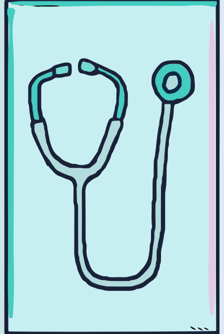
Abu Dhabi University, under the sponsorship of RTX, is organizing:

The 11th Undergraduate Research and Innovation Competition (URIC)

جامعة أبوظبي
Abu Dhabi University

SmartSteth

An AI-Enabled Smart Stethoscope for Cardiac and Pulmonary Disease Detection



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About SmartSteth

SmartSteth utilizes a traditional 3M Littman classic III stethoscope with a Raspberry Pi 4 microprocessor, aiming to record heart sounds and lung sounds and pass them through a preprocessing block, a feature extraction block, and a classification block that identifies their abnormalities and possible diseases.

The Aim of SmartSteth

01 Analyses heart and lung sound data

02 Enhances early detection of cardiac and respiratory issues

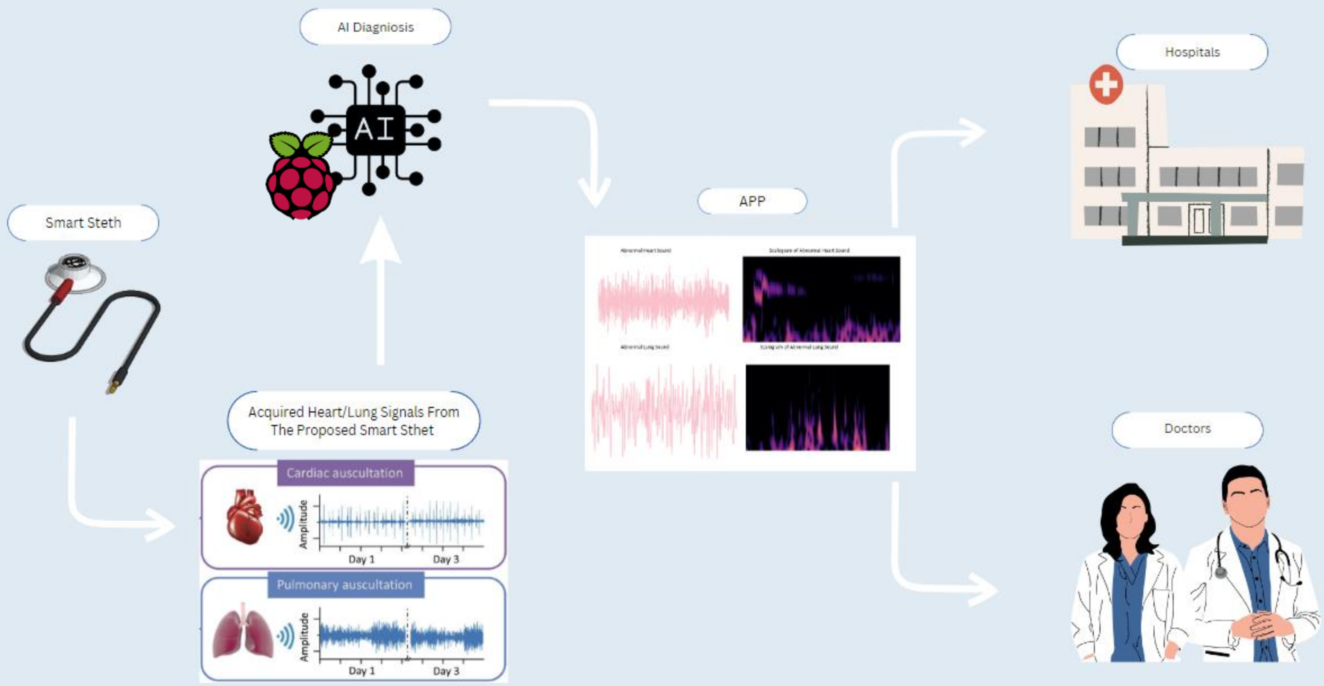
03 AI algorithms for heart and lung sound analysis

04 Facilitate remote monitoring of patients

05 Enables communication between patients and healthcare providers

06 Incorporates LCD for real-time visualization

System Overview



A simple Prototype

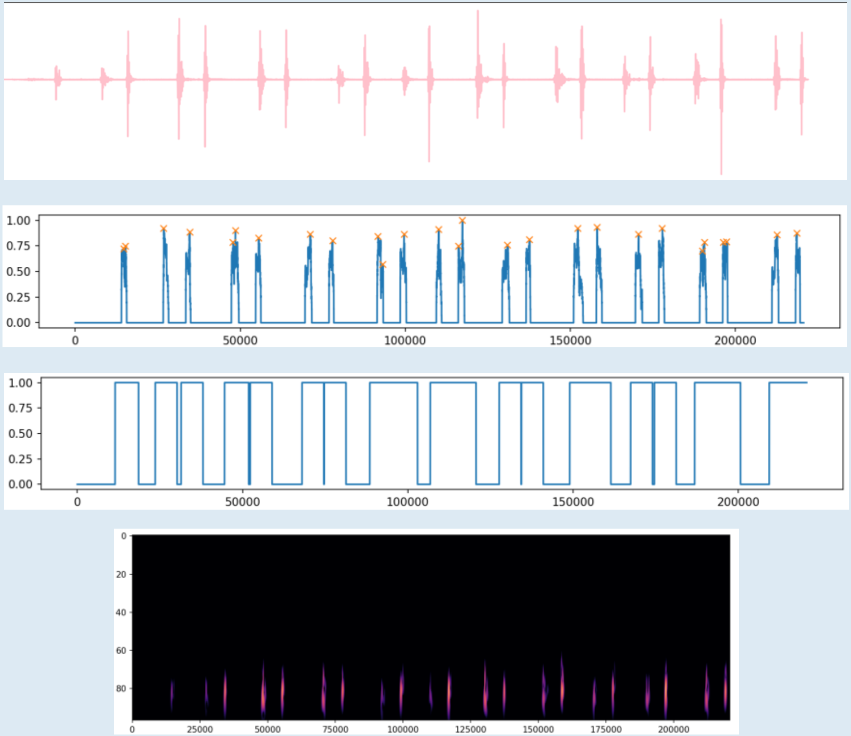
The prototype is implemented using a 3M Littmann Classic III stethoscope chest piece, and a commercial microphone with an AUX end, this prototype is then connected to Raspberry Pi 4 with the AUX input.

Scan the QR code to view the 3D Design!

preprocessing

Heart Sound		Lung Sound	
Bandpass	20-200 Hz	Bandpass	50-1000 Hz
Band reject	50-1000 Hz	Band reject	20-200 Hz

scalograms


1.00
0.75
0.50
0.25
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150000
200000
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20
40
60
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25000
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75000
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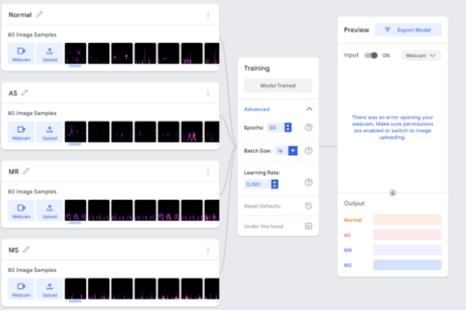
125000
150000
175000
200000

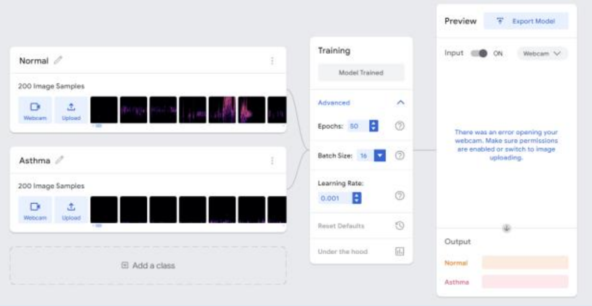
classification model

Heart Sound

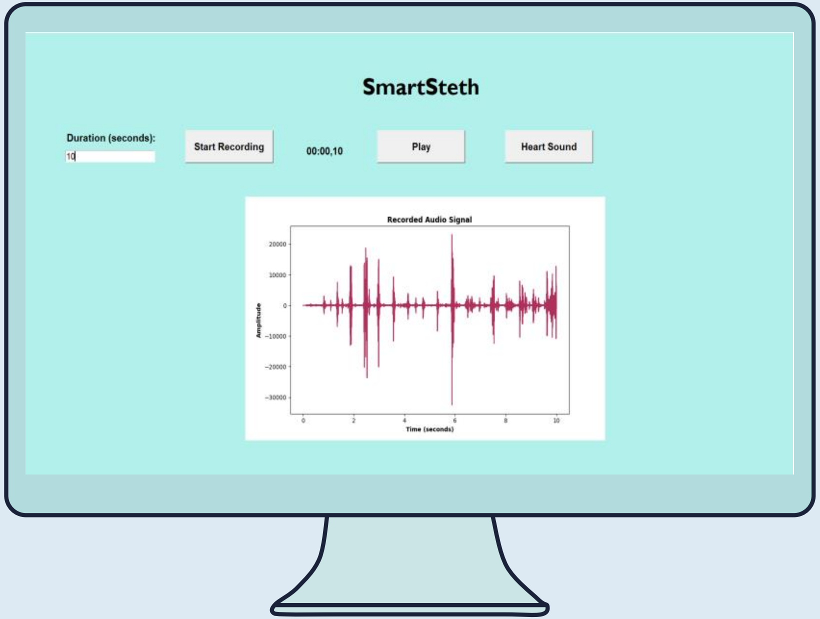


Accuracy : 98.75%
Precession: 97.5%
Recall: 97.5%
F1 Score: 97.5%

Lung Sound



Accuracy : 99.44%
Precession: 99%
Recall: 100%
F1 Score: 99.5%



Our use of AI

AI is used in developing the classification model using machine learning to identify the recorded signals features and classify them based on their features to normal and abnormal, in addition to the ability to identify the types of diseases they're associated with.

COMPARISON

Between SmartSteth and commercially existing digital stethoscopes

Product	Noise Reduction	Bluetooth Connection	Compatible with	Record Keeping and Auto Referral	Report Generation and Sharing	LCD Display	AI Detection
Littmann CORE Digital Stethoscope	✔	✔	Android & iOS	✔	✔	✔	✗
KaWe Planet Stethoscope	✗	✗	✗	✗	✗	✗	✗
KaWe Pinard beech wood stethoscope	✗	✗	✗	✗	✗	✗	✗
Weinmann Stethoscope	✗	✗	✗	✗	✗	✗	✗
Stemoscope	✗	✔	Android & iOS	✔	✔	✗	✔
FriCARE Pink Stethoscope	✗	✗	✗	✗	✗	✗	✗
SmartSteth	✔	✔	Android & iOS	✔	✔	✔	✔

Our Target

Cardiologists

High-fidelity sound capture, advanced heart sound analysis algorithms, and real-time ECG integration. This smart stethoscope assists cardiologists in diagnosing and monitoring cardiac conditions more accurately. The ability to seamlessly connect with electronic health records (EHR) systems enhances workflow efficiency in busy cardiology practices.

Medical Education

Educational modules, sound library, and student performance tracking. This smart stethoscope serves as an invaluable tool in medical education by allowing students to practice auscultation, compare their findings with a comprehensive sound library, and receive feedback. Educators can monitor student progress and customize learning modules.

Publishing SmartSteth

SmartSteth: An AI-Enabled Smart Stethoscope for Cardiac and Pulmonary Disease Detection

Samah Osama Eltayeb, Gena Dahi Abazed, Leqaa Salah Hassan, Supervisor: Taimur Hassan (IEEE Member)

***Abstract*—This capstone project introduces an AI-enabled smart stethoscope designed to enhance cardiovascular disease diagnosis. Utilizing the precision of the 3M Littmann Classic 3 Stethoscope, the prototype integrates a customized condenser microphone for improved sound capture. Motivated by the limitations of conventional stethoscopes, the project focuses on automating the analysis of breathing and heartbeat patterns through AI, signal processing, and advanced hardware. The normal data were collected using the SmartSteth prototype, and the abnormal data were collected from open-source databases, then they were passed to Raspberry Pi for signal processing and disease diagnosis. Moreover, the results of our classification showed accuracy in differentiating and identifying heartbeat sounds of 98.75 % percent, and differentating between normal and asthmatic lung sound of 99.44%.**

***Index Terms*—Medical Systems, Ophthalmology, Retina, Deep Learning.**

I. Introduction

Cardiovascular diseases (CVDs) are conditions that affect the heart or blood vessels, and they are one of the major causes of death, based on the World Health Organization (WHO), about 17.9 million lives globally are taken away by CVDs. Many methods for diagnosing heart-related issues have been developed over the years including an Electrocardiogram (ECG), which records the electrical activity of the heart and shows how fast the heart is beating the rhythms of the heartbeat, and the strength of the electric pulses, but it can have limitations in detecting structural abnormalities. An Echocardiogram (echo), uses ultrasound to create images that show the structure and function of the heart. Finally, the phonocardiogram (PCG), is the graphical representation of heart sounds (HS) and murmurs, which can provide information about the acoustic activity of the cardiac cycle. Heart sounds can be captured using traditional stethoscopes (acoustic stethoscopes), but detecting abnormalities mainly depends on the doctor or physician's listening skills and experience, which makes it possible for a wrong diagnosis. Digital stethoscopes have been developed to enhance diagnostic precision by converting acoustic sounds into electronic signals, electronic signal processing, noise reduction, and the ability to transmit data for further analysis, their implementation was useful during COVID-19 where immediate intervention was crucial to enable physicians to remotely access patients' heart sounds in real-time [1]. In [2], some researchers discussed the designing process of digital stethoscopes, as it is important to consider the ergonomics, acoustic performance, and electric signal acquisition of the implemented and to evaluate its performance through active involvement and feedback from physicians.

II. Related Works

Many researchers have proposed heart sound screening methods. A brief review of the main steps followed for the implementation process is presented in the subsequent sections:

1) Data Collection: The accuracy and reliability of AI and machine learning (ML) trained classification models depend mainly on the data used for training. Throughout the different literature we reviewed, there were different methods to collect the data either by using a commercially available digital stethoscope or with their developed prototype, some recorded data from groups of volunteers who had normal and abnormal heart sounds. The data selection is based on the researcher's aim of the research or project, a lot aimed to only classify the heart and/or lung sounds as normal and abnormal, and some aimed to further classify the type of abnormality such as in [3] "mitral stenosis, mitral regurgitation, and aortic stenosis heart sound", in [4] "normal, and aortic stenosis (AS)", similarly in [5] "normal, moderate or severe aortic stenosis (AS)", and in [6] they focused on detecting arrhythmias "normal beats, supraventricular ectopic beats, and ventricular ectopic beats". Some had PCG with noises to test their method with filtration and identification, in [7] they preferred to add speech noises while recording the PCG data, in [8] they recorded PCG with on ambient and children's crying, and in [9] they mixed the normal sounds from the data sets with a dataset of hospital ambient noise to get the noisy signals.

2) Pre-Processing: Pre-processing methods are very important for the accuracy of the results from the classification models, this stage includes noise removal and filtering, normalization, and re-sampling techniques. To remove noises from the PCG and lung sound signals, it is important to know their normal and abnormal frequency range, normal heart sounds range from 20 to 150 Hz, and heart sound murmurs range from 30 to 700 Hz. Normalization is the process of organizing data entries to ensure they appear similar across all fields and records, making information easier to find, group, and analyze. Not a lot of researchers mentioned normalizing the data in the pre-processing of the signals, however, in [3] they used the normal normalization (Z-score) to convert the data from the time domain to the frequency domain, in [10] they used amplitude normalized from [1,-1] to reduce amplitude variability, and in [11] normalization was through using the square operation (scaling all the data to be the same distance from the origin) where it leads to make the peak signal more prominent and weaken the noise.

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