A SURVEY ON COMPRESSION TECHNIQUES FOR ECG SIGNALS

Ranjana Chaturvedi, Mrs. Yojana Yadav

Student, Department of ET & T, Chhatrapati Shivaji Institute of Technology, Durg, India
Associate Professor, Department of ET & T, Chhatrapati Shivaji Institute of Technology, Durg, India

Abstract: Electrocardiogram (ECG) signal play important role in diagnosis and survival analysis of heart diseases. Various techniques have been proposed over the years addressing the signal compression. Compression of ECG signals is desirable for three reasons: economic use of storage data, reduction of the data transmission rate and transmission bandwidth conversation. In this paper a comparative study of Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Discrete Cosine compression and Discrete Wavelet Transform (DWT) is used. Different ECG signals taken from MIT-BIH arrhythmia database are tested. The experimental results are obtained for Percent Root Mean Square Difference (PRD) and Compression ratio (CR). The result of ECG signal compression shows better compression performance for DCT and DWT with appropriate PRD. The main purpose of this research work is to compare the major techniques of ECG signal compression in a single view.

Keywords: ECG, Data compression technique, Compression ratio, PRD.

I. INTRODUCTION

In recent years, many researches have made on ECG compression technique but still there is a need for a compression technique which provides higher compression with quality reconstruction. ECG signal contain large amount of information that requires much more storage space, large transmission bandwidth and long transmission time, therefore it is advantageous to compress the signal by storing only the essential information needed to reconstruct the signal [8]. From engineering point of view, an ECG signal is periodic. Figure 1 show one cardiac cycle of the signal which is also known as the R-R interval with three indicated parts: P wave, QRS complex, and the T wave. These waves are the result of contraction and expansion of the heart muscles. The P wave is due to the depolarization of atria whereas QRS complex reflects the rapid depolarization of right and left ventricles. The T-wave represents the repolarisation (or recovery) of the ventricles [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 [8][9]. Compression algorithms are classified into: 1) Direct time domain technique 2) Transformational approaches 3) Parameter extraction technique In direct methods, the original ECG signal samples are compressed directly, and in transformed and in transformation method the original samples are first transformed and then compressed. In parameter extraction methods, the features of the processed signal are extracted and then these features are used for reconstruction of the signal [2]. Various time domain compression algorithms for ECG signals can be found in the literature. These methods are based on the idea of extracting few significant signal samples to represent the signal and then decoding the same set of samples. The time domain algorithms are based on fast heuristics in the sample selection process. These techniques are faster but suffer from sub optimality. Examples of such techniques are the FAN algorithms [3] and the AZTEC algorithms [4]. Time domain algorithms were further improved by SLOPE [5] and AZTDIS [6] techniques. The cardinality constrained shortest path (CSSP) algorithms presented in [7] is based on a mathematical modeled as nodes in graph and then optimization techniques are applied for achieving higher compression ratio.
II. METHODOLOGY

Following transform are generally used

A. Discrete Sine Transform (DST):

DST is fourier related transform similar to discrete fourier and it uses purely matrix. It implies different boundary conditions [13]. The DST is implemented by equation (1):

\[ y(x) = \sum_{n=1}^{N} x(n) \sin \left( \frac{\pi}{N} kn \right) \]

Where k= 1, 2, 3 …………N and n= 1, 2 …N

B. Fast Fourier Transform (FFT):

FFT is an algorithm to compute the Discrete Fourier Transform & its inverse. The number of complex multiplication to compute DFT is \( N^2 \). But in FFT it reduces the computation to \( N \log_2 N \) [7]. The FFT of any function is computed by equation (2):

\[ X(k) = \sum_{j=0}^{N-1} x(j) \omega_{N}^{j-k} \]

Where,

\[ x(j) = \left( \frac{1}{N} \right) \sum_{n=1}^{N} X(k) \omega_{N}^{j-k} \]

\[ \omega_{N} = e^{-\frac{2\pi i}{N}} \]

is an Nth root of unity[13].

C. Discrete Cosine Transform (DCT):

DCT is closely related to DFT. It transforms a signal from spatial representation into frequency representation. DCT represents a signal as a sum of varying magnitude and frequency. It implies different boundary condition & often used in signal & image processing for lossy data compression has strong “energy compaction property” & it provide high de-correlation [8][15].

\[ y(k) = \omega(k) \sum_{n=1}^{N} x(n) \cos \left( \frac{\pi}{N} (2n-1)(k-1) \right) \]

Where

\[ \omega(k) = \begin{cases} 1 & k = 1 \\ \frac{1}{\sqrt{2}} & 2 \leq k \leq N \end{cases} \]

D. Discrete Cosine Transform-II (DCT-II):

The DCT-II is the most commonly used form, and is often simply referred to as ”the DCT”. This transform is exactly equivalent (up to an overall scale factor of 2) to a DFT of 4N real inputs of even symmetry where the even-indexed elements are zero. That is, it is half of the DFT of the 4N inputs \( y_n \) where \( y_{2n}, y_{2n+1} = 0 \), for \( 0 \leq n < N \), \( y_{2N} = 0 \), and \( y_{4N} = y_n \) for \( 0 < n < N \).

\[ X_k = \sum_{n=0}^{N-1} x_n \cos \left( \frac{\pi}{N} (n + \frac{1}{2}) k \right) \]

The DCT-II implies the boundary conditions: \( x_n \) is even around \( n=1/2 \) and even around \( n=N-1/2 \); \( X_k \) is even around \( k=0 \) and odd around \( k=N \) [17][18][19].

The testing criteria for the compression algorithm performance consist of the compression ratio and error values. The compression ratio (CR) is defined as the size (data storage byte) ratio of the original signal to that of the compressed signal. The error is measured as the percent mean square difference (PRD) between original and reconstructed signal. The aim of ECG compression is to maximise the CR (8) while minimising the PRD (9). The CR and the PRD definitions are indicated below:

\[ CR = \frac{\text{Data size before compression}}{\text{Data size after compression}} \]

\[ PRD = \frac{\sum_{i=1}^{N} (s_i - \hat{s}_i)^2}{\sum_{i=1}^{N} s_i^2} \cdot 100 \]

Where \( N \) is the number of data samples, \( s(t) \) is the original signal and \( \hat{s}(t) \) is the reconstructed signal[12].

III. RESULTS

This section basically dealt with the results obtained for DCT, FFT, DST and DCT-II transform applied over ECG data taken from MIT-BIH database. The following table shows the values of compression ratio and percentage root mean square difference. It is found in the literature that for compression domain higher CR and lower PRD are required.

<table>
<thead>
<tr>
<th>METHODS</th>
<th>CR</th>
<th>PRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCT</td>
<td>91.6800</td>
<td>0.8392</td>
</tr>
<tr>
<td>FFT</td>
<td>89.5723</td>
<td>1.0237</td>
</tr>
</tbody>
</table>

TABLE: 1

THIS RESULT IS TAKEN FROM [16][20].
IV. CONCLUSION

The main objectives of this paper are to present the major techniques of ECG signal compression. This paper surveys techniques of past years. Among the four techniques presented, DST provides lowest CR and distortion is also high. FFT improves CR and lowers PRD. So FFT is better choice than DST. Next is DCT which gives higher CR up to 91.68 with PRD as 0.8392. But DCT-II provides an improvement in terms of CR of 94.28 but PRD increases up to 1.5729. Thus an improvement of a discrete cosine transform (DCT)-based method for electrocardiogram (ECG) compression is presented as DCT-II. In future more advance techniques like polynomial approximation, can be employed to achieve higher CR and lower PRD. Similarly more performance parameters like saving percentage can be included to make an accurate compression system for ECG signals.

REFERENCES


BIOGRAPHIES

Ranjana Chaturvedi (B.E.) has completed her engineering from Government engineering College Bilaspur (kon).She is pursuing ME in communication engineering branch from Chhatrapati Shivaji Institute of Technology, Durg, Chhattisgarh.

Mrs. Yojana Yadav (M.Tech) is currently working as Associate Professor in the Department of Electronics & Telecommunication Engineering in Chhatrapati Shivaji Institute of Technology, Durg (C.G), India and having total 07 Years Experience of Teaching. She has published two research papers in National conference and one research paper in International Journal.