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Artificial Electronic Ear to Diagnose the Asthmatic and Non-Asthmatic Person

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Abstract: Many methods and techniques are used to diagnose the asthma but this mostly techniques/methods have high cost and take more time to give the result. Many researchers used signal processing to diagnose the respiratory diseases. But they have some disadvantage that some methods were more complex and some methods takes more time to give the result. The focus of this paper is to diagnose the asthma in the low cost, less time without using heavy devices and less complexity. In this paper to diagnose the asthma breath sound of humans used because affected people and normal people have different breath sound. Since breath sounds are stochastic signal, autocorrelation, magnitude square coherence etc. techniques used which is the techniques of applied statistical signal processing approaches.

Keywords-Artificial Electronic ear; exhale breath, breath sound analysis, asthma detection, statistics signal processing.

I. INTRODUCTION BREATH

Breathing develops one of the basic and crucial features for the survival of all the living beings. “Breathing is the combination of mainly oxygen, nitrogen, carbon-dioxide, inert gases and water vapour and trace amounts-parts per million by volume to parts per trillion of volatile organic compounds”, [1]. Inhalation and exhalation take place instantly one after the in a sequel. Different subject have different breathing rate according to the activity she/he into. For example, the breathing rate of the subject who is sleeping is different than when he is doing physical activity like walking, running or workout. Breathing rate decrease when the subject is stationary or in asleep,[5]. With the help of breath sound we can identify the respiratory diseases.

A. Breath sounds

We can divided breath sounds in two modes first is normal second is abnormal. These sounds come from the lungs or heart when we inhale or exhale. We can heard these sounds on using a stethoscope or simply when breathing.[1]

a) Normal breath sound
b) Abnormal breath sound

Breath sounds can specify troubles inside or around the lungs like obstructions, inflammation, or infection. An abnormal breath sound can specify fluid in the lungs or asthma. Breath sounds are an essential part of detection many different clinical conditions.

a) Normal breath sounds

Normal breath sounds are not ordinarily heard when a subject breathes. Rather, they are heard using a medical apparatus term as stethoscope. An ordinary breath sound is same as sound of air. A doctor can hear ordinary breath sounds by positioning the stethoscope on our chest, back, collarbone, and ribcage.

Some normal breath sounds are:-

- Bronchial Sounds
- Bronchovesicular sounds
- Vesicular sounds

b) Abnormal breath sounds

Some abnormal breath sounds are heard ordinarily in the case of severe. Some can only heard by the medical apparatus.

Some abnormal breath sounds are:-

- Crackles
- Wheezes
- Stridor

B. Causes of Abnormal Breath Sounds

Abnormal breath sounds are generally markers of troubles throughout the lungs. General causes of abnormal breath sounds are:

- Pneumonia
- Fluid in the lungs
- Heart failure
- Abnormally thick chest wall
- Reduced airflow
- Emphysema
- Asthma
- Bronchitis
- Lung diseases
- Foreign body in the lungs or airways

Since breath sounds detects the diseases of humans. The breath of normal person gives different sound to an abnormal person, which can be detected by many methods or techniques such as auscultation, bronchoscopy, x-ray, CT scan, spirometry, etc.and some researchers used signal processing, neural network etc. to diagnose the asthma. In this paper we propose a method which detect the asthma through breath sound of human. Using different approaches of statistics signal processing. Such as stochastics, autocorrelation, magnitude square coherence, hypothesis testing etc.

Before explaining the experimental analysis firstly we presented some concepts which are helpful to understand the analysis algorithm. Artificial Electronic Ear is the system which is based on the signal processing of sound waves and work as just same as human ear.

A. Stochastic process/stochastic approach-

In probabilistic theory, stochastic process is the collection of random variable.[2]
Definitions of a stochastic process-
Defination2:- X(t) is a cyclostationary stochastic process with period T if and only if $F_{x(t)}(x)$ is periodic in t with period T.[2]
Where
X(t) is a signal.
$F_{x(t)}(x)$ is a Fourier series.

B. Cyclostationary signal-

Cyclostationary process are process whose statistical parameters, autocorrelation and mean, follow periodicity. Therefore as it times varies autocorrelation and mean also change with periodicity. This periodicity is known as second order periodicity. Mostly stochastic process produced by technical process shows cyclostationarity.
Mathematically cyclostationary defined as
$M_x(t+T_0) = M_x(t)$
$R_x(t+T_0, r)=R(t,tou)$
Where
$R_x(t,r)=E\{x(t+(r/2))x^*(t-(r/2))\}$.[2]
$M_x(t)$ is the mean of process x(t) at time t
$R_x(t,r)$ is the autocorrelation process of x(t) with time difference r
E{.} is the expected value.

C. *Auto-correlation function*:-

Autocorrelation is the relationship between shifted cyclic frequency of the same signal. Autocorrelation is also known as second order mean. It can be defined as cross-corelation of a signal with itself. It finds the repeating pattern of signal. It is used to analyse the function or series of value. E.g. time domain signals.

D. Fourier series:-

Every periodic signal can be represent infinite number of sine and cosine

$$a_0 + \frac{1}{2}\left[\sum_{n=-\infty}^{\infty}(a_n - ib_n)e^{i\omega_n t}\right] + [\frac{1}{2}\sum_{n=-\infty}^{\infty}(a_n + ib_n)e^{-i\omega_n t})]$$

It can be evaluate as

$$F_X^{\{\alpha\}} = \sum_{n=-\infty}^{\infty} F_X^{\alpha} e^{jn\alpha t} = R_X^{\{\alpha\}} \quad [2]$$

Any periodic discrete-time signal, with a period of *N*, can be expressed as a linear combination of *N* complex exponential functions.

$$x(n)=\sum_{k=0}^{n-1} ce^{j2\pi kn/N} [2]$$

It is called discrete time Fourier series
where
$j = \sqrt{-1}$
$e^{i\theta}=\cos\theta + i\sin\theta$
Given the signal x(n) the Fourier coefficient can be calculate by

$$C_k = \frac{1}{N}\sum_{n=0}^{N-1} x(n)e^{-j2\pi kn/N} \quad [2]$$

These Fourier coefficients are generally complex-valued. They provide a description of the signal in the frequency domain. The coefficient C_k has a magnitude and phase associated with a (normalized) frequency given by
$\omega_k=2\pi k/N$

E. Cumulative distribution function:-

In statistics and probability theory, the cumulative distribution function (cdf), explains the probability that a real valued random variable X with a given probability distribution will be found to have a value less than or equal to X.
$F_X(x)=P(X<=x)$ [2]
X is the random variable
X is the mean
$P(a<X<=b)=F_x(b)-F_x(a)$
Probability lies in the semi closed interval [a,b]

F. Magnitude square coherence function:-

Magnitude square correlation function is the squaring of the magnitude of spectral correlation density function
Spectral correlation density function is $S_x^{\alpha}(f)/\ [S_x(f+\frac{\alpha}{2})\ S_x(f-\frac{\alpha}{2})]$
Its magnitude square is
$|S_{xaa}^{\alpha}(f)|^2 / [|S_{xa}^{\alpha}(f+\frac{\alpha}{2})|^2\ |S_{xa}^{\alpha}(f-\frac{\alpha}{2})|^2]$ [2]
Where
$S_{xaa}^{\alpha}(f)$ is the fourier transfer of the autocorrelation of acute asthma
$S_{xa}^{\alpha}(f+\frac{\alpha}{2})$ and $S_{xa}^{\alpha}(f-\frac{\alpha}{2})$ are the frequency shift version of x asthma.

II. PREVIOUS WORK

In the paper "A Signal Processing Approach for the diagnosis of Asthma from Cough Sounds" Mahmood Al-z to diagnose the asthma. According to this paper cough sounds are non-stationary and stochastic signals. They used time frequency transform techniques to deal with cough sound signals which shows the characteristics of the cough sound signals. Weigner distribution and Wavelet packet transform used to analyse the cough sound signals used in this paper. In this paper the time frequency domain extracted the features of cough sounds are used as classifier of asthmatic and non-asthmatic.

Their results shows that the introduced method gives 100% accuracy with the actual physician detection of asthma. They used noise free room to record the breath

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sound sample. They compare the unknown cough sound to the cough sound of similar age and gender.

In the paper "Study of Lung and Heart Diagnosis Application Based on Frequency Seperation of Breath Sound" Muhammad Sukrisno Mardiyanto et al () introduced lung and heart detection application based on frequency separation of breath sound frequency. They examine that how to separate and process the breath sound frequency into lung sound frequency and heart sound frequency. They used modulation filtering method to separate the breath sound frequency into heart sound frequency and lung sound frequency. In this paper, they study of lung and heart diagnosis application to be implemented in the diagnosis tool is investigated based on frequency separation of breath sound. They use Fourier Transform to windowing and transformed breath sound recording. They applied audio frequency to differentiate generated time-frequency modulation frequency. Therefore second transformation is applied to the temporal trajectory og magnitude component of each audio signal.
In the paper "Acoustic based Assessment of Respiratory Diseases using GMM Classification" Mayorga P. et al present a technique utilizing lung sounds for an applying evaluation of patient fitness as it associates with respiratory disorders. In order to achieve this, appropriate established methods within the speech processing field were applied to estimate lung sounds attained with a digital stethoscope. Established methods applied in the analysis of asthma include spirometry and auscultation, but on applying more perceptive electronic stethoscopes, which are presently available and application of computable signal analysis methods propose prospects of improved detection. They introduce an audio analysis methodology based on the Gaussian Mixed Models (GMM) which should support in wider analysis, recognition, and detection of asthma based on the frequency domain evaluation of wheezing and crackles.

III. EXPERIMENTAL ANALYSIS

In this section, the experimental analysis which obtained by applying the statistical signal processing. The breath sounds were recorded with the help of microphone and laptop at the sampling rate of 44100 Hz. It is more than the twice of maximum frequency of the audible sound. Therefore it is enough to capture all the information embedded in signal.

The recording took place with noise free box at SMS hospital Jaipur. 25 samples of asthma patient were taken through random sampling. The training and testing done by different set of volunteers. Before explanation of experiment we presented few concepts which are helpful to understand the experimental analysis.

All manmade signals exhibit periodicity (periodicities) with respect to one or more than one statistics such as mean, variance, second order mean etc. Therefore applied stochastic approach on this data by the definition of stochastic approach if $F_{x(t)}(x)$ is periodic in t with period T then this stochastic process is a cyclostationary process.

where
$F_{x(t)}(x)$ is a fourier series
According to the autocorrelation function
$R_x(t,r)=E\{x(t+(r/2))x^*(t-(r/2))\}$
$R_x(t,r)$ is the autocorrelation process of x(t) with time difference r.
E{.} is the expected value.

Since, it is known that any periodic function can be represented using Fourier series, therefore, the probability space autocorrelation function is given as

$$R_X^{\{\alpha\}} = \sum_{n=-\infty}^{\infty} R_X^{\alpha} e^{jn\alpha t} = R_X(\tau)$$ [2]

Where, R_X^{α} are the Fourier coefficients of individual components at different cyclic frequencies, α .Furthermore, these Fourier coefficients are equal to the CDFs (Cumulative Distribution Functions) evaluated at different sampling instants and hence we can re-write the above equation as:

$$F_X^{\{\alpha\}} = \sum_{n=-\infty}^{\infty} F_X^{\alpha} e^{jn\alpha t} = R_X^{\{\alpha\}}$$ [2]

Where, F_X^{α} is a Cumulative Distribution Function which is defined as

$$F_X^{\alpha} = Prob[X(t+\tau) < x]$$ [2]

Therefore, probability space autocorrelation function can also be found out by calculating Cumulative Distribution Function at every sample of a sampled signal. If this autocorrelation function is periodic then it is called cyclic autocorrelation function and shows the presence of a signal.

The fast fourier transform (FFT) of autocorrealion shows the frequencies in sample or population is periodic or polyperiodic. It shows in this sample that this sample is periodic.
To diagnose that the random sample is asthmatic or non-asthmatic
Magnitude square coherence value applied
$|S_{xaa}^{\alpha}(f)^2| / [|S_{xa}(f+\frac{\alpha}{2})|^2 \, |S_{xa}(f-\frac{\alpha}{2})|^2]$

Where
$S_{xaa}^{\alpha}(f)$ is the fourier transfer of the autocorrelation of acute asthma
$S_{xa}^{\alpha}(f+\frac{\alpha}{2})$ and $S_{xa}^{\alpha}(f-\frac{\alpha}{2})$ are the frequency shift version of x asthma.

The ratio of magnitude square of frequency shift version of set of samples set and magnitude square of acute asthmatic sample. It gives the magnitude square correlation of statistics of sample set.

Then with the same procedure applied for the random sample or random person which we want to define the person is asthmatic or not. For this magnitude square correlation is calculate with the ratio of magnitude square

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of acute asthmatic sample to magnitude square of random sample which we want to define with frequency shift version. In the last step applied hypothesis testing. In hypothesis testing distribution of data should be known. To know the distribution fit test applied in Matlab.

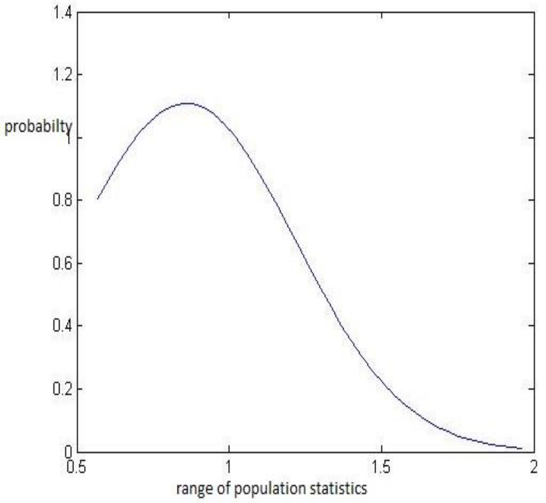

Fig 1 graph of normal distribution

Showing this graph we analyse that this is a normal distribution. Now z-test applied to calculate the hypothesis which gives the value zero or one. it means the value of random patient is lie in which region null hypothesis region or rejecting the null region.

If the result of null hypothesis is zero, it means it lie in the region of null hypothesis. If hypothesis is true or value is one, it means it reject the null hypothesis. In this experiment null hypothesis means the patient is not asthmatic. And rejecting the null hypothesis means patient is asthmatic. We saved the each function result in matlab to reduce the complexity and time to give output in less time.

Experimental setup

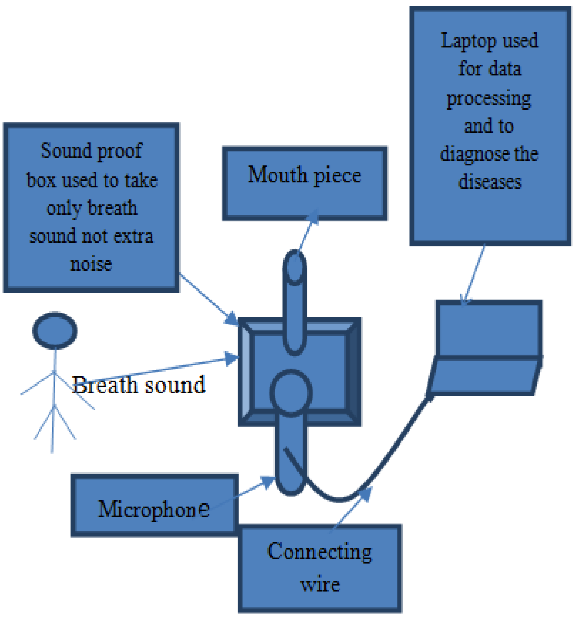

Fig. 2 Experimental setup

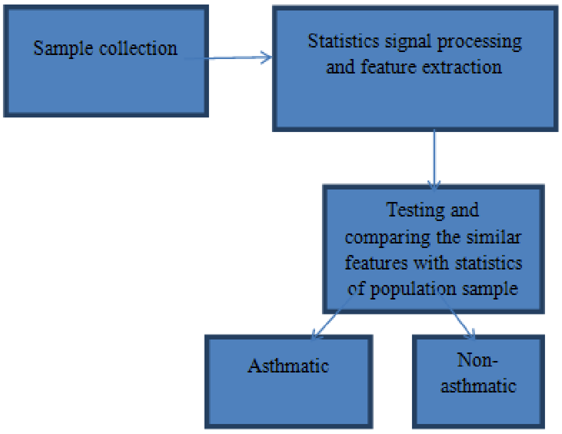

Fig. 3 asthma diagnosis system overview

For an unknown breath sound to undetermined health status, the characteristics are extracted and used to discriminate that breath sound is asthmatic or non-asthmatic. The inputs can be of any types male, female, can be of any age such as children, old, young etc. The extracted characteristics are compared with the statistics characteristics. Since the characteristics of asthmatic person and non-asthmatic person have different in breath sound. In the last result of the system categorised as the person is asthmatic or non-asthmatic. Fig. 2 and 3 shows the levels of asthma detection from breath sound based on characteristics extraction and classification.

IV. CONCLUSION AND DISCUSSION

In this paper, a new method for detecting asthma from breath sound using statistical signal processing was discussed. The introduced method was to detect the asthma from breath sound using stochastic approach, autocorrelation, magnitude square correlation and hypothesis to define the patients breath sample is asthmatic and non-asthmatic.

This method to diagnose the asthma gives the almost 100 per cent accuracy with the real physician diagnosis. To reduce complexity statistics result of each function saved to direct call in matlab workspace. Which reduce the time and complexity both. This whole experiment shows that asthma can be diagnose through breath sound of person on using statistical signal processing approach.

To analyse the result we test the system with different statistics such as we used 10, 20, 25 and 36 statistics sample population for testing. In which we analyse that on increasing the sample statistics accuracy and performance also increases. Still it requires more testing and analysis to increase the accuracy and performance.

To increase the accuracy the number of sample in population should be increase. Because more population statistics more accuracy and performance. It is analyse by the experiment. More ever more studies should be requiring recording the exact breath sound, to give the better hypothesis testing and to discriminate the level of asthma.

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