Respiratory Wheeze Sound Analysis Using Digital Signal Processing Techniques

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Abstract— Auscultation and interpretation of lung sounds by a stethoscope had been an essential method of diagnosing pulmonary diseases. However this method has always been unreliable due to poor audibility, inter-observer variations (between different physicians). Thus computerized analysis of lung sounds for diagnosis of pulmonary diseases is seen as a convenient method. In the present paper different lung sounds have been analyzed for wheeze detection and classification to Monophasic or Polyphonic using MATLAB(Matrix Laboratory software). The presented algorithm integrates and analyses the set of parameters based on ATS (American Thoracic Society) definition of wheeze and the previous researches. It is very robust, computationally simple and yielded overall sensitivity of 90% for wheeze episode detection and accuracy of 91%. The algorithm differentiates between monophasic wheezes and polyphonic wheezes with sensitivity of 91% and accuracy of 70%. In case of other lung sounds the proposed algorithm excluded normal sounds from being identified as a wheeze with the specificity of 90%.

Keywords— Wheeze properties; Respiratory Sounds; Digital Signal Processing

I. INTRODUCTION

The importance of the paper is based on the difficulty of examining patients, especially pediatrics, making it even more difficult to properly diagnose the condition and execute the treatment. The ability to differentiate between the numerous types of respiratory sounds, especially wheezes, can be one of the most important skills perfected by the physician. Understanding airway anatomy and distinguishing between upper and lower airway noises is sometimes a challenge [1].

Electronic auscultation; recording of lung sounds during normal breathing and the analysis of the lung sounds after transferring them to the computer is considered as reliable, portable, simple, non-invasive and inexpensive technique [2].

From reference [3] to reference [19] are references which have been done relatively to the present technique that guides us in the paper.

The brief review of those previous papers clarified that the detection of wheezes and the study of some of their features are not enough to diagnose the pulmonary pathology. In the present paper wheezes will be quantified and qualified. This may help the physician to locate the place of obstruction and its severity due to the features of quantifying and qualifying of wheezes. Literature reports wide frequency range for wheezes. The old ATS defined wheeze as having the pitch of < 400 Hz and the duration of 250 msec. Subsequently, the ATS Committee described wheeze occurring in adults, older children and infants as having duration of > 250 msec. Also the predominant peak frequency for wheeze was described to be 225 Hz for infants and ≥ 400 Hz for adults and older children. The virtual auscultation CD (Compact Disk) by 3M Littman mentions the duration of wheezes as ≥ 200msec and the dominant frequency of wheeze as ≥ 300 Hz for adults and 225 Hz for infants. On the other hand the predominant energy of normal lung sound lies in the frequency range of 100-200 Hz. There is neither musical character in the normal lung sound nor distinct peaks above 200 Hz [20] [21].

II. SUBJECTS AND METHODS

The methods are examined on different lung sounds which could be normal or adventitious. Anonymously lung sounds are collected from two sources. Public repositories [22] [23] [24] that are provided by online database, consist of 63 different lung sounds. Private repository from a clinic of pediatrician contains 143 lung sound files collected electronically by using stethoscope (3M Littman Electronic Stethoscope Model 3200) via Bluetooth.

The proposed approach detects and characterizes the wheezes in lung sounds by using the MATLAB. The approach consists of two stages. The first stage is respiration stage consisting of the respiration detector, the respiratory rate detector and the respiratory phase onset detector. The second stage is the wheeze stage consisting of the wheeze detector, quantifier and qualifier.

Signal transformation block is used before the respiration stage for two goals. The first goal is obtaining signal representation form that is useful for feature extraction in the respiration stage, and the second goal is removing random noise spikes in the input waveform as shown in “Fig.1”.

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The respiration detector detects regions in the acoustic signal over which breathing is present. There the respiratory rate detector computes the respiratory rate per minute and the respiratory phase onset detector detects the onset-times of each respiratory phase shown in “Fig.”2.

Fig.1.Time vs. Magnitude of the input signal, with an approximate curve manually fitted to its envelope which is the output of the signal transformation block.

The wheeze detector employs a time-dependent frequency analysis on the signal. The estimated power spectral density is done using auto regressive model by order 100. The method looks for a prominent and isolated peak in the estimated power spectral density of the signal by applying a series of threshold tests to all detected peaks in the power spectrum that lie within a specific frequency range. The wheeze quantifier detects the total number of wheezes and their onset times. The wheeze qualifier calculates the duration, mean frequency, and frequency trend of each wheeze epoch. Each wheeze epoch consists of sequential wheeze frames, where each wheeze frame equals 300msec. It also classifies each wheeze epoch as: monophonic (same pitch all over the frames or single frame in the epoch), polyphonic (different pitches all over the wheeze epoch), sibilant (high pitch mean frequency) or sonorous (low pitch mean frequency) according to the fundamental frequency of each wheeze frame that was detected as valid peak in the wheeze detector block. It also calculates the duration of total wheezing present in the signal over the entire region of interest as a percentage. The duration of that region is shown in “Fig.3”.

Fig.3. Block diagram of the wheezes analysis system.

III. RESULTS

The lung sound samples analyzed by the proposed algorithm include inspiration, expiration, monophonic, polyphonic, sibilant and sonorous wheezes. To establish the robustness of the algorithm to rule out false positives, other lung sounds are also analyzed by the same algorithm. They include normal, abnormal and other adventitious lung sounds. The results of the proposed method for wheeze file were saved as JPEG (Joint Photographic Experts Group) images, which are shown in “Fig.4” and “Fig.5”.

Fig.4. Analysis of the respiratory sound: Green: The signal vs. Time (in seconds) to know its breathing intervals, the respiratory rate and the onsets of the phases of respiration incase of wheeze sound.
Table I shows the results of the proposed approach on the World Wide Web data. The results of the approach on the data collected from the private clinic are classified according to the patients’ sex, age and respiratory lung sounds, as shown in “Fig.6”, “Fig.7” and “Fig.8”.

**TABLE I. RESULTS OF THE PROPOSED METHOD ON THE WORLD WIDE WEB DATA**

<table>
<thead>
<tr>
<th>Types of Lung Sounds</th>
<th>No. of Samples</th>
<th>Detected Correctly</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of Wheeze Sounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monophonic wheeze</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Polyphonic wheeze</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>II Other Lung Sounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Sounds</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Other Adventitious Sounds</td>
<td></td>
<td>24</td>
</tr>
</tbody>
</table>

The overall program sensitivity and accuracy for wheeze episode detection are 90% and 91% respectively. The algorithm differentiates between monophonic wheezes and polyphonic wheezes with sensitivity of 91% and accuracy of 70%.

**IV. DISCUSSION**

In the presented research wheezes in the lung can be detected as obstruction in the airways and its location may be specified by understanding the different types of wheezes. The sibilant wheeze is high pitch coming from narrow airway tube or severe obstruction. The sonorous wheeze is low pitch coming from wide airway tube or mild obstruction. The monophonic wheeze is single-tone coming from one airway tube and the polyphonic is multi-tone coming from more than one closely located. The inspiratory wheeze indicates upper airway obstruction and the expiratory wheeze indicates lower airway obstruction due to the airflow mechanism of respiration. The pathology of the patient can be diagnosed by three types of wheeze: inspiratory or expiratory, sonorous or sibilant and monophonic or polyphonic.
Continuous adventitious breath sounds are wheezes rhonchi and stridor. Stridor is most commonly a result of obstruction in the portions of the airway which are outside of the chest cavity. It is an important distinction, since obstruction of the airway within the chest cavity usually presents as wheezing.

The results of the presented research show: a higher accuracy in patients above two years of age, the sensitivity in detecting monophonic wheezes higher than polyphonic wheezes and 93% of the stridor sounds were identified as monophonic wheeze.

So far, other researchers like Hashemi and his colleagues reached 89% of accuracy in classifying wheezes to monophonic and polyphonic [13]. They used the MLP neural network as a classifier on the COPD and asthma subjects only. Their problem is the computational complexity of the artificial neural networks and the absence of normal and other different adventitious subjects. The present research solves this problem by classifying the wheezes simply using given set of parameters based on the ATS definition of wheeze. Emanet and others found that advanced analytical techniques are gaining popularity in many fields including healthcare and medicine [18]. Their classification reached about 90% of accuracy on predicting asthma. This shows that there is possibility to increase the accuracy of the presented research. This increase occurs by using two different methods. The first is increasing the number of normal and adventitious subjects. The second is using spirometry and bronchoscope to validate the presented program.

V. CONCLUSION

Physicians can use this system to help them in detection of the lung obstructive disease and it may specify the location of the obstruction in the lung according to the analysis of lung sounds. All they need to download the MATLAB compiler and run the executable file of the research program.

REFERENCES