ECG Data Compression

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ABSTRACT
Electrocardiogram (ECG) signal play important role in diagnosis and analysis of heart diseases. For effective detection and diagnosis of cardiac diseases, the ECG data are continuously recorded, stored and transmitted. But long-term continuous monitoring generates large amount of data which becomes difficult for storage as well as for transmission. Therefore a efficient ECG data compression algorithm is needed that gives better compression ratio and less loss of data in reconstructed signal. This paper presents a wavelet transform and turning point algorithm based ECG data compression. The data is taken from physionet and implemented using discrete wavelet i.e daubechies (db7) wavelet. Then energy packing efficiency of wavelet coefficients is found and then turning point algorithm is applied to the wavelet coefficients to get compressed form of data and reconstruction is done using inverse wavelet transform. These steps are implemented in MATLAB.

Keywords
ECG,discretewavelettransform,turningpointalgorithm,compression ratio,inverse wavelet transform.

1. INTRODUCTION
Electrocardiogram (ECG) data is used to diagnose heart diseases in patient. The volume of ECG data is necessarily large, as a long period of time is required in order to gather enough information about the patient. ECG signal contains large amount of information that requires much more storage space, large transmission bandwidth, therefore it is advantageous to compress the signal by storing only the essential information needed to reconstruct the signal [1]. ECG compression methods are classified as: lossless and lossy. In lossless method, compressed signal is reconstructed in exact form of original signal. And in lossy method, compressed signal is reconstructed with some cost of error.

1.1 Electrocardiogram (ECG):
ECG signal is a recording of the electrical activity of the heart over time produced by an electrocardiograph and is well established diagnostic tool for cardiac diseases. ECG signal is monitored by placing sensors at defined position on chest and limb extremities of the subject [2]. The following four steps in the generation of the ECG signal can be monitored.

1. The S-A node (natural pacemaker) creates an electrical signal.
2. The electrical signal follows the natural electrical pathways through both the atria. The movement of the electricity causes the atria to contract, which helps to push blood into the ventricles.
3. The electrical signal reaches A-V node (electrical bridge).There, the signal pauses to give the ventricles time to fill with blood.
4. The electrical signal spreads through the His-purkanji system. The movement of electricity causes the ventricles to contract and push blood out to lungs and body.

The ECG signal is shown below:

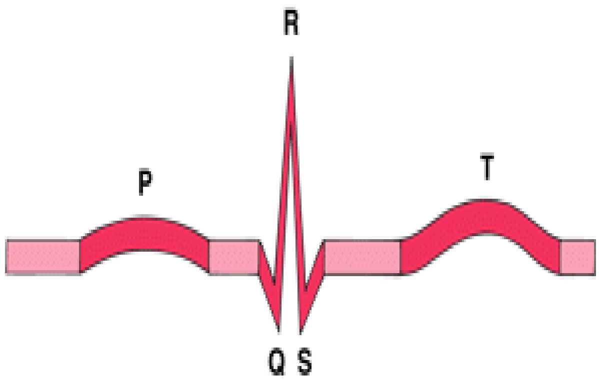


Fig.1: Schematic Representation of ECG signal

ECG signal is composed of five waves such as P,Q,R,S and T. The P wave represents the atrial depolarization where the blood is squeezed from atria to the ventricles. The QRS complex is when the ventricles depolarize and squeeze the blood from the right ventricle to the aorta. The T wave represents the period of time when the ventricles repolarizes (get ready for the next heart beat) [2].

1.2 Wavelet Transform:
The recently introduced wavelet transform is a member of a class of time-frequency representation. Wavelet transform can be used to perform multi resolution decomposition. Since this process can be considered as sub-band coding technique, it offers the opportunity for the data compression [3]. The DWT is the appropriate tool for the analysis of the ECG signal.

The key issues in DWT and inverse DWT are signal decomposition and reconstruction respectively. The basic idea behind decomposition and reconstruction is low-pass and high-pass filtering with the use of down sampling and up sampling respectively. One can choose the level of decomposition based on desired frequency [5]. Low frequency components are approximation and high frequency components are called details. The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components. This is called wavelet decomposition tree.

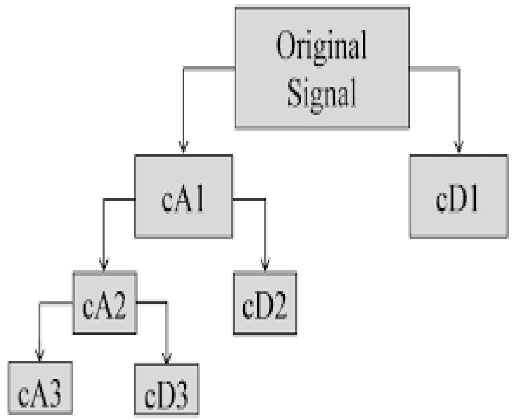


Fig.2: Wavelet decomposition tree

Discrete wavelet transform transform can be used to analyze, or decompose signals. The other half of the story is how those components can be assembled back to the original signal with no loss of information. This process is called reconstruction. The mathematical manipulation that effects reconstruction is called inverse discrete wavelet transform.

1.3 Turning Point Algorithm:

The turning point (TP) algorithm was originally developed to reduce the sampling frequency of an ECG signal. TP is based on the concept that ECG signals are normally oversampled at four or five times faster than highest frequency present [1]. TP provides a way to reduce the effective sampling rate by half by selectively saving important signal points.

1.4 Need For Data Compression:

The volume of ECG data produced by monitoring system can be quite large over a long period of time and ECG data compression is often needed for efficient storage of such data. Similarly, when ECG data needs to be transmitted for telemedicine application, data compression needs to be utilized for efficient transmission [4][6]. The necessity of efficient data compression method for biomedical signals is currently widely recognized.

2. PROPOSED WORK

The proposed work is implemented as shown below:

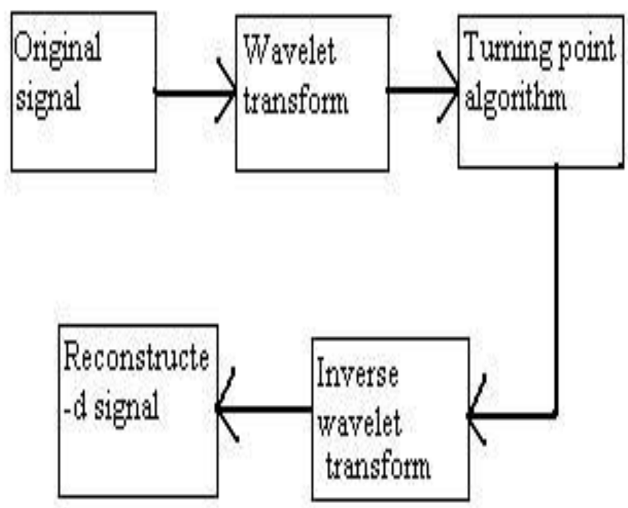


Fig.3: Proposed block diagram

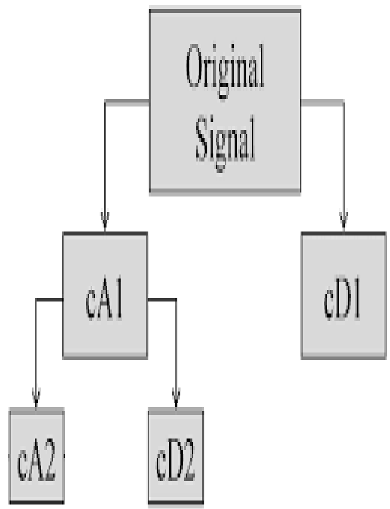
1. Original signal(input):

Data collection is one of the most important part. MIT-BIH arrhythmia database is selected from the physionet. The ECG signals selected for this work are sampled at 360 Hz [7]. Twenty ECG records are taken from physionet and the proposed algorithm is tested on them.

2. Wavelet Transform:

There are many different types of wavelets available. Selecting a wavelet function, which closely matches the signal is of great importance in wavelet based application. Daubechies wavelet families are similar to the shape of QRS complex of ECG. Hence daubechies wavelet (db7) is selected in this work. Wavelet transform is applied to the ECG data points which decomposes the signal into approximation and detail bands. Depending on the sampling frequency of the selected ECG data, the decomposition level is selected. In this work, as the sampling frequency of selected ECG data is 360 Hz and the frequency of ECG signal is 100 Hz, the decomposition up to level 2 is selected as it gives desired information of ECG signal at this level. At level 3 the frequency is 45 Hz, and at this level the appropriate information of the ECG signal is lost.

After decomposition, the energy efficiency of each sub band is found. Since wavelet decomposes the signal in two bands, the approximation band is the smallest band in size and it includes high amplitude approximation coefficients [8]. The energy contribution of each decomposition band to the whole decomposition coefficients is found and it is seen that 99% of energy is concentrated in approximate coefficient.So approximate coefficients of level 2 is selected and turning point algorithm is applied for these coefficients.



3. Turning Point Algorithm:

The algorithm processes three data points of approximate coefficients at a time. It stores first sample point and assigns it as the reference point k [11]. The next two consecutive points become k+1 ad k+2. The algorithm retains either k+1 or k+2, depending on which point preserves the turning point(i.e slope change) of the approximate coefficients. It saves the point where the slope changes and the process is further continued to get compressed form of data. The steps are as follows:

- Consider approximation coefficients of level 2 i.e ca2 of wavelet decomposition.

- Take first three samples and check for the condition as below:

S1=sign (ca2 (k+1)-ca2(k))

S2=sign (ca2 (k+2)-ca2 (k+1))

If (s2-s1)>0, then save ca2 (k+1)

else save ca2(k+2)

4. Inverse Wavelet Transform:
It has been seen how discrete wavelet transform can be used to decompose signals. Next step is to get back the original signal with no loss of information. This step is called reconstruction. Reconstruction is done using inverse wavelet transform. The wavelet reconstruction process consists of up sampling which is nothing but lengthening a signal component. In this work "waverec" is used to get the reconstructed signal with no loss of information [9][10].

3. RESULTS AND DISCUSSION

3.1 Results

The main objective of this work was to implement a low complexity ECG data compression which gives good compression ratio. In this work, the energy content of each sub band is found as shown in table-1 and compression ratios are shown in table-2. Compression ratio of approximately 8:1 is found without any distortion in the reconstructed signal. The compression ratios have been calculated for 20 records. The compression ratio is given by:

Compression Ratio= Original data size/Compressed data size

Compression ratio is given as the ratio of original data size to the compressed data size without taking into account the factors such as database size, lead selection, reconstruction error and noise level.Higher the compression ratio, smaller the size of the compressed data.

Results of record 117 and 119 are shown in following figures

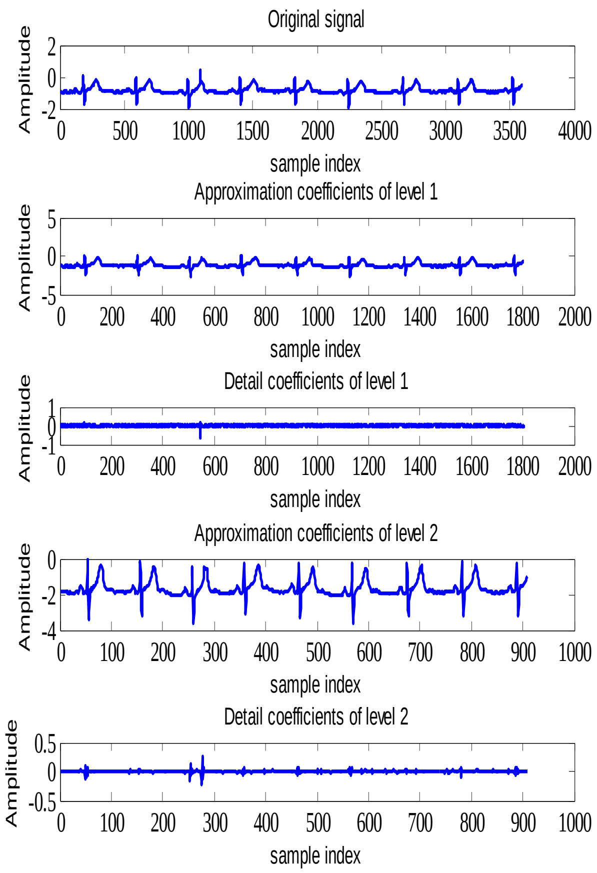


Fig. 4.1: Decomposition structure of record 117

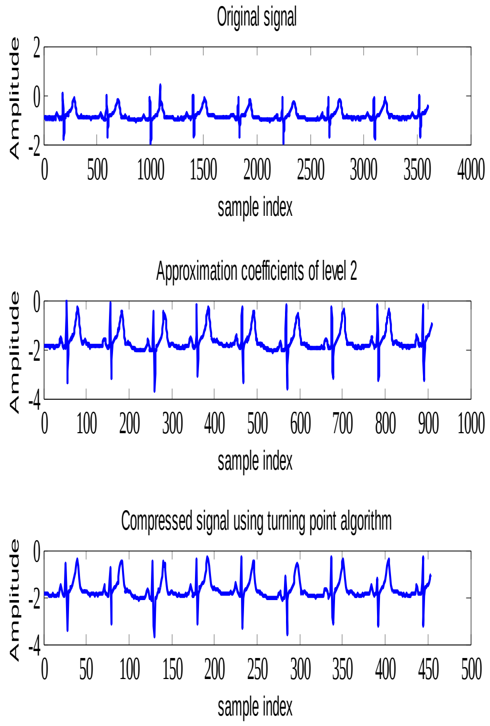


Fig.4.2: Approximation coefficients of level 2 andcompressed signal of record 117

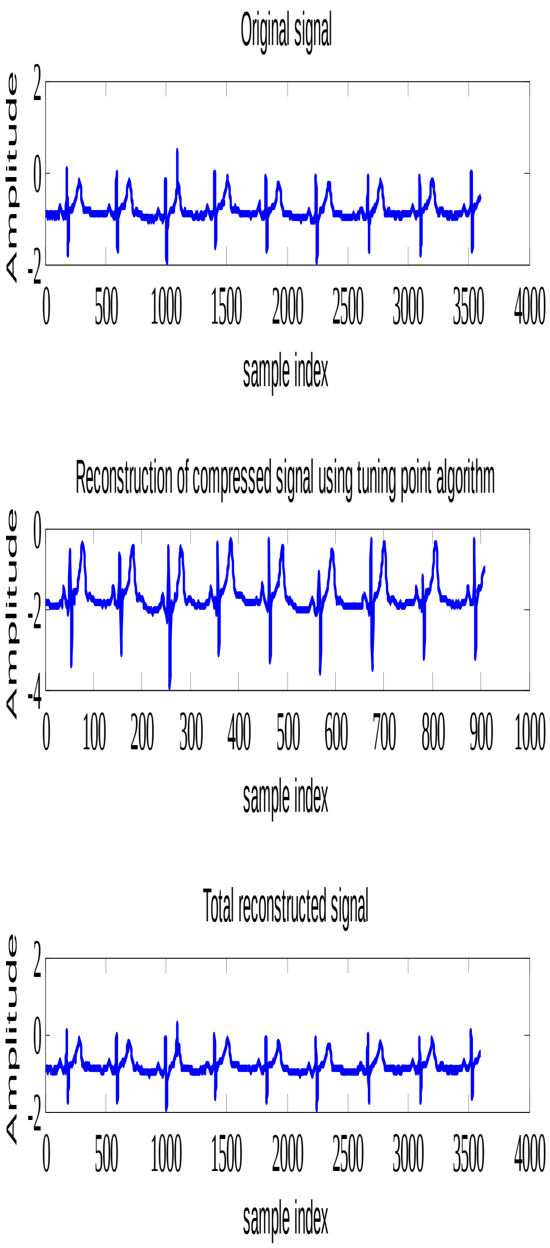


Fig.4.3: Reconstructed signal of record 117

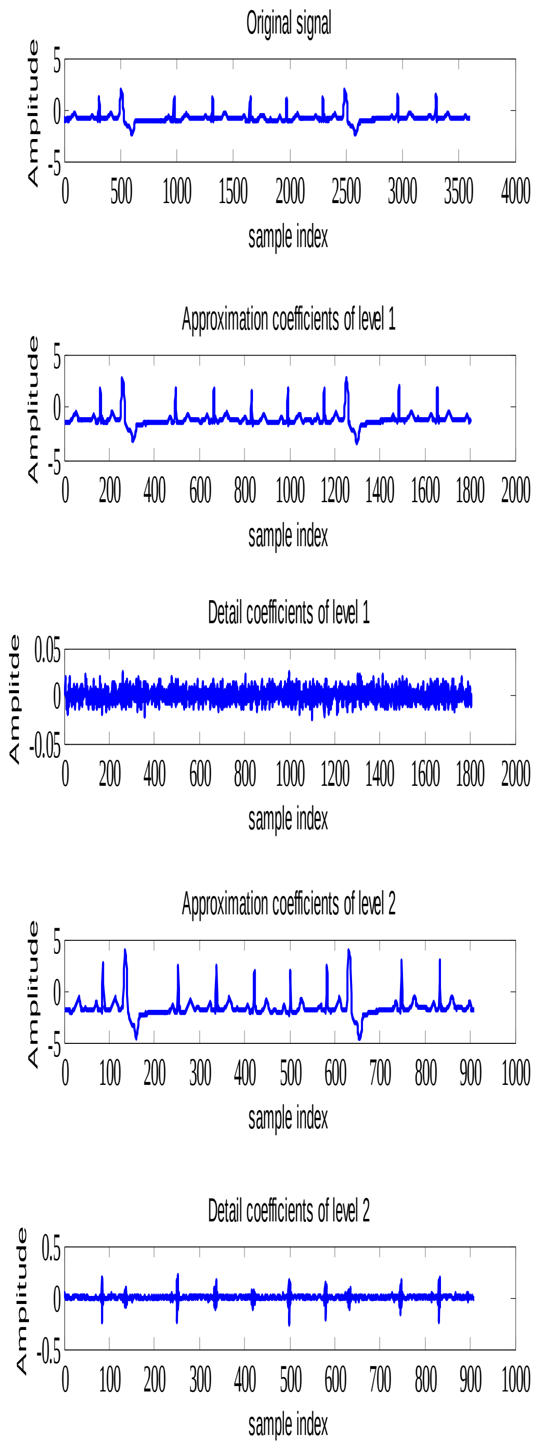


Fig.5.1: Decomposition structure of record 119

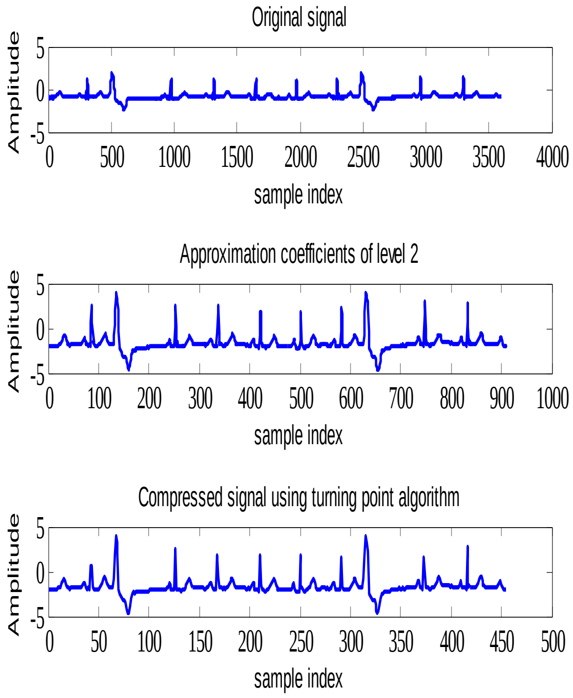


Fig.5.2: Approximation coefficients of level 2 and compressed signal of record 119

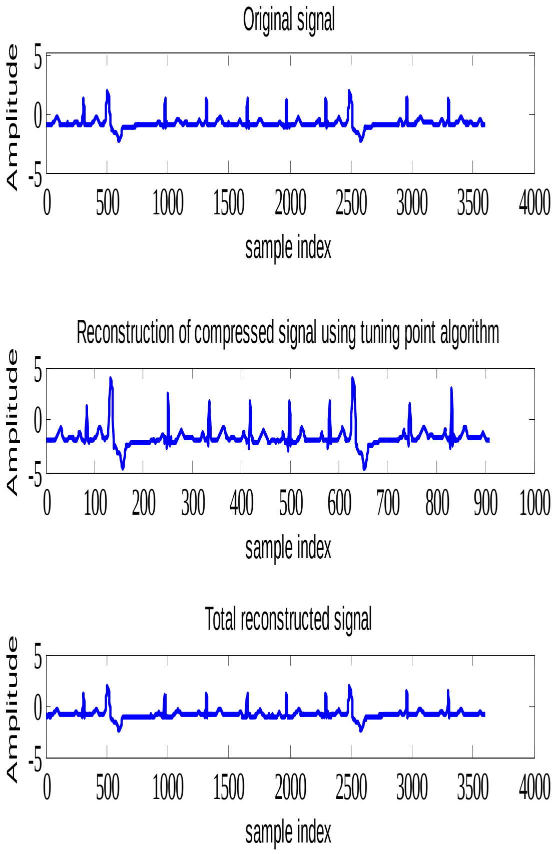


Fig.5.3: Reconstructed signal of record 119

Table-1: Energy values in respective sub bands of wavelet decomposition structure.

Records	Ca2	Cd2	Cd1
100	99.70	0.2798	0.0150
101	99.57	0.3548	0.0689
102	99.93	0.0566	0.0058
103	99.76	0.2213	0.0130
104	99.22	0.7050	0.0738
105	99.91	0.0739	0.0128
106	99.34	0.6227	0.0356
107	99.89	0.0970	0.0031
108	99.86	0.1174	0.0176
109	99.93	0.0619	0.0067
111	99.76	0.2051	0.0348
112	99.99	0.0057	0.0016
113	99.49	0.4823	0.0228
114	99.60	0.3705	0.0239
115	99.83	0.1569	0.0059
116	99.89	0.0944	0.0068
117	99.96	0.0146	0.0194
118	99.96	0.0351	0.0022
119	99.96	0.0284	0.0025
121	99.99	0.003	0.0020

Table-2: Compression Ratio values for different records

Records	Compression Ratios
100	7.9381
101	7.9295
102	7.9379
103	7.9295
104	7.9295
105	7.9295

106	7.9295
107	7.9295
108	7.9295
109	7.9295
111	7.9295
112	7.9295
113	7.9295
114	7.9273
115	7.9295
116	7.9295
117	7.9251
118	7.9295
119	7.9295
121	7.9295

3.1 Discussion

Table-1 shows the values of energy in respective sub band. The values of energy content is calculated for 20 records taken from the physionet. From table-1, it shows that the maximum energy content is concentrated in approximate coefficients than the detail coefficients.

Table-2 shows the values of the compression ratio for 20 records taken from the physionet. For all 20 records, it is seen from table-2 that the compression ratio is7.9 i.e the compression ratio is approximately 8:1.

The data points taken from the physionet is wavelet transformed so that it is decomposed upto level 2. Level 2 is selected based on the sampling frequency of the selected record and also the frequency of the ECG signal. Level 3 gives the distorted form of waveform and the information is not appropriate for use, so in this work the decomposition upto level 2 is selected. Then the energy content of each sub band is determined which shows that the maximum concentration of energy is found in approximation coefficients. Then turning point algorithm is applied for these approximation coefficients to get the compressed form of data. Then the inverse wavelet transform is used to get the reconstruction of the compressed data to the original form.

4. CONCLUSION

The ECG is a conventional means of a biomedical signal for the diagnosis of heart diseases. The amount of ECG data produced by monitoring systems is quite large and ECG data compression is needed for efficient storage of such data. To record ECG signal, a large amount of data should be saved [6].To reduce the space for data storage, compression must be used, but only if the difference between reconstructed and original signal is minimal.

The implementation of “ECG data compression” is done successfully. It shows that the ECG data compression using discrete wavelet transform and turning point algorithm gives good compression ratio and the quality of the ECG signal is not distorted on reconstruction and a good amount of data reduction is also achieved. Reconstruction is same as that of the original signal. This technique not only provides efficient storage space but also gives the efficient transmission capability in the telemedicine applications.

The future scope of this work is that even higher compression ratio can be found with no loss of information and within a short period of time that can be very helpful in biomedical field.

5. REFERENCES

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