Techniques for Automatic Heart Sound Analysis

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ABSTRACT
Valvular heart disease (VHD) is a common global health problem [6]. Cardiac auscultation is the most effective early diagnosis strategy for detecting VHD. Therefore, techniques to improve traditional cardiac auscultation can have a dramatic effect on the health of patients worldwide. One such proposal for improving the cardiac auscultation process is with the aid of automatic heart sound analysis (AHSA). In this literature review we identify usability methodologies used in medical systems, as well as digital signal processes used to analyze heart sounds. The purpose is to be able to identify methodologies that can help increase the accuracy of auscultation data capture, for an online corpus of heart sounds.

INTRODUCTION
Cardiopulmonary auscultation is one of the most common patient evaluation techniques practiced by medical professionals. They provide valuable diagnostic and prognostic patient information. An online corpus of heart sounds could provide a valuable resource that medical practitioners can use for training and analysis. The system can also be useful for finding and detecting pathological conditions. The usability techniques to use on such a system is vital to understand, as an easier to use system will lower the risk of incorrect data being obtained. We will therefore explore areas that will help limit the error report rate of this system, examining software and hardware used across the field. We will also briefly explore common analysis techniques used on the data obtained from auscultations.

CARDIAC AUSCULTATION
Cardiac auscultation is the process of analysis a patient’s heart through the use of a stethoscope. This is usually performed by a trained physician. The physician listens to the sound of the atroventricular and semilunar valves. Blood flow pushing against these valves when they close create an acoustic pressure wave, commonly known as the heartbeat. It is this event that AHSA wishes to detect.

There are two part to a cardiac auscultation: the capture of the heart sound and analysis of the captured data. Almost all literature on heart sound analysis used an electronic stethoscope [4] for heart sound capture from an auscultation. Analysis on the heart sound is used to aid diagnosis of VHD.

Cardiac cycles of a heart sound
A healthy heartbeat causes two distinct sounds: the first is caused by the relaxation of the heart muscle. The closing the semilunar valves stops blood flowing back from the aortic and pulmonary valve producing the first noise known as S1. The second sound, is caused by the closing of the atroventricular valves, blood flowing from the atria to the ventricle collides with the valves causing the second distinct noise of the heartbeat known as S2. The period between S1 and S2 is known as systole, while the period after S2 is known as diastole.

SIGNAL PROCESSING TECHNIQUES
Rakovic, P., et al. [5] outlines time-frequency signal processing approaches. They test the application of the Short Time Fourier Transform (STFT), which is obtained by applying a Fourier Transform to segments of the captured signal at a time. It was found that STFT can be used to effectively detect the frequency of S1 and S2, however further analysis to detect murmurs remain problematic with STFT due to its restriction on resolution.

Wavelet Transforms were found to be more effective at detecting heart murmurs [7]. Wavelet Transforms utilize a higher dimension is order to be able to make a distinction between the amplitude change in systole. The turbulent flow of blood that the Wavelet Transforms detects can see through the noise and accurately identify a murmur during systole and diastole.

USING USABILITY HEURISTICS TO EVALUATE PATIENT SAFETY OF MEDICAL DEVICES
(Johnson, et al. 2003) proposed to modify the traditional heuristic evaluation method of assessing software usability and apply it to medical devices. A small study was constructed that included 4 graduate students. Two of the graduates were from the School of Health Information Sciences at UT Houston, with the rest of the participants being from the Department of Psychology at Rice University. The student’s task was to perform a heuristic evaluation on two 1-channel infusion pumps. The researchers had 3 objectives from this study. First, they wanted to evaluate whether the modified heuristics could be applied to a medical device. Second, they wanted to identify whether the heuristic evaluation on an infusion pump could detect usability issues, which could result in medical errors. Finally, they wanted to see whether the
modified heuristic could be used effectively to compare two different infusion pumps.

(Johnson, et al. 2003), found that the students identified more usability errors and risks in Pump 1 compared to Pump 2. This accurately reflected the independent analysis undertaken by the first author, who is an expert in heuristic evaluations. The researchers concluded that the modified heuristic evaluation they proposed, could be used to identify a great proportion of the main usability issues in the medical devices.

Usability issues have a clear link to the data error report rate of a system [1]. The results of this paper can be used to justify the use of a modified heuristic evaluation to minimize the risk of error report rate. From the physical recording taken by the digital stethoscope to the evaluation of the data entry front end.

Cardiopulmonary Auscultation Simulation Teaching System [2]
(Wang Lu and Shuli Liang, 2011), proposed a cardiopulmonary simulation teaching system. It was hypothesized that a cardiopulmonary auscultation simulator could improve the learning rate of medical students compared to those who went through the traditional classroom method. Their system incorporates a simulation patient, electronic stethoscope, remote control, and a PC receiver with a corresponding software package – illustrated in Figure 1.

Figure 1. Main interface of the Cardiopulmonary Auscultation Teaching Simulator. Sourced from (Wang Lu and Shuli Liang, 2011) [1]

The system used the electronic stethoscope to simulate heart and lung sounds. There are 27 RFID tags imbedded within the simulation patient on the front and back. Heart and lung sound samples can be associated with each RFID tag to create an accurate noise based on the position of the electronic stethoscope. A set of conditions can be programmed into the device that can be switched at the control of the user. The software shows the current position of the stethoscope and the associated characteristics, such as waveform and detected diseases.

Experimental results showed that the accuracy rate of detection for the system was 98%, taken from a hospital sample. A study was done on a sample of 20 medical students. The students completed an auscultation test before and after going through a basic simulation teaching lesson. The results found that students performed better after being exposed to the simulator. They then concluded that a cardiopulmonary auscultation simulator was feasible for teaching medical students.

This study is relevant as it showcased the effectiveness of simulation to improve learning in cardiopulmonary auscultation, thus decrease the error report rate. Systems such as this can clearly benefit from being linked to an online corpus of heart sounds. Increasing the accuracy of the simulator by utilizing data produced from an online corpus of heart sounds. Similar systems can also be used to train medical practitioners in order to learn how to create reliable entries for an open database.

Detection and characterization of usability problems in structured data entry interfaces in dentistry [3]
(Walji, et al. 2013) evaluated the usability of a common electronic health record (EHR) database, used by dentists. The EHR interface allowed dentists to input diagnostic terms, using different input methods, to create an entry for a patient. The study focused on the usability of structured data entry. A TURF unified framework is proposed to measure complexity of a structured data entry.

(Walji, et al. 2013), commenced fieldwork at two clinical sites in order to determine what dentists were currently able to accomplish using the EHR system in place. Participants were taken from the Harvard School of Dental Medicine (HSDM) and the University of California, San Francisco (UCSF). They found that 22.41% of users were able to complete a simple diagnosis while no participants were able to complete a complex one. Through the user study the authors were able to identify 24 high-level usability issues.

The paper found that a combination of different usability evaluations resulted in more usability issues being found in structured data entry, along with an update to terminology increased the clarity of the study for participants.

This study highlighted the importance of utilizing a broad sample size of participants and also a mix of usability evaluation strategies. Particularly, in structured data entry aspects of the heart sound online corpus, need to be evaluated closely, such as categorization and missing expected functions.

SUMMARY
In this paper we have looked at usability methodologies that can aid in creating a robust evaluation of a heart sound
online corpus. We have also taken a brief look at digital signal processing for analyzing heart sounds. It is clear that more research will be necessary to provide accurate aids for cardiac auscultations.

REFERENCES


