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A Review Article of Adaptive ECG Signal Time Frequency Analysis and Signal Quality Assessment Using AI

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Abstract- This review paper deals with the study and analysis of ECG signal processing by means of various tools ,techniques and algorithms. 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. discrete Wavelet transform or so), detection of any abnormalities in ECG and so on. Finally, in the concluding part about its technological implementation using various small, inexpensive and easy to use devices.

Keywords- Feature Extraction, SVM, PSO, ECG, DWT.

I. INTRODUCTION

Signal processing today is performed in the vast majority of systems for ECG analysis and interpretation. The objective of ECG signal processing is manifold and comprises the improvement of measurement accuracy and reproducibility (when compared with manual measurements) and the extraction of information not readily available from the signal through visual assessment.

In many situations, the ECG is recorded during ambulatory or strenuous conditions such that the signal is corrupted by different types of noise, sometimes originating from another physiological process of the body. Hence, noise reduction represents another important objective of ECG signal processing; in fact, the waveforms of interest are sometimes so heavily masked by noise that their presence can only be revealed once appropriate signal processing has first been applied.

Electrocardiographic signals may be recorded on a long timescale (i.e., several days) for the purpose of identifying intermittently occurring disturbances in the heart rhythm. As a result, the produced ECG recording amounts to huge data sizes that quickly fill up available storage space.

Transmission of signals across public telephone networks is another application in which large amounts of data are involved. For both situations, data compression is an essential operation and, consequently, represents yet another objective of ECG signal processing. Signal processing has contributed significantly to a new understanding of the ECG and its dynamic properties as expressed by changes in rhythm and beat morphology [1-5].

II. RESEARCH MOTIVATION

The rapid advancement in the fields of electronic and communication technologies and new developments in computational algorithms such as deep learning and big data analysis have resulted in new ways of providing health care [6]. The bulky medical apparatus have been replaced by smaller electronic gadgets connected with personal computers, laptops and smart phones. For example, the company Bio [10].

III. DIGITAL FILTERS

The aim of the pre-processing is to achieve a noise free signal and enhance its features accurately. Digital filters can be categorized into two major types as shown in Fig. 4, i.e. fixed type of filters where the coefficients of the filters are fixed and

adaptive filter where the coefficients change adaptively. Fixed filters are well suited for stationary environment and can be used for eliminating the power line interference 60/50 Hz noise [11]. When we know which frequency is to be eliminated, fixed filters are the best choice. In case of no stationary signals such as ECG, filters designed using advanced learning algorithms are the optimum choice.

After reviewing the literature carefully, we have chosen adaptive filters as a potential candidate for the processing of ECG signal because of its flexibility to adapt to the changes in the signal. As ECG is a non-linear signal, adaptive filters are well suited for its processing [12-15].

IV. LITERATURE REVIEW

Fatemeh Afghah, ECG Language processing (ELP): A new technique to analyze ECG signals: Background: A language is constructed of a finite/infinite set of sentences composing of words. Similar to natural languages, the Electrocardiogram (ECG) signal, the most common noninvasive tool to study the functionality of the heart and diagnose several abnormal arrhythmias, is made up of sequences of three or four distinct waves, including the P-wave, QRS complex, T-wave, and U-wave. We evaluated the proposed approach on two tasks, including the classification of heartbeats and the detection of atrial fibrillation in the ECG signals. Overall, our technique resulted in better performance or comparable performance with smaller neural networks compared to other deep neural networks and existing algorithms.

Arun Kumar Sangaiah, An intelligent learning approach for improving ECG signal classification and arrhythmia analysis: The recognition of cardiac arrhythmia in minimal time is important to prevent sudden and untimely deaths. The proposed work includes a complete framework for analyzing the Electrocardiogram (ECG) signal. The three phases of analysis include 1) the ECG signal quality enhancement through noise suppression by a dedicated filter combination; 2) the feature extraction by a devoted wavelet design and 3) a proposed hidden Markov model (HMM) for cardiac arrhythmia classification into Normal (N), Right Bundle Branch Block (RBBB), Left Bundle Branch Block (LBBB), Premature Ventricular Contraction (PVC) and Atrial Premature Contraction (APC).

V.Gupta, A Comparison of ECG Signal Pre-processing Using FrFT, FrWT and IPCA for Improved Analysis: Electrocardiogram (ECG) is a diagnostic tool for recording electrical activities of the human heart non-invasively. It is detected by electrodes placed on the surface of the skin in a conductive medium.

In medical applications, ECG is used by cardiologists to observe heart anomalies (cardiovascular diseases) such as abnormal heart rhythms, heart attacks, effects of drug dosage on subject's heart and knowledge of previous heart attacks. Recorded ECG signal is generally corrupted by various types of noise/distortion such as cardiac (isoelectric interval, prolonged depolarization and atrial flutter) or extra cardiac (respiration, changes in electrode position, muscle contraction and power line noise).

Hemant Amhia, Stability and Phase Response Analysis of Optimum Reduced-Order IIR Filter Designs for ECG R-Peak Detection: Cardiovascular health and training success can be assessed using electrocardiogram (ECG) data. For over a quarter of a century, an individual's resting heart rate is varying more. As a result, it has become the subject of inquiry and reveals the intricate relationship between the human body and its environment.

GeWang, ECG signal denoising based on deep factor analysis: This study proposed a novel ECG signal denoising algorithm based on the deep factor analysis. The major technical innovations include a layer-by-layer denoising deep neural network built based on the factor analysis, in which a top-down strategy is used to reconstruct the signal.

DezhaoJiao, The chaotic characteristics detection based on multifractal detrended fluctuation analysis of the elderly 12-lead ECG signals: ECG analysis is an important method of heart disease diagnosis. During the diagnostic process, many signal characteristics are hidden in the 12-lead ECG. To research these characteristics and improve diagnostic efficiency, it is very urgent to study the 12-lead ECG signal.

Prashant Kumar, Time-domain HRV Analysis of ECG Signal under Different Body Postures: Heart rate variability (HRV) is a cardiac estimate derived from the ECG signal. The analysis of HRV offers techniques of evaluating input into the cardiac rhythm non-invasively.

Himali Singh, Detection of sleep apnea from heart beat interval and ECG derived respiration signals using sliding mode singular spectrum analysis: The heartbeat interval (HBI) signal (RR-time series), and electrocardiogram (ECG) derived respiration (EDR) signal quantify the information about the cardiopulmonary activity, and monitoring these two signals simultaneously will provide more information for the sleep apnea detection. This paper proposes a novel approach to detect sleep apnea using both HBI and EDR signals. The approach consists of the decomposition of both HBI and EDR signals into reconstructed components (RCs) or modes using a data-driven signal processing approach namely, the sliding mode singular spectrum analysis (SM-SSA), extraction of features from each RC, and the use of classifier for the detection of sleep apnea.

The features such as the mean and the standard deviation values are extracted from the instantaneous amplitude (IA) and instantaneous frequency (IF) of each RC of both HBI and EDR signals. The classifiers, such as the stacked auto encoder based deep neural network (SAE-DNN), and support vector machine (SVM) are considered to classify normal and apnea episodes using the statistical features obtained from the RCs of HBI and EDR signals. The proposed approach is evaluated using different public databases such as apnea-ECG database, University College Dublin (UCD) database, and Physionet challenge database, respectively.

Y.S.Alshebly, Isolation of Fetal ECG Signals from Abdominal ECG Using Wavelet Analysis: Electrocardiogram (ECG) is a method of monitoring the electrical activity produced by the heart. The extraction of the fetal ECG (FECG) from the abdominal ECG (AECG) is challenging since both ECGs of the mother and the baby share similar frequency components, adding to the fact that the signals are corrupted by white noise.

WeijieWang, Revisiting signal processing with spectrogram analysis on EEG, ECG and speech signals: Biomedical signal processing is the utilization of digital signal processing techniques, such as Fourier transform, filtering, spectral estimation and wavelet transform to biomedical complications, such as the analysis of breathing cycle, cardiac signals, brain signals, etc. Digital filters are used to preserve the in-band signals and to block out-of-band noise. Low-pass, high-pass, band-pass, and band-stop filters are commonly used for filtering applications.

Mahesh Chandra, Design and analysis of improved high-speed adaptive filter architectures for ECG signal denoising: In this paper, improved high-speed adaptive filter-based denoising architectures are proposed and implemented using the Xilinx Virtex-6 series FPGA platform.

The performance of the proposed DF-RDLMS, TDF-RDLMS and TF-RDLMS implementations is analyzed and compared with that of the existing adaptive filter architectures as well as state-of-the-art wavelet-based denoising architectures. The proposed adaptive filter implementations are found to perform better than existing adaptive filter architectures and wavelet-based architectures.

PéterKovác, Diagnostic quality assessment for low-dimensional ECG representations: There have been several attempts to quantify the diagnostic distortion caused by algorithms that perform low-dimensional electrocardiogram (ECG) representation. However, there is no universally accepted quantitative measure that allows the diagnostic distortion arising from denoising, compression, and ECG beat representation algorithms to be determined. Hence, the main objective of this work was to develop a framework to enable biomedical engineers to efficiently and reliably assess diagnostic distortion resulting from ECG processing algorithms. We propose a semiautomatic framework for quantifying the diagnostic resemblance between original and denoised/reconstructed ECGs.

Amulya Agrawal, ECG-iCOVIDNet: Interpretable AI model to identify changes in the ECG signals of post-COVID subjects: So far, we have not come across any other study with an in-depth ECG signal analysis of the COVID-recovered subjects. In this study, it is shown that the shallow ECG-iCOVIDNet CNN model performed good for distinguishing ECG signals of COVID-recovered subjects from those of healthy subjects.

A.S.A.Huque, HMM-based Supervised Machine Learning Framework for the Detection of fECG R-R Peak Locations: This work pursues hidden Markov model (HMM)-based supervised machine learning frame-work for the determination of the location of fECG QRS complex from the composite abdominal

signal. HMM is used to model the underlying hidden states of the observable time series of the extracted and separated fECG data with its QRS peak location as one of the hidden states.

Abel JD, Krupa D, Samiappan R, Kumar, Pravin Kumar S: Despite the rapid growth in the area of adult ECG signal processing and monitoring systems, the morphological analysis of fetal ECG signals lags farther behind and demands much attention. Non-invasive fetal Electrocardiography is the safest approach for monitoring the fetus health condition by processing the abdominal ECG (AECG) signals acquired by placing electrodes on the mother's abdomen.

Paper Title	Author	Result	Methodology	Parameters	Scope of the study
A novel Discrete Wavelet-Concatenated Mesh Tree and ternary chess pattern based ECG signal recognition method	Turker Tuncer	The 96.60% maximum classification accuracy is achieved for the MIT-BIH dataset using k-NN and 97.80% accuracy is achieved using SVM for St.	eighborhood component analysis (NCA)	classification accuracy	n future works, the proposed method can be used for image processing.
Time-domain HRV Analysis of ECG signal under Different Body Postures	Prashant Kumara	The frequency-domain analysis result uggests, supine posture has a higher LF/HF ratio.	Power spectral density (PSD)	RR Interval, Frequency-domain LF/HF	Extended for non-linear HRV analysis

ECG Language processing (ELP): A new technique to analyze ECG signals		We can see that our method can result in better performance or omparable perfor- mance with smaller neural networks compared to other deep neu- ral networks and existing algorithms.	Recurrent neural network (RNN)	*Specificity, sensitivity*	uture work includes, but not limited to, improving the segmentation and cre- ating the vocabulary steps to improve the performance of the de- tection process.
omprehensive survey of computationa ECG analysis: Databases, methods and applications	Elena Merdjanovska	This paper provides a comprehensive survey on the variety of both ECG data and computational methods in various applications:	*Segmentation*	accuracy	future contribution is providing ECG data from mobile sensors to public repository
ECG-iCOVIDNet: Interpretable AI model to identify changes in the ECG signals of post-COVID subjects	Amulya Agrawal	he proposed model yields an *F*1-score of 100%.	onvolution neural network (CNN)	accuracy	Further, there are many interpretability methods that can be employed to draw inferences on the decisions made by the AI model.

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he continuous wavelet transform using for natural ECG signa arrhythmias detection by statistical parameters	R.A. Alharbey	The wavelet packet transform was used for comparison. All combinations have given reasonable results, but continuous wavelet transform with standard deviation taken for the third sub signal have given the superior results.	continuous wavelet transform (CWT)	Sensitivity	urthermore, future work of fractional mathematical biologica model of HIV might be done with the stability [8,9].

V. CONCLUSION

ECG signal carries some vital information about the heart and it is one of the important tools for the doctors to for diagnosing the heart related diseases. In the past a lot of work has been presented by various researcher to extract the features from the ECG signal so that the analysis of ECG become automate and easier.

The analysis of ECG signal depends upon the accurate detection of various features of ECG signal. In this review paper some of the important algorithm of ECG feature extraction presented in the past has been discussed. From the discussion it is clear that wavelet transform is one of the important tools for extracting out QRS complex and other features from the ECG signal.

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