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Compression of ECG Signal Using Fast Fourier Transform Technique-A Survey Approach

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Abstract

Electrocardiogram (ECG) is a graphic tracing of the variations in electrical potential caused by the excitation of the heart muscle and detected at the body surface. ECG plays a significant role in diagnosing most of the cardiac diseases. Many types of ECG recordings generate a vast amount of data. ECG compression becomes mandatory to efficiently store and retrieve this data from medical database. ECG data compression technique is needed to reduce the amount of data to be transmitted, stored and analyzed, without losing the clinical information content. Thus, the need for effective ECG compression techniques is of great importance. Many existing compression algorithms have shown some success in electrocardiogram compression; however, algorithms that produce better compression ratios and of minimum PRD data in the reconstructed signal are needed. In the present report, we discuss the survey of work done by various researchers.

1. Keywords

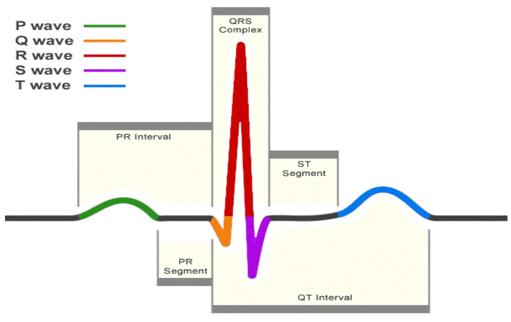
ECG, Compression, Fast Fourier Transform (FFT), Compression Ratio (CR), Percentage Root Mean Square Difference (PRD), Compression Time (CT), Space Saving (SS), Compression Factor (CF).

2. Introduction

An electrocardiogram (ECG) is a non-invasive method to record the variation of bio-potential signal of human heart beats. The ECG detection which shows the information of heart and cardiovascular condition is essential to enhance the patient living quality and appropriate treatment[3].

The need for ECG compression exists in many transmitting and storage applications. Transmitting the ECG signal through telephone lines, for example, may save a crucial time an unnecessary difficulty in emergency cases. Effective storage is required of large quantities of ECG information in the intensive coronary care unit. ECG monitoring usually require continuous 12 or 24-hours ambulatory recording. For good diagnostic quality, each ECG lead should be sampled at a rate of 250-500 Hz with 12 bits resolution. The information rate is thus 11-22 Mbits/hour/lead approximately. The monitoring device must have a memory capacity of about 100- 200 Mbytes for a 3-lead recording. Memory costs may render such a solid state device impractical. In practice, efficient data compression may be achieved only with lossy compression techniques (which allow reconstruction error).

3. Waves and intervals



In ECG signal compression algorithms the goal is to achieve a minimum information rate, while retaining the relevant diagnostic information in the reconstructed signal. All ECG compression algorithms have used simple mathematical distortion measure such as the percentage mean square difference (PRD) for evaluation the reconstructed signal. It is used to evaluate the compression result[2].A typical ECG tracing of a normal heartbeat(or cardiac cycle) consists of a P wave, a QRS complex and a T wave. A small U wave is normally visible in 50 to 75% of ECGs. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave[1].

4. Compression Techniques

4.1.Direct Method

In this samples of the signal are directly used to provide the compression. In addition, they are highly sensitive to sampling rate, quantization level and high frequency interference [3].

4.2.Parameter Extraction Method

Here, the signal is analyzed and some important features are determined before storing them. Reconstruction is then carried out by the use appropriate interpolation schemes. But as the modelling emphasizes more on the high amplitude region, the low amplitude region, which is crucial for the reconstruction of small significant components get neglected [3].

4.3.Transformation Method

In this original samples of ECG are subjected to a (linear) transformation and the compression is performed in the entirely new domain[3]. This divides the signal into frequency components and allocates bits in the frequency domain efficiently. The input signal is divided into blocks of data and then stored in the frequency domain in the form of a vector. Then the entries in the vector are de-correlated which helps one to retain only the useful information. Its main focus is to minimize the number of addition and multiplication operations by using the symmetry property of the waveforms.

Transform method provides higher coding results as compared to the time-domain and parametric extraction method. One of the technique using this method is using Fast Fourier Transform (FFT) Technique[5].

4.3.1.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.

5. Performance parameters

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

5.1. 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.

5.2. Percentage 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.

5.3. 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[5].

$$CF = \frac{size\ of\ original\ signal}{size\ of\ source\ signal} \times 100$$

5.4. 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[5].

5.5. Space Savings

Space Savings is defined as the reduction in size relative to the uncompressed size.

$$SS = 1 - \frac{compressed\ size}{uncompressed\ size}$$

6. 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)

6.1.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.

6.2.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.

6.3.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

6.4.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.

7. Comparison

1) The research work of Anamitra Bardhan Roy, Debasmita Dey, Devmalya Banerjee, Bidisha Mohanty gave compression ratio(CR) 0f 162.795.
2) The research work of Mayur Kumar Chhipa gave compression ratio(CR) of 89.57 and percentage mean square difference(PRD) of 0.01.
3) The study of Min Yang gave compression ratio(CR) of 89.57 and percentage mean square difference(PRD) of 1.1661.
4) The research work Manjari Sharma, A.K. Wadhwani gave compression ratio(CR) of 89.57 and percentage mean square difference(PRD) of 1.0237.
5) Vikram Dangi, Amol Parab, Kshitij Pawar gave compression ratio(CR) of 0.191, Space Saving(SS) of 0.8090, compression factor(CF) of 5.23 and percentage mean square difference(PRD) of 7.05.

8. Conclusion

The research paper of Anamitra Bardhan Roy, Debasmita Dey, Devmalya Banerjee, Bidisha Mohanty showed maximum compression ratio and research paper of Mayur Kumar Chhipa showed minimum Percentage Mean Square Difference. The future work mainly concentrates on developing an algorithm for efficient storage of ECG. Moreover, additional statistical data like compression factor (CF) , compression time (CT) and space savings (SS) will be utilized for evaluating the performance of an algorithm in ECG compression.

9. References

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