ECG Signal Compression Implementation by a New 2-Dimensional Transform Technique

Pushpendra Singh, Om Prakash Yadav, Yojana Yadav

Abstract- Electrocardiogram signal compression algorithm is needed to reduce the amount of data to be transmitted, stored and analyzed, without losing the clinical information content. This work investigates a set of ECG signal compression schemes to compare their performances in compressing ECG signals. These schemes are based on transform methods such as discrete cosine transform (DCT), fast fourier transform (FFT), discrete sine transform (DST), and their improvements. An improvement of a discrete cosine transform (DCT)-based method for electrocardiogram (ECG) compression is also presented as DCT-II. A comparative study of performance of different transforms is made in terms of Compression Ratio (CR) and Percent root mean square difference (PRD).The appropriate use of a block based DCT associated to a uniform scalar dead zone quantiser and arithmetic coding show very good results, confirming that the proposed strategy exhibits competitive performances compared with the most popular compressors used for ECG compression. Each specific transform is applied to a pre-selected data segment from the CSE database, and then compression is performed.

Keywords- Compression Ratio, Compression factor, Compression time, ECG, PRD.

I. INTRODUCTION

An ECG signal is a graphical representation produced by an electrocardiograph, which records the electrical activity of the heart over time. The ambulatory monitoring system usually requires continuous 12 or 24-hours ambulatory recording for good diagnostic quality. For example, with the sampling rate of 360 Hz, 11 bit/sample data resolution, a 24-h record requires about 43 MByte per channel. So, 12-channel system requires nearly 513.216 M-Byte of storage disks daily.

Because of the tremendous amount of ECG data generated each year, an effective data compression schemes for ECG signals are required in many practical applications including ECG data storage or transmission over telephone line or digital telecommunication network. ECG data compression techniques are typically classified into three major categories; namely direct data compression [3]-[4], transform coding [5]-[8], and parameter extraction methods [9]-[11]. The direct data compression methods attempt to reduce redundancy in the data sequence by examining a successive number of neighboring samples. These techniques generally eliminate samples that can be implied by examining preceding and succeeding samples.

Even though many compression algorithms have been reported so far in the literature, not so many are currently used in monitoring systems and telemedicine.

In this paper a new compression technique asked on transform coding-II and QRS complex estimation is proposed. There are two motivations in this work. The first motivation is the QRS complex estimation using the extraction of significant features of ECG waveform. The second motivation is the selection of the threshold levels in each sub band such that high CR and low PRD are obtained. The significant features of ECG waveform are extracted to estimate the QRS complex.

Then, the estimated QRS-complex is subtracted from the original ECG signal. After that, the resulting error signal is discrete cosine transformed and the coefficients are threshold based on the energy packing efficiency. Finally the significant coefficients are coded and stored or transmitted.

II. COMPRESSION UTILITY

Compression techniques have been around for many years. However, there is still a continual need for the advancement of algorithms adapted for ECG data compression. The necessity of better ECG data compression methods is even greater today than just a few years ago for several reasons. The quantity of ECG records is increasing by the millions each year, and previous records cannot be deleted since one of the most important uses of ECG data is in the comparison of records obtained over a long range period of time. The ECG data compression techniques are limited to the amount of time required for compression and reconstruction, the noise embedded in the raw ECG signal, and the need for accurate reconstruction of the P, Q, R, S, and T waves. [20-22].

III. COMPRESSION TECHNIQUES

Lossless compression algorithms: the Run Length Encoding Algorithm, Huffman Encoding Algorithm, Shannon Fano Algorithm, Lempel Zev Welch Algorithm, Discrete Cosine Transform, Fast Fourier Transform, Discrete Sine Transform and Discrete Cosine Transform-II are implemented and tested with a set of ECG signal. Performances of the compression methods are also evaluated at the end of the paper.

[A] Huffman fano Approach

Huffman fano Algorithms calculate the frequencies first and then generate a common tree for both the compression and decompression processes [5]. Huffman Encoding and Shannon Fano approaches are implemented and executed independently.

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[B] Discrete Cosine Transform (DCT)

A discrete cosine transform (DCT) [19] expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies [9]. Discrete Cosine Transform is a basis for many signal and image compression algorithms due to its high de-correlation and energy compaction property [10].

[C] Fast Fourier Transform (FFT)

A fast Fourier transform (FFT) [11] is an efficient algorithm to compute the discrete Fourier transforms (DFT) and it's inverse [12]. An FFT is a way to compute the same result more quickly. Computing a DFT of N points in the naive way, using the definition, takes $O(N^2)$ arithmetical operations [13], while an FFT can compute the same result in only O(N log N) operations. Fast Fourier Transform is a fundamental transform in digital signal processing with applications in frequency analysis, signal processing etc [10]. The periodicity and symmetry properties of DFT are useful for compression.

[D] Discrete Sine Transform (DST)

Discrete sine transform (DST) [14] is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using a purely real matrix. DST implies different boundary conditions than the DFT or other related transforms [15].

[E] Proposed Method (DCT-II)

The most common variant of discrete cosine transform is the type-II DCT [16]. The DCT-II is typically defined as a real, orthogonal (unitary), linear transformation. DCT-II can be viewed as special case of the discrete Fourier transform (DFT) with real inputs of certain symmetry [17]. This viewpoint is fruitful because it means that any FFT algorithm for the DFT leads immediately to a corresponding fast algorithm for the DCT-II simply by discarding the redundant operations.

IV. PERFORMANCE EVALUATION

Depending on the nature of the application there are various criteria to measure the performance of a compression algorithm [18]. Following are some measurements used to evaluate the performances of lossless algorithms.

[A] Compression Ratio (CR)

Compression ratio is the ratio between the size of the compressed file and the size of the source file [23].

$$\text{Compression Ratio} = \frac{\text{size after compression}}{\text{size before compression}} \quad (1)$$

[B] Compression factor (CF)

It is the inverse of the compression ratio. That is the ratio between the size of the source file and the size of the compressed file.

$$\text{Compression Factor} = \frac{\text{size before compression}}{\text{size after compression}} \quad (2)$$

[C] Percent root mean square difference

PRD is the most prominently used distortion measure is the Percent Root mean square Difference (PRD) [18] that is given by

$$PRD = \left[\frac{\sum_{n=1}^{L_b}[x(n)-x'(n)]^2}{\sum_{n=1}^{L_b}[x(n)]^2}\right]^{(1/2)} \quad (3)$$

where x(n) is the original signal, x'(n) is the reconstructed signal and Lb is the length of the block or sequence over which PRD is calculated. PRD provides a numerical measure of the residual root mean square (rms) error.

[D] Compression Time (CT)

It is defined as the total time elapsed during the compression of original ECG signal. If the compression and decompression times of an algorithm are less or in an acceptable level it implies that the algorithm is acceptable with respective to the time factor. With the development of high speed computer accessories this factor may give very small values and those may depend on the performance of computers.

All the above methods evaluate the effectiveness of compression algorithms using file sizes. There are some other methods to evaluate the performance of compression algorithms. Compression time, computational complexity and probability distribution are also used to measure the effectiveness.

V. RESULTS AND DISCUSSION

CSE database has been used to test the performance of the compression techniques. The ECG data is sampled at 333 Hz. The amount of compression is measured by CR and the distortion between the original and reconstructed signal is measured by PRD. The comparison table shown in Table 1, details the resultant compression techniques. This gives the choice to select the best suitable compression method. A data compression algorithm must represent the data with acceptable fidelity while achieving high CR. As the PRD indicates reconstruction fidelity; the increase in its value is actually undesirable. Although proposed method provides maximum CR, but distortion is more. So a compromise is made between CR and PRD.

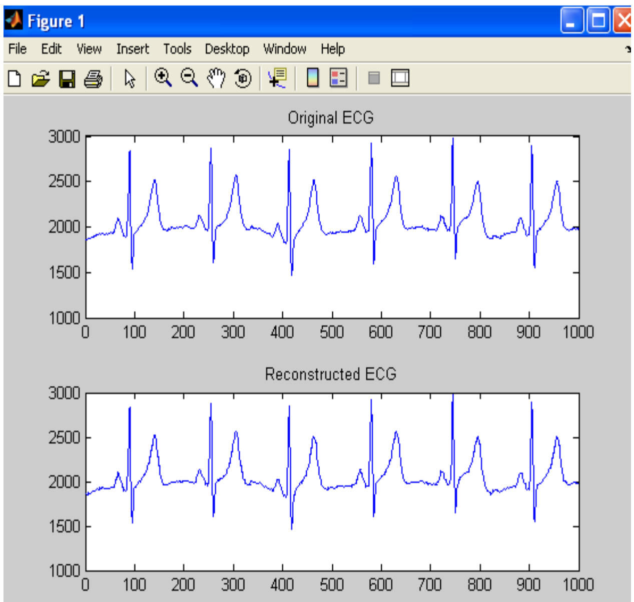

Figure 1. Fano compression analysis

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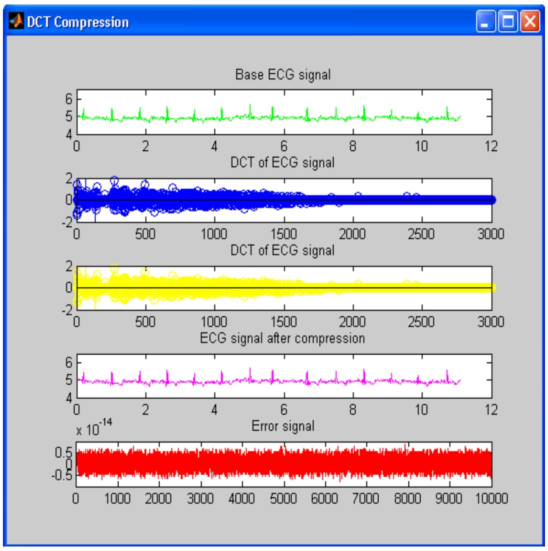

Figure 2. DCT compression analysis

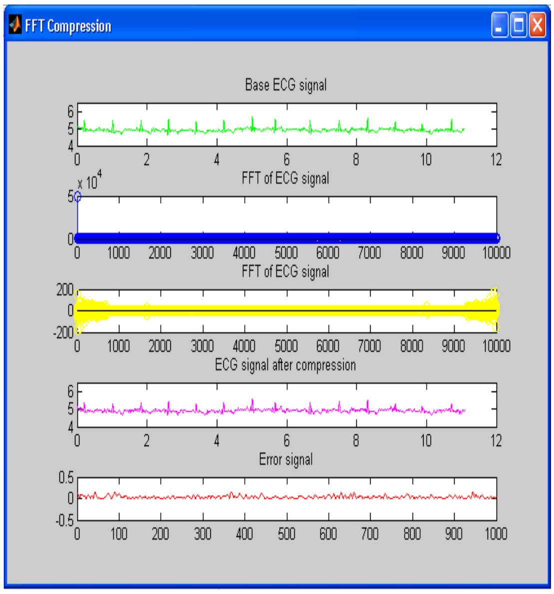

Figure 3. FFT compression analysis

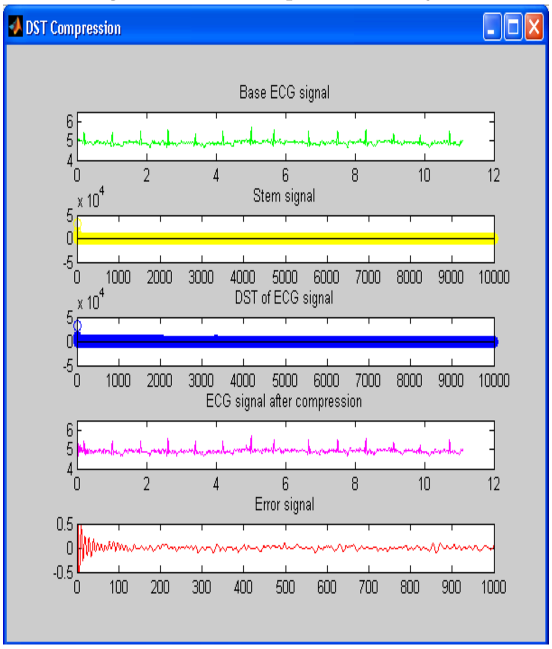

Figure 4. DST compression analysis

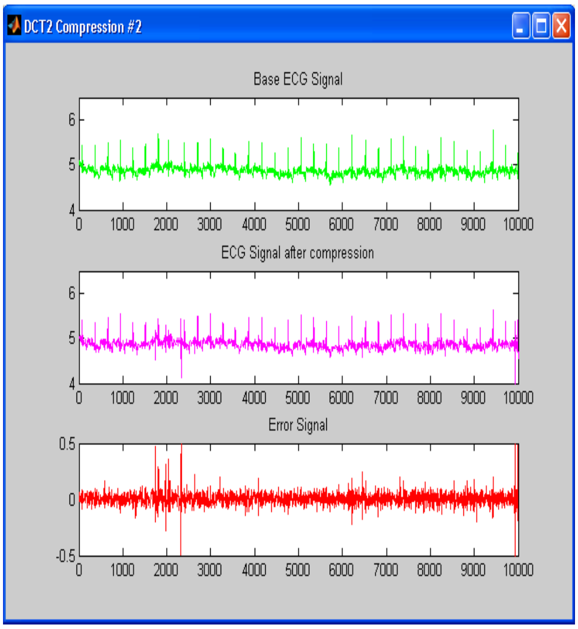

Figure 5. Proposed DCT-II compression analysis

Table1. Performance of Compression Techniques

Method	CR	CF	PRD	CT
FANO	74.47	0.0134	1.0949	0.151020
DCT	93.96	0.0106	6.1200	6.193842
FFT	94.75	0.0105	0.9230	5.466393
DST	87.90	0.0113	1.2468	5.479781
Proposed	98.57	0.0101	1.0164	0.508601

VI. CONCLUSION

Among the five techniques presented, Fano provides lowest CR but distortion is low.. Next is DST which gives higher CR 87.90 with PRD as 1.2468. FFT gives higher CR as 94.75 and PRD is also low as 0.9230 But DCT-II provides an improvement in terms of CR of 98.57 but PRD increases up to 1.0164. Thus an improvement of a discrete cosine transform (DCT)-based method for electrocardiogram (ECG) compression is presented as DCT-II in terms of amount of compression. The appropriate use of a block based DCT-II associated to a uniform scalar dead zone quantiser and arithmetic coding show very good results, confirming that the proposed strategy exhibits competitive performances compared with the most popular compressors used for ECG compression.

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