2. REVIEW OF LITERATURE

2.1. INTRODUCTION

Health monitoring systems developed in the recent past have evolved advanced methods of observing the changes that the various organs of the human body undergo. This helps diagnosing precisely the disease that an individual suffers from. Cardiology, as a branch of medicine, deals with heart, one of the most vital organs. In this field of medicine, quite a large number of research studies have been carried out and they have brought about a breakthrough in the methods of treatment of various heart diseases. There are studies reported in the international journals, relating to preprocessing, namely, denoising, deblurring, feature extraction and classification are presented here. The studies on Wavelet Transform (WT) and Artificial Neural Network (ANN) in the field of ECG signal analysis are also reported here.

2.2. PREPROCESSING

i) Denoising

[MOC12] published a paper on Comparison of ECG Signal Denoising Algorithms in EMD and Wavelet Domains. This paper presents a detailed analysis on the Electrocardiogram (ECG) denoising approaches based on noise reduction algorithms in Empirical Mode Decomposition (EMD) and Discrete Wavelet Transform (DWT) domains. Compared to other denoising methods such as filtering, independent and principal component analysis, neural networks, and adaptive filtering, EMD and wavelet domain denoising algorithms are found more effective in the reduction of noise from the ECG signal. Denoising methods in EMD domain depends on the number of intrinsic mode functions (IMFs) to be discarded or noise compensated and that in wavelet domain rely on the number of decomposition levels as well as selection of threshold value for each level. This paper provides the performance analyses of ECG signal denoising algorithms in EMD and wavelet domains thus comparing their effectiveness in reducing the noise. For analysis purpose, extensive simulations are carried out using the MIT - BIH database and the performances are evaluated in terms of standard metrics namely, SNR improvement in dB, Mean Square Error (MSE) and Percent Root Mean Square Difference (PRD). Results show that denoising schemes involving both EMD and
wavelet domains are able to reduce noise from ECG signals more accurately and consistently in comparison with noise reduction algorithms in EMD or wavelet domain alone.

[MAM13] have come out with a paper on **Performance Comparison of Wavelet Thresholding Techniques on weak ECG Signal Denoising**. The Electrocardiogram (ECG) signal is a biological non-stationary signal which contains important information about rhythms of heart. ECG signals can be buried by various types of noise. These types can be electrode movement, strong electromagnetic effect and muscle noise. Noisy ECG signal has been denoised using signal processing. This paper presents a weak ECG signal denoising method based on interval-dependent thresholds of wavelet analysis. Several experiments were conducted to show the effectiveness of the interval-dependent thresholding method and compared the results with the soft and hard wavelet thresholding methods for denoising. The results are evaluated by calculating the root mean square error and the correlation coefficient.

[SRS13] have published a paper on **Noise Cancellation on ECG and Heart Rate Signals Using the Undecimated Wavelet Transform**. This paper presents a new approach to eliminate the noise found in ECG signals due to artifacts and cardiac rhythm. This work is carried out using the Undecimated Wavelet Transform (UWT). The signals were acquired using a MATLAB SIMULATION of bioelectrical. The ECG signals are obtained through the implant of electrodes connected to a channel of the front-end board. The cardiac rhythm is then obtained using an optic dactilar sensor connected to an independent channel of the ECG signal. In order to get a better identification of the acquired signal the Wavelet filter D6 (Daubechies) was chosen, primarily because its scaling function is closely related to the shape of the ECG, fitting very well with the applications constraints. The processed signals were further analyzed using SIMULATION and MATLAB. The application to denoise the ECG signals was developed by MATLAB 2008Rb and is capable of graphically representing the data before and after it is processed.
[HMA07] have made a study on A Mathematical Algorithm for ECG Signal Denoising using Window Analysis. The presence of parasite interference signals could cause serious problems in the registration of ECG signals and many works have been done to suppress ElectroMyoGram (EMG) artifacts, noises and disturbances from electrocardiogram (ECG). Recently, newly developed techniques based on global and local transforms have become popular such as wavelet shrinkage approaches and time - frequency dependent threshold. Moreover, other techniques such as artificial neural networks, energy thresholding and Gaussian kernels are used to improve previous works. This review summarizes windowed techniques of the concerned issue. A mathematical method was conducted based on two sets of information, which are dominant scale of QRS complexes and their domain. The task is proposed by using a varying - length window that is moving over the whole signals. Both the high frequency (noise) and low frequency (base - line wandering) removal tasks are evaluated for manually corrupted ECG signals and are validated for actual recorded ECG signals. Although, the simplicity of the method, fast implementation, and preservation of characteristics of ECG waves represent it as a suitable algorithm, there may be some difficulties due to pre - stage detection of QRS complexes and specification of algorithm’s parameters for varying morphology cases.

[KAR12] has presented a paper in a conference on Adaptive Noise cancellers and Wavelet Transform Analysis of ECG Signal for Remote Patient Monitoring. The electrocardiogram (ECG) is a graphical representation of heart's functionality and is an important tool used for diagnosis of cardiac abnormalities. In the clinical environment during acquisition, the Electrocardiographic (ECG) signal encounters various types of artifacts. These artifacts strongly affect the ST segment. Cancellation of the artifacts in ECG signals is an important task for better diagnosis; hence there is a need of filtering the ECG signal. In this paper LMS / NLMS / ENLMS - based adaptive filters algorithm are used to analyze the efficient and simplified adaptive noise cancellers for ECG signals. ECG, noise signals are generated using MATLAB code. After analysis of the best algorithm, the desired signals produced by the algorithm will be compressed and transmitted to a central node. The signals are compressed using wavelet transform.
[SAN12] have come out with a paper with the title **Wavelet: A Technique for Analysis of ECG**. In the context of medical reports showing that the number of heart patients is increasing day-by-day, it is important to analyze the ECG waveform in an efficient manner. ECG waves commonly change their statistical properties over time, tending to be non-stationary. For analyzing this kind of signal wavelet transforms are a powerful tool. The main tasks in ECG signal analysis are the detection of QRS complex (i.e. R-wave), and the estimation of instantaneous heart rate by measuring the time interval between two consecutive R-waves. Wavelet transforms provide simultaneous time and frequency information. The wavelet transform decomposes the Electrocardiogram (ECG) signal into a set of frequency band. In the wavelet-based algorithm, the ECG signal has been denoised by removing the corresponding wavelet coefficients at higher scales. The analysis has been done on ECG data files of the MIT-BIH Arrhythmia database.

[NAB11] have published a paper on **Noise Removal Using Adaptive Noise Canceling, Analysis of ECG Using MATLAB**. This paper introduces a way of automating the diagnosis of cardiac disorders using an expert system developed on the basis of information derived from the analysis of Electrocardiogram (ECG) using MATLAB and also provides the online monitoring of cardiac patient. Cardiologists use ECG as a definitive indicator of the condition of the human heart using certain well-defined rules and their own experience to diagnose the condition of patient. The decision process is made systematic by developing a visualization tool using proven algorithm for processing the information contained in the typical ECG. The information can be of great help to a general practitioner, to identify the specific problem and treatment without any delay.

[SAF12] have published a paper on **Wavelet diagnosis of ECG signals with Kaiser Based Noise Diminution**. The evaluation of distortion diagnosis using Wavelet function for Electrocardiogram (ECG), Electroencephalogram (EEG) and Phonocardiography (PCG) are already in use. However, some of the technological and economic issues remain challenging. The work in this paper focuses on the reduction of the noise interferences and analyzes different kinds of ECG signals. Furthermore, a physiological monitoring system with a programming model for the filtration of ECG is
presented. Kaiser based Finite Impulse Response (FIR) filter is used for noise reduction and identification of R-peaks based on Peak Detection Algorithm (PDA). The two approaches that are implemented for detecting the R-peaks are Amplitude Threshold Value (ATV) and Peak Prediction Technique (PPT). Daubechies wavelet transform is applied to analyze the ECG of driver under stress, arrhythmia and sudden cardiac arrest signals. From the obtained results, it has been found that the PPT is an effective and efficient technique in detecting the R-peaks compared to ATV.

**ii) Deblurring**

[ZGG12] published a paper on **Reducing the Gaussian Blur Artifact from CT Medical Images by Employing A Combination of Sharpening Filters and Iterative Deblurring Algorithms**. Images obtained through imaging systems are considered as degraded versions of the original view. Computed Tomography (CT) images have different types of degradations such as noise, blur and contrast imperfections. This paper handles the issue of deblurring CT medical images affected by Gaussian blur. Image deblurring is the procedure of decreasing the blur amount and grant the filtered image with an overall sharpened form. In this paper, the authors considered the Laplacian sharpening filter and the iterative Richardson - Lucy algorithm, and implemented a mixture of these two techniques to process the CT medical images. The suggested technique is applied to medical images that are synthetically and naturally degraded by blur. Moreover, an evaluation between the proposed combination and each employed technique is provided, along with the accuracy in calculation using the universal image quality index (UIQI).

[ZDM12] published a paper on **Restoring Degraded Astronomy Images using a Combination of Denoising and Deblurring Techniques**. The aim of image restoration is to restore the image affected by degradations to the most desired form. It comprises a set of techniques applied to the degraded image to remove or reduce the cause of degradations. This study focuses on Astronomy images. Astronomy images suffer from mainly two types of degradations: atmospheric turbulence blur and additive white Gaussian noise. This study presents a new method to restore astronomy images by proposing a hybrid method that combines three techniques to restore a degraded image.
The first technique is phase preserving algorithm used for the denoising operation. Then a normalization operation is employed to provide the image its natural grayscale intensity. After that Richardson Lucy deblurring algorithm is used to deblur the image depending on the Point Spreading Function (PSF) determined earlier. When the deblurring process is completed, the anticipated image will be in the most desirable form.

[WXL11], in their paper on **Sparsity - Based Image Deblurring with Locally Adaptive and non - locally Robust Regularization**, speak generally about deblurring of any images. Important structures in photographic images such as edges and textures are jointly characterized by local variation and nonlocal invariance (similarity). Both of them provide valuable heuristics to the regularization of image restoration process. In this paper, they propose to explore two sets of complementary ideas: 1) locally learn PCA - based dictionaries and estimate the sparsity regularization parameters for each coefficient; and 2) non-locally enforce the invariance constraint by introducing a patch-similarity based term into the cost functional. The minimization of this new cost functional leads to an iterative thresholding - based image deblurring algorithm and its efficient implementation is discussed. Their experimental results have shown that the proposed scheme significantly outperforms several leading deblurring techniques in the literature on both objective and visual quality assessments.

[XIP11] have published a paper on **Restoration for Weakly Blurred and Strongly Noisy Images**. In this paper they present an adaptive sharpening algorithm for restoration of an image which has been corrupted by mild blur, and strong noise. Most existing adaptive sharpening algorithms cannot handle strong noise well due to the intrinsic contradiction between sharpening and denoising. To solve this problem they proposed an algorithm that is capable of capturing local image structure and sharpness, and adjusting sharpening accordingly so that it effectively combines denoising and sharpening together without either noise magnification or over - sharpening artifacts. It also uses structure information from the luminance channel to remove artifacts in the chrominance channels. Experiments illustrate that compared with other sharpening approaches, their method can produce state - of - the - art results under practical imaging conditions.
KEA05 have come out with a new method for deblurring in their paper on A Spatially Adaptive Nonparametric Regression Image Deblurring. They proposed a novel nonparametric regression method for deblurring noisy images. The method is based on the local polynomial approximation (LPA) of the image and the paradigm of intersecting confidence intervals (ICI) that is applied to define the adaptive varying scales (window sizes) of the LPA estimators. The LPA - ICI algorithm is nonlinear and spatially adaptive with respect to smoothness and irregularities of the image corrupted by additive noise. Multiresolution wavelet algorithms produce estimates which are combined from different scale projections. In contrast to them, the proposed ICI algorithm gives a varying scale adaptive estimate defining a single best scale for each pixel. In the new algorithm, the actual filtering is performed in signal domain while frequency domain Fourier Transform operations are applied only for calculation of convolutions. The regularized inverse and Wiener inverse filters serve as deblurring operators used jointly with the LPA - design directional kernel filters. Experiments demonstrate the state - of - art performance of the new estimators which visually and quantitatively outperform some of the best existing methods.

iii) Feature Extraction

KAS10 made a survey of ECG Feature Extraction Techniques - A Survey Approach. ECG Feature Extraction plays a significant role in diagnosing most of the cardiac diseases. One cardiac cycle in an ECG signal consists of the PQRST waves. This feature extraction scheme determines the amplitudes and intervals in the ECG signal for subsequent analysis. The amplitudes and intervals value of PQRST segment determines the functioning of heart of every human. Recently, numerous researches and techniques have been developed for analyzing the ECG signal. The proposed schemes were mostly based on Fuzzy Logic Methods, Artificial Neural Networks (ANN), Genetic Algorithm (GA), Support Vector Machines (SVM) and other Signal Analysis techniques. All these techniques and algorithms have their advantages and limitations. This paper as a prelude discusses various techniques and transformations proposed earlier in literature for extracting feature from an ECG signal. In addition this paper also provides a comparative study of various methods proposed by researchers in extracting the feature from ECG signal.
[RAG12] in their paper on A Unified Approach of ECG Signal Analysis, review the research works on Signal Analysis. ECG being the bio-potentials generated by the muscles of the heart result in an electrical signal called electrocardiogram (ECG), is one of the most important physiological parameters, ECG is being extensively used for knowing the state of the cardiac patients. Feature extraction of ECG is the most essential task in the manual and automated ECG analysis for use in instruments like ECG monitors, Holter tape recorders and scanners, ambulatory ECG recorders and analysers. Recently, artificial intelligent tools such as neural networks, genetic algorithms, fuzzy systems, and expert systems have frequently been reported for detection and diagnostic tasks. This paper, therefore, is an attempt to review the work done by the different researchers in the area of ECG signal processing, analysis and interpretation during last five decades.

[HON06]’s paper on ECG Feature Elements Identification for Cardiologist Expert Diagnosis, proposes a reliable method for Cardiologist Expert Diagnosis based on ECG Elements Identification. This method analyzes ECG Key features (P - wave, QRS complex, T - wave). It includes noise purification, sample design for digital ECG, Understanding of the HP ECG Criteria Program and The Extended Measurements Report. This project report synthesizes the advantages of Math, Multiple Function Analysis, Database and Knowledge Base, and Expert System to explore the mechanism of “ECG Feature Elements Identification for Cardiologist Expert Diagnosis”. This report proposes an integral method of ECG information flow for its area computing, a differential method of ECG information flow for its slope computing and a convolution method for true ECG wave form element extraction even though confuse with each other or incomplete. This method can implement ECG report in real time and provide exact explanations for the diagnostic decision obtained. This method can offer mean (standard) values estimation for parameters and Confident Interval computing for predictive accuracy (above 85%). This method solved following problems: noise purification, incomplete and confusing ECG element’s key features identification, Decision - Rule Base, and Expert Diagnosis Model - For Cardiologist Expert Diagnosis research topic.
[NAR11] have worked on **Wavelet based QRS detection in ECG using MATLAB.** Their paper deals with the detection of QRS complexes of ECG signals using derivative based / Pan-Tompkins / wavelet transform - based algorithms. The ECG signal contains an important amount of information that can be exploited in different manners. This signal allows for the analysis of anatomic and physiologic aspects of the whole cardiac muscle. Different ECG signals from MIT - BIH Arrhythmia database are used to verify the various algorithms using MATLAB software. Wavelet based algorithm presented in this paper is compared with the AF2 algorithm / Pan - Tompkins algorithms for signal denoising and detection of QRS complexes and meanwhile better results are obtained for ECG signals by the wavelet based algorithm. In the wavelet based algorithm, the ECG signal has been denoised by removing the corresponding wavelet coefficients at higher scales. Then QRS complexes are detected and each complex is used to find the peaks of the individual waves like P and T, and also their deviations.

[RUA10] did a research on **Detection of QRS Complexes of ECG Recording based on Wavelet Transform Using MATLAB.** The main tasks in ECG signal analysis are the detection of QRS complex (i.e. R - wave), and the estimation of instantaneous heart rate by measuring the time interval between two consecutive R - waves. After recognizing R - wave, other components like P, Q, S and T can be detected by using window method. In this paper, a QRS complex detector is described based on the Dyadic wavelet transform (DyWT) which is robust in comparison with time - varying QRS complex morphology. The performance of the DWT - based QRS detector is illustrated by considering problematic ECG signals from Common Standard for Electrocardiography (CSE) database. Its performance is compared to some of the QRS detectors developed in the past.

[SON11] did a research on **Detection of QRS complex in ECG signal using Multiresolution Wavelet and Thresholding Method.** The Electrocardiogram (ECG) is a diagnostic tool that measures and records the electrical activity of the heart in exquisite detail. Interpretation of these details allows diagnosis of a wide range of heart conditions. Automatic extraction of time plane features is important for cardiac disease diagnosis. This paper presents a multi - resolution wavelet transforms - based system for detection and evaluation of QRS complex. As the first step of this paper they use the selective
confident method to find the QRS complex, at the next step they use a threshold method to find the QRS complex and finally they apply the composition of first step algorithm and thresholding method which shows robust ability of finding QRS compared to other methods. Achieved overall accuracy of R and QRS detection for only 4 $d$ scale without threshold is 84.48%, the composition of 3 4 5 $d$, $d$, $d$ without threshold 93.23%, only 4 $d$ with threshold 90%, and 3 4 5 $d$, $d$, $d$ with threshold 98.2%.

iv) Classification

[SAW10] have published a paper on Robust R - Peak and QRS detection in Electrocardiogram using Wavelet Transform. In this paper a robust R - Peak and QRS detection using Wavelet Transform has been developed. Wavelet Transform provides efficient localization in both time and frequency. Discrete Wavelet Transform (DWT) has been used to extract relevant information from the ECG signal in order to perform classification. Electrocardiogram (ECG) signal feature parameters are the basis for signal Analysis, Diagnosis, Authentication and Identification performance. These parameters can be extracted from the intervals and amplitudes of the signal. The first step in extracting ECG features starts from the exact detection of R - Peak in the QRS Complex. The accuracy of the determined temporal locations of R - Peak and QRS complex is essential for the performance of other ECG processing stages. Individuals can be identified once ECG signature is formulated. This is an initial work towards establishing that the ECG signal is a signature like fingerprint, retinal signature for any individual identification. Analysis is carried out using MATLAB Software. The correct detection rate of the peaks is up to 99% based on MIT - BIH ECG database.

[ALN11] has made a study on ECG Beat Classification using Optimal Projections in Overcomplete Dictionaries. Wearable Health Monitoring Systems (WHMSs) enable ubiquitous and unobtrusive monitoring of a variety of vital signs that can be measured non-invasively. These systems have the potential to revolutionize healthcare delivery by achieving early detection of critical health changes and thus possibly even disease or hazardous event prevention. Amongst the patient populations that can greatly benefit from WHMSs are Congestive Heart Failure (CHF) patients. For CHF management the detection of heart arrhythmias is of crucial importance. However, since WHMSs have
limited computing and storage resources, diagnostic algorithms need to be computationally inexpensive. Towards this goal, they investigate in this paper the efficiency of the Matching algorithm in deriving compact time-frequency representations of ECG data, which can then be utilized from an Artificial Neural Network (ANN) to achieve beat classification. In order to select the most appropriate decomposition structure, they examine the effect of the type of dictionary utilized (stationary wavelets, cosine packets, wavelet packets) in deriving optimal features for classification.

The results show that by applying a greedy algorithm to determine the dictionary atoms that show the greatest correlation with the ECG morphologies, an accurate, efficient and real-time beat classification scheme can be derived. Such an algorithm can then be inexpensively run on a resource-constrained portable device such as a cell phone or even directly on a smaller microcontroller-based board. The performance of their approach is evaluated using the MIT-BIH Arrhythmia database. Provided results illustrate the accuracy of the proposed method (94.9%), which together with its simplicity (a single linear transform is required for feature extraction) justify its use for real-time classification of abnormal heartbeats on a portable heart monitoring system.

[THA12] has presented a paper in a conference on Classification of Cardiac Arrhythmia via SVM. This paper shows the classification results in term of performance of Support Vector Machine (SVM) classifier in separating the multi-class arrhythmia dataset. SVM is a classification tool that outperforms several classification methods. By pre-selecting sets of feature classifying the training dataset in pairwise-class fashion can provide most accurate score of separation. Selection of dimensional features can be unrestrictedly allowed in grouping classifications which are less complex in computation as compared to that using the constant dimension in classifying feature parameters.

[GGJ10] made a study on Heart Arrhythmia detection Using Continuous Wavelet Transform and Principal Component Analysis with Neural Network Classifier. The aim of this study is to develop an algorithm to detect and classify six types of electrocardiogram (ECG) signal beats including normal beats (N), atrial premature beats (A), right bundle branch block beats (R), left bundle branch block beats (L),
paced beats (P), and premature ventricular contraction beats (PVC or V) using a neural network classifier. In order to prepare an appropriate input vector for the neural classifier several preprocessing stages have been applied. Continuous wavelet transform (CWT) has been applied in order to extract features from the ECG signal. Moreover, Principal component analysis (PCA) is used to reduce the size of the data. Finally, the MIT - BIH database is used to evaluate the proposed algorithm, resulting in 99.5% sensitivity (Se), 99.66% positive predictive accuracy (PPA) and 99.17% total accuracy (TA).

[MAM10] have published a paper on Automated ECG Profiling and Beat Classification. The recent trend in clinical and telemedicine applications is the high demand of automation in (electrocardiogram) ECG signal processing and heart beat classification. A real - time patient adaptive cardiac profiling scheme using repetition detection is proposed in this paper. A novel local ECG beat classifier is introduced to profile each patient’s normal cardiac behavior. As ECG morphologies vary from person to person, and even for each person, it can vary depending on the person’s physical condition, having such profile is essential for various diagnosis (e.g. arrhythmia) purposes, and can successfully raise an early warning flag for the abnormal cardiac behavior of any individual. Experimental results show that our technique follows the MIT/BIH arrhythmia database annotations with high accuracy.

[ASM10] made a study on Support vector machine - based arrhythmia classification using reduced features of heart rate variability signal: This paper presents an effective cardiac arrhythmia classification algorithm using the heart rate variability (HRV) signal. The proposed algorithm is based on the Generalized Discriminant Analysis (GDA) feature reduction scheme and the support vector machine (SVM) classifier. Initially 15 different features are extracted from the input HRV signal by means of linear and nonlinear methods. These features are then reduced to only five features by the GDA technique. This is not only reduces the number of the input features but also increases the classification accuracy by selecting most discriminating features. Finally, the SVM combined with the one - against - all strategy is used to classify the HRV signals. The proposed GDA and SVM - based cardiac arrhythmia classification algorithm is applied to input HRV signals, obtained from the MIT - BIH arrhythmia database, to discriminate six different types of cardiac arrhythmia. In particular, the HRV
signals representing the six different types of arrhythmia classes including normal sinus rhythm, premature ventricular contraction, atrial fibrillation, sick sinus syndrome, ventricular fibrillation and 28 heart block are classified with an accuracy of 98.94%, 98.96%, 98.53%, 98.51%, 100% and 100%, respectively, which are better than any other previously reported results. Conclusion: An effective cardiac arrhythmia classification algorithm is presented. A main advantage of the proposed algorithm, compared to the approaches which use the ECG signal itself is the fact that it is completely based on the HRV (R - R interval) signal which can be extracted from even a very noisy ECG signal with a relatively high accuracy. Moreover, the usage of the HRV signal leads to an effective reduction of the processing time, which provides an online arrhythmia classification system. A main drawback of the proposed algorithm is however that some arrhythmia types such as left bundle branch block and right bundle branch block beats cannot be detected using only the features extracted from the HRV signal.

[MSN10] have come out with a paper on Detection of Facial Changes for ICU Patients Using KNN Classifier. This paper presents an integrated system for detecting facial changes of patient in a hospital in Intensive Care Unit (ICU). The facial changes are most widely represented by eyes movements. The proposed system uses color images and it consists of three modules. The first module implements skin detection to detect the face. The second module constructs eye maps that are responsible for changes in eye regions. The third module extracts the features of eyes by processing the image and measuring certain dimensions of eyes regions. Finally a neural network classifier is used to classify the motion of eyes either it open, half open or close. From 300 samples of face images, it is found that the maximum classification accuracy of 93.33% was obtained for the proposed features and classification technique.

v) Use of MATLAB

[IHT12] have published a paper on Study and Analysis of ECG Signal Using MATLAB & LABVIEW as Effective Tools. This paper deals with the study and analysis of ECG signal processing by means of MATLAB tool effectively. Study of ECG signal includes generation & simulation of ECG signal, acquisition of real time ECG data, ECG signal filtering & processing, feature extraction, comparison between different
ECG signal analysis algorithms & techniques (i.e. Wavelet transform or so), detection of any abnormalities in ECG, calculating beat rate and so on using the most familiar and multipurpose MATLAB software along with LABVIEW. The proper utilization of MATLAB functions (both built-in and user defined), toolbox and Simulink can lead the researchers to work with ECG signals for processing and analysis both in real time and by simulation with great accuracy and convenience.

[LUO12] have come out with a paper on Using SIMULINK and MATLAB for real-time ECG Signal Processing. This paper describes a model for processing ECG signal for analyzing respiratory sinus arrhythmia (RSA) and heart rate variability (HRV). We implemented the model in SIMULINK and MATLAB. Model had to work as real-time application for biofeedback purposes. The measurement card HUMUSOFT AD512 measures ECG signal using xPC Target Library. Processing of ECG signal in SIMULINK results in heart rate (HR) signal. SIMULINK detects QRS complex in ECG signal and computes HR, which carries the information about HRV and RSA. The analysis of HRV calculates parameters in time and frequency domain. SIMULINK sends HR signal to MATLAB, which determines and plots bars with relative spectral components, number of breaths in minute, period of breathing. Plots also include HR signal and its FFT transform and respiration pacer.

[NIP12] have published a paper on Signal Processing of ECG Using MATLAB. The ECG signal, even rest ECG, is often corrupted by artifacts produced by varies sources of either artificial or biological nature. Main artificial artifacts are power line interference, Impulse noise, Electrostatic potentials and noise of electronic devices. The main biological artifacts are motion artifacts and muscle artifacts (EMG signal). The present work introduces the digital filtering method to cope with the noise artifacts in the ECG signal. The ECG lead - II signal is taken. The Butterworth IIR filter and FIR type1 filters are applied on the ECG signal. The basic bandwidth used for the ECG monitoring is from 0.5 Hz to 100 Hz.

2.3. WAVELET TRANSFORM

[ACR06], in their book The Physiological Basis of the Electrocardiogram, explain how the myocardial contraction causes circulation of blood in the human body.
Before attempting any signal processing of the electrocardiogram (ECG) it is important to first understand the physiological basis of the ECG in order to review measurement conventions of the standard ECG, and to review how a clinician uses the ECG for patient care. The material and figures in this chapter are taken from the reading list given under bibliography at the end of this thesis. The heart is comprised of muscle (myocardium) that is rhythmically driven to contract and hence drive the circulation of blood throughout the body. Before every normal heartbeat, or systole 1, a wave of electrical current passes through the entire heart, which triggers myocardial contraction. The pattern of electrical propagation is not random, but spreads over the structure of the heart in a coordinated pattern which leads to an effective, coordinated systole. This results in a measurable change in potential difference on the body surface of the subject. The resultant amplified (and filtered) signal is known as an electrocardiogram (ECG or sometimes EKG). A broad number of factors affect the ECG, including abnormalities of cardiac conducting fibers, metabolic abnormalities (including a lack of oxygen or ischemia) of the myocardium, and macroscopic abnormalities of the normal geometry of the heart. ECG analysis is a routine part of any complete medical evaluation, due to the heart’s essential role in human health and disease, and the relative ease of recording and analyzing the ECG in a non-invasive manner. Understanding the basis of a normal ECG requires appreciation of four phenomena: the electrophysiology of a single cell, how the wave of electrical current propagates through myocardium, the physiology of the specific structures of the heart through which the electrical wave travels, and last how that leads to a measurable signal on the surface of the body, producing the normal ECG.

[WBS92], Numerical Recipes in C - The Art of Scientific Computing: This is the most reliable source of the Wavelet Transform techniques. The chapters on Wavelet Transforms contain greater details of various types of Wavelet Transforms such as Fourier Transform and the Discrete Wavelet Transform and explain Daubechies Wavelet Filter Coefficient. On the spectral applications this book abounds in numerical examples of applications. This also deals with Wavelet filters in the Fourier Domains and Wavelet Transform in milli - dimension. The computation techniques are demonstrated with formulae together with the illustrative pictures of wavelets.
[MER05] has prepared a report called **Wavelet Theory and Applications**. This report gives an overview of the main wavelet theory. In order to understand the Wavelet Transform better, the Fourier Transform is explained in detail. This is indeed an introduction into wavelet theory and application. The wavelet applications mentioned here include adjustment of audio signals. In the Fourier Transform, the global frequency content is retrieved but the time information is lost. This problem is overcome by Short Time Fourier Transform (STFT) which gives the time frequency content of a signal. The Discrete Wavelet Transform (DWT) uses filter banks to perform the wavelet analysis. The DWT decomposes the signal into wavelet coefficients which represent the signal in various frequency bands.

[PAA05] made a review on **Wavelet transforms and the ECG**. The wavelet transform has emerged over recent years as a powerful time-frequency analysis and signal coding tool favored for the interrogation of complex on stationary signals. Its application to biosignal processing has been at the forefront of these developments where it has been found particularly useful in the study of these, often problematic, signals: none more so than the ECG. In this review, the emerging role of the wavelet transform in the interrogation of the ECG is discussed in detail, where both the continuous and the discrete transforms are considered in turn.

[SSN08] published a paper on **ECG Signal Analysis Using Wavelet Transforms**. This paper deals with the study of ECG signals using wavelet transform analysis. In the first step an attempt was made to generate ECG waveforms by developing a suitable MATLAB simulator and in the second step, using wavelet transform, the ECG signal was denoised by removing the corresponding wavelet coefficients at higher scales. Then QRS complexes were detected and each complex was used to find the peaks of the individual waves like P and T, and also their deviations.

[PAO02] published a paper on **An Introduction to Wavelet Transforms**. Wavelet transforms have become one of the most important and powerful tool of signal representation. Nowadays, it has been used in image processing, data compression, and signal processing. This paper will introduce the basic concept for Wavelet Transforms, the fast algorithm of Wavelet Transform, and some applications of Wavelet Transform.
The difference between conventional Fourier Transform and modern time - frequency analysis are also discussed.

[POY12] published a paper on **ECG Signal Compression Implementation by a New 2 - Dimensional Transform Technique**. Electrocardiogram signal compression algorithm is needed to reduce the amount of data to be transmitted, stored and analyzed, without losing the clinical information content. This work investigates a set of ECG signal compression schemes to compare their performances in compressing ECG signals. These schemes are based on transform methods such as discrete cosine transform (DCT), Fast Fourier Transform (FFT), discrete sine transform (DST), and their improvements. An improvement of a discrete cosine transform (DCT) - based method for electrocardiogram (ECG) compression is also presented as DCT-II. A comparative study of performance of different transforms is made in terms of Compression Ratio (CR) and Percent root mean square difference (PRD). The appropriate use of a block based DCT associated to a uniform scalar dead zone quantizer and arithmetic coding show very good results, confirming that the proposed strategy exhibits competitive performances compared with the most popular compressors used for ECG compression. Each specific transform is applied to a pre-selected data segment from the CSE database, and then compression is performed.

[NMV11] have published a paper on **Application of Wavelet Techniques in ECG Signal Processing: An Overview**. ECG signals are non - stationary, pseudo periodic in nature and whose behavior changes with time. The proper processing of ECG signal and its accurate detection is very much essential since it determines the condition of the heart. The analysis of ECG signal requires the information both in time and frequency, for clinical diagnosis. Hence the wavelet transforms becomes handy for analyzing these types of the signals. In this paper, the researchers have given an overview of some wavelet techniques published in journals and conferences since 2005 onwards for processing the ECG and also we have compared the performance, advantages and limitations of these techniques.

[PAS03] has done a research on **Complex Wavelet Transforms and their Applications for M.Phil**. Standard DWT (Discrete Wavelet Transform), being
non-redundant, is a very powerful tool for many non-stationary Signal Processing applications, but it suffers from three major limitations: 1) shift sensitivity, 2) poor directionality and 3) absence of phase information. To reduce these limitations, many researchers developed real-valued extensions to the standard DWT such as WP (Wavelet Packet Transform) and SWT (Stationary Wavelet Transform). These extensions are highly redundant and computationally intensive. Complex Wavelet Transform (CWT) is also an alternate, complex-valued extension to the standard DWT. Recent developments in CWTs are classified into two important classes first is, Redundant CWT (RCWT) and second is Non-Redundant CWT (NRCWT). Denoising and Edge detection applications are investigated with DT-DWTs. Promising results are compared with other DWT extensions, and with the classical approaches. After thorough investigations, it is proposed that by employing DT-DWT for Motion estimation and NRCWT for Compression might significantly improve the performance of the next generation video codecs.

[APM12] have made on ECG Analysis using Continuous Wavelet Transform (CWT). One of the important steps in the ECG analysis is to accurately detect the different waves forming the entire ECG. The wavelet transformation is worth investigating in P-wave and T-wave recognition. The benefit of the wavelet based ECG approach is that T-wave abnormalities can be assessed without the need for T-wave end point identification. The wavelet transformation is a new promising technique in non-invasive electro cardiology providing improved methods for late potential detection. The proposed paper work aims to analyze a given ECG by using wavelet transform and to identify the Arrhythmia. The present approach and results can be implemented in the ECG machines to give analysis report along with the ECG of the patient. The accurate and authentic analysis of the ECG in ECG machine is very much in demand today. Further, it is proposed to extract certain arrhythmia patterns from the ECG of different patients to enable an ECG machine to correlate the analysis based on the history.

[MAR12] have made ECG Analysis based on Wavelet Transform and Modulus Maxima. In their paper, they have developed a new technique of P, Q, R, S and T-Peaks detection using Wavelet Transform (WT) and Modulus maxima. One of the
commonest problems in electrocardiogram (ECG) signal processing, is baseline wander removal suppression. Therefore they have removed the baseline wander in order to make easier the detection of the peaks P and T. Those peaks are detected after the QRS detection. The proposed method is based on the application of the discretized continuous wavelet transform (Mycwt) used for the Bionic wavelet transform, to the ECG signal in order to detect R - peaks in the first stage and in the second stage, the Q and S peaks are detected using the R - peaks localization. Finally the Modulus maxima are used in the undecimated wavelet transform (UDWT) domain in order to detect the other peaks (P, T). This detection is performed by using a varying-length window that is moving along the whole signal. For evaluating the proposed method, they have compared it to other's techniques based on wavelets. In this evaluation, they have used many ECG signals taken from MIT - BIH database. The obtained results show that the proposed method outperforms a number of conventional techniques used for their evaluation.

[BBC11] have made **ECG Wavelet Analysis for the Detection of Gene Mutations in Patients with Brugada Syndrome**. Wavelet transform (WT) is applied to digital electrocardiograms (ECG) acquired during positive Ajmaline test for Brugada syndrome (BrS) in 12 patients with and 14 patients without gene mutations. Continuous WT was applied to the QRS complex and the ST - T wave on leads V1 to V3 in 4th and 3rd intercostal space (i.c.s.) (Group A, 13 pts) and leads V1 and V2 from 4th, 3rd and 2nd i.c.s. (Group B, 13 patients) using 256 levels. In group A, there was significantly higher QRS energy at high frequencies in patients with mutations (n = 4) both at baseline and during maximum drug effect. In group B, patients with mutations (n = 7) had higher QRS energy at low frequencies and higher ST - T energy at low frequencies at baseline and during drug effect. Continuous WT can help identify carriers of gene mutations among patients with BrS, especially when applied to leads V1 and V2 from the 4th to 2nd i.c.s.

[ZLD10] made a study on **Predicting Method for Acute Hypotensive Episodes Based on Wavelet Transform and Support Vector Machine**. The occurrence of acute hypotensive episodes (AHE) in intensive care units (ICU) seriously endanger the lives of patients, and are depended mainly on the expert experience of doctors to treat currently. How to detect and predict AHE in advance, has become a clinical problem which is highly paid attention to by the medical world. In this paper, the theory of Medical
Informatics has been applied to achieve the prediction of the occurrence of AHE. In their study, the mean arterial blood pressure (MAP) signals of those who experienced AHE and those who not, are both described on different scales by using wavelet transform. Through the extraction of the median and maximum from the wavelet coefficients for learning and training based on support vector machine (SVM), a predicting model with a predictive accuracy of 90% has been developed. The experiment demonstrates that this approach has better prediction accuracy comparing with the one which extracts statistical parameters from the MAP signals directly, and is beneficial to early prediction of AHE and intervention.

2.4. ARTIFICIAL INTELLIGENCE AND NEURAL NETWORKS

RAR96]’s book titled Neural Networks: A Systematic Introductions, thoroughly covers the most widely applied mechanisms that involve adapting weights in feed forward networks of uniform differentiable units. In addition to chapters on the background, fundamentals and variations on back propagation techniques, there is treatment of related questions from statistics and computational complexity. This book also covers recurrent networks including the general associative net and the models of Hopfield and Kohonen. Some chapters are dedicated to fuzzy logic, modular neural networks, genetic algorithms and an overview of computer hardware developed for neural computation. This book indicates the most remarkable trend of neural computation which is maturing and becoming integrated with traditional disciplines.

SER93 has made a survey of research projects on Intelligent Systems in Patient Monitoring and Therapy Management. Although today’s advanced biomedical technology provides unsurpassed power in diagnosis, monitoring, and treatment, interpretation of vast streams of information generated by this technology often poses excessive demands on the cognitive skills of health care personnel. In addition, storage, reduction, retrieval, processing, and presentation of information are significant challenges. These problems are most severe in critical care environments such as Intensive Care Units (ICUs) and Operating Rooms (ORs) where many events are life-threatening and thus require immediate attention and the implementation of definitive corrective actions. This article focuses on Intelligent Monitoring and Control (IMC), or
the use of Artificial Intelligence (AI) techniques to alleviate some of the common information management problems encountered in health care environments. The article presents the findings of a survey of over 30 IMC projects. A major finding of the survey is that although significant advances have been made in introducing AI technology in critical care, successful examples of fielded systems are still few and far between. Widespread acceptance of these systems in critical care environments depends on a number of factors, including fruitful collaborations between clinicians and computer scientists, emphasis on evaluation studies, and easy access to clinical information.

[DAG07], has written a book with the title *Principles of Artificial Neural Networks Advanced Series on Circuits and Systems. Vol. 6*. This book has been evolved out of a graduate course material on Neural Networks. Artificial Neural Networks as dealt with here provides not only an understanding into the important computational architecture and methodology but also an understanding of the mechanism of the biological neural network. The author in the later chapters of the book tries to give some demonstration to support the idea that neural networks are indeed a valid and efficient tool to deal with very large memories. The concepts dealt with here paves the way for concrete applications in control, communications and medical devices such as artificial limbs and organs and in neural prostheses. Case studies have been included for solving speech recognition, character identification and parameter estimation problems. The author asserts that the building blocks of NN are so simple yet the field is exciting.

[ASA12] in their paper on *A Web - Based Patient Support System Using Artificial Intelligence to Improve Health Monitoring and Quality of Life*, describe the use of Artificial Intelligences for improving quality of life. The burden of lifestyle diseases such as diabetes has reached epidemic proportions during the last decade in India. An estimated 75 million people in India would become diabetic by 2025. However, the existing healthcare infrastructure is inadequate to meet the demands of this exploding population. Provisioning a web - based patient support system that helps in patient centered decision making and physician centered health monitoring would greatly help to reduce the treatment cost and improve the quality of life among patients. Extracting useful knowledge from very large web-based medical database and providing scientific decision-making is very difficult and yet critical. Applying Artificial Intelligence
techniques for heterogeneous and large databases can deal with this problem. This paper explores the potential of artificial intelligence techniques particularly for web-based medical applications. In addition, a model for web-based medical diagnosis and prediction is proposed.

[WWF08] have published an online article on Artificial Intelligence in Medical Application: An Exploration. The advancement in computer technology has encouraged the researchers to develop software for assisting doctors in making decision without consulting the specialists directly. The software development exploits the potential of human intelligence such as reasoning, making decision, learning (by experiencing) and many others. Artificial Intelligence is not a new concept, yet it has been accepted as a new technology in Computer Science. It has been applied in many areas such as education, business, medicine and manufacturing. This paper explores the potential of artificial intelligence techniques particularly for web-based medical applications. In addition, a model for web-based medical diagnosis and prediction is proposed. In most developing countries insufficiency of medical specialists has increase the mortality of patients suffering from various diseases. The insufficiency of medical specialists will never be overcome within a short period of time. The institutions of higher learning could however, take an immediate action to produce as many doctors as possible.

[YAP96] published a paper on Use of Methodological Diversity to Improve Neural Network Generalisation. Littlewood and Miller present a statistical framework for dealing with coincident failures in multiversion software systems. They develop a theoretical model that holds the promise of high system reliability through the use of multiple, diverse sets of alternative versions. In this paper, their framework has been adapted to investigate the feasibility of exploiting the diversity observable in multiple populations of neural networks developed using diverse methodologies. The researchers here evaluate the generalization improvements achieved by a range of methodologically diverse network generation processes. It is attempted to order the constituent methodological features with respect to their potential for use in the engineering of useful diversity. The use of relative measures of the diversity between version sets is explored as a guide to the potential for exploiting interset diversity.
have come out with a paper on **Nature Inspired Clustering Methods in The Electrocardiogram Interpretation Process in Cardiology**. The paper focuses on the field of Artificial Intelligence techniques and their use in biomedical data processing. It concentrates on the clustering techniques inspired by various ant colonies and other nature concepts. The paper evaluates the use of the following nature inspired methods: Ant Colony inspired Clustering, Ant Colony inspired method for Decision Tree generation, Radial Basis Function Neural Networks with different learning algorithms. It also compares them to classical approaches, such as K-means and hierarchical clustering. The methods have been evaluated using the annotated MIT - BIH database. Use of the Dynamic Time Warping measure improved Sensitivity about 0.7% and Specificity about 0.9% when compared to classical feature extraction. The best-performing method is the agglomerative hierarchical clustering ($Se = 94.3$, $Sp = 74.1$). However it is practically unusable as it demands memory and computational skill. Acceptable results (complexity vs. error) have been obtained by the Ant Colony inspired method for decision tree generation ($Se = 93.1$, $Sp = 72.8$).

[SHS10] has done a research on **Fusion beats extraction from ECG using neural network based soft computing techniques**. This paper presents a new concept by application of MATLAB-based tools in the same weighted neural network algorithms. This will help to reduce the hardware requirements, make network more reliable and thus a hope to make it feasible. To do so various networks were designed using the MATLAB-based tools and parameters. Two classes of networks were designed, but with different training algorithms, namely Perceptron and Back propagation. They were provided training inputs from the data obtained from the standard MIT-BIH Arrhythmia database. After training different forms of networks, they were tested by providing unknown inputs as patient data and the results in the whole process from training to testing were recorded in the form of tables. There are many types of abnormalities in ECGs like Ventricular Premature Beats, Asystole, Couplet, Bigeminy, Fusion beats etc. In this paper only fusion beats have been discussed and so results associated with it only have been given, though the same principle was used to make networks for analyzing normal as well as ventricular premature beats too. The results for the fusion beats were best in the case of Feed Forward network algorithm. The
percentage of correct classification is 96%. The results are compared with the previous work which concludes that the Feed Forward network with back propagation Training algorithm is best for fusion beats classification.

[KAA04] have published a paper on **Medical Diagnosis Using Neural Network**. This research is to search for alternatives to the resolution of complex medical diagnosis where human knowledge should be apprehended in a general fashion. Examples of successful application of NN show that human diagnostic capabilities are not as good as the neural diagnostic system. This paper describes a modified feed forward neural network constructive algorithm (MFNNCA), a new algorithm for medical diagnosis. The new constructive algorithm with back propagation offers an approach for the incremental construction of near-minimal neural network architectures for pattern classification. The algorithm starts with minimal number of hidden units in the single hidden layer; additional units are added to the hidden layer one at a time to improve the accuracy of the network and to get an optimal size of a neural network. The MFNNCA was tested on several benchmarking classification problems including cancer, heart disease and diabetes. Experimental results show that the MFNNCA can produce optimal neural network architecture with good generalization ability.

### 2.5. CONCLUSION

From the description of the books quoted, the essential concepts of this research, namely, Wavelet Transform and Artificial Intelligence could be made clear. This chapter also has presented some of the studies on the preprocessing stages, namely, denoising, deblurring, feature extraction and classification that have been used in carrying out their research. The synopses of the studies using Wavelet Transform and Neural Network based on Artificial Intelligence contain a variety of uses of the techniques in the ECG analysis. These studies show that there is a research gap in diagnosing the major heart diseases in order to save time for immediate treatment to be given to the heart patients.