DSP BASED PORTABLE ECG MONITORING SYSTEM

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Abstract:
An electrocardiogram (ECG) gives important information to doctors to analyse heart related abnormalities such as arrhythmias or monitor drug effects. For an ambulatory system, there is a requirement for continuous monitoring. Hence, the data generated is huge and needs huge storage space. As the data is huge, it needs to be compressed before transmission. The compression of data is carried out using a suitable compression methodology. In this work, a real time DSP based portable ECG monitoring system is developed to acquire the ECG signal in real time. The acquired data is compressed before transmission. This helps with efficient storage management. The system helps monitor ECG signals in real time and is useful to doctors for diagnosis.
Key words: ECG, Compression, DSP, Acquisition.
DOI: 10.24297/j.cims.2023.4.23

1. Introduction

The ECG signal is a very useful signal for diagnosis. In an ambulatory or continuous monitoring system, the ECG signal needs to be monitored for 24 hours. A typical ECG signal is depicted in Fig. 1. Due to the huge collection of data, an efficient processor for collection, storage, and processing is required. Typically, a 3-channel, 24 hour ambulatory ECG requires more than 50 MB of storage space. At the same time, the precise and quick information from the ECG signal must be made available at the doctor's end. The ECG signal has various peaks, as shown in Fig. 1. The peaks are identified as P,Q,R etc. In emergency situations, monitoring the ECG in real time is an important issue.

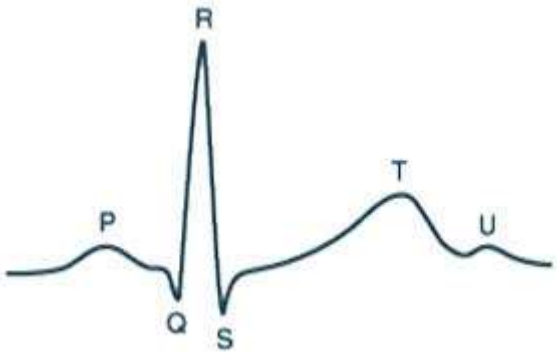

Fig. 1.1 The ECG signal

It is essential to record the ECG signal continuously to assess heart abnormalities. As the data is huge, transmission to the doctor's desk becomes difficult. Hence, a suitable compression technique is required before transmission. The compression technique must be able to restore the diagnostically suitable components of the signal. Though the researchers are continuously working in this area, the acquisition and transmission of clinically important signals without distortion is a big challenge. In this research work, a system consisting of the Acquisition and compression of ECG signals is implemented.

An efficient compression technique is required for the ECG signal to decrease the storage requirement. The main focus is on a better compression ratio. It is a time consuming process to do the diagnosis by taking continuous prints of ECG signal. The time is a crucial factor in ECG monitoring system. The proposed system helps doctors with diagnosis. Whenever the monitored signal shows some abnormality an SMS (Short Message Service) alert can be given to the doctor's hand held device.

2. Literature Survey

2.1 Acquisition of ECG signal

Ramesh M V [1] proposed a low cost wireless sensor system. The system is most suitable for giving warnings about heart diseases to doctors. The ECG monitoring system developed by Goh Chun Seng et al. [2] used Digital Signal Processing hardware.

R. Suknesh et.al [3] developed a "GSM-based ECG Tele-alert System". The research paper introduces a system that detects abnormalities in the ECG signal and sends an SMS alert to the doctor using the GSM system. The system helps the subject take necessary precautionary measures. CHI Jian Nan et al. [4] proposes "DSP based Portable ECG Monitor". The system helps monitor cardiac disease, The researcher has developed a portable ECG Monitor using a controller.

The paper by Noureddine [5] presents a real time acquisition of an ECG signal. The ECG signal is transmitted to a smart phone through wireless technology.

2.2 Necessity of Compression

Compression of ECG signal is required to remove the redundancy in a data set. The compression of signals has a direct impact on storage and bandwidth. The data compression should be able to preserve the important features which are clinically significant. The two major categories of compression techniques are lossy and lossless technique. The ECG signal has some redundant components. The lossy compression technique is suitable for ECG signals. There are three different techniques [6] of compression used for the ECG signal. The compression techniques are classified as Direct techniques, Transform based techniques and parameter extraction techniques.

Direct data compression technique

It is a time domain technique. The different techniques of Direct compression methods are available. Some of the techniques are Time Epoch Coding (AZTEC) [7], modified AZTEC, FAN [8,9] etc.

Transform based compression technique

The different transformation based compression techniques are the Fourier transform [10,11], Karhumen Louve Transform (KLT) [12-13], Discrete Cosine Transform [14-16], wavelet transform, and Walsh Hadamard Transform (WHT) [17]. The Wavelet Transform achieves higher CR. The wavelet transform captures both the time and frequency information simultaneously [18,19,20]. Transform based compression methods achieve a higher compression ratio as compared to direct methods [21].

Parameter extraction compression technique

The parameter extraction methods use prediction techniques. [22].

Summary

The literature survey reveals that there is a lot of scope to work on the existing acquisition methods. It also gives a clear indication that the acquisition module must be compact, capable of real time acquisition, and be able to remove interferences.

In this research work, the main focus is on the transform based compression methodology. The work is carried out to understand the relevance of compression of ECG signals.

3. Acquisition of ECG signals using a DSP Based CORTEX M4 System

ARM's Cortex-M4 is Digital Signal Controllers (DSC) and it provides a blend of traditional MCU and DSP functionality. It is worth mentioning that the DSP functionality is built right into the **Instruction Set Architecture(** ISA) rather than being implemented via a coprocessor interface.

The ECG sensor is used to acquire the data in real time using the ARM CORTEX M4 kit. The sensor is connected to the ARM Cortex kit and is shown in Fig. 3.1.

To detect the electrical activity of the heart, suitable electrodes are used. The acquired ECG signal is of low amplitude. Hence, proper amplification will be done after the acquisition. The amplified ECG signal goes through filtering and digitization stages.

Fig.3.1 The ECG sensor is connected to the CORTEX M4 bit

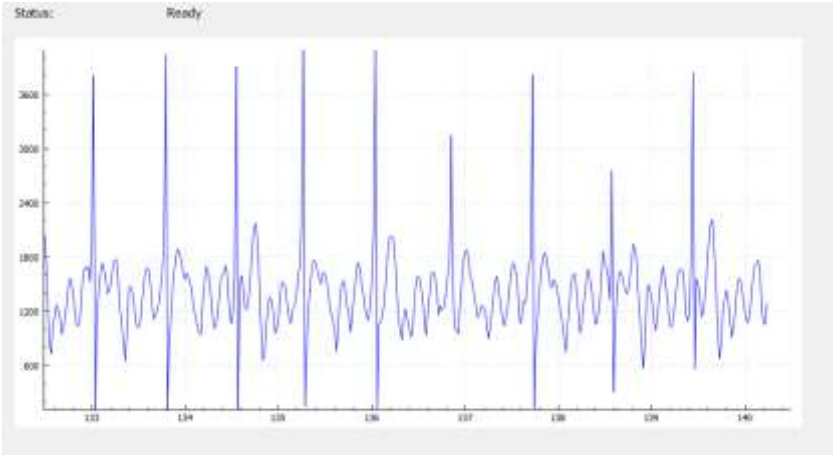

Fig. 3.2 The acquisition of ECG signal

MikroPlot is a PC application that is used to create an interactive plot for analyzing the collected data and is shown in Fig 3.2. The plot helps the doctors to analyze the acquired ECG signal.

4. Compression of the ECG Signal

The ECG signal is passed through a compression stage before transmission. The various transform based techniques are tested to select the best transform. The transform based techniques used are DWT (Discrete Wavelet Transform), FFT (Fractional Fourier Transform) and DCT (Discrete Cosine Transform). Standard performance measures such as CR (Compression Ratio) and PRD (Percent Root Mean Square difference) are used. CR and PRD are expressed in eq.1 and 2 respectively.

$$CR = \frac{\text{Number of bits represented by the original signal}}{\text{Number of bits represented by the compressed signal}} \quad (1)$$

$$\text{PRD} = \sqrt{\left[\frac{\sum_{n=0}^{M-1}[x_0(n)-x_r(n)]^2}{\sum_{n=0}^{M-1}[x_o^2(n)]}\right]} X\ 100 \quad \% \quad (2)$$

Original data is represented by x_0,The reconstructed data is represented by x_r and number of samples is represented by M.

4.1 Methodology used

The MIT-BIH data base is used for the experimentation. Initially, it is necessary to remove the noise and distortion. The unwanted baseline wander noise is removed by the High pass filter and power line interference is removed by the Band stop filter. To improve the CR, a threshold value is selected. The threshold value is calculated as a small percentage of R peak. The coefficients that fall below the threshold value are neglected. The results obtained for the various transform based compression techniques are as shown below:

The Results of DWT, FFT and DCT are presented in Table1- Table 3. The input and output ECG signals using DWT Transform is shown in Fig. 4.1.

Table1: The DWT result

No. of samples	Threshold	CR%	PRD
256	01	75.0	0.84
256	02	64.4	0.12

Threshold 01-0.5% of the R peak
Threshold 02- 0.05% of the R peak

Table 2: The FFT result

No. of samples	Threshold	CR%	PRD
256	01	60.74	0.07
256	02	76.75	0.12

Table 3: The DCT result

No. of samples	Threshold	CR%	PRD
256	01	78.8	0.85
256	02	64.4	0.104

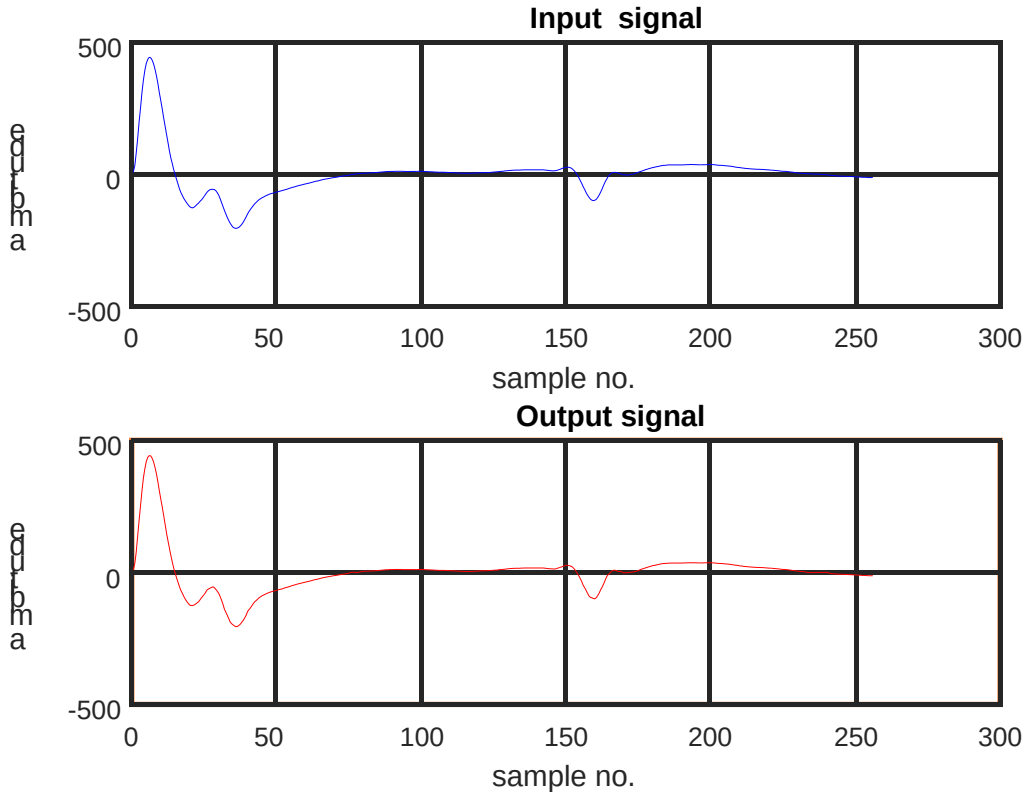

Fig 4.1: input and output ECG signal using DWT Transform

5. Results and discussion

Acquisition

The real time acquisition of the ECG signal using a DSP processor is useful for transmitting the signal to the doctors' desk. The DSP processor has the advantage of real time processing, low power consumption. The DSP processor works efficiently to compute the complex mathematical calculations involved in the digitization of the signal.

Compression:

The various transform based compression techniques are implemented. As shown in Table 1, the Threshold levels used for the computation are 0.05% and 0.5% of the R peak. The CR and PRD are calculated for 256 samples. The faithful reproduction of the signal is dependent on the lower value of PRD. The input and output signals for DWT are shown in Fig. 4.1.

Table 2 shows the CR and PRD computation for the Fractional Fourier Transform. The DWT shows higher CR as compared to the Fractional Fourier transform. From Table 3, it is clear that the DCT shows the highest CR as compared to other transforms. Though the FFT produces a good CR value, complex multiplications and additions are required for the computation of the FFT. Moreover, the DWT is more suitable for compression of non-stationary ECG signals as it

gathers both the frequency and location of time information. The DCT, represents the majority of the energy with a few transform coefficients. From the above experimentation, it is observed that the DWT and DCT are the suitable transforms for ECG signal compression.

6. Conclusion

The research work has focused on developing a complete system consisting of acquisition, and Compression. The acquisition system is developed to acquire the ECG signal in real time. Real time data acquisition is important in the medical field as it helps the doctors to monitor the situation in case of an emergency. This also helps the subjects get immediate medical attention The data that is monitored is huge considering the various ECG leads. An efficient compression technique is developed to reduce the transmission bandwidth and cost. The compression technique also helps reduce the storage requirement.

The complete system developed in this research is useful for monitoring the ECG signal. The proposed system is capable of transmitting data to remote places without any limitation on the distance.

Acknowledgement

The author is grateful to BCUD, Savitribai Phule Pune University, Pune for sponsoring the research project.

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