Compression of Electrocardiograph Signal using Fast Fourier Transform Technique

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Abstract

This research paper presents an Electrocardiography (ECG) compression based on optimized quantization of Fast Fourier Transform (FFT) coefficients. The ECG to be compressed is partitioned in blocks of fixed size, and each FFT block is quantized using a quantization vector that are specifically defined for each signal. The Percent Root-Mean-Square Difference (PRD) was adopted as a measure of the distortion introduced by the compressor. We also present traces of test signals before and after the compression/decompression process. The results show that the proposed method achieves good compression ratios (CR). The objective is realized by constructing and designing an algorithm & software for compression which would enable optimal storage of ECG signals in the database for future references.

1. Keywords

ECG, Compression, Fast Fourier Transform (FFT), Compression Ratio (CR), Percentage Root Mean Square Difference (PRD)

2. Introduction

In this paper, an Electrocardiogram (ECG) signal is compressed based on Fast Fourier Transform (FFT) and QRS-complex estimation. The ECG signal is pre-processed by normalization and mean removal. Then, an error signal is formed as the difference between the pre-processed ECG signal and the estimated QRS-complex waveform. This error signal is fast fourier transformed and the resulting fourier coefficients are threshold by setting to zero all coefficients that are smaller than certain threshold levels. The threshold levels of all sub-bands are calculated such that minimum percentage root mean square difference (PRD) and maximum compression ratio (CR) are obtained. The resulted threshold FFT coefficients are coded using the coding technique given in. Simulation results show that the proposed algorithm leads to high CR associated with low distortion level. The main features of this compression algorithm are the high efficiency and high speed. 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.

3. FFT Technique

The Fast Fourier transform (FFT) is defined by the formula:

$$X_k = \sum_{n=0}^{N-1} x_n e^{-nk2\pi i/n},$$

where k is an integer ranging from 0 to $N-1$.

The algorithm first computes the FFTs of the even-indexed inputs x2m(x0,x1,…,xN-2) and odd-indexed inputs x2m+1(x1,x3,…,xN-1), and combines those two results to produce the FFT of the whole sequence. The algorithm runs at its maximum speed when N is the power of two. The equation becomes:

$$X_k = \sum_{m=0}^{N/2-1} x_{2m} e^{-mk4\pi i/N} + \sum_{m=0}^{N/2} x_{2m+1} e^{-(2m+1)4ki\pi/N}$$

We can factor out he common multiplier $e^{-k*2pi*\frac{i}{N}}$ out the second sum we obtain:

$$X_k = \sum_{m=0}^{N/2-1} x_{2m} e^{-mk\frac{2\pi i}{N/2}} + e^{-k\frac{2\pi i}{N}} \sum_{m=0}^{N/2-1} x_{2m+1} e^{-mk\frac{2\pi i}{N/2}}$$
$$= E_k + e^{-k\frac{2\pi i}{N}} O_k$$

Because of the periodicity properties of the FFT, the outputs for N/2≤k<N from a FFT of length N/2 are identical to the outputs for 0≤k<N/2. The whole equation becomes:

$$X_k = \begin{cases} E_k + e^{-\frac{2\pi i}{N}k} O_k & \text{if } k < N/2 \\ E_{k-N/2} - e^{-\frac{2\pi i}{N}(k-N/2)} O_{k-N/2} & \text{if } k \geq N/2 \end{cases}$$

This equation expresses the FFT of length N recursively in terms of two FFTs of size N/2which can reduce the computation time by hundreds.

4. Performance parameters

The effectiveness of an ECG compression technique is described in terms of:

4.1. Compression Ratio (CR)

CR is the ratio of the original data to compressed data without taking into account factors such as bandwidth, sampling frequency, precision of the original data, word- length of compression parameters, reconstruction error threshold, database size, lead selection, and noise level. It is given by[5]:

$$CR = \frac{original\ file\ size}{compressed\ file\ size}$$

Higher the CR, smaller is the size of the compressed file.

4.2. Percentage Root Mean Square Difference (PRD)

PRD is a measure of error loss. This measure evaluates the distortion between the original and the reconstructed signal. PRD calculation is as follows[5]:

$$PRD = 100 \times \sqrt{\frac{\sum_{i=1}^{n}\left(ORG(i) - REC(i)\right)^2}{\sum_{i=1}^{n}(ORG(i))^2}}$$

Where ORG is the original signal and REC is the reconstructed signal. The lower the PRD, the closer the reconstructed signal is to the original ECG data.

5. Methodology

ECG signals are compressed by using many techniques. One of the most important technique is FFT (Fast Fourier Transform).

FFT is a technique used to convert analog signal to digital signal.

In FFT, the total process takes five steps:-

1. Input signal
2. Compression (counter A)
3. Compression (counter B)

5.1.Compression Stage (counter A)

There are two stages for compression. In first stage of compression there is a counter A. It identifies the non-zero values of the signal before compression.
After compression length of the compressed signal is compared with the length of the actual signal.

5.2.Zero Padding

If the length of the compressed signal is less than the length of the actual signal, then zero padding is done to make equal the lengths of compressed and actual signal.

5.3.Compression Stage (counter B)

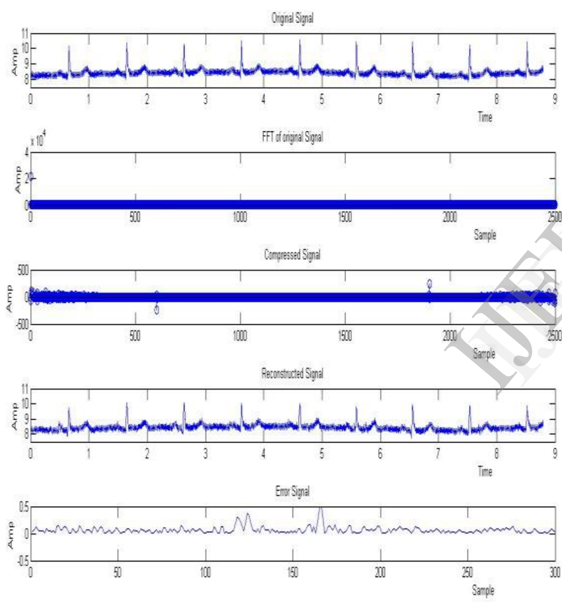
Now the signal is passed through the counter B. It identifies the non-zero values after the compression of the signal.

After compression length of the compressed signal is compared with the length of the actual signal

5.4.Truncation

Now after compression if the length of the compressed signal is greater than the length of the actual signal, then TRUNCATION of the signal is done.

6. Result



SIGNAL	CR	PRD
ecg.mat	87.56	0.9376

7. Conclusion

In this paper, method for compressing ECG signal based on fast fourier transform has been discussed. The key idea lies in the estimation of QRS-complex signal from a given ECG signal. The QRS-complex is estimated using parameters extracted from the original ECG signal. It results in higher CR with less PRD. FFT technique will require further investigations in order to improve the clinical usefulness of this novel signal processing technique. Simultaneously diagnostic and prognostic significance of wavelet techniques in various fields of electro cardiology needs to be established in large clinical studies.

8. References

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