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ECG Data Compression Using DWT

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Abstract— Although digital storage media is not expensive and computational power has exponentially increased in past few years, the possibility of electrocardiogram (ECG) compression still attracts the attention, due to the huge amount of data that has to be stored and transmitted; the amount that grows (depending upon the sampling rate, quantization levels and number of sensors) at the rate of 7.5-540 KB per minute per patient, depending upon the time and amplitude, sampling rate and number of sensors.

Besides the increased storage capacity for archival purposes, ECG compression allows real-time transmission over telephone networks, economic off-line transmission to remote interpretation sites, improves Holter monitor systems and enables efficient ECG rhythm analysis algorithms. A wide range of compression techniques based on different transformation techniques like DCT, FFT; DST & DCT2 were evaluated to find an optimal compression strategy for ECG data compression. Wavelet compression techniques were found to be optimal in terms of compression.

Index Terms— ECG, Compression, DCT, DWT, CR and PRD

I. INTRODUCTION

The "Electrocardiogram" (ECG) is an invaluable tool for diagnosis of heart diseases. The volume of ECG data produced by monitoring systems can be quite large over a long period of time and ECG data compression is often needed for efficient storage of such data. Similarly, when ECG data need to be transmitted for telemedicine applications, data compression needs to be utilized for efficient transmission. While ECG systems are found primarily in hospitals, they find use in many other locales also. ECG systems are used by paramedics responding to accident scenes in emergency vehicles. They are also used by clinicians at remote sites. Certain military and/or space missions also employ ECG. A growing area of use for ECG is the 24-hour holters that are leased by consumers. These portable ECG devices record and store the data for subsequent interpretation by a doctor.

The objective of this project is to develop and implement a low-complexity lossy ECG encoding algorithm capable of at least a 2:1 compression ratio (CR) for use in applications like Holter Monitor & ECG rhythm analysis etc. Different lossy compression techniques were evaluated in terms of coding efficiency as well as suitability for ECG waveform application, random access within the signal and complexity of the decoding operation. A coder-decoder based on a new emerging transformation technique; called as "Wavelet Transform" coding is chosen and found to give a better compression ratio of at least 2:1 on real-world offline ECG signals tested while having a low encoder - decoder complexity and fast random access to arbitrary parts of the ECG signal. In our experiments, the resulting algorithm produces much better compression ratios than competing techniques while retaining the essential characteristics of the ECG waveform.

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II. ELECTROCARDIOGRAM (ECG)

An electrocardiogram is simply a measure of voltage changes in the body. Any large electrical event can be detected. The electrically-active tissues in the body are the muscles and nerves. Small brief changes in voltage can be detected as these tissues 'fire' electrically. The heart is a muscle with well-coordinated electrical activity, so the electrical activity within the heart can be easily detected from the outside of the body

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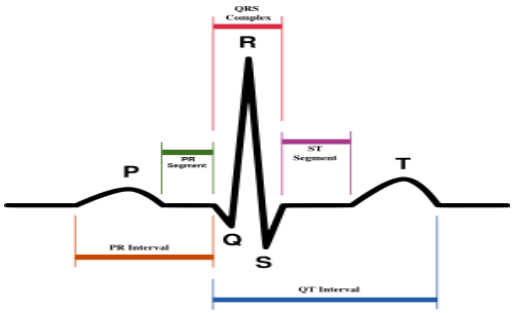

Fig 2.1 Schematic Representation of Normal ECG

The above diagram shows the schematic representation of normal ECG waveform. A normal heartbeat or cardiac cycle has P wave, a QRS complex and a T wave. A small U wave is sometimes visible in 50 to 75% of ECGs.

III. ECG COMPRESSION TECHNIQUES

Many existing compression algorithms have shown some success in electrocardiogram compression; however, algorithms that produce better compression ratios and less loss of data in the reconstructed data are needed.

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This project will provide an overview of several compression techniques and will formulate new emerging algorithms that should improve compression ratios and lessen error in the reconstructed data.

Finally, an easy to use computer program will be written in "MATRIX LABORATORY (MATLAB)", which will allow its user to compare various compression schemes and analyze reconstructed electrocardiogram records through a graphic interface, without detailed knowledge of the mathematics behind the compression algorithms.

3.1Data Compression Techniques:

In ECG data compression scheme, the idea is to represent the signal/information with fewer bits. Any signal that contains some redundancy can be compressed. Generally, there are two types of compression techniques: "Lossless" and "Lossy" compression.

As mentioned, lossy ECG compression is typically done in the time domain as it is viewed by the cardiologist as a waveform on a screen or piece of paper.

3.3.2 Lossless Compression:

A lossless compression scheme is one where the output of the decoder is identical to the input to the encoder, as shown in Figure 4.2. The term compressor is not entirely accurate when applied to a lossless system. The decoded signal is an exactly the same to the original signal x[n].

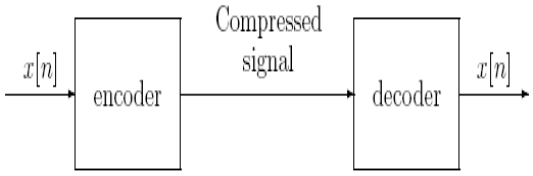

Fig 3.3 Block Diagram of Lossless Compression Technique

The lossless Compression techniques such as Null suppression, Run-Length coding, Diatomic coding, Pattern substitution, Differencing, Facsimile, Statistical –Huffman and LZ family are less suitable as the reconstruction of signal is perfect while compression ratio is poor.

3.3.3 ECG Compression Scheme:

The objective of this project is to obtain a time-frequency domain approximation of the ECG signal using lossy compression scheme based on a new emerging method of transformation i.e. "Wavelet Transform".

IV. WAVELET TRANSFORM & WAVELET FAMILY

By using mathematical transforms such as the Fast Fourier Transform or Discrete Cosine Transform, it is possible to compress data to a very high degree. But, however, these processes usually require large computing efforts.

Suppose for example, the Discrete Cosine Transform (DCT) is currently widely used for compressing data such as images (JPEG), video (MPEG) and audio (MP3). However, it has also been used for compressing medical signals such as ECG data. Using original data x with N data points, the DCT can be defined as;

$$X(k)=\alpha(k)\sum_{n=0}^{N-1}x(n)\cdot\cos\left[\frac{\pi(2n+1)k}{2N}\right] \qquad 0\le k\le N-1$$

Where,

$$\alpha(0)=\sqrt{\frac{1}{N}}\ , \qquad \alpha(k)=\sqrt{\frac{2}{N}}\ \ for\ 1\le k\le N-1$$

Using this equation, it is possible to transform the original signal into a spatial domain. By truncating the signal in the transformed domain and then Run-Length encode the signal, it is possible to achieve high degrees of compression.

V. RESULTS & CONCLUSIONS

In this paper, we have presented an effective ECG Data Compression algorithm to be implemented in MATLAB based on a newly developed mathematical tool i.e. Wavelet Transformation. There exist many algorithm schemes based on different transformation techniques. So for reliability & existence of our presented algorithm, we have compared it with other compression algorithm scheme based on Discrete Cosine Transform (DCT). To reach our goal, we followed certain steps which include observing & analyzing the different waveforms and determining various performance evaluation parameters like CR & PRD obtained in MATLAB using algorithms for these two techniques.

In such comparison, it is found that the wavelet compression technique is very effective compared to DCT compression method. The algorithm that we have implemented using wavelet transform technique seems to be the best choice for ECG data compression. A high compression ratio (CR) is achieved with a relatively low Percent RMS Difference (PRD). As compared DCT technique, our method is found to give excellent reconstruction of ECG signals providing better CR and PRD.

VI. TABLE 1

DCT Compression	DWT Compression
CR = 90%	CR = 95%
PRD about 1%	PRD less than 1%
Algorithm Execution Time about 7sec	Algorithm Execution Time about 3sec

A computer based ECG systems are in use in Critical Cardiac Care Unit. In these centers, such computer based ECG instruments continuously monitor ECG of the heart patients. These computers store ECG data of the patients. For this requirement, as the disk spaces in computers are limited, an effective solution over this is utilized which is Compression of such ECG data. Hence, storing of compressed ECG data reduces disk spaces. Thus, from the obtained results, it can be concluded that ECG compression based Wavelet Transformation is the most appropriate and efficient method which can be implemented to save expensive disk spaces & to allow efficient use of available bandwidth for remote ECG analysis.

Moreover,

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It provides excellent reconstruction of ECG signals to be used by Physicians for correct diagnosis of Heart diseases and efficient storage of such information. In these areas, our system proves to be invaluable.

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