13th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

APPLICATION OF DISCRET WAVELETS TRANSFORM AND LINEAR PREDICTION CODING FOR ANALYSIS AND COMPRESSION OF ECG SIGNALS

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ABSTRACT
The electrocardiogram (ECG) is widely used because it is a non-invasive way to establish clinical diagnosis of heart diseases. Therefore, ECG processing has been a topic of great interest and is most commonly used in applications such as monitoring. Long-term records have also become commonly used to extract or detect important information from the heart signals.
In these cases, the quantity of data grows significantly and compression is required for reducing the storage required and transmission times. Several methods have been applied for ECG signals using many different techniques. The aim of this paper is to apply the discrete wavelets transform (Debauchie wavelet) and linear prediction coding (based on Durbin algorithm) as basic tools for analysis, compression and prediction of ECG signals. The ECG signals are extracted from the MIT-BIH database, the results show the high efficiency of a two used methods.
A test on real ECG signals has led to an almost perfect reconstruction of original signal with low reconstruction error for DWT method and a good estimation of ECG signal forLPC method.
Key words: Electrocardiogram (ECG), Cardiac arrhythmia, Compression, Prediction, Discrete Wavelet Transform, Linear Prediction Coding, Durbin Algorithm, MIT-BIH database.

1. INTRODUCTION
The electrocardiogram (ECG) signal, a graphical recording of the electrical potentials generated in association with heart activity, is one of many important physiological signals commonly used in clinical

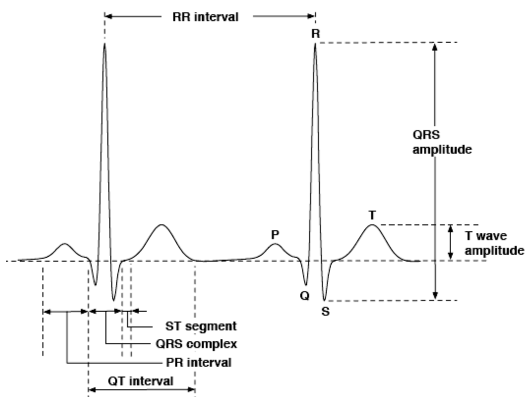


Figure 1. An example of ECG signal and its components.

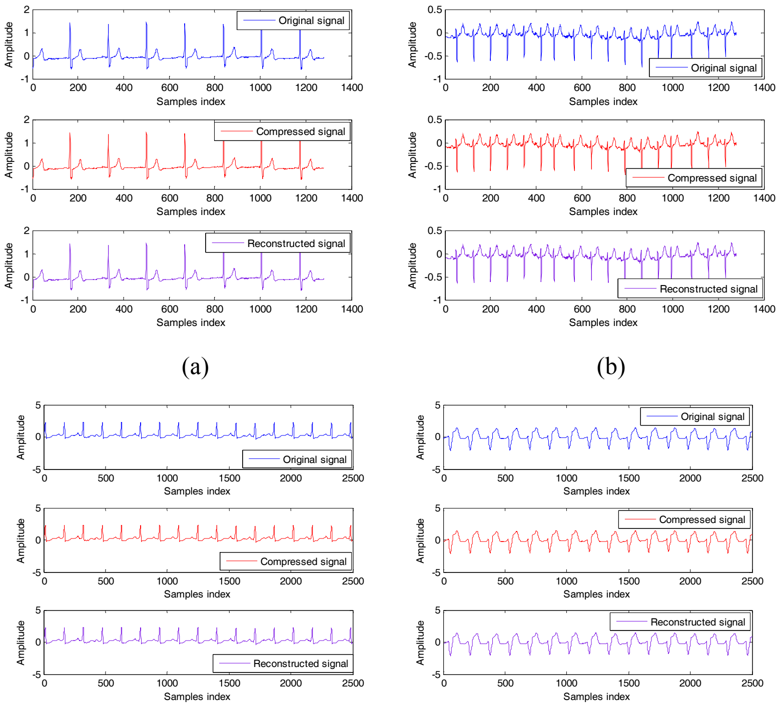
practice. As the activity of the heart can be visualized from an ECG signal obtained by measuring the potential difference of two points on the skin, the ECG can provide valuable cardiac information. The monitoring and analysis of the ECG has been a useful technique for diagnosis of cardiac disease for several decades. [1].

2. WAVELET TRANSFORM

The WT of a signal is the decomposition of the signal over a set of functions obtained after dilation and translation of an analyzing wavelet. The ECG signals which consisting of many data points, can be compressed into a few features by performing spectral analysis of the signals with the WT. These features characterize the behavior of the ECG signals. Using a smaller number of features to represent the ECG signals is particularly important for recognition and diagnostic purposes. Discrete Wavelet Transform is also referred to as decomposition by wavelet filter banks. This is because DWT uses two filters, a low pass filter and a high pass filter to decompose the signal into different scales. The output coefficients of the LPF are called approximations while the output coefficients of the HPF are called details. The approximations of the signal are what define its identity while the details only imparts nuance [2]. The DWT can be calculated at different resolutions using the Mallat-algorithm to utilize successive lowpass and high pass filters to compute DWT [2].

2.1. Method, material and experimental results of DWT compression algorithm

ECG records taken from MIT-BIH were used to experimentally assess the performance of the proposed method. The algorithm was tested using a variety of signals, from normal ECG's to ventricular tachycardia and supraventricular arrhythmia database. We tested several wavelets; in this study we used the Debauchies wavelet ''DB5'' with four level of decomposition (scale) and a fixed threshold. The performance of the algorithm was tested using only the first 10 seconds of each record.



(c) *(d)*

Figure 3. Compression results : (a) for recod 16272, (b) for record 821, (c) for record CU10, (d) for record CU06.

Figure 3 gives the original, compressed and reconstructed respectively, for different signals and allow visual assessment of the quality of several reconstructed signals. It can be observed that the morphological information of the original signal is well preserved. Table 1 shows information about different used ECG signals and results of reconstruction error for each record.

Table 1. Reconstruction error.

Database reference	Record link	Signal duration	Sampling frequency and bit resolution	Reconstruction error
MIT-BIH Normal Sinus Rhythm Database (NSRDB)	16272	10s	128 Hz with 10bit	$2.9621\ 10^{-11}$
CU Ventricular Tachy-arrhythmia Database (CUDB)	Cu10, Cu6	10s	250 Hz with 12 bit	$1.1423\ 10^{-10}$ $1.4677\ 10^{-10}$
MIT-BIH Supraventricular Arrhythmia Database	821	10s	128 Hz with 10bit	$1.9659\ 10^{-11}$

3. LPC COEFFICIENT PREDICTION FOR ECG DATA

The basic idea behind LPC analysis is that each expression sample is approximated as a combination of past samples.

Equation (1) defines the LPC principle where the value of the present output, *s(n)*, can be predicted approximately by a linear combination of *p* past samples; *p* is called the order of LPC.

$$s(n) = \sum_{j=1}^{p} a_j s(n-j) \qquad (1)$$

The goal of the LPC analysis is to find the best prediction coefficients *aj* so that the predicted sample is a good approximation of the original sample. This optimization process is performed by minimizing the energy of the prediction error. This involves choosing *aj* to minimize the mean energy, *E*, in the error signal over a frame or window of data set:

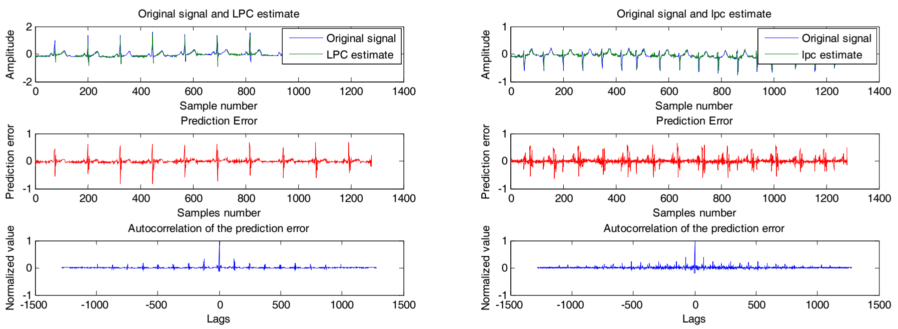
$$E = \left\{ \sum_{-\infty}^{\infty} \left[s(n) - \sum_{j=1}^{p} a_j s(n-j) \right]^2 \right\} \qquad (2)$$

The values of *aj* that minimize *E* are found by setting all derivatives $\delta E / \delta a_j$ equal to zero. The Durbin's method was used to calculate the LPC coefficient.

Where a_j are the coefficients of the prediction error filter and $a(0) = 1$.

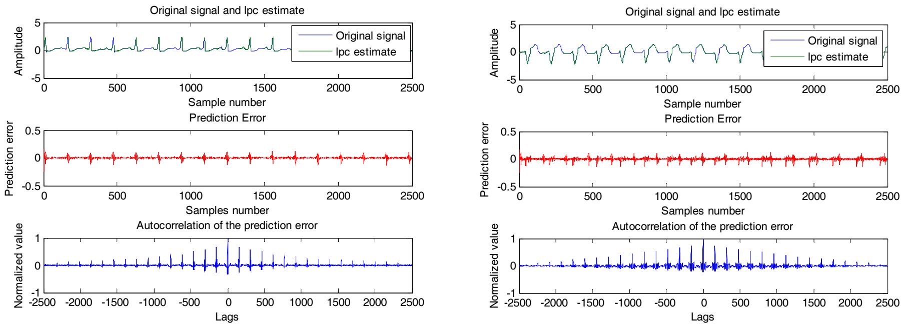
3.1. Method, material and experimental results of LPC compression and prediction

The LPC method was tested on ECG data from MIT-BIH Database .We used the same data as before. Figure 4 and 5 give the original, estimated signal, prediction error and the autocorrelation of prediction error, respectively, for different signals. It can be observed that the morphological information of the original signal is well preserved with good estimation of ECG signal. For our case we used four LPC coefficients.



(a) (b)

Figure 4. Original, estimated ECG signal; error of prediction; and Autocorrelation of the prediction error: (a) for recod 16272, (b) for record 821.



(a) (b)

Figure 5. Original, estimated ECG signal; error of prediction; and Autocorrelation of the prediction error: (a) for recod cu10, (b) for record cu06.

Table 2 gives a value of LPC coefficients for each record

Table 2. Compression LPC results

Data reference	Record link	Signal duration	Sampling frequency and bit resolution	Lpc coeeficient values			
				a(0)	a(1)	a(2)	a(3)
MIT-BIH (NSRDB)	16272	10s	128 Hz-10bits	1.0000	-1.4301	1.1212	-0.4990
CUDB	Cu10 Cu6	10s	250 Hz -12 bit	1.0000 1.0000	-2.6240 -1.9533	2.4112 1.0242	-0.7796 -0.0626
MIT-BIH SVDB	821	10s	128 Hz -10bits	1.0000	-1.4221	0.8399	-0.2847

4. RESULTS AND DISCUSSION

In order to validate the two methods, a matlab simulation model was implemented for the analysis, compression and predicted signal. Experimental results show that the proposed methods achieve a good compression results with effectively reconstruction quality, and excellent preservation of ECG signal. According to the results listed in table 2, and the different figures show above, LPC method gains improvement on the coding performance in terms of compression and prediction of ECG signal.

5. CONCLUSION

The ECG signals are extracted from the MIT-BIH database; the results show the high efficiency of the two used methods. The two methods used to reduce the size of the ECG signal by using coefficients, the DWT and LPC coefficients can be used as a parameter characterizing the ECG signal to detect or predict an arrhythmia as in the case of neural network (input parameters).

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