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ECG Data Compression using Turning Point Algorithm

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Abstract— In this paper, emphasis has been given to compress ECG data using Turning Point Algorithm which compresses the ECG data in the ratio 2:1. For this we have acquired different ECG signals using POLYPARA system and MIT-BIH database and using MATLAB software we implemented the algorithm and obtain the results for different ECG signals and found that the Turning Point Algorithm produces a fixed compression ratio of 2:1.

***Index Terms*— Compression ratio, ECG Compression, MIT-BIH database, Turning Point Algorithm.**

I. INTRODUCTION

An electrocardiogram is a recording of electrical activity of heart over the time produced by an electrocardiograph. Electrical impulses originate in the sinoatrial node of the heart and travel through the heart muscle where they impart electrical initiation of systole or contraction of the heart [1].The electrical waves can be measured at selectively placed electrodes (electrical contacts) on the skin. Electrodes on different sides of the heart measure the activity of different parts of the heart muscle. An ECG displays the voltage between pairs of these electrodes, and the muscle activity that they measure, from different directions, also understood as vectors. After acquiring the signal, different ECG signal compression techniques using MATLAB software are implemented by several researchers [2-6].

A typical computerized medical signal processing system acquires a large amount of data that is difficult to store and transmit. We need a way to reduce the data storage space while preserving the significant clinical content for signal reconstruction. This process is called data compression.

A data reduction algorithm seeks to minimize the number of code bits stored by reducing the redundancy present in the original signal. We obtain the *reduction ratio* by dividing the number of bits of the original signal by the number saved in the compressed signal. We generally desire a high reduction ratio but caution against using this parameter as the sole basis of comparison among data reduction algorithms. Factors such as bandwidth, sampling frequency, and precision of the original data generally have considerable effect on the reduction ratio. A data reduction algorithm must also represent the data with acceptable fidelity. In biomedical data reduction, we usually determine the clinical acceptability of the reconstructed signal through visual inspection. We also measure the residual, that is, the difference between the reconstructed signal and the original signal. Such a numerical measure is the percent root-mean-square difference, PRD, and is mathematically given by

$$PRD = \left\{ \frac{\sum_{i=1}^{n} \left[x_{org}(i) - x_{rec}(i) \right]^2}{\sum_{i=1}^{n} \left[x_{org}(i) \right]^2} \right\}^{\frac{1}{2}} \times 100\% \qquad (1)$$

Where n is the number of samples and x_{org} and x_{rec} are samples of the original and reconstructed data sequences. A *lossless* data reduction algorithm produces zero residual, and the reconstructed signal exactly replicates the original signal. However, clinically acceptable quality is neither guaranteed by a low nonzero residual nor ruled out by a high numerical residual. For example, a data reduction algorithm for an ECG recording may eliminate small-amplitude baseline drift. In this case, the residual contains negligible clinical information. The reconstructed ECG signal can thus be quite clinically acceptable despite a high residual. There are two classes of data reduction

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techniques for the ECG. The first class, significant-point-extraction, includes the turning point (TP) algorithm [6], AZTEC (Amplitude Zone Time Epoch Coding) [2], and the Fan algorithm [5].

These techniques generally retain samples that contain important information about the signal and discard the rest. Since they produce nonzero residuals, they are *lossy* algorithms. In the second class of techniques based on Huffman coding, variable length code words are assigned to a given quantized data sequence according to frequency of occurrence. A predictive algorithm is normally used together with Huffman coding to further reduce data redundancy by examining a successive number of neighboring samples [7].

II. METHODS

The turning point (TP) algorithm was originally developed to reduce the sampling frequency of an ECG signal from 200 to 100 Hz .The algorithm developed from the observation that, except for QRS complexes with large amplitudes and slopes, a sampling rate of 100 Hz is adequate.TP is based on the concept that ECG signals are normally oversampled at four or five times faster than the highest frequency present. For example, an ECG used in monitoring may have a bandwidth of 50 Hz and be sampled at 200 sps in order to easily visualize the higher-frequency attributes of the QRS complex. Sampling theory tells us that we can sample such a signal at 100 sps. TP provides a way to reduce the effective sampling rate by half to 100 sps by selectively saving important signal points (i.e., the peaks and valleys or turning points).This is the reason behind selecting Turning Point (TP) over other direct data compression techniques.

The algorithm processes three data points at a time. It stores the first sample point and assigns it as the reference point X_0. The next two consecutive points become X_1 and X_2. The algorithm retains either X_1 or X_2, depending on which point preserves the turning point (i.e., slope change) of the original signal. The TP Algorithm produces a fixed compression ratio of 2:1 and the reconstructed signal resembles the original signal with some distortions.
The steps of Turning Point are as follows:

i. Acquire the ECG signal.

ii. Take the first three samples and check for the condition as mentioned below:

$$(X_1-X_0)*(X_2-X_1)<0$$
(or)
$$(X_1-X_0)*(X_2-X_1)>0$$

iii. If the above condition-1 is correct then X_1 is stored else X_2 is stored.

iv. Reconstructing the compressed signal.

The compression ratio of Turning point algorithm is 2:1, if higher compression is required then the same algorithm can be implemented on the already compressed signal so that it is further compressed to a ratio of 4:1. But after the 2nd compression, the required data in the signal may be lost since the signal is overlapped on one another. Therefore, TP algorithm is limited to compression ratio of 4:1. TP algorithm can be applied on the already compressed data to increase the compression ratio to 4:1.

III. REQUIREMENTS

a. Acquisition of ECG Signals: The normal ECG signals are acquired using POLYPARA System. The diseased ECG signals are collected from MIT-BIH database [8].
b.MATLAB Software: MATLAB Version R2009b is used for implementing the programs.
c. PC configuration with 2 GB RAM, 320 GB HARD DISK and 2 GHz Intel Processor.

IV. RESULTS

The plots of the normal and diseased ECG signals are shown in figure below as few sample cases. The plots consist of three parts: original signal, compressed signal and reconstructed signal.

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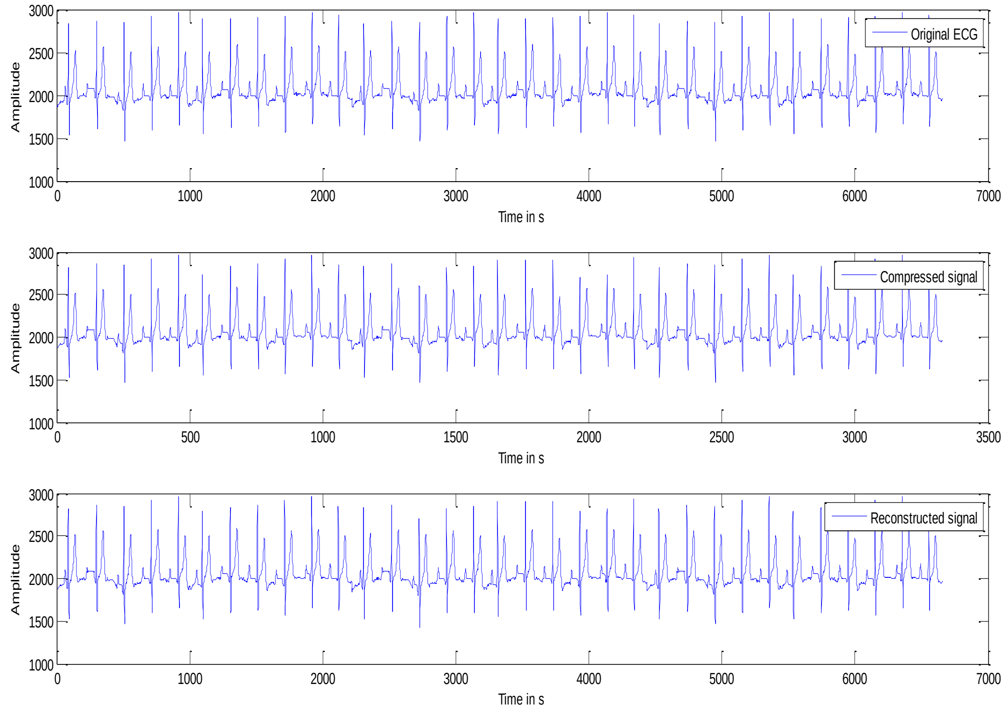

Fig 1 (Normal ECG)

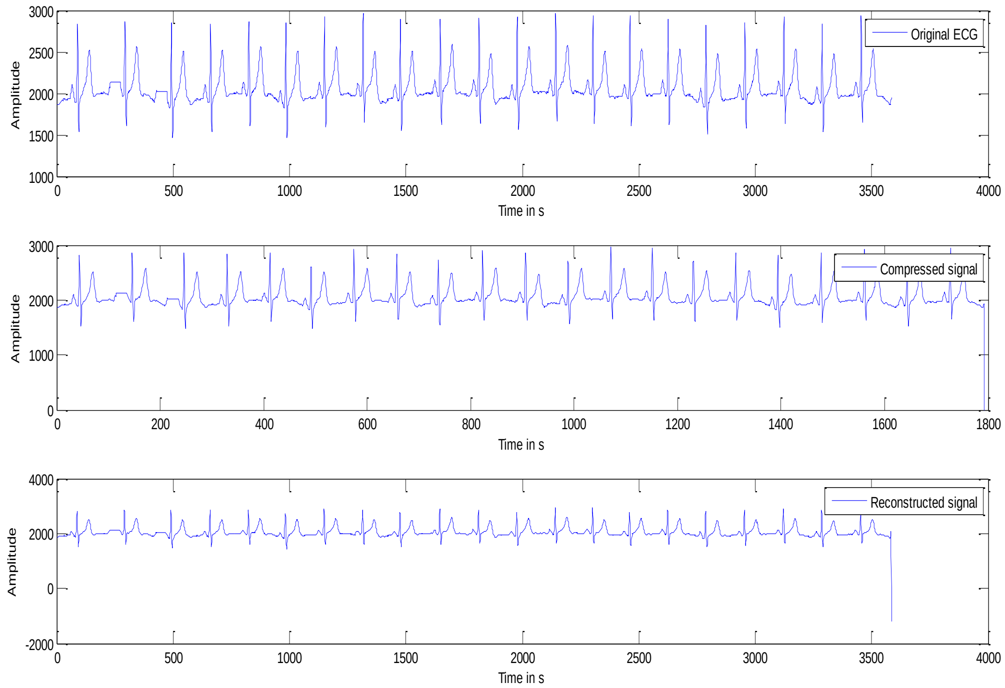

Fig 2 (Normal ECG)

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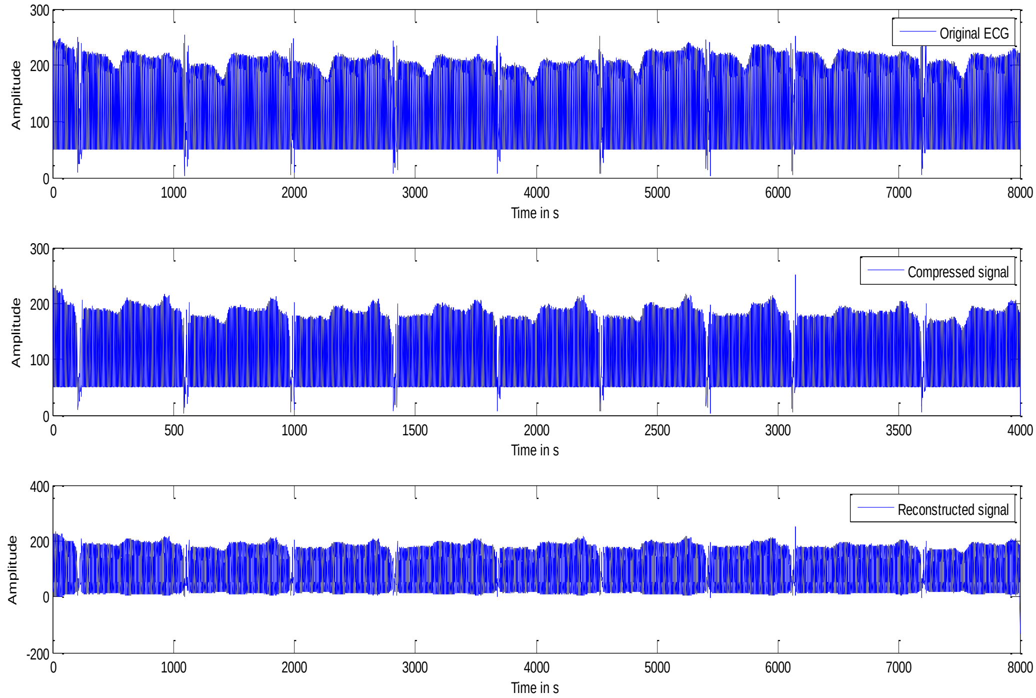

Fig 3 (Arrhythmia ECG)

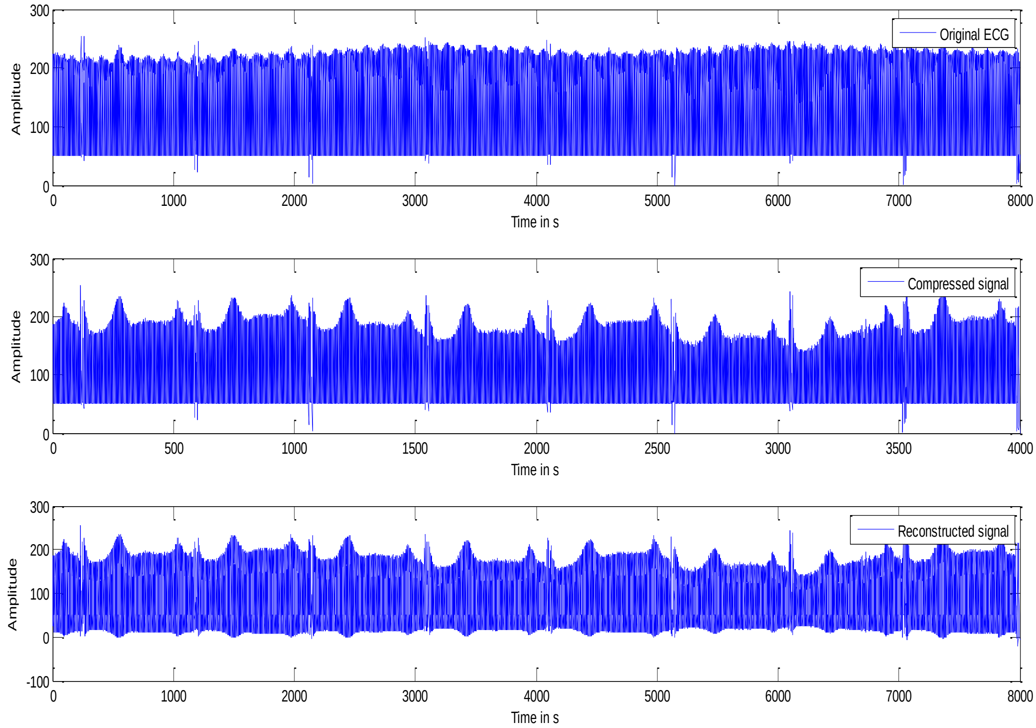

Fig 4 (Arrhythmia ECG)

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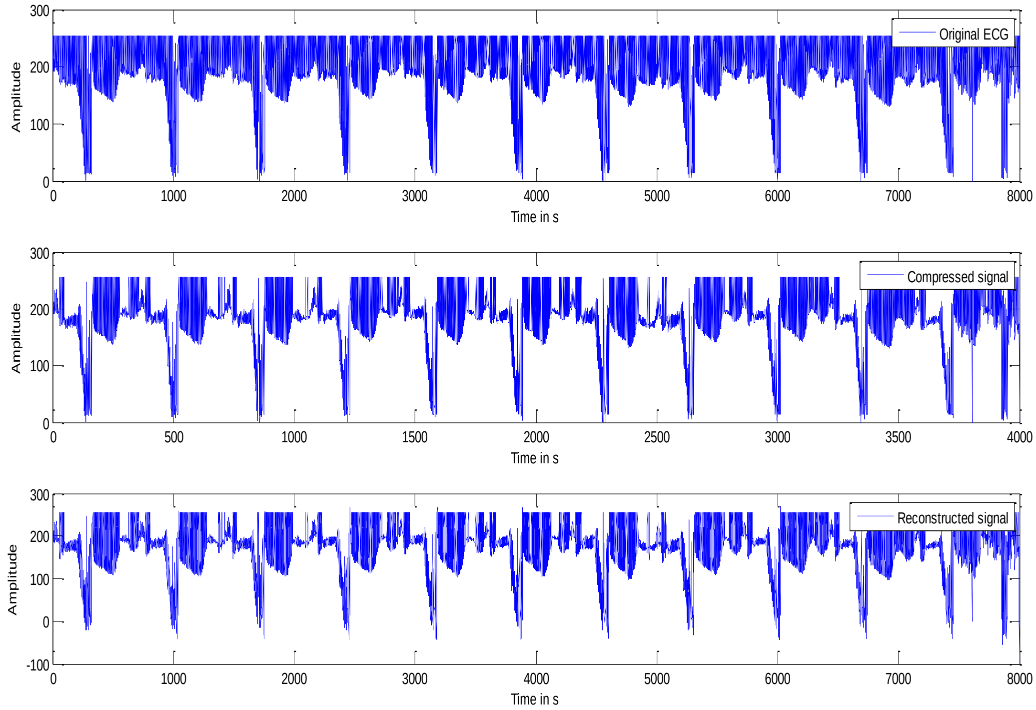

Fig 5 (Congestive Heart Failure ECG)

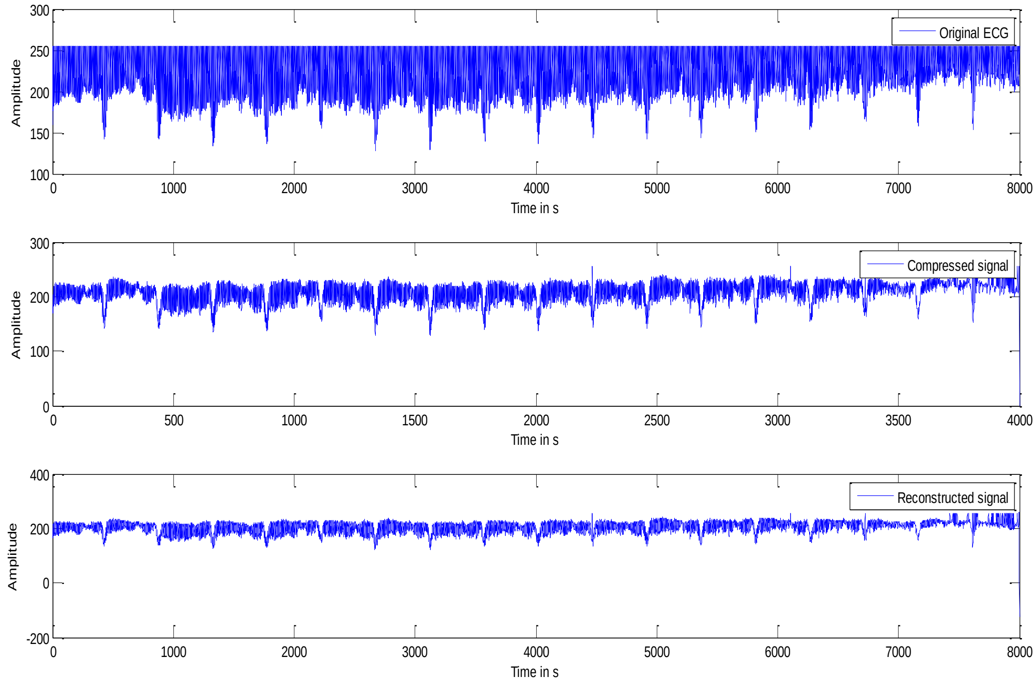

Fig 6 (Congestive Heart Failure ECG)

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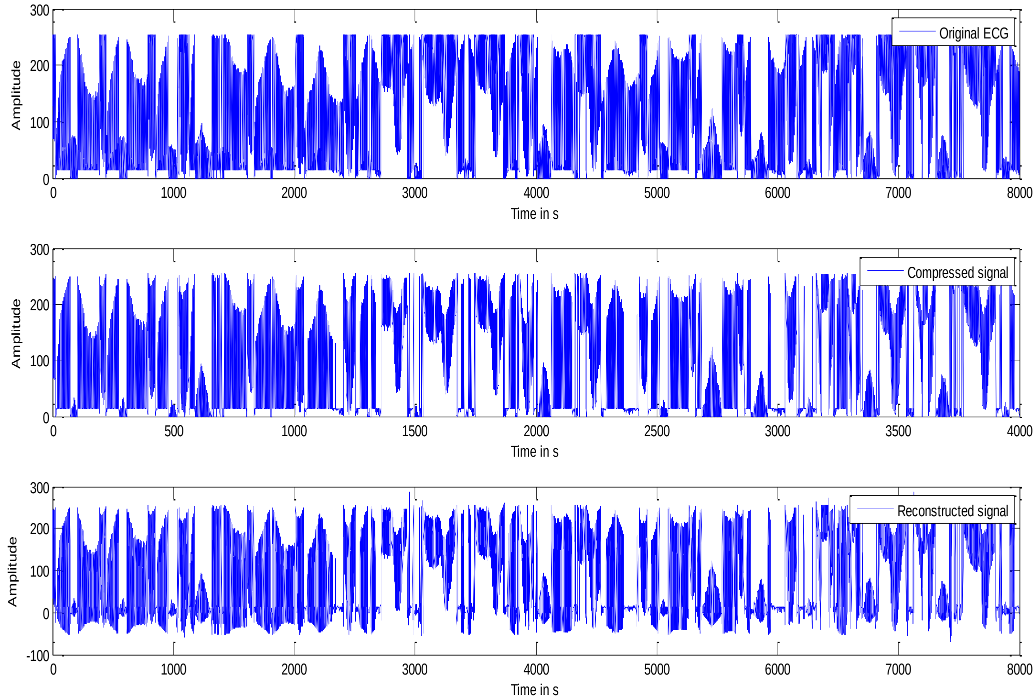

Fig 7 (Malignant Ventricular Arrhythmia ECG)

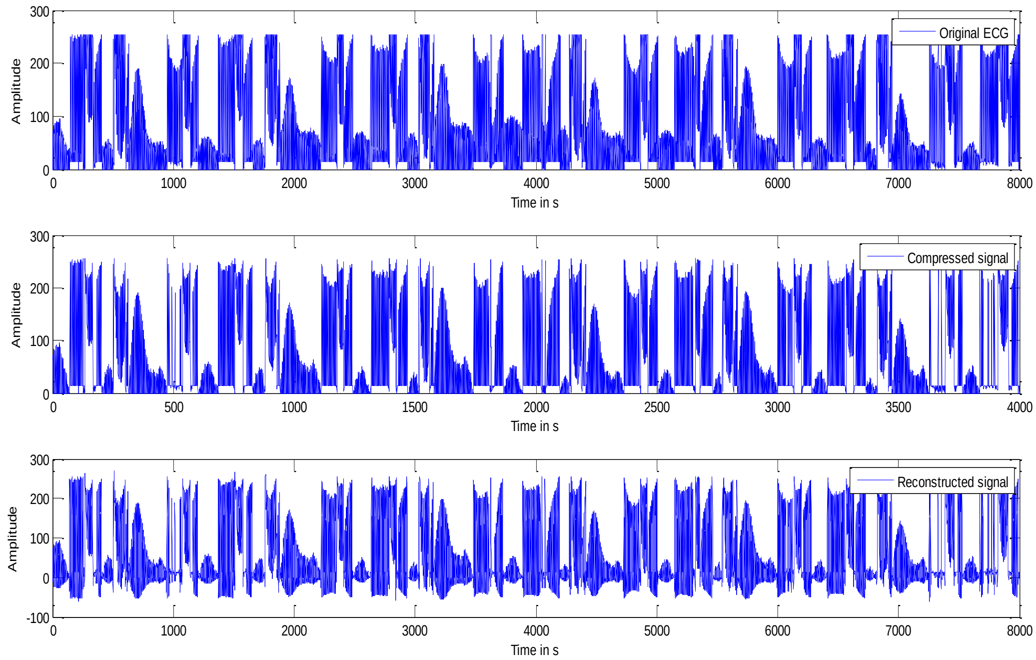

Fig 8 (Malignant Ventricular Arrhythmia ECG)

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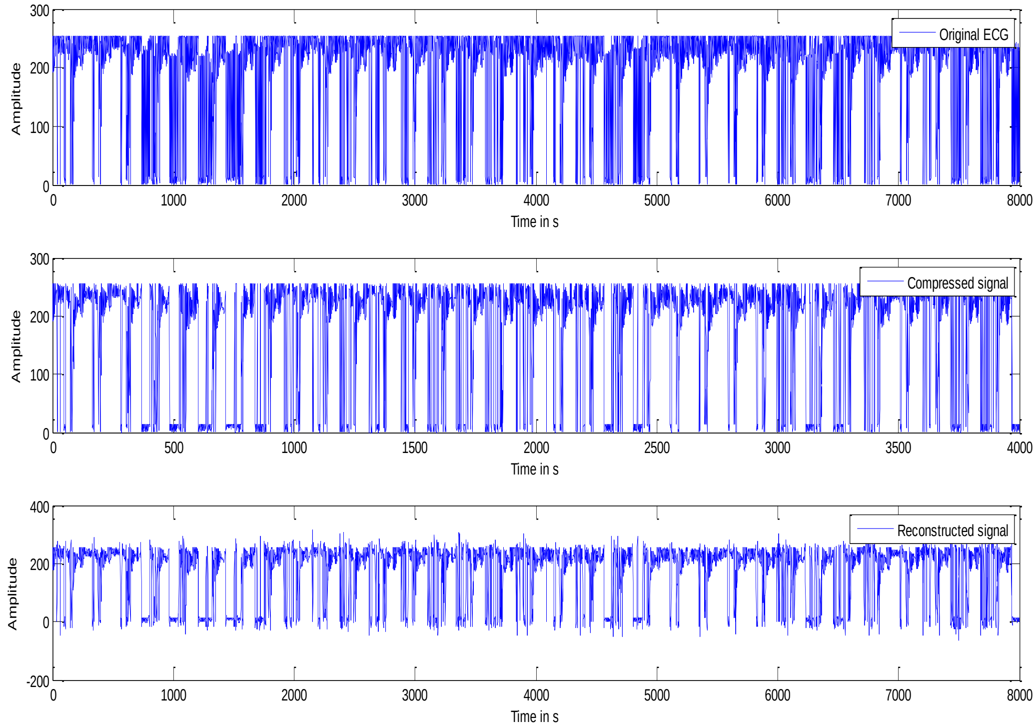

Fig 9 (Normal Sinus Rhythm ECG)

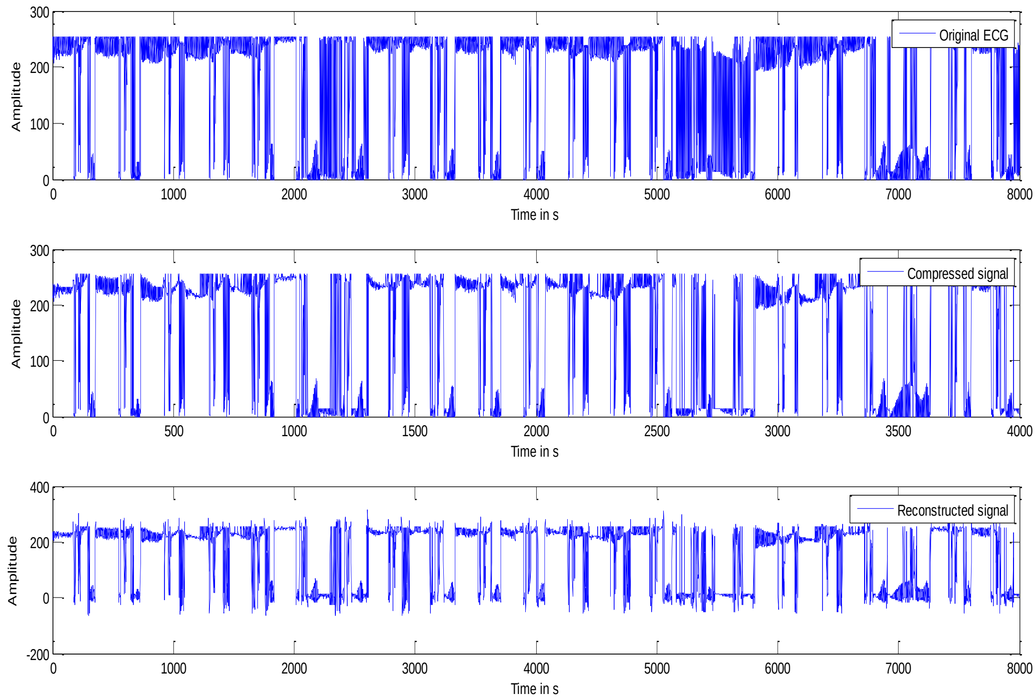

Fig 10 (Normal Sinus Rhythm ECG)

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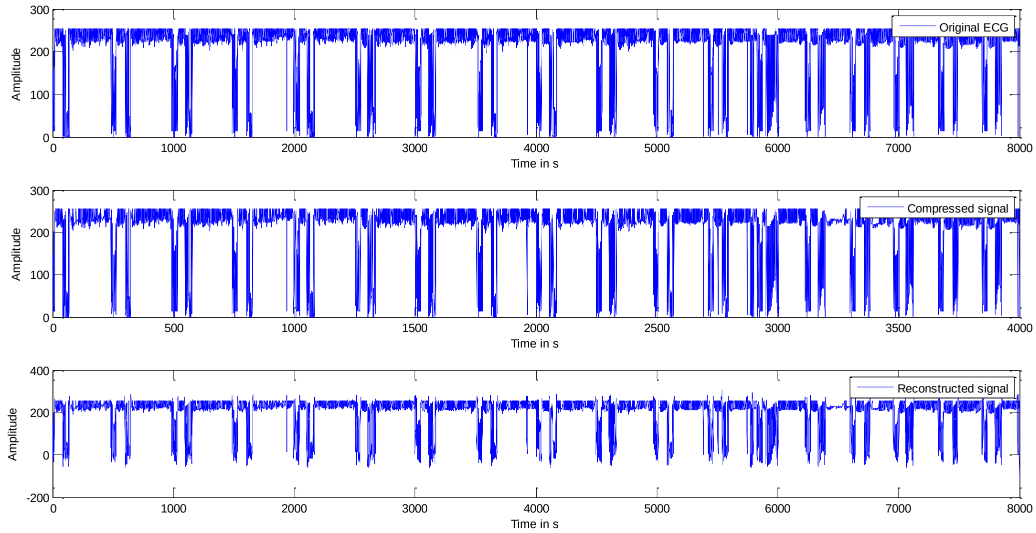

Fig 11 (Supra-Ventricular Arrhythmia ECG)

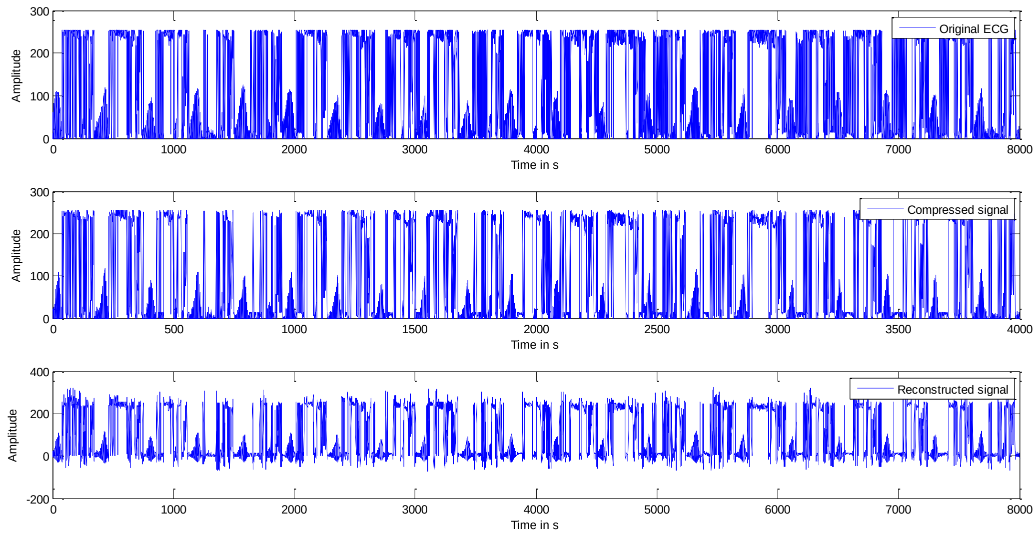

Fig 12 (Supra-Ventricular Arrhythmia ECG)

V. CONCLUSION

In all the results of normal and diseased ECG data the compression ratio is 2:1. Moreover from the results it is observed that the morphology of the compressed signal is not getting deteriorated. This shows that the Turning Point Algorithm for ECG Compression always produces a reduction ratio of 2:1 without much distortions in the reconstructed signal and this satisfied our goal of using Turning Point Algorithm. If we want to increase the compression ratio the same algorithm can be applied on the compressed signal.

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We are very much thankful to all the members of the website: http://www.physionet.org for providing the different diseased ECG data and without these ECG data this work would not have been possible.

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