International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 02, Issue – 05, May – 2017, PP – 36-40

Adventitious signal identification and estimation of alveolar exudates

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Abstract: Exudates are unwanted lipids propagated by blood vessel. Identification and estimation of exudates in bronchioles through the use of image processing techniques is addressed in this paper. This provides significant information that allows for an accurate diagnosis, registration, classification and visualization of bronchioles generating adventitious sound. Identifying and counting exudates of asthmatic bronchiole is carried out by image processing techniques. Simultaneously the the adventitious sound produced by the exudates is analyzed by Hilbert Huang Transform (HHT). Various morphological filtering operations are carried out on the alveolar images to segregate exudates and quantify their strength. The blobs in the spectrogram and the frequencies emphasized in HHT indicate the presence of exudates in the alveoli. HHT is very useful to analyze nonlinear and nonstationary abnormal lung sounds like crackles. Finally the first Intrinsic Mode Function (IMF) of Empirical mode decomposition (EMD) from thus obtained sound wave from alveolar exudates is plotted.

Keywords: Exudates; edge detection; alveoli; crackle;

I. Introduction

Wheezing is a chronic disease that produces adventitious sounds that is the result of a clinical expression of a lower airway obstruction and usually it is reversible. Alveolar hyper responsiveness is recorded by decreased alveolar airflow after broncho provocation. Wet air, heavy workout, viral upper respiratory infection, the smoke of cigarette and lung allergens inside and outside the house triggers and it provoke airway obstruction [1]. The main factor to develop exudates is a loss of the ciliated respiratory epithelium and the transudation of oedema fluid into the bronchial lumen. The shedding of the bronchial mucosa or in the pathogenesis of the asthmatic attack is a characteristic feature of bronchospasm [2]. Bronchioles become obstructed by organizing exudate and polypoid masses and thus determine the adventitious sound of wheezes. Specialized imaging algorithms are used to estimate the site of pulmonary emphysema in a simulation study[3]. Utmost priority must be taken to recognize exudates in alveoli to take care of public health issue and to improve management strategies like early recognition of symptoms thereby reducing the number of deaths due to exudates in alveoli. Hilbert-Huang Transform (HHT) is an excellent method for analysis of crackles, a nonlinear and nonstationary data that developed by Huang et al [6].

II. METHODS

Exudates are detected from the alveolar image using edge detection and feature estimation techniques. Exudates are brilliant lipids spilled from a vein. The replaced liquid has a tendency to remain nearby to the injury, giving the most part is characterization features.

Exudates detection in alveoli involves the following steps :

- Pre-processing an alveolar image.
- Eliminating the outer border.
- Determining circular border of an image.
- Estimating the blood vessels in an image.
- Final recognition.

A binary image containing true and false exudates are determined. Binary image removes blood vessels. After completion of pre processing, the rectangular border on an image is removed. The undesired regions like the border of the image is grouped into a logical array, which converts numeric values to logical. The next step is the detection of blood vessels. Image filtering function extracts the blood vessels and blood vessels removed image is converted into a binary image. Exudates are identified after removing all unwanted regions like blood vessels, rectangular border and circular border.

The detection of the blood vessels in an image follows the steps mentioned below. The accurate and precise removal of blood vessels which are falling outside the region of interest takes place in this step. Potential of determination of exudates potential in an image is increased further.

The following algorithm is used to remove blood vessels using morphological gradient.

Step1: Use structural elemental method with ball shape.
Step2: Apply morphological closing method with structuring elements
Step3: Store the blood vessels removed an image.

Step by step exudates region detection Methodology:

Step1: Remove gray scale circular border from the image.
Step2: Remove rectangular box border from the output of the step1.
Step3: Apply morphological filtering to identify all connected regions.
Step4: Enhance the distinction of the gray scale brightens image using histogram equalization method.
Step5: Translate the Step4 result into a binary image with the threshold value of 0.85.
Step6: Get the Dark features by inverting the result obtained in the step5.
Step7: Compute logical AND operation the Dark features with an image with Exudates produced in the step3 to remove false Exudates.
Step8: Output the Exudates.
Step9: Determine the potential exudates and calculate the pixels count on it.
Step10: Output the Number of pixels affected with the Exudates.

Exudates are identified after removing all unwanted regions like blood vessels, rectangular border and circular border [5].

A. Detection of the blood vessels in an image.

In this step removal of blood vessels which are outside the region of interest takes place and hence exudates potential in an image is estimated.

The following algorithm is used to remove blood vessels using morphological gradient:

Step1: Use strel method with ball shape.
Step2: Apply imclose method with structuring elements found in step1.
Step3: Store the blood vessels removed an image.

RGB to gray transformation can be utilized to concentrate the green channel of the picture, which leads to improved exudate differentiation. Thus green channel is extracted.

The middle channel is non-direct channel sort and which is used to decline the impact of the disorder without obscuring the sharp edge. The operation of the middle channel is orchestrating the pixel values in either climbing or sliding request and after that registers the middle estimation of the zone pixels performing Median Filtering.

A simple shape is extracted by applying threshold technique where the images are observed as a result of processing to split from the background. The variable limit is utilized for the element of brilliant injuries of the alveolar pictures.

The next pre-processing step is edge detection [5]. The popular edge detection method like the canny filter is applied after smoothing an image using low pass filter.

False Exudates separated by relabeling and edge detection are removed. All the false Exudates are wiped out as indicated by its size and area.

III. EMD And Spectrogram Interpretation

Leonard Euler introduced the identity

$$\exp(jz) = \cos(z) + j\sin(z)$$

This notation was used by Fourier in the Fourier Transform. Later Charles P. Steinmetz would use this notation to identify the complex equation of basic harmonic wave.

$$\exp(j\omega t) = \cos(\omega t) + j\sin(\omega t)$$

Equation gives bases for the FT. Gabor's equation of the Euler formula and analytic waveform.

$$\Psi(t) = \upsilon(t) + i\gamma(t)$$

These are the bases for Hilbert Transform. The Hilbert Transform is applicable to a wider class of phenomena, such as non-linear and non-stationary data. Here, the Hilbert Transformation of a function of time □ (t) is another function of time of different shape □ (t) [7]. The crackling sound is an abnormal lung sound generated during an asthma attack. The generated crackles are analyzed by HHT and spectrogram plot gives the frequency distribution. The single IMF of the crackle wave is computed and justified with the alveolar image.

IV. Results

Fig 1:Original Image

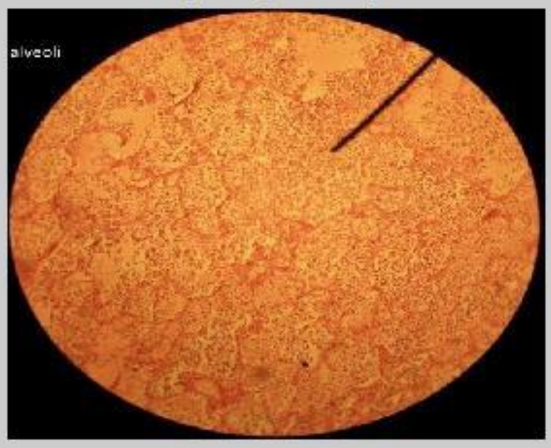
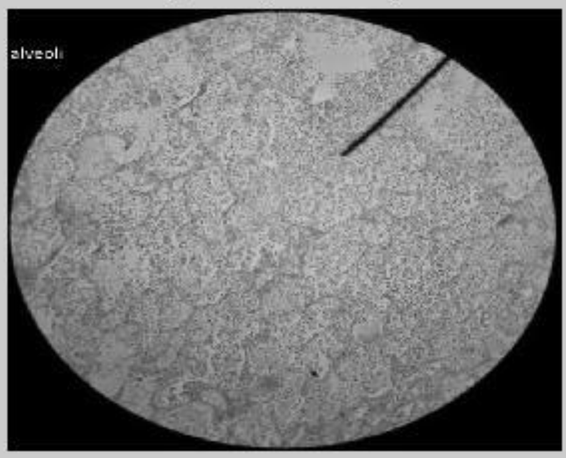


Fig. 2:Grayscale Image



The figure 1 is the original alveolar image with exudates and its gray scale image is in figure 2.The alveoli image and its grayscale image is displayed and edge detected image shown in figure 3 is thus utilised for drawing the border (fig. 4).

Fig. 3:Edge detected image

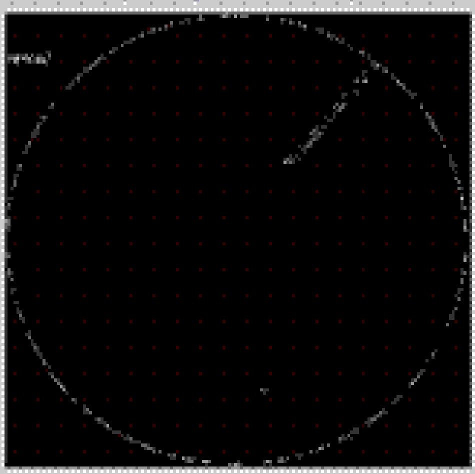
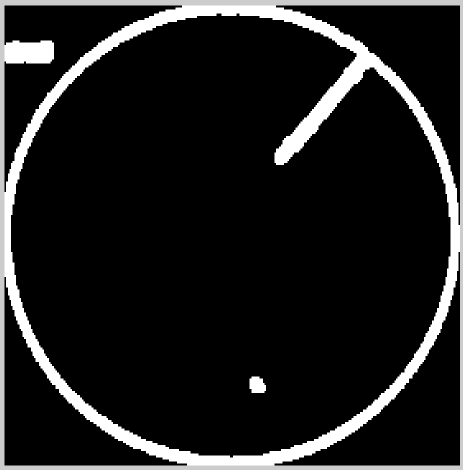


Fig. 4:Circular shaped Border



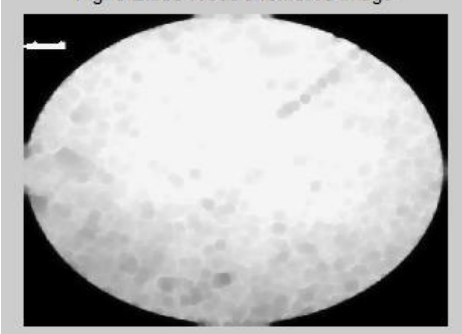


Fig. 5:Blood vessels removed image

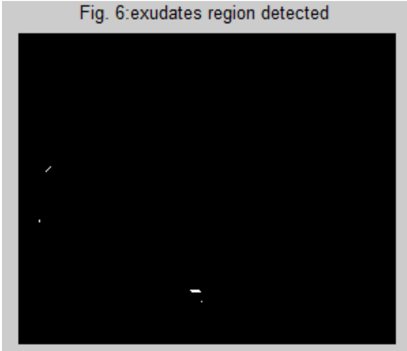


Fig. 6:exudates region detected

Figure 5 shows the blood vessels removed image which gives estimated exudates shown in figure 6. The sites of exudates are determined after removing the blood vessels. There are totally 32 exudates in the circular region of alveoli as detected by the applied algorithm. The initial IMF of crackle which is sampled at 10,000 obtained by EMD is shown in figure 7.

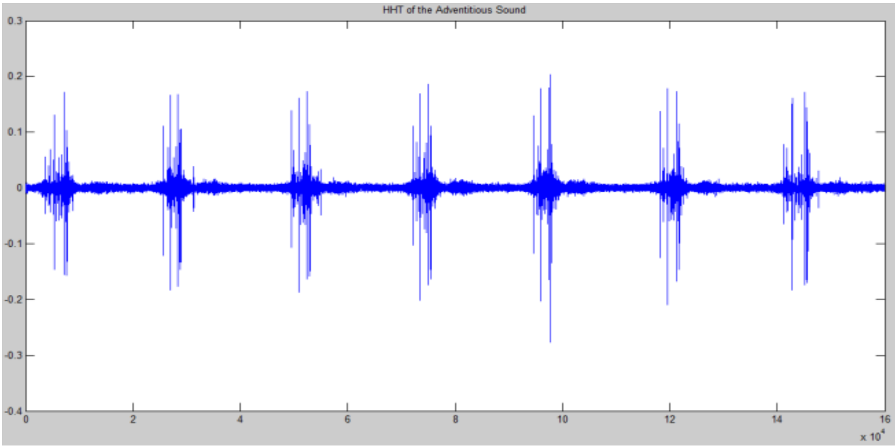


Fig. 7 – The first IMF of an discontinuous adventitious sound generated due to alveolar exudates.

The total of 90-degree phase shift (Hilbert transform filter) and spectrogram of crackles thus produced due to exudates in alveoli, time in seconds vs frequency in hertz is plotted.

The characteristic of crackle is described below. The vertical red line marks the the plotted maximum pitch of crackle at -80.46 dB and -00.955 Hz indicating maximum spike of the time plot.

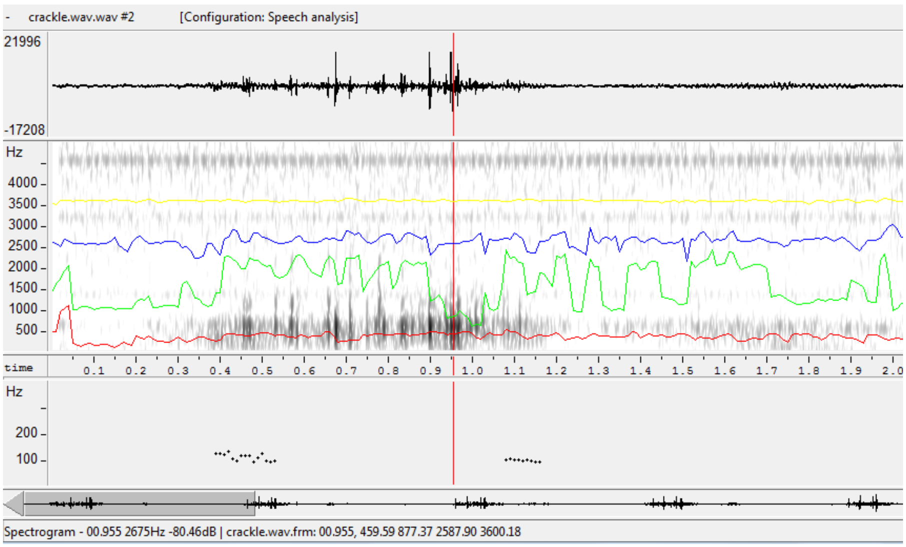


Fig. 9 – Spectrogram analysis discontinuous adventitious sound

The proposed algorithm estimates the fine and hidden exudates are estimated. The above spectrogram plot shows the blobs corrsponding to crackle sounds. These spectrogram blobs match exactly with the time plots of the recorded alveolar sounds. The total number of exudates for alveoli is identified as 32. The crackles recorded from the same subject is also analyzed using the HHT.

V. Applications And Challenges

Automatic detection of exudates in an asthmatic patient in real time is a challenging task. A fine examination of exudates which cause adventitious sound, by the specialized doctor or nurse is a difficult task, as sensitivity and specificity of alveolar exudates detection are very low. The dual advantage of the analysis of the crackles produced by such exudates and exudates detection by image processing techniques help the physician in diagnosis and patient in health management. The present work makes an attempt to fulfill the above goals. It gives an early detection of wheezing so that further procedure can be taken up by the pulmonologist.

VI. Conclusion

The present study has strongly suggested that the origin of abnormal lung sound due to exudates in alveoli can be attributed to pathological features of lungs and its bronchioles and alveoli. These exudates modify the sound property. Not all, but some types of adventitious sounds in asthma patients may occur by the same mechanism due to sudden over inflation of the lung caused by asthmatic attack. Exudates detection algorithm has achieved a reasonably good accuracy in identifying all potential exudates in an alveoli image with a maximum error of 15%. The crackles formed by exudates is analyzed as audio signal, while the visual analysis is carried out as alveolar images. The IMF thus obtained reveals the frequency details and spectrogram gives the time frequency distribution of such adventitious sound which is discontinuous gives the detailed information with respect to the wave. Further Ensemble EMD is the better approach if the data is complicated due to several exudates encountered with alveoli.

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