Medical Learning Murmurs Simulation with Mobile Audible Augmented Reality

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Abstract

This paper presents the development of a mobile Augmented Reality (AR) heart rate murmur simulator that can be used for clinical teaching for medical trainees. Traditional medical training often requires the trainees to have hands on experience with real patients. However, it is not often possible to find certain types of heart murmurs with patients available for training. To overcome this limitation, we have developed a wearable clothing system using mobile audible AR that provides heart murmur simulation for facilitating medical learning experience. In this paper we describe the proposed system, a user evaluation study and directions for future work.

Keywords: Human computer interaction, Augmented Reality.
CCS Concepts: • Human-centered computing~Mixed / Augmented Reality

1 Introduction

Augmented Reality (AR) combines the user's view of virtual cues with the real-world environment. This paper describes a mobile audible AR application for murmur simulation in medical learning. The medical field is continuously exploring new technology to improve the learning experience. Recent technological advances have allowed AR experience to be possible on palm-sized or eye-wear personal mobile devices. These devices have also been used to provide a range of different medical AR training experiences.

Hearing and recognizing heart murmurs is part of the fundamental training for medical students. Heart murmurs are the sounds of breathing and flow of blood into the heart, and may reflect disease pathologically. This project focuses on the development of a low cost and low footprint mobile audible AR heart murmur simulation system for medical trainees.

The system uses a mobile phone paired with an electronic stethoscope and a cloth with imprinted AR tracking markers. Using this heart murmurs can be heard and an AR visualization of the audio data can be seen. This AR system allows trainees to experience murmur simulation on a real human body instead of using static laboratory equipment.

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2 Background

Our research builds on previous work on medical training, AR for medical education and cloth based AR tracking. The current state of the art for heart murmur training is to use physical simulators. Figure 1, shows typical medical grade murmur simulators, which are capable of providing a physical heartbeat and realistic audio. However, these hardware are extremely costly and can only be institutionally owned. It is also common that medical students receive training on recognizing murmurs under the supervision of an instructor using real patients with different murmur patterns.

Figure 1: *Sam and Harvey, medical grade laboratory simulator.*

AR has previously been used for a variety of different medical applications, such as for virtual reality diagnostic imaging and AR for patient treatment visualization (Sielhorst et al., 2008; King et al., 2016). AR has also been used for medical education in areas such as showing virtual CT data onto the body of a trainee and viewing human anatomy with AR in Biology class (Zhu et al., 2014; Bacca et al., 2014; Kamphuis et al., 2014). Figure 2 shows a typical mobile AR experience overlaying virtual anatomical information over a real person.

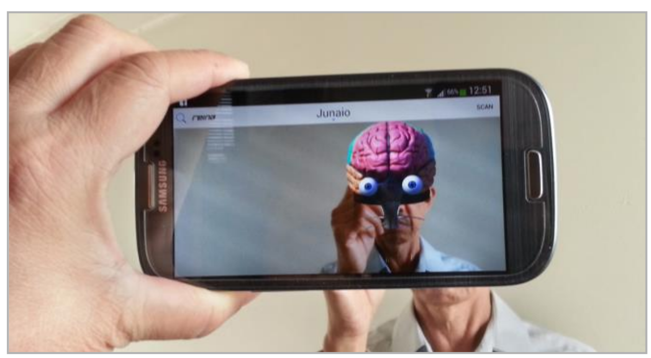

Figure 2: *AR experience with visual graphical visual content.*

There has been a variety of previous research on using cloth for AR tracking (Trauman, 2015; Hilsmann and Eisert, 2009; Cushen and Nixon, 2012; Bradley et al., 2009). This research has allowed AR content to be shown on stretchable surfaces or the clothes of a moving person. In our research, we are developing a mobile AR application that overlays visual and audio cues on clothing for convenient medical training.

3 Method and Apparatus

In this section, we present an early prototype of a wearable clothing system that works with audible AR and provides murmur training. Figure 3 shows the workflow of the system. The system requires two people, a user wearing the cloth imprinted with a number of small AR markers and another user using the mobile audible AR application with an electronic stethoscope. A customized group of small sized markers were imprinted on clothing that has pre-embedded murmur audio information. AR tracking is performed from the markers when video from the mobile device is sent to a tracking server for processing. Mobile audible AR users can hear different types of murmurs when pointing the application at different areas of the cloth around the heart region. The audio information was sourced from medical grade provider and includes heartbeat, breathing and chest murmur patterns. The printed markers on the cloth enabled the stethoscope user to experience different types of medical grade pre-sampled murmurs, especially those with identifiable symptoms that may require medical attention.

The embedded medical data representation for AR can also include optional three-dimensional (3D) virtual models, static images, and minor animations to compliment the murmur audio. For instance, a simplified heart anatomy or a visual diagram of an augmented set of lungs.

To create the AR application, specific areas of the human heart were studied and considered for audible AR simulation, as shown in figure 4. Table 1, illustrates a set of AR murmurs that are significant for medical learning processes; most of these murmurs represent common symptoms for diagnosis. Several murmurs can occur in multiple areas of the heart simultaneously, so it is crucial for medical trainees to learn how to accurately identify different murmurs.

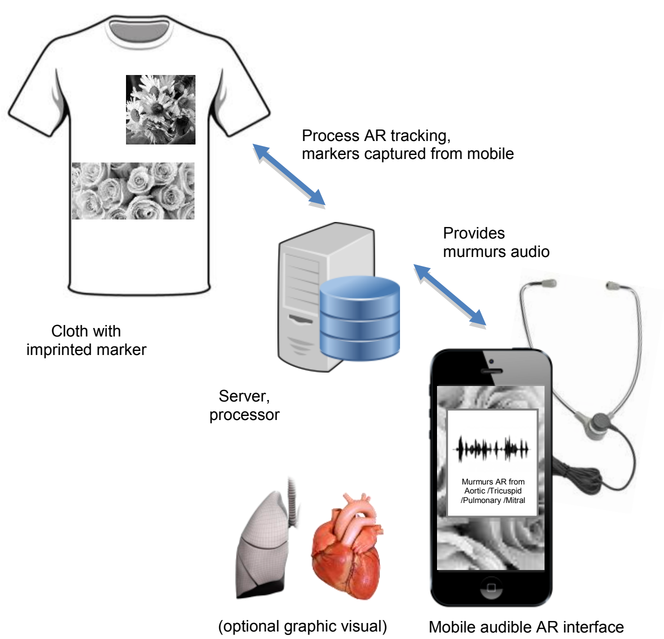

Figure 3: *Proposed system, cloth works with mobile audible AR.*

The prototype illustration (figure 4) is surrounded with group of markers pre-embedded with murmurs audio. A 2D Image-based AR tracking method was used to support the audible AR experience, using the server-based Layar [Layar, 2016] tracking library. The prototype system is also transferable to other platforms which supports image-based tracking mechanism.

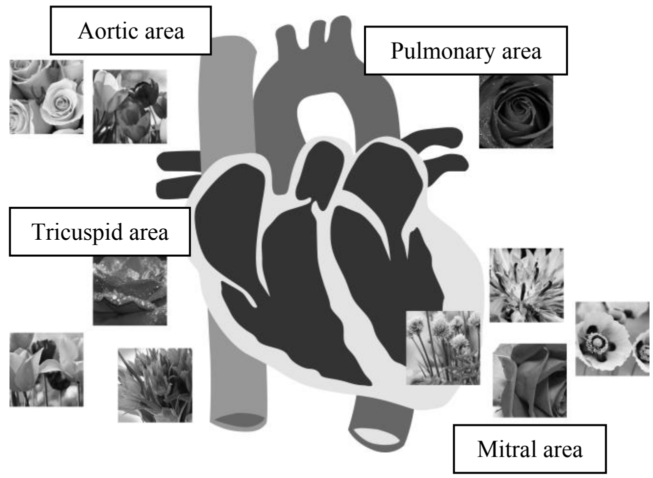

Figure 4: *areas of heart representation with AR murmurs.*

Table 1: possible detection of murmurs

Areas /position	Possible murmurs detection
Aortic area	Aortic valvular stenosis
	Early diastolic aortic regurgitation
Pulmonary area	Pulmonic valvular stenosis
Mitral area	Acute mitral regurgitation
	Mitral stenosis
Tricuspid area	Tricuspid regurgitation
	Tricuspid stenosis
	Pericardial friction rub
	Early diastolic aortic regurgitation

Figure 5, shows the different murmur digital wave patterns. Medical trainees need to acquire the ability to identify different types of murmurs for diagnostic purposes. For example, the audio for Acute Mitral Regurgitation Insufficiency murmur would have high pitch sound and Mitral Stenosis Murmur Normal Sinus Rhythm would have the lowest pitch audio quality. With the AR murmur simulator, digitized audio content can be assigned or customized to suit various medical simulations.

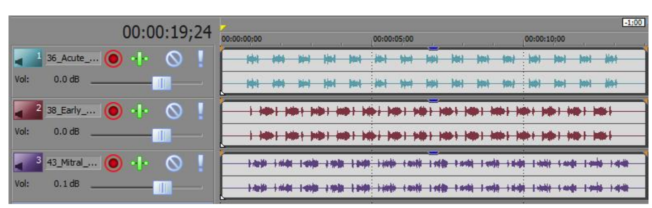

Figure 5: *Different murmur digital wave patterns.*

The audio played back is intended to be capable of providing an authentic experience on an AL-60 electronic stethoscope (AL-60, 2016). The AL-60 electronic stethoscope simulates the audio experience of acoustic stethoscopes used by most medical professionals. A stereo earpiece can be used as an alternative and lower-cost configuration, however the performance may vary depending on different manufacturer's hardware.

The prototype system was developed on Android and the Samsung N910C and N920I tablets that provide reasonably stable AR tracking on the tracking cloth. Figure 6 shows the interface with visual cue of mobile audible AR when a murmur is tracked and heard by the medical student. This low-cost workflow and AR user configuration uses mobile tablets and devices that are widely available. Therefore, it allows AR murmur training to be provided in a wide variety of educational settings.

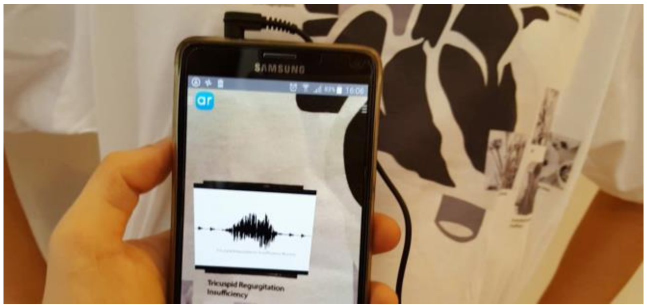

Figure 6: *Mobile audible AR Interface.*

4 User Study

A pilot study was conducted to evaluate our prototype. A set of 15 medical students were involved in the test, 9 female, and 6 male ranging in age between 20 to 23 years old *(SD = 1.21)*. The focus of the user study was to measure the usefulness of the prototype. Participants were requested to configure the electronic stethoscope with a mobile phone, and run the prototype application twice, once with the visual annotation aid, and once without, listening for audible murmurs each time.

During the trials, each participant was asked to put on a T-shirt imprinted with AR markers and become the subject model for the next participant (see figure 7). Usually the subject model was allowed to sit or lay down in a clinical environment to mimic a mock patient visit session. The experiment conductor explained the processes and provided a complete demonstration. Each participant completed the tasks in about 10 minutes. We use a within-subjects experimental design, where each participant experiences both of the AR visual display conditions.

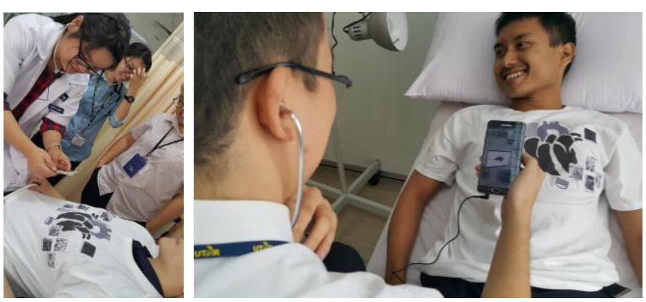

Figure 7: *Participants testing the prototype system.*

Before running the trials we got participant feedback on how easy it was to configure the stethoscope with mobile device with the AR application (S1). This was done by collecting qualitative feedback in response to the questions shown in table 2. Answers where captured on a Likert scale of 1 to 7 in which 1 is "strongly disagree" and 7 is "strongly agree".

After each trial we collected quantitative feedback about the prototype system from the participants using the same questions and Likert scale. Condition C1 was using the application with visual feedback, and C2 was without any visual aid. Our key interest was to understand the perceived ease-of-use and usefulness of the prototype by the participants, and how they describe their experience with our system.

After participants completed the two trials they put on the T-shirt imprinted with AR markers and become the subject model for the next participant (S2). After doing this, they were also asked how easy it was to use the tracking shirt using the same questions in Table 2 and Likert scale responses.

Table 2: Survey questions

Q1	I found it easy to use
Q2	I found it natural to use
Q3	I found it reliable
Q4	I found it physically challenging
Q5	I found it mentally challenging
Q6	I found it useful

Figure 8 shows the average results of the C1 and C2 survey questions. A Wilcoxon Signed Rank test was used to analyze the results to check for significant difference between the results of the using visual (C1) and non-visual interfaces (C2). For Q1, using a one-tailed test we found that participants felt that the visual aid made the interface significantly easier to use than the interface with non-visual cues, $Z = -1.82$, $p = 0.03$. For Q2, finding the interface natural to use, there was a near significant difference between C1 and C2, with $Z = -1.60$, $p = 0.06$. There was no difference between conditions it terms of how reliable participants felt each condition was (Q3), $Z = -0.17$, $p = 0.44$. In terms of the physical challenge, participants felt that the non-visual condition (C2) was significantly more physically challenging (Q4) than the visual condition (C1), $Z = -2.191$, $p = 0.014$. Similarly, C2 was felt to be more mentally challenging (Q5) than C1, $Z = -2.31$, $p = 0.01$. Finally, C1 was viewed as being more useful (Q6) than C2, $Z = -1.87$, $p = 0.03$. Overall, these results show that the interface with visual aids was better than the not using any visual aids.

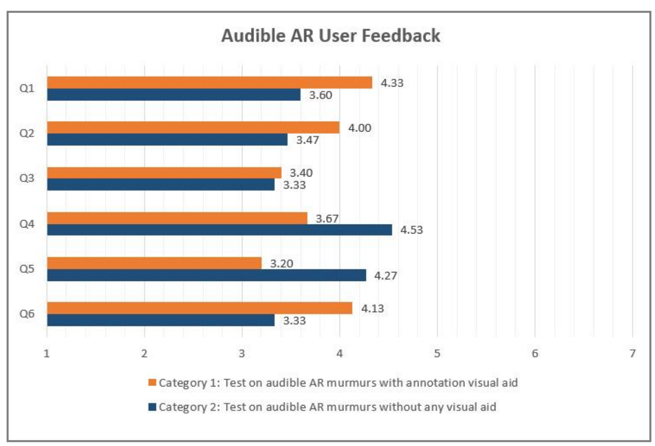

Figure 8: *average results of C1 and C2 survey question.*

Figure 9 shows the average results of S1 and S2 survey questions. As can be seen from the graph, users found the configuration of the stethoscope (S1) relatively easy (Q1) and useful (Q6), but it was also rated above average in terms of physical (Q4) and mental challenge (Q5). Similarly from S2 users found it easy to wear the tracking T-shirt (Q1) and that it was useful (Q6), but it was an above average physical challenge to use (Q4).

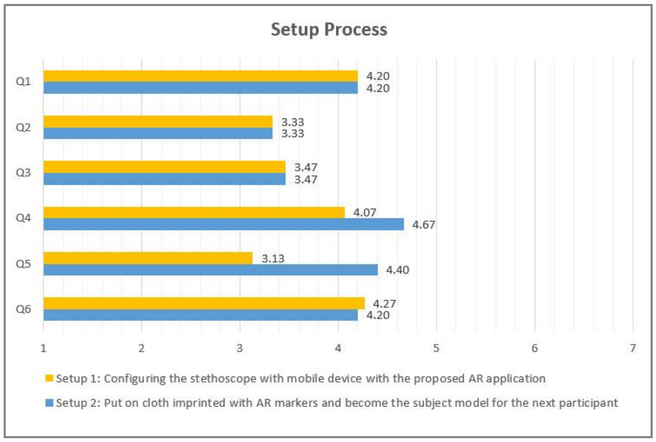

Figure 9: *Average results of S1 and S2 survey question.*

In addition to the survey, we asked participants for their comments on the system usability. Users said they ".. *like the idea of it being portable.. ", "The idea is pretty good, affordable and portable",* and *"It is usually challenging to remember all murmurs and I hope this new app can help me about it"*. However users also felt that *".. it is quite difficult to use..", "Markers are hard to detect under different lighting",* and users felt *".. quite exposed and uneasy wearing the shirt and scanned by others".*

During each trial, we observed that the strength of the internet connection affected the stability of AR tracking. All of participants were new to AR and some of them were not sure how to operate it consistently. Participants also provided the following ideas for improvements:
i. The tracking T-shirts could be made available in different sizes.
ii. The tracking shirt could put on a mannequin for working alone.
iii. AR markers can be printed on clip-on badges to avoid creases, this could be used on mock patients for examination.

5 Discussion

Most users felt that having the interface with visual cues was more useful as it provides clear visual feedback for an AR murmur audio is being tracked. It can be confusing when the system is used without visual feedback, as users could not be sure if an AR audio cue will be played. If there is no audio feedback users move on to the next marker to search for other murmurs to be heard, as a result users were moving the mobile application around without getting much murmurs being experienced.

The use of AR and cloth tracking simulates the physical experience of holding a digital stethoscope to check on a heart murmur. In addition, audible AR also allows the users to be able to hear uncommon heart murmurs that rarely occur during a diagnosis of a real patient. However, there are still various obstacles and design issues that need to be solved. For example, creases in the tracing cloth can result in potential inaccuracy of image-based tracking, or failure of the tracking altogether.

6 Conclusions

This paper presents a medical education system teaching about heart murmurs using mobile audible Augmented Reality. The system runs on existing mobile hardware using cloth based tracking, and so is low cost and can be easily used in a wide variety of setting. Users felt that the system was natural and easy to use, and the use of additional visual cues made the system much more useful. Participants also made several good suggestions for improving the system.

In the future, we would like to further improve our efforts in designing the mobile audible AR for different murmurs scenarios and explore the suitability of the proposed system being tested in medical examination. We plan to conduct more extensive evaluation studies to measure the educational outcomes of using the system. Finally, we will explore ways to improve the tracking accuracy such as using hybrid approaches that combine multiple AR tracking methods.

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