International Journal of Scientific and Technical Advancements
ISSN: 2454-1532

Simulative Evaluation and Analysis of ECG Signals using DCT, FFT and DWT Compression Techniques

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***Abstract*—** Electrocardiogram (ECG) is the biomedical process of recording the cardiovascular activity of human or a person's heart over a period of time using number of electrodes placed on a patient's body. Physiological signals could be heart beat, body temperature and brain vibes etc. Here physiological signal considered is ECG signal. ECG Signals need large storage space for signal construction and more bandwidth for transmitted ECG signal analysis, respectively. This paper comprises three physiological signal compression techniques based on frequency transformation. It uses discrete cosine transform (DCT), Fast Fourier Transform (FFT), Discrete Wavelet Transform (DWT) to compress the ECG signal. The proposed algorithms are tested for compression from MIT-BIH arrhythmia database and the performance is evaluated by using compression ratio(CR) and percent root-mean-square difference (PRD) , Mean square error (MSE), peak signal to noise ratio (PSNR) n Higher the compression ratio, lower will be the reconstruction error and lower should be the PRD, higher will be the efficiency. Quality of the reconstructed ECG signal which is measured through PSNR.

***Keywords*—** ECG compression; CR; PRD; MSE; PSNR; DCT; FFT; DWT.

I. INTRODUCTION

Electro cardio gram (ECG) is a signal for recording and analysis cardiovascular activity of human's heart. It is generally installed for continuous acquisition and digital storage of cardiac records. This needs huge amount of storage space and large transmission bandwidth for remote ECG signal analysis .ECG signal compression is done to separate valid signal components from undesired artifacts components to obtain accurate ECG signal [1]. ECG signals are recorded from patients for both monitoring and diagnostic purposes.

Due to low cost and non-invasion, ECG signal has been widely used for heart diseases diagnosis and ambulatory monitoring resulting in enormously large volume of the data. In course of a 24-hrs ECG observation or in a multichannel biological signal acquisition system , real-time data compression methods are required for the effective use of communications channels such as cloud computing , wired channels and wireless environment[2] .The ECG data compression is also required for the need of transmission of ECG signals across intensive care units(ICUs), tele-medical services, home care units, far away space programs, sports, military, health monitoring, private cellular networks and wireless communication channels [3-4]. Therefore, storage of computerized data becomes necessary. However, the storage has limitation which made ECG data compression as an important issue of research in biomedical signal processing.
Number of ECG signal compression algorithms has come into play through various researches. Very Earlier direct signal compression methods were introduced in which direct signal compression of signal samples the original signal in time-domain samples itself. Then other technique which came into play was parameter extraction methods which were through extraction of some particular parameters of the ECG signal. These extracted were used to represent the ECG compressed signal [4], [6].

Now days, used ECG signal compression methods are based on transform based techniques. It first converts original ECG signals to frequency domain signal then compressed ECG signal is followed by inverse transformation in order to reconstruct the original ECG signal back [2].

In above context, therefore, this paper presents some new results based on transform based technique such as DCT, FFT and DWT for ECG signal compression. The paper is organized as follows. A brief introduction has been given in this section on the existing compression techniques of ECG signal. Section 2 discusses overview of different transforms based compression techniques such DCT, FFT and DWT. Section 3 presents how processing of ECG signals happens for compression and methodology for ECG compression based on these techniques. Finally, a comparison is done through certain parameters, which is obtained with these transforms techniques is carried out in Section 5, followed by conclusions and results.

II. TRANSFORM BASED COMPRESSION TECHNIQUES

In this paper, three transforms based techniques DCT, FFT and DWT are used for the ECG signal compression.

DCT Compression

DCT is widely used for ECG data compression. A discrete cosine transform (DCT) is a finite sequence of data points in the terms of a sum of cosine functions oscillating at different frequencies [10]. DCT compression technique changes time domain ECG signals into frequency domain ECG signals without the loss of original information. In particular, a DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. Operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), DCT uses only real numbers, it express a function or a signal in terms of a sum of

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cosines with different frequencies and amplitudes. DCT is often used in signal and image processing, because it has a strong "energy compaction" property.

DCT algorithms have four mandatory steps: dividing a signal in N sub-parts;

DCT computation for each block;

Thresholding & Quantization of the DCT coefficients;

And encoding of the quantized DCT coefficients.

FFT Compression

A fast Fourier transform (FFT) computes the discrete fast Fourier (DFT) of a sequence, or its inverse. Fourier compression converts a ECG signal from its original domain often time to a representation in the frequency domain and vice versa without the loss of original information [8]. A Fast Fourier transform (FFT) is a finite sequence of data points in the terms of a sum of Fourier functions oscillating at different frequency [12].

A preprocessed ECG signal is transformed to frequency domain by applying FFT to the signal using Matlab code 'fft'. The transformation operation actually aims at de-correlating the original ECG signal information and transforming large information content present in the original signal into a relatively smaller set of transformed coefficients as this technique possess strong energy compaction property . Thus, leads to compression of the original ECG signals.

DWT Compression

Wavelets are mathematical functions which are totally perfect for non- stationary signals i.e. ECG signals that cut up data into different scale-shift components. The wavelet decomposition splits the analyzing signal into average and detailed coefficients, using digital type finite impulse response (FIR) filters. The main task of this wavelet analysis (decomposition and reconstruction) is to find out a good analyzing function for performing an optimal decomposition. Wavelet-based ECG compression methods have been shown to perform well. Basically it gives multiple resolution decomposition of a signal [6].

The ability of DWT to separate out main signal components has led to a number of wavelet-based techniques which supersede those based on traditional Fourier methods. The discrete wavelet transform has interesting mathematics and fits in with standard signal filtering and encoding methodologies [9-11]. It produces few coefficients, and the user does not have to worry about losing energy during the transform process or its inverse. While the DWT is faster and maps quickly to the sub-band coding of signals.

III. PROCESSING AND METHODOLOGY FOR ECG COMPRESSION

In this paper, as stated erlier, the ECG compression is achieved through different frequency transformation techniques such as DCT, FFT and DWT. The Block -Diagram of ECG compression based on transform is shown in figure 1. ECG Compression is performed through certain steps:

1. ECG signal Pre-Processing Phase- It consists of Downloading of ECG signal from Physiobank ATM and creating a database for ECG signals.
2. DCT/FFT/DWT implementation on ECG signal for compression.
3. Then achievement of ECG compression.
4. Transmission /storage of compressed signal
5. At receiver, application of Inverse DCT/FFT/DWT to reconstruct the original signal back.
3. Detection of error present in reconstructed Signal.

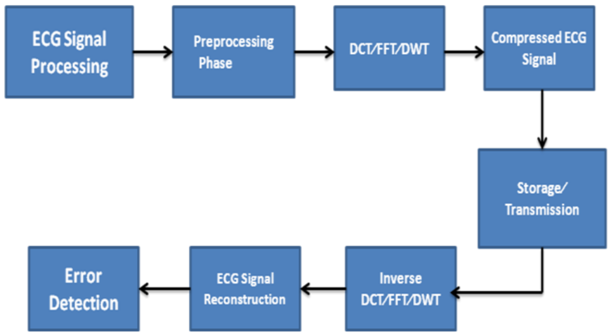

Fig. 1. Block – Diagram for ECG Compression for various transform Techniques.

Whereas flow chart in fig. 2 presents the whole methodology of ECG compression through Matlab, how ECG signal gets downloaded in Matlab through an On- Line database and certain parameters are calculated for the performance evaluation of different transform techniques.

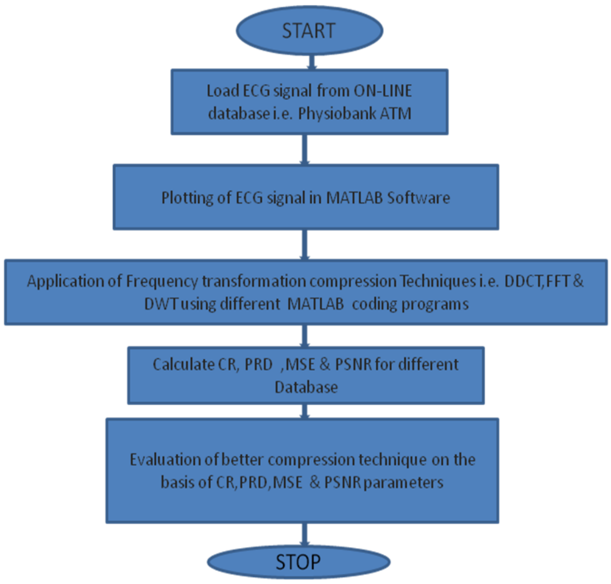

Fig. 2. Flow chart presents ECG compression methodology for Matlab

IV. RESULTS AND CONCLUSIONS

In this paper, ECG compression is done using a methodology of different transforms such as DCT, FFT and DWT. The performance of these techniques can be evaluated by considering certain parameters of the reconstructed signal as compared to the original signal. For this purpose, following

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ISSN: 2454-1532

some important parameters [22-24] for analysing the quality of reconstructed signals are considered

Compression Ratio (CR)

CR is the ratio of the original data to compressed data. It is given by:

CR = Compressed file size / Original file size

Higher the value of CR, higher is the degree of compression.

Percent Root Mean Square Difference (PRD)

Percentage Root Mean Square Difference (PRD) is a measure of signal lost during transmission. A parameter to measure of reconstruction error i.e., PRD is calculated as follows: where Xorg and Xrecon are the samples of the original and reconstructed signals respectively .

$$\mathrm{PRD} = \left[\sum_{i=1}^{n} \frac{(X_{\mathrm{org}} - X_{\mathrm{recon}})^2}{(X_{\mathrm{org}})^2} \right]^{1/2} \times 100,$$

While low PRD indicates the efficient reconstruction of ECG signal, thereby preserving the significant clinical information even after compression.

Mean Square Error (MSE)

It is the average of the squares of the errors or deviations, that is, the difference between the estimator and what is estimated.

$$\mathrm{MSE} = \frac{1}{n} \sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2$$

MSE is basically the mean of squares of errors.

MSE should always be low for better reconstruction of a signal.

Peak Signal to Noise Ratio (PSNR)

It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of the signal.

PSNR is most easily defined via the mean squared error (MSE).

$$\begin{aligned} PSNR &= 10 \cdot \log_{10} \left(\frac{MAX_I^2}{MSE} \right) \\ &= 20 \cdot \log_{10} \left(\frac{MAX_I}{\sqrt{MSE}} \right) \\ &= 20 \cdot \log_{10} (MAX_I) - 10 \cdot \log_{10} (MSE) \end{aligned}$$

Where MAX1 is the maximum possible value of signal.

Whereas Higher PSNR is a measure of higher signal quality at output.

Simulation Evaluation and Analysis of ECG Compression

ECG signal records have been obtained from MIT-BIH Arrhythmia Database (PhysiobankATM) [28]. Here, DCT, FFT and DWT compression techniques are employed for same ECG signal (ECG record 101) and the simulation evaluated results are obtained in each case are included in Table I. In all three techniques, Global thresholding is applied. Fig. 3 shows the plot of the original ECG signals is obtained from physio bank (MIT-BIH record 100) and its reconstructed versions. While figure 4. Depicts graphs for all the three transforms through all four considered parameters.

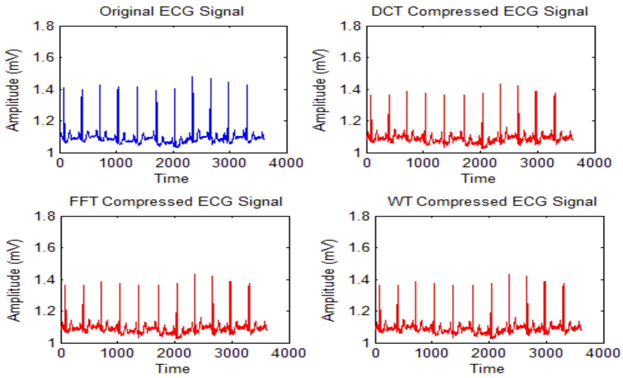
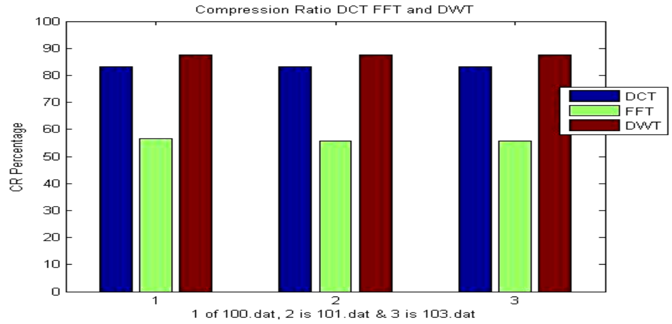
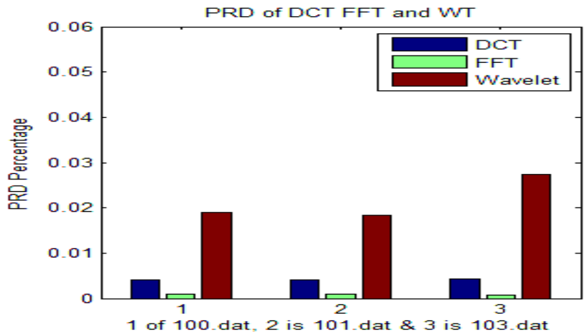


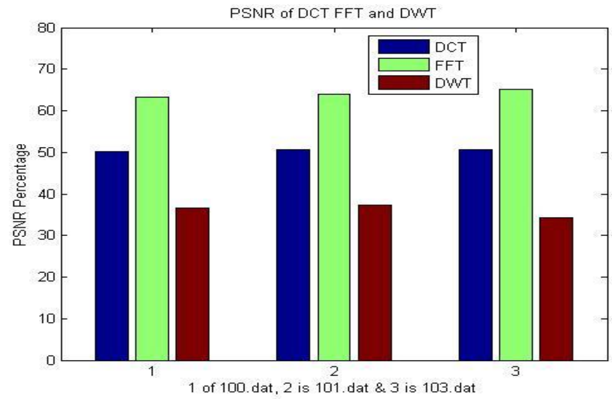
Fig 3. (a) Original ECG signa for 101.dat signal, (b) DCT Compressed ECG Signal, (c) FFT Compressed ECG Signal DWT, (d) DWT Compressed ECG Signal



a) Compression Ratio for the ECG records 100.dat, 101.dat, 103.dat



b) PRD Percentage for the ECG records 100.dat , 101.dat , 103.dat



c) PSNR Percentage for ECG records 100.dat, 101.dat, 103.dat

Fig. 4. A comparative analysis of the performance in different transforms (DCT, FFT and DWT) (a) CR (b) PRD (c) PSNR

Table I. Fidelity assessment parameters in different transforms for different ECG Records.

Record No.	Method	Performance Metrics			
		CR	PRD	PSNR	MSE
100.dat	DCT	83.1025	0.0040	50.0729	1.8776e-05
	FFT	55.5556	8.6844x 10-04	63.2728	8.98e-07
	DWT	87.502	0.0189	36.5074	4.2674e-04
101.dat	DCT	83.1025	0.0040	50.6305	1.8845e-05
	FFT	55.5556	8.4379e-04	64.0802	8.5160e-07
	DWT	87.509	0.0183	37.3728	3.9900e-04
103.dat	DCT	83.1025	0.0042	50.6479	2.1771e-05
	FFT	55.5556	7.8101e-04	65.2543	7.5377e-07
	DWT	87.504	0.0274	34.3541	9.2739e-04

It is evident from table I and fig. 4 that the good compression ratio can be obtained with these transforms with good signal quality measuring parameters. The FFT transform based ECG signal compression gives best quality signal in terms of PSNR and minimum PRD which indicates efficient reconstruction of ECG signal but has least compression ratio (CR). Whereas DCT gives moderate CR with moderate PSNR, PRD and MSE. The wavelet transform based compression gives highest compression ratio (CR) and a comparable PRD with comparable PSNR quality factor for ECG Signal but also DWT is easy to implement and has advantage of extracting no overlapping information about the signal.

Therefore, these transforms can be effectively used for ECG signal compression while preserving necessary clinical information.

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