ABSTRACT

Biomedical signals from many sources including heart, brain and endocrine system pose a challenge to researchers who may have to separate weak signals arriving from multiple sources contaminated with artifacts and noise. The analysis of these signals is important both for research and for medical diagnosis and treatment. The main difficulty in dealing with biomedical signals is the extreme variability of the signals and the necessity to operate on case to case basis. Another important aspect of biomedical signals is that the information of interest is often a combination of features that are well localized temporally or spatially and other that are more diffused. This requires the use of analysis methods sufficiently versatile to handle events that can be at opposite extremes in terms of their time-frequency localization. So, a robust method is to be designed which work in most circumstances rather than under very specific assumptions. Biomedical signals due to its enormous virtues are widely applied in several medical applications; Electrocardiogram, Electroencephalogram and Electromyogram are to name a few. However, these signals experience the addition of noise and result in an inefficient performance.

Denoising or the removal of noise is hence a major preprocessing task for such signals, and it has been carried out by different schemes for the past few years. Among the several schemes, wavelet-based denoising has taken the universal place in the signal-processing area. Wavelet transform has been an innovative method for the analysis and processing of non-stationary signals such as bio-signals in which both time and frequency information is vital. From the wide range of applications of wavelets, the most important application is the removal of noise from biomedical signals, which is gifted by thresholding wavelet coefficients in order to separate signal from noise. In the present work a combined scheme of applying denoising and compression for biomedical signals has been presented. Using traditional methods, it is hard to eliminate the noises present in the signals. A detailed analysis of Discrete Wavelet Transform (DWT) denoising using various wavelet families on biomedical signals (ECG, EMG and EEG) is presented in the thesis. The main intention of the work is to explore the wavelet function that is optimal in identifying and denoising the various biomedical signals. Nevertheless, Wavelet transforms offer better results for denoising the bio-medical signals, identification of the optimal Wavelet type is crucial. Therefore, the Artificial Neural Network (ANN) has been proposed in order to optimally select the Wavelet types to denoise the signals by using a learning back
propagation algorithm. The application of ANN enables the selection of the optimal wavelet for each type of bio-medical signal. The proposed Wavelet Transform based frequency thresholding is used for noise removal of the noise corrupted decomposed biomedical signals. Then the signal is reconstructed using inverse wavelet reconstruction method. To reduce the storage size, hybrid wavelet Shannon-Fano coding is used for compression of denoised signal. Efficiency of the method used vis a vis existing techniques for the denoising of ECG, EEG and EMG signals has been evaluated and compared in terms of Signal to Noise Ratio (SNR), Percent Root Mean Square Difference (PRD), Mean Square Error (MSE) and Compression Ratio (CR).

Index Terms— DWT, ECG, EEG, EMG, Neural Network, Wavelet Frequency Thresholding
INTRODUCTION

Signal and system are the two major components in signal processing. A signal is a physical quantity having the characteristics of varying w.r.t. time and space and the system is a process whose input and output is a signal.

Biomedical signal generally represents a collective electrical signal attained from any organ, signifying a physical variable of interest. This signal can be expressed with respect to its amplitude, frequency and phase as well as it is on the whole a function of time. In common, the observations gained from the physiological activities such as gene and protein sequences, neural and cardiac rhythms, tissue and organ images of organisms are said to be biomedical signals. Depending upon their source, application or signal characteristics, the biomedical signals are classified. They can be either continuous or discrete. A number of signal sources may result into a biomedical signal. Those sources are bioelectric Signals, bioimpedance signals, bioacoustic signals, biomagnetic signals, biochemical signals and bio-optical signals.

Biomedical signal covers a wide range of signals including Electro-Oculogram (EOG) signal, Electroneurogram (ENG) signal, Electrogastrogram (EGG) signal, Phonocardiogram (PCG) signal, Carotid Pulse (CP) signal, Vibromyogram (VMG) signal, Vibroarthogram (VAG) signal, Electrocardiogram (ECG), Electroencephalogram (EEG) and Electromyography (EMG) signal. More precisely, the significant and widely applied biomedical signals are Electrocardiogram (ECG), Electroencephalogram (EEG) and Electromyography (EMG).

The biomedical signals are recorded, they need to be analysed. The major operations of signal processing include:

1) Signal acquisition and reconstruction,
2) Quality improvement including filtering, smoothing and digitization,
3) Feature extraction,
4) Signal compression,
5) Prediction.

In other words, the analysis includes, information gathering i.e. inferring a system by phenomena measurement, diagnosis of malfunction or deformity and monitoring the system for continuous or periodic information. Therapy and control which is modifying the system behaviour with
respect to the result of the above listed activities guarantees a definite result and finally the evaluation which is to make it able to meet functional requirements, perform quality control, or qualify the treatment effectiveness.

**Objectives**

From the literature it is obvious that there is a strong need of an efficient classifier for deciding the optimal wavelet family for denoising different biomedical signals. Since each biomedical signal has its unique nature and characteristics, the classifier must be trained in an efficient way with the nature of each signal for accurate classification of optimal wavelet. Moreover we are in need of an effective biomedical signal compression algorithm achieving best CR and PRD values.

Based upon the above listed directions, the problem for this work is formulated as:

- To find the optimal wavelet for biomedical signal.
- To focus on reducing time and storage space, however at the same time signals must be denoised efficiently with the optimal wavelet.

Once the optimal wavelet is found, biomedical signals will be denoised using this wavelet with focus on reducing time and storage space. Biomedical signals considered will be ECG, EEG and EMG.

**Methodology Used to Achieve Objectives**

The main motive of the thesis lies on denoising signals with the most suitable wavelet, which is classified using Artificial Neural network. It results in less overhead time, since the classification algorithm is already trained for almost all of the members of wavelet family. Moreover a hybrid compression algorithm is applied after the denoising process and thus a less space is needed for storing compressed information and is used for reconstruction of the original signal. Thus the objectives of minimum space and less time are achieved in the thesis only by using simple methods for denoising, classification and compression. The following steps will be carried out to achieve the objectives:

- Discrete Wavelet Transformation for the signals will be applied, which will be performed by means of a low pass and a high pass filter, yielding approximation and detailed
coefficients respectively. This process continues for a fixed number of decomposition levels.

- The signal will be decomposed using the Shift Invariant method.
- Then for each level of decomposition, the wavelet frequency thresholding for the detailed and approximation coefficients will be applied resulting in denoised signal.
- The artificial neural network will be trained initially with the properties of each wavelet and the nature of the biomedical signals. By using the parameters the optimized wavelet transform will be selected which is best suitable for denoising using the neural network classifier.
- As there is a strong need of an effective biomedical signal compression algorithm for achieving the best CR and PRD values. For this purpose, both Shannon Fano algorithm and wavelet transform will be combined. The signals obtained after classifications will then be compressed using hybrid wavelet Shannon-Fano coding algorithm.

Block diagram of these steps is show in figure 1.1 followed by the detailed representation by flow chart in figure 1.2

![Block Diagram](image)

**Fig 1.1: Main steps of the proposed system**
Fig 1.2: Flow chart of the proposed system
Organization of the Thesis

The thesis is organized as follows.

Chapter 1 presents an introduction of the proposed system model followed by the introduction of biomedical signals and wavelet transform. Chapter also deals with a detailed survey of the and outcome from the literature studied. The problems of the existing studies have been presented followed by the main objectives of this thesis. The methodology used to achieve the objectives has also been discussed in the chapter.

Chapter 2 gives the detail description about the biomedical signals used for analysis in the thesis. The origin and recording of the ECG, EEG and EMG signals has been studied in this chapter. The Wavelet transformation scheme will also be explained with detailed mathematical representation followed by their types. Types of wavelet transform such as Continuous Wavelet Transforms (CWT) and the Discrete Wavelet Transforms (DWT) will be given. Followed by DWT, wavelet filters will conclude the second chapter.

Chapter 3 deals with the various decomposition and denoising techniques in mathematical and diagrammatic representations. The chapter explains the different thresholding techniques for denoising. Wavelet frequency thresholding based denoising is used in the thesis and its details will be presented in this chapter. The chapter concludes with the graphical results of denoising for the three biomedical signals.

Chapter 4 Signal Reconstruction and compression techniques are given in this chapter. Reconstruction by IDWT is explained in detail followed by the signal compression by Shannon Fano algorithm. The evaluation criteria for compression (PRD and CR) have been demonstrated through Graphical representation.

Chapter 5 presents the general conclusions of the thesis and proposes possible improvements and directions of future research work.
CONCLUSION
Based on the findings during the period of Ph.D research work it can be concluded that Biomedical signals are non-stationary signals whose analysis requires better time and frequency resolution. Such analysis includes, denoising and compression. So, a detailed analysis of the denoising and compression process of various wavelet families and biomedical signals such as Electrocardiogram (ECG), Electromyography (EMG) and Electroencephalography (EEG) has been presented in the thesis. The conclusion of the thesis is as follows:

Chapter 1: In chapter 1 a detailed literature was studied about the techniques used in the analysis of the biomedical signals. It was found that Wavelet transform has been a very novel method for the analysis and processing of non-stationary signals such as bio-signals in which both time and frequency information is required. The objective of the thesis was set from the gaps found during the literature survey. The methodology to be used for achieving the objectives has been explained in chapter 1.

Chapter 2 concludes with the study of the three biomedical signals namely ECG, EEG and EMG which have been used for analysis in the thesis work. The origin, nature and process of recording these signals have been explained in this chapter. Wavelet transform, which is the method used for the analysis has also been discussed.

Chapter 3: In chapter 3, the three biomedical signals were denoised. Initially the biomedical signals which were collected from the databases were without noise. Subsequently the noise was added to those signals by using a MATLAB program and then the number of samples had been chosen for further processing. In the thesis, samples of the signals were chosen from MIT-BIH database from www.physionet.org and a variety of statistical parameters of the noisy biomedical signals were calculated. The parameters of such signals were studied for the purpose of training the classifier. Then the Shift Invariant method was used for the decomposition of noise added signals, where the noisy signals were decomposed at level three using various wavelet families. The decomposition made the signals easy to be employed for denoising. Then thresholding scheme was applied for denoising process. Among the existence of various threshold schemes, wavelet frequency thresholding was applied in this work. Thus after decomposition, noise removal had been done. The results of the calculated parameters such as SNR and MSE have been compared with the existing methods.
Chapter 4: After denoising had been completed, the decomposed signal needed to be brought back to its original form. For this sake, reconstruction was applied to the denoised signals. By using wavelet reconstruction method the original signal was reconstructed. Wavelet reconstruction method is nothing but the step by step inverse process of decomposition. A Neural Network classifier had been employed for classifying the best wavelet among the different wavelet families for a biomedical signal. It employed approximately 16 different wavelets from 5 different wavelet families. The Neural Network was trained using a Back propagation algorithm, which is one of the most efficient training algorithms for classifier. The Neural Network automatically classified the optimal wavelet for denoising by using a set of selected parameters, with the main objective of classifying the optimized wavelet for signal denoising. The signals were then compressed using a hybrid wavelet-Shannon Fano coding algorithm. The compression algorithm showed a better Compression Ratio (CR) and Percent Root Difference (PRD). The results showed that this Neural Network efficiently classified the optimal wavelet for each of the biomedical signals. In the analysis part, there was a comparison of the proposed method results with other denoising as well as compression methods and the efficiency of the work has been proved in terms of the evaluation parameters MSE, SNR, CR and PRD.
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List of Publications

International Journals


3. Geeta Kaushik, Dr. H.P. Sinha, Dr. Lillie Dewan, “Analysis of DWT Signal Denoising On Various Biomedical Signals By Neural Network” Accepted for publication in International Journal of Signal and Imaging System Engineering from Inderscience Journals.

National Conference