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# Acquisition and analysis of lung sounds for classification of asthma severity

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**Abstract**

**Introduction and Aim:** Abnormal breath sounds like wheezes are observed in patients with lung disease.The most common cause of recurrent wheezing is asthma attacks.

**Materials and Methods:** Current methods make use of spirometer and peak flow meter techniques for severity classification which can be applied only for adults since it requires forced breathing. Hence this study aims at overcoming the drawback by classifying asthma severity based on wheeze sound analysis and also thrives to acquire sound signals in a cost-effective manner.In this proposed work,unique, simple, piezoelectric ceramic plate (PES) is used to record the lung sounds. The signals are acquired using LabVIEW software for further analysis.

**Results:** Analyses of these sounds are carried out using multiresolution analysis. The obtained lung sounds are pre-processed by means of specific filters to obtain wheeze sounds which are then used for a feature extraction process using Mel-frequency cepstral coefficients (MFCC). The extracted features are then evaluated by the MFCC features which are then subjected to a classification process using the K-nearest neighbour (KNN) and Support vector machine (SVM) algorithm for the classification process.

**Conclusion:** The performance of the two classifiers are compared and evaluated to obtain the best result. Thus, asthma severity is classified into mild, moderate and severe levels and can be used as an effective diagnostic process.

**Keywords:**Piezo electric sensor, MFCC, K-NN, SVM.

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## Introduction

Asthma is a vital health concern worldwide. It is one of the most common long-term diseases of children as well as in adults. Asthma causes wheezing; breathlessness, chest tightness, and coughing at night or early in the morning. Triggers in the environment cause the airways to be sensitive which leads to swelling, increased

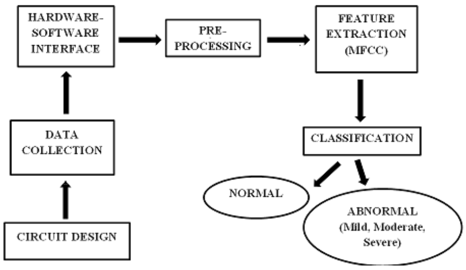


**Fig 1. Block Diagram for Acquisition and Analysis of Lung Sounds for Classification of Asthma Severity**

production of mucous and spasms of the bronchial tubes. An asthma attack mayinclude coughing, chest tightness, wheezing, and trouble breathing. Acquisition and Analysis of Lung Sounds for Classification of Asthma Severity consists of five stages. First stage is to design a circuit for acquisition of lung sounds. A combination of amplifiers and resistors are used for this. Next stage is to collect data from both normal and abnormal subjects. The collected data are interfaced using DAQ and is pre-processed in the LabVIEWsoftware. Next stage consists of obtaining the Mel-Frequency Cepstral Coefficients. The coefficients are obtained using MATLAB code. From the obtained coefficients, statistical features were calculated for performing the classification. The obtained features were given to the classifier[2]. The classifier classifies the data based on feature vectors into normal and abnormal data with respect to severity levels of mild, moderate and severe. Finally, the efficiency of the classifier has been determined by means of comparing the resultant output.

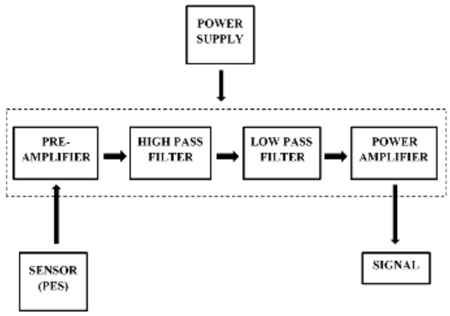


**Fig 2. Signal Conditioning System**

The hardware design of the electronic lung sound acquisition system is composed of power supply, sensor, preamplifier, high-pass filter, low-pass filter and power amplifier[1]. The basic circuit of amplifiers designed for the acquisition of breath sounds using AD620 amplifier and other operational amplifiers.

The hardware design of the system comprises of the following components,

- Sensor - Piezo electric ceramic plate
- AD620 (Instrumentation amplifier)
- IC741 (Operational amplifier)
- Resistor (10k Ω,1k Ω,100k Ω)
- Capacitor (0.1μf)

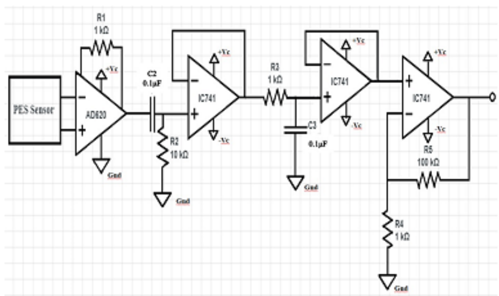


**Fig 3. Signal Conditioning Circuit**

**Hardware-software interface**

The signal is obtained via interfacing the circuit with the software using DAQ. Data acquisition systems, abbreviated by the acronyms DAQ, convert analog waveforms into digital values for processing.

The components of data acquisition systems include:

• Sensors that convert physical parameters to electrical signals.

• Signal conditioning circuitry that convert sensor signals into a form which can be converted to digital values.

• Analog-to-digital converters that convert conditioned sensor signals to digital values.

**Preprocessing**

Preprocessing is done using LabVIEW software by means of signal processing toolkit. The detection of lung sounds is done by the multiscale product of wavelet approximation coefficients. Multiresolution analysis is used for this purpose.

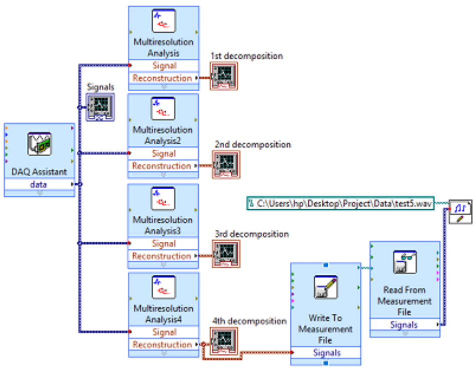


**Fig 4. Block diagram for lung sound detection**

Wavelet deformation is done on this signal in order to obtain the specific range of frequency. As the Multiresolution Analysis VI decomposes the signal according to the level we specify, it reconstructs the signal from the frequency bands that we select. Four scales were used in the wavelet decomposition with the fourth order Bior1_3 wavelet as the mother wavelet.

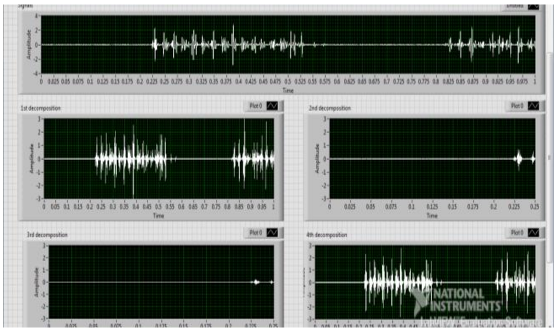

**Fig 5. Decomposed signal**

**Obtaining mel-frequency cepstral coefficients**

A Matlab code is executed to obtain the MFCC coefficients. In sound processing, the mel-frequency cepstrum (MFC) is a representation of the short-term power spectrum of a sound, based on a linear cosine transform[3, 4] of a log power spectrum on a nonlinear Mel scale of frequency.

It provides a parametric representation of the biological signals of speech. MFCCs are commonly derived as follows:

• Take the Fourier transform of (a windowed excerpt of) a signal.

• Map the powers of the spectrum obtained above onto the mel scale, using triangular overlapping windows.

• Take the logs of the powers at each of the mel frequencies.

• Take the discrete cosine transform of the list of mel log powers, as if it were a signal.

• The MFCCs are the amplitudes of the resulting spectrum.

**Feature extraction**

Features are extracted using MFCC by executing the MATLAB code.

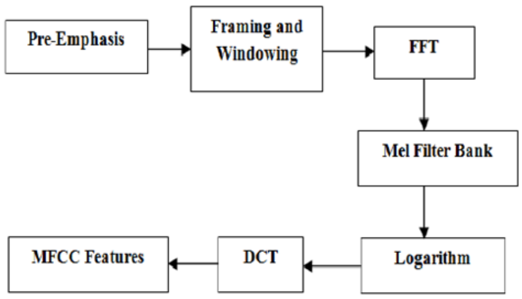


**Fig6. Block diagram for obtaining MFCC features**

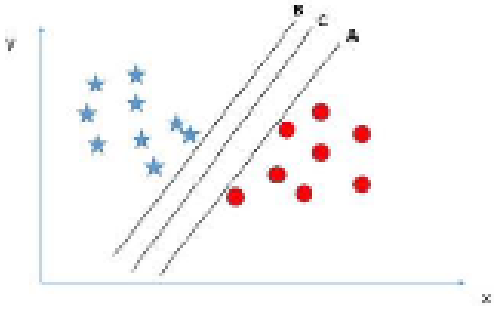

**Fig7. Linear SVM**

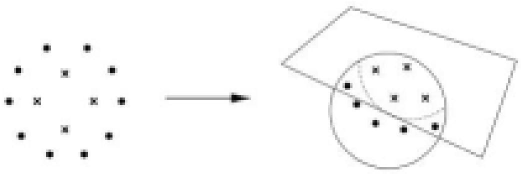

**Fig8. Non-linear SVM**

### Classification of severity levels

### Classifiers

SVM and KNN classifiers are used to classify the severity levels and a comparison is made on their efficiency.

### Support vector machine

Support Vector Machine is a supervised machine learning method that is widely used for data analysing and pattern recognizing [5]. It is used when the data has exactly two classes. SVM constructs a hyper plane or set of hyper planes in a high or infinite-dimensional space, which can be used for classification. An SVM classifies data by constructing the best hyper plane that separates all data points of one class from those of other class.The hyper plane is capable of separating the two classes into two, through a straight line then it is known as linear SVM. If there is no possibility for separating the two classes through a linear hyperplane then an irregular shaped hyperplane is created. It is known as non-linear SVM.

### K-nearest neighbour

The k-nearest neighbour algorithm (k-NN) is a non-parametric method used for classification. The input consists of the k closest training sets in the feature space.

In k-NN classification, the output is a class membership. An item is classified by a majority vote of its neighbours, with the object being assigned to the class most common among its k nearest neighbours. The nearest neighbour is determined based on the measure of Euclidean Distance and the City Block Distance. Here Euclidean distance is used.

### Classification

The classification learner app is used for training and classification purposes. The Classification Learner app trains models to classify data. Using this app, we can explore supervised machine learning using various classifiers [6]. We can explore the data, select features, specify validation schemes, train models, and assess results. We can perform automated training to search for the best classification model type, including decision trees, discriminant analysis, support vector machines, logistic regression, nearest neighbours, and ensemble classification.

We can perform supervised machine learning by supplying a known set of input data (observations or examples) and known responses to the data (e.g., labels or classes). We use the data to train a model that generates predictions for the response to new data [7,8]. To use the model with new data, or to learn about programmatic classification, we can export the model to the workspace or generate MATLAB code to recreate the trained model.

Functions used are,

1. *Kurtosis* - This MATLAB function returns the sharpness of the peak of a frequency-distribution curve.
2. *Moment* - This MATLAB function returns the central sample moment of X specified by the positive integer order
3. *Mean* - This MATLAB function returns the mean of the data samples
4. *Standard Deviation* - This MATLAB function returns the square root of variance of the data.

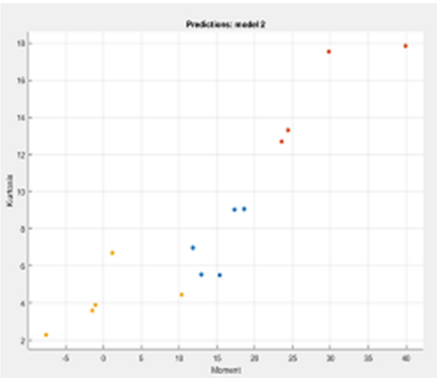

**Fig9. Trained SVM plot**

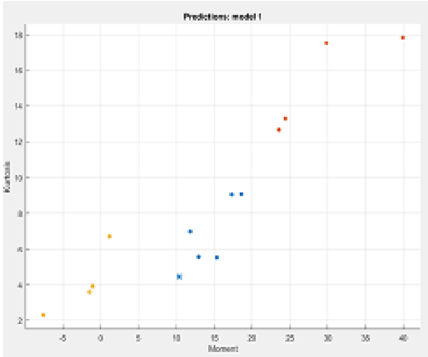

**Fig10. Trained k-NN plot**

**Results and discussion**

In this project, 20 lung sound data were acquired from patients of the Asthma Studio (Pulmonology Clinic) out of which 5 were normal and 15 were abnormal. Data were acquired from 20 subjects with and without asthma. Fig.12 shows the output of the original signal acquired from normal subject and Fig.13 shows the output of the original signal acquired from asthmatic subject.

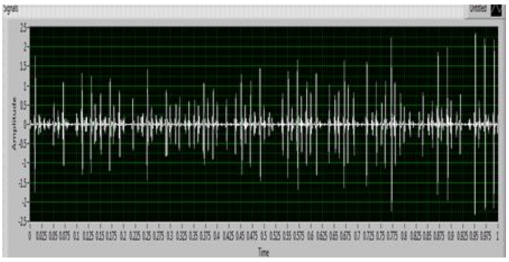

**Fig11. Original signal acquired from normal subject**

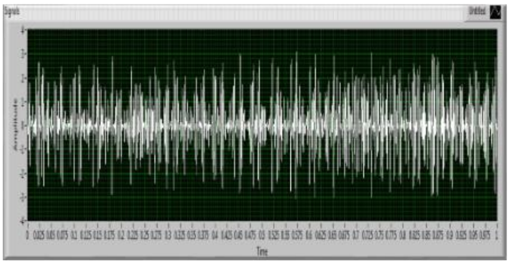

**Fig12. Original signal acquired from asthmatic subject**

After acquiring the lung sounds, multiresolution analysis was carried out by means of wavelet decomposition upto fourth order in order to detect lung sounds without any noise interference. Wavelet transform can characterize the local regularities of the signal. Thus Fig.13 and Fig.14 shows the final level of decomposition for normal and asthmatic subject respectively.

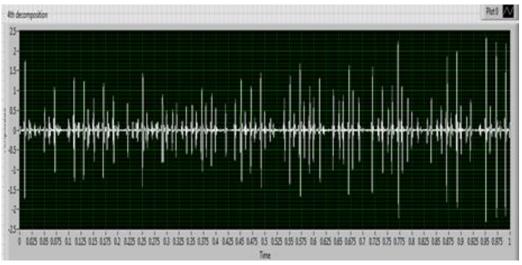

**Fig13. Final level decomposition-Normal subject**

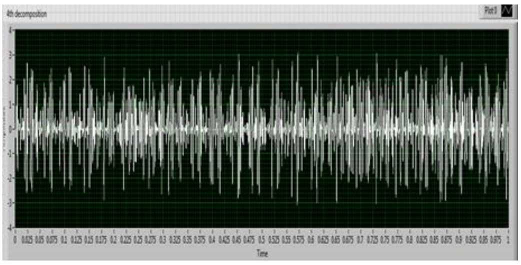

**Fig14. Final level decomposition-Asthmatic subject**

Mel Frequency Cepstral Coefficient algorithm was implemented to obtain feature values. Fig.14 shows the resultant plot for the acquired lung signal and the respective mel frequency cepstrum. In this analysis 13 coefficients of MFCC were computed for feature extraction and from those coefficients kurtosis, moment and mean values were calculated for all the subjects which are tabulated below in Table 1.

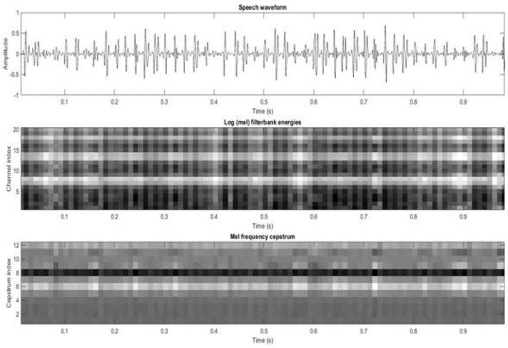


**Fig15. Mel Frequency Cepstrum of acquired lung signal**

| SUBJECT | MOMENT | KURTOSIS | MEAN | RESPONSE |
|---|---|---|---|---|
| 1 | 15.354 | 5.501 | 1.355 | Normal |
| 2 | 12.947 | 5.54 | 1.287 | Normal |
| 3 | 17.342 | 9.036 | 1.282 | Normal |
| 4 | 18.604 | 9.065 | 1.365 | Normal |
| 5 | 29.817 | 17.54 | 1.307 | Moderate |
| 6 | 39.932 | 17.845 | 1.345 | Moderate |
| 7 | 23.576 | 12.695 | 1.363 | Moderate |
| 8 | 24.408 | 13.314 | 1.312 | Moderate |
| 9 | -7.583 | 2.29 | 3.63 | Severe |
| 10 | -1.46 | 3.597 | 2.64 | Severe |
| 11 | 1.17 | 6.7 | 3.8 | Severe |
| 12 | -1.04 | 3.9 | 2.9 | Severe |

***Table.1 Feature values***

The table describes the different feature values for around 12 subjects with the expected response. These values are used as training data in the later process of classification. The set of vectors from the MFCC features were used as the input for the classifier. After training the model, test data are given to the prediction function command to obtain the desired result in terms of normal, moderate and severe. The classification results for the detection of the asthma severity level tested for 5 subjects are shown in Table.2

| SUBJECT | KNN CLASSIFIER | SVM CLASSIFIER | EXPECTED RESPONSE |
|---|---|---|---|
| 1 | Normal | Normal | Normal |
| 2 | Moderate | Moderate | Moderate |
| 3 | Severe | Severe | Severe |
| 4 | Normal | Moderate | Normal |
| 5 | Normal | Moderate | Normal |

***Table.2 Classified output***

## Conclusion

The objective of lung sound acquisition and analysis is to bring about improvements to monitoring and diagnosis of respiratory disease in particular, asthmatic condition. The design of the circuit is simpler when compared to previous works related to the classification of asthma severity. This method did not add any noticeable artifacts to the constructed signal. Furthermore, the proposed technique for the acquisition of lung sounds is far easier than any other acquisition methods. Also, the calculation of Mel frequency cepstral coefficients and usage of classifiers gives an immediate result for classification within minutes. The placement of the sensor does not cause any discomfort to the patient while acquiring. Also, no direct supply of power is required since batteries are used. This provides no risk of shock and also data can be collected as and when required. With the existing techniques, the clinicians cannot conclude upon the severity level without prescribing expensive tests. But this method is cost effective and gives the severity classification easily. Also, most available techniques do not apply to children aged below 10. But this proposed technique for the acquisition and analysis of lung sounds is applicable to all age groups. Thus, in this project, when classified, it is found that K-NN has better accuracy of 97.4% in classifying asthma severity. In future, this study can be used in classification of commonly misdiagnosed respiratory diseases. This may also be used as a tool for pulmonary research. Other than asthma, diseases like COPD (Chronic obstructive pulmonary disease) can also be classified based on this paper.

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