Keen Ear

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CERTIFICATE OF CORRECTIONS & APPROVAL

Certified that work contained in this thesis titled "Keen Ear" ,carried out by Abdul Rehman and Ramiz Siddiqui under the supervision of Dr. Saddaf Rubab for partial fulfillment of Degree of Bachelor of Computer Software Engineering, in Military College of Signals, National University of Sciences and Technology, Islamabad during the academic year 2020-2021 is correct and approved. The material that has been used from other sources it has been properly acknowledged / referred.

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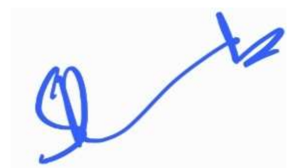

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Abstract

In this modern world of today, everything is being automized. Data Science, Machine Learning and Artificial Intelligence are fields that are being exploited to make strides in almost all walks of life. A lot of jobs that were considered to be impossible without human effort are now being done not just automated programs but with minimum amount of processing too. These advantages of Data Science to extract the most useful information from the rawest of data, can and is being used to further the field of healthcare as well.

It is no secret that respiratory diseases are some of the most life-threatening diseases of all. Five of the most common respiratory diseases are actually most common cause of overall deaths around the world. It is evident that an important part to the treatment of these respiratory diseases like asthma, bronchitis, COPD, URTI etc. is timely diagnosis. The faster the disease is diagnosed the faster it can be treated. The problem that is generally faced in this process is that different respiratory diseases have different diagnosis methods and the time taken in carrying these out can be very vital if used in the treatment of the patient.

This project was development of a Machine Learning and Data Science project that will be able to reduce this extra time that is used up in diagnosis of the patient's exact disease and which if used for the patient's treatment can be extremely vital. This thesis looks at the process of development of an ML model that is able to tell a patient's respiratory disease after listening to the respiratory audio of the patient.

This project also produces a tangible device that employs said ML model to take the respiratory audio of a patient in live time and process the audio to extract important data from it and using that data the ML model would be able to classify the patient's respiratory diseases. Thus, giving a one-stop respiratory disease diagnosis option to doctors and patients alike.

The programming practices and concepts used in this project are Machine Learning, Data Science, Data Analysis, Microprocessor and Embedded Programming.

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1. INTRODUCTION

1.1 Overview

Respiratory diseases are a burden worldwide. Five of such diseases are actually the biggest causes of acute illness and death. These disease require careful treatment and more importantly, timely diagnosis. There are a lot of respiratory diseases that range from viral, bacterial, and genetic and it is important that the patients and physicians find out exactly which disease it is for the treatment process to begin.

1.2 Problem Statement

Diagnostic process for a respiratory disease can be a time-taking process, with different diseases having different testing methodologies and procedural routes. These multiple different diagnostic approaches can also be uneconomical. This problems calls for there to be a one step to approach to correctly identify the respiratory disorder in a patient.

1.3 Approach

The solution provided in Keen Ear is to address the exact problem. Respiratory audios from respiratory patients was recorded along with a few healthy respiratory audios for control. These audios were to be used to train an ML model that could classify similar audios. This model was then to be deployed on microprocessor with means of an input from a live patient, thus classifying and diagnosing a patient's respiratory disease in real time.

1.4 Scope

The scope of the project is to help the doctors and diagnosticians in the process of diagnosis of respiratory diseases by writing a machine learning code that can tell different diseases apart based on their respiratory audios. The project will give a hardware device that can take respiratory voice of a patient at live time and predict a respiratory disorder that the patient might have like Tuberculosis, COPD, Asthma, Bronchitis etc.

1.5 Objectives

The primary objective of this project was the completion and fulfillment of prerequisites of the final year project. This will include building individual scientific and AI skills and presenting the perfect details of the project. This project shall aid to build the necessary skills that would allow our group members to become capable of penetrating into the industry without confronting unnecessary hurdles. Project tasks will include a brief survey of the known techniques to create such application which may include open-source libraries and platforms like scikit-learn and Tensor flow and pick the techniques and technology which helps the students map to the requirements in the best way. To understand and implement the end-to-end software development and deployment process in the context of AI-based software, keeping in view the practices and concerns of the industry. Additionally, the end goal of this project is to develop a gadget that both doctors and patients could take advantage of. The goal of this gadget would be to help the doctors in healthcare system in diagnosis and reduce the cost in diagnostic procedures for the patients.

1.6 Overview of the Document

This document covers the entire process of our project 'Keen Ear'. It includes the Literature Review, Requirements Specifications and Design and Architecture as its main chapters. Each of these are further divided in sub-chapters with details provided.

The sections and subsections of the document are mentioned in the table of contents before Introduction. The document may be read sequentially, or any section can be gone through first. There is no necessary reading order. The section header names are self-explanatory of the content they contain.

1.7 Document Convention

The document conventions followed in this document are in conformance with the standards of CSE Department of Military College of Signals (MCS), NUST.

1.8 Intended Audience

The intended audience of this SRS Document for Keen Ear are personnel at CSE Department of MCS, NUST and other interested parties. Personnel at CSE Department include Project Supervisor, UG FYP Evaluation Panel, other instructors and all the interested students.

2. LITERATURE REVIEW

2.1 Respiratory Diseases

Respiratory diseases, or lung diseases, are neurotic ailments that primarily affect the normal working of organs that are responsible for air exchange and essentially, breathing in humans and other air-breathing animals. Said organs are considered to include trachea, bronchi, bronchioles, alveoli, pleurae, pleural cavity, and the nerves and muscles of respiration. Respiratory diseases range from mild and self-limiting to lethal and deadly. There are number of possible ways to classify these respiratory diseases like the primary organ affected, causes, signs and symptoms and other patterns that parallel the disease.

2.2 Respiratory Diseases around the World

Respiratory diseases have posed as an immense and alarming threat to humans throughout the history, up until and including now. Five of the most common respiratory diseases (also referred to as the Big Five) are common causes of illness-related deaths.

- According to a source, 65 million individuals have moderate to serious chronic obstructive aspiratory infection (COPD), from which around 3 million pass on every year, making it the third driving reason for death around the world – and the numbers are ever-expanding.
- Around 334 million individuals experience some form of asthma, which is the most well-known ongoing illness of adolescence, influencing 14% of children universally. The pervasiveness of asthma in kids is rising which is as alarming a situation as any.
- For quite a long time, acute lower respiratory tract infections have been among the main three reasons for death and incapacity among kids and grown-ups alike. Albeit the

weightage is hard to evaluate, it is assessed that lower respiratory parcel contamination causes almost 4 million deaths yearly and is a main source of death among kids under 5 years of age.

- Besides, acute lower respiratory tract infections in youngsters incline for ongoing respiratory sicknesses further down the road. Respiratory parcel diseases brought about by influenza kill somewhere in the range of 250,000 and 500,000 individuals and cost somewhere in the range of US$71 and 167 billion yearly.
- In 2015, 10.4 million individuals created tuberculosis (TB) and 1.4 million individuals passed on from it.

2.3 Respiratory Diseases in Pakistan

- According to a study by WHO from 2011, in Pakistan about 14.60% people die due to Influenza & Pneumonia, about 5.56% due to tuberculosis, about 4.75% due to lung diseases while about 0.51% die due to asthma.
- About 300 million people were suffering from asthma in all over the world. In comparison, 5 out of every 100 persons in Pakistan.
- The frequency of chronic bronchitis in patients over 65 is 14% and 6% in rural females and males, respectively, and 9% (with no sex difference) in urban areas.
- Pakistan is ranked 7th among the 22 highest tuberculosis disease burden countries in the world. In 2006 the number of all TB cases was 76,668 compared to 97,245 in 2004.

2.4 Audio Analysis in HealthCare

Audio Analysis as a concept refers to analysis of an audio data to extract meaningful and concerning information from it. In case of its use in healthcare, the human voice in different forms can provide a lot of information regarding a person’s health. The term often used for this ‘vocal biomarker’. A vocal biomarker is a signature, a feature, or a combination of features from the audio signal of the voice that is associated with a clinical outcome and can be used to monitor patients, diagnose a condition, or grade the severity or the stages of a disease or for drug development. The use of said biomarkers has proved to be very effective in diagnosis of a lot of diseases and classes of diseases. Parkinson's Disease, Alzheimer's, Mild Cognitive Impairment, Multiple Sclerosis, Cardiometabolic and Cardiovascular Diseases are a few diseases, the diagnosis and treatment of whom have been made much easier with the use of Audio Analysis. Moreover, more recently, considerable research activity has emerged to use respiratory sounds.

3. REQUIREMENTS SPECIFICATIONS

3.1 Interface Requirements

3.1.1 User Interfaces

Keen Ear will give a hardware device as final product. The GUI will be displayed on a screen. It will consist of a few buttons to make certain inputs to the microprocessor. These buttons will prompt the user to record their (respiratory) audio. This audio will be input through a hardware input mechanism (as described in Section 3.2) and processed and passed along to the ML code. The ML software will then predict a respiratory disease and the result will then be visualized towards the user through an LED display.

3.1.2 Hardware Interfaces

For hardware device, a stethoscope head, modified with enhanced-sensitivity microphone will be connected to a microprocessor (i.e., Raspberry Pi) that has the Keen Ear ML Algorithm installed on it. An LED Display will be used to display the output from the microprocessor.

3.1.3 Software Interfaces

- Python, TensorFlow, Keras and Librosa are the tools that will be used for ML.
- R for Data analysis
- Scratch for embedded programming.
- Python Module PyQt5 for GUI
- Other python Libraries include Scikit-Learn, numpy, pandas and pyAudio.

3.1.4 Communication Interfaces

Keen Ear is an ML based project with a hardware product, so communication interfaces are not applicable to it.

3.2 Functional Requirements

3.2.1 Capture Audio

Keen Ear will be able to capture the respiratory audio of a patient at live time, through an input mechanism. This is an important functionality as all the other functionalities will be dependent on the audio recorded in this feature.

FR-1: The device shall prompt the user to give their respiratory audio.
FR-2: The device shall be able to record the audio.
FR-3: The device shall wait for user input to start audio recording.
FR-4: The device shall show error message in case system is unable to get user audio correctly.

3.2.2 Disease Prediction

Disease Prediction will help the user know as to which disease the patient has. This is the key feature of the product. The ML algorithm will predict the disease for the patient using the audio recorded. The patient's audio will either be classified as 'healthy' or a disease like COPD, Asthma, Bronchitis, Tuberculosis etc.

FR-5: The system shall be able to predict a respiratory disease relative to user's input audio.
FR-6: The system shall be able to classify the input audio as healthy.
FR-7: The system shall be able to process the respiratory audio input by the user.

3.2.3 Display Results

This will help the user to see the result of disease prediction on an LED display.

FR-8: The system shall be able to process the result from the ML algorithm.

FR-9: The system shall be able to display the result on the LED display.

3.3 Non-Functional Requirements

3.3.1 Performance Requirements

NFR-1: The response time of the device should not be more than 30 seconds while processing the audio.

NFR-2: The response time of the device should not be more than 30 seconds while the ML Algorithm performs disease prediction.

NFR-3: The device shall be able to maintain multiple sessions successively.

NFR-4: The performance of the system should be consistent for all users who use the system successively.

3.3.2 Software Quality Attributes

NFR-5: The device shall be available 24/7 for use.

NFR-6: The average downtime for either of the device or the ML code should not be more than 20 minutes.

NFR-7: The device shall be easy to use by doctors and adult members of public.

NFR-8: The device interface shall be intuitive and self-explanatory.

3.3.3 Safety Requirements

NFR-9: The system shall be able to correctly predict the respiratory disorder.

NFR-10: The device shall display the correct result on the LED display.

4. SYSTEM ARCHITECTURE

4.1 Overview

Keen Ear will be able predict the respiratory disease that the user has after listening to the user's respiratory audio. It would facilitate both doctors and patients. It will be a device with a stethoscope head which will be used to capture the user's respiratory audio and the ML model will then classify that audio into one of the respiratory disease, which will then be displayed on the displayed to the user.

4.2 Architectural Design

This section shows a block diagram of the project giving an overview of how different components of device will work together.

The input audio will be passed through a modified stethoscope. It will be the input mechanism of a digital stethoscope modified by a sensitive microphone to capture the best audio. The audio will then be passed to the microprocessor. The microprocessor will pass the audio to the ML Model which will classify the audio to one of the respiratory disease. The respiratory disease will then be displayed on the device using an LED Display.

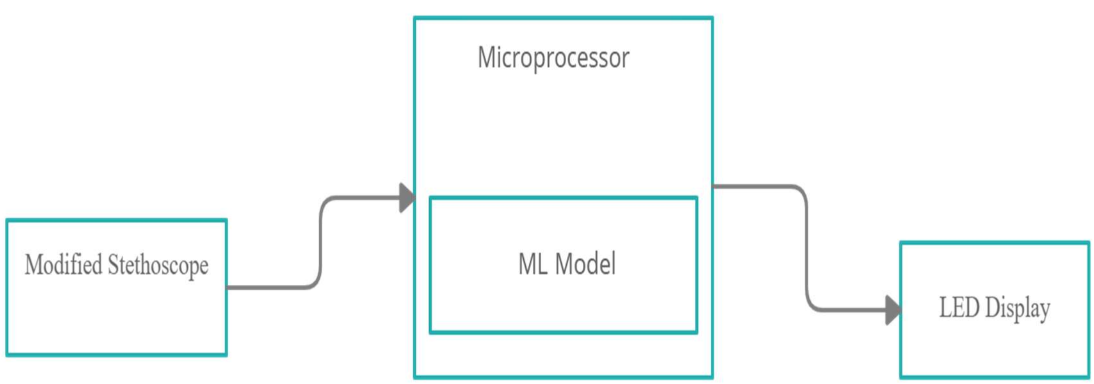

Figure 1: Architectural Design

4.3 Decomposition Description

4.3.1 Component Diagram

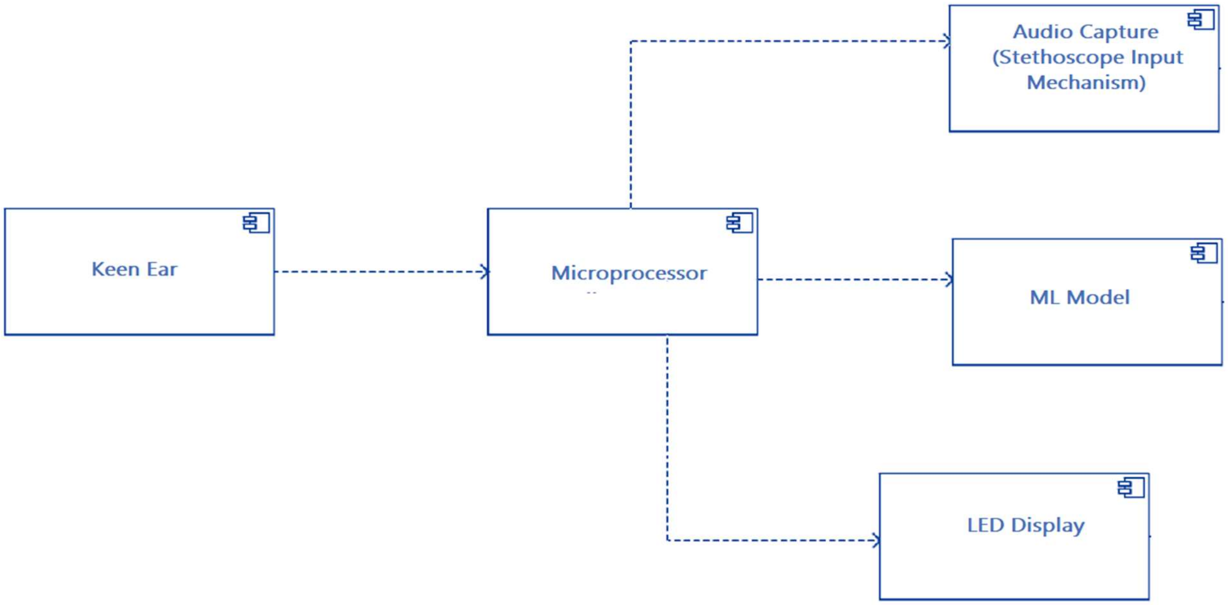

Figure 2: Component Diagram

4.3.2 Sequence Diagram

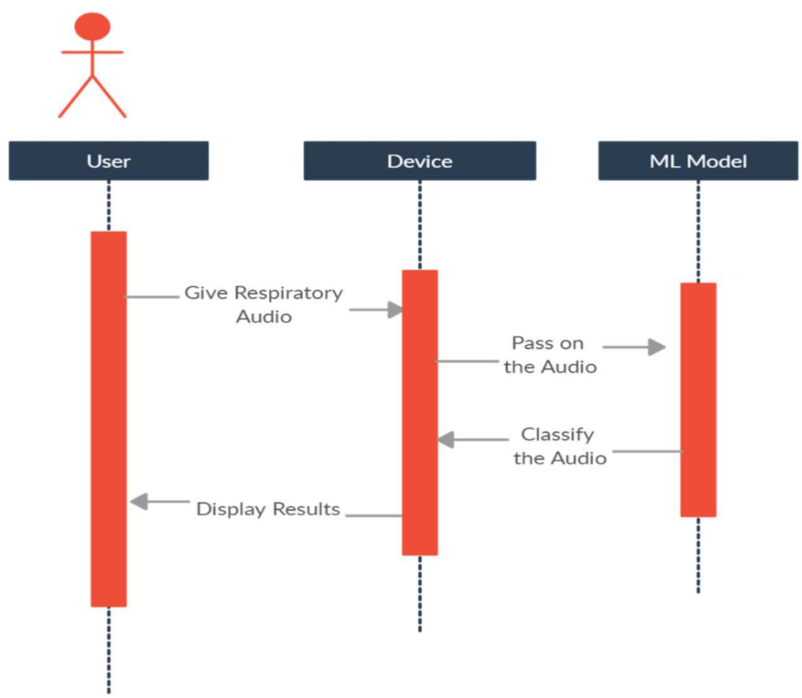

Figure 3: Sequence Diagram

4.4 Design Rationale

Keen Ear is a hardware device that requires different components to work together. This is the reason that the architecture given in Section 3.1 was selected and the microprocessor was selected as the core of the architecture. Keen Ear would work best if a central control entity (a microprocessor in this case) acts as an interface between all the other components.

4.5 Data Design

4.5.1 Data Description

The data used for the development of the Machine Learning Model comes from a 2017 study called 'A Respiratory Sound Database for the Development of Automated Classification'. They have made their data open source online for use in other projects. The data is of two types, audio files and text data. We will be using the audio data that is respiratory audios of patients with different respiratory diseases captured using different machines.

4.5.2 Data Dictionary

Name	**Description**
Microprocessor	A raspberry Pi microprocessor, that acts as the core of the device. It controls and transfers data among all other components
Stethoscope head	It is a bell of a stethoscope to get the respiratory audio of the patient.
Microphone	An enhanced-sensitivity microphone, to modify the audio captured by the stethoscope for better quality of the audio for the classification process
Keen Ear(the ML Model)	It is the Machine Learning model that classifies incoming audios into different respiratory diseases. It is the basis of the whole project. It is trained using python libraries like,

	• Pandas • Numpy • Scikit-learn. • pyAudioAnalysis
Audio Data	The data that has been used to train and test the ML model described above. These are .wav files. The names of files contain following information, • Patient number (101,102,...,226) • Recording index • Chest location (Trachea (Tc), {Anterior (A), Posterior (P), Lateral (L)}{left (l), right (r)}) • Acquisition mode (sequential/single channel (sc), simultaneous/multichannel (mc)) • Recording equipment (AKG C417L Microphone, 3M Littmann Classic II SE Stethoscope, 3M Litmmann 3200 Electronic Stethoscope, WelchAllyn Meditron Master Elite Electronic Stethoscope)

Table 1: Data Dictionary

5. HARDWARE DEVICE DEVELOPMENT

5.1 Equipment

i. Stethoscope

A medical stethoscope to grab the respiratory audio from a patient by placing the head of the stethoscope on patient/user's chest.

Figure 4: Stethoscope used for Keen Ear

ii. Microphone

A sensitive condenser microphone placed and adjusted on the inside of the stethoscope head to enhance the incoming respiratory audio from the stethoscope.

Figure 5: Microphone used for Keen Ear

iii. Microprocessor

A microprocessor which is the main processing unit of the hardware device and the base of the architecture. All other components and equipment are connected to the microprocessor. The microprocessor model used for Keen Ear is Raspberry Pi 4 Model B (4GB RAM).

Figure 6: Microprocessor (Raspberry Pi 4) used for Keen Ear

iv. LCD

An LCD Screen to display the GUI of the project. The screen used for the project was a 5-inch HDMI Interface TFT LCD Module with a resolution of 800x480.

Figure 7: LCD Screen used for Keen Ear

v. Other Accessories

Other accessories like adapters and connecters used to connect and make different major components compatible are listed as follows,

- An HDMI-to-micro-HDMI adapter to connect the LCD Screen to the Raspberry Pi
- A soundcard adapter to make the Raspberry Pi compatible with accepting the audio through the microphone input mechanism.
- A 2A power supply to the screen
- An 8A power supply to the Raspberry Pi.
- A connecter to convert 3-pin 3.5mm microphone jack to a two-pin microphone jack.

5.2 Architecture

Following are points detailing the architecture of the hardware device developed in this project,

- A stethoscope with a sensitive microphone fit inside it, in its head to get the audio that the stethoscope collects and enhance it for further uses.
- The microphone is connected to the microprocessor thus passing on the collected audio to the microprocessor through a connecter and a sound card.
- An LCD Screen connected to the same microprocessor for the purposes of User Interface.

5.3 Final Design

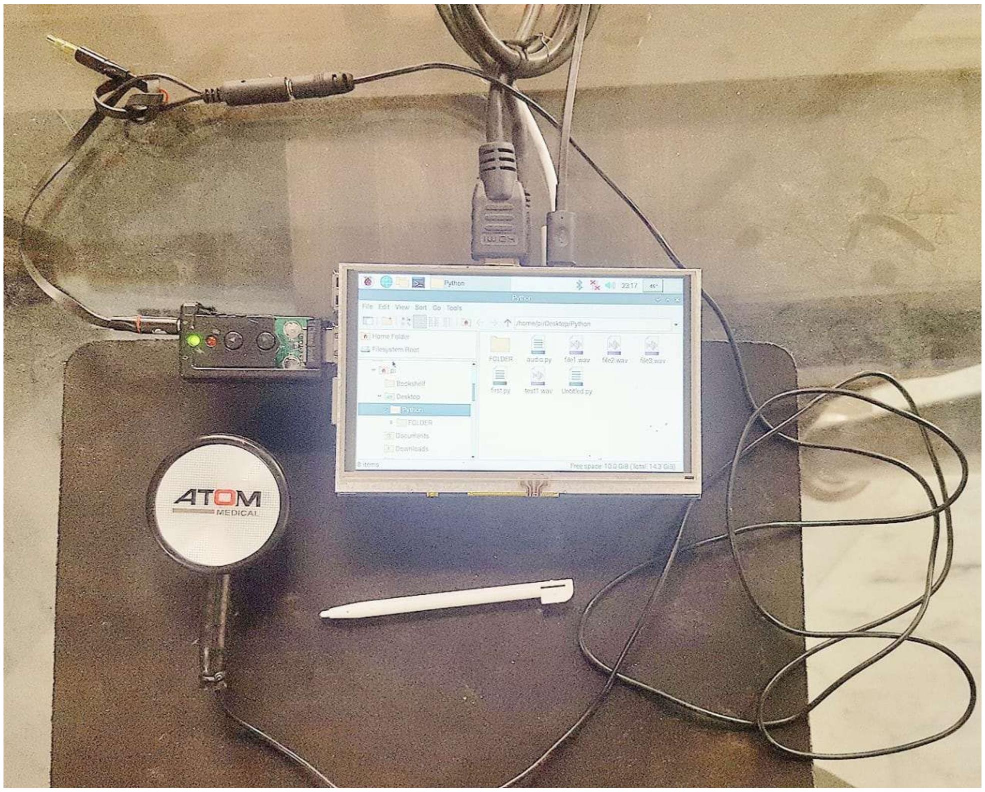

Figure 8: Final Hardware Design of Keen Ear

6. WORKING

6.1 Screen Images

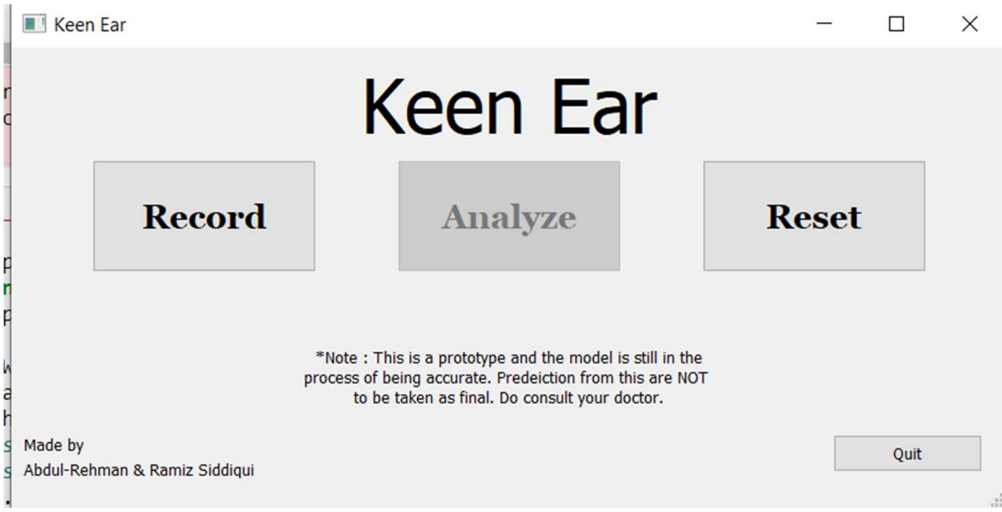

Figure 9: GUI for Keen Ear (Screen 1)

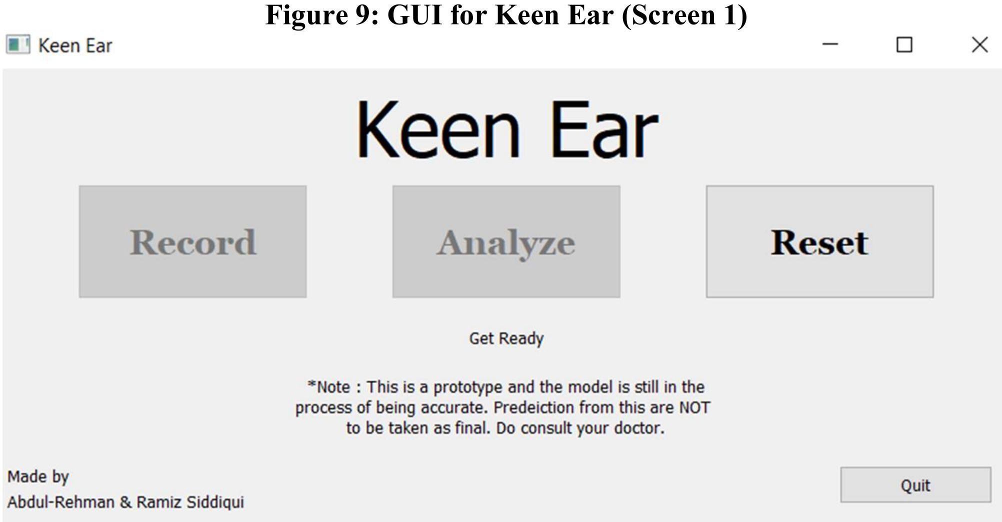

Figure 10: GUI for Keen Ear (Screen 2)

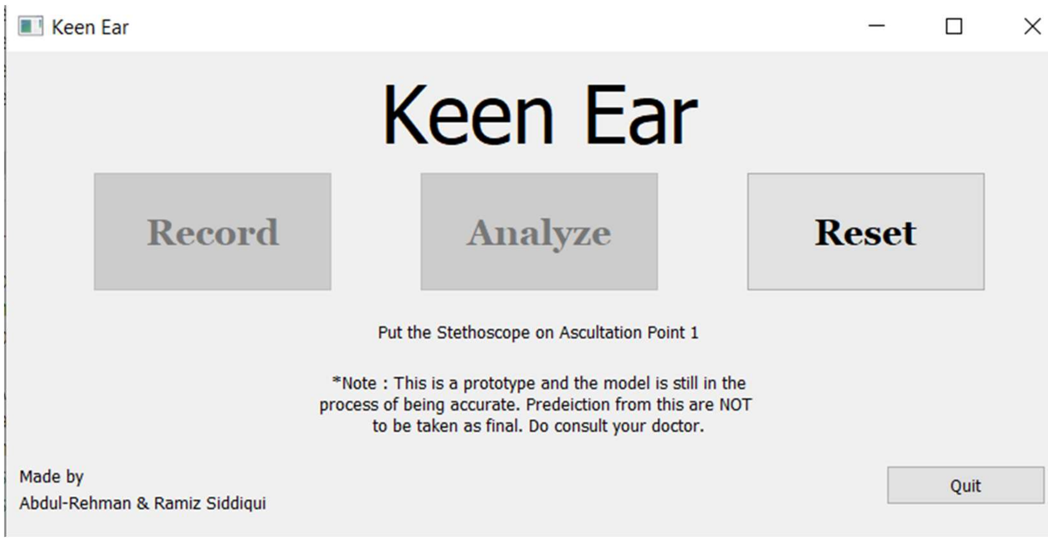

Figure 11: GUI for Keen Ear (Screen 3)

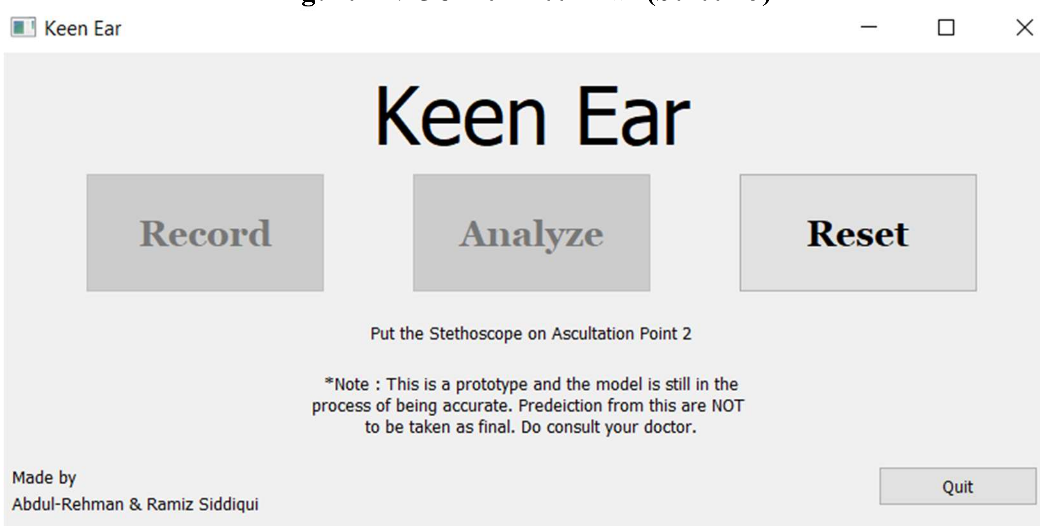

Figure 12: GUI for Keen Ear (Screen 4)

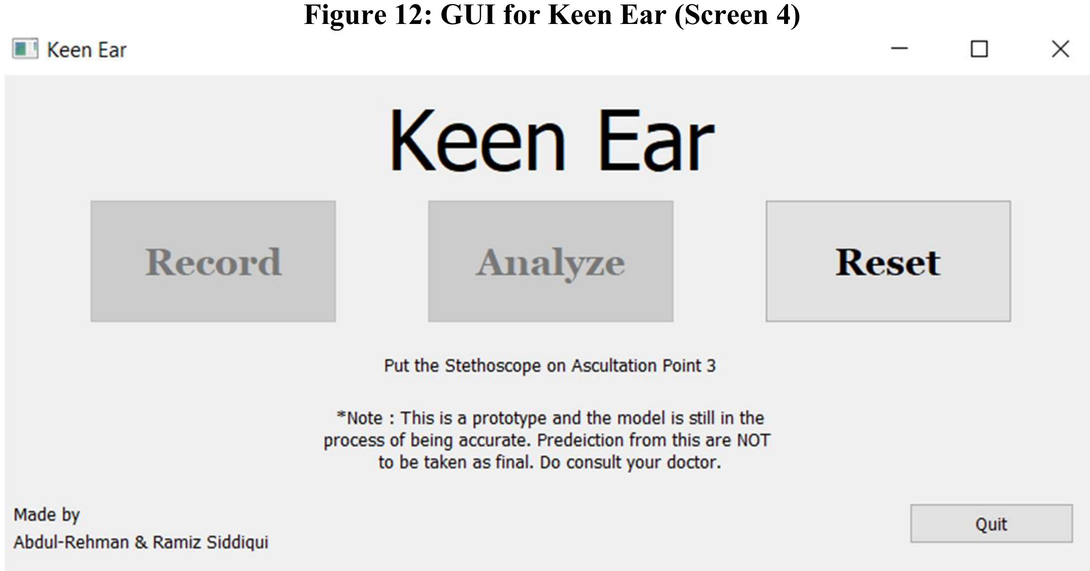

Figure 13: GUI for Keen Ear (Screen 5)

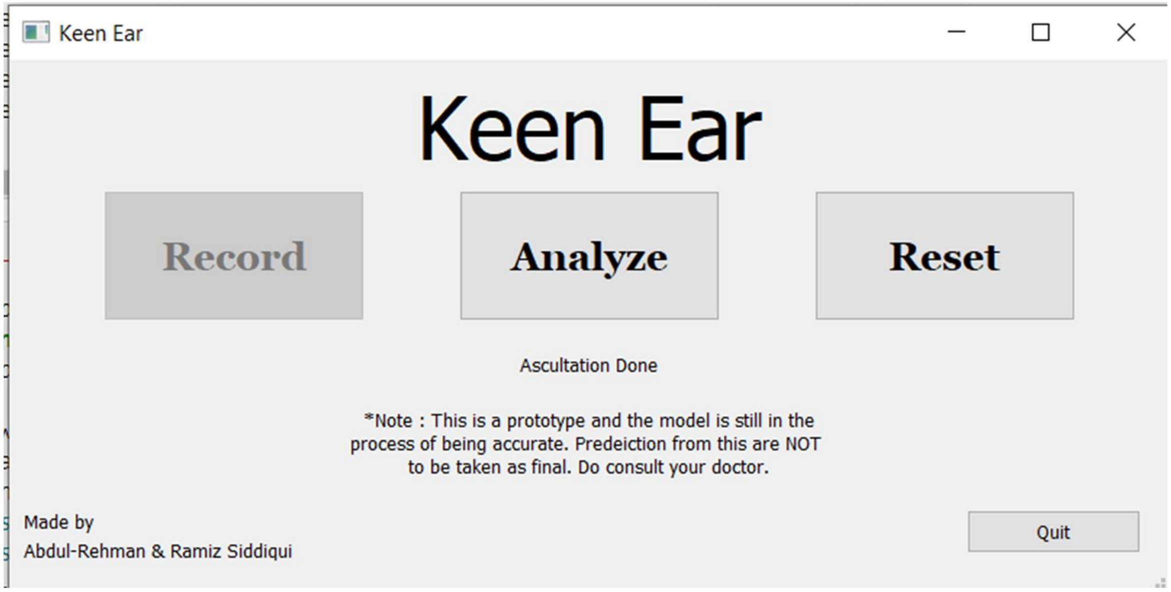

Figure 14: GUI for Keen Ear (Screen 6)

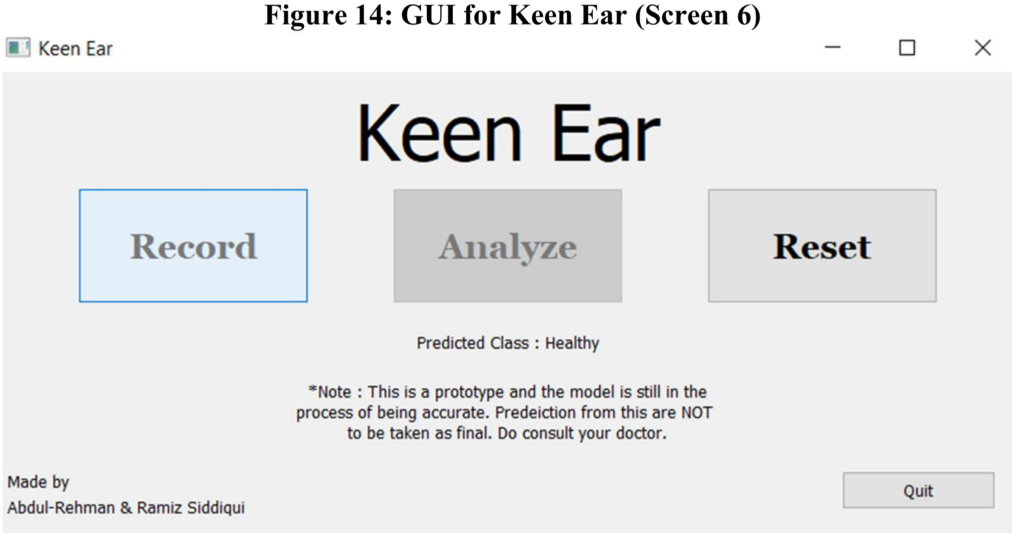

Figure 15: GUI for Keen Ear (Screen 7)

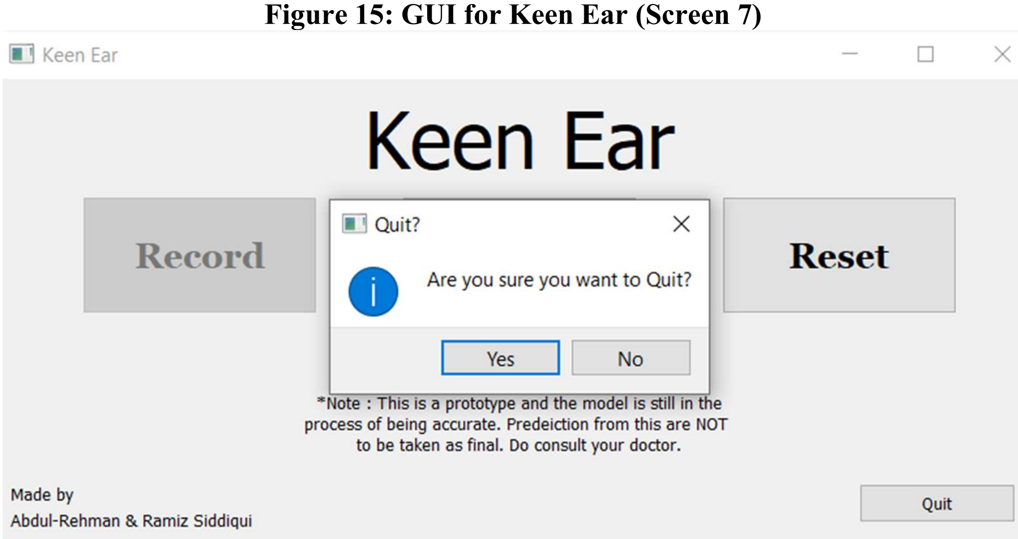

Figure 16: GUI for Keen Ear (Screen 8)

6.2 Use Case

6.2.1 Use Case Diagram

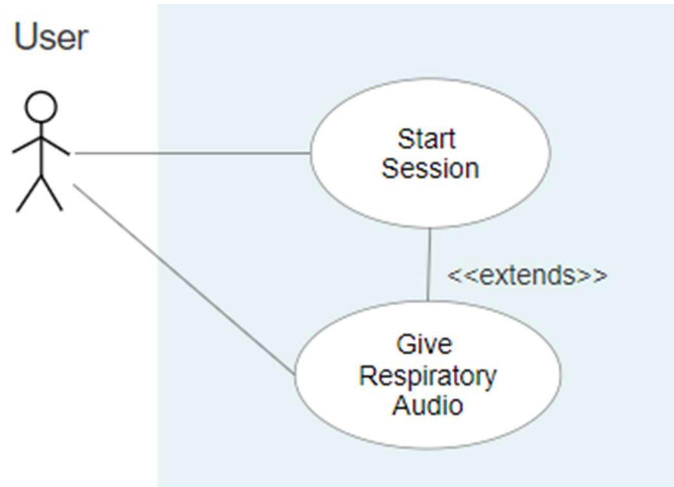

Figure 17: Use Case Diagram (Start Session and Give Audio)

6.2.2 Use Case Description

6.2.2.1 Start Session

Use Case	Start Session
Actors	User
Description	This use case shows that the user will have to start a session by pressing a button on the device.
Normal Flow	The device will turn on and will prompt the user for their next input.
Alternative Flow	The device may not turn on correctly.
Pre-Condition	The device is in correct working condition with all of the components and subcomponents in correct condition as well.
Post Condition	The device will wait for the user's next input, which would be start capturing of the respiratory audio
Includes	N/A
Extends	Give Respiratory Audio

Assumptions	The device is working properly.

Table 2: Use Case Description (Start Session)

6.2.2.2 Give Respiratory Audio

Use Case	Give Respiratory Audio
Actors	User
Description	The user will be able to give the respiratory audio by placing the stethoscope of the device on their chest.
Normal Flow	The audio is captured by the device without any problems.
Alternative Flow	The audio is not correct in terms of either quality or length, in which case the user will be prompted to start over.
Pre-Condition	The user has successfully started the device and the device is prompting the user to give the audio.
Post Condition	The audio was passed and analyzed by the ML component of the system and the results will be displayed on the output mechanism (LED Display).
Includes	N/A
Extends	N/A
Assumptions	The device started up successfully.

Table 3: Use Case Description (Give Respiratory Audio)

6.3 Real-Time Usage & Working

The user/patient starts a session by pressing/clicking on the 'Record' button on the screen (visible in the GUI Screenshots in Section 6.1). This will trigger the 'Record' sequence and certain prompts will be displayed on the screen to guide the user through the process of recording the respiratory audio. These prompts will be as follows (in order),

Get Ready

Place Stethoscope on Auscultation Point 1

Place Stethoscope on Auscultation Point 2

Place Stethoscope on Auscultation Point 3

Auscultation Complete or Auscultation Done

The user/patient will have to hold the stethoscope on each of the auscultation points for 5-10 seconds while the device grabs the respiratory audio of the user/patient. Audios from each point will be recorded and saved (as .wav files) separately and then combined into one file in the next step.

Once the auscultation is complete, the 'Analyze' button will be enabled to the user. When this button is pressed. The audio file will then be passed to the preprocessor and predictor function.

The preprocessor function will extract the necessary respiratory features and store them in a format that is compatible with the predictor function.

The predictor function will load the Keen Ear ML model (saved as .pkl file) as a pickle using pickle library and get a prediction from the model against the patient's respiratory data.

This result will then be displayed on the GUI window for the user to see.

User can repeat this process by recording a new audio(s) or re-analyzing the same audio. They can also reset and quit window using the similarly titled buttons.

6.3.1 Assumptions and Dependencies

6.3.1.2 Assumptions

The assumption regarding the working of Keen Ear as detailed in the previous section are that all the components of the device are connected to each other in correct design and architecture that compliments their compatibility with each other. Further it is also assumed that device is turned on correctly with adequate (and separate) power supply to both the LCD Screen and the microprocessor.

It is also assumed on the user's part that they have previous knowledge of using this particular device or appropriate intuition to use it correctly with any previous knowledge.

6.3.1.3 Dependencies

The working of the methods and functions described in previous subsections of this chapter are dependent on correct import and installation of certain Python modules and libraries on the underlying device (in this case, the microprocessor). Following are the Python modules that are needed to be imported.

- numpy
- librosa
- pickle
- time
- pydub
- pyaudio
- wave
- os
- tensorflow
- keras
- PyQt5

6.3.2 Code Snippets

6.3.2.1 Recorder Function

```
def record (name):
    CHUNK = 1024
    FORMAT = pyaudio.paInt16
    CHANNELS = 2
    RATE = 44100
    RECORD_SECONDS = 5
    WAVE_OUTPUT_FILENAME = name+".wav"

    p = pyaudio.PyAudio()

    stream = p.open(format=FORMAT,
                    channels=CHANNELS,
                    rate=RATE,
                    input=True,
                    frames_per_buffer=CHUNK)

    frames = []

    for i in range(0, int(RATE / CHUNK * RECORD_SECONDS)):
        data = stream.read(CHUNK)
        frames.append(data)

    stream.stop_stream()
    stream.close()
    p.terminate()
```

```
    wf = wave.open(WAVE_OUTPUT_FILENAME, 'wb')
    wf.setnchannels(CHANNELS)
    wf.setsampwidth(p.get_sample_size(FORMAT))
    wf.setframerate(RATE)
    wf.writeframes(b''.join(frames))
    wf.close()
```

6.3.2.2 Preprocessor function

```
class preprocessor():
    def __init__(self, audio_path):
        self.audio_path = audio_path

    def extract_features(self, max_pad_len):
        try:
            audio, sample_rate = librosa.load(self.audio_path,
res_type='kaiser_fast', duration=20)
            mfccs = librosa.feature.mfcc(y=audio,
sr=sample_rate, n_mfcc=40)
            pad_width = max_pad_len - mfccs.shape[1]
            mfccs = np.pad(mfccs, pad_width=((0, 0), (0,
pad_width)), mode='constant')

        except Exception as e:
            print("Error encountered while parsing file: ",
audio_path)
            return None

        return mfccs
```

```
    def to_numpy(self, mfcc):
        return np.array(mfcc)

    def reshape(self, features):
        return np.reshape(features, (1,*features.shape,1))
```

6.3.2.3 Predictor Function

```
class InferenceModel():
    def __init__(self, model_path):
        self.model_path = model_path
    def predict(self, feature):
        with open(self.model_path,'rb') as f:
            model = pickle.load(f)()
        pred = model.predict(feature)
        pred_class = self.decodePred(pred)
        return pred_class
    def decodePred(self, pred):
        ind = np.argmax(pred, axis=1)
        classes = ['Bronchiectasis', 'Bronchiolitis', 'COPD', 'Healthy', 'Pneumonia', 'URTI']
        pred_class = classes[int(ind)]
        return pred_class
```

6.3.2.4 Model file

Figure 18: Screenshot of model.pkl file in directory

7. CONCLUSION & FUTURE WORK

The results from this ML model give a decent enough accuracy to form a baseline. With more data the model could be much more accurate and could even at some point be good enough for public release. The original problem statement of lengthy diagnostic process regarding the respiratory disorders was however addressed during this project. The development of this device does open up a possibility of a one-stop device that could be the answer to the diagnosis of respiratory diseases.

Another angle of future betterment in this project could be use of better equipment with better capabilities to perform the job that it is supposed to do in the right conditions. For example, a high sensitivity condenser that was specifically made to pick up sounds as light as a breath would increase the efficiency of the device by bounds.

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9. APPENDICES

Appendix A – Notes from meeting with physician

As part of our research about our project, we sat down with an actual physician to talk about the idea of our project and to find out, not only if the idea were possible and feasible but also if it would be a useful product in the field of healthcare. The response we got was positive. Following are a few points that were discussed in out meeting with Dr Muhammad Abubakar Mujahid, Postgraduate resident orthopedics (PGR) Madina teaching hospital, Ex resident General surgery Allied hospital Faisalabad.

We first explained the idea and basic of our project. We explained the reasoning and concept the idea and detailed him about an abstract design and architecture of the device that we wanted to develop.

He assured that a device like this would be a major help in the process of diagnosis of respiratory disease s should the precision and accuracy of its prediction be good enough.

His few concerns about the usability of the device by non-technical people like other doctors and physicians were dealt be out explanation that the device will be designed with GUI on a touch screen LCD making the user interface quite simple.

He guided and trained us on the use of stethoscope on respiratory positions. He introduced and explained to us, auscultation points that are very important when getting the correct audio from organs like lungs, heart etc. He further told us about the 3 optimum auscultation points to get the best respiratory audio from a patient.

On the topic of stethoscopes, he recommended us with a model of stethoscope that was both technically and financially viable for our project.

He lastly lauded us on this unique idea that would be a great help to diagnostics and physicians and wished us good luck in our journey.

Appendix B – Turnitin Report

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