Reconstruction of respiratory signal from ECG

Pranav K. Patil, Swetal K. Phepale, Prof. U.R. Bagal

Abstract -Several physiological signals are used for diagnosis of diseases in clinical practice. Electrocardiography is a method used to record electrical activity of heart and the record of electrical activity of heart is known as electrocardiogram (ECG). It is used for diagnosis of cardiovascular diseases. Stress ECG may be useful for diagnosis of cardiovascular disorders. In general practice, it is recorded using clinically accepted standard lead configuration with electrodes placed on the body surface. The recorded ECG is contaminated with interference due to body movements and respiration commonly called artifacts. ECG with artifacts may introduced error in computed ECG parameter. Frequency ranges of ECG (0.02-150 Hz) and respiration (0.2-2 Hz) are overlapping. Use of digital filter is not suitable for suppression of artifacts in ECG. Adaptive filter may be used for suppression of respiration related signal. It needs respiration signal as a reference. ECG free respiration signal may be recorded by sensing the respiration at nostrils using thermistor. Thermistor may cause error in signal due to self-heating and slow response in case of fast breathing during or just after exercise. Respiration related signals can be obtained using ECG. The features of ECG such as amplitude of R- peak, P-peak, T-peak Q-valley and S-valley along with R-R interval and wavelet based methods can be used for extraction of respiratory signal.

Keywords: Electrocardiogram, cardiovascular diseases, respiration signal, Digital filter, Thermistor.

1 INTRODUCTION

The electrocardiogram (ECG) is a record of an electrical activity of cardiac muscle. It is extensively used for diagnosis of heart diseases. It can also be used for monitoring patients at home and in telemedical applications. ECG recorded from chest surface is influenced by motion of the electrodes with respect to skin, and by changes in the electrical impedance of the thoracic cavity due to change in air volume inside the thorax. The disturbance in ECG caused by movement of body with respect to electrode is called motion artifacts. Signals due to respiration is another disturbance introduced in the recorded ECG called as respiration artifacts. In general recorded ECG is contaminated with motion and respiration related signal. The frequency bands of ECG, motion artifacts and respiration signal is overlapping. The use of filter for separation of respiration signal from ECG is not suitable. Wavelet based methods and adaptive filtering can be used for suppression of respiratory artifacts from ECG. Adaptive filtering requires reference signal for suppression of respiratory artifacts. Simultaneously recorded respiration signal can be used as a reference for adaptive filter. Along with ECG respiration signal can be recorded using thermistor placed at nostrils, strain gauge around the abdomen and use of capacitive or inductive transducer. Use of these transducer for picking up respiratory signal are more prone to motion artifacts. Picking up respiration signal using thermistor at nostril have limitation in its use during exercise or in fast breathing thermistor won't respond to fact changes in temperature also it has limitation related to self-heating property. Respiratory signals are traditionally recorded by devices such as pressure sensors attached to a strain gauge or a thermistors placed at the nose. However, there are two common disadvantages of using these devices: First, the complex devices involved might interfere with natural physiological breathing. Second, such devices cannot be used for certain clinical purposes, for example, ambulatory or long-term monitoring in naturalistic settings. Therefore, the development of a convenient method to record or estimate respiratory signals is important from a clinical perspective. Use of respiratory signal contaminated with motion artifacts as a reference for adaptive filtering does not suppress the respiratory artifacts effectively.

It is proposed to extract the respiration signal from recorded ECG using features of ECG such as R-R interval, R-peak, P-peak, T-peak, Q and S valleys. Use of wavelet transformation and empirical mode decomposition is also proposed the features of respiration signal are compared to the simultaneously recorded respiration.

1.1 Electrocardiography (ECG)

The electrocardiograph (ECG) is used to record an electrical activity of the heart. Electrical signals from the heart characteristically precede the mechanical function. Monitoring of ECG has clinical significance. It provides valuable information about a wide range of cardiac disorders. ECG is characterized by waves called P, Q, R, S, T and U. ECG is recorded using surface electrodes in clinically accepted standard lead configuration. Major complexes in ECG. The P-wave is first positive wave and it is also called 'atrial complex'. It is associated with depolarization of atrial muscles. Atrial repolarization is not recorded as a separate wave in ECG because it is merging with ventricular repolarization. Normal time duration of P wave is around 100 ms. Next wave is 'QRS' complex which is associated with repolarization of atria and depolarization of ventricles. Time duration 0.08–0.10 s. T wave is associated with repolarization of ventricular muscle and its duration is 0.2 s. 'U' wave is not always observed in ECG and it may be associated with repolarization of papillary muscle.

'P-R' interval is an interval measured from onset of 'P' wave and onset of 'Q' wave. It is associated with delay in conduction of impulse from AV node and its duration is 0.18 s. 'Q-T' interval associated with atrial repolarization and ventri-

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cular repolarization. Its duration is 0.4 to 0.42 s. 'S-T' segment is called isoelectric period and its duration is 0.08 s. 'R-R' interval duration is 0.8 s.

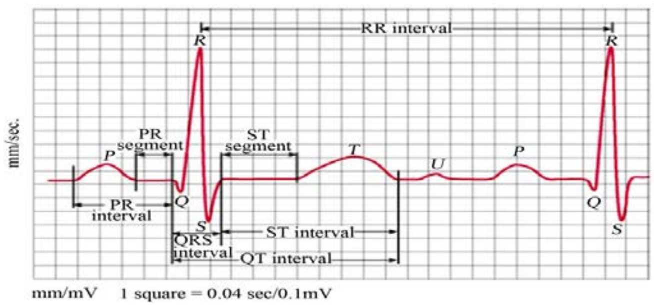

Fig 1: A typical ECG.

2 Literature Survey

2.1 Previous work on extracting respiration information from the ECG:

Moody et al. reported a method for generating an ECG derived respiratory waveform (EDR) based on area of normal QRS complex. Felblinger et al. use the amplitude of the R wave to obtain an EDR. The height of each R peak is plotted as a step function to represent the respiratory signal. Results are compared visually against the reference respiratory signal, which was obtained from a pneumatic pressure belt.

A new nonlinear technique, referred to as Empirical Mode Decomposition (EMD), has recently been pioneered by N.E. Huang et al. for adaptively representing non-stationary signals, The starting point of the Empirical Mode Decomposition (EMD) is to consider oscillations in signals at a very local level. The EMD method achieved through a linear sum of the components that approximates the original ECG signal. In this work, EMD on univariate time series has been examined. However, recently, a multivariate version of the EMD (MEMD) has been successfully proposed. The starting point of EMD is to locally estimate a signal as a sum of a local trend and a detail signal component, the local trend is a low frequency part, and the local detail accounts for high frequencies. Local trend is called residual and Local detail is Intrinsic Mode Function.

3 Method

In this proposed project the basic motive is to reconstruct the respiratory signal from ECG signal using MATLAB software. ECG signal and respiratory signal simultaneously acquired from ECG monitoring and respiration rate monitoring through laptop using NI DAQ card (USB 6009) and data acquisition at a sampling rate of 500Hz. Display in LabVIEW software. The data will be processed in matlab software to reconstruct respiratory signal from ECG. Methods used to reconstruct respiratory signal from ECG is given below.

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3.1 Reconstruction of respiratory signal using ECG peaks

In this method first we detect R peak using Pan Tomkins Algorithm. The algorithm includes a series of filters and methods that perform low pass, high pass, derivative, squaring, integration, adaptive thresholding and search procedure. After getting R peaks we find P, Q, S and T peaks from R peak using windowing function. By joining of all P, Q, R, S and T in ECG we reconstruct respiratory signal using P, Q, R, S, T peaks respectively. Here is flow chart for ECG peak Detection Algorithm.

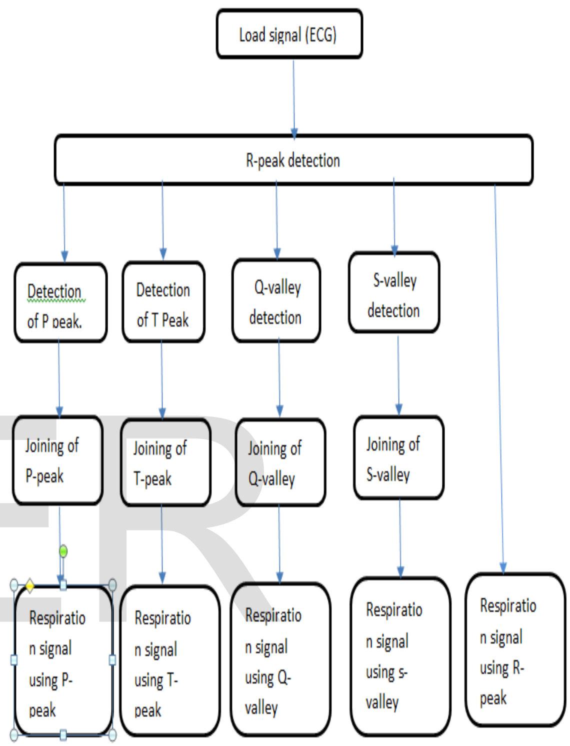

Fig. 2.Flow chart for ECG peak Detection Algorithm.

3.2 Reconstruction of respiratory signal using R-R interval

In this proposed method, this is a measurement of time between two consecutive R-peaks. We reconstruct respiratory signal from R peaks. First we calculate time interval from R-R interval in matlab software and then we reconstruct the respiratory signal.

The time intervals between the R peaks are known as the R-R intervals and are used to calculate the heart rate. Heart rate can be calculated by,

$$Sample\ frequency \times 60 R_{Peak\,2} - R_{Peak\,1} = bpm$$

3.3 Reconstruction of respiratory signal using wavelet decomposition

The WT is implemented using digital filters. The general strategy is to pass a sampled signal simultaneously through two specially designed filters, i.e. through both a low and a high pass filter, followed by down sampling the output of the filter. This process of filtering splits the signal into a detail signal, output of a high pass filter and one low resolution signal, the output of a low pass filter. The low resolution signal can be further decomposed into a second detail signal and a low resolution signal by passing through the same two filters and then down sampling. The output from the high pass filter is used without down sampling to get a detail signal because the rate of QRS detection is increased in this case, as it avoids the loss of information.

Based on the paper the EDR signal can be derived using DWT. If the ECG signal is decomposed till the Nth level of decomposition, and the detail signal of 8th decomposition is reconstructed, we get the RS (Respiratory Signal). The value of N depends upon the sampling rate. This is because the maximum frequency that can be represented is taken equal to fs/2, where fs is the sampling frequency. Because of the fact that the range frequency of RS is 0.2–0.4 Hz, it is necessary to compute the decomposition, level corresponding to this range.

3.4 Reconstruction of respiratory signal using Empirical Mode Decomposition (EMD)

An Empirical Mode Decomposition (EMD) has been introduced by Huang et al. EMD achieved through a linear sum of the components that approximates the original ECG signal. The starting point of EMD is to locally estimate a signal as a sum of a local trend and a detail signal component: the local trend is a low frequency part, and the local detail accounts for high frequencies. In EMD, the high-frequency (detail) components are referred to as Intrinsic Mode Function (IMF) and the low frequency part is called residual. The procedure is then applied gain to the residual, considered as a new times series, extracting a new IMF and a new residual.

Given a signal $x(t)$, the effective algorithm of EMD can be summarized as follows:

1. Identify all extrema (maxima and minima) of $x(t)$;
2. Generate the upper and lower envelope $(e\min(t), e\max(t))$, by connecting the maxima and minima points separately with cubic spline;
3. Compute the local mean $\gamma(t) = (e\min(t) + e\max(t))/2$;
4. Extract the detail $d(t) = x(t) - r(t)$;
5. Iterate on the residual $r(t)$.

At the end of the decomposition process, the EMD method expresses the signal $x(t)$ as the sum of a finite number of IMFs and a final residual.

$$x(t) = \sum_{n=1}^{N} (h_n(t) + r(t))$$

Where $hn(t)$ are the IMFs and $rn(t)$ is a final residual, which is less than an arbitrarily chosen threshold. EMD decomposes a signal x (t) into its components called intrinsic mode functions (lMFs) $hn(t)$, n =1, 2, ...,N and the residual $r(t)$.

4 Signal Processing

As a part of study the ECG and Respiratory signals were acquired simultaneously from 05 subjects with age [from 20 years to 25 years], height [from 4′1″ to 5′10″], and weight [from 39 kg to 70 kg]. The recordings were carried out in a lab-setup. The recordings were carried out at rest. The signals were acquired using data acquisition from with 8/12 channel interfaced with laptop PC. The sampling frequency set to 500 Hz. The digitized signals values were stored as xlsx file.

The acquired signals were processed in mat lab. The .xlsx files were opened in mat lab software. Mains 50 HZ pickup was suppressed using 50 Hz notch filter with taking care of phase shifting. ECG R-peaks were detected using pan-Tompkins algorithm whereas other Peaks in ECG signals were detected from R-peak using simple windowing programs. We also reconstruct respiratory signal using R-R interval by calculating manually R-peaks in Matlab. Another method we implement is wavelet decomposition to reconstruct respiratory signal.

5 Result

The simultaneous study of both respiratory signal and ECG (Electrocardiogram) signal leads to indirect monitoring of both the signal and we can derive a respiratory signal from an ECG signal. The results show that algorithms are able to reconstruct the Respiratory waveform. In this, we take reading of healthy subjects using DAQ card (USB 6009) and lab view software. This signal can be further processed into matlab.

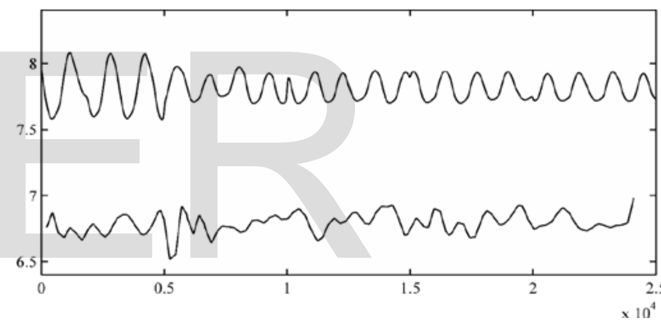

Fig 3: Reconstruction of respiratory signal using Q valley

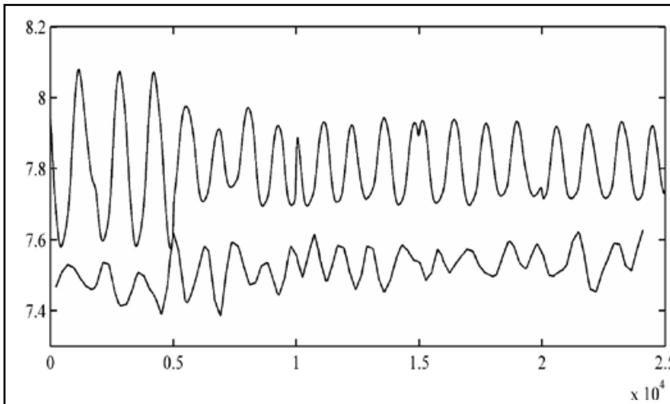

Fig 4: Reconstruction of respiratory signal using R peak.

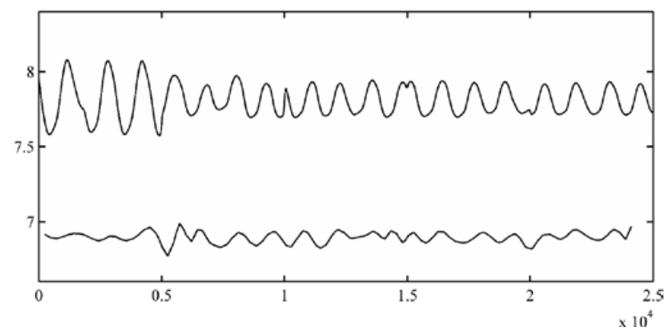

Fig 5: Reconstruction of respiratory signal using R peak

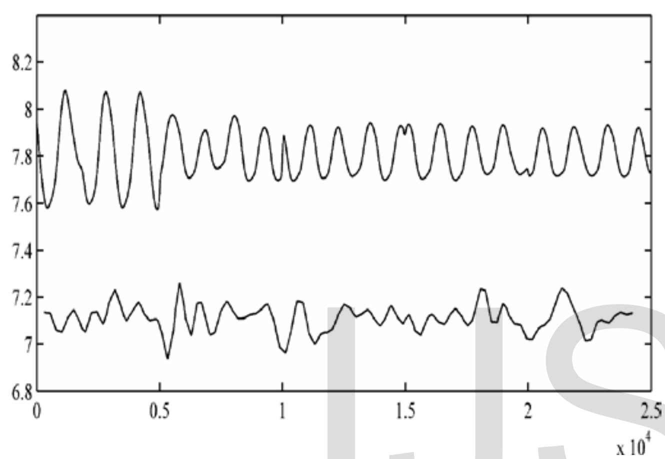

Fig 6: Reconstruction of respiratory signal using T peak

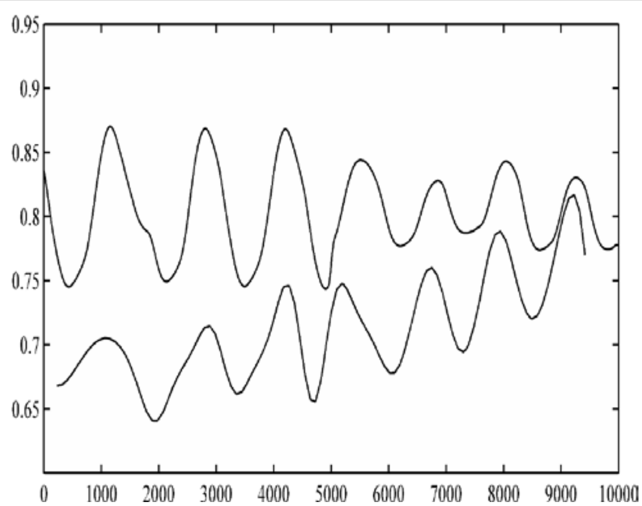

Fig 7: Reconstruction of respiratory signal using R-R interval

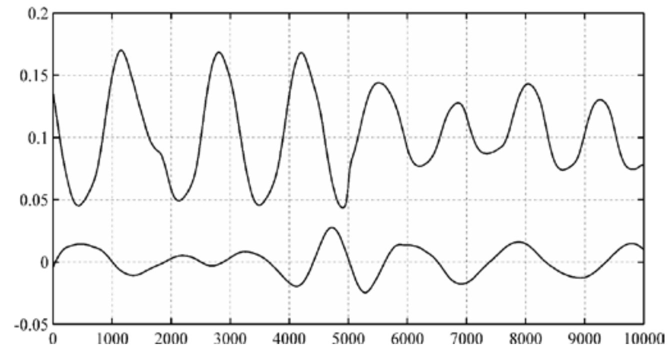

Fig 8: Reconstruction of respiratory signal using wavelet transfomation

In figure, upper trace shows original respiratory signal and lower trace shows different methods to reconstruct respiratory signal from ECG peaks, R-R interval and wavelet transformation respectively.

TABLE 1:

Shows quantitative measurement of differences of original Respiration peaks and ECG

	OR-Q	OR-R	OR-S	OR-T
Average	0.00	-0.08	0.02	0.01
Standard Deviation	0.34	0.34	0.32	0.26
Min	-0.55	-0.59	-0.61	-0.52
Max	0.76	0.73	0.70	0.45
Range	1.31	1.32	1.31	0.96

6 Conclusion

The analysis is carried for five subject.We have reconstruct respiratory signal from ECG signal.The wavelet transform is found to be better technique for reconstruction of ECG signal as compared to other methods.

Acknowledgment

The authors are thankful to Dr K G Narayankhedkar, Director General and M.G.M group of Engineering Colleges, Dr S K Narayankhedkar, Principal MGM College of Engineering and Technology, Navi Mumbai, Dr G D Jindal, Head Biomedical Engineering Department MGMCET for their encouragement right through this development.

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