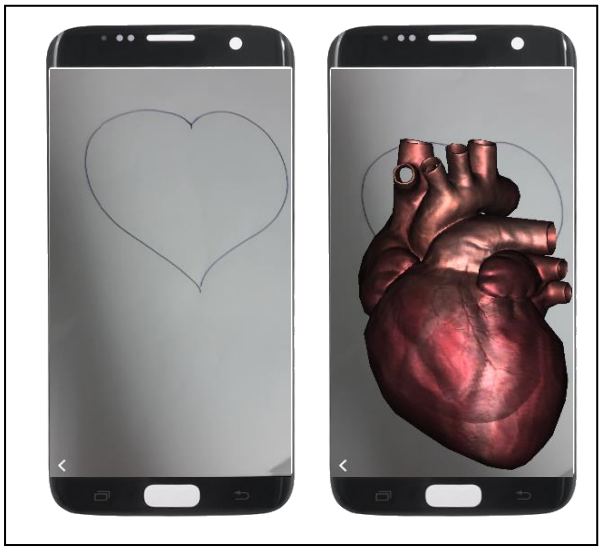

Figure 5. "Draw and Learn" option.

Figure 4. Detailed information about the organ.

To evaluate the effectiveness and usability of the proposed application, it was tested by around 53 students from the Genius Kids Center in Abu Dhabi, UAE. This is an educational center which is dedicated to teach selected excellent students in order to enhance their creativity and problem-solving skills. The first part of the test was on the degree of difficulty in using ARA features on a three-level scale (easy, medium, and difficult). A summary of students' feedback is shown in Figure 6. Among the 53 students, 81% found it easy to use. They expressed their willingness to use it and to take full advantage of it once released and made available for users. While 15% of the students stated that ARA had medium difficulty in using it, 4% found it difficult to use. Moreover, we collected students' feedback on their experience with each individual ARA feature and the results are shown in Figure 6. It turns out from students' responses that the feature "Human body detection" was the most used one, all students used it. Organ drawing recognition and organ visibility control features come in the second and third positions, respectively, in terms of usage. While the feature sharing captured scenes using social media platforms was the least used one.

4. CONCLUSION

In summary, ARA is an Augmented Reality mobile application proposed to help students to learn human anatomy in an interactive manner. Using any smart device, users can visualize human organs as 3D models by pointing the device to a human face. ARA serves as an important tool to improve teaching effectiveness in the field of biology. Users of ARA can be of any age. In addition, ARA has several features like recognizing the drawn organs by users and displaying the corresponding object in 3D, providing information and details about each organ as text or audio, and controlling the visibility of the organs when they are visualized as 3D images. ARA supports two languages Arabic and English. The application was developed taking into consideration several usability features, as it contains simple instructions and user-friendly interfaces for first-time users. It has room for growth since more organs can be added to finally include the entire body with its complete systems. Furthermore, the application has been implemented using Unity and therefore can be running on iOS or Android platforms. ARA does not need any markers/targets in order to visualize the human body. This will assist in saving users' time and money, not to mention helping the environment by reducing paper consumption.

The "Connect to Smartwatch" feature in Figure 2, which will be implemented in the future, enables the user to connect a smartwatch with a heart monitor to ARA in order to get the user's heart rate. Then, the application displays an animated 3D image of a heart along with the heart rate. Also, with this option, the user can learn more about the heart, the maximum heart rate, and how it changes when exercising in an attempt to show how to keep it normal.

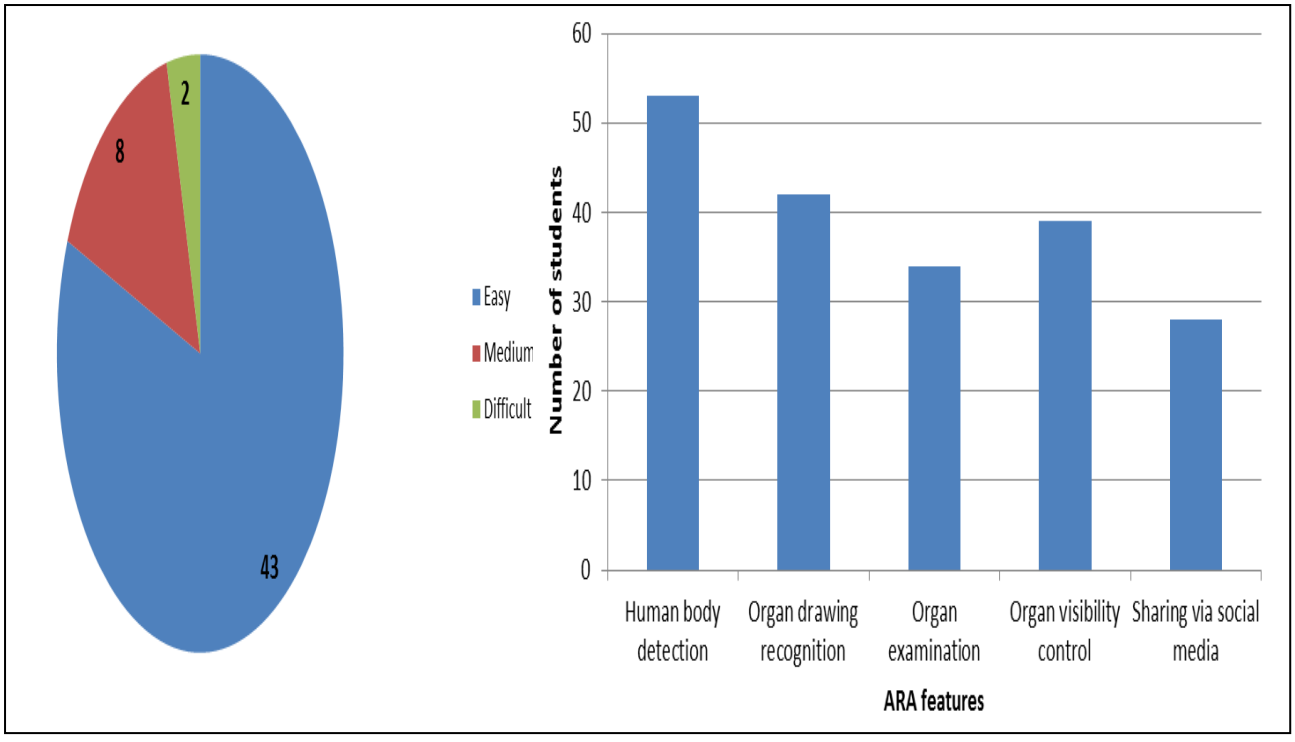

Figure 6. Students' feedback on ARA usability.

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Samia Loucif received her B.Sc. degree in computer science from Constantine University, Algeria, her Master's degree in computer science from Constantine University with the collaboration of University of Glasgow, Scotland, and her Ph.D. degree in computer science from University of Glasgow, UK. Currently, she is Associate Professor in the College of Technological Innovation, Zayed University. She taught in the Department of Software Engineering, ALHOSN University, UAE. Prior to joining ALHOSN University, Dr. Loucif was a Post-doctoral research fellow with the Faculty of Engineering, Moncton University, Canada, and Assistant Professor in UAEU, respectively. Her current research interests include parallel computer architectures, high performance computing, on-chip networks, performance evaluation and mathematical modelling, and cognitive networks. Dr. Loucif has served on technical program committees of over 30 interactional conferences and workshops. She was member of the organizing committees of several international conferences, reviewer of several well-established journals. Dr. Loucif is a member of the IEEE Computer Society and IEEE Communications Society

Murad Al-Rajab earned his PhD from the University of Huddersfield in the United Kingdom, and has more than 13 years of professional, teaching, and research experience. He is an Instructor in the Department of Software Engineering, ALHOSN University, UAE. His primary research interests include machine learning in bioinformatics, mobile learning and applications, smart cities applications, algorithm design and analysis, and computer science education. He has published research papers in multiple refereed journals and international conferences.

Reem Salem received her B.Sc. degree in software engineering from ALHOSN University, UAE. Currently, she is a Teaching Assistant in the Department of Software Engineering, ALHOSN University, UAE. Ms. Reem has published conference papers in international conferences.

Abdullah Hesham, is a BSc graduate in Software Engineering

Doaa Mahely, is a BSc graduate in Software Engineering

Mhd Alaa Ajlouni, is a BSc graduate in Software Engineering