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A Comprehensive Review on Diagnosis and Classification of Various Respiratory Diseases

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***Abstract*— Lung diseases are a serious problem because they are the third most common cause of mortality worldwide. If a person exhibits typical symptoms, a disease should be suspected, and a breathing test that evaluates the function of the lungs should be used to confirm the diagnosis. Simply stated, auscultations could not be very useful and might even give false information. The major objective of this paper is to provide a current overview on the diagnosis and classification of various respiratory diseases based on numerous parameters as well as to shed light on the history of various lung diseases. The review concludes by highlighting a technique for gathering lung sound signals and a classification of lung disorders that have been developed to increase the effectiveness of auscultation diagnosis of pulmonary disease.**

Keywords: COPD, URTI, Bronchiolitis, Bronchiectasis, Pneumonia, Healthy, Time Domain

I. INTRODUCTION

Lungs, the principal organs of the human respiratory system, can be affected by a variety of disorders. Chronic obstructive pulmonary disease (COPD), asthma, pneumonia, upper respiratory tract infection (URTI), lower respiratory tract infection (LRTI), bronchiectasis, bronchiolitis, and other disorders are examples. COPD is a common chronic inflammatory lung disease that is primarily caused by smoking. It causes breathing difficulty, cough, production of mucus (sputum), and wheezing.2,3 These symptoms are also common in asthma disease,4 which is another most common and widespread lung diseases that is associated with airway obstruction in the lungs. It causes recurrent episodes of wheezing, breathlessness, chest tightness, and coughing, particularly at night or early in the morning. Pneumonia is an infection that can be caused by bacteria, viruses, and fungi and inflames the air sacs called alveoli in one or both lungs. It causes coughing that may cause mucus production, fever, chest pain, and shortness of breath.[1] An upper respiratory tract infection (URTI) is a respiratory illness that occurs commonly in both children and adults and is a major cause of mild morbidity. It is caused by several families of viruses, such asrus, parainfluenza, respiratory syncyeno virus, Metapneumovirus, influenza, enterovirus, and the recently discovered bocavirus.

URTIs affect the upper respiratory tract, including the nose, sinuses, pharynx, or larynx.9,10 LRTI symptoms, on the other hand, vary and depend on the severity of the infection, and it is the leading cause of paediatric mortality and morbidity in low and middle-income countries.[2]The less severe infections can have the same symptoms as bronchiolitis or bronchiectasis. Bronchiectasis is a long-term condition where the airways of the lungs become abnormally widened. It can make the lungs more vulnerable to infection, resulting in a build-up of excess mucus. It causes a persistent cough which usually brings up phlegm (sputum), and breathlessness. Bronchiolitis is also a common lung infection among infants that occurs when small breathing tubes (bronchioles) become infected. There are several clinical options for diagnosing pulmonary diseases. For the diagnosis of pulmonary problems, imaging modalities such as chest x-rays, CT scans, and magnetic resonance imaging (MRI) are employed. In contrast, the risk of repeated doses of harmful radiation, the cost of machines, and the inconvenience of deploying them in remote regions are only a few of the challenges of adopting imaging modalities, particularly for many third-world patients. Spirometers are also commonly used to measure the volume of inspired and expired air by the lungs, as well as to detect abnormal ventilation patterns. However, a spirometer requires a skilled operator, is expensive, ineffective at detecting obstructive restrictive defects, and necessitates a large number of patient breathing motions and forceful breathing. An arterial blood gas analyser (ABG) can also be used to assess lung problems using arterial blood gas exchange (pO2 and pCO2).However, the ABG test is expensive and requires an invasive procedure. [3] Despite rapid and continual technological advancements in the field of chest disease detection, auscultation remains the most widely used and indispensable lung disease diagnostic tool. Lung sounds, which are collected using a stethoscope, are key indicators of respiratory health and diseases. They provide vital information regarding the health of the lungs. A stethoscope is a handy, easy, low-cost and completely non-invasive diagnostic tool used to identify lung disorders based on lung sounds. On the other hand,

auscultation with a stethoscope gives a limited and subjective perception of respiratory sounds. Subjectivity leads to discrepancies in the interpretation of lung sounds by various medical experts. Subjectivity and inconsistency is caused by the physician's hearing capability, experience, and ability to distinguish and define various sound patterns. Furthermore, the stethoscope recording is highly susceptible to noise. Noise signals mask crucial characteristics of lung sound signals, thus leading to incorrect diagnosis of lung diseases. To overcome the constraints of the manual diagnosis technique, many machine learning and deep learning approaches for automatic classification of lung disease based on lung sound signals have been developed in various literatures.[9] Proposed a Welch spectral method for estimation of power spectral density (PSD) of lung sounds and a support vector machine (SVM) for classification of lung diseases as normal, asthma, and COPD claiming an accuracy of 93.3%. [10] proposed a respiratory sound-based classification of pulmonary diseases as normal or COPD using SVM and an accuracy of 83.6% was reported. Convolutional neural network (CNN) and deep neural network (DNN) techniques have been also proposed in the literature for the classification of lung abnormalities.[11] employed a CNN-based approach for the classification of lung diseases (crackles, crackles combined with wheezes, wheezes, and normal) and an accuracy of 63.09% was reported using spectrogram images. Likewise, Quan et al, performed classification of asthma severity using DNN to classify asthma severity, achieving a maximum classification accuracy of 91.1%. However, the majority of these and other approaches proposed for lung disease classification are either designed for specific or limited lung disease classification, are less accurate, or use the exclusive time or frequency domain analysis technique, which is inefficient for analysis of non-stationary lung sound signals. This study presents the design and construction of an electronic stethoscope for effective lung sound signal acquisition, as well as a multiresolution signal analysis technique for multi-classification of the most common lung disorders using a machine learning approach.

Disease

a)COPD (Chronic Obstructive Pulmonary Disease)

Chronic obstructive pulmonary disease (COPD) is a chronic inflammatory lung ailment that reasons obstructed airflow from the lungs. Symptoms encompass breathing difficulty, cough, mucus(sputum) manufacturing and wheezing. It's usually resulting from lengthy-term exposure to irritating gases or particulate count number, most usually from cigarette smoke. Human beings with Chronic Obstructive Pulmonary Disease are at multiplied chance of developing coronary heart disease, lung cancer and a selection of different situations. Emphysema and chronic bronchitis are the two maximum not unusual situations that contribute to COPD. Those two situations generally arise together and can range in severity among people with COPD. Chronic bronchitis is inflammation of the lining of the bronchial tubes, which deliver air to and from the air sacs (alveoli) of the lungs. it is characterized by every day cough and mucus (sputum) production. Emphysema is a situation in which the alveoli at the cease of the smallest air passages (bronchioles) of the lungs are destroyed due to detrimental exposure to cigarette smoke and other worrying gases and particulaterely. Although COPD is a revolutionary ailment that gets worse through the years, COPD is treatable. With proper management, the general public with COPD can obtain top symptom manipulate and high-quality of lifestyles, in addition to decreased hazard of different related situations.

b) URTI (Upper Respiratory Tract Infection)

Upper Respiratory Tract infection (URTI) or "the not unusual cold" is a symptom complicated normally resulting from several families of virus; these are the rhinovirus, coronavirus, parainfluenza, breathing syncytial virus (RSV), adenovirus, human metapneumovirus and influenza. Occasionally the enterovirus is implicated in summer. These days, the newly found bocavirus (related to the parvovirus) has additionally been linked to URTI. The term "URTI" might be a misnomer as it incorrectly implies an absence of lower respiration tract signs and symptoms. URTI happens typically in each youngsters and adults and is a major cause of mild morbidity. URTIs have a high price to society, being accountable for neglected paintings and pointless hospital treatment. Sometimes they have extreme sequelae. Often seemed as trivial, URTIs do not receive serious interest in clinical school curricula.

c) Pneumonia

The signs and symptoms of pneumonia vary from mild to severe, depending on factors such as the type of germ causing the infection, and your age and overall health. Mild signs and symptoms often are similar to those of a cold or flu, but they last longer. Signs and symptoms and signs and symptoms of pneumonia may additionally include:

1) Chest aches when you breathe or cough
2) Confusion or modifications in mental consciousness (in adults age sixty-five and older)
3) Cough, which may additionally produce phlegm
4) Fatigue
5) Fever, sweating and shaking chills
6) Lower than ordinary body temperature (in adults older than age sixty-five and people with susceptible immune systems)
7) Nausea, vomiting or diarrhea
8) Shortness of breath

Newborns and infants won't show any sign of the contamination, they'll vomit, have a fever and cough, appear stressed or tired and without energy, or have problem breathing and eating.

d) Bronchiectasis

Bronchiectasis is a situation where damage causes the tubes to your lungs (airways) to widen or increase pouches. It makes it tough to clear mucus out of your lungs and may cause common infections. Coughing lots with pus and mucus is the primary symptom of bronchiectasis. Bronchiectasis cannot be cured but may be controlled with treatment. Healthcare vendors categorize bronchiectasis primarily based on what the damage to bronchiectasis is

the maximum excessive form and additionally categorize bronchie Providers additionally categorize bronchiectasis as focal (in one area) or diffuse (in many regions throughout your lungs). Traction bronchiectasis occurs when scarring to your lungs pulls your airways out of shape. Signs of bronchiectasis consist of:
1)Cough with lots of mucus and pus.
2)Repeated colds.
3)Bad-smelling mucus.
4)Shortness of breath (dyspnea).
5)Wheezing.
6)Coughing up blood (hemoptysis).
7)Swollen fingertips with curved nails (nail clubbing).

e) Bronchiolitis

Bronchiolitis is a not unusual lung infection in young kids and toddlers. It causes infection and congestion inside the small airlines (bronchioles) of the lung. Bronchiolitis is sort of constantly caused by a plague. Normally, the height time for bronchiolitis is in the course of the winter months. Bronchiolitis begins out with symptoms similar to the ones of a not unusual cold, but then progresses to coughing, wheezing and sometimes trouble respiration. Signs and symptoms of bronchiolitis can remain for several days to weeks. Most youngsters get higher with care at domestic. A small percent of children requires hospitalization. For the first few days, the symptoms and signs of bronchiolitis are just like the ones of a chilly:
1.Runny nostril
2.Stuffy nose
3.Cough
4.Mild fever (no longer constantly present)
There can be per week or extra of trouble breathing or a whistling noise while the kid breathes out (wheezing). Many infants also have an ear infection (otitis media).

f) Healthy

Healthful lungs will let you breathe effortlessly, without discomfort or pain. They supply oxygen on your bloodstream to maintain the relaxation of your frame wholesome. While your lungs are healthful, you are more likely if you want to do the sports you like and feature a terrific nice of lifestyles. Healthful lungs appearance and feel like sponges. They're crimson, squishy, and flexible enough to squeeze and make bigger with each breath. Their main process is to take oxygen out of the air you breathe and bypass it into your blood. While you inhale, air enters your frame via your windpipe, or trachea, the tube that connects your mouth and nostril with your lungs. The air then travels thru bronchial tubes, which flow air inside and out of your lungs. All alongside your airways, mucus and hair-like structures referred to as cilia get rid of dust or dirt that is available in with the air. Air continues transferring via your airways till it reaches tiny balloon-like air sacs in your lungs, known as alveoli. From there, the oxygen movements into your blood. Whilst you exhale, your lungs put off carbon dioxide out of your blood in a method called fuel alternate. Smoking throws this whole process out of stability.

II. MECHANISMS OF BREATH SOUND PRODUCTION

Normal breath sound is produced by the air flow through the trachea-bronchial tree. However, not all types of airflow produce breath sounds. Only turbulent and vorticose airflow generates breath sounds. Airflow moves parallel to the walls in a parabolic shape as the air in the central layers moves faster compared to the peripheral layers, with little or no transverse flow. Thus, there is little mixing or collision between gas layers. Laminar flow pattern follows the Poiseuille equation.

Capture techniques

Acquisition

Various methods and tools have been described to capture sound:

- Using one microphone: This is the most frequently-used method. Usually, the sensor is an electret microphone. The most common sampling frequency used is that of telephony codecs (8k Hz), an analog-to-digital conversion with a 16-bit resolution. Another option is using an accelerometer, which is less sensitive to background noise but offers a much poorer performance compared to electret microphones.
- Using several microphones and 3D Representations: This technique makes it possible to identify where the sounds originate. It is a dynamic method that shows structural and functional properties, useful for diagnosis.
- Emitting a sound then analyzing its propagation. This technique, described by Mazic et al. consists of emitting a sound through a loudspeaker placed in the patient's mouth. The method processes the characteristics of the signal's propagation through the respiratory airways and chest, analyzing energy ratios, signal time delays and dominant frequency.
- Closed-loop controlled ventilation measurement.

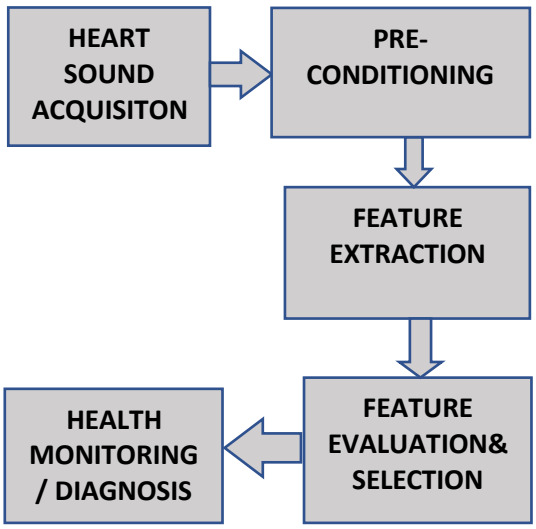

Fig 1:Elements of Signal Processing System

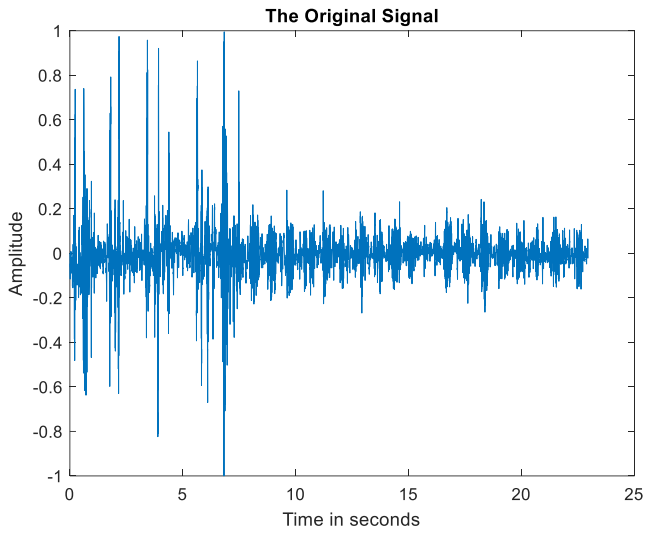

Fig 2:Original Signal of COPD

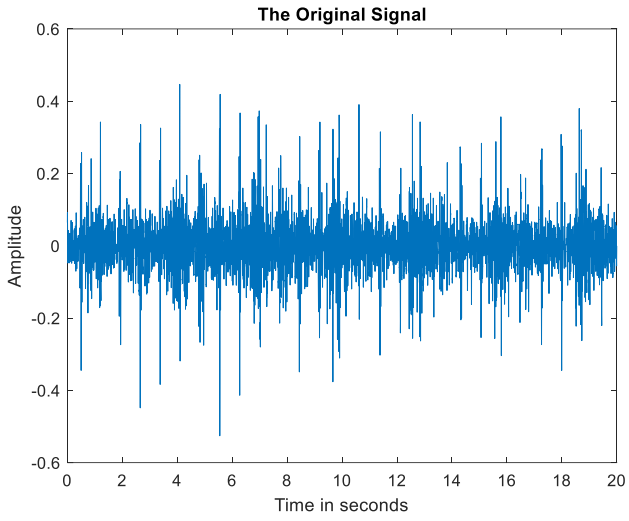

Fig 3: The Original Signal of Bronchiectasis

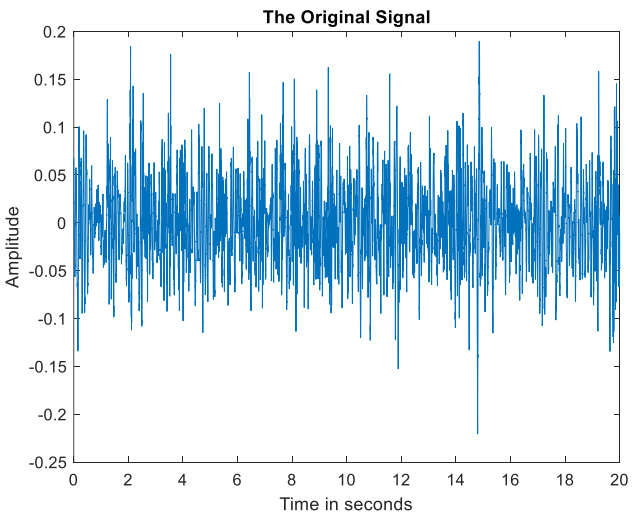

Fig 4: The Original Signal of Bronchiolitis

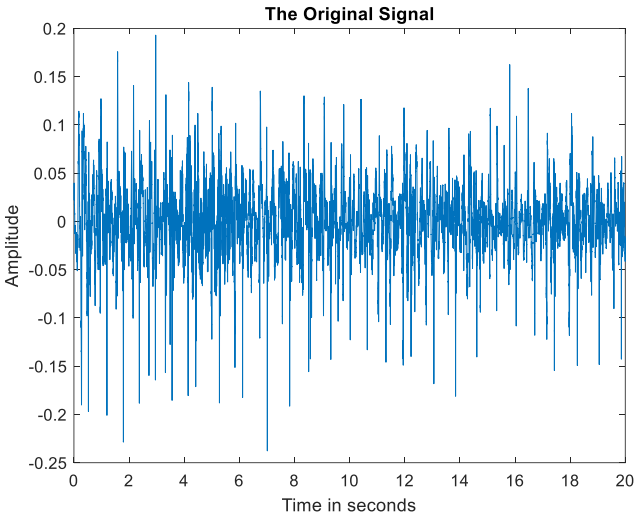

Fig 5:The Original Signal of Healthy

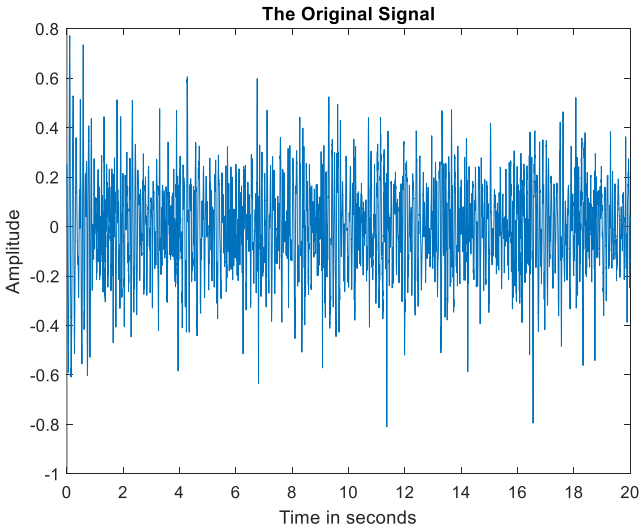

Fig 6: The Original Signal of Pneumonia

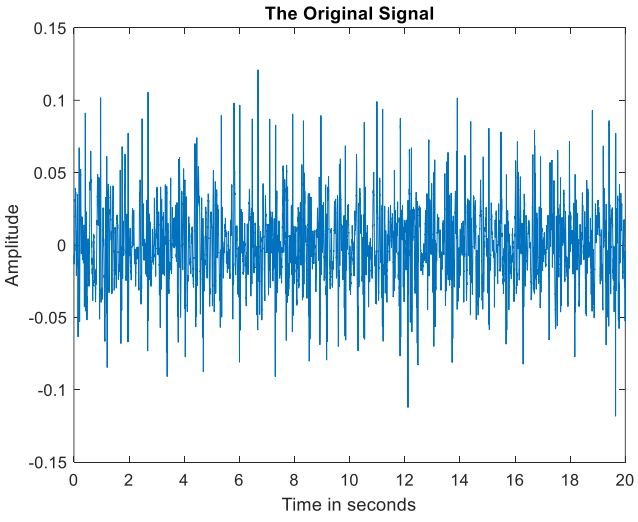

Fig 7: The Original Signal of URTI

Methods

a)Data Acquisition

To identify relevant studies for the review, the datasets are collected from ICBHI 2017 Challenge which contains information of about 300 patients recordings of various diseases. The search was conducted using the following keywords: COPD (Chronic Obstructive Pulmonary/Lung/ Respiratory/Airway Disease), Healthy, Bronchitis, URTI (Upper Respiratory Tract Infection, Pneumonia, Bronchiolitis. In addition, further studies were identified from reference lists of review articles yielded by the search. Figure 1 shows the basic elements of signal processing system. Fig. 2-7 shows the original signal of COPD, Bronchiectasis, Bronchiolitis, Healthy, Pneumonia and URTI.

b) Data Pre-Processing

Denoising techniques were employed to denoise the signals without affecting essential aspects of the lung sounds. This was conducted using high pass filter. Time domain analysis approach is done which provides good localization.

c) Feature Extraction

Feature extraction used for the extraction of features of the lung sound signals. Feature Extraction was conducted using MATLAB. Some of the features that can be extracted are mean, Root mean square (RMS), Shape factor, Kurtosis, Skewness, Peak value, Crest factor, Impulse factor, Clearance factor, Total Harmonic Distortion (THD), Signal to Noise and Distortion Ratio (SINAD), Peak amplitude, Band power, Number of zero crossing, Lyapunov exponent, Empirical Mode Decomposition etc.

d) Feature Selection & Evaluation

Prior to training, feature selection was undertaken to choose the most important features and remove undesired or redundant features. Then evaluation is done based on the obtained results. Accuracy, sensitivity, specificity, and threshold matrices are used to evaluate how well each characteristic distinguishes between distinct lung sound signals. The sensitivity determined by:

$$\text{Sensitivity} = \frac{\text{True positives}}{\text{True positives + False negatives}}$$

The specificity calculated as:

$$\text{Specificity} = \frac{\text{True negatives}}{\text{False positives + True negatives}}$$

To calculate the real positive and true negative fractions the following is the mathematical expression:

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + TN + FP + TN)}$$

III DISCUSSION AND CONCLUSIONS

Auscultation of lung sounds provide vital information about the physiology and pathology of lungs and airways obstruction. Accurate lung diagnosis of lung sounds requires the ability to distinguish normal breathing sounds from various abnormal adventitious sounds. Some analysis techniques such as empirical mode decomposition and multiscale entropy techniques have been used for analysis of lung sounds. Lung sounds of top lung diseases from online annotated lung sound signals were found. They have been studied using various time domain features and evaluated. Each disease has its own separability. On these a noninvasive method based on a time domain feature can be used to determine a disease from LSs appears more optimistic.

In this paper, a time domain analysis with some basic features is done which avoids complicated machine learning methods which can be time-consuming. Time domain analysis furnish the transitory response of a system to be examined, and it allows a better understanding. The proposed method could be improved in accuracy, sensitivity and specificity and to obtain a more robust result.

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