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# Respiratory Sound Analysis for Identifying Lung Diseases: A Review

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Abstract: For diagnosis of lung disease, lung sound auscultation plays an important role. Lung sound provides important information regarding underlying condition of lungs. Advances in the field of signal processing have led to development of automated tools for diagnosis of respiratory diseases using lung sound. This paper investigates the previous work undertaken by various researchers on automated respiratory sound diagnosis using visual and statistical methods. Based on this analysis, future work which can advance knowledge in the important area for remote healthcare is explored.

Keywords: Lung disorder, Respiratory sound, Visual analysis, Statistical analysis.

#### 1. Introduction

Respiratory sound provides important information regarding the present condition of the lung. Auscultation is the skill of listening to the sounds in the body by using a stethoscope to diagnose abnormalities. Lung sound auscultation gives useful information for diagnosing abnormalities and disorders in the respiratory system [1].As auscultation depends on the skill of the physician therefore it is subjected to false diagnosis by untrained physician. Therefore it requires a professionally well trained physician to recognize the abnormalities exactly [2].As Lung auscultation is a subjected to the experience, ability, and auditory perception of the physician. To overcome these problems researchers stated to develop copter based lung sound analysis system, In early 1980s research on lung sound analysis using computer started to appear in the literature. During recent years there is been vast improvement in digital processing techniques so there is need to apply these techniques in the field of respiratory sound analysis [3].

This paper discusses some of the methods which were applied recently in computer based lung sound analysis.

#### 2. Lung Sound Classification

Mainly lung sound are divided into two categories namely normal lung sound and adventitious lung sound .The adventitious lung sound are classified as continues and discontinues respiratory sounds [5].The continues respiratory sounds are further classified as wheeze and ronchi where as discontinues respiratory sounds are classified as fine and coarse crackles. These sounds represent the underlying lung abnormality/diseases which are given in Table 1.

# 3. Overview of Literature

The available literature presents analysis of lung sound by different approaches such as visual analysis, statistical analysis and machine learning approach where as some used image processing [9,10]. These approaches utilize different methods for acquisition of lung sound and their respective analysis. In this paper review on two approaches namely visual analysis and statistical analysis is presented.

#### **3.1 Visual Analysis**

In this method the spectrum of respiratory sounds were plotted and physician visually diagnose the respiratory sounds abnormality. From frequency contains the lung disorder is identified .The lung disorder are identified using different characteristics of spectrum such as frequency intensity of signals, peak frequency etc. This method requires the physician with prior knowledge of normal and abnormal spectrum of lung sound which will depend upon the experience and expertise of physician. The time domain and frequency domain waveform obtained for visual analysis is given in Fig 1 to Fig 6. The summary of previous literature regarding visual analysis is given in table 2.

 Table 1: Characteristics of lung sound [4-7]

Respiratory	Dominant	Pitch	Duration	Disorders		
sound type	frequency					
	range					
Normal	150-1000 Hz	High/Low	N/a	N/a		
Wheeze	>200 Hz	High	>250 ms	Asthma, pneumonia		
Rhonchi	<200 Hz	Low	>250 ms	Chronic obstructive pulmonary disease (COPD), acute (or) severe bronchitis		
Coarse crackles	200-2000 Hz	Low	<30 ms	Pneumonia, pulmonary fibrosis, congestive heart failure (CHF), idiopathic		
Fine crackles	200-2000 Hz	High	<10 ms	Pulmonary fibrosis (IPF)		

#### **3.2 Statistical Analysis**

This method deals with the analysis of respiratory sounds based on statistical parameters such as higher order crossing, analysis of variance (ANOVA), lacunarity-based analysis and Fisher discriminant analysis. Table 3 summarizes this method evolving statistical analysis of lung sound.

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400 Frequency Hz Figure 2: Spectrum of respiratory sound of normal subject

500

200

300

700

600

800

900



Figure 3: Time domain waveform of respiratory Sound of abnormal (Bronchitis) subject



Figure 4: Spectrum of respiratory sound of abnormal subject



Figure 5: Spectrogram of normal lung sound.



Figure 6: Spectrogram of abnormal lung sound

#### 4. Discussion

From this review an insight is obtained into various method of respiratory sounds analysis using computer based analysis. The articles used in this review are summarized into two groups. The work carried out in past mostly concentrate on lung sound analysis rather than developing a robust diagnosis tool. Few researchers were successful in developing tools for diagnosis of respiratory sound. Yamashita and Matsunaga presented a pulmonary emphysema diagnostic tool [36]. Li and Liu developed a lung disorder diagnostic tool for pneumonia and asthma. Zolnoori and Zarandi developed a tool for diagnosis of asthma [37]. Sibghatullah khan et al was successful in detection of asthmatic children from their lung sound [35]. The major challenge in computer base respiratory sound analysis is to correctly correlate the respiratory sound to their respective underlying lung diseases which has not been done by many researchers in the past. Also as asthma can be completely cured if detected in earlier age the diagnosis of child asthma is also an important aspect of research in which there has been very few studies available. Next major challenge is the way in which the respiratory sounds were acquired .Some researchers used digital stethoscope where as others researchers used sensors base approach .Another important issue is the source from which respiratory sound data is obtained .Very few researchers used data from hospitals where as most of the researchers used data from lung sound CDs used for training the doctors and nurses. This data is not suitable for machine learning because of lack of vastness and supervised machine learning requires a larger data set for training the model .Also implementation of these techniques in telemedicine application is another dry area in which there is vast scope of research [35].

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Table 2: Summary of literature on visual analysis of lung sound						
Reference	Analyzed: Sound/Disorder	Sensor type	Dataset	Sensor: Position/Location	Method	
[11]	Crackles	Air-coupled dynamic-type microphone	4 tuberculosis and 2 chronic bronchitis	Chest wall	Fast fourier transform	
[12]	Normal, asbestosis and pulmonary edema	Electret microphone	15 subjects with lungs disorder and 5 normal subjects	Posterior basal segments of the lobes	Karhunen-loeve transformation	
[5]	Normal and wheeze	Contact microphone (piezoelectric transducers)	20Patients and 5normal	Chest wall	Fast fourier transform	
[13]	Lung sounds	Microphone	Not mentioned	Trachea	Fast fourier transform	
[14]	Lung sounds	Piezo-electric transducers/microphone	493 sounds	Trachea, chest right, base right, base left	Fast fourier transform	
[15]	Normal and pathological	4 Electret microphone	24 healthy and 17 pathological	Chest wall	Fast fourier transform	
[16]	Lung sounds	Electret microphone	Not mentioned	Chest wall	Fast fourier transform	

 Table 3: Summary of literature on statistical analysis of lung sound

Reference	Analyzed: Sound/Disorder	Sensor type	Dataset	Sensor: Position/Location	Method
[18]	Fine crackles, coarse crackles, and squawks	Electret microphone	6-Fine crackles, 5-Coarse crackles and 5Squawks	Over the lungs	Wavelet-based de-noising and higher order crossing-discrimina-tion analysis
[19]	Respiratory sounds	EMT25C, Siemens Accelerometer	7 –trachea and 10-lungs	Trachea and lungs	ANOVA
[20]	Detecting explosive lung sound	Electrets Microphone	Patients with pulmonary pathology	Over the lungs	FD analysis
[21]	Wheeze, Rattles, and Crackles	Acoustic analysis –sensor (Siemens EMT 25C)s	102 subjects	The right upper zone (anterior chest)	Validity and reliability using k-statistic
[22]	Wheeze and crackle	14 cannel Sony ECM-44BPT electrets microphones	Not mentioned	Posterior chest wall	Wavelet decomposition and kurtosis
[23]	Crackles	Electret microphones	5 fine crackles, 5 coarse crackles, 4 normal and 4 wheezing.	Over the lungs	Wavelet packet transform for de-noise. FD analysis
[24]	Wheeze Time- frequency analysis of wheeze sound	5 Electret microphones (ECM-77B, Sony)	13 patients	Trachea, right and left axillae, and right and left posterior bases	Time-frequency analysis of wheeze sound
Reference	Analyzed: Sound/Disorder	Sensor type	Dataset	Sensor: Position/Location	Method
[25]	Normal and wheeze	Electret microphone (ECM-77B, Sony)	7 healthy and 7 asthmatic cases	Over the lungs	Time-frequency distribution, histogram, sample entropy features, discrimination analysis
[26]	Normal, Fine, and coarse crackles	Electret microphones	Normal and simulated data	Over the lungs	Time-variant Autoregressive (TVAR) model
[27]	Crackles	25 channel Electret microphone	Patients with pneumonia	posterior surface of the thorax	Hilbert-Huang spectrum
[28]	Normal, crackles, and Wheezes	Contact accelerometer (EMT25C, Siemens) and Electret microphone (ECM140, Sony)	Not mentioned	Chest wall, neck and mouth	Wavelet transform and Lipschitz regularity analysis
[29]	Wheeze and non-wheeze from patients with asthma and COPD	14 channel Sony ECM-44BPT Electrets microphones chest piece	246 wheeze and non-wheeze	Posterior chest wall	Kurtosis, Renyi entropy, f50/ f90 ratio and meancrossing irregularity and Fisher Discriminant Analysis (FDA
[30]	Fine crackles, coarse crackles, and squawks	DBS database	Not mentioned	Over the lungs	Lacunarity-based discrimination analysis

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[31]	Crackles	14 cannel Sony	Patents with Cystic	Lower left lung	Kurtosis, Percentile Frequency
		ECM-44BPT Electrets	bronchitis		f90, Kullback-Liebler Distance
		microphones			and linear discriminant analysis
[10]	Respiratory sounds	18 piezoelectric sensors	82 patients	Posterior to the	Wilcoxon's signed-ranks test and
				patient's back	Mann-Whitney U test

# 5. Recommendation and Future Scope

Some recommendations we observed are here given with future scope discussed at last.

- a) *Type of sensor*: A good comparison of sensors used in computer base respiratory sound analysis is given in Kraman 2006[38]. In most cases, Electret microphones or contact microphone mounted on a stethoscope was used. The most important selection criteria in choosing the sensors should be its ability to acquire wide frequency range (150 to 2,000 Hz) for respiratory sound analysis. Also the sensor should have high selectivity and signal to noise ratio.
- b) Sensor position: CORSA (computerized respiratory sound analysis) and RALE (respiratory acoustics laboratory environment) provides standard for positioning the sensor for lung sound acquisition. They also provide data collection procedure that must be followed for faithful auscultation.
- c) Removing noise: The main source of noise in lung sound acquisition is heart sound. The heart sound contain the dominant frequency range which is less than 150 Hz, whereas the respiratory sounds dominant frequency range are above 150 Hz and below 2,000 Hz [39]. A well designed band pass filter would be sufficient for removing the heart sound from lung sound.
- d) *Signal processing:* There is need to apply advanced signal processing techniques in the respiratory sound analysis .as said earlier previous works have concentrated more on time and frequency domain analysis. As lung sound signals are non stationary there is need to apply time frequency analysis techniques in this field.
- e) *Feature extraction and classification*:Different feature extraction and classification techniques were used by previous researches such as Artificial Neural Network, Gaussian mixture model, Hidden Markov model, and fuzzy logic .As machine learning is gaining importance from last decade [32] there is need to apply artificial intelligence techniques such as support vector machine (SVM), genetic algorithm (GA), and optimization technique such as particle swarm optimization (PSO) in computer based respiratory sound analysis. Some researchers were successful in applying such techniques in the past [33-34] There is also need to apply hybrid model to improve classification.

# 6. Conclusion

The literature review attempts to summarize different articles in systematic way describing computer based respiratory sound analysis by previous researchers. The research is divided into two groups and then respective approach is briefly explained. The critical factors needed for successful diagnosis of lung disorders are also discussed. The overview provides strong evidence that potential exists in the field of computer based lung sound analysis though the research in this area is been carried out since last three decades there is still lot more scope for improvement. Also there is need to implement this techniques in resource poor regions of word through telemedicine application.

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