Development and Testing of Student Auscultation Trainer Software

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***Abstract*—Student Auscultation Trainers are commonly used in medical classrooms to enhance students' auscultation skills through practical learning. However, many of these trainers are costly and pose challenges for student interaction. To address this, we have developed a user-friendly, interactive software Graphical User Interface (GUI) that seamlessly integrates wirelessly with any auscultation trainer manikin or stethoscope. Our software offers a wide array of features, including nearly 12 different heart sounds, 8 lung sounds, and 1 bowel sound across 10 distinct auscultation sites. Additionally, it provides visual aids such as a phonocardiogram and graphical representations of specific auscultation sites for each selected condition, facilitating intuitive learning for students.**

***Index Terms*—Auscultation training, Embedded Systems, Graphical User Interface, MQTT, Internet of Things**

I. INTRODUCTION

A student auscultation trainer is a specialized medical education tool used to teach students how to listen to and interpret sounds produced by the body, typically using a stethoscope. These trainers are often designed to simulate various physiological conditions such as heart murmurs, lung sounds, and bowel sounds. They provide a realistic learning experience for students to develop their skills in auscultation, which is the process of listening to internal sounds of the body for diagnostic purposes.

The trainer typically consists of an anatomically correct manikin of human torso along with a stethoscope and an interactive, user-friendly software or Graphical User Interface (GUI). The manikin or torso serves as the physical model of the human body and is designed to replicate the anatomical structures relevant to auscultation, such as the chest for heart and lung sounds or the abdomen for bowel sounds. The manikin is often made of realistic materials to provide a life-like experience for students. On the other hand, the stethoscope is specially designed for auscultation training. It plays back sounds produced by the manikin when it is placed at any one of the anatomically correct locations. These stethoscopes are typically high-quality and may have multiple interchangeable chest pieces or diaphragms to simulate different conditions or body areas.

The last crucial component of the student auscultation trainer is the interactive software or GUI. The software consists of several features including:

1) **Sound Library:** The software may contain a library of recorded auscultation sounds representing normal and abnormal conditions. Students and trainers can listen to these sounds and learn to recognize them.
2) **Phonocardiogram:** A phonocardiogram or phonogram displays the acoustic characteristics of body sounds, such as the amplitude (loudness) and frequency of the sound over time. They are used in medical diagnostics and education to analyze and interpret the sounds produced by the body.
3) **Manikin Views:** These views provide a graphical representation of the manikins anterior and posterior views. Different areas of the manikin highlight to show the selected auscultation point for guidance.

A. *Commercially Available Auscultation Trainers*

Commercially available student auscultation trainers vary in features and complexity, but they generally aim to provide a realistic and effective learning experience for medical students and healthcare professionals. These trainers often incorporate a combination of physical models, high-quality stethoscopes, and software to simulate various physiological conditions and guide students through auscultation exercises.

Some well-known brands in this space include Cardionics and Reality Works, among others. An overview of some products and their features is provided in Table I.

B. *Project Scope*

Our project aims to develop software Graphical User Interface (GUI) that enables user interaction with the Student Auscultation Trainer. It offers a dynamic platform where students and trainers can explore various physiological conditions affecting different parts of the human body, from the intricacies of cardiac murmurs to the subtle nuances of lung sounds and bowel movements. Upon selecting a condition, users can listen to sounds directly within the software or using the physical trainer or stethoscope that are wirelessly connected with our software. Therefore, our software allows emulation of authentic clinical scenarios and empowers medical students to refine their auscultation skills with confidence, preparing them for the diverse challenges they'll encounter in their future practice.

TABLE I
COMMERCIALLY AVAILABLE STUDENT AUSCULTATION TRAINERS

S.No.	Trainer Name	Manufacturer	Features
1	SAM4 Auscultation Trainer [1]	Cardionics	– User-friendly software on smartphone / tablet – Library of 37 heart sounds, 11 heart-lung combinations, 26 lung sounds, 9 bowel sounds and 6 bruit sounds – LED lights strategically placed at each auscultation point – listen to sounds using a real stethoscope – Bluetooth connection feature
2	SAM Basic [2]	Cardionics	– User-friendly software on laptop / computer – library of 18 heart, 20 lung, 6 bowel sounds and 1 bruit sound – Sounds played as soon as the stethoscope's chest piece is placed on one of the anatomically correct locations
3	Auscultation Trainer [3]	Reality Works	– An attachment that affixes to any stethoscope – Clear torso that details major organs – Anatomical landmarks built into the trainer – Removable skin overlay – Sounds play only when the stethoscope attachment is placed over corresponding auscultation sites – Provides 21 sounds and over 40 scenarios
4	Heart and Lung Sounds Adult Torso [4]	Gaumard Scientific	– Sounds play only when the stethoscope is placed over correct auscultation site – Sensor network hidden beneath the skin – Virtual Stethoscope included with multiple heart and lung sounds

II. SYSTEM DEVELOPMENT

The Student Auscultation Software includes a number of features in order to provide the best learning and teaching experience to students and medical professionals. Our software offers users the choice of up to 12 distinct heart sounds, 8 lung sounds, and 1 bowel sound, spread across 10 auscultation points on the human torso. These sounds can be played directly within the software, accompanied by visual representations of their corresponding phonocardiograms to enrich better understanding. Moreover, the graphical user interface (GUI) also provides clear guidance on the specific auscultation points where a medical student should position their stethoscope for each selected medical condition, ensuring precise practice and skill development.

A. Collection of Auscultation Sounds Library

A total of 21 sounds have been collected for auscultation. Among these, 12 Heart sounds and 8 Lungs sounds were provided by [5] whereas 1 bowel sound was provided by [6].

The different points on the human torso are marked in Fig. 1.

The following is the list of conditions associated with each of the numbered points shown in the image. The first letter indicates whether the condition corresponds to Heart (H), Lungs (L) or Bowel (B). The next two numbers indicate the sound number as saved in the playlist. The remaining part contains information about the condition being diagnosed.

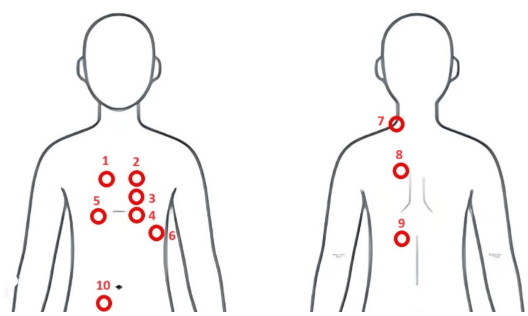

Fig. 1. Auscultation Sites considered in Software

1) Point 1 - H02_Aortic Stenosis, L01_Bronchial breath sounds
2) Point 2 - H03_Fixed Splitting Second Heart Sound, H11_Splitting Second Heart Sound
3) Point 3 - H01_Aortic Regurgitation
4) Point 4 - H05_Innocent Murmur
5) Point 5 - L02_Coarse Crackles
6) Point 6 - H04_Fourth Heart Sound, H06_Mid Systolic Click, H07_Mitral Regurgitation, H08_Mitral Stenosis, H09_Mitral Valve Leaflet Prolapse, H10_Normal Heart, H12_Third Heart, L05_Pleural Rubs
7) Point 7 - L07_Stridor
8) Point 8 - L06_Rhonchi, L08_Wheeze
9) Point 9 - L03_Fine Crackles, L04_Normal Vesicular

10) Point 10 - B01_Right Upper Quadrant

Auscultation of heart sounds should be conducted carefully over at least five locations on the anterior chest wall as shown in Fig. 2. On the other hand, all fields of the chest wall should be examined for lungs auscultation, including the chest wall anterior, posterior and flanks.

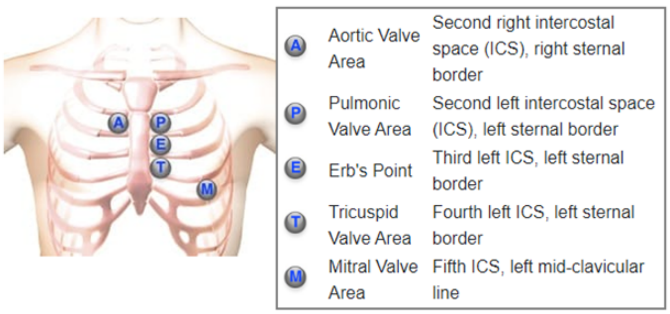

Fig. 2. Location of various heart sounds [5]

B. Development of Software GUI

The software GUI has been developed using the Python PyQt5 library. It provides an interactive user interface, allowing users to select different physiological conditions from the collection of auscultation sounds for heart, lungs or bowel and play them from within the software. The selection of each sound displays the phonocardiogram of the respective sound on the screen which can help students gain a better understanding of the nature of different sounds. Furthermore, the software also highlights the respective auscultation site for each sound.

The software front-end is shown in Fig 3.

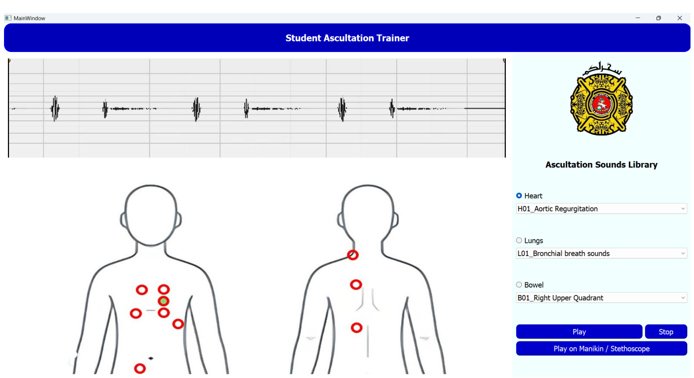

Fig. 3. Software Graphical User Interface

C. Wireless Communication between Software and Manikin / Stethoscope

In modern student auscultation trainers, wireless communication between the software and the manikin or stethoscope enhances flexibility, convenience, and realism in training scenarios. One of the most common ways to achieve this wireless communication of data is using MQTT (Message Queuing Telemetry Transport) protocol.

MQTT is a lightweight and efficient messaging protocol designed for constrained devices and low-bandwidth, high-latency, or unreliable networks. It follows a publish-subscribe messaging pattern, where clients (publishers) send messages to a central broker, and other clients (subscribers) receive messages based on their subscriptions. In our case, both the software GUI and the manikin or stethoscope devices act as MQTT clients. The software serves as a publisher that can send the user selections to the manikin and stethoscope to play the selected sounds.

Wireless communication between the software and the manikin/stethoscope can be achieved using standard networking technologies such as Wi-Fi or Bluetooth. However, in order for each device to work effectively, it must connect to the MQTT broker over the wireless network. Mosquitto is an open-source MQTT message broker that facilitates communication between MQTT clients. It acts as a central hub, and allows devices to communicate with each other using the publish-subscribe messaging pattern. In this pattern, devices can publish messages to specific topics, and other devices can subscribe to those topics to receive the messages over a common network.

MQTT and Mosquitto offer scalability and flexibility to our system, allowing multiple clients to connect to the broker simultaneously. This architecture supports the integration of additional components or extensions to the auscultation trainer system without significant overhead.

Some key features of Mosquitto include:

1) **Lightweight:** Mosquitto is designed to be lightweight and efficient, making it suitable for use on resource-constrained devices.
2) **Security:** It supports various security features such as TLS encryption and authentication mechanisms, ensuring that communication is secure even over untrusted networks.
3) **Scalability:** Mosquitto can handle a large number of concurrent connections, making it suitable for deployments ranging from small-scale to enterprise-level.
4) **Persistence:** It supports message persistence, allowing messages to be stored even if clients are offline. This ensures that messages are not lost and can be delivered to clients when they reconnect.

III. System Testing

Hardware and software integration has been completed by utilizing Mosquitto MQTT Broker. It is installed on a Laptop to make a local area communication between software GUI and other hardware devices such as ESP32/ NodeMCU microcontrollers over the same network. A comprehensive diagram is shown in Fig. 4.

The main steps for running our software are described in the following steps:

1) Install and Setup Mosquitto MQTT Broker on the system.

Fig. 4. Hardware Software Integration of Auscultation Trainer Software

2) Install the software GUI using the instructions specified in the GitHub repository: https://github.com/fabeha-raheel/embedded-project
3) Determine the IP of our system and modify the MQTT_BROKER_IP parameter in the software files
4) Run the software
5) Connect the manikin or stethoscope to the same WiFi or Bluetooth network and configure the correct IP address for the Broker.

IV. Limitations and Future Directions

While student auscultation trainers offer significant benefits in medical education, they also have limitations and areas for future improvement. While modern trainers aim to replicate physiological conditions accurately, there is still room for improvement in simulating a wide range of pathological states and variations in patient anatomy. Future directions could involve integrating advanced simulation technologies, such as virtual reality or augmented reality, to enhance realism. There is also a need for rigorous validation studies to demonstrate the effectiveness of student auscultation trainers in improving clinical skills and diagnostic accuracy.

Furthermore, while wireless communication enhances flexibility, it also introduces potential security risks. Future developments should prioritize robust encryption and authentication mechanisms to protect sensitive patient data transmitted between software and hardware components. Apart from this, improving the user experience and ergonomics of auscultation trainers can enhance usability and engagement. Future directions could involve user-centered design approaches and iterative feedback from students and instructors to refine the interface and physical design of these tools.

V. Conclusion

In conclusion, our project has developed a sophisticated Graphical User Interface (GUI) software for the Student Auscultation Trainer, revolutionizing the way medical students refine their auscultation skills. By seamlessly integrating with physical instruments of the trainer such as the manikin and stethoscope, our software provides an immersive learning experience. Through this approach, we empower medical students to navigate authentic clinical scenarios with confidence and precision, ultimately preparing them for the diverse challenges they'll encounter in their future practice.

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