An Augmented Reality based Dynamic Heart Visualization Mobile application for Patients

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Abstract. Augmented reality is increasingly applied in medical education mainly because educators can share knowledge through virtual objects. This research describes the development of a web application, which enhances users' heart disease knowledge with regards to the anatomy of the human heart by means of augmented reality. Evaluation is conducted in two different facets. In the first one, a three-dimensional human heart module is evaluated in the ISO method. In the second, evaluation aims at identifying usability issues by means of the cognitive walkthrough method. Task completion is appreciated in the light of the standard set of cognitive walkthrough questions. Augmented reality content miss-hits are revealed by means of the first evaluation in an effort to enhance the educational utility of the three-dimensional human heart. Cognitive walkthrough provides further improvement points, which may further enhance usability in the next software release. Standardized methodologies are utilized in an effort to improve the application before its wider piloting to proper target populations. Such evaluations are considered important in experiential learning methods aiding online education of anatomy courses.

Keywords: Augmented Reality · Mobile Application · Heart

1 INTRODUCTION

Significant advances in technology in recent times have made many things possible such as creating a virtual world or enhancing real-world objects and sensors through multiple sensory modes. Augmented Reality (AR) is one of the latest technologies that involve the overlay of computer graphics in the real world [1]. Augmented Reality is known to be a virtual object that is generated by a computer through the real environment seen by a mobile phone, tablet, or AR glasses. AR presents a semi-true and false image, which is the combination of real and virtual, some people commonly describe it as the "third eye" [2]. AR has undergone considerable improvement in recent years. Many special techniques and hardware devices were developed, but the important breakthrough came with the spread of smart mobile phones [3]. Mobile devices have become an essential

part of daily life, and mobile applications now act as one of the most important sources of information and entertainment [4].

The use of AR applications in the medical industry has grown over the years. It has proven to be helpful to both doctors and students. Students can be educated about different diseases through AR as well as it can be used for complicated surgeries, helping doctors to perform them with high accuracy [7]. Medical rehabilitation, medical consultation, medical diagnosis, and medical training are also some fields where AR has been introduced.

The human heart is one of the most important organs of the human body. It helps us to pump enough blood to deliver a continuous supply of oxygen and other nutrients to the brain and the other vital organs [8]. As a result, heart disease is one of the most significant causes of mortality in the world today. It is difficult to identify heart disease because of several risk factors. And it is more difficult for hospital personnel to help a patient to understand heart disease [9].

Although an ample amount of research has been done in this field, there is no concrete solution for mass people who don't have any idea of heart or medical terms. As a result, most of them become tense when they hear about these diseases. Therefore, the objectives of this project are: a) to develop an AR-based application to provide the patients a better understanding of their heart diseases, b) to show a cross-sectional animated view for easier understanding. The next section presents a brief overview of related works in the area of cardiovascular diseases. Section III details the obtained research gaps from the literature review. Section IV is the problem statement. The final section concludes the article with the project objective.

2 PROJECT OBJECTIVES

The objectives of our project are as follows:

a. To develop an AR-based mobile application to help the patients understand their heart diseases more clearly. b. To evaluate the usability of the developed system.

3 LITERATURE REVIEW

A background study was done to get a better insight into AR-related applications. Related literature was collected from google scholars, Researchgate, Chi conference, and academia.edu. Articles related to AR and its implementation in various sectors were our focus of study. AR applications, Visualization, Use of AR in the medical sector, Application of AR in heart research are some notable keywords that helped us find those articles.

The swift development of AR has led to significant progress in some recent works, for instance, Gaming has been the leading sector in the use of AR, as a result of which gamers have experienced immense creativity, innovation, and unforgettable experiences. Also in the medical sector, it is proven to be very useful in helping doctors to perform them with high accuracy and in Healthcare Education [7]. Exploratory research was conducted on the application of Virtual Reality (VR) and AR in Medical and Healthcare Education by

Min-Chai Hsieh [2]. In this study, various works on VR and AR were discussed. The use of AR in autism treatment, limb pain treatment, and anatomy teaching was specifically highlighted here as they are the most common use of AR in recent years.

Many works have been done before using AR in the medical sector. A study by Michael H Kurniawan [10] shows that AR 3D models were used in learning human anatomy. For creating the AR application, a 3 steps job was done: i) Camera vision ii) Capture and Tracking, and iii) Identification. The AR engine that was used is the AndAR with the Unity and Vuforia AR frameworks that are made for the mobile platform. Student learning is done by pointing the camera at the marker device which is already determined. Users can interact by touching the screen or moving the device to see 3D models that appear from different angles.

Research conducted by Marzieh Dehghani et al. [11] presented a comparative study on AR-based infographics to enhance the learning of the heart and cardiac cycle in biology class. In this study the effect of AR and infographics on student learning in biology courses on the topic of circulation in the body (heart section) was examined. The output format which is the AR and infographics together outperform the only infographics and only AR group. Also, a different study [12] described the development of a web application, which enhances the user's medical knowledge with regards to the anatomy of the human heart by means of augmented reality. Also to evaluate this AR-based web application, two methods were proposed. In the first one, the feasibility of a three-dimensional human heart module was evaluated by one investigator under the supervision of an expert. The second evaluation was aimed at identifying usability issues by using a set of cognitive walkthrough questions over some medical students. A paper also proposed an AR supported mobile application for diagnosing heart diseases by heart sound analysis [13]. The discussed model analyzes signals instantly and gives rapid feedback over the interface supported by virtual or mixed reality objects combining both real and virtual worlds in a common ground. This paper also evaluated its performance in the context of different perspectives. Another study [14] discussed the principles required to design AR systems based on evaluating it's usability. It contributed to fulfilling our objective to work for the masses.

Analyzing the recent works, it is clearly seen that most of the AR-based applications were made for educational purposes. Few works have been done to make it more interactive by adding a data description [3] feature. Some studies were also done to evaluate the usability and importance of AR more than others. There is not much work describing heart diseases when normal people need more education on the diseases rather than the knowledge of anatomy. Also, most of the work includes 3D images but very little work has been done to show the cross-section of a heart in the form of animation.

A preliminary study of the existing studies clearly reflects the use of AR applications for educational purposes for the students but a lack of concern in patients' understanding of the medical sector. Most people don't have a clear knowledge about what heart disease is and how it is affecting them. Human anatomy knowledge may be important for the students but not necessarily for the patients dealing with heart diseases. Also, patients need an easier way to learn about their diseases rather than critical medical words and complex anatomy systems. Much better interaction between patients and the doctor can

be obtained by the use of AR that is dedicated to learning about diseases. Hence, there exist significant gaps in research that need to be addressed.

4 METHODOLOGICAL OVERVIEW

There is an insignificant need of AR for learning about the objects that need to be visualized. Effective planning is needed to achieve that goal and before beginning the development process, a proper problem statement is needed. Agile methodology is considered to be best in this case as design of the system should be user-friendly and constant user feedback is needed. It is very helpful when requirements change during the development process. This is an adaptive method to take control of the working process anytime. Design, development and implementation all three phases run in parallel as feedback between these phases are necessary.

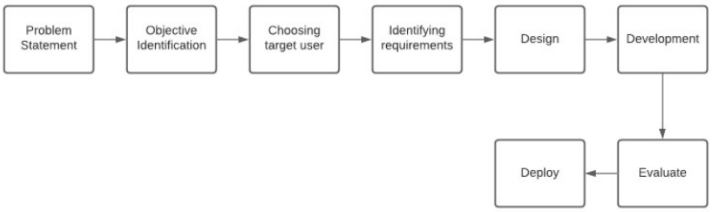


Fig. 1: Flowchart of the methodology

A proper literature review can lead to having a better idea about the problem statement and objective of the project. A target user is needed and their requirements must be fulfilled to make the project successful. Proper and efficient design and development are the key to make the project work successfully. And lastly an evaluation is done to check how effective and efficient the system is and if the users are satisfied or not.

4.1 Design

The system flowchart was created during the design process. The design process entails creating a conceptual model for the mobile AR application, which includes the AR technology that will be utilized, the teaching and learning approach that will be employed, and the components that will be used in this mobile AR application. As per the figure,, the user will first launch the app from here he can touch “Play” to start the AR camera. After that, the user will point the camera at the image at the selected heart picture. If the image target is detected as a valid target, the corresponding AR scenario will be displayed on the screen with its comprehensive information. Furthermore, users can interact with the object. Then the user will have three buttons (Rotation, Scaling, Back). Rotation will rotate the heart model until the button is pressed again. Scaling button will make the 3D model bigger in every aspect. And the Back button will reshape the size to its original size.

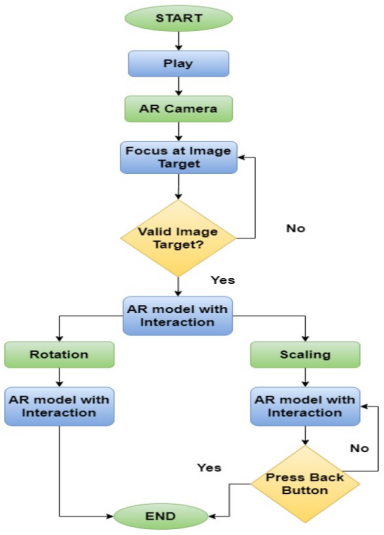


Fig. 2: System Flowchart

4.2 Development

1 Installing Unity Unity is a platform to build real-time 2D, 3D projects for games, animation, augmented reality, architecture, engineering etc. The latest version "Unity 2019.4 LTS" was installed with necessary packages e.g. Visual Studio 2019, Android SDK etc. A free license was claimed to use all functions.

2 Installing Vuforia Vuforia is a cross-platform Augmented Reality (AR) and Mixed Reality (MR) application development platform, with robust tracking and performance on a variety of hardware (including mobile devices and mixed reality Head-Mounted Displays (HMD). Unity's integration of Vuforia allows us to create vision apps using a drag-and-drop authoring workflow. A package was imported into Unity to use Vuforia. After installing, an automatically generated license key is used to access all the packages of Vuforia. Then a database was created to save the Image Target and linked with the project. There is a rating system that determines the quality of the image target. All images used in this application are above four stars.

3 Image Target Configuration The AR camera (provided by Vuforia) is aligned as necessary and the image target or image targets are assigned into the environment which serves as the reference point for the AR scenario. Targeted images are recognized by contrasting extracted natural features from the camera image against the uploaded target resource database.

4 Object Generation The main target is to make a proper scenario on top of a specific image target. To create this scenario, different Unity packages and assets (image, material, color etc) and low poly objects (various geometrical shapes) are used.

5 Interaction Unity provides various UI elements (Button, AR Button) for interaction. Buttons can be placed on the canvas which is visible like other buttons while AR buttons

are used to find out the hidden information of the object. Three buttons have been implemented so that users can interact with the AR scenario.

5 Evaluation

5.1 Method 1: ISO

ISO method involves identifying the activities for which standards are used, and then investigating how these activities, supported by the use of standards, contribute to the creation of value for the company. We gathered 10 participants to do this evaluation and tested the models through their observations according to their response time needed,number of attempts needed,task completion time,task completion time needed,etc. Task 01: Rotate Heart Model Task 02: Scale Heart Model

The profile of the 10 participants are given below: Samantha Momtahina Haque -22 yrs Shahanaj Begum-45yrs Tahsin Fairuz-27 yrs Shahir Hossain- 23 yrs Salma Begum-30 yrs Arifa Rahman - 28 yrs Mizanur Rahman- 32 yrs Rabeya Begum -34 yrs Lutfor Rahman - 37 yrs Masud Reza Kabir - 42 yrs

Evaluation Matrices	Data Type	Task	Average	Min	Max
Effectiveness	Response Time	T1	20.08 s	12 s	31.3 s
		T2	21.41 s	12.4 s	35.3
	Number of Attempts	T1	1.4	1	3
		T2	1.3	1	2
Efficiency	Task Completion Time	T1	26.56 s	17 s	50 s
		T2	27.7 s	17.3 s	39.3 s
	No. of time asked for assistance	T1	0.2	0	1
		T2	0.2	0	1
Satisfaction	Overall satisfaction	-	4/5	3	5
	Easy to use	-	.8/1	0	1
	Easy to learn	-	.9/1	0	1
	Future use	-	.8/1	0	1
	Recommendation	-	-	-	

Fig. 3: Table 1: Result

Indicator 1: Effectiveness

Effectiveness is the capability of producing a desired result or the ability to produce desired output. The assessment metrics for evaluating the system are Response time and Number of attempts to complete the task which are measurable, relevant and responsive. The parameters for measuring are response time and number of attempts to complete the task.

Response Time of the AR model: When a heart image is placed in front of the AR camera, the time it takes to focus the image and show the virtual 3D heart model is considered as response time here. The effectiveness has been evaluated with an association of 10 participants including students. The average Response time for task 1 was 20.08 and for task 2 was 21.41 which seems to be larger than the expected response time. It is because the user was using it for the first time and it took a little bit more time than usual but the task was completed successfully in most of the cases. The highest time taken to complete task 1 is 31.3 s and lowest is 12 s.

Number of Attempts to complete the task: The average number of attempts to do the task is 1.4 for task 1 and 13 for task 2. Here 7 out of 10 people could complete the tasks on their first try and It didn't take more than 3 attempts to complete the tasks.

Indicator 2: Efficiency The parameters used for measuring efficiency are task completion time and number of times for asking help.

Task Completion Time: The average task completion time for task 1 is 26.56 s with minimal time of 17 s and highest 50 s. It is more than the expected time which is 15 seconds. As it was used by the users for the first time, it took more time than usual but the task was completed successfully. Average task completion time was 27.7 second and minimum time was 17.3 s and maximum time was 39.3 seconds. All the users could complete their task properly and 3 out of 10 users had to try for a second time.

No. of time asked for assistance: Only 2 out of 10 people asked for help in both of the tasks. The average number of people asking for help is 0.2. 8 out of 10 people could finish the task without taking help. Most frequently asked help was for task 1 as they could not hold the picture properly and it was not focused and the model was not seen.

INDICATOR 3: Satisfaction A google form with a set of questions was given to the participants to measure their satisfaction level. The form and its output is given in the appendix. Point system was used to measure satisfaction.

5.2 Method 2: Cognitive Walkthrough

10 people evaluated this system and introduced the problems that users may face.

Questions: Q1. Is the effect of the current action the same as the user goal? Q2. Is there a control for action visible? Q3. Will the user recognize the action as the correct one? Q4. Will users understand feedback?

Task 01: Rotate Heart Model

a.Place an image in front of the AR camera b.Press the "Rotation" button to start rotation. c.Press the "Rotation" button again to stop rotation.

Task 02: Scale the Heart model

a. Place an image in front of the AR camera b. Press the "Scale" button to start scaling. c. Press the "Back" button to return to its original shape.

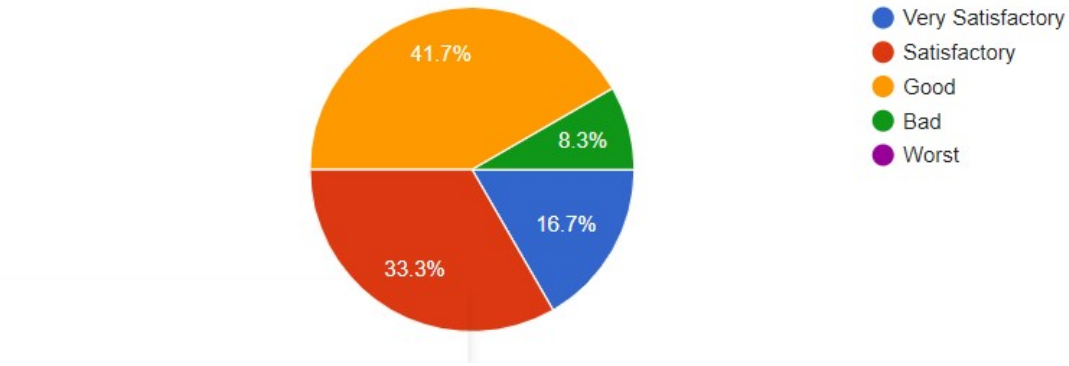
6 Appendix

Task 01	Place an image in front of the AR camera	Press the “Rotation” button to start rotation	Press the “Rotation” button again to stop rotation
Q1	Yes(100%)	Yes(100%)	Yes(100%)
Q2	Yes(100%)	Yes(100%)	Yes(100%)
Q3	Yes(100%)	Yes(100%)	Yes(10%) No(90%) (A separate button is needed to stop the rotation)
Q4	Yes(40%) No(60%) (An acknowledgment option is needed)	Yes(100%)	Yes(40%) No(60%) (Feedback text is needed)

Task 02	Place an image in front of the AR camera	Press the “Scale” button to start scaling	Press the “Back” button to return in its original shape
Q1	Yes(100%)	Yes(100%)	Yes(100%)
Q2	Yes(100%)	Yes(100%)	Yes(100%)
Q3	Yes(100%)	Yes(30%) No(70%) (separate button needed for “scaling in” and “scaling out”)	Yes(30%) No(70%) (a separate button is needed to stop the rotation)
Q4	Yes(40%) No(60%) (An acknowledgment option is needed)	No(feedback text is needed)	Yes(40%) No(60%) No(feedback text is needed)

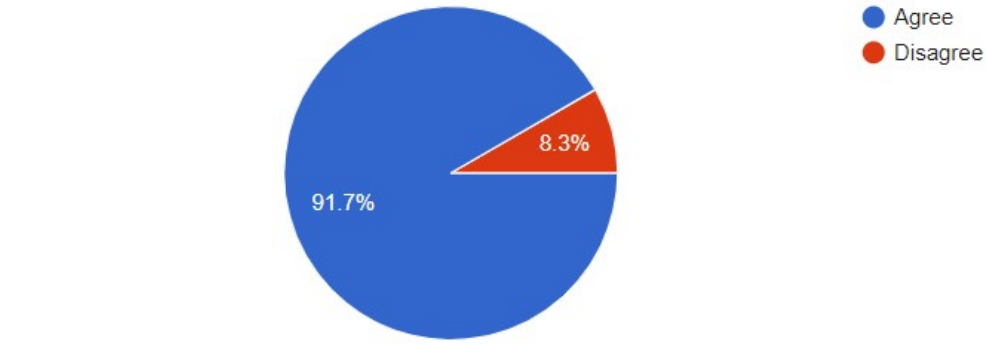
1. Is the overall project satisfiable to the user?

12 responses



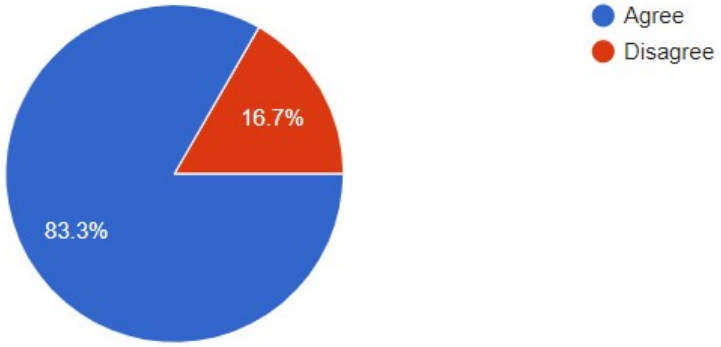
2. Is the application easy to use?

12 responses



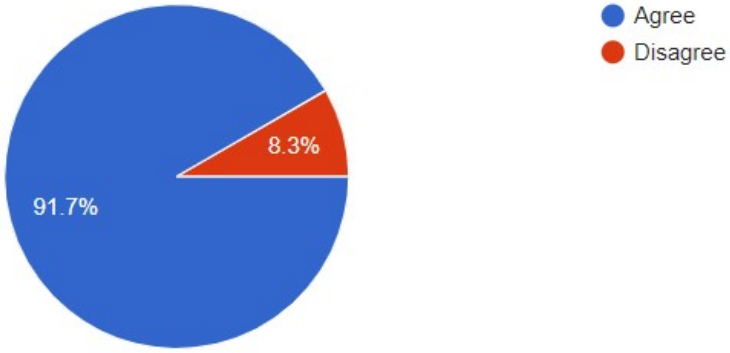
3. Is the application easy to learn?

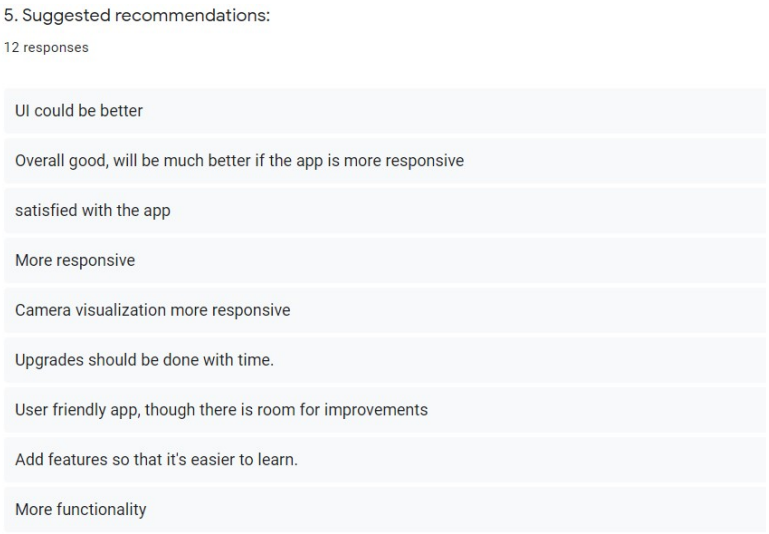
12 responses



4. Is the application expected for future use?

12 responses





7 CONCLUSION

Considering all of the above, it is understood that the design and the implementation of this application using AR and incorporating the three-dimensional model of the heart of the human body, is relatively a new way for the visualization of illiterate people and it is a difficult process altogether. However, what the current piece of research shows is that it is feasible and doable. Our long-term aim is to develop different visualizations of various body parts,thereby enhancing self directed learning, life-long learning and distance education. The latter are all contemporary demands of medical education in a slowly but surely changing landscape equipped with niche technologies.

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