

Respiration Rate Measurement: A Digital Signal Processing Approach

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Abstract: *This paper presents development of a Digital signal processing Algorithm to measure respiration Rate by using chest impedance signals. And Chest Impedance technique is used to acquire the respiratory data from a subject using two Ag/Ag-Cl electrodes. An ADS1292R Analog to Digital Converter Hardware which collects data from subject when chest impedance of subject changed. A signal processing Algorithm mainly consist of Digital filtering, Polynomial curve-fitting and Peak Detection Logic for respiration rate Measurement with relative accuracy.*

Index Terms - *Respiration Rate, Digital Signal processing, Ag/Ag-Cl electrodes, Digital filtering, Polynomial curve-fitting, Peak Detection.*

1. Introduction

Respiration rate (RR) is a vital parameter in monitoring an individual's health condition and can be used for the prediction of various health crises. The respiration rate of a normal adult individual is in the range of 10-16 breaths/minute. Based on the degree of requirements, respiration rate can be measured in different ways, such as inductive, resistive, thermistor, pressure and impedance type [2]. In this project, Impedance Pneumography technique is used to acquire the respiratory data from a subject using two Ag/Ag-Cl electrodes. The primary focus of this project is to develop a signal processing algorithm to measure the respiration rate non-invasively for continuous health monitoring.

1.1 Present Day Scenario and Motivation

Some of the techniques like thermistor and strain gauges have been used in the past for obtaining the respiration rate, but these methods failed to give accurate measurements. The volume can be accurately measured by using spirometry and pneumotography, but these techniques are not supported for continuous and ambulatory monitoring of subjects. Now a day, for long term continuous monitoring of respiration rate, an impedance technique is used. It is a bio-impedance recorder for respiration rate measurement. Without the use of any specific sensors respiration data can be acquired by using Ag/Ag-cl electrodes.

1.2 Objective of the Project

Various techniques which make use of thermistor and strain gauges have been used in the past for obtaining the respiration rate. However, these methods failed to give accurate measurements. Spirometry and pneumatography are not suitable for continuous monitoring of respiration rate. So, Impedance pneumography technique is used. The main objective of this work is to design a signal processing algorithm for continuous health monitoring of an individual by non-invasive measurement of respiration rate.

1.3 The mechanics of Breathing

Breathing is a process that involves inspiration and expiration. Many different muscles are involved in the breathing process. Diaphragm is the largest muscle that assists in the breathing action. The diaphragm is situated below the lungs and separates it from the stomach. The lungs expand when diaphragm moves downwards, this is called inspiration or inhalation. As the diaphragm relaxes the air is exhaled out of the lungs bringing it back to its original position. This process is called expiration or exhalation.

During inspiration, there is increase in the intrapleural space and an increase in negative pressure. Chest volume expands, and the diaphragm is flattened. During Expiration, the pressure in the lungs is higher than that of the atmosphere; this causes air to move out of bronchioles, through airways and to the atmosphere. Chest volume reduces, and the diaphragm is in a dome shape. The figure 1.3 shows the mechanism of breathing and Electrode placement.

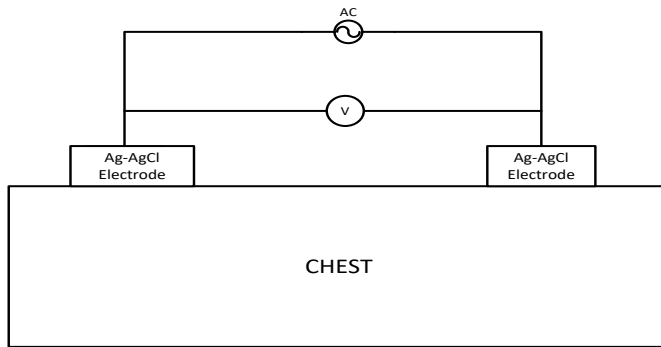


Figure 1.3: Two electrode arrangement for respiration rate measurement

2. Methodology

This chapter explains the various steps involved in the respiration rate measurement. The various steps include data acquisition, filtering, curve fitting and peak detection.

2.1 Block diagram for respiration rate measurement

The respiration rate is measured in accordance with the thoracic impedance of the chest, using ADS1292R data acquisition system. An alternating current in the range of milli Amperes is injected into the right and left sides of the chest. This current acts as the carrier. The Ag-AgCl electrodes pick up the signals from the chest during both inspiration and expiration. The current causes a potential difference across the Ag-AgCl electrode skin interface as a result a voltage drop occurs at the Analog-to-Digital Converter (ADC) interface. A signal processing algorithm is developed to measure respiration rate which includes pre-processing, curve fitting and peak detection. The basic block diagram for the respiration rate measurement illustrated in the Figure 2.1.

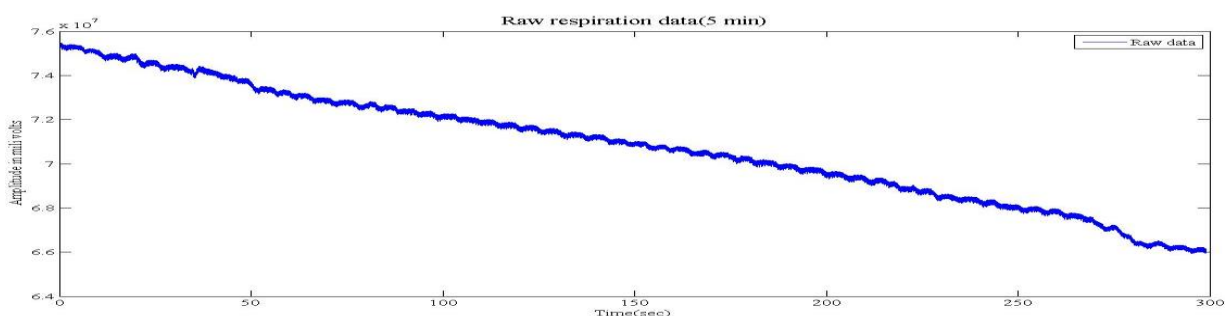


Figure 2.1 Block Diagram for respiration rate measurement

2.2 Data collection

Respiratory data is collected from 10 normal subjects at DEBEL, DRDO Bangalore. The data is collected in three different positions namely sitting, standing, and supine. Two electrode arrangements were used to collect data. Ag-AgCl electrodes were placed at the right side and left side of the chest. A voltage drop occurs in ADC due to chest impedance, this drop-in voltage is the output of ADC [1]. This acquired data is transmitted serially to the PC through data cable using serial peripheral interface. The data is collected for 5mins in sitting, standing, and supine positions. The collected data is analysed using MATLAB Software. The collected raw respiratory data is shown in figure 2.2

Figure 2.2: Raw respiratory data (5minutes)



2.3 Noise in Respiratory signals

The respiratory data contains base line wandering, power line interference and motion artifacts.

2.3.1 Base line Wandering

The wandering of base line is mainly due to the gross movements of the subject and the mechanical strain on the electrode wires. Base line drift arises due to the improper contact between electrode and skin [1][3]. The base line wander are low frequency components ranging from 0.15Hz to 0.5 Hz.

2.3.2 Electrode contact noise

This noise occurs due to improper contact between electrode and skin. In some cases, electrode itself becomes a source of noise [3]. The electrode contact noise can be made as randomly occurring rapid baseline transition. Figure 3.8 shows that the data decays exponentially because of electrode contact noise.

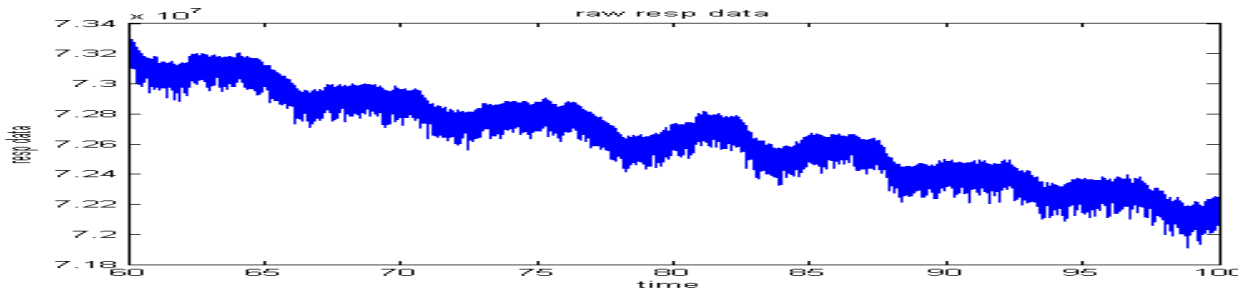


Figure 2.3: The data decays exponentially because of electrode contact noise

2.3.3 Power line interference (PLI)

Power line interference is centrally located at 50 Hz and it has bandwidth which is less than 1 Hz. Power line interference (PLI) is a disturbance elevating while measuring bio-potential. PLI mainly occurs in 50Hz power lines [9]. A 50 Hz notch filter is used to remove the power line interference. The frequency bandwidth between 0.1 to 3 Hz is preferred while implementing the project.

2.4 Digital filtering

The IIR filter was designed for the following specifications: Order $N=1$, Sampling rate (fs) = 125 sps and Cut-off frequency (f_c) = 0.1 Hz. And the FIR filter was designed for the following specifications, Order: $N=128$, Sampling rate: $fs=125$ sps & Cut-off frequency $f_c= 3$ Hz.

Both filters are implemented using the MATLAB functions and used the same for filtering purpose.

2.5 Polynomial Curve Fitting

After applying Filters to the raw data, a signal with frequency of 0.1 Hz to 3 Hz is obtained. The main aim is to count the number of peaks in the filtered data. The filtered data did not have smooth curves to detect peaks. Instead of going directly for peak detection, curve fitting method is used to smoothen the filtered data. **Polyfit** and **polyval** are the two inbuilt functions in MATLAB which are used to fit a polynomial to a set of data points quickly and easily. The best fitted data is obtained by first order polynomial linear equation. A polynomial can also be used to fit the data in a quadratic sense. The general formula for a polynomial is:

$$f(x) = a_0x^N + a_1x^{N-1} + a_2x^{N-2} + \dots + a_{N-1}x + a_N \quad (1)$$

The coefficients of the polynomial are obtained by using POLYFIT function (which can be used to simulate a curve to fit the data) according to the degree used. POLYVAL generates a curve to fit the data based on the coefficients found using POLYFIT function [5]. The degree of a polynomial is equal to the largest value of the exponents of the independent variable x . In this project 12th degree of polynomial is used for curve fitting of the filtered data.

2.6 Peak Detection

The peak detection is performed by using the Turning point algorithm [6]. Turning point algorithm is simple and faster. A simple mathematical criterion is used to find positive or negative slopes shown in equation 1.

$$\text{Slope} = \begin{cases} 0 & x = 0 \\ +1 & x > 0 \\ -1 & x < 0 \end{cases} \quad (1)$$

If the slope is zero, then the output is zero. For positive and negative slopes it yields +1 and -1 respectively. The turning point occurs only when turns change from positive to negative or vice versa [6]. Here the peaks which are within 1 sec were ignored. This is a repetitive process for a long set of data. The respiration rate is updated for every ten seconds. For this work we used MATLAB function called **findpeaks** for detecting peaks in the signal.

2.4 Algorithm Flowchart

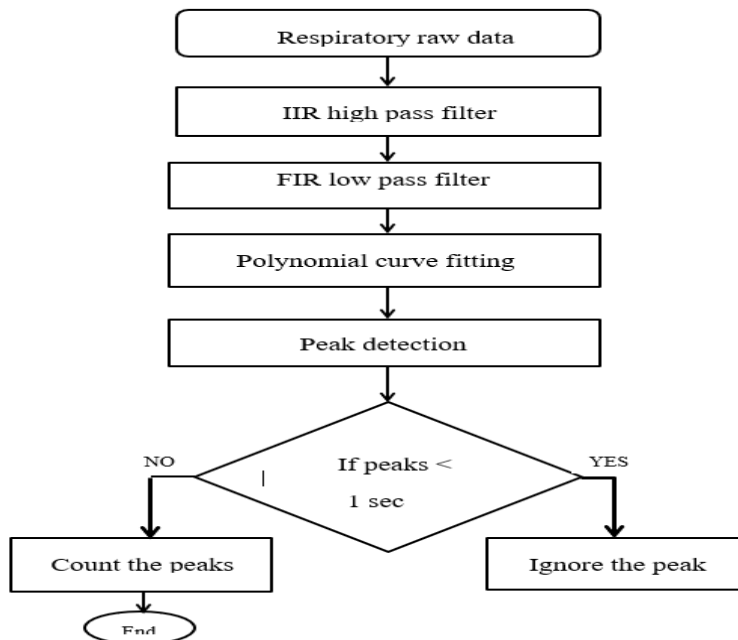


Fig 3.14 Flow diagram for respiration rate measurement

3. Results and Analysis

This chapter presents the results of the respiration rate measurements. The results include respiration rate calculated for standing, sitting and supine positions. The respiration rate is obtained successfully in all three positions for a normal subject in the laboratory.

3.1. Digital filtering:

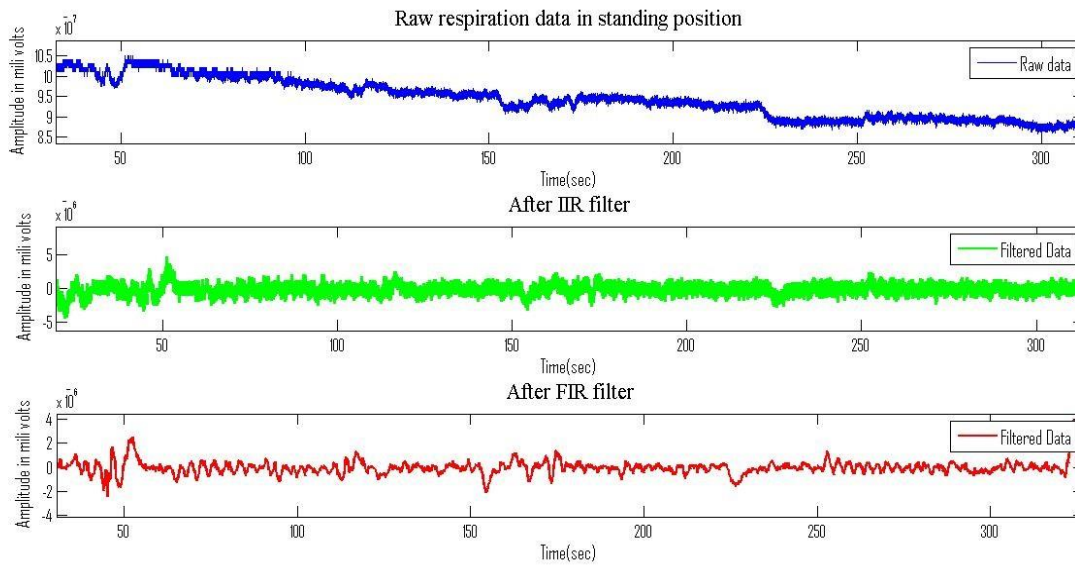


Figure 3.1: Filtering output in standing position

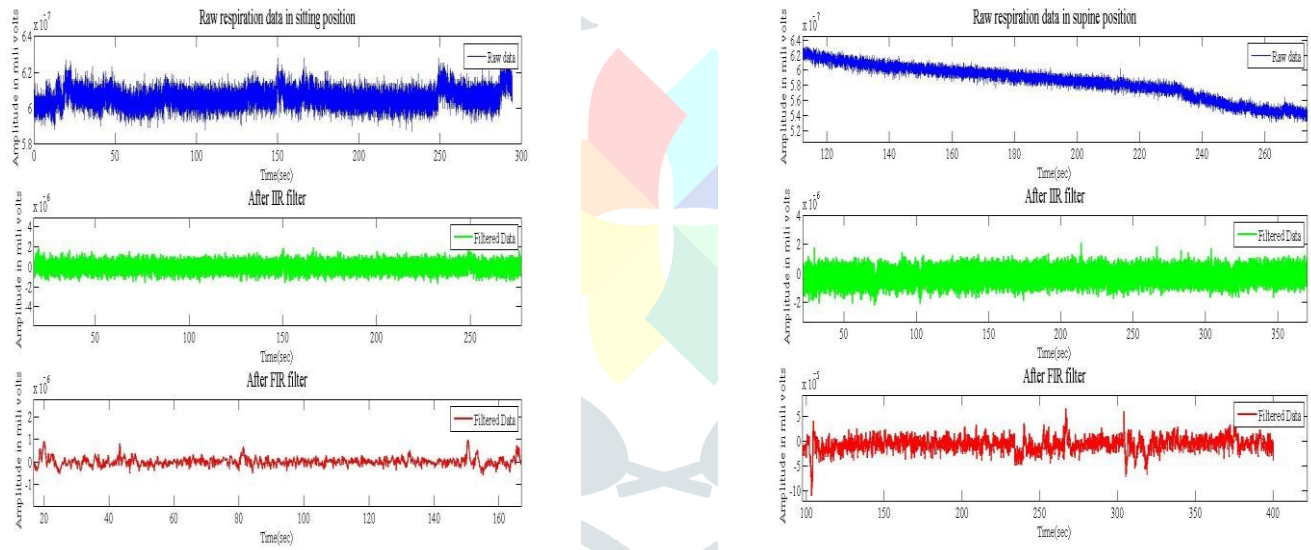


Figure 3.2: Filtering output in sitting and supine position

3.2. Curve Fitting:

After filtering, curve fitting is performed by choosing a polynomial of degree 12. Curve fitting is performed for one minute of filtered data taking three windows of 20 sec each in all three positions: standing, sitting, and supine.

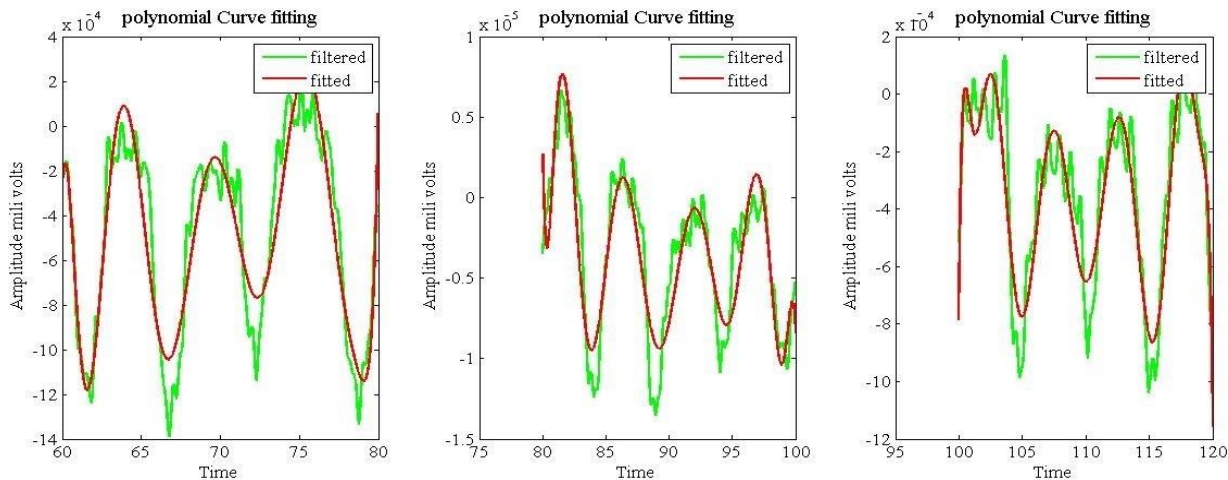


Figure 3.2 over plot of one min filtered and curve fitted data

3.3. Peak detection and Total respiration rate count/min

Each turn happens from positive to negative values, counted the number of turns per minute and found the Average Respiration rate of 12 to 14 per minute. Logic of peak detection explained in 2.6

4. Conclusion and future scope

Respiration rate is an important vital parameter to monitor patient health. The rate is controlled by medulla oblongata and pons of the brain. Here, the respiration rate measurement was carried out non-invasively using Chest Impedance technique. The ADS1292R ASIC was used for the data collection. The hardware consists of two channels for acquiring ECG and Respiration. However, this project is limited to respiration measurement. The data was collected from subjects using two Ag-AgCl electrodes. The recorded data was then processed using MATLAB. An algorithm was developed to remove the artifacts from the respiratory data for the detection and counting the no. of peaks. The data was collected for ten subjects and the individual respiratory rate was measured successfully. This technique is suitable for non-invasive and continuous monitoring of respiration rates in three positions: sitting, standing and supine position. The average respiration rate of an individual in three positions is shown in the bar graph below.

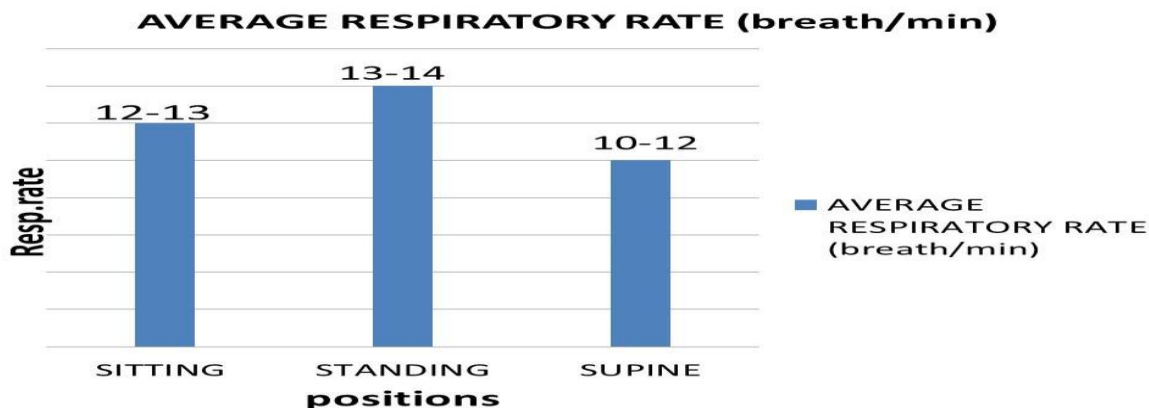


Figure 4.1: Average respiratory rate obtained from this work

5. References

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